Walnut Creek Wetland Park Inventory

Natural Resources Measurements – Spring 2019

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2019 April 30 – FINAL DRAFT

Walnut Creek Wetland Park Inventory

2019 April 30 (Final Draft)

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Walnut Creek Wetland Park Natural Resource Inventory

Final Draft 2019 April 26

Executive Summary

Walnut Creek Wetland Park is a 58-acre site in Raleigh, NC, that falls between Little Rock Creek and the Walnut Creek Greenway. Surrounded by two neighborhoods, Rochester Heights and Biltmore Hills, and Carnage Middle School, the site provides opportunities for community members to gain educational experience and interact with nature. A 1990's effort by Partners for Environmental Justice led to the site being cleaned and proposed to be a nature center. This was approved in 2003, and the on-site Norman and Betty Camp Education Center was built shortly after. In 2017, the City of Raleigh Parks and Cultural Resources Department worked with community members to develop a Master Plan for the park that defined a vision for its future. We partnered with Walnut Creek Wetland Park to conduct a natural resource inventory, crucial to the implementation of the master plan. The aspects of the plan that we assisted with were recommendations for planning a community garden and nature play area, a density map of Chinese Privet in the park, the water quality in Little Rock Creek, plans for a trail to connect the south side of the park to the north side of the park and a wildlife inventory in the park.

Community Garden & Nature Play

To engage groups such as children and the disabled, the Master Plan for Walnut Creek Wetland Center incorporates a community garden and a nature play area. These areas allow community members to engage with each other and the park, while learning about and interacting with natural systems. The space for the nature play area was designated by park staff in accordance with previous plans. We consulted online materials and staff at local parks, such as Prairie Ridge Ecostation in Raleigh, NC. We also developed a risk matrix to evaluate the relative risks of different equipment. We recommend a Fairy Mailbox, Bell Tree, Intentional Incline, Tree Cookie Art Station, Stump Steps, Fossil Dig Pit, and Ball Tunnel (Figure E1). Because the proposed nature play area is close to the parking lot and stream, we also recommend that the area be enclosed with a fence.

Severity	Probability Risk Matrix	Insignificant	Minor	Moderate	Major
	Rare	**Fairy Mailbox, Bell Tree, Intentional Incline, Tree Cookie Art**	**Fossil Pit Ball Tunnel**	**Dig Pit Music Area**	
	Possible	**Stump Steps**	**Balance Beams**		**Tunnel**
	Almost Certain			**Water Feature Cistern**	
	Severity Key:	Insignificant: Breathe in dust.	Minor: Cut, Scrape, Bruise	Moderate: Sprains, hit head	Major: Breaks, contusions

Figure E1. Risk Matrix for Probability and Severity of Child Injury

The proposed space for the garden was also designated by park staff members, and in this area we collected soil samples to determine what amendments would need to be made to create productive soil. We also consulted with staff from nearby community gardens and knowledgeable local gardeners, who strongly encouraged the use of raised beds due to the convenience and accessibility that raised beds offer. Given this recommendation and the discovery that the soil was poor for planting, we recommend that raised beds be used in the garden area, with some of the raised beds being wheelchair accessible. We recommend four different types of plants and beds at the park: pollinator plants, sensory plants, local and historical plants, and edible plants. Each of these plants provides different benefits to the members of the community and allow them to gain new insights into the value and history of native plants.

Invasive Plants

Chinese Privet is an invasive species of plant that is prevalent throughout the southeastern United States, including in the Walnut Creek Wetland Park. We conducted field sampling and used ArcGIS to create a density map of the percent coverage of Chinese Privet throughout the wetland park.   Chinese Privet is densest along the banks of Walnut Creek and other creeks in the Park, but also present throughout the whole park other than in consistently flooded areas (Figure E2). This information will allow park staff and volunteers to plan invasive species clean-ups so that they focus on park areas that need large-scale removal of Chinese Privet.

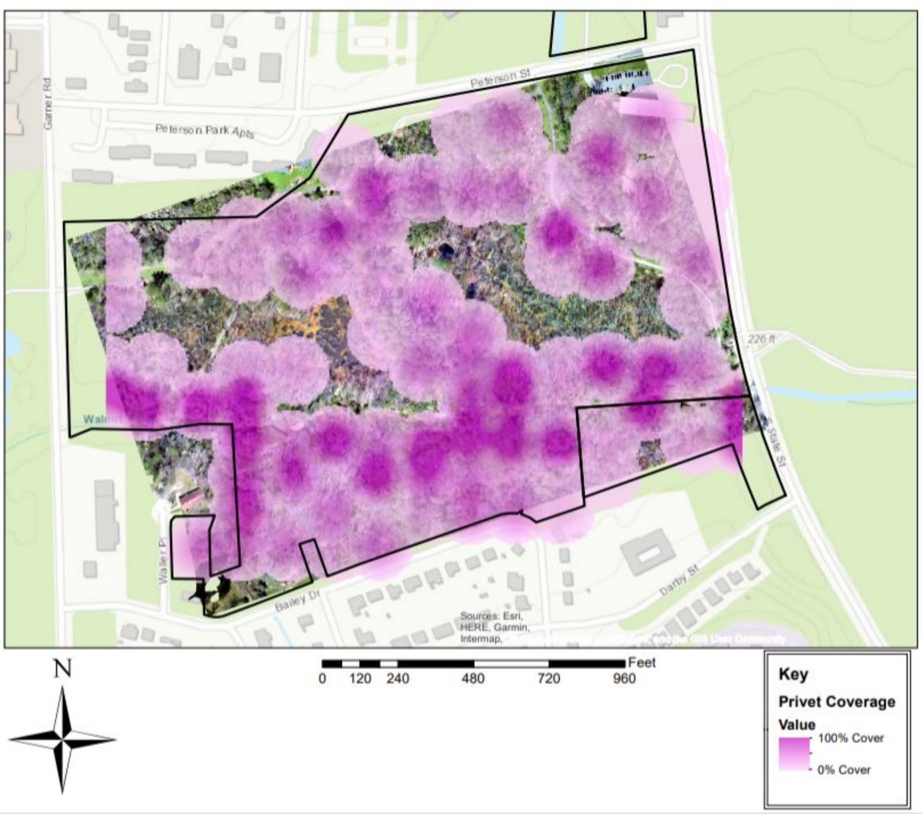


Figure E2. Density Map of Chinese Privet in Walnut Creek Wetland Park

Water Quality in Little Rock Creek

Walnut Creek Wetland Park has previously identified the presence of *E. coli* in Little Rock Creek and wanted more information about the concentration of it throughout the creek as well as the inlets that possibly contributed to the *E. coli* concentration. This would allow City of Raleigh Staff to create a plan to limit *E. coli* concentrations in the creek. We tested 11 different places that were near inlets along the creek between Chavis Park and the Wetland Park for *E. coli* as well as temperature, pH, nitrate, specific conductance and dissolved oxygen.

Sampling indicated that the levels of *E. coli* were generally higher than State guidelines allow, particularly during and for up to a week after heavy rain events (Figure E3). The source of the *E. coli* may be a sewage leak, but the data seem to indicate that it is most likely from animal waste being washed into the creek. The levels of nitrate, pH, and dissolved oxygen were all suitable for aquatic life and indicated overall good stream health.

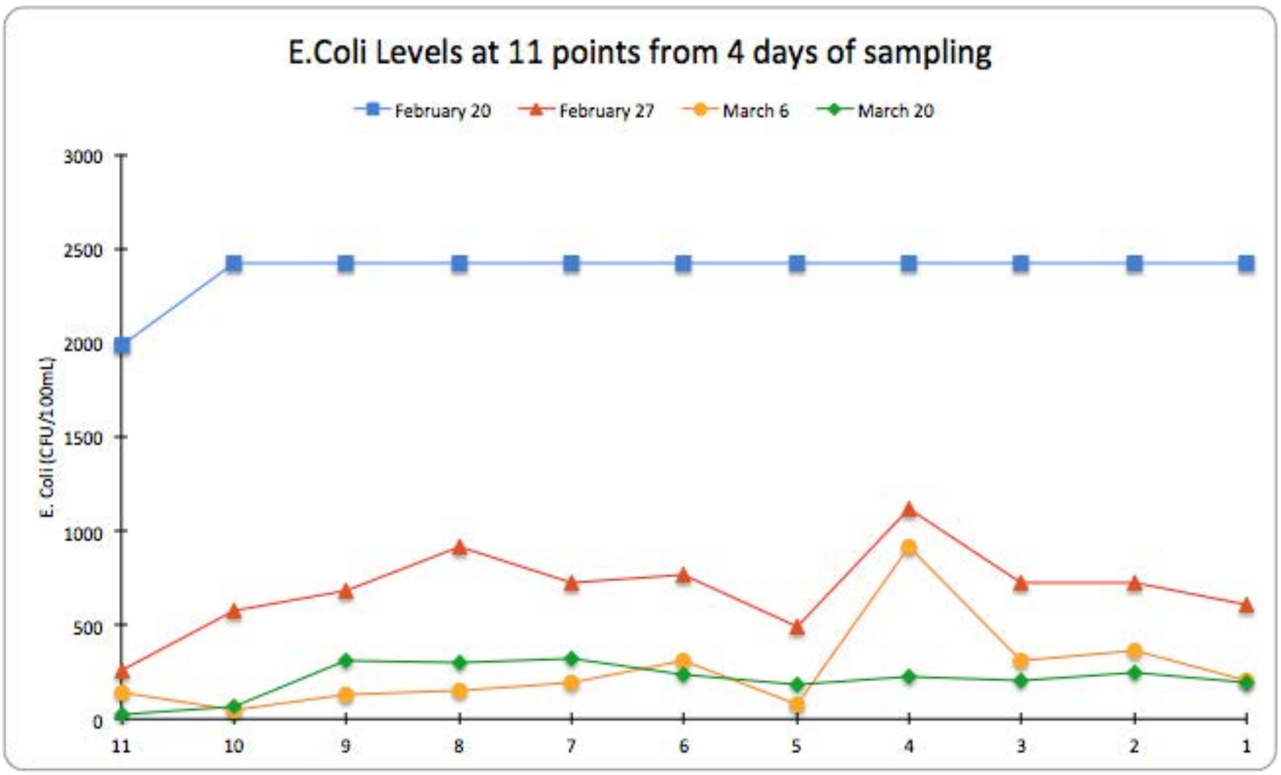


Figure E3. E. Coli levels at 11 points of sampling from 4 days of sampling, with February 20th indicating the date of a major rain event.

Southside Connector Trail

One of the main development goals noted in the master plan for Walnut Creek Wetland Park is a trail that runs through the southern region of the wetland. The purpose of this trail is to provide a more accessible entrance for the Rochester Heights community to the south of the park. There are many long-term plans in place to make this happen, however, the director of the park would like a simple mulched or similar path to be put in place within the next 1-2 years. We evaluated the moisture levels of the soil and the standing water levels at various locations in the area of study to determine if mulch would be a viable option. Three possible routes were mapped out through the area, with mulch being a possibility for the majority of each (Figure E4). In some areas, however, we are recommending a grounded boardwalk comprised of simple wooden planks to provide some resistance against the flooding that often occurs.

Figure E4. Three proposed pathways to connect the south side of Walnut Creek Wetland Park to the rest of the park and the Walnut Creek Wetland Center.

Wildlife

We conducted a wildlife inventory at the Walnut Creek Wetland Center that focused on four main elements: mammals, herpetofauna, fish, and birds. This inventory will provide Raleigh Parks, Recreation, & Cultural Resources with valuable information for environmental education. Although our main purpose was a presence and absent study, we also wanted to be able to provide pictures and recordings of wildlife within the park for the nature center. Methods for obtaining wildlife inventory include electrofishing (Figure E5), Sherman live traps, camera trapping, coverboards, wildlife audio recording system, and incidental sightings that were reported to us. Overall, we identified 66 species at Walnut Creek Wetland Park: 12 species of mammals, two amphibians, 7 reptiles, 12 fish, and 31 bird species.

Figure E5. The Wildlife group demonstrating electrofishing methods in Walnut Creek.

1. Introduction

Walnut Creek Wetland Park is a 58-acre park located in Southeast Raleigh (Figures 1.1-1.2). A Wetland Center educational building and associated parking were constructed in 2008 on the northeast corner of the park (Figure 1.2), opened to the public in 2009, and renamed the Norman and Betty Camp Education Center in 2018. The City of Raleigh Parks, Recreation, & Cultural Resources manages the park, which consists of many different species and plants. Hardwood and Cypress trees dominate the wetland, and both Walnut Creek and Little Rock Creek runs through the park. The north side of the park faces Carnage Middle School while the southern portion of the park borders the Rochester Heights neighborhood (Figure 1.2).

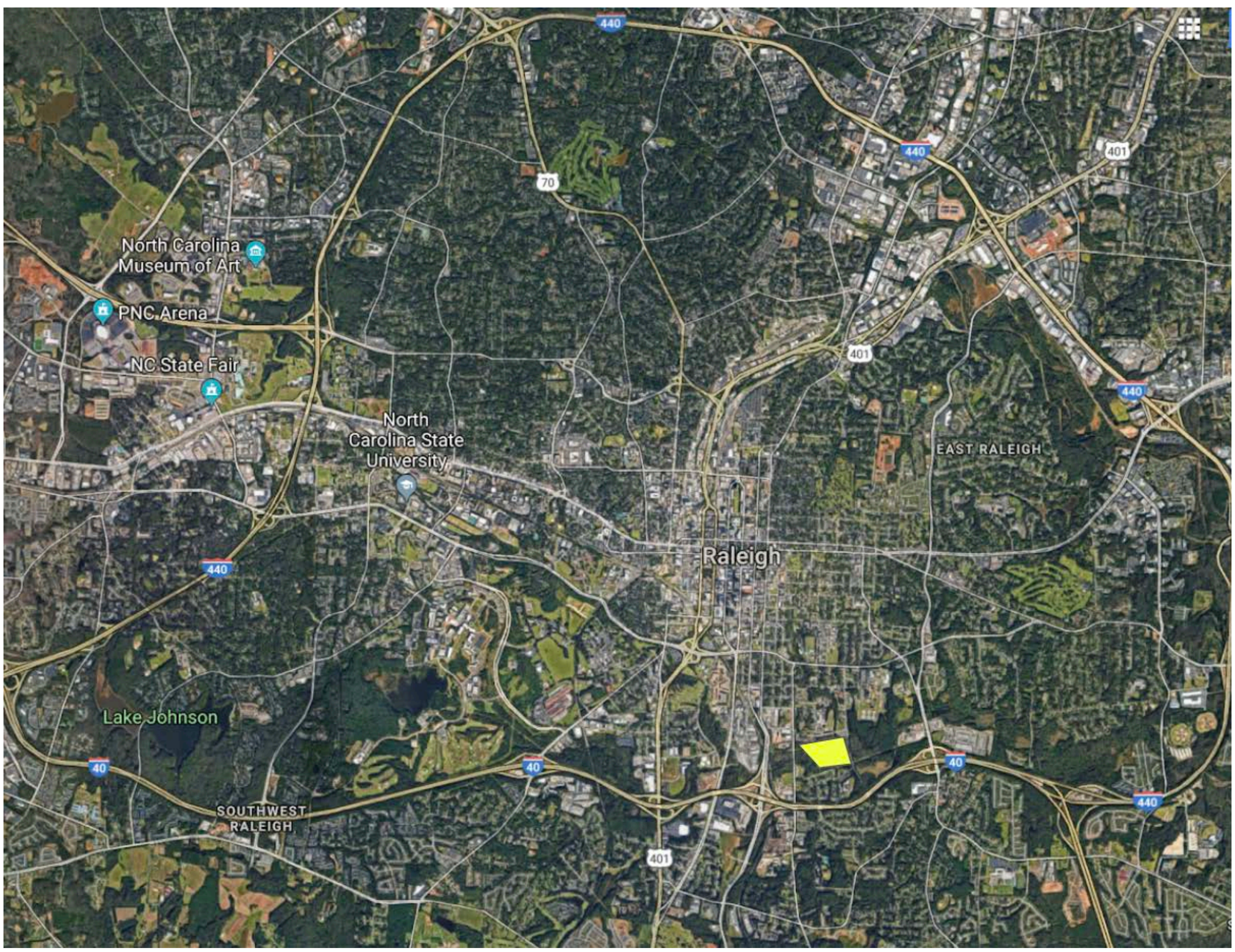


Figure 1.1. *Walnut Creek Wetland Park (in bright yellow) is located in southeast Raleigh.*

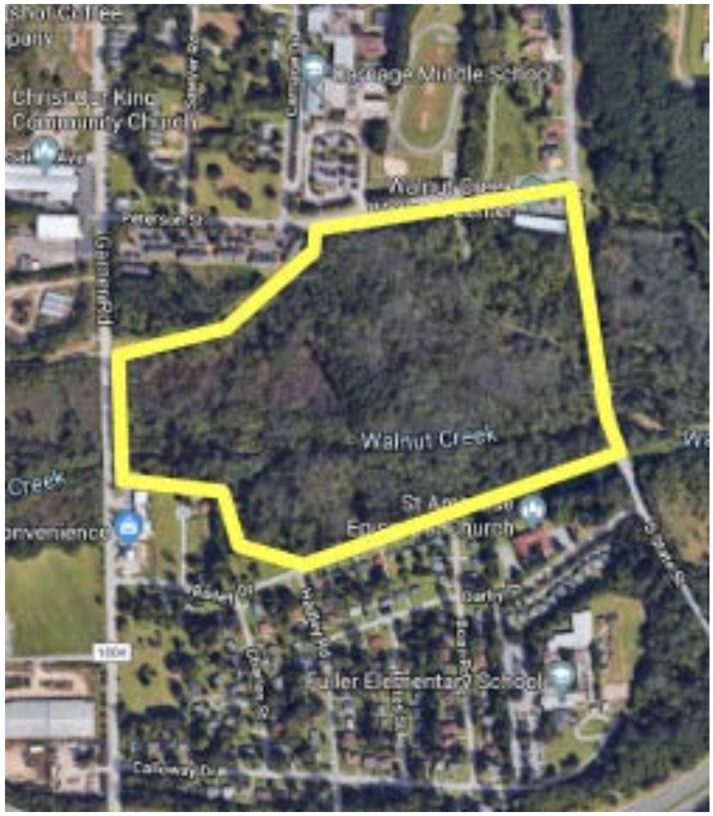


Figure 1.2. *Walnut Creek Wetland Park with Rochester Heights neighborhood to the south and Carnage Middle School to the north.*

1.1. Brief History

The Walnut Creek Wetland Park is a major development for the community and the environment in southeast Raleigh, especially because this area holds a lot of history and has been neglected and misused in the past. This area has been home to black communities since the 1800s when the land was used by African-American farmers. Rochester Heights, which is located south of Walnut Creek, was built after World War II on land owned by the brother of Raleigh's first black mayor and continues to be a community for African-Americans (Raleigh Parks 2017). Also nearby is Shaw University, a school established for free blacks after the Civil War. This area clearly has a deeply rooted connection to African-American communities in Raleigh. During the early to mid 20th century, the City of Raleigh was developing and land owners began to use Walnut Creek as a dumping ground. Because there was not a proper sewage system and treatment plant established until 1958, the water quality of the wetland declined. Since the wetland is located extremely close to downtown Raleigh, the land was developed to create more neighborhoods near the city. Problems arose with flooding in these communities, and combined with the poor quality of the wetland, this made the value of the property in the area decline. Walnut Creek became a low income, predominantly black community in southeast Raleigh by the mid 20th century.

Community action for Walnut Creek began in the 1970s, when floodplain regulations and sediment control regulations were adopted. The National Environmental Policy Act, State Environmental Policy Act, and the Clean Water Act regulations helped to create a better future for Walnut Creek. Interstate I-40 was rerouted because of these regulations and community opposition, saving the wetland from having a major interstate run through it. People began to take notice of Walnut Creek, and how mistreating it had left its condition poor. The Partners for Environmental Justice created the Walnut Creek 2000 Plan, which called for restoration of more than 300 acres of land, as well as improving water quality in the Neuse River basin (Raleigh Parks 2017). A few key goals of this plan were “increasing environmental and habitat restoration, improving water quality and quantity, providing an educational and recreational outlet for residents, and supporting potential funding for park improvements.” As goals from the Walnut Creek 2000 Plan came to fruition, the Walnut Creek Wetland Center opened in 2009; the center was renamed The Norman and Betty Camp Education Center in 2018 in honor of Dr. Norman Camp and his wife, Betty, who played a major role in its creation. The center’s main purpose is to educate the community about Walnut Creek, and the important role the wetlands play in keeping the community healthy. The wetland center hosts programs for children of all ages, and also plan community clean ups for Walnut Creek.

1.2. Purpose and Need

We collaborated with Walnut Creek Wetland Park staff to provide inventory information in support of the Walnut Creek Wetland Park Master Plan (Raleigh Parks 2017). We established five research teams, each focused on an issue or question that Wetland Park staff expressed: exploring design of a community garden and nature play area, locating invasive Chinese privet populations within Walnut Creek, identifying a suitable foot path that connects Rochester Heights to the Walnut Creek Wetland Center, examining the water quality of Little Rock Creek, and updating the wildlife inventory of Walnut Creek. Each team aims to learn more about Walnut Creek, and make it a safe and enjoyable environment for the community to use.

The Garden and Play Area Team had the goals of exploring the design and location of a community garden and a nature play area within the park. One goal of Walnut Creek Park is to engage people of all ages, teach them about nature, and stimulate their senses and learning abilities. This team researched how to properly achieve this goal within areas that children and adults can have fun and connect with nature.

The Invasive Species Team examined the population of Chinese Privet within Walnut Creek Park. They wanted to find areas where Chinese Privet was heavily dense, so that they could help the Walnut Creek Wetland Center mitigate the invasive species population.

The Southside Connector Trail Team wanted to provide better access to the park from the southside, which borders Rochester Heights. To find the best pathway, they collected soil samples to see where the ground was too wet, which would call for either a detour or a boardwalk path. The goal was to give those who live in Rochester Heights a better, safer way to access the park besides walking along roads with no sidewalks.

The Water Quality Team's main goal was to collect more data on the E. Coli concentrations within Little Rock Creek, and try and find hotspots along the creek in order to better mitigate the problem. In addition to E. Coli, the team also assessed the overall health of the stream by collecting.

The Wildlife Team wanted to provide the Walnut Creek Wetland Center with an updated wildlife inventory for Walnut Creek Park. They used Sherman traps, electrofishing, camera trapping, and cover boards in order to conduct this wildlife inventory.

Since the mid 1900s, the Raleigh community has sought to improve the condition of Walnut Creek, and to create a better space for those living in the Walnut Creek community. This area has a rich history, and has faced environmental issues for many decades. With the information we have compiled, the Walnut Creek Wetland Park can continue to make improvements within the wetland to provide a healthy, beautiful park for the community to use.

2. Community Garden & Nature Play

2.1. Overview and Summary

Our goals were to (a) identify a suitable configuration of planting beds and plants for a community garden in the Walnut Creek Wetland Park and (b) identify an appropriate design for a nature play area that would maximize the enjoyment and safety of visitors.

Creating a community garden with a walking path and recreational area would encourage people from adjacent communities to increase their interaction within the park. Community gardens promote connection and interaction with the outdoors, which is important for mental and physical health. Our proposed garden will contain local, historical and native plants, which will help promote community engagement and interaction.

The play space is intended for all children less than 10 years old but primarily for children between ages 3-7. The incorporation of a nature play area in the park is important for the development of children who visit the park, as it allows them to interact with nature in a safe but realistic environment (McCurdy Et. Al., 2010). The location for the nature play area should be safe and include an abundance of natural elements that foster children's appreciation of the natural environment (Fjortoft, 2001). We conducted soil data research, consulted fellow nature play areas and carried out a risk-benefit analysis to determine which aspects would be beneficial at the park.

2.2. Community Garden

Our objective was to examine the feasibility of a community garden and identify potential approaches to creating one. The purpose of the community garden is to help with community involvement by encouraging others to work together for a common goal and teach the importance of sustainable and attainable food (McCurty Et. At. 2010). The goal is to show that having a variety of plants in community gardens is important; a garden with a variety of plants that are historical, native, and local will encourage an immersive and educational experience for the community within the garden.

Walnut Creek Wetland Park staff have identified an area across Peterson Street from the Wetland Center for a community garden (Figure 2.1) which was further constrained by construction of a rain garden in the area's southwest corner (Figure 2.2). Soil samples were collected to determine whether the area is compatible for a garden and whether the soil is acceptable to be used for recreational purposes (see Section 7.1.1). The soil samples indicated that the current soil would require significant amendment to support plant life, so it was determined that raised beds would be the most feasible. Visiting neighboring gardens in Raleigh was important so that we could explore plant types and common layouts (see Section 7.1.3). We learned through consultation that raised beds might be a better approach anyway because of a myriad of reasons but mainly because they offer accessibility to a variety of people. We want to incorporate everyone in the community garden and by making everything wheelchair accessible, we can do just that. A community garden offers a place for people of all abilities to relieve stress and gain the benefits

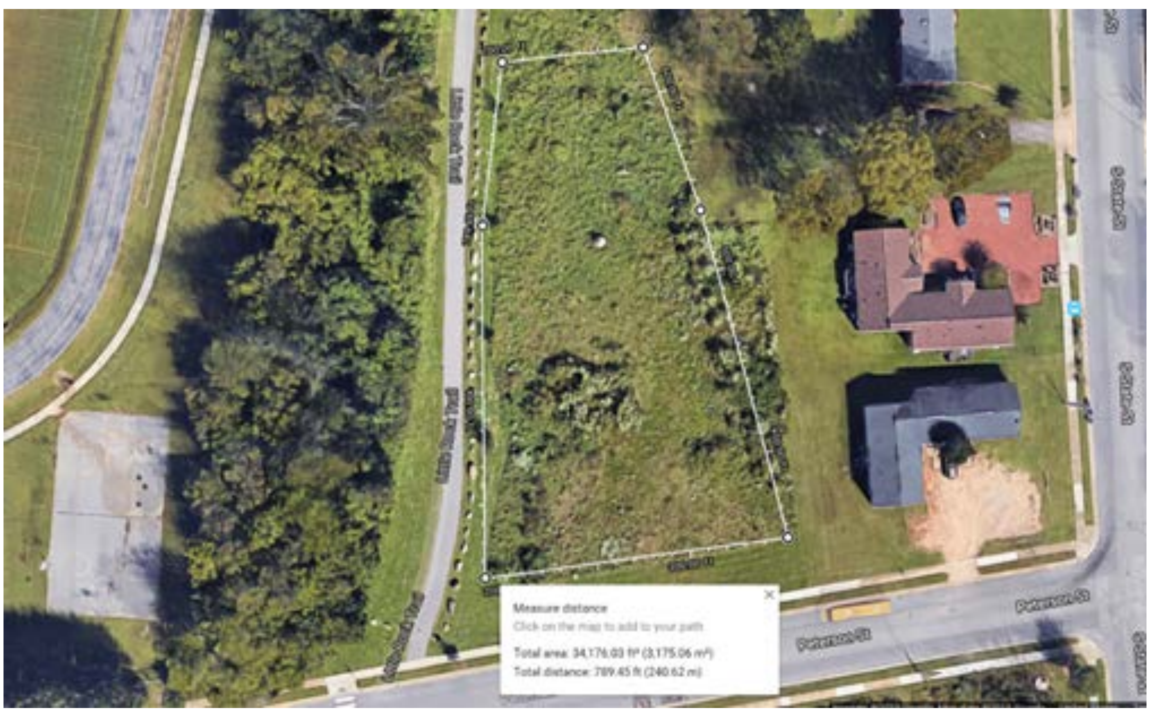


Figure 2.1. *Map outline of the area identified by Walnut Creek Wetland Center staff for community garden, across the street from the conference center, next to the greenway.*

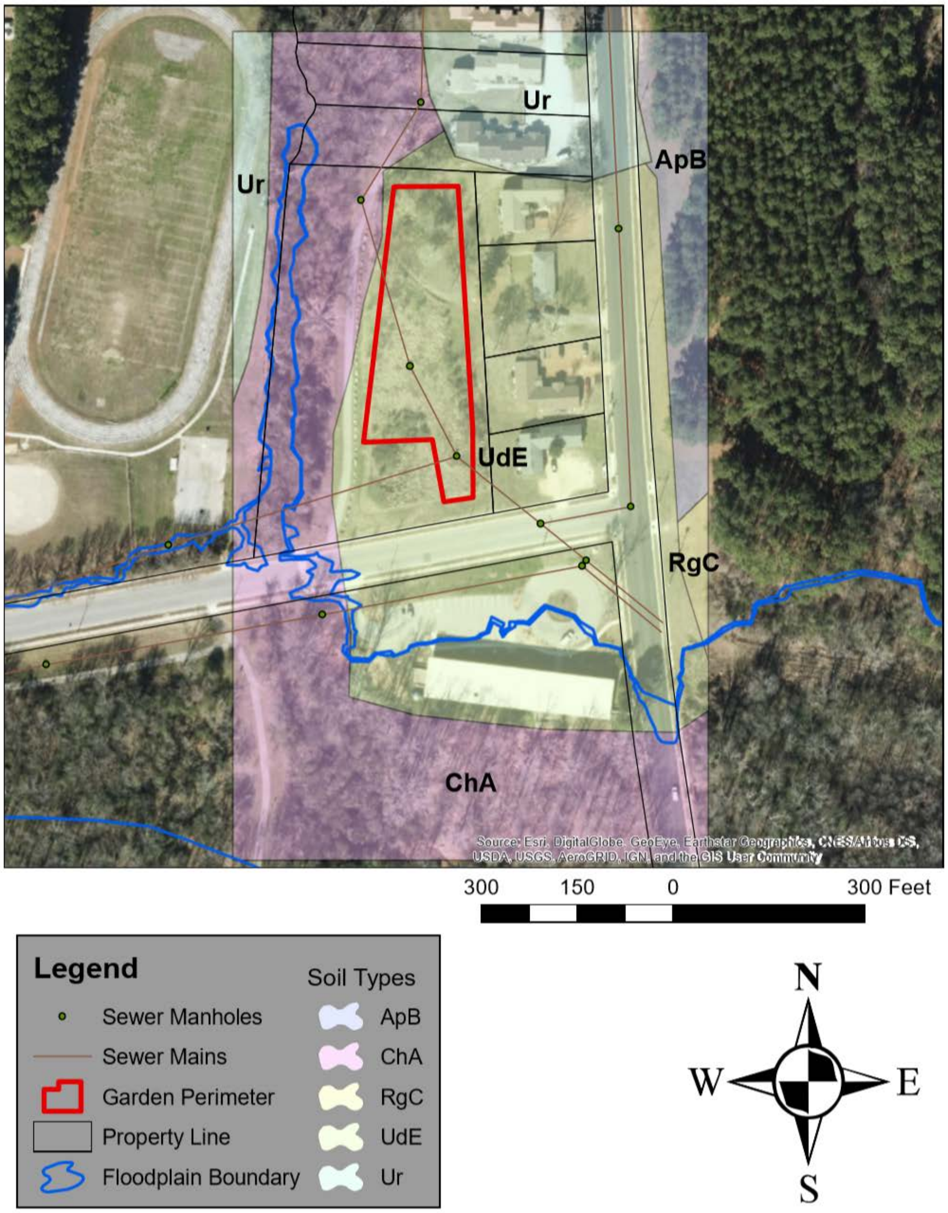


Figure 2.2. *Site proposed for a community garden, outlined in red, eliminating from consideration for the area to be used for a rain garden. This map shows the sewer line, the soil types (Table 2.1), the property lines, and the floodplain boundary. (Data Source: Wake County and USDA)*

that come from working in a garden. Designing a garden that is accessible to all people means that everyone in the community feels welcome and can get involved (Bravo, 2015). Therefore, we recommend raised beds as well as the inclusion of an assortment of pollinator, native, food, and sensory plant types.

Table 2.1. *Description of the soil types reference in the Figure 2.1 map.*

Soil Type Symbol	Soil Name and Slope
ApB	Appling Sandy loam, 2 to 6 percent slopes
ChA	Chewacla and Wehadkee soils, 0 to 2 percent slopes frequently flooded
UdE	Udorthents loamy, 0 to 25 percent slopes
RgC	Rawlings-Rion complex, 6 to 10 percent slopes
Ur	Urban Land

We sampled soil in the garden area to determine whether it would support growth of the desired plants (see Section 7.1.1, Figure 2.3). The soil was deficient in phosphorus (Figure 2.4) but overall sufficient in potassium (Figure 2.5). Phosphorus is used by plants to help form new roots, make seeds, fruit and flowers and even help fight disease (Boone et al, 1999). Potassium helps plants make strong stems and keep growing fast. Humic matter percentages were too low (Figure 2.6) while pH levels were too high (Figure 2.7). Humic matter aids with fertility and water retention in soils while pH influences the availability of essential nutrients. The soil's cation exchange capacity is relatively low (Figure 2.8). The cation exchange capacity influences soils ability to hold on to essential nutrients and provides a buffer against soil acidification.

With the results of this sampling, we concluded that the soil will need intense remediation to support robust plant growth. In addition, through consultation with other nearby community gardens, it was recommended that we consider raised beds due to the ease of raised beds in comparison to planting directly in the ground.

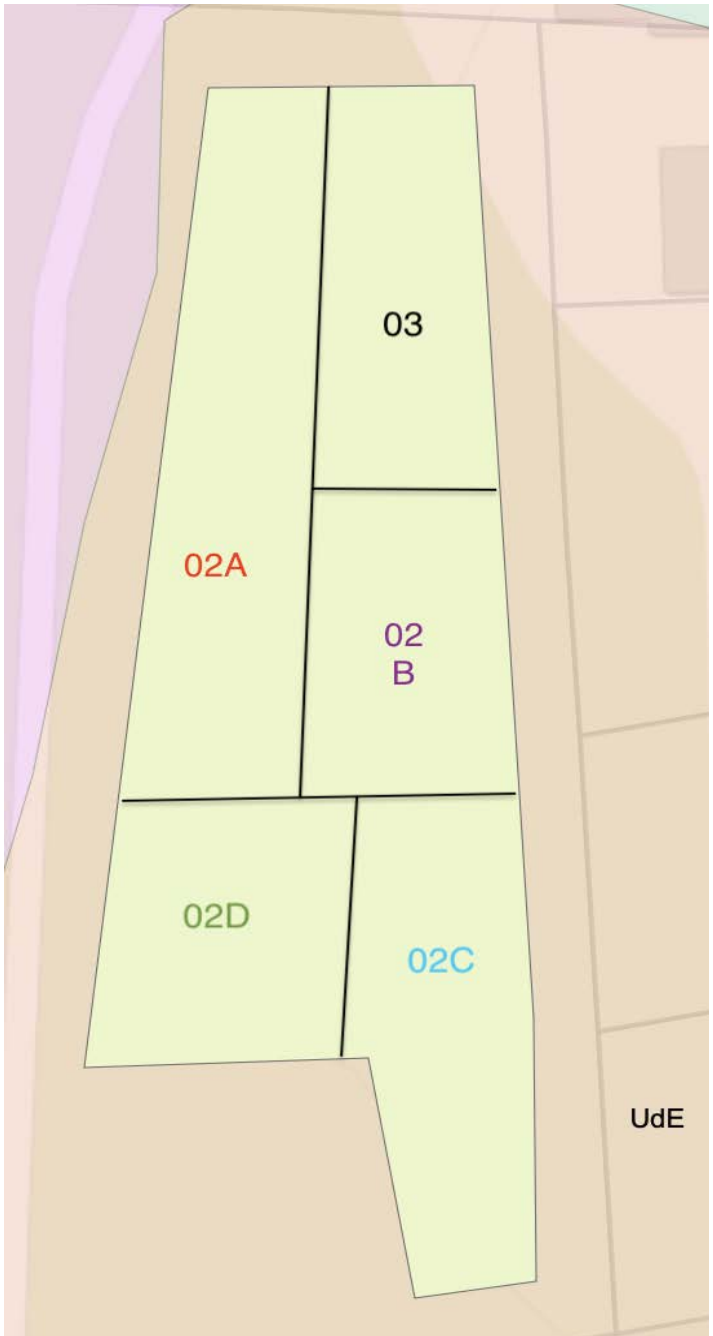


Figure 2.3. *The perimeter of the garden area along with where soil samples were taken. Soil was extracted from the ground using a soil auger in three locations within each of the labeled areas then mixed for testing (see Section 7.1.1)..*

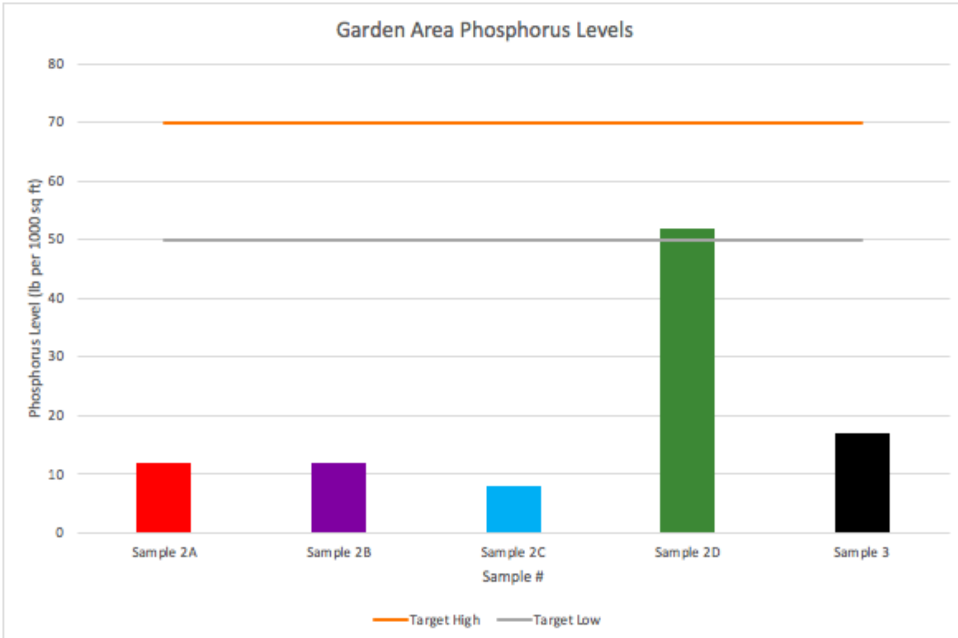


Figure 2.4. *The phosphorus levels within the outlined garden area. The recommended phosphorus level is outlined by the grey Target Low line and orange Target high horizontal lines. Other than the Sample 2D area, the rest of the sample areas had phosphorus levels well below the recommended values.*

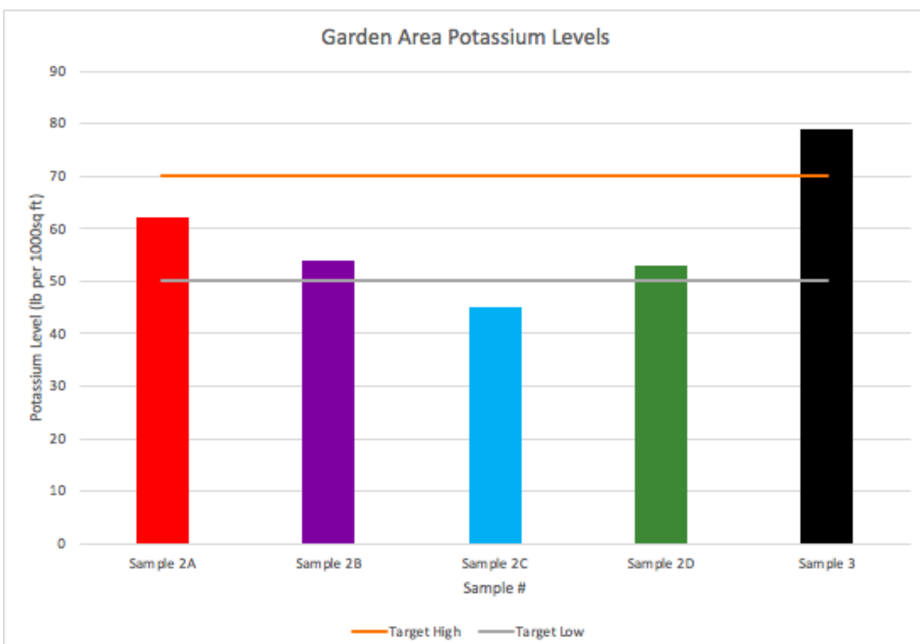


Figure 2.5. *The results of potassium levels within the outlined garden area. The recommended potassium level is outlined by the grey Target Low line and orange Target high horizontal lines. Sample 2A, Sample 2B, and Sample 2D areas are within the recommended levels of potassium. The Sample 2C area is below recommended levels. The Sample 3 area is oversaturated with potassium and above the target level.*

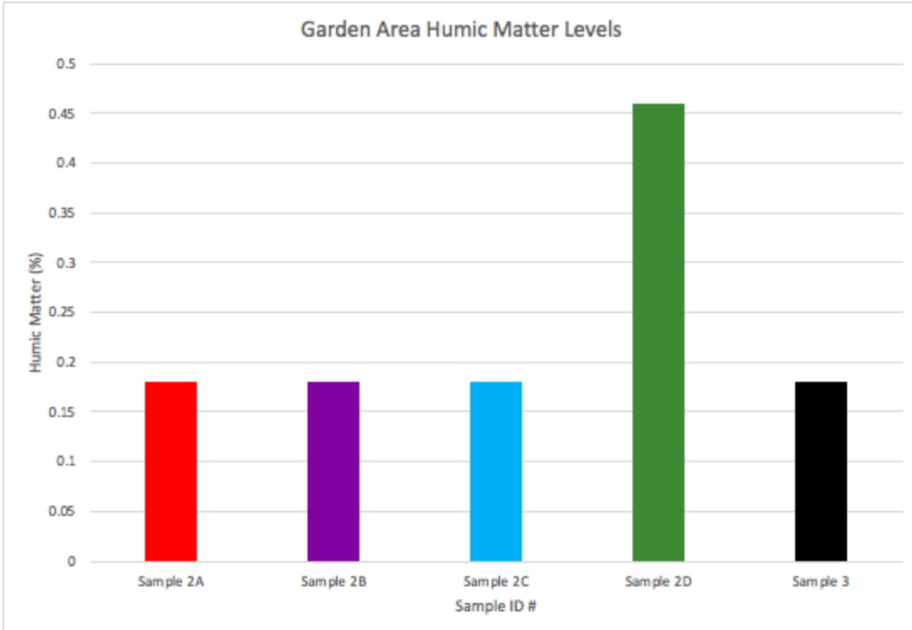


Figure 2.6. *The garden area humic matter levels. Humic matter is important for plant growth because it helps with fertility and water retention in the soil.*

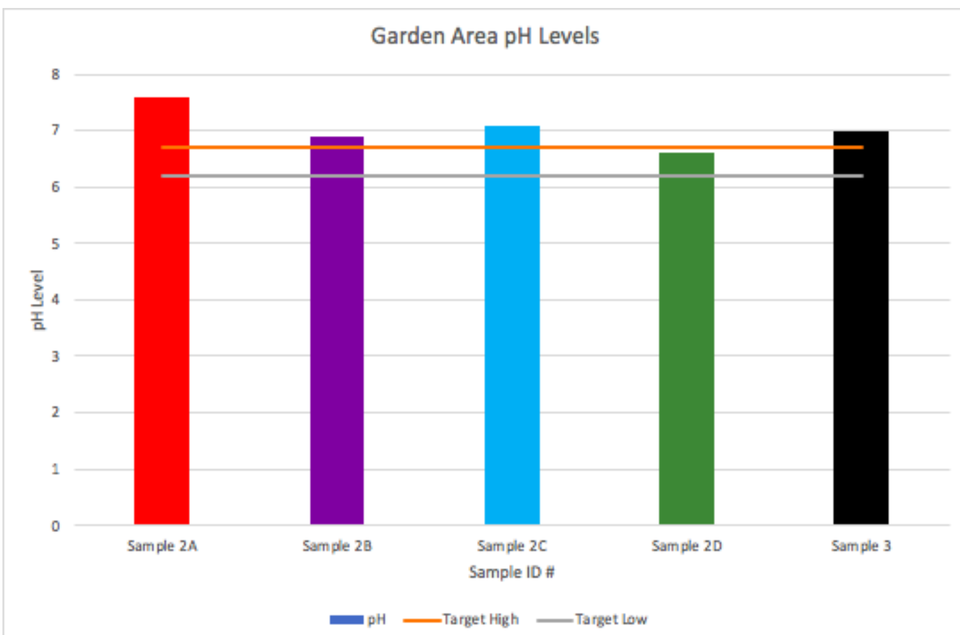


Figure 2.7. *The pH levels within the outlined garden area. The recommended pH level is outlined by the grey Target Low line and orange Target high horizontal lines. The only sample area with the recommended pH level is the Sample 2D area. The rest of the sample areas have higher pH levels than what is recommended.*

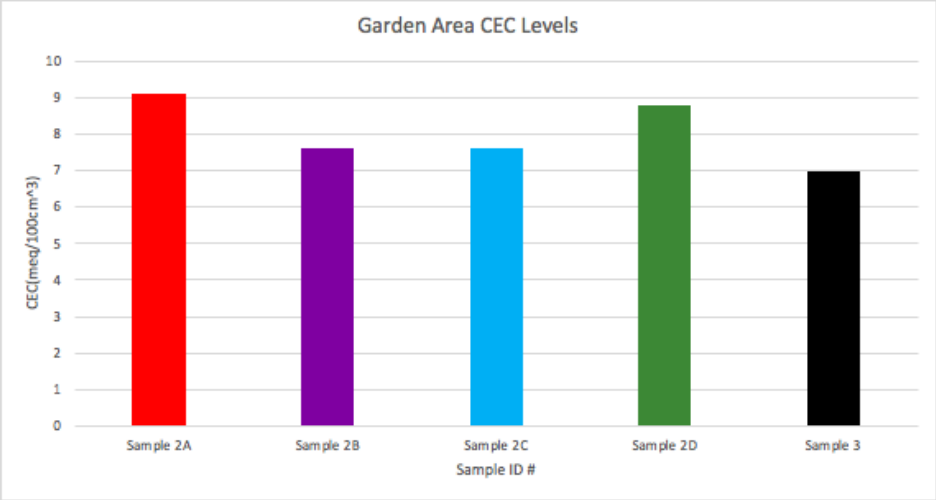


Figure 2.8. *The soil test results of the cation exchange capacity levels. CEC Cation Exchange Capacity is a characteristic of soil that influences its ability to hold on to essential nutrients and provides a buffer against soil acidification.*

2.3. Community Garden Recommendations

Use Raised Beds. Raised beds are the best option for the garden based upon the soil conditions in the proposed area and the desire to make the garden accessible to people who cannot bend or kneel down to the ground (Bravo 2015). Raised beds should be maximum 5 feet wide if they need to be reached from all sides; when one side is up against the wall the maximum should be 4 feet wide (Figure 2.9). The height for the raised beds should be 20 inches to 35 inches tall.

Figure 2.9. *Image of raised beds (Bravo, 2015).*

The recommendations for wheelchair accessible beds are that each should be 5 feet wide, so they can be reached from all sides (Figure 2.10). The height of the beds should be 34 inches tall. This means the bed should start 27 inches up from the floor to include enough space for a wheelchair. This empty space for the wheelchair needs to extend 19 inches under the bed. The bed needs to have a height 7 inches of soil for the plants; making the overall height 34 inches (Bravo, 2015).

Figure 2.10. *Images of wheelchair accessible raised beds (Bravo 2015)*

Use Pollinator Plants. Pollinator garden includes plants that attract a variety of pollinator species such as bees, butterflies, and hummingbirds (Table 2.2). Pollinator plants not only draw beautiful wildlife to the garden for the community to watch and appreciate, but they also help draw pollinators to the area that can help the entire garden thrive. Pollinator plants usually contain a very strong smelling odor, or brightly colored flowers to attract pollinators from a far (North Carolina Native Plant Society, 2017).

Include Historic & Native Plants. Historic plants are very important to sustaining natural ecosystems, including community gardens. Historic and native plants are plant species that are local to a specific region in the world or climate. Each part of North Carolina has many different climate and soil types that allow preferred growth of specific plant species. Native species of plants also have native “checks” or predators that keep the species from becoming overpopulated which is a quick way to destroy an ecosystem (North Carolina Native Plant Society, 2017). The area surrounding Walnut Creek Wetland Park were historically farming for minority populations

(Walnut Creek Wetland Park Master Plan, 2017). Including these types of historic plants in the garden help to teach the local area the history of the place they live in.

Develop a Sensory Garden. Sensory items in a garden are crucial for child growth and sensorineural stimulation. Sensory items include different smells, different feelings, as well as different looks of specific plants. Literature has shown that children exposed to "sensory gardens" tend to have more pleasant and meaningful nature interactions resulting in higher brain stimulation. Sensory gardens encourage children, including children with special educational needs, to promote educational development and stimulate social skills. (Hussein, 2012).

Use Edible Plants. Demonstrating to the local community that they can grow their own food at home is a great way to connect the local families with nature. Fruits and vegetables grown at home also provide incentive for younger children to eat more healthy and take pride in providing for themselves (Rosenow & Wirth, 2009).

Table 2.2: *Recommended plants for each bed (Pollinator/sensory/historic/edible) (North Carolina Native Plant Society, 2017).*

Plant Category	Recommended Plants
Pollinator Plants	Easten Blue Star, Swamp Milkweed, Wood Anemone, Northern Maidenhair Fern, Dwarf Crested Iris, Aster Carolinianus, Cimicifuga Racemosa
Sensory Plants	Rosemary, Lemon Balm, Lambs Ear, Aloe, Basil, and Lavender
Food Plants	Figs, Pears, Chestnuts, Peascans, Persimmons, Plums, Bean species, Cherry Tomatoes, Cucumbers, Watermelon, and many other seed species available at the local farmers market
Historic Plants	Easten Blue Star, Swamp Milkweed, Wood Anemone, Northern Maidenhair Fern, Dwarf Crested Iris, Aster Carolinianus, Cimicifuga Racemosa.

2.4. Nature Play Area

Our objective for the nature play area was to show how you can create a safe, fun area out of nature-made equipment. Play areas are important because they can help develop sensory and cognitive function in young children (Fjortoft, 2001). Visits to Prairie Ridge Ecostation in Raleigh, NC (see Section 7.1.3), gave examples of successful nature play equipment which helped with the selection of equipment that could be recommended to Walnut Creek Wetland Park. The purpose behind visiting a similar nature play area was to gain perspective on how essential it is for children to gain these important skills, and also to explore natural equipment ideas. To ensure the safety of each proposed piece of equipment we conducted a risk matrix analysis to determine potential risk as well as benefit of the activity (see Section 7.1.3). Any activity that was deemed to be “high likelihood” and “high consequence” was eliminated, resulting in a list of equipment that could be an asset at Walnut Creek.

The nature play area was strategically planned to incorporate the most beneficial natural playground equipment for childhood development (Rosenow & Wirth, 2009). The proposed location for the nature play area was determined through discussions with the Park Director, in order to allocate room for other future park projects in the area (Figure 2.11).

We conducted soil sampling in the nature play space area (see Section 7.1.1). It was important to sample soil in this area to make sure the soil was not too acidic or harmful for the children to play in. It was unlikely for there to be any issue, however, it was a necessary action to negate all forms of potential harm (Boone Et. Al., 1999).

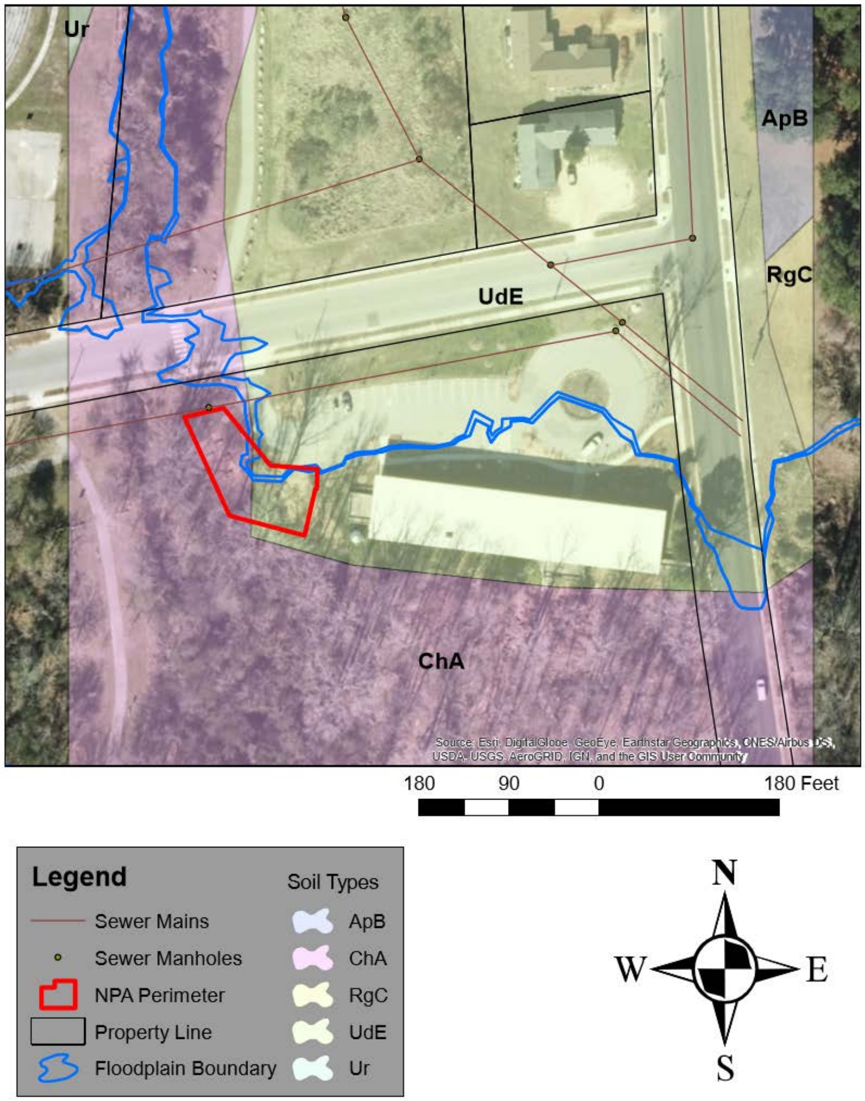


Figure 2.11. *Proposed site for Nature Play Space. This map shows the sewer line, the soil types (see Table 2.1), the property lines, and the floodplain boundary. (Data Source: Wake County and USDA)*

Risk benefit analyses can be important in determining whether an action or item is beneficial or has too high of a risk associated with it. We conducted a risk benefit analysis to determine whether aspects from various other nature play areas would be useful in the Walnut Creek location (see Section 7.1.3). Each proposed station in this playground is required to fall under green or yellow risk levels equating to low level of probability or severity of injury (Figure 2.12). If the proposed play area element was placed in the red section, it should be rejected in the final playground layout.

Probability		Severity			
		Insignificant	Minor	Moderate	Major
	Rare	**Fairy Mailbox, Bell Tree, Intentional Incline, Tree Cookie Art**	**Fossil Pit Ball Tunnel**	**Dig Pit Music Area**	
	Possible	**Stump Steps**	**Balance Beam**		**Tunnel**
	Almost Certain			**Water Feature Cistern**	
	Severity Key:	Insignificant: Breathe in dust.	Minor: Cut, Scrape, Bruise	Moderate: Sprains, hit head	Major: Breaks, contusions

Figure 2.12 *Risk Matrix for Probability and Severity of Child Injury*

2.5. Nature Play Area Recommendations

The features found to be favorable and being recommended for use at Walnut Creek include a fairy mailbox, a bell tree, an intentional incline, a tree cookie art station, a fossil pit, a ball tunnel and stump steps (Figures 2.13-22).

Figure 2.13. A “fairy mailbox” is similar to a “gnome home” where children are able to send and receive gifts from fairies. All of the items items found in the park, encouraging engagement and imagination within children. The installment of a fairy garden will be a fun, low risk attraction that will be highly beneficial to children’s imagination and play.

Figure 2.14. The bell tree is a simple tree that has bells tied onto it. When a child or strong breeze shakes the tree it makes sounds which engage a child’s senses. The bell tree is a low risk attraction that allows sensory growth in children by listening and touching the tree.

Figure 2.15. An intentional incline is essentially a few small hills made of excess soil. These can be strategically placed within the park to encourage children to use them as a means to get from one end of the nature play area to the next. It encourages children to work on their muscular growth as well as balance.

Figure 2.16. Tree cookies, slices from a fallen tree, can be used to draw on with chalk. The “cookies” are reusable and the chalk is able to be washed off intentionally or overtime by the rain. The cookie is a different medium than normal paper which stimulates more creativity and artistic thought.

Figure 2.17. The fossil pit is a 4ft x 4ft pit lined by petrified wood and filled with a fossil mixture. This fossilized mixture includes fossils of insects, plants, shark teeth, aquatic vertebrates which can be obtained from a North Carolina mine that has a large amount of these fossils available to be picked up.

Figure 2.18. The ball tunnel is created with a split PVC pipe and several blocks that can be stacked to adjust height, which is one of the only unnatural pieces of equipment in the park. The pipes can be taken apart and put together to be designed as the child pleases, this will encourage problem solving and mental stimulation. The objective is to roll the ball down the ramp, and with different sized balls this will also help muscle building.

Figure 2.19. The stump steps are an item with minimal risk that are easy to design and maintain. The stump steps are small slices of fallen trees of differing heights that can help to build muscles, balance and foot eye coordination. These stumps allow children to hop from one spot to the next while changing the height and distance between steps.

There are three additional features we recommend tentatively, because they have a slightly higher risk. These features include a dig pit, music area and balance beams.

Figure 2.20. The dig pit is a large area, that has been emptied and filled with a sand/soil mix and will be accompanied with small shovels to allow children to engage in physical activity while using creativity. This is slightly dangerous as the children would be able to accidentally or intentionally injure each other with shovels or sand. This would also offer only slightly different benefits than the fossil dig pit, which has slightly less risk associated with it due to the nature of its set up and the materials used with it.

Figure 2.21. A “music area” is comprised of a series of natural materials such as wood which is strung from a wooden frame. Children can make music with this by hitting the materials with different naturally made “drumsticks”. This is a beneficial piece of a nature play space due to the collaboration children can have with each other and the sensory stimulation that this allows. This is also, however, something that could allow children to injure themselves and others, due to the nature drumsticks as well as the rope and other equipment used in its construction. Though it is a beneficial feature, the risks of it could potentially be high and therefore more consideration must be made by park workers before it is used at Walnut Creek.

Figure 2.22. Balance beams are constructed using falling logs, which are situated to encourage children to improve their balance, coordination and cooperation with other children. Injuries from this are possible and the risk associated is moderate, as children are capable of falling from it and getting cuts, scrapes and bruises. This means that there is a fairly high risk and it may not be acceptable.

There are two features that we do not recommend, because they carry high risk in this setting due to size, location, or children tendencies: a cistern and a large underground tunnel.

Walnut Creek Wetland Park already has access to a large cistern of rainwater which was proposed to be used in order to incorporate a water feature into the nature play area. Though, to ensure that this would be a safe and feasible source for water for the nature play area, research went into whether a cistern of untreated rainwater would be safe for play purposes. Research (Rosenow & Wirth, 2009) showed that rainwater collected by roof catchments can contain contaminants such as lead and other sediment that may have built up at the bottom between and during rainstorms. Though this could be treated, it would take a lot of investment and regular maintenance and testing in order to ensure that the water remains safe for use. Though this is an option, it was determined that the input and risk behind using the rainwater cistern as a source of water for the nature play area was larger than the benefit that would come out of it.

Other parks, such as Prairie Ridge, feature a tunnel covered in dirt for children to crawl through in the nature play area. This can be good for building the immune system of children, encouraging nature interaction, as well as helping to build muscles and natural skills that cannot be learned in traditional ways. However, the risks of this type of structure are high and problems such as failure of structure, harm to children if used inappropriately, and contusions may arise.

Our overall goal was to help bridge the gap between the park and community through less traditional methods and teach the importance of recreation in nature. By incorporating recreational areas and activities that can be used by all ages it will make the park more inviting to the surrounding area. The nature play space and community garden can add the aspect of community involvement to the Walnut Creek Wetland Park to continue to make it a park the Raleigh area has the privilege of utilizing.

3. Invasive Plants

3.1. Overview and Summary

Invasive plant species are a growing problem across the globe. Invasive species are plant and animal species that infiltrate areas they did not originate within (Hanula and Horn, 2011). This migration of species into different territories may harm the native plant and animal communities. In the southeastern United States, particularly in the forests, invasive species compete for nutrients, shade, and space with native plants, while damaging the natural ecosystems in place (Hanula and Horn, 2011). This is an even larger issue in wetland areas like the Walnut Creek Wetland Park that are also faced with a myriad of other environmental issues, ranging from pollution to nutrient influx (Zedler and Kercher, 2004). Invasive plants in wetlands can overpower native plants more easily than in other habitats, as wetlands are more vulnerable to changes in ecosystem composition. Wetlands also function as sinks, and as such gather substantial amounts of pollutants, nutrients, and debris that contribute to invasive plant survival and rapid growth (Zedler and Kercher, 2004). Lastly, these invasive species do not positively affect the native ecosystems; they form monotypes that are detrimental to the native systems.

In the Walnut Creek Wetland Park, one species of concern is the Chinese privet. For our study we examined the extent and growth of this invasive shrub within the park and estimated the percentage of the land that is covered by Chinese privet. Our intention was to highlight the areas with high land cover percentage from the species and present it to the park staff as a density map, supported with a drone view of the map highlighting an aerial view of the park. This density map will identify the locations the park staff should focus its invasive removal efforts on and go on to assist future volunteer work to rid the park of invasive species such as Chinese privet, and give the native community a chance to grow again.

3.2. Invasive Chinese Privet

Ligustrum sinense, or better known by its common name Chinese privet, is a plant in the *Oleaceae* family that is native to China, Vietnam, and Taiwan. Here in the southeastern United States, it was introduced by landscapers as a hedge plant in 1852 (Swearingen and Bargeron, 2016, Figure 3.1), but it has since become a troublesome invasive species. It can be found as far north as Massachusetts and as far west as Texas. It can grow up to the size of a small tree and it spreads quickly, allowing it to quickly take over an area. The main issue with it as an invasive species is that it overgrows and shades out native understory species and young tree seedlings, completely changing the plant diversity of a forest and damaging the structure and balance of the ecosystem.

Figure 3.1. *Chinese privet (Ligustrum sinense) is an invasive plant native to parts of Asia. Shown here are a young stalk (top) and a closeup of privet leaves (bottom).*

Chinese privet is relatively easy to identify, due to its opposite, simple, rounded leaves with smooth edges (Figure 3.1). The flowers are small and white, and the fruit is a shiny blue/black color. Very few plants have opposite leaves besides maple, buckeye, ash, dogwood, and a few others, so the opposite leaves of the Chinese privet serve as a great identification method. Chinese privet is also green year-round, so it stuck out quite a lot among all the other plants that had lost their leaves.

Figure 3.2. *A large cluster of adult privet, found near Little Rock Creek.*

Stacie Hagwood, Director of Walnut Creek Wetland Park, noted many of the invasive plant in the Walnut Creek Wetland Park, including Chinese privet, arrived as seeds during flooding events (Stacie Hagwood, personal communication). It will grow anywhere in the park that is not saturated or flooded with water, and years of this taking place has led to Walnut Creek having some areas that are completely overrun with Chinese privet (Figure 3.2).

3.3. Privet Densities Mapping of Walnut Creek Wetland Park

We developed a map of Chinese privet cover by sampling privet cover in the field within 10ft-radius circles on a grid of 150ft x 150ft (see Section 7.2). Privet in Walnut Creek Wetland Park is most prevalent along the waterways within the park and less prevalent along the trails around the Wetland Center (Figure 3.3). The denser privet along the two creeks is in line with the waterborne nature of privet dispersal (see Section 3.2). The less dense privet near the Wetlands Center and along walking paths is due to the constant landscaping around those areas.

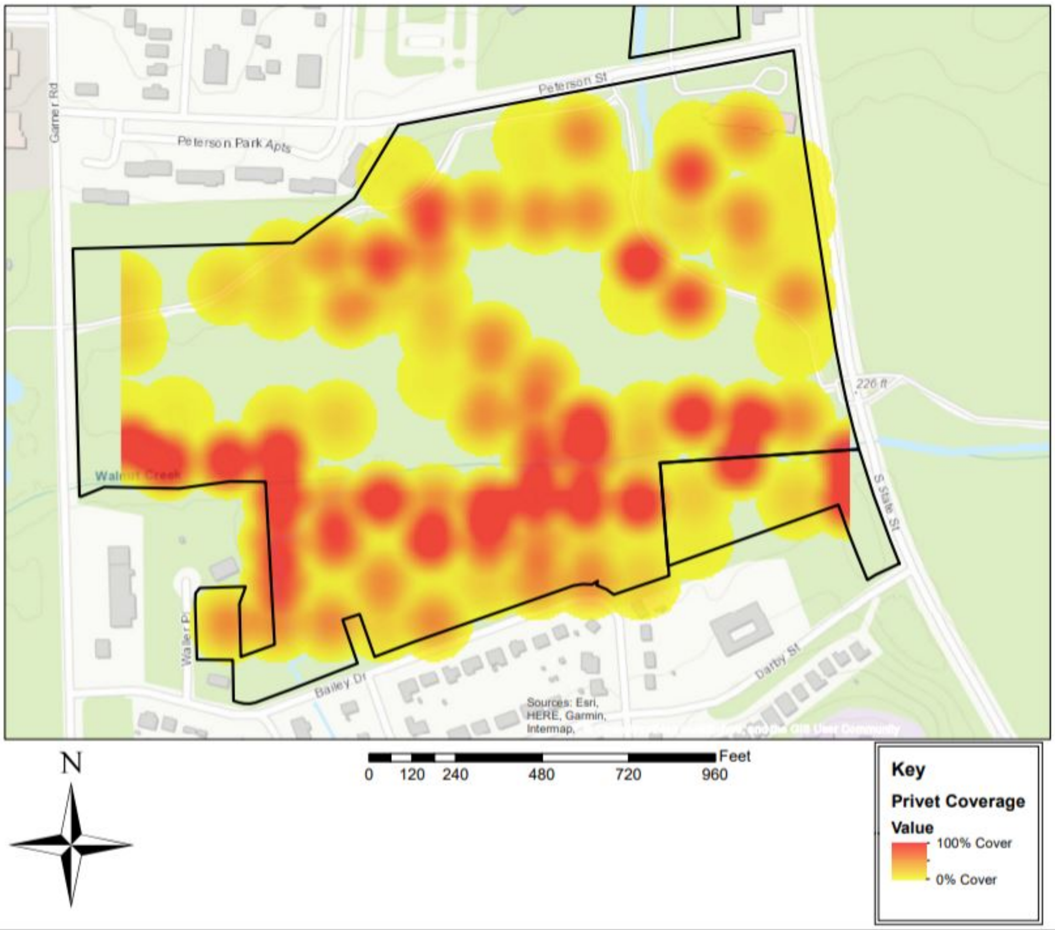


Figure 3.3. *Map showing privet densities. Darker areas indicate denser privet while lighter areas indicate less privet coverage.*

We engaged Evan Arnold, a drone pilot, to collect true color imagery of the park (see Section 7.2.4). This true color imagery was then used in conjunction with our established density map to produce Figure 3.4. The two large ‘blank’ spots in the center of the park are due to those areas being inaccessible mostly due to hazardous conditions: these areas are covered with deep water and deceptively deep mud. As such, we were unable to determine the privet coverage in these areas through field sampling. However, the true color imagery provided by Evan Arnold and processed by Justyna Jeziroska reveals these areas to be free from privet. This is consistent with privet’s intolerance of being submerged (see Section 3.2). Since the purpose of this map is to provide removal crews with valuable information, and those two areas are hazardous, it was deemed unnecessary to collect data at those points beyond what could be observed via drone photography.

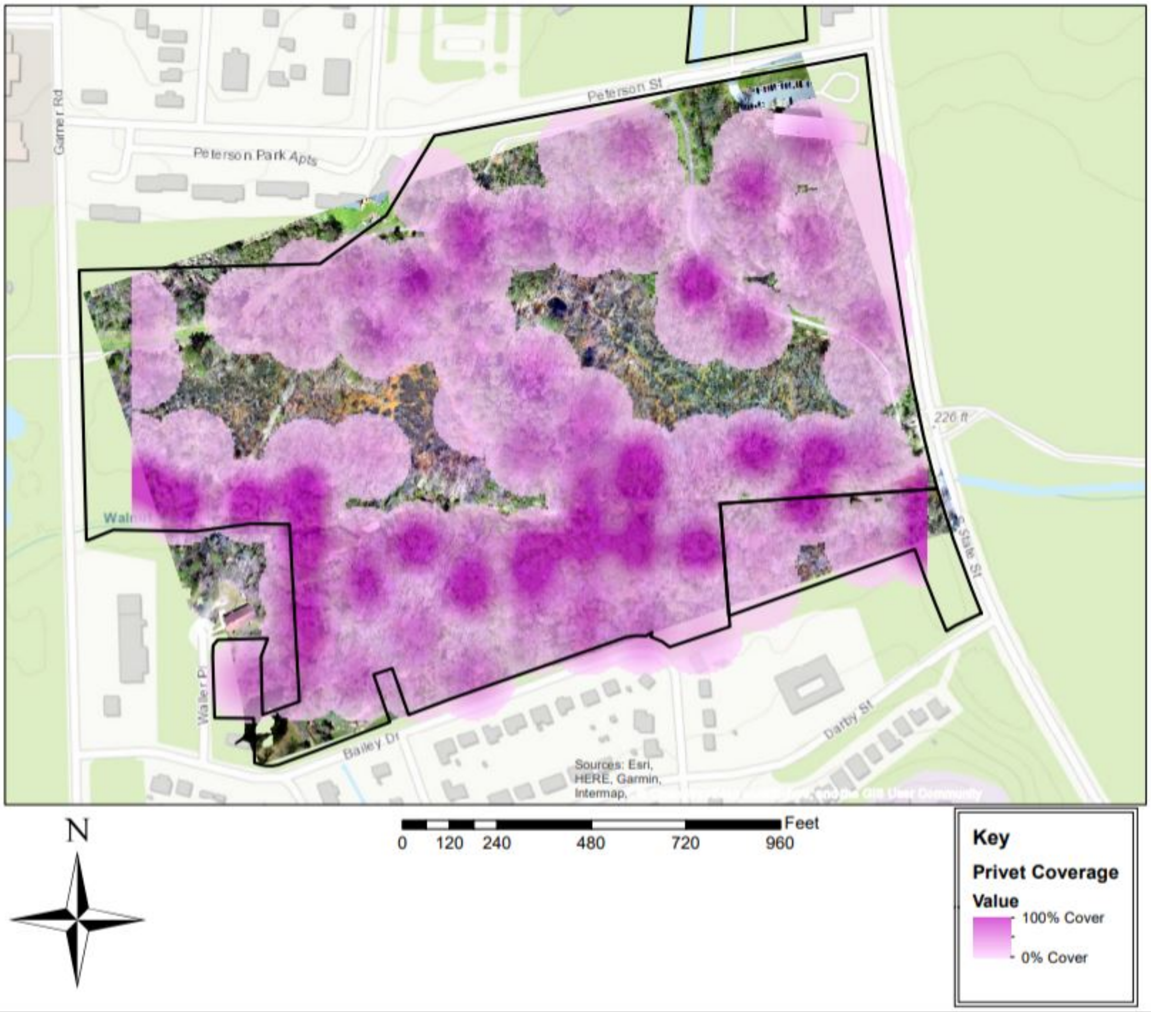


Figure 3.4. *Map showing privet concentrations in relation to flooded areas.*

3.4. Recommendations

We believe that a density map of the Chinese privet coverage throughout the park is the best way to convey which key areas to focus on going forward in dealing with the removal of the privet. In addition to showing the hot spots, the density map also conveys what areas will need to be dealt with using special methods due to the presence of mature adult privet. We consulted with Bryan England, assistant director of Wilkerson nature preserve, on strategies to deal with removing Chinese privet. Young privet shrubs can easily be uprooted by hand or with the help of a small shovel. However, a single adult privet will require the use of a small team of two to three volunteers with shovels to kill completely.

Figure 3.5. *A privet stump sporting new growth.*

If adult privet is cut at the stump, it will not perish, but rather survive and continue to create new growth (Figure 3.5). It must be continually cut back whenever new growth appears and eventually it will wither and die. Cutting back adult privet with a saw and keeping an eye on new growth for several years would be a much less physically intensive task, but more time consuming than removing all of the root bases at once (Bryan England, personal contact). It is at the discretion of the wetland center which path to take. Another thing that must be dealt with is the juvenile privet stalks, which can be found throughout the park. These must be pulled whenever found, otherwise if allowed to grow they can become too much for a single person to deal with. Due to the influx of seeds from upstream sources, young privet will continually pop up around the wetland, and as a result will need to be continually watched for. In addition, because adult privet has been allowed to flower throughout the park for years, young privet shrubs will continue to pop up in even greater numbers long after the adult privet has been fully dealt with. The best time of year to work on clearing privet will be November through March, when most green leafy plants have receded to the cold, as privet stays green year-round. With careful park wide management, privet can be mitigated, and eventually reduced to a very small, manageable level throughout the park.

5. Southside Connector Trail

5.1. Overview and Summary

Walnut Creek Wetland Park is located on the corner of Peterson St. and State St. in southeast Raleigh, and the wetland itself extends out to the south and to the west. There are trails through parts of this area, but none connect to the southernmost portion of the park. This part of the wetland is adjacent to Rochester Heights, a residential neighborhood (Figure 5.1). A plan has been put in place by Raleigh Parks, Recreation, and Cultural Resources that includes the construction of a pathway that will begin near Rochester Heights, traverse the park, and exit on

Figure 5.1. *This aerial photo is of Rochester Heights. Saint Ambrose Episcopal Church is also visible in the upper right corner of the photo. The forested area at the top of this map, just north of the road, is the southernmost portion of Walnut Creek Wetland Park.*

State Street. Our team walked along the proposed pathway and evaluated the landscape in the area of interest. The landscape is flooded in many areas, overgrown, and riddled with litter that was either dumped locally or washed in from upstream (see section 7.4.1). One of the hopes expressed to us by officials in Raleigh Parks, Recreation, and Cultural Resources was for footpath traffic to discourage the anonymous dumping that frequently occurs. We explored the rest of our area of study (the southeastern half of the park) to scout out any other areas that may be conducive to a pathway. The areas we selected for our final pathway recommendations were based on soil samples, trends in standing water levels, and visual observations. As a result of our observations and supporting research, we are proposing three possible routes.

5.2. Purpose of Trail

Walnut Creek Wetland Park is bordered on the south side by a community called Rochester Heights. Currently, there is no developed path that allows for easy access to the park for this community. A path would allow easier access to the Wetland Park, hopefully increasing community participation in park activities and increasing awareness of the natural habitat. With more access to the park, the goal is that the public would gain more of an appreciation and awareness of the natural habitat in their backyard. This heightened appreciation and an increase in foot traffic has potential to decrease the frequency of dumping in this area. This path would also be a safer alternative to walking on the roadway to get to the park, as there currently is no sidewalk in Rochester Heights along the route to Walnut Creek Wetland Park.

5.2.1. Sidewalk

One of the options for connecting the community to the park is to construct sidewalks along the route to make these streets safer for pedestrians. There is room for a sidewalk along Bailey Drive, Boaz Road, and Darby Street, should the city decide to implement one (Figure 5.2). For sidewalks to be a viable option, people would need to start a petition (Sidewalk Petition Program, 2019). A petition notice would be mailed to the property owners along the segment of street that would be impacted, and property owners would have 45 days to respond. If at least half of them agree to the sidewalk, then the case goes to city council for approval. If approved, the sidewalk would take two to three years to be completed.

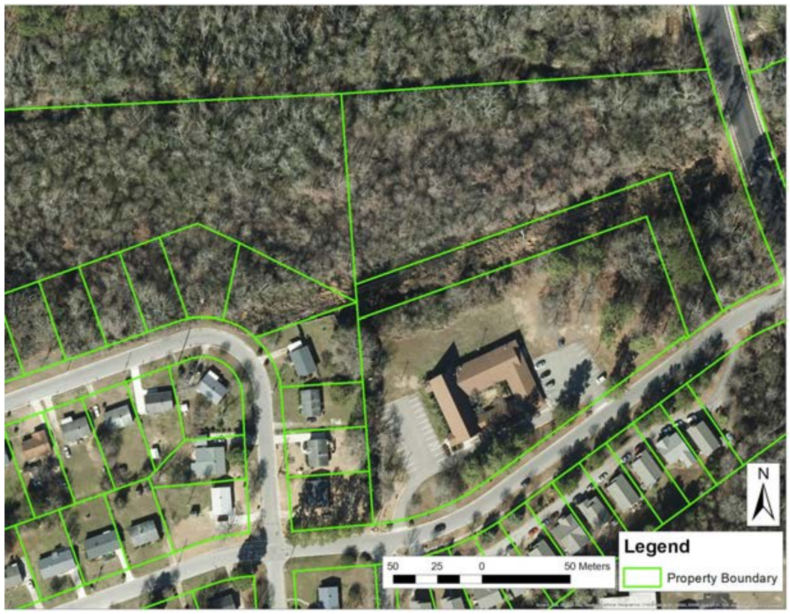


Figure 5.2. *The green lines indicate property boundaries. There is adequate space on either side of the displayed roads to construct sidewalks.*

5.3. Soil Conditions in Area of Interest

We took soil samples at nine different locations along our potential pathway routes (Figure 5.3.) Our main motivation was to determine soil saturation. It was fairly simple to see how saturated the soil was through visual observation and feel. We also took note of the soil coloration. We did not notice any gray soils. The absence of gray colors indicates that the soils, even in areas we deemed heavily saturated, were not saturated long enough to create the reduction reaction that would produce gray soil (Pezeshki, 2012). If this had been the case, any path construction would be difficult. The range of soil saturation that we encountered can be represented by three sites: site 4, 5, and 7 (Figure 5.4.) Site 4 shows a very dry area. Site 5 has fairly moist soil, but it is not fully waterlogged and could still provide stable ground for a pathway. Site 7 shows very saturated soil that would require sturdier pathway materials (see section 5.5.) The pathways that we are proposing (see section 5.5.7.) consist mostly of soils that are similar to site 4, although there are a few areas with soil similar to that at site 7.

Figure 5.3. *This map indicates the locations of our soil samples.*

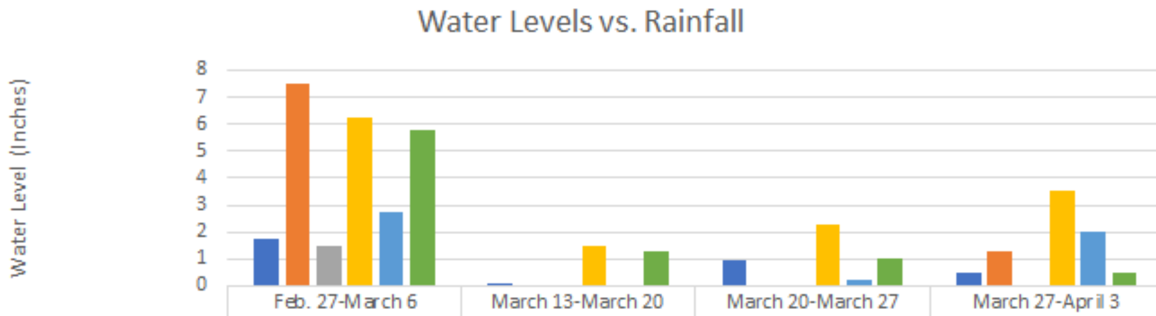
Site 4 Site 5 Site 7

Figure 5.4. *These photos show the soil conditions at three of our sampling sites. We dug until we found standing water, so that is why the samples extend to different depths. All of the nine sampled sites fall within a moisture range represented by these three sites.*

5.4. Water levels

The water level measurements were taken to observe the effect that rainfall had on different sites along the potential pathways. The water level measurements were taken at five locations along the potential pathways (Figure 5.5.) Not surprisingly, we found that standing water levels were much higher after periods of rainfall, but even during week long periods where rainfall only totaled 0.01inches (March 13-March 20), standing water still persisted in some areas (Figure 5.6.) Site three consistently had standing water, and this information will be helpful in determining if a path should be placed here. This also tells us that in the event of pathway construction crossing this site, a flood tolerant material would be needed.

Figure 5.5. *The sites of standing water sampling can be seen here. These sites correspond with the general area of our potential paths.*



	Feb. 27-March 6	March 13-March 20	March 20-March 27	March 27-April 3
Total rainfall (inches)	1.75	0.01	0.93	0.49
SITE 1	7.5	0	0	1.25
SITE 2	1.5	0	0	0
SITE 3	6.25	1.5	2.25	3.5
SITE 4	2.75	0	0.25	2
SITE 5	5.75	1.25	1	0.5

Figure 5.6. *The amount of rainfall in a week compared to the number of inches of standing water present at 5 locations in the area of study. The highest amount of rainfall recorded was 1.75 inches, and during the week following this rainfall the park had up to 7.5 inches of standing water in some areas.*

5.5. Proposed Trails

We are proposing two different trail surfaces: mulched pathway and a grounded wooden boardwalk (Figure 5.7.) These two methods are affordable and can be implemented fairly quickly. Mulch will be placed in the areas that tend to remain dry, and wooden boards will be implemented in wetter areas. There are various options for grounded wooden boardwalk construction. Lumber can be harvested from the trees that would need to be cleared for pathway construction; it could be used either as is, or dried for 3-6 months (Table 5.1). The other option is to purchase lumber that would be treated to resist decay from the elements.

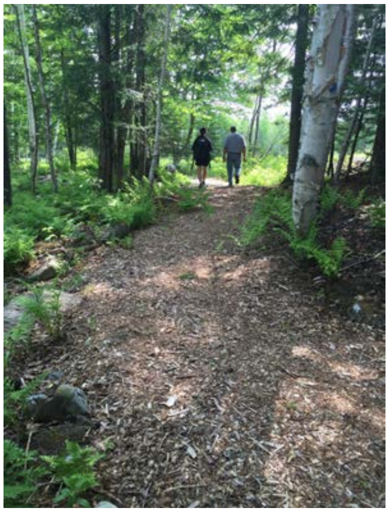


Figure 5.7. *The photo on the left shows the type of mulch pathway we are proposing (image from MaineTrailFinder.com). The photo on the right shows a simple wooden pathway in Strongsville, OH that we are using as a model for our suggested boardwalk (image from AllTrails.com).*

Based on our examination of site conditions, we propose three possible trail routes (Figure 5.8). While not all of the paths begin at the same location, they all end at State Street. The ending point is at the bridge over Walnut Creek; this location was chosen because it is where the presence of guardrail begins, which would provide a safer trail exit. This area is uphill, so the construction of a simple wooden staircase would be required.

The Powerline Path. The powerline path, measuring at 0.19 miles, begins at the end of Boaz Drive and runs beneath a set of powerlines. The majority of the powerline path could be easily mulched with only minimal need for construction of grounded boardwalks at the very beginning of the path. Because this trail will run through a Duke Energy Easement, there are certain requirements that need to be met in order to comply with their standards. The trail cannot be wider than 12 feet, there must be at least 25 feet separating the trail and any Duke Energy electrical equipment, structures of any kind are prohibited, and Duke Energy reserves the right to shut the trail down at any time (Duke Energy, 2014).

Table 5.1. *The advantages and disadvantages of various trail construction materials (Personal Communication, Dr. Phil Mitchell and Dr. Dave Tilotta).*

Material	Advantages	Disadvantages
Mulch	-Easily made with a portable chipper -Would provide a way to recycle wood products	-Would require frequent upkeep, especially after heavy rain events
Harvested lumber (undried)	-Would provide a way to recycle wood products -Would require less maintenance -Would last 5 years	-The wet terrain and the remote locations of some areas would make it difficult to bring a portable sawyer to the site
Harvested lumber (dried)	-Would provide a way to recycle wood products -Would require less maintenance -Would last 6 years	- The wet terrain and the remote locations of some areas would make it difficult to bring a portable sawyer to the site
Purchased lumber	-Would last 10-15 years -Is treated for increased longevity and durability	-Would waste a great deal of lumber during the clearing process

The Scenic Route. The scenic path, running in between the creek and powerline path, follows a less direct route but offers a more natural experience. This route is 0.47 miles long. This route would require more construction of grounded boardwalks than the other two options to cope with the amount of standing water in the area. However, this pathway would allow park visitors to fully experience the wetland and would present an opportunity for a deeper immersion into nature.

The Creek Path. The third path suggested on the map follows directly along Walnut Creek, measuring at 0.44 miles. This path still takes a scenic route through the wetland but avoids areas with large amounts of standing water. By taking the high ground along the creek bank, this path can be primarily mulched, avoiding higher construction costs. The area along the creekside is densely overgrown with Chinese privet and will require intensive clearing to construct this path. Any woody plants in this area that need to be cleared for pathway construction could be used for mulch.

Figure 5.8. *Our three potential pathway routes can be seen here.*

4. Water Quality in Little Rock Creek,

4.1. Overview and Summary

Our objectives were to locate the source of high levels of *E. coli* in Little Rock Creek and to gain an understanding of the overall health of the stream. *E. coli* poses a threat to the water-based environmental learning that takes place at Walnut Creek Wetland. Locating the source will allow others to mitigate or eliminate the threat altogether. We selected 11 sampling sites along Little Rock Creek at which either stormwater inlets or significant tributaries entered the stream (see Section 7.3.1, Figure 4.1). At each point we tested for total coliform and *E. coli* (see Sections 7.3.2-7.3.3). We also measured dissolved oxygen, pH, specific conductance, and temperature at each point (see Section 7.3.2); each of these parameters are important indicators of stream health.

E. coli levels are higher than NC Department of Environmental Quality standards allow. Dissolved oxygen, pH, specific conductance, and temperature all indicated a relatively healthy stream. None of our samples tested positive for nitrite or nitrate, which suggest that fertilizer in runoff is not a problem.

4.2. Purpose of Creek Sampling

Little Rock Creek is classified by the NC Division of Water Resources as a Class C waterway, described as “Waters protected for uses such as secondary recreation, fishing, wildlife, fish consumption, aquatic life including propagation, survival and maintenance of biological integrity, and agriculture. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner” (NCDEQ, undated). Little Rock Creek flows into the Walnut Creek Wetland Park (Figure 4.1) and when staff at Walnut Creek Wetland Park found high levels of *E. coli* in the water, they wanted to know where this *E. coli* was coming from. The purpose of our research was to sample various points along Little Rock Creek that may be contributing to the high levels of *E. coli* downstream. Testing for *E. coli* is important because if left undetected, individuals are at risk for ingesting the bacteria, causing serious health risks. *E.*

coli testing can also be used to monitor fecal matter contamination. The reason why this is so significant for the Walnut Creek Wetlands Park is because Park staff often hosts activities in or near the stream.

We also looked for overall health of the stream by measuring temperature, pH levels, Specific Conductance, Dissolved Oxygen levels, and nitrate/nitrite levels. Examining stream health is important for various reasons. Agriculture and recreational activities depend on a healthy stream. A healthy stream also provides food and habitat for aquatic life (SERC, undated).

4.3. *E. coli.*

The NC Department of Environmental Quality lists the *E. coli* standard for Class C waters as less than or equal to 200 Colony Forming Units (CFU)/100mL (NC Division of Water Resources). The majority of our measurements were above this level, especially downstream, closer to the Wetland Park (Figures 4.2-4.3), particularly following rainfall (20 & 27 February). Our last two days of sampling, March 6th and 20th, showed *E. coli* levels significantly less than our first two days of sampling.

When comparing data from site to site, there do not seem to be any extremely strong indications that one site is worse or better than another. Exceptions may be sites 4 and 11, with 11 having slightly lower *E. coli* levels and site 4 having slightly higher *E. coli* levels than other sites.

Our *E. coli* data varied a lot depending on the day of sampling. Our first two days of sampling, February 20th and 27th were both higher than is recommended for Class C recreational waters. We believe it is likely the data varied based on how close it was to a rain event. The day before our February 20th sampling was a very heavy rain event, which elevated the levels of *E. coli*. Many of the results showed *E. coli* levels greater than 2,420 CFU/100mL, which is the maximum our sampling equipment would allow us to measure.

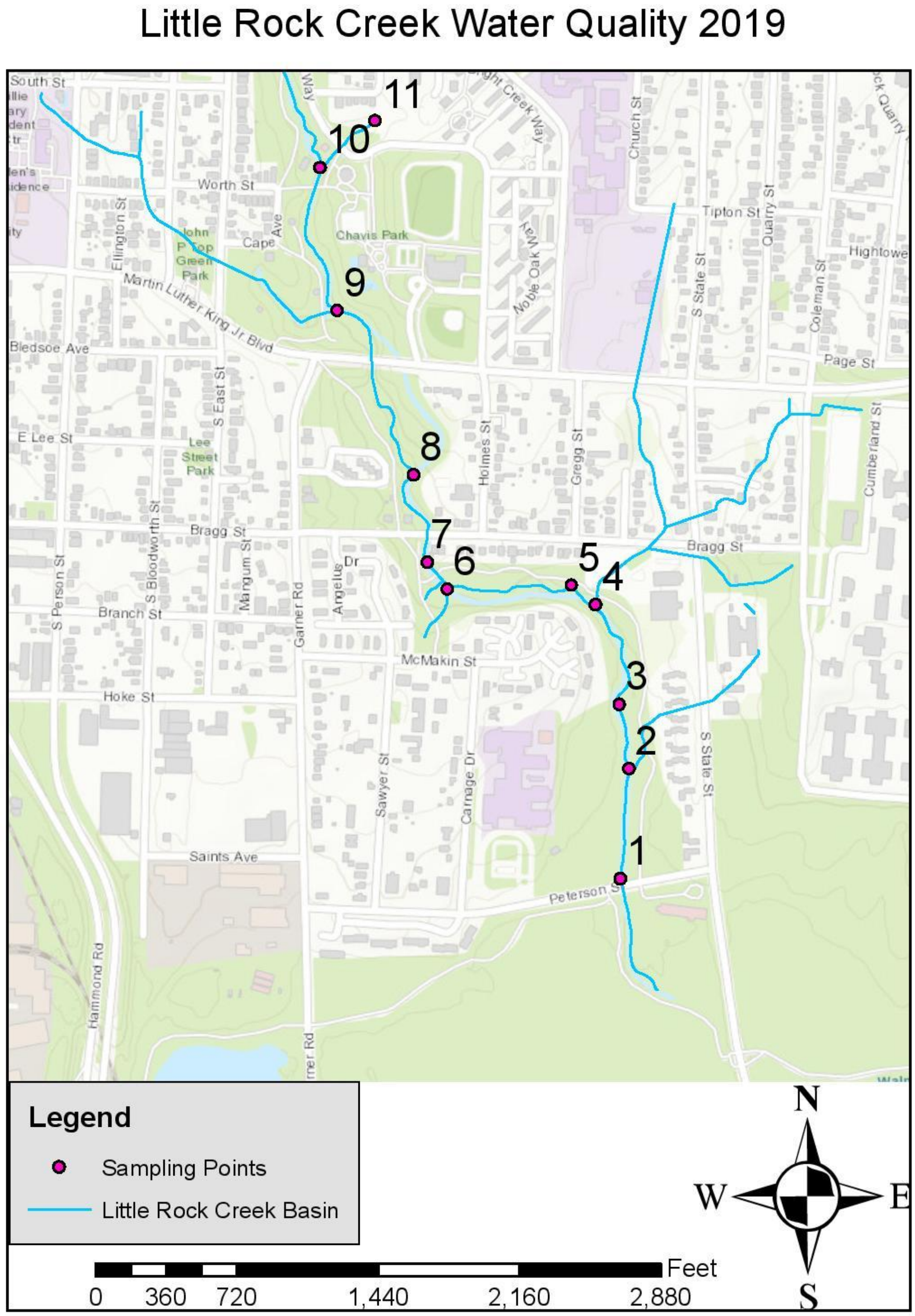


Figure 4.1. *Little Rock Creek flows from north to south. Here we show our sampling points from where the Creek exits stormwater pipes at Chavis Park (near point 10) to just north or the Walnut Creek Wetland Park (point 1).*

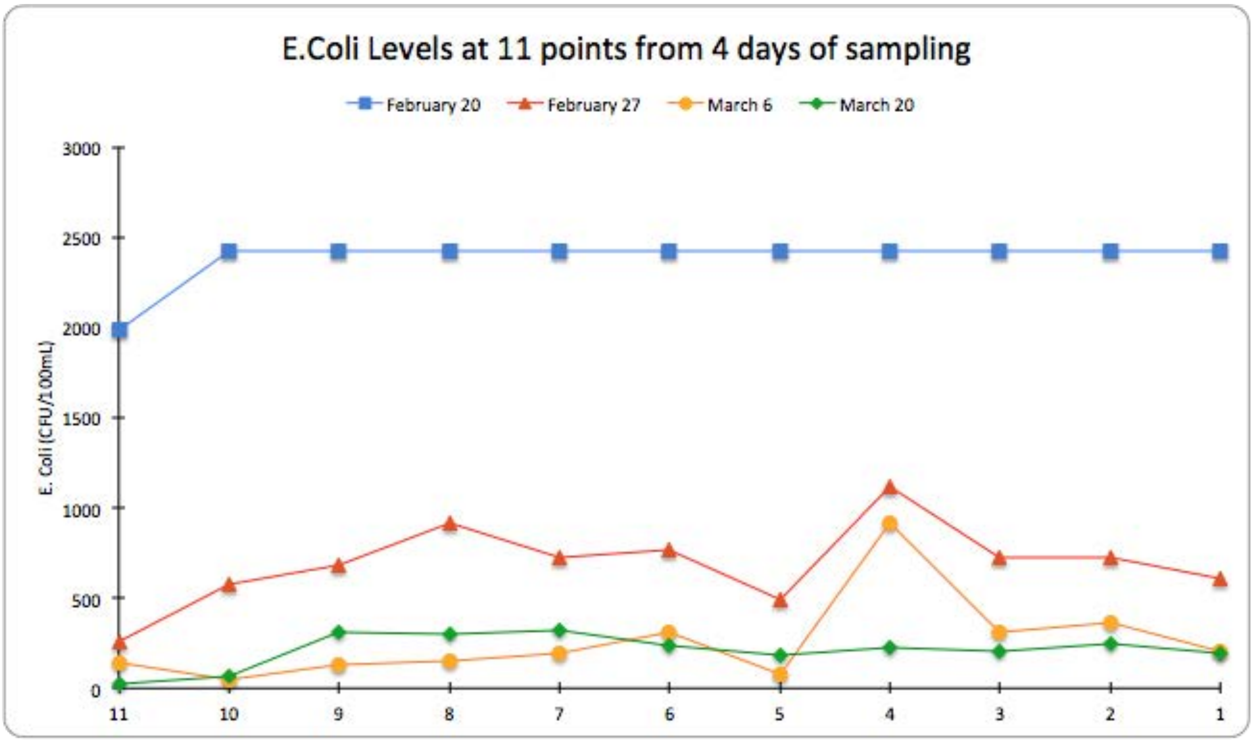


Figure 4.2. *E. coli data displaying the sample date, the point of sampling, and the measurement in CFU/100mL. The stream flows from left to right along the x-axis with major inflows at points 10, 9, & 4.*

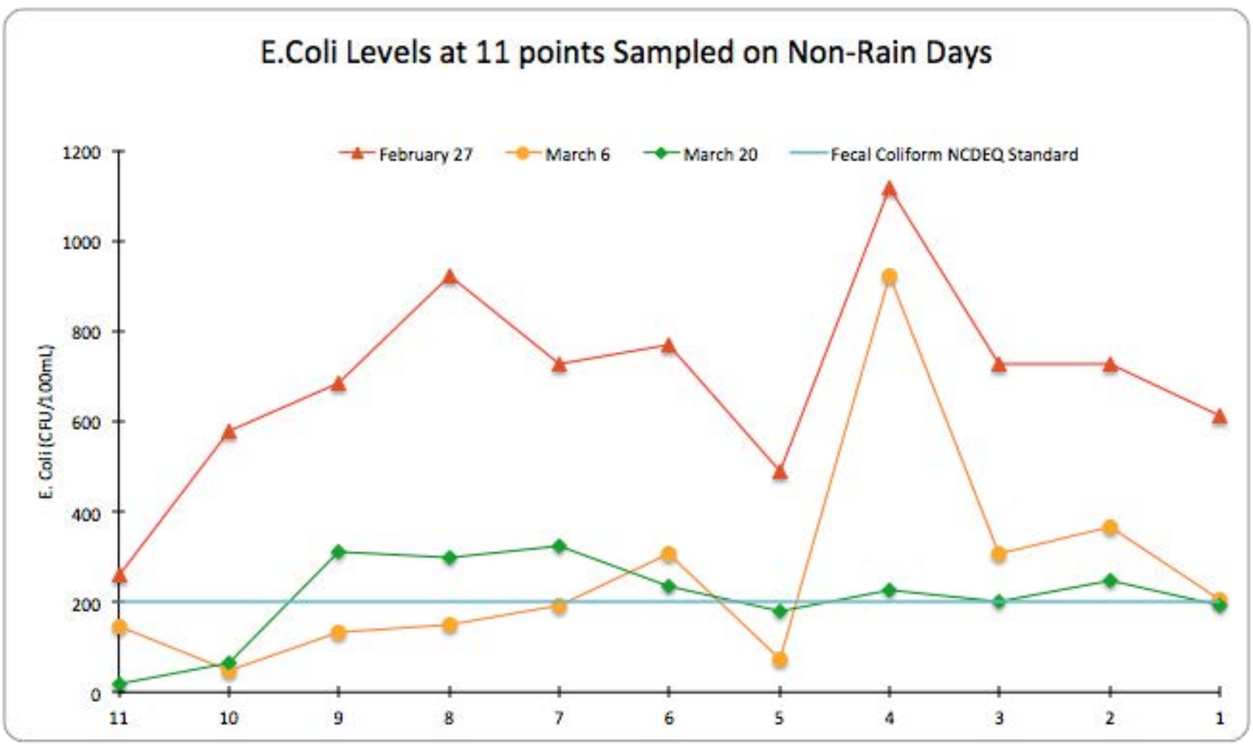


Figure 4.3. *E. coli data excluding our first day of sampling, February 20th which was our only significant rain event throughout the study period. The stream flows from left to right along the x-axis with major inflows at points 10, 9, & 4.*

4.4. Health of Little Rock Creek

We examined the health of Little Rock Creek using four parameters measured with a YSI sampling probe: temperature, pH, dissolved oxygen, and specific conductance (Section 7.3.2).

pH Levels Healthy. pH is the measure of hydrogen ion concentration in a solution. pH can only be measured if there is water in the solution, with that being said, it measures how acidic or basic a solution is (Helmenstine 2019). pH, along with many other parameters, is a way to determine the health of a stream. All of our monitoring data was close to neutral ranging between 6 and 8 (Figure 4.4). NCDEQ standards recommend that for Class C waters pH should be between 6 and 9 (Surface Water Quality Standards).

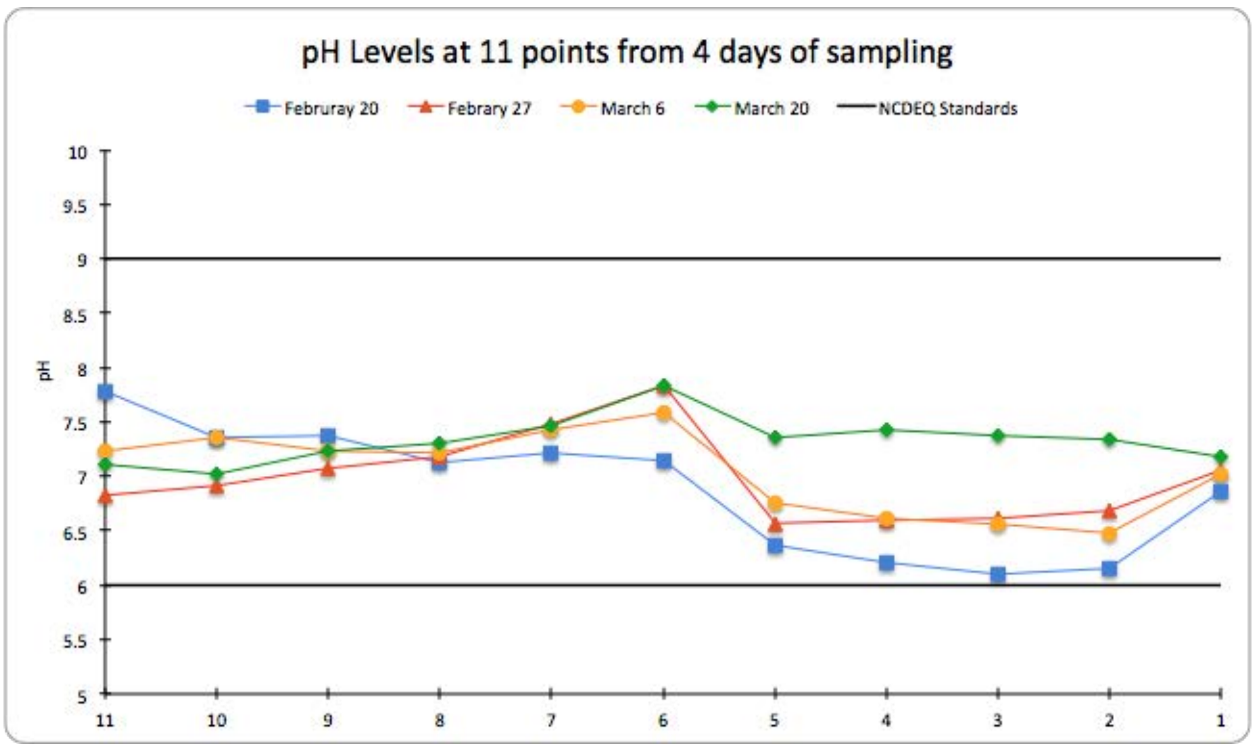


Figure 4.4: *Chart of pH measurements as well as NCDEQ standards for Class C waters. The stream flows from left to right along the x-axis with major inflows at points 10, 9, & 4.*

Water Temperature was Variable. Temperature is an important factor in determining what species can live in the habitat. Water temperature is affected by air temperature, quantity of shade provided by vegetation around the stream, quantity of pollutants in the water, water depth, the flow of groundwater, and the flow and frequency of stormwater runoff. Little Rock Creek is an urban stream exposed to development, human disturbances, and human pollution, which means it is prone to heating up. Our data shows that rain events are very important to keeping water temperatures low (Figure 4.5). Besides the variability displayed by the rain event, our temperature data was fairly consistent. However, our two most upstream points, 11 and 10, showed slightly higher temperature data compared to the rest of the results downstream.

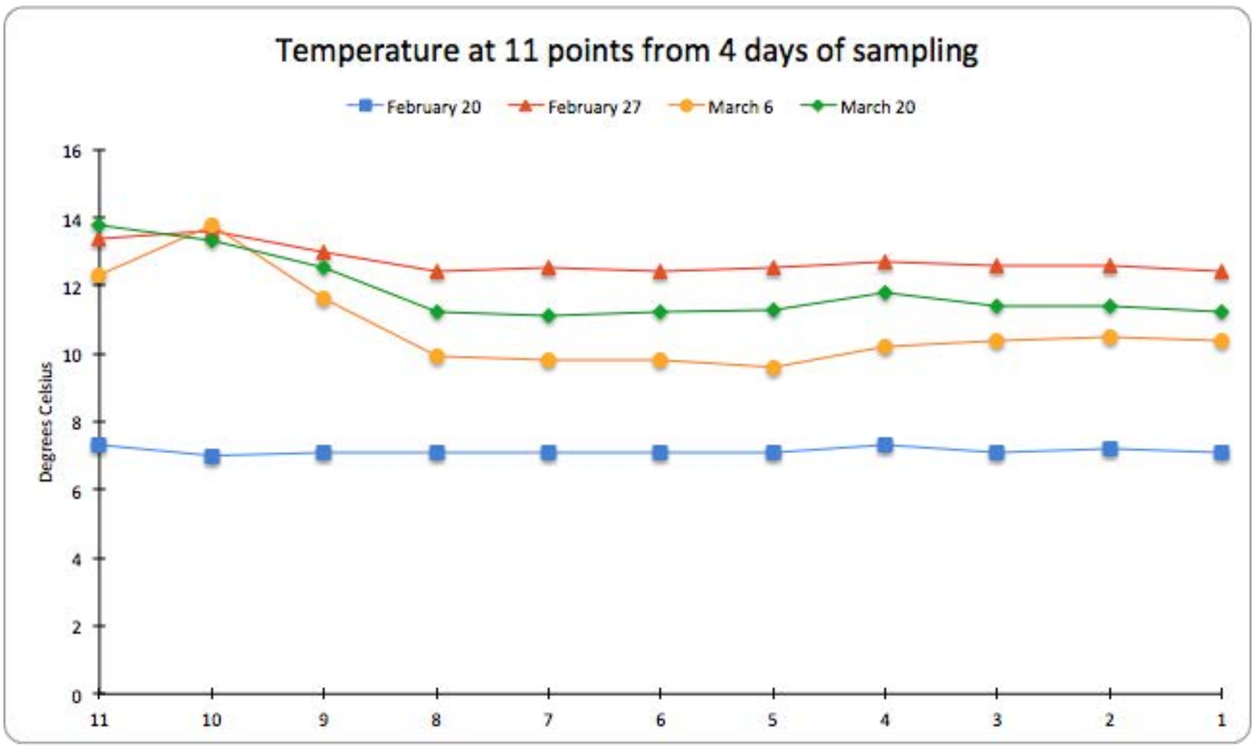


Figure 4.5. *Chart of temperature measurements for our four sampling days. The stream flows from left to right along the x-axis with major inflows at points 10, 9, & 4.*

Dissolved Oxygen at Healthy Levels. Dissolved oxygen is the amount of free oxygen in water or another liquid. Dissolved oxygen is a primary factor is determining what can live in the body of water and as a result is a good indicator of overall stream health. NC Department of Environmental Quality does not currently have regulatory standards for dissolved oxygen for Class C waters. There are several varying non-regulatory suggestions for healthy dissolved oxygen levels that we have used to compare our data to. In this analysis we will use suggestions from The Water Resource Center. This resource explained that there is a spectrum of dissolved oxygen levels resulting in different levels of stream health (Oram, n.d.). The fact that all of our measurements were above the 7 mg/L mark signifies that the water has plenty of oxygen to support fish life (Figure 4.6).

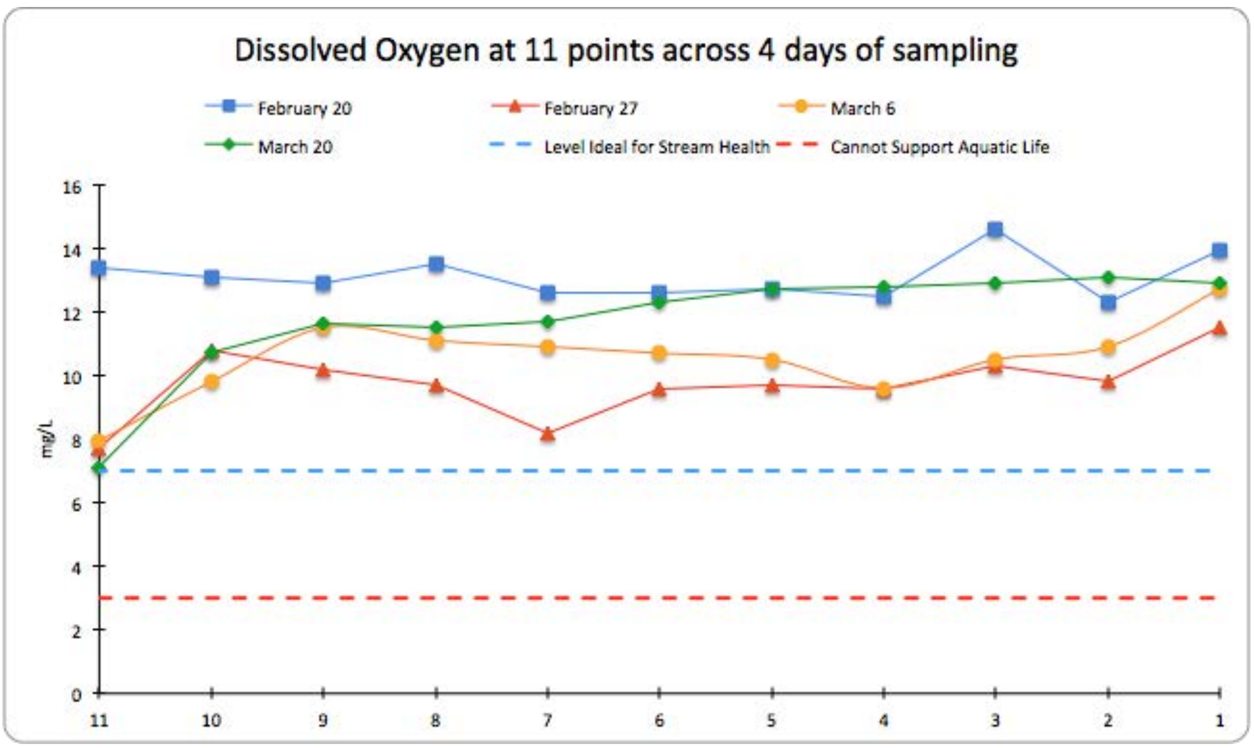


Figure 4.6. *Chart of our dissolved oxygen measurements and recommended levels by The Water Resource Center. The stream flows from left to right along the x-axis with major inflows at points 10, 9, & 4.*

Specific Conductance. Water or aqueous solutions ability to conduct electrical current is known as specific conductance. Inorganic compounds such as phosphorus and nitrite, temperature, and geology of the site are all factors that influence conductance. It can also serve as an indicator of pollution within surface waters. The February 20 sampling day showed significantly lower specific conductance levels. This is likely due to the fact that the heavy rainfall diluted the inorganic solids in the stream.

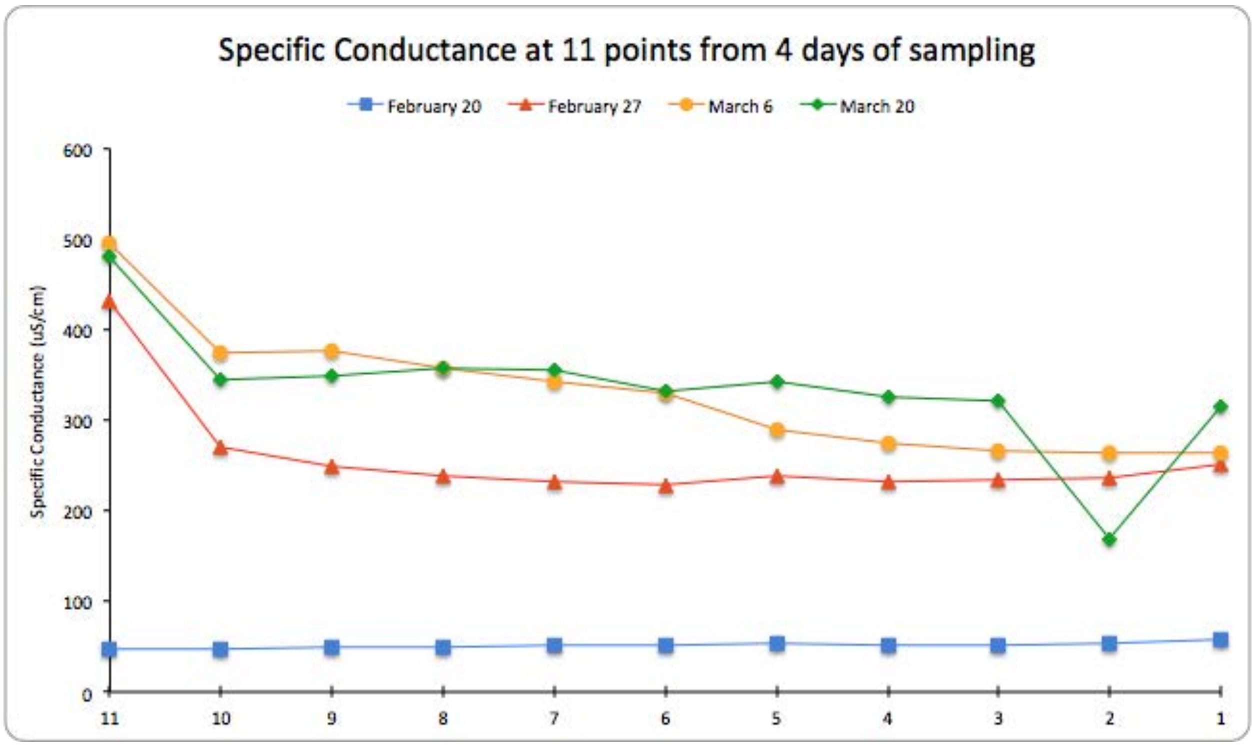


Figure 4.7. *Chart of specific conductance measurements for all sample locations and dates. The stream flows from left to right along the x-axis with major inflows at points 10, 9, & 4.*

Nitrate and Nitrite not Detected. Nitrate and nitrite occur naturally in the nitrogen cycle and can be organic and inorganic. Through the process called nitrification, ammonia-Oxidizing bacteria converts ammonia to nitrate and nitrate-oxidizing bacteria converts nitrite into nitrate (AWWA 2002). This process, along with atmospheric fixation and nitrogen fertilization contributes to nitrate and nitrite into the environment. Nitrate and nitrite can serve as an essential plant nutrient, but when accumulated in surface water they can act as a pollutant. Eutrophication and algal blooms are common results of nitrate or nitrite accumulation, both factors that reduce stream health and induce hypoxic conditions (NOAA 2018). We did not detect any nitrate or nitrite.

4.5. Recommendations

The overall quality of the stream was healthy with the major exception of elevated *E. coli* measurements. The majority of *E. coli* levels we measured were above the 200 CFU/100mL limit set by the NCDEQ for Class C waters. After a heavy rain event, these concentrations increased significantly to levels well above the NCDEQ standards making it unsafe for humans contact. Only after a long period of dry weather is it possible for Little Rock Creek to achieve safe levels of *E. coli* bacteria. Specific conductance and temperature both correlated with each other at levels healthy enough to sustain wildlife. The pH, and dissolved oxygen were tested and the levels for both of these parameters are within the range necessary to support aquatic life. Nitrite and Nitrate were also tested for at each point and found to be 0.

One improvement for our research methods would be to collect more water samples at the same points. By collecting more samples our data accuracy would improve "...as sample size increases, the standard error decreases, or gets more precise. Put another way, as the sample size increases so does the statistical precision of the parameter estimate" (Brown 2007). We were ubale to pintout the location of the *E. coli* contamination. Although the exact source of the *E. coli* wasn't discovered, the tributary entering Little Rock Creek at site 4 might be contributing significant levels the *E. coli*.

Further recommendations include restricting water-related park activities for one week after heavy rainfall. We recommend this because of the *E. coli* spikes during the rain and the week after. We also recommend that doggy bag stations be introduced to along trails, and that a year-long study be conducted to understand the seasonal effects on *E. coli* concentration and overall stream health.

6. Wildlife

6.1. Overview and Summary

Our objective was to expand and update the wildlife inventory for Walnut Creek Wetland Center Park. Our group did this through a variety of survey methods such as camera trapping, audio sampling, electrofishing, and Sherman trapping. Overall, we identified 66 species present at Walnut Creek Wetland Center. We captured 12 species of mammals, 11 of which were captured by camera traps and 1 of which was captured using Sherman live traps. We found evidence of 9 herpetofaunal species (two species of amphibian and seven species of reptiles) of which two were found under coverboards, one was recorded using wildlife audio recording system, one was captured on a camera trap and five were seen incidentally. We identified 14 species of fish while electrofishing. Our inventory yielded a total of 16 different species of birds, using a custom Wildlife Audio Recording System, camera traps, and incidental sightings.

6.2. Mammals

We inventoried mammals using camera traps (see Section 7.5.1), Sherman Live Traps (see Section 7.5.2) and incidental sightings (see Section 7.6.5). Camera traps are motion activated cameras that take pictures of large scale movement in the environment. They're good for capturing medium to large sized mammals such as beavers and deer, as well as larger bird species such as ducks and geese. Sherman Live Traps are foldable, box-style steel traps designed to capture small mammals. The opening is 2 x 2 inches, and about 8 inches long.

Throughout our time at the Wetland Park, we identified 16 species of mammals (Table 6.1).

6.3 Herpetofauna

We identified nine species of herpetofauna in Walnut Creek Wetland Park. During our time sampling coverboards we discovered two different species of snakes (See Section 7.5.4). On two occasions we found one rough earth snake (Figure 6.1) under a wood coverboard. On another

Table 6.1. *Mammals Found in Walnut Creek Wetland Park in 2015 and 2019. D=species detected; blank- species not detected.*

Species	2015	2019	Detection Method
Coyote (*Canis latrans*)	D	D	Camera Trap
Domestic Dog (*Canis lupus familiaris*)	D	D	Camera Trap
Eastern Cottontail *(Sylvilagus floridanus)*		D	Incidental Sighting
Eastern Gray Squirrel *(Sciurus carolinensis)*	D	D	Camera Trap
Gray Fox *(Urocyon cinereoargenteus)*	D	D	Camera Trap
Groundhog *(Marmota monax)*		D	Camera Trap
Muskrat (*Ondatra zibethicus*)		D	Camera Trap
North American Beaver (*Castor canadensis)*		D	Camera Trap
North American Raccoon *(Procyon lotor)*	D	D	Camera Trap
North American River Otter *(Lontra canadensis)*		D	Camera Trap
Red Fox *(Vulpes vulpes)*		D	Camera Trap
Unidentified Cricetidae		D	Camera Trap
Virginia Opossum (*Didelphis virginiana)*	D	D	Camera Trap
White Footed Mouse *(Peromyscus leucopus)*		D	Sherman Trap
White-tailed deer *(Odocoileus virginianus)*	D	D	Camera Trap
Woodchuck *(Marmota monax)*	D	D	Camera Trap

occasion, we saw three Dekay's Brown Snakes at the same time all under one wood coverboard. We found that organisms were attracted more to the wood type cover boards than any other type of material used for cover boards. We discovered the other four species of herpetofauna through incidental sightings (See Section 7.5.6). One species was discovered through camera traps (see Section 7.5.1). One species was discovered by the wildlife audio recording system (see Section 7.5.3).

Table 6.2. *Herpetofauna Found In Walnut Creek Wetland Park. WARS=Wildlife Audio Recording System.*

Species	**Number Observed**	**Detection Method**
Common Snapping Turtle (*Chelydra serpentina*)	1	Incidental Sighting
Dekay's Brown Snake (*Storeria dekayi*)	3	Cover Board
Eastern Ratsnake (*Pantherophis alleghaniensis*)	1	Incidental Sighting
Florida Cooter (*Pseudemys floridana*) (Figure 6.1)	1	Camera Trap
Green Anole (*Anolis carolinensis*)	1	Incidental Sighting
Green Frog (*Lithobates clamitans*)	1	Incidental Sighting
Rough Earth Snake (*Haldea striatula*)	2	Cover Board
Southern Black Racer (*Coluber constrictor*)	1	Incidental Sighting
Spring Peepers (*Pseudacris crucifer*)	N/A	WARS

Figure 6.1. *Rough earth snake (left) and Florida cooter (right) were among the herpetofauna we detected.*

6.4 Fish

We identified 14 different species of fish from Walnut Creek and Little Rock Creek during the 2019 backpack electrofishing survey (Table 6.3, see Section 7.5.5). One fish in the sample exhibited Popeye's Disease. Popeye's disease, which is bulging of the eye and can be accompanied by redness, can persist for several days and gradually disappear (Ferguson & Hayford 1941). Because only one individual (Bluegill) was found this is likely just to be an abnormality. It is important to note however that another Bluegill was found to have Popeye's Disease from the 2015 survey as well (Walnut Creek Wetland Center Inventory 2015). The fish species diversity from our findings were compared to those of the previous studies conducted in the spring of 2010 and 2015 (Table 6.3, Walnut Creek Wetland Center Inventory 2015) Major shifts in sample abundance were found in several species over all three surveys. While some species increased in sample abundance, others decreased. This shows that the community structure in Walnut Creek is not stagnant and may be susceptible to changes in water quality. Our recommendation for any future surveys is to take water quality data and vegetation percent coverage to determine why there are shifts in community structure.

Table 6.3. *Fish species presence and absence over 3 surveys from 2010, 2015, and 2019. The 2010 and 2015 data is from Walnut Creek Wetland Center Inventory 2015. Species with large fluctuations in abundance are highlighted in bold text.*

Species	**2010**	**2015**	**2019**
Amercian Eel (*Anguilla rostrata*)	0	6	0
Bluegill (*Lepomis macrochirus*)	**87**	**6**	**26**
Bluehead Chub (*Nocomis leptocephalus*)	3	0	1
Creek Chubsucker (*Erimyzon oblongus*)	0	0	1
Eastern Mosquitofish (*Gambusia holbrooki*)	**30**	**3**	**0**
Eastern Mudminnow (*Umbra pygmaea*)	1	2	0
Flat Bullhead (*Ameiurus platycephalus*)	2	1	6
Gizzard Shad (*Dorosoma cepedianum*)	0	4	0

Green Sunfish (*Lepomis cyanellus*)	6	0	3
Largemouth Bass (*Micropterus salmoides*)	2	1	2
Margined Madtom (*Noturus insignis*)	0	7	2
Northern Hogsucker (*Hypentelium nigricans*)	1	0	0
Pumpkinseed (*Lepomis gibbosus*)	0	0	3
Redbreast Sunfish (*Lepomis auritus*)	**62**	**16**	**7**
Redfin Pickerel (*Esox americanus americanus*)	1	1	1
Roanoke Darter (*Percina roanoka*)	0	1	0
Rosyside Dace (*Clinostomus funduloides*)	1	0	0
Satinfin Shiner (*Cyprinella analostana*)	**23**	**7**	**0**
Spottail Shiner (*Notropis hudsonius*)	9	2	32
Swallowtail Shiner (*Notropis procne*)	**13**	**127**	**18**
Tessellated Darter (*Etheostoma olmstedi*)	**25**	**54**	**5**
White Shiner (*Luxilus albeolus*)	12	3	2

6.5 Birds

We detected 16 different species of birds (Table 6.5, next page), using a custom Wildlife Audio Recording System (see Section 7.5.3), camera traps (see Section 7.5.1), and incidental sightings (see Section 7.5.6).

Table 6.5. *Birds detected in Walnut Creek Wetland Park. WARS=Wildlife Audio Recording System.*

Species	Number Observed	Detection Method
American Goldfinch (*Spinus tristis*)	1	Incidental Sighting
Barred Owl (*Strix varia*)	N/A	WARS
Blue Jay (*Cyanocitta cristata*)	N/A	WARS
Brown Thrasher (*Toxostoma rufum*)	1	Camera Trap
Canada Goose (*Branta canadensis*)	8	Camera Trap, WARS
Carolina Chickadee (*Poecile carolinensis*)	N/A	WARS
Cedar Waxwing (*Bombycilla cedrorum*)	N/A	WARS
Common Grackle (*Quiscalus quiscula*)	3	Incidental Sighting
Great Blue Heron (*Ardea herodias*)	1	Camera Trap
Mallard (*Anas platyrhynchos*)	9	Camera Trap
Northern Cardinal (*Cardinalis cardinalis*)	1	Camera Trap
Northern Mockingbird (*Mimus polyglottos*)	N/A	WARS
Red-shouldered Hawk (*Buteo lineatus*)	N/A	WARS
Red-tailed Hawk (*Buteo jamaicensis*)	1	Camera Trap
White-throated sparrow (*Zonotrichia albicollis*)	1	Incidental Sighting
Wood Duck (*Aix sponsa*)	2	Camera Trap

7.1. Methods: Community Garden & Nature Play

7.1.1. Soil Sampling

Garden. The staff from Walnut Wetland Creek Park identified an area they proposed for the community garden. After an initial visual assessment of the site we identified five regions with distinct vegetation (Figure 7.1.1).

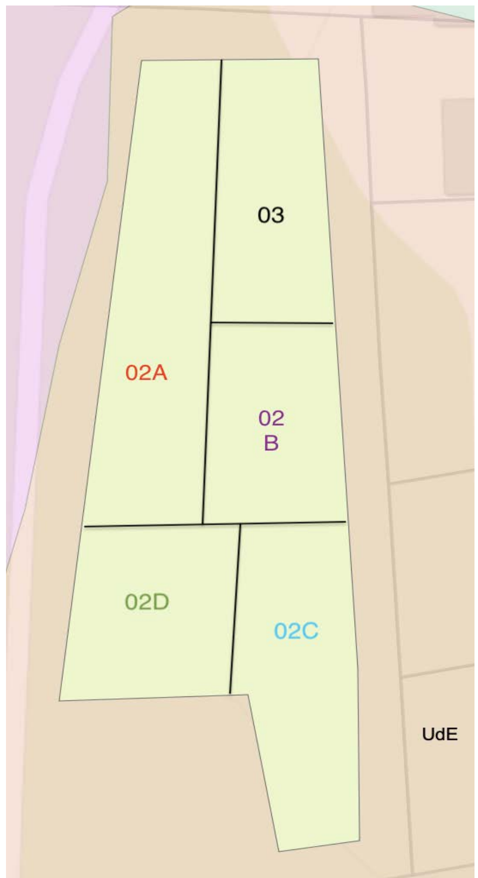


Figure 7.1.1. *Map of the quadrants used when collecting soil cores for soil testing from the North Carolina Agronomics Division.*

Within each of these regions, we collected and combined three soil samples, about 4-6 inches deep, using a soil auger as recommended by the NC Agronomics Division (NC Agronomics Division, 2013). ArcCollector was used to mark areas where the soil samples were collected in order to ensure that the locations of the sampling were known. After all of the samples were collected from all of the regions, the boxes were taken to the North Carolina Department of Agriculture and Consumer Services to be processed. The results were returned from the lab two weeks later which provided the levels of Potassium, Phosphorus, pH, Humic Matter, and Cation Exchange Capacity.

Nature Play Area. The soil sampling done in the area proposed by the Walnut Creek Wetland center was to ensure good drainage in the soil, which can be an important factor when putting in a nature play area. (Stoddard, 2015). Following the same method used in the desired garden area, we collected and combined three, 4-6 inch deep soil samples from the site using a soil auger, as recommended by the NC Agronomics Division (NC Agronomics Division, 2013). ArcCollector was used to mark areas where the soil samples were collected in order to ensure that the locations of sampling were known. After the sample was collected from the of the region, the box was taken to the North Carolina Department of Agriculture and Consumer Services to be processed. The results were returned from the lab two weeks later which provided the levels of Potassium, Phosphorus, Ph, Humic Matter, and Cation Exchange Capacity Level.

7.1.2. ArcGIS Mapping

The ArcGIS maps required data collected from outside sources as well as the border data we collected using ArcCollector. Property line data and floodplain data were downloaded from the WakeGov website (2019). The soil data were downloaded from the USDA's Web Soil Survey (2019). The sewer manhole and sewer line data was sent to us via email from the City of Raleigh- Public Utilities Department (2019).

After consulting with Stacie Hagwood, director at Walnut Creek Wetland center, an area was set out that would be appropriate as the area for a community garden. The border of this area was then mapped out with ArcCollector, with reference to property boundaries. During soil sampling, data points were also mapped.

After consulting with Stacie Hagwood, director at Walnut Creek Wetland center, an appropriate area was selected for the nature play space. After a rain event, we mapped the wettest areas by the proposed site to ensure the topography of the area was best suitable for a nature play space. The final border of this area was then mapped out with ArcCollector

7.1.3 Process and Planning

Garden Planning Procedure. Meetings with park director determined that wheelchair accessible beds would be beneficial to the community and accessibility would an important aspect to incorporate into the garden plans. Garden bed dimensions that would be wheelchair accessible were researched and potential areas for wheelchair accessible beds were surveyed. At The Raleigh City Garden, we talked to Rebekah Beck (2019) and at the Raleigh Wellfed Garden we talked to Morgan Malone (2019). These garden staff were consulted to get a better understanding of the best things to use in a community garden and ideas of different types of plant species. The next step was to determine the garden themes for the Wetland Center which concluded to Pollinator, Sensory, Native, and Local Foods to all be included within the garden. Plant options for each type of garden were found on local gardening websites and NC Native Plant registries (North Carolina Native Plant Society 2017).

Nature Play Space Consultations. A list of ideas for the nature play area was created by visiting Prairie Ridge Park. Before the visit, we compiled a list of questions to ask Jan Weems and Amanda Bowers, our contacts at Prairie Ridge.

- Do you know of any water features that are used in nature play areas?
    - If so… do you know how that water is treated? (We have a cistern of rainwater that they want to use for the kids, any suggestions are appreciated)
- What do you think are the most important aspects of a Nature Play Area as far as engaging kids & helping to support their development?
- What are important safety features to consider which will allow the kids to still explore & develop but keep them from getting hurt? (In reading saw the parts about making sure to think about risk differently but what are specific ideas?)
- What would you suggest as far as aspects that could help children interact with others in this environment? (What would help encourage them to interact with each other?)

During the visit, notes and pictures were taken while touring the areas.

Nature Play Space Risk Matrix. To determine which equipment we would recommend, our team conducted a risk matrix for each piece of equipment. Our risk matrix was based largely on the risk matrix used at Prairie Ridge, which was created in collaboration with professional consultants and park staff. This defined the risks in relation to activities being insignificant, minor, moderate or major. Insignificant risk was defined as risk equivalent to breathing in dust. Minor risk was defined as c uts, scrapes and bruises. Moderate risk was defined as sprains or potential damage to the head. Major risk was defined as breaks and contusions. It was then determined whether the probability of risk was rare, possible or almost certain. Once all of this was defined, we determined the risk and probability associated with each piece equipment and recommended items that had a reasonable risk and probability. This meant pieces of equipment that fell under insignificant risk that were rare or possible probability were recommended as well as those identified as a minor risk with rare probability.

7.2. Methods: Invasive Plants

7.2.1. Focusing on Privet

We collected data for the invasive plant, Chinese privet (*Ligustrum sinense*). On our first visit to the park, we scouted the park to establish a sense of how large our sampling area was. We walked through the park to familiarize ourselves with the physical characteristics of privet. We also focused on being able to differentiate the various life stages of privet. We used pictures online to delineate what was Privet and what was not Privet (Wilcox, 2007).

7.2.2. Creating a Sampling Approach

The Walnut Creek Wetland Park is approximately 58 acres in size. Our sampling took place in the area of the park located to the south and west of the wetland center. This sampling area was around 56.5 acres. To plan our sampling points, with the help of Jackie Hausle (course teaching assistant), we created a GIS map to determine where our sampling points would be. We over-layed the map with a grid that would space each sampling point by around 150 feet. The grid consisted of 15 North-South lines and 15 East-West lines. We did this so that our sampling would be unbiased. We also wanted to aim for at least 100 sampling points. Our overall goal was to create a heat map to show the hot spots of Privet located in the park (EPA, 2002).

7.2.3. Calibrating Sample Measurements

To determine how much Privet was located at each sampling point, we used a 10 foot diameter circle around each sampling point. We chose 10 foot boundary because it was a large enough area that we could actually see all the Privet. We then used a “Count Step” method to determine what a 10-foot diameter circle would look like. Each person used their natural walking pace to determine how many steps it would take to cover 10 feet. We used the Daubenmire Method to determine a percentage range estimate for how much Privet was taking up the 10-foot diameter circle, because people are better at determining approximate ranges than exact estimates of things like percent cover (Coulloudon, 1999). We used six percent coverage ranges: 0-5%

coverage, 5-25% coverage, 25-50% coverage, 50-75% coverage, 75-95% coverage, and 95-100% coverage (Coulloudon, 1999). To calibrate these percentage ranges, our group went to various random spots in the park to agree upon what each percentage range looked like. After our sampling calibrations were completed, we moved onto actually taking samples.

7.2.4. Using GIS

We used the Collector for ArcGIS application, Version 19.0.1, to collect data at our sampling points. We then used our preloaded map that Jackie Hausle helped us create, to locate each point at the intersection of each line using the GPS function on our phones. We decided to work in three sets of pairs so that if there was any difference in opinion on how much percent coverage there was, we were able to agree on one set percentage range. Once we reached the sampling location, we would record our GPS location, sample ID, date and time, percent coverage range, observers' names, and any comments we thought were important for that sampling point. We allotted five days to complete our sampling of the park. There were many areas within the park that were inaccessible due to flooding. There were also areas in the park that had no privet because the samples points were in the stream, on the walking path, or an area that we could not get to. At the end of our sampling, we had collected data for 116 sampling points.

7.2.5. Drone Image

On April 3nd 2019, Evan Arnold (Institute for Transportation Research & Education) conducted a drone flight over the entirety of the southern part of the park. During the flight, the drone took pictures at specific points along the flight path that would later be stitched together to form one image of the wetland park. We over-layed our heat map over the drone image of the park. This image was very useful in showing the areas of the park which were inaccessible as well as the dense Privet areas. The flight report was also given to us as well, which shows the different parameters the drone collected.

7.4. Methods: Southside Connector Trail

7.4.1. Visual Observations

Our initial visit to the Southside of Walnut Creek Wetland Park revealed a variably flooded topography. The area has collected litter and debris that washes in from upstream, and we deduced that this area has served as an unofficial dumping ground, due to the presence of large items such as furniture and workout equipment. Parts of the area were too overgrown or too flooded for our team to access. We determined that soil samples were needed to evaluate the saturation levels of the soils at various locations. We also decided to take measurements of the standing water levels at five different locations along the topography; these measurements would be cross-referenced with weekly rainfall levels to determine if there was any relationship. Based solely on our visual observations, we decided that some areas of the topography would allow for a wider variety of pathway materials, while other, more flooded areas, would be much more limited, or perhaps were inadequate for trail construction all together.

7.4.2. Soil Testing

Nine different soil samples were taken along our proposed pathway areas (Figure 7.4.1.) We chose these sites because we believed that they were the best areas for pathway construction, and wanted to explore the soil conditions. We utilized a soil auger to take the samples, and since the auger "bucket," (the part that digs into the ground and catches the newly disturbed soil) is only eight inches deep, we had to take multiple samples in the same column and lay them out in a half PVC pipe to get a better view of the soil profile with depth. The soil textures and colors were evaluated to make predictions on the moisture content. When a soil is saturated for long periods of time, it often has gray coloration, known as gleying (McKeague, 1964). This characteristic of soil is often found in wetland environments. We looked for any signs of gleying during our sampling as this would indicate that the site experiences frequent flooding and would not be suitable for a trail. We also evaluated the soil texture in the field using standardized soil texturing procedures (Purdue Agronomy, n.d.). A sandier soil will allow for more drainage, while a soil with more clay will retain more moisture. A coarse textured soil will retain its strength when saturated whereas finer soils will lose their strength and durability when saturated (Ekblad and Isacsson, 2011). All of these evaluations were useful when determining if an area would be able to support foot traffic.

Figure 7.4.1. *This map depicts the sites of soil sampling and evaluation. These were chosen based on the locations of our potential pathways to evaluate soil texture and moisture content, which provide information on soil stability.*

7.4.3. Water Level Measurements

Standing water levels were measured at five different locations (Figure 7.4.2.) The locations were chosen because they are along or near our potential pathway routes, and we noticed standing water in all of these locations and wanted to analyze how the water levels changed over time. We measured on four different occasions and compared the number of inches of standing water with how much rainfall there had been the week before. Each measuring day took place on a Wednesday at around midday, and the rainfall data was added up from the previous Wednesday to the day of measurement up until 1:30 pm. The rainfall data were complied from the USGS rainfall data website, where measurements were recorded from a rain gauge located adjacent to Walnut Creek Wetland Park on State Street (USGS, 2019).

Figure 7.4.2. *This map depicts the sites of standing water level measurements. They were chosen along some of the more saturated areas of this region to assess how flooded the topography can become after rainfall events.*

7.4.4. Research

Throughout the observation and data collection process, we conducted research on previous wetland construction projects (Wetland boardwalks, Haw River State Park), to determine which aspects of the area we should study, and compared the advantages and disadvantages of using different materials in pathway construction. The team also met with Dr. David Tilotta and Dr. Phil Mitchell in the Department of Forest Biomaterials at NC State University to discuss the possibility of using on-site lumber for trail construction. The purpose of this research was to put together a comprehensive cost-benefit analysis of the different pathway materials and methods.

Powerlines. One of the potential pathways runs directly under the powerlines behind St. Ambrose Church (Figure 5.8) We determined that these powerlines are owned by Duke Energy Progress and began to research what steps would need to take place to get permission to build a trail in this area (Duke Energy, 2014).

Wood products. To gain a better understanding of the different materials that could be used in trail development, we sought the help of the Department of Forest Biomaterials at North Carolina State University. Dr. Phil Mitchell and Dr. Dave Tilotta met with us to discuss the option of using the wood products on-site in trail projects. This would provide an opportunity to recycle the wood products.

Sidewalk. The possibility of implementing a sidewalk was considered to solve this problem. We determined if a sidewalk could be placed along Bailey Drive, Boaz Road, and Darby Street by contacting Jeff Essic from North Carolina State University Libraries and through using GIS property line data. We also found information on the process of approval and implementation on the Raleigh Petition Program website (Sidewalk Petition Program, 2019).

7.3. Methods: Water Quality Methods

7.3.1. Planning

To collect the necessary data needed for this project, a substantial amount of preparation was needed before heading into the field. The original goal was to have 10 points spread throughout Little Rock Creek at points of interest. These points of interest would be chosen based on factors such as storm drain inlets, water runoff inlets and other significant tributaries. To ensure that all points of possible entry were documented, the creek was walked from the Walnut Creek Wetland Center to Chavis park, which is where the stream daylights. While choosing sample sites, we decided on 11 points instead of 10.

7.3.2. Data Collection

At all 11 sample sites, 100 ml water samples were collected upstream of each point along Little Rock Creek, Raleigh, NC, for *E. Coli* testing. Each sample was stored in an ice cooler immediately after the sample was taken as a means to preserve the sample's integrity and prevent contaminants from breaking down. E. Coli water samples were immediately taken to CNR Water Quality Lab and subjected to the Colilert test and incubated at 35℃ in order to detect and quantify E.coli and total coliform. After 24-26 hours of incubation, results were recorded and analyzed.

Using a YSI Professional Series Multiparameter Water Quality meter with a Qanto Probe, temperature, pH, dissolved oxygen, and specific conductance were measured at each sample point. Before taking measurements each sample day, all YSIs were calibrated for each parameter using calibration methods described in the YSI Professional Plus User Manual. The process used to calibrate for each of these parameters is as follows; to calculate pH, the YSI meter was submerged in a Fisher Chemical buffer solution with a pH of 7.00, specific conductance was calibrated by submerging the YSI in a conductivity standard of 500 µS/cm, dissolved oxygen was calibrated using the oxygen solubility table provided by YSI Incorporated in the YSI Manual.

7.3.3. Lab Testing and Data Analysis

E. Coli water samples were prepared in the lab after data collection. Before our first sampling day, Professor Litzenberger taught us all of the laboratory practices to properly handle the samples and the equipment. For each of the 11 water samples, an appropriate amount of water was poured out to reach the 100mL line. Colilert Medium was poured into each of the samples, then each sample was inverted carefully until all medium was dissolved. Each water sample was placed in a Quanti-tray and then run through the Quanti-tray sealer. Finally, all 11 Quanti-trays were placed in the incubator for 24-26 hours at 35℃ (Quanti-Tray*/2000, 2013).

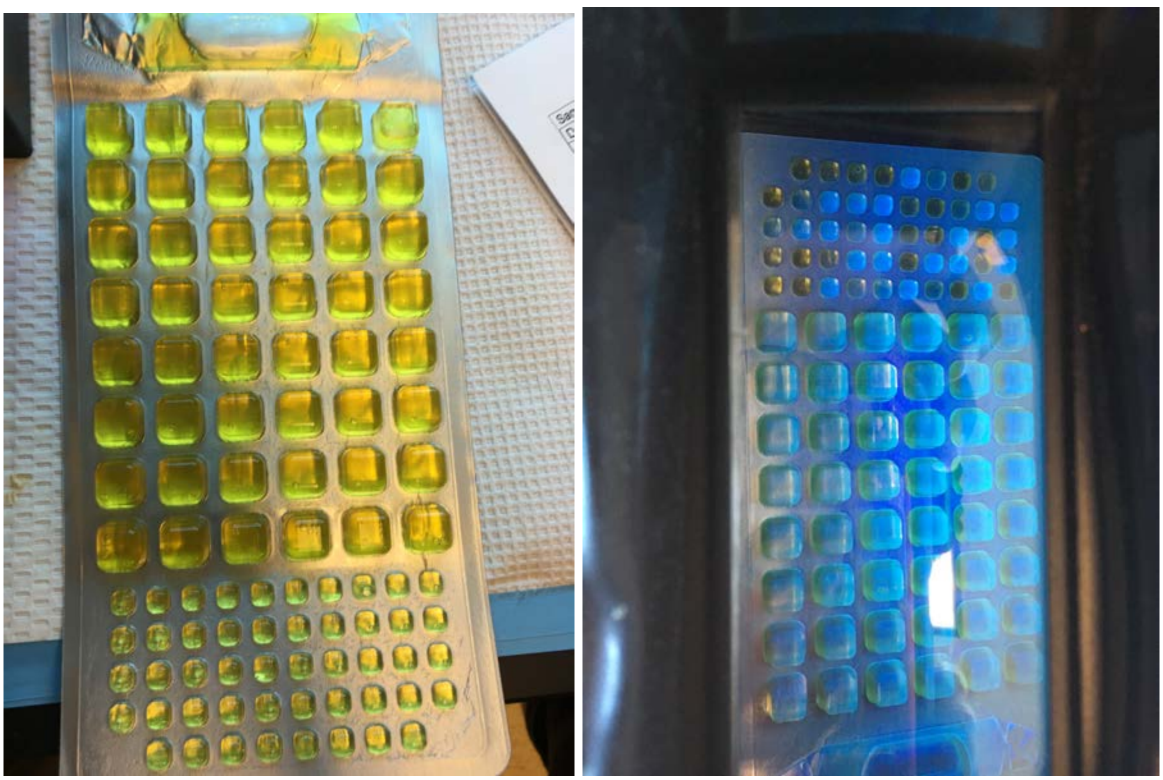


Figure 7.3. Quanti-tray water sample that is positive for total coliform with an index greater than 2419.16 MPN (left). Quantitray water sample that is positive for E.coli with an index less than 2419.16 MPN (right).

After 24-28 hours, each sample was observed under a ultraviolet light to determine if there is a presence of E. Coli. The number of boxes that flow under ultraviolet light was counted to determine the concentration of E. Coli in each sample.

7.5. Methods: Wildlife

7.5.1. Camera Trapping

Medium- and large-sized mammals were detected through the use of non-baited camera traps over three-week deployments throughout Walnut Creek Wetland Center (Table 7.5.1). Camera traps are motion activated cameras. Ten cameras were deployed, with only two of the cameras producing problems for data collection. Cameras were deployed following eMammal protocol following instructions of battery usage, detection distance, and trigger sensitivity (eMammal 2019). Identification of animal species normally is done through eMammal software and is subject to expert review and mapped in Microsoft Excel, however some technical difficulties resulted in eMammal not receiving our teams' photos in time for analysis. Instead, we produced identified the different kinds of species we found, without the exact numbers of individuals.

Table 7.5.1. *Camera Trap Deployment Locations and Retrieval Dates.*

Deployment #	Date Deployed	Date Retrieved	Latitude	Longitude
1	2019.02.06	2019.02.27	35.7585262	-78.6294987
2	2019.02.06	2019.02.27	35.758177	-78.629638
3*	2019.02.06	2019.02.27	35.75792	-78.630049
4	2019.02.13	2019.03.06	35.7585102	-78.6242436
5	2019.02.13	2019.03.06	35.7589101	-78.6244733
6	2019.02.13	2019.03.06	35.7580147	-78.6243865
7*	2019.03.06	2019.03.27	35.756740	-78.628920
8	2019.03.06	2019.03.27	35.7574494	-78.6275863
9	2019.03.06	2019.03.27	35.7570891	-78.6270646
10	2019.03.06	2019.03.27	35.75792	-78.630049

* Data not usable for eMammal. Camera 3 captured video instead of still photographs; camera 7 was stolen.

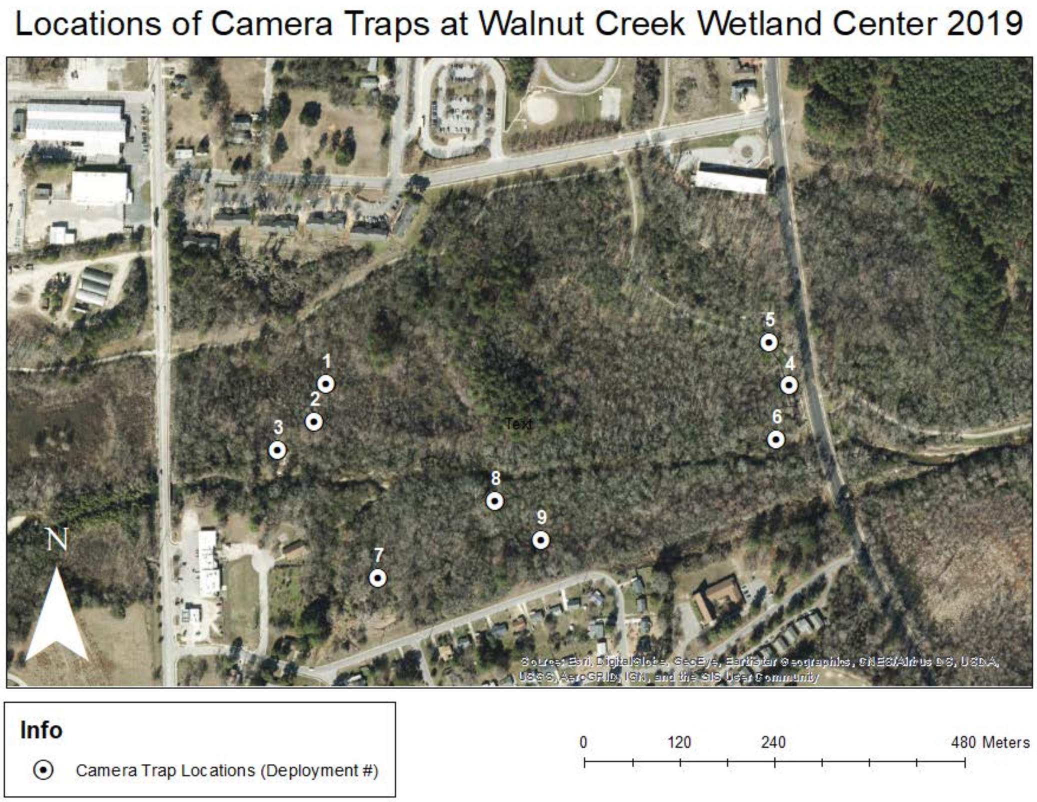


Figure 7.5.1: *Camera Trap Deployment Location Map*

* Deployment 3 was replaced by deployment 10 at the same location

7.5.2. Sherman Trapping

We deployed 14 Sherman live traps to inventory small mammals (Figure 7.5.2). Our team's trapping protocol was approved by NC State's Institutional Animal Care and Use Committee (Protocol 18-019-T) and permitted by the NC Wildlife Resources Commission (Permit 18-SC00989). A Sherman live trap is a foldable, box-style steel trap designed to capture small mammals (Figure 7.5.2). The opening is 2x2 inches, and about 8 inches long. When a small mammal enters the trap, the door closes behind it and secures the mammal within the trap (H.B. Sherman Traps, 2015). Per protocol, the traps were baited with dry oats, and provisioned with 2-4 cotton balls for warmth and bedding to help the mammals get through the night. The Sherman live traps were deployed from April 7th, and retrieved April 11th (4 nights). All traps were put on the Southern end of the Walnut Creek Wetland Center, Latitude 35.7564, Longitude -78.6285, in various locations with high amounts of foliage, rocks, and wood. They were hidden and covered by loose foliage, and secured in small nooks for the mammals to go in. The traps varied from 5m to 20 m apart within a relatively small area between two stormwater ditches, roughly 100x100 feet in area. By each trap, there was an orange flag tied to a tree to help identify where each trap was located. When animals were captured, they were placed in a large Ziploc bag, had their sex identified, and marked with non-toxic nail polish to identify if the mammal was recaptured during future captures. Unfortunately, we believe the nail polish washed off from the small mammals, so we are unsure if we got any mammal recaptures.

There were 36 instances of traps that did not close, 6 traps that closed with no mammals inside, 12 traps that captured small mammals, and 2 traps that captured mammals that ended up dying over the course of 4 nights (Figure 7.5.3).

Figure 7.5.2. *Sherman live trap (*https://www.shermantraps.com/ *https://www.nhbs.com/sherman-trap-small-folding-aluminium).*

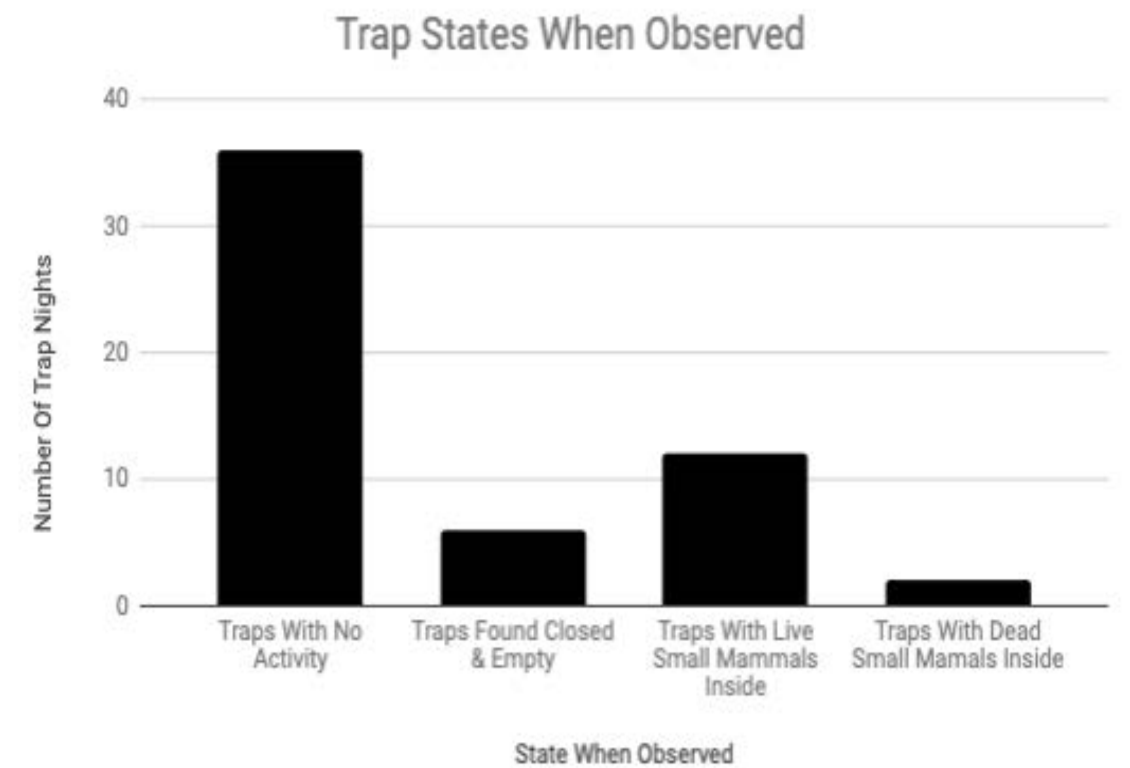


Figure 7.5.3. Sherman trap states when observed. Cumulative observations after five nights of trapping.

7.5.3. Wildlife Audio Recording System

The Wildlife Audio Recording System was based on a project Robin Whytock called the Solo Field Recorder (Whytock 2018). To build the system, a water-resistant electrical junction box was used as the casing. The components were as follows: casing, Raspberry Pi 2, microSD card x2, microUSB cable, 3.5mm microphone, SoundBlaster sound card, DS3231 clock module and a 20,000 mAh rechargeable battery (Figure 7.5.4).

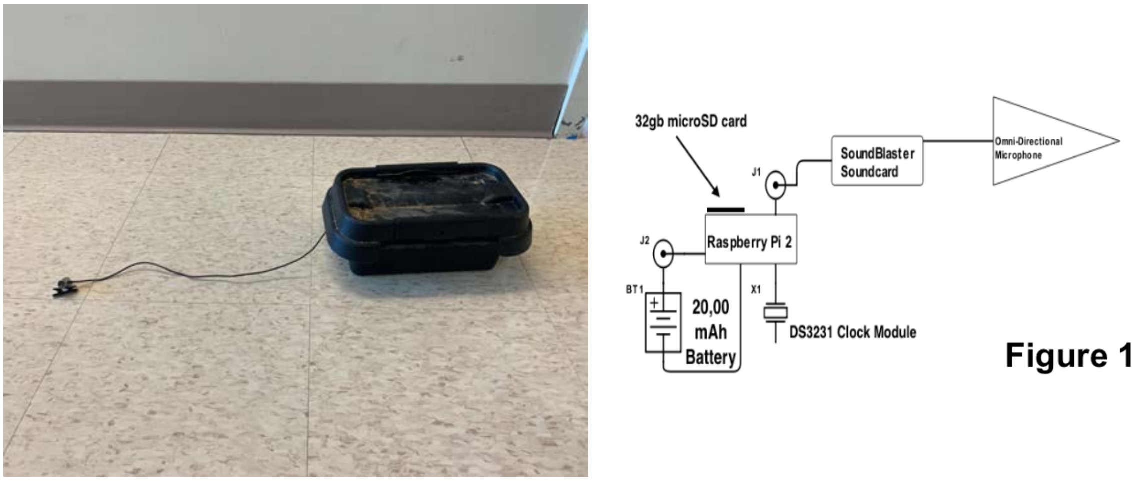


Figure 7.5.4. *Wildlife Audio Recording System, including schematic diagram.*

The wildlife audio recording system (WARS) was deployed twice. The first deployment was on February 21st through the 24th and the second deployment was from March 20th through the 23rd. The deployment consisted of charging the power supply ahead of time and clearing the microSD card. The code was adapted from Robin Whytock’s SOLO github project site . In terms of finding an adequate location for deployment, a couple of factors were considered. First, because of the sensitive electronics within the device, a location had to be found that would not be prone to excessive flooding. Second, the device had to be an adequate distance away from roads to minimize background noise from vehicle traffic. Once a location was found, the computer was plugged into the power supply via a micro-USB cable and the system was then activated. The lid was then snapped into place with the microphone cable running out of the ports. The microphone clip was snapped onto a branch in a way that minimized rustling from nearby foliage. The technician provided a sample recording by speaking the phrase “Test. Test. Test. Today’s date is X.” This provides decibel values that were valuable for later analysis of the data and ensures that the system is working properly. The location of the system was then recorded using a GPS-enabled app such as Google Maps or ArcCollector.

Upon retrieval, the system was located and the microphone was unclipped from the branch it was attached to. The system’s casing was opened and the power supply was disconnected from the Raspberry Pi. The microSD card was inserted into a computer and the original data was copied and deleted from the microSD card. The battery was recharged and the system was ready for the next deployment.

In terms of audio analysis, the audio files are automatically put into folders with corresponding dates and times. It is imperative to note that the typical file time assigned to each audio file is slightly incorrect. Individuals must use the date and time that is a part of the file's title to determine the time of the recording. Files were uploaded into Audacity (2019) where the analysis began. Analysis consisted of a visual inspection of the audio wavelength visualization within Audacity and noise isolation began. To perform noise isolation, a portion of the audio clip where no noise is present is highlighted and a noise profile is compiled (Effect > Noise Reduction > Get Noise Profile > Highlight Entire Clip > Effects > Noise Reduction > OK). From there, the portion of the audio clip containing wildlife noises are then highlighted and then made into a seperate file (File > Export > Export as MP3). These files are then provided to a wildlife expert to identify what species the noises come from.

Northern Mockingbird	*Mimus polyglottos*	02-21_14-12-49.wav
Red-shouldered Hawk	*Buteo lineatus*	02-21_14-12-49.wav
Canada Goose	*Branta canadensis*	02-21_14-12-49.wav
Cedar Waxwing	*Bombycilla cedrorum*	02-21_14-12-49.wav
Carolina Chickadee	*Pocecile carolinensis*	02-21_14-20-06.wav
Blue Jay	*Cyanocitta cristata*	02-21_14-20-06.wav

7.5.4. Cover Board Sampling

A cover board is a piece of wood, tin, carpet, or similar material placed on the ground to provide cover for reptiles and amphibians. The coverboards at Walnut Creek Wetland Park were made from three different types of material; wood, carpet, and tin. There were five cover boards of each type of material and 10 logs. A cover board sample was conducted every Wednesday during the months of February and March. The sample consisted of checking the cover boards that were previously installed at Walnut Creek Wetland Park and the logs of wood that were near the cover boards. To conduct samples we would lift up each cover board/log and document what was found on the back of the board and on the ground below the board. When checking the cover boards for presence of animals, slowly lift the board off the ground a few inches at a time. The slower the board is lifted the greater the chance to see an animal before it scurries away (Rodomsky-Bish, 2015).

7.5.5. Electrofishing

We conducted a backpack electrofishing survey, following the Standard Operating Procedure Biological Monitoring: Stream Fish Community Assessment Program (2013), of Walnut Creek and small section of Little Rock Creek on April 3rd 2019 with the help of Matt Stillwell and Dan Donahoe from the North Carolina Department of Environmental Quality. Using a pulsed DC current from the battery powered backpack unit, the pulse is delivered into the water by an anode while a cathode trails behind (Northrop 1967). The current puts the fish in a state of galvanotaxis which relaxes a fish’s muscles and makes the fish swim towards the anode.

Our survey was done 140 m downstream and 140 m upstream along Walnut Creek near the intersection of S. State Street. In addition to Walnut Creek, we also survey 30 m upstream in Little Rock along its intersection at walnut Creek. Each survey team consisted of one person using the backpack electrofisher with dual shockers and three other team members using dip nets to collect the specimens. After the survey we brought the fish on shore to identify and count them. Afterwards the specimen were identified we released them back into Walnut Creek.

7.5.6. Incidental Species Sightings

While conducting surveys of our primary wildlife objectives, we observed a variety of incidental species. These incidental species represented fauna common to wetland ecosystems. The incidental species encountered were among the reptile, avian and amphibian classes. All project teams participated in the recording of the incidental sightings by taking a location point in ArcGIS and noting the specific species observed.

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