Designing a Rain Garden on Campus at the University of Illinois

Implementing and Raising Awareness of

Sustainable Stormwater Runoff Management Techniques

CEE 398 Project Based Learning

Final Report

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Executive Summary

The purpose of this project group is to design a new rain garden on the campus at the University of Illinois at Champaign-Urbana. A rain garden is comprised of a depression made in the ground, soil with high water permeability, and native plants with long roots. It provides a more sustainable way to manage storm water runoff than the traditional storm sewer systems. The garden facilitates storm water infiltration directly into the ground.

The benefits of implementing a rain garden near areas with frequent flooding include decreased flooding, water quality improvement, and increased aesthetic appeal. The final objective of the project is to propose the project to a sustainability group on campus called the Student Sustainability Committee (SSC). The proposal will consist of a list of plants, soil composition and quantities, 3D computer renderings of what the rain garden would look like, a budget for its construction, and a short summary of its hydrological aspects.

Our group communicated with the Facilities and Services department and Professor Art Schmidt at the University to find areas suitable for planning the garden. After evaluating several locations around campus with flooding issues which were proposed to us, our group determined that this garden will be constructed between the Performing Arts Annex and the Wood Engineering Laboratory, near the F4 parking lot. After selecting the location, the group determined the approximate amount of water that would be flowing into the garden to be 34 cubic meters. After further research, we selected a specific mixture of engineering soil to be placed in the rain garden. Using the amount of water needed to be captured and the porosity of the soil, we concluded that the required volume of engineered soil is about 75 cubic meters. The cost of excavating the native soil, purchasing new soil, and purchasing the plants to inhabit the rain garden was estimated to be $10,600. Using average rainfall data from the past century, this garden would be able to capture all rain fall from 97% of the days in the year.

The rain garden is designed for a location near a path with significant foot traffic, so this garden also presents an opportunity to educate the public about the importance of sustainable practices. Our project group also proposes to put signs in front of the rain garden to inform those walking past of the hydrological benefits that the garden, which seems to be nothing more than a bed of plants and flowers, has to offer.

Introduction and Background

Stormwater flooding is an ongoing problem for many communities. The impermeable nature of the surfaces in the area, such as asphalt roads, turf lawns, and buildings is the primary cause of flooding in developed areas. The most common solution to this flooding issue is the development of storm sewer systems with large capacities that can quickly drain storm water from streets and out to nearby bodies of water. However, this solution has many problems. For example, because the all water is collected and sent to the same water stream, runoff from a large storm often causes increased flooding downstream. Also, various kinds of contaminants such as, oil and fertilizers often lay on impermeable roads and sculpted lawns. Stormwater runoff will wash them off and carry them into the receiving streams (Chicago Botanic, 2017). At the University of Illinois, most rainfall and accompanying contaminants flow through the underground conveyance system to Boneyard Creek, which then continues east and out of town. This method of preventing flooding does not completely solve the problem and increases the potential negative impact. Implementing a different technique of storm water management could both capture runoff and increase the rate at which the water infiltrates into the ground.

In 1990, the concept of a "rain garden" was first introduced as a cost-effective way to control storm water runoff in Prince George's County, Maryland (Beier, 1995). Rain gardens address the issue of flooding at the source. Instead of flowing over the impermeable surfaces before draining away into a conveyance system or flooding elsewhere, some of the water infiltrates directly into the ground. A rain garden is usually located at the low points of the terrain and consists of species of both small and large vegetation like grasses, shrubs, bushes, and trees that together serve as ground cover to simulate a prairie environment (Beier, 1995). A rain garden removes pollutants from water by allowing them to settle into the soil, where the roots of plants and microbes will absorb and filter storm water runoff through natural processes. According to Larry Coffman, the associate director for programs and planning for the Prince George's County Department of Environmental Resources, "[the rain garden] combines environmentally sensitive site design with pollution prevention to form a comprehensive approach to water quality problems" (qtd. in Beier 1995).

Despite the environmental benefits of implementing rain gardens in developed areas, identifying these ditches as effective alternatives to storm sewer systems can be difficult for someone unaware of rain gardens and sustainable wastewater management techniques. Just as developing and implementing these techniques are important, educating the public and getting them interested and involved with the processes is necessary if these projects and ideas are to gain traction in the future.

A rain garden currently on campus at the University of Illinois, called the *Red Oak Rain Garden*, is located just southwest of Allen Residence Hall. It was dedicated April 19, 2007 and was the first rain garden on campus (Illinois News Bureau, 2007). The purpose was to sustainably drain storm water. However, after 10 years, the garden has fallen into disrepair and is currently under renovation. By studying the *Red Oak Rain Garde*n and its performance throughout the past decade, our project team believes it is possible to design a rain garden with all the discussed benefits, a higher performance, and a longer lifetime.

Objectives

The objectives of the project are to offer alternative storm water management techniques on campus. The proposal consists of a schematic design of a new rain garden on the University of Illinois' campus, calculating an economic evaluation of the hypothetical construction, and estimating the garden's environmental and social impact. Designing a new rain garden includes determining the shape, vegetation, and measurement tools. As increasing public awareness of the benefits of rain gardens and other sustainable infrastructure solutions is a principle factor in planning the garden, the orientation and signage related to the rain garden will be designed to best capture public interest. The final deliverables for this design project will be a written report, site plan, and budget, and a proposal to submit to the SSC.

Methodology

To accomplish the objectives within the given time frame, the team organized the project into three major tasks, outlined below.

<u>Task 1: General Rain Garden Research</u>

The first step of the project was to collect background information about rain gardens by researching on the internet and interviewing experts. Throughout the entire timeline of the project, Professor Art Schmidt was a primary resource for general information and details of elements within the design process.

Task 1a – Components

Plant types, soil types, shape and size of gardens, typical rain garden construction methods, and their desired characteristics were researched online (i.e. shade preferences of plants, hydrology and porosity of soil, etc.).

Task 1b – Site Information

Since the plan was to base the garden on the redesigned rain garden near Allen Hall, Morgan White, who works at Facilities and Services, was contacted about the information concerning that garden. Eric Green, a landscape architect who specializes in rain gardens, shared his knowledge of rain garden design. Finally, the landscape department at the University provided information regarding plant types and general design principles.

Task 2: Rain Garden Design Plan

Our project group used the research to develop a design for the garden.

Task 2a – Deciding Location

The location of the rain garden, between the Architecture Annex and the Wood Engineering Laboratory, was decided from a list of possibilities provided by Facilities and Services. The requirements for the garden included being near high foot traffic (for greater public visibility) and existing issues with storm water draining. To select the location, the group contacted both Professor Schmidt and Morgan White with questions concerning the possible locations and limitations.

Task 2b – Component Assessment and Organization

Using the data collected from research and interviews, the components of the garden were planned. The shape and size of the garden were defined to optimize drainage and ease of pedestrian interaction based on the research and location constraints.

Task 3: Create Deliverables

Task 3a – Project Proposed Cost Estimate

The project group generated a budget necessary to fully construct the garden. This includes the cost of excavation, planting, and materials. We omitted labor costs for reasons that will be described later. Because many factors can cause large fluctuations in total costs of rain garden construction, most estimations were composed of analogous projections from similar projects. Also, the cost of manual labor was not calculated except for excavation work since the plan is to have the SSC fund the project in which case the remaining labor and maintenance would be provided by volunteers.

Task 3b – 3D Rendering

To add a visual component and to create the most appealing proposal possible, 3D renderings of the rain garden in the specified location were created using Revit 2017. Photographs of the original location and maps of the layout were used to approximate the area. Then, the garden was designed using the plant types available in Revit.

Task 3c – Compile Proposal

The proposal is the compilation of the cost estimate, 3D rendering, and text describing the benefits of implementing a rain garden at the proposed site. The purpose of the proposal is to be given to the Student Sustainability Committee (SSC).

Results and Discussion

With the goal of creating a proposal for the Student Sustainability Committee, our team determined the specific characteristics of the rain garden by gathering information and calculating dimensions.

Location

After considering multiple locations around the UIUC campus with flooding issues, our project team decided to design it directly west of the Architecture Annex building. A picture of the location can be seen in Figure 1. A preliminary aerial sketch of the rain garden is depicted in Figure 2.

Figure 1: Current pedestrian view of location facing northwest

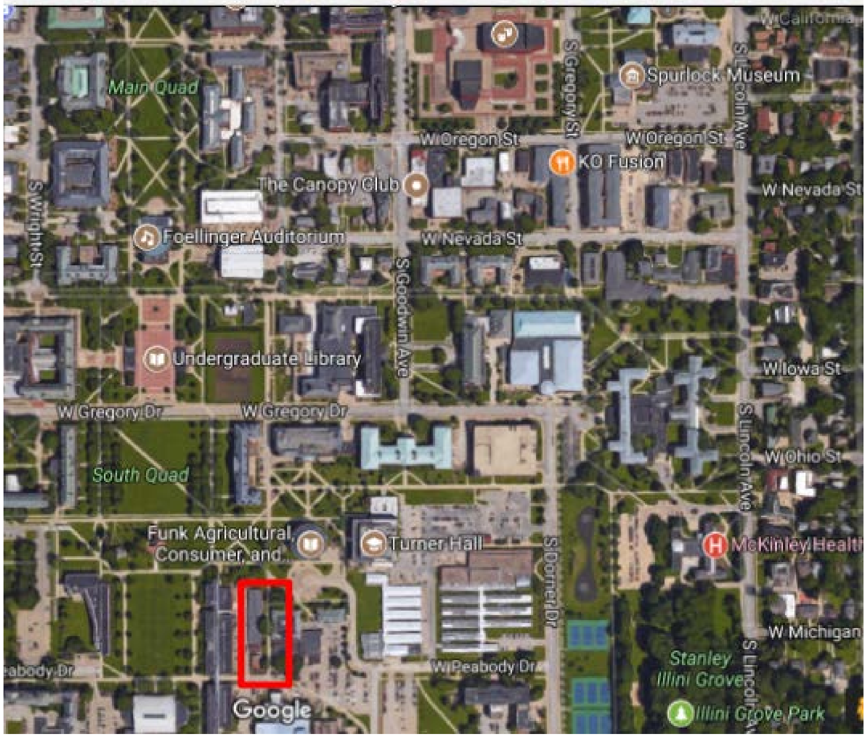

Figure 2: Satellite view of the University of Illinois Campus, rain garden area highlighted in red (Google, 2017).

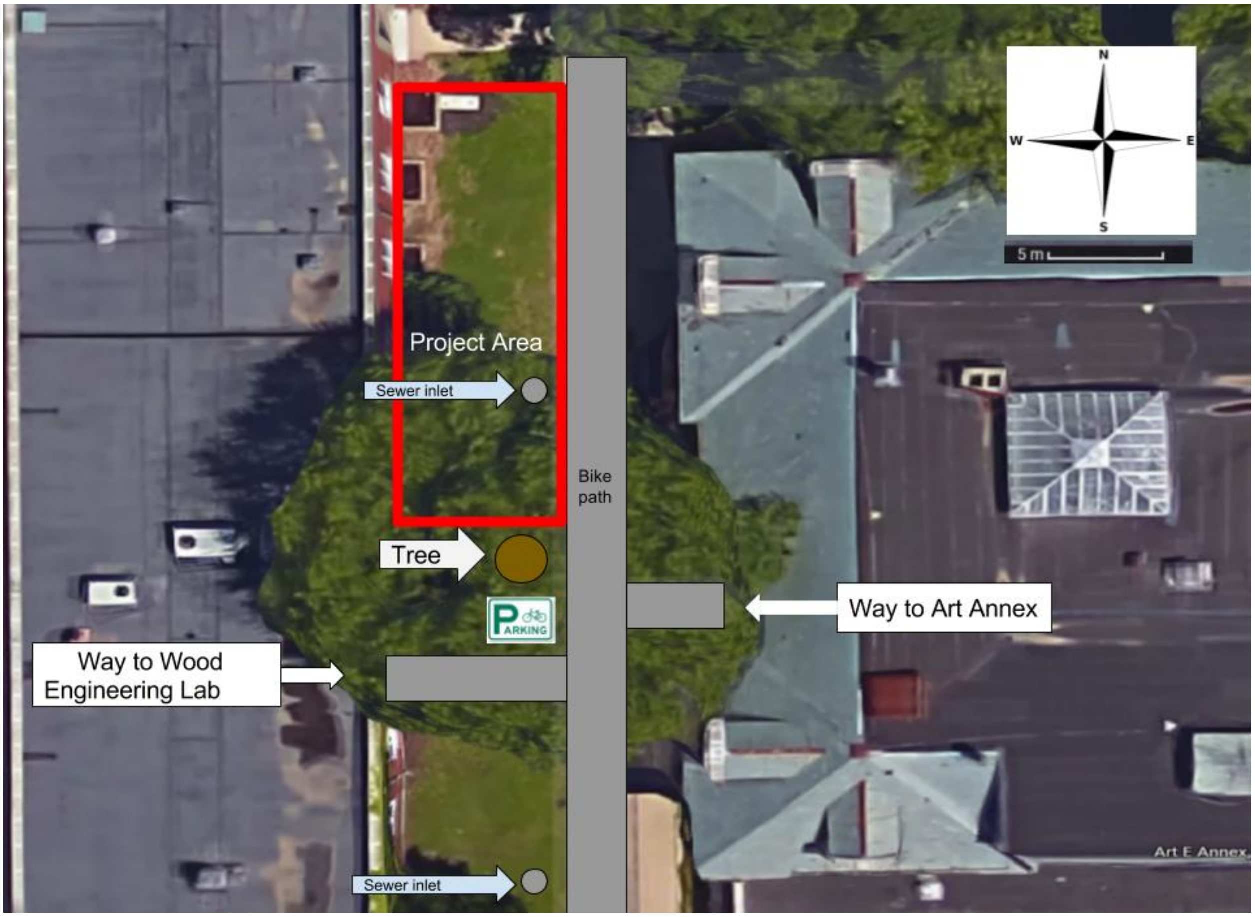

Figure 3: Annotated satellite view of current rain garden area (Google, 2017).

Plant Selection

For the design of a rain garden, one important step is to choose its plant species. The University of Wisconsin-Madison Arboretum recommends 30-60% of the plants be grasses or sedges and the rest can be forbs, also known as wildflowers, because this ratio mimics the natural structure and character of a native prairie (U Wisconsin-Madison, 2017). Ecologically, forbs depend on grasses for structural support and grasses hold the soil with their root systems. We will use native plants because they are adapted to local conditions, benefit wildlife, have deep root systems, and are often perennial, which means that they live for more than two years (Prairie Rivers Network, 2017).

To address the recommendation of grasses and sedges, Frank's sedge (Appendix A) will be the best choice because it grows only one to two feet in height, which means it will not dominate the view of the entire array of plants. It can tolerate very shady and very bright sunlight, which means it can be planted throughout the garden (Prairie Rivers Network, 2017).

Additionally, because aesthetic appeal is an important characteristic of the rain garden, bloom times for forbs are necessary to consider. The bloom time of forbs should correspond with the academic semesters because students are the main demographic that will look at the garden. Based on a list of native plants suitable for rain gardens in Illinois, the earliest time at which plants start blooming is April and the latest time at which they stop is October (Prairie Rivers Network, 2017). The forb species were chosen so that at least two species will be blooming from April to May and from August to October.

The main constraint in plant selection is the amount of shade around the garden. Because it will be placed in a narrow corridor, oriented north to south, between two buildings, it will be in the shade of surrounding buildings for most of the day except at peak sun times. Also, the tree standing at the southern half of the garden will contribute to shade. Consequently, a shade-tolerant plant species must be chosen for the southern part of the garden that lies under the tree. For the northern part of the garden, the plant species should tolerate partial shade, which is defined as three to six hours of sunlight per day (U Wisconsin-Madison, 2017). The specific plant species chosen for this rain garden and their attributes are listed in Table 1. In the table, if the plant species prefers shade, it means that it can tolerate less than 3 hours of direct sun per day. If it prefers partial shade, it can tolerate 3 to 6 hours of sunlight per day, and if it prefers sun, then it needs more than 6 hours of sunlight per day (U Wisconsin-Madison, 2017). Images of the plants are depicted in Appendix A. The array of colors that will be seen during various months of the year are depicted in Figure 4.

Table 1: Plant species and their attributes (Prairie Rivers Network)

Plant Name	**Location**	**Sunlight exposure preference**	**Bloom Time (Month)**	**Color**	**Height (ft.)**
Orange Jewelweed	Under tree	Shade-Partial	6-9	Orange	2-5
Big-leaved Aster	Under tree	Shade-Partial	8-10	Blue	2-4
Virginia Bluebell	Under tree	Shade-Partial	4-5	Purple	1-3
Jack-in-the-pulpit	Under tree	Shade-Partial	4-7	Green	1-2
Black-eyed Susan	In open space	Partial-Sun	6-10	Yellow	1-3
Blue Vervain	In open space	Partial-Sun	6-10	Purple	2-5
Jacob's Ladder	In open space, closer to walls	Partial	4-6	Purple	1-2
Columbine	In open space	Partial-Sun	4-6	Pink	1-3
Frank's sedge	Everywhere	Anything	6-7	Green	1-2

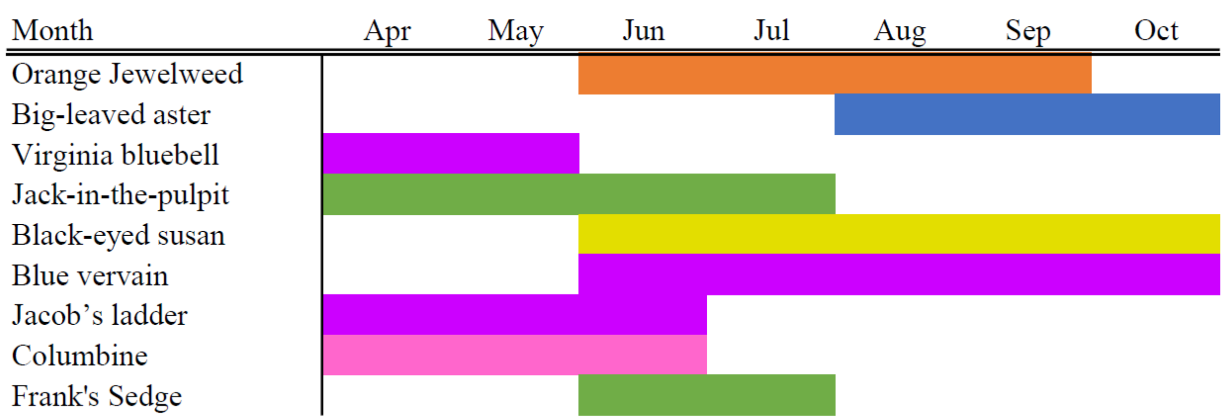

Figure 4: The variety of colors visible during various months in the rain garden (from Table 1)

Hydrology and Soil Calculations

To find how much material we needed, how much excavation was necessary, and the cost to complete the construction of our rain garden, it was necessary to calculate the dimensions of the rain garden. The calculations of the dimensions, which include a hydrological calculation and general measurements, are organized in the steps below. A more detailed version of the calculations can be found in Appendix B.

1. Measure every piece of area on google map with scale.
    a. The area for rain garden. (6.700m * 22.60m = 151.4 m^2)
    b. The total area of the region that, by assumption, will drain to our rain garden, using Figure 5. (about 1323 m^2)
2. The amount of water that our rain garden will be able to hold is calculated by multiplying the area of the region by 1 inch. (1323 m^2 * 0.0254m = 33.60 m^3)
3. Divide the volume of the water by the porosity to get the volume of engineered soil needed. (33.60 m^3 / 0.450 = **74.68 m^3)**
4. The required excavation depth of rain garden is 74.68 m^3 / 151.4 m^2 = **0.4933 m**.

Figure 5: Measurements used to calculate the total area of impermeable surfaces (Google, 2017).

During year 1981-2010, only on an average number of 10.1 days in a year did the precipitation exceed 1.0 inch. Thus, because the rain garden is designed to hold the 1.0 inch of rain fall from the surrounding impermeable surfaces, it will be able to hold the rainfall about 355 days in a year (Angel, 2017).

Next, the total volume of soil was calculated. The volume of water to be drained was divided by the average porosity of the soil (ratio of the volume of air voids to the total volume). The voids are where the water would be contained. To find the average porosity, the composition of the soil must first be determined. Table 2 contains the numbers used in this calculation.

Table 2: Soil average porosity, total volume of soil, total cost of soil

	Sand (Well-graded)	Topsoil (silt)	Compost
Porosity	0.32	0.445	0.67
Percent of Soil	50%	20%	30%
		Average porosity	**0.45**
		Volume of water to be drained (m^3)	33.6
		Total Volume of Soil Needed (m^3)	**74.7**
Unit cost (per m^3)	$240.00	$0.00	$0.00
Percent of Soil	50%	20%	30%
Volume (m^3)	37.3	14.9	22.4
Cost	$8,960.00	$0.00	$0.00
		Total Cost of Soil	**$8,960.00**

From a brochure partially funded by the EPA, a good soil mix for rain gardens is 50-60% sand, 20-30% topsoil, and 20-30% compost (Mass Audubon). From a soil survey of Champaign County done by the USDA in 1998, the topsoil is mostly silty soil (USDA, 1999). The porosity ranges from 0.21 to 0.68, so an average value of 0.445 is assumed (Geotechdata, 2013). From a research article about physical and chemical properties of compost, the porosity ranges from 0.6069 to 0.7247, so the mean value of 0.67 is assumed (Khater, 2015). The porosity of sand depends on its granularity. We chose the type of sand that yields the lowest total cost. Sand is the least porous material, which means more of it would be needed to drain the same amount of water, so we decided that sand should be the lowest recommended fraction of the soil, which is 50%. Compost has a higher porosity than topsoil, so we decided that compost should be 30% of the soil and 20% of the soil should be topsoil.

Next, the total cost of the soil must be found. The topsoil does not have a cost because it is already in place. Compost is also free of charge because it can be obtained easily from nearby sources, such as university dining halls, which produce a lot of food waste. The cost of sand depends on the unit price of the sand that is purchased as well as the porosity, which affects the total amount of sand needed. We tried different products of sand with varying porosities and unit prices to see which leads to the lowest total cost. We decided to use a well-graded sand, specifically Garden Pro All Purpose Sand from Lowe’s. We also looked at a fine and coarse sand product. The fine sand that we looked at is called extra fine sand, so from a range of porosities from 0.26 to 0.49, we assumed a high value of 0.49 (Agri Supply, 2017). For the coarse sand, we assumed an average porosity of 0.35 from a range from 0.26 to 0.43 (Lowe’s, 2017)

(Geotechdata, 2015). In addition to the cost of the sand, the excavation costs resulting from the total soil volume also had to be considered.

Budget

For the specific purposes of this proposal, we have decided to omit labor costs except for those associated with higher-skilled operations such as vehicle operations. This is because the SSC is comprised of volunteers that do most of the labor associated with this type of project within their own group. Therefore, they would weigh labor as a cost on their own terms. The labor costs for the higher-skilled operations are included in the costs of those operations.

We decided that only one seed packet for each plant species is necessary because we need to first plant them and see if they grow well. The ones that do not grow well would be replaced.

A layer of mulch should be added because of benefits such as aiding moisture retention in soil, control of weed growth, and protection from erosion (Patterson, 2017). A 3-inch layer is recommended (Clean Water Campaign, 2017).

In our calculations for the general budget, we estimated the soil costs based on data from Lowe's, the excavation from a City of Champaign engineer's pay estimate of a project called Washington St., the mulch cost from MidlandHardware, and the seed packet costs from Prairie Moon Nursery and Roundstone Native Seed, LLC.

Table 3 summarizes the budget calculation.

Table 3: The overall budget for the rain garden construction

Item	**Unit**	**Quantity**	**Unit Price**	**Value**
Soil	m^3	75	$119	$8,914
Earth Excavation	m^3	78	$12.43	$969.19
3" Mulch Layer	m^3	11.5	$61.80	$711.08
Flowers	seed packet	8	$2.50	$20.00
Frank's Sedge	seed packet	1	$4.61	$4.61
			Total Budget	**$10,618.88**

3D Model

To create a proposal that best described the physical characteristics of the rain garden, our project team developed a 3D representation of the rain garden and the surrounding features using Revit 2017 from Autodesk. Two views are displayed in Figure 6 and 7. Figure 8 is a proposed site plan of the area.

Figure 6: A 3D rendering of the 3D model at 1:30 PM, looking southwest

Figure 7: A 3D rendering of the 3D model at 1:30 PM, looking northwest

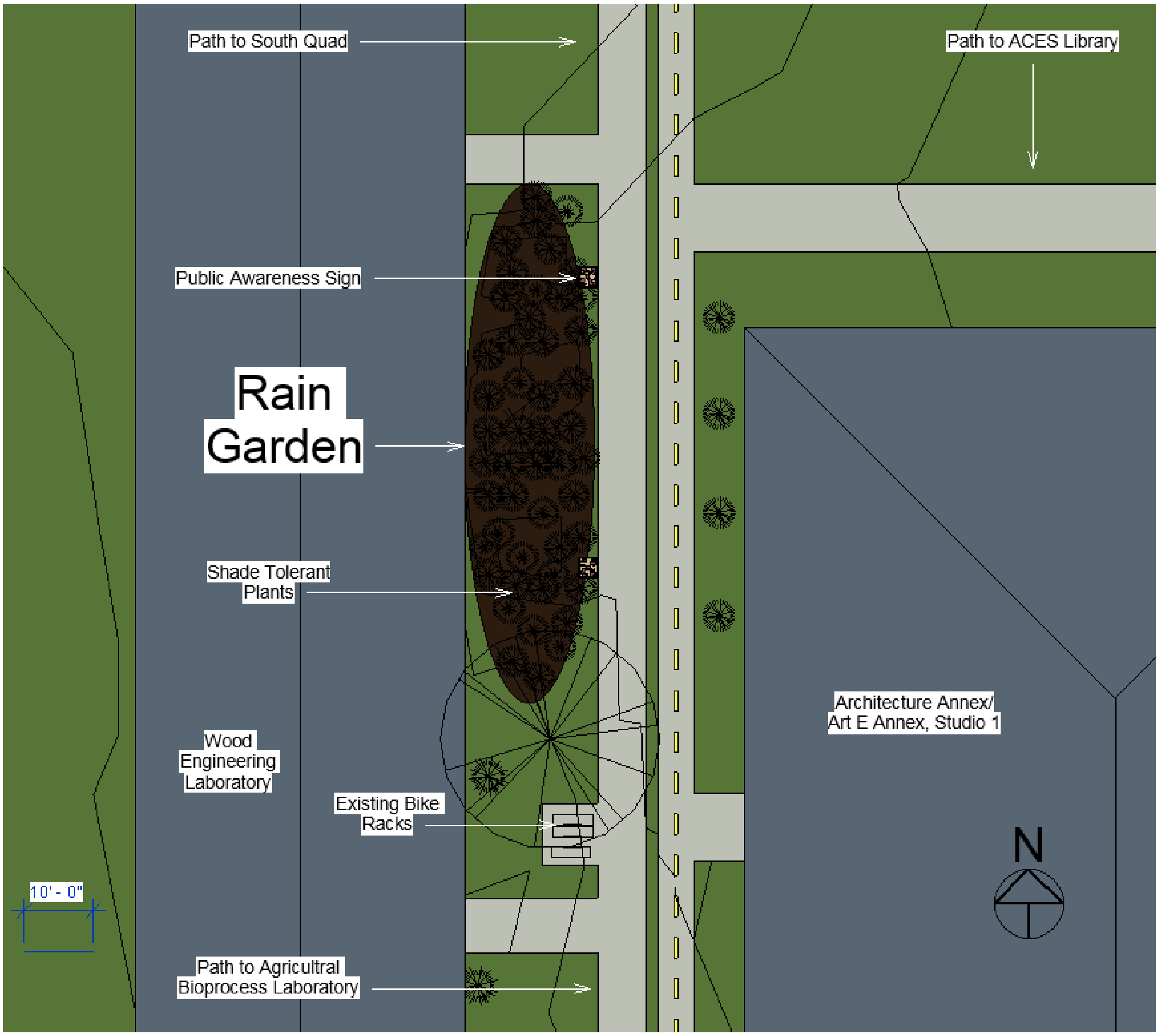

Figure 8: Site plan of 3D model

Final Proposal

Our project team collated information from our project into a proposal to give to the SSC. The proposal is in Figure 9.

Designing a Rain Garden for the University of Illinois Campus to Promote Sustainability
Pieter Svenson, Elisabeth Tarpey, Steven Su, Yikai Ye

The purpose of this project is to design a new rain garden on the campus at the University of Illinois at Champaign-Urbana. A rain garden is comprised of a depression made in the ground, soil with high water permeability, and native plants with long roots. It provides a more sustainable way to manage storm water runoff than the traditional storm sewer systems. The garden facilitates storm water infiltration directly into the ground.

The benefits of implementing a rain garden near areas with frequent flooding include decreased flooding, water quality improvement, and increased aesthetic appeal. From anecdotal reports, the sidewalk between the Preforming Arts Annex and the Wood Engineering Laboratory (shown in Figure 2) will have standing puddles even after a slight rainfall. The rain garden is designed for a location near a path with significant foot traffic, so this garden also presents an opportunity to educate the public about the importance of sustainable practices. Our project group also proposes to put signs in front of the rain garden to inform those walking past of the hydrological benefits that the garden, which seems to be nothing more than a bed of plants and flowers, has to offer.

The approximate amount of water that would be flowing into the garden is 34 cubic meters. Using the amount of water needed to be captured and the porosity of the engineered soil, we concluded that the required volume of engineered soil is about 75 cubic meters. The cost of excavating the native soil, purchasing new soil, and purchasing the plants was estimated to be $10,400. Using average rainfall data from the past century, this garden would be able to capture all rain fall and thus solve flooding problem that location for 97% of the days in the year.

Figure 1: 3D Rendered Image of the Garden

Figure 2: Proposed Site Plan

Table 1: Proposed Budget for the Rain Garden

Item	Unit	Quantity	Unit Price	Value
Soil	m^3	75	$119	$8,914
Earth Excavation	m^3	78	$12.43	$969.19
3" Mulch Layer	m^3	11.5	$61.80	$711.08
Flowers	seed packet	8	$2.50	$20.00
Frank's Sedge	seed packet	1	$4.61	$4.61
			Total Budget	**$10,618.88**

Figure 9: The proposal to be sent to the SSC

Conclusions

If constructed, this rain garden will provide many benefits, such as significantly reduced flooding, improved aesthetic appeal of an area with a dilapidated appearance, and education for the public about the importance of sustainability. The square footage of the garden was calculated to be about 150 square meters, the depth was calculated to be 0.5 meters, and the soil chosen had a porosity of 0.45. The final cost of the garden is about $10,620. With the designed capacity of the garden, flooding issues in that location should be eliminated for 97% of the days in the year.

The calculated budget, using unit costs for the sand, was over $10,000. It is possible that this will make it harder for the SSC to approve because it puts the project in a pool with much higher budgeted projects, making it harder to compete for the funds. However, it is possible that by contacting the local wastewater treatment, we can get significant reductions in soil costs. A large amount of sediment is washed into the treatment plant constantly and the town spends money to haul it out. An agreement could be made so that the nutrient-rich soil and sand dredged from the wastewater is used for the rain garden and the fertilization of the plants inside (Schideman, 2017). More research is necessary for this step to be made, however.

If the proposal is accepted as it is presented now and signs are placed in front of the rain garden, the final product should provide all the benefits discussed previously.

Acknowledgements

Throughout the course of this project, our team received help and advice from many mentors and professors at the University of Illinois. This list includes, but is not limited to, Professor Arthur Schmidt, Morgan White, Professor Jeffery Roesler, Kathleen Hermon, Professor Lance Schideman, Eliana Brown, Eric Brown, Kunal Patel, Michael Neal, Professor Mary Hays, and the staff of the Facilities and Services at the University of Illinois.

References

Agri Supply (2017). “Extra Fine Sand.” (7 Dec. 2017) <agrisupply.com>.

Angel, Jim (2017). “Official 1981-2010 Climate Normals.” *Illinois State Water Survey*, Champaign, IL (10 Dec. 2017) <isws.illinois.com>.

Beier, Ann (1995). “Urban Runoff Notes.” *News-Notes*, Washington D.C.

Chicago Botanic Garden (2017). “EcoFriendly Storm Absorbers.” *Rain Gardens*, Glencoe, IL. (12 Oct. 2017) <chicagobotanic.org>.

City of Champaign (2014). “Engineer’s Payment Estimate for Washington St. Project.” Champaign, IL (15 Dec. 2017).

Clean Water Campaign (2017). “Rain Gardens for Home Landscapes.” Atlanta, GA. (15 Dec. 2017).

Geotechdata (2013). “Soil Porosity.” (7 Dec. 2017) <geotechdata.info>.

Google LLC (2017). “Google Maps.” *Google*, Mountain View, CA (10 Dec. 2017) <maps.google.com>.

Green, Eric (2017). Personal Communication. Urbana, IL (13 Oct. 2017)

Inside Illinois (2007). “Red Oak Rain Garden.” *Illinois News Bureau*, Illinois. (12 Oct. 2017) <news.illinois.edu>.

Khater, El-Sayed G (2015). “Some Physical and Chemical Properties of Compost.” *International Journal of Waste Resources*, Benha, Egypt. (7 Dec. 2017) <omicsonline.org>.

Lowe’s (2017). “Garden Pro 40-lbs All-Purpose Sand.” (7 Dec. 2017) <lowes.com>.

Lowe’s (2017). “Sakrete 900-lb All-Purpose Sand.” (7 Dec. 2017) <lowes.com>.

Maryland Biodiversity Project (2017). “Frank’s Sedge.” (15 Dec. 2017) <marylandbiodiversity.com>.

MidlandHardware (2017). “2 Cubic Feet HardWD Mulch.” (15 Dec. 2017) <midlandhardware.com>.

Patterson, Susan (2017). “Mulch For The Garden – Learn About The Benefits Of Using Mulch.” *Gardening Know How* (15 Dec. 2017) <gardeningknowhow.com>.

Prairie Moon Nursery (2017). “Seeds.” (15 Dec. 2017) <prairiemoon.com>.

Prairie Rivers Network (2017). “Native Plants Suitable for Illinois Rain Gardens.” *Rain Gardens*, Champaign, IL. (9 Nov. 2017) <prairierivers.org>.

Prairie Rivers Network (2017). “Rain Gardens for Illinois.” *Rain Garden Brochure*, Champaign, IL. (9 Nov. 2017) <prairierivers.org>.

Roundstone Native Seed, LLC (2017). “Frank’s Sedge (Carex frankii).” (15 Dec. 2017) <roundstoneseed.com>.

Rutgers University (2017). “Rain Garden Manual of New Jersey.” *New Jersey Agricultural Experiment Station,* New Brunswick, NJ. (14 Dec. 2017) <www.water.rutgers.edu>.

Schideman, Lance (2017). Personal Communication. Urbana, IL (12 Dec. 2017)

United States Environmental Protection Agency (USEPA), (2004). *Stormwater Best Management Practice Design Guide*, *Volume I, General Considerations,* USEPA Report EPA/600/R-04/121, 179 p.

University Wisconsin-Madison (2017). “Rain Garden Species Selection.” *Earth Partnership for Schools,* Madison, WI. (9 Nov. 2017) <arboretum.wisc.edu>.

United States Department of Agriculture (1999). *Soil Survey of Champaign County, Illinois Part I*.

USEPA (2017). “What is Green Infrastructure?” *Green Infrastructure*, Washington D.C. (12 Oct. 2017) <epa.gov>.

Appendices

Appendix A

Figure A-1: Frank's Sedge (Maryland Biodiversity Project, 2017)

Figure A-2: Orange Jewelweed (Prairie Moon, 2017)

Figure A-3: Big-leaved Aster (Prairie Moon, 2017)

Figure A-4: Virginia Bluebells (Prairie Moon, 2017)

Figure A-5: Jack-in-the-pulpit (Prairie Moon, 2017)

Figure A-6: Black-eyed Susan (Prairie Moon, 2017)

Figure A-7: Blue Vervain (Prairie Moon, 2017)

Figure A-8: Jacob’s Ladder (Prairie Moon, 2017)

Figure A-9: Columbine (Prairie Moon, 2017)

Appendix B

Average Porosity

$$0.32(50\%) + 0.445(20\%) + 0.67(30\%) = 0.45$$

Total Volume of Soil Needed

$$\frac{total\ volume\ of\ water\ to\ be\ drained}{average\ porosity} = \frac{33.6m^3}{0.45} = 74.7\ m^3$$

Total Cost of Soil

$$76.7\ m^3\ soil * \frac{0.5\ m^3\ sand}{m^3 soil} * \frac{\$240}{m^3\ sand} = \$8{,}960$$

Cost of mulch

$$Quantity = 151\ m^2\ garden * 3\ in. mulch * \frac{0.0254\ m}{in} = 11.5\ m^3$$

$$Cost = 11.5\ m^3 * \frac{\$61.80}{m^3\ mulch} = \$10{,}618.88$$

Reflections

This project was completed for a class in Civil and Environmental Engineering to get experience through project-based learning. Our project team has benefited greatly from the valuable engineering expertise of the professors in the class and applying what we learned from them to a project of our own. For whatever comes our way in our careers, the students in this project team can better find solutions to problems and convey them in a professional and comprehensible way.

Had our team gotten another chance to design a rain garden, there might be a few things we would change or add. In the original scope of the project, our team had wanted to implement sensors within the rain garden to collect data which would allow future students to better understand the hydrological behavior of rain gardens. These sensors could include those measuring temperature, acidity, and water drainage speed. As deadlines quickly approached, however, we decided our time would be best spent on formulating a complete design of a rain garden that would definitely provide the other stormwater and publicity benefits. If our team had the opportunity to design another rain garden, we would likely want to include these components and schedule our time accordingly.

Another thing the team would like to change if this project was done again would be the distribution of work. During the course of the semester, the team was often pressed to meet deadlines and as a result some members ended up carrying the brunt of the work load. If this project was done again, the team would make an effort to ensure all deliverables were completed ahead of schedule so all team members contributed equally.

Individually, some members learned more about hydrology, computer-aided design, and general best-management practices for developing a more sustainable society. Learning while working on a project gives the process a tangible gratification that is impossible to get in a class based on lecturing and textbook readings. Also, through this project and the class that facilitated it, each team member has grown in ability to manage a project, communicate with project team members, and ideate solutions to difficult problems. The completion of this project can be most accredited to the structure of the course and the professors leading it.