Brooklyn College Rainways

Macaulay Honors College Seminar Three: The Science of NYC
Professor Cheng, October 18, 2012

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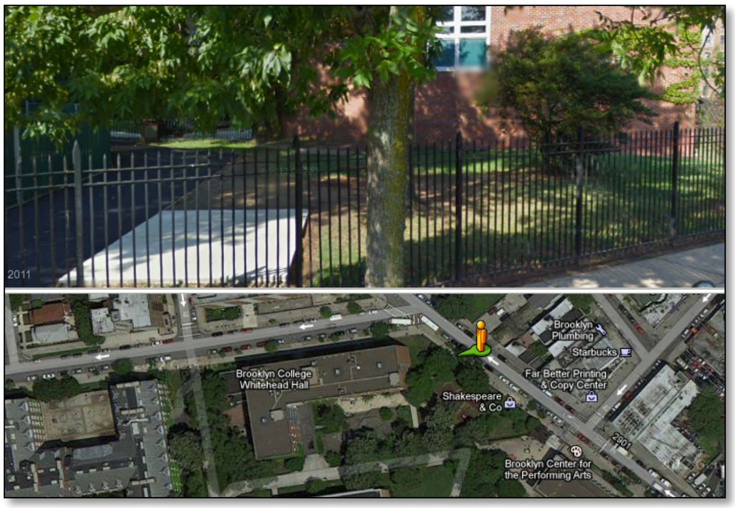
PROJECT LOCATION:



Our project space, located outside the eastern wall of Whitehead Hall.

An overhead-view diagram of our project space after all alterations have been made.

PROJECT OVERVIEW:

Our group has divided our green infrastructure implementation project into several main aspects. *The first aspect* involves the installation of two drainage pipes on the eastern-most side of Whitehead Hall that will lead rainwater down into a series of rainwater storage barrels. The liquid stored in these rain barrels will be used to water a rain garden that will be planted just a few feet from the barrels in the grass patch outside of Whitehead Hall.

The empty space outside of Whitehead Hall's east side (facing Campus Road).

The second aspect of our project involves the addition of 18-inch metal pinwheels to the side of Whitehead Hall. These pinwheels will be in the pathways of the downspouts. As water flows down the building, it will spin the pinwheels, which will in turn spin small motors on the side of Whitehead Hall. These motors will be hooked up to small battery chargers that can charge a variety of objects (rechargeable golf cart batteries, small electronic devices, etc.).

The third aspect of our project focuses on the creation of the rain garden next to the rainwater storage tanks. This garden will feature a variety of plants native to the New York area that are beneficial in a rain garden setting. It will also have a variety of other positive effects including: One, pollination support for local birds and insects (Monarch butterflies in particular), Two, the beautification of the eastern-most side of the Brooklyn College campus, and Three, the provision of a peaceful and aesthetically-pleasing backdrop for the children and adult teachers and supervisors in the Early Childhood Center's playground area.

The fourth and final aspect of our project focuses on the sidewalk areas of Campus Road (from James Hall to Whitehead Hall). The outside areas of these sidewalks (where grass would normally be found) have been covered with concrete tiles, and some sections are inaccessible due to dead tree stumps being in the way. Our group will remove this concrete tiling and replace it with grass patches and various plants. We will also remove the dead tree stumps and replace them with new baby trees. This will provide a larger space for rainwater to be collected on sidewalks, and the collected rainwater will encourage the growth of newly planted grass and trees.

SECTION ONE:
RAIN BARREL SYSTEM AND RAINWATER STORAGE

This section of our project deals with the roof of Whitehead Hall, the amount of rain that falls on the eastern-most section of it, and ways we can store/reuse that rain water to our advantage. First, we'll discuss the system in which rain will be directed towards the barrel systems.

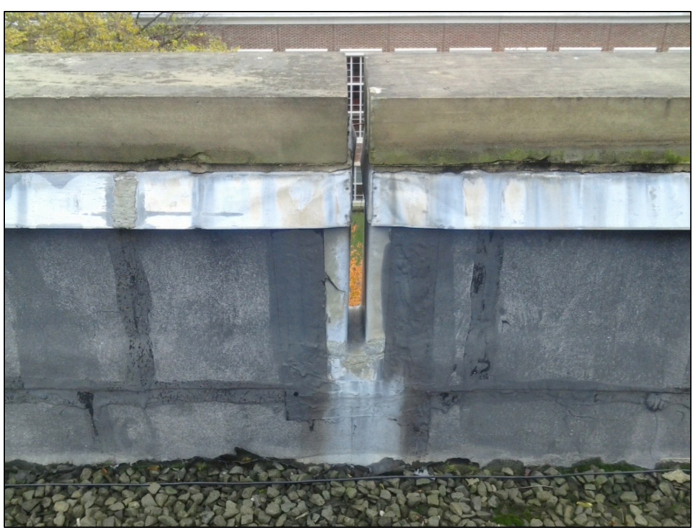
The roof of Whitehead Hall is separated by small walkways that have been laid down for maintenance and custodial staffs to use for moving around. These tiles measure about two feet by two feet, and they're about two inches off the ground. Since they're so high up, they serve as an excellent barrier between sections of the roof (meaning that during a one inch rainfall, the rain water will remain the same in any given section of the roof). The eastern-most section of the roof measures approximately 37 feet wide by 67 feet long, meaning that there is a 2,479 square foot area of coverage.

The eastern side of the Whitehead Hall roof.

The rock layer on the Whitehead Hall roof.

The only other thing on this roof space is a layer of rocks about two inches off the ground. These rocks are very small, so rainwater can easily flow through them while. They also serve the purpose of filtering large debris (such as leaves, dirt and other garbage that may end up on the roof) from the water. This helps to reduce the risk of any gutter clogging or backing up.

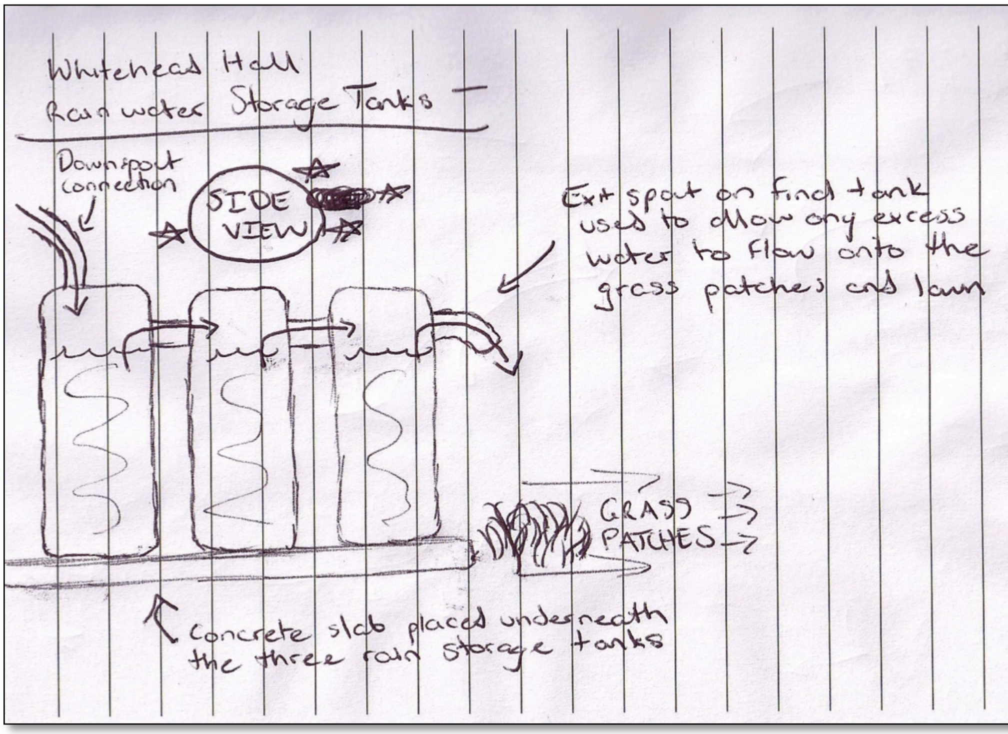
In this area, there is one spout on the wall that exists for the purpose of draining water if the water level ever rises too high on the roof. Currently, the bottom of this drain is about six inches off the ground. Our plan would involve lowering the bottom of this spout by another five inches, so it could allow rainwater to escape from the roof much more easily. This modified spout would be copied, and a second spout would be place on the other end of the eastern roof wall. With two spouts available to allow rainwater to escape, our group is able to maximize the amount of rainwater that can be collected.



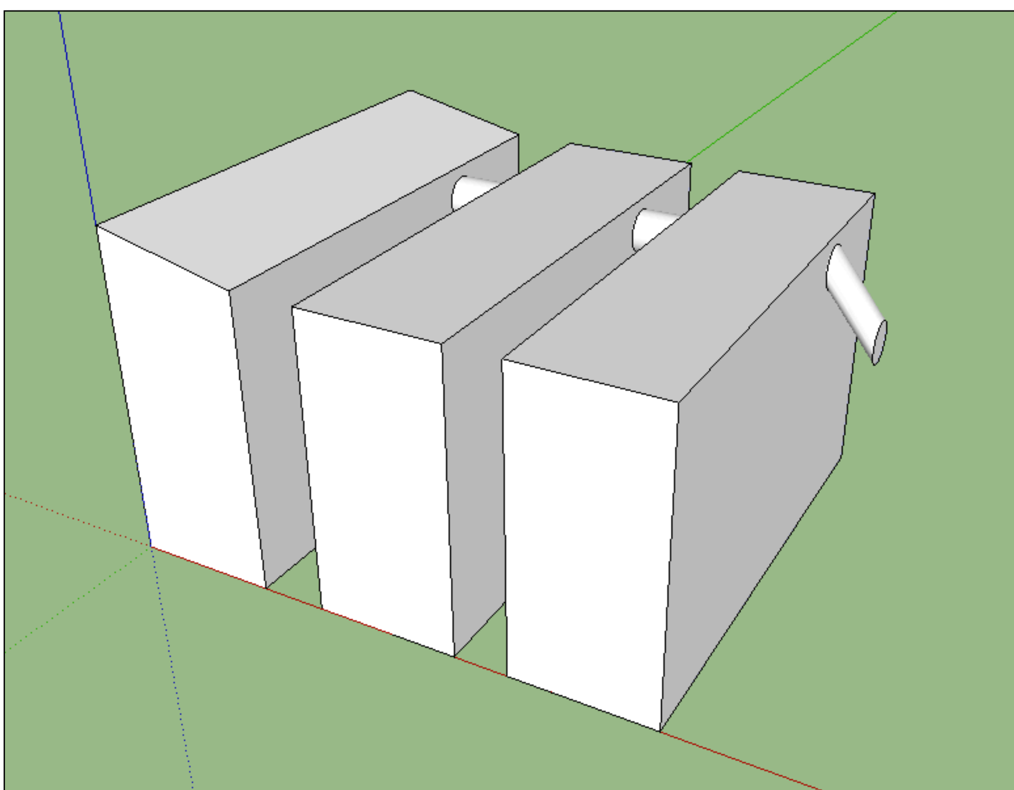
The pre-existing rain spout on the side of the Whitehead Hall roof. Our project involves lowering its base by five inches and then adding a second spout on the other side of the eastern roof wall.

As the water flows over these spouts, it flows through two small gutters that will be installed on the side of the building. Each gutter travels halfway down the building, and then allows the water to pass to a second set of gutters while spinning two small pinwheels that will also be installed on the side of the building. The purpose of the pinwheels is to turn a series of pulleys that will turn the motors of the charging station that will be installed around the corner of the building (see Section Two). After the water passes through the second gutters (the ones below the pinwheels), it funnels into the two rainwater "holding areas" against the bottom of the side of Whitehead Hall.

The two rain barrel systems that will be installed each have three containers (sized approximately twelve feet by two and a half feet by six feet each). When the first container fills up with water, an exit pipe will redirect the water flow to a second tank. When that tank fills, another exit pipe will redirect the water flow again to a third tank, and when that tank fills, the water will be let out into our rain garden.



The original concept drawing (side view) of our rainwater storage tank.



A rough draft of our rainwater storage tank concept made in Google SketchUp.

The two tanks will be installed on the east wall of Whitehead Hall (the façade facing Campus Road). One will be installed on the left side of the windows already located in the eastern wall, and the other will be installed on the right side of the windows. On the left side of the windows, there already exists an unused concrete slab that measures eight and a half feet by fourteen feet. This is the perfect area to place the tanks, mainly because it will ensure that the tanks do not sink into the ground when filled with water. We will add a second concrete slab on the right side of the windows for the second tank.

An overhead view of the existing concrete slab on the east side of Whitehead Hall. Our group will make a duplicate of this slab on the left side of the image so we can place two rain storage tanks down instead of one.

Two rain storage tanks are implemented because they are more efficient than one. With only one gutter system and rain storage tank, the most water that could be held would be approximately 550 cubic feet. The second rain storage tank will double that amount, capturing up to 1,100 cubic feet of water. That means that during a one inch rainfall, approximately half of the water that falls on the east section of Whitehead Hall's roof will be capture and stored for future use, while the other half will either flow down into the rain garden or remain on the roof to flow into the pre-existing Brooklyn College drainage system inside Whitehead Hall.

SECTION TWO: CHARGING STATION

There are only so many things we can do to relocate water until we have nowhere else to put it. Due to that fact, our project focuses less on trying to completely remove rainwater from our Brooklyn College campus and more on using that water in a more efficient manner while it's there. By changing the position of the water and monitoring flow, we can generate enough energy to create a semi-sustainable power source. We are going to mimic the mechanism that power plants use for creating energy and storing it, pumped storage hydroelectricity.

Pumped storage hydroelectricity pumps water from lower levels to higher levels during off peak hours (which is low cost), stores it, and then during high peak hours (which is maximum cost) releases it to be used. The use of peak hours is key here because there is energy being used to pump this water to a higher level. It is absolutely necessary to have this water pumped because by doing so, we are creating potential energy, which will be transferred to kinetic energy once the water is moved back to the lower level. As we move the water to greater heights, the amount of energy that we can generate increases almost exponentially, because gravity, 32 m/s/s, allows the water to accelerate at a much greater rate than it would on its own. Acceleration is important because whether the water falls with or without gravity, it will be at the same height. With gravity, acceleration increases, which consequently increases the final velocity of the water as it hits the turbine. With a greater final velocity, the turbine can rotate a greater amount and generate more power.

The left corner of the east side of Whitehead Hall. After turning the corner of the building, our pulley system will spin the motors at our charging station, providing useable power for all sorts of on-campus purposes.

There are five factors that determine the amount of power created by this hydroelectric mechanism. They are tracked in the rule:

$$\text{Power (megawatts)} = n * p * Q * g * h$$

Where: n is the dimensionless efficiency of our turbine(s), p is the density of water in kg/m/m/m, Q is flow of water in m^3/s, g is acceleration due to gravity, and h is the height difference (of the water) between the inlet and outlet.

We have a lot of control over the four latter of those factors. The density of water will change only slightly as outside temperatures change (unless the water freezes), so that won't drastically change the amount of power produced. We will have almost total control over the flow of water because of the mechanisms we put on both the inlet (entrance spout) to the tank and the outlet (exit spout) from the tank. This is important because we would absolutely want to manipulate water flow in times of plentiful rain compared to a dry few days. By fully opening the outlet while keeping the inlet halfway closed on a rainy day, we can ensure that the pipes on the inlet won't become too full of water and burst. Gravity is self-explanatory and we rely on it to drive our mechanism, so we have as much control over it as we need. While we can decide how high we want to raise the water and the tank, we are somewhat limited in that regard because of campus specifications. However, since we are not looking to produce massive amounts of power, the height shouldn't be an issue.

The aforementioned power equation gives power in units of megawatts. A megawatt is a pretty large unit of power. To put that in context, the average household uses less than 1 megawatt-hour of power per month. The power generated will be used to recharge the batteries on the carts that the maintenance crew uses to collect garbage and navigate the campus. We will most likely be able to fully charge one cart per day, estimating two full charges per cart per week (assuming a fleet of three carts). This number widely varies based on the amount of rainfall during any given week.

Many of these carts that the campus maintenance staff uses run on 42-volt rechargeable batteries. Whether we use rechargeable C/10 batteries (achieves full charge in 10 hours using 10 amps/hr) or C/20 batteries (achieves full charge in 20 hours using 5 amps/hr), the battery requires approximately 100 amp-hours to be fully charged. To determine power, in watts, we multiply the voltage of the battery by the amount of amp-hours.

Power (watts)=volts x amp-hours

The estimated power required to fully charge one of these batteries in megawatts is 0.004200 megawatts, a relatively small amount. This number will vary a little because while the battery is referred to as a 42-volt, it actually varies by about 2 volts in both directions because batteries produce energy based on a difference in voltage. Even though the estimations made for this project fall into a small margin of error, this is an efficient way to use excess rainwater, in terms of displacement and energy transduction.

The space around the corner of the east wall of Whitehead Hall. Our group will install the charging motors/stations right against the currently empty space against the brick wall. Our pulleys can either be re-routed over the exit doors on the side of the building, or they can run under the small step at the exit.

SECTION THREE: RAIN GARDEN

A rain garden is a great green-infrastructure option for dealing with excess water during events such as storms and flooding. It provides an environment to divert water into, where it will be absorbed by plants rather than leaking into undesirable areas, such as streets, ground depressions, or sewers. Water passing through a rain garden will be filtered to an extent, removing unwanted pollutants from the environment. At the same time, a rain garden can create an aesthetically pleasing environment wherever it is planted.

The grassy space outside Whitehead Hall is ready for a makeover. Our group plans to plant a new rain garden.

Our rain garden will serve to collect excess rainwater from our gutter/barrel system. The garden area is located in front of the barrel system, and can take up to 2,300 square feet of space. In addition to temporarily storing water and filtering out pollutants, our rain garden will feature plants that provide colorful blooms throughout the year, and will support the area's local population of pollinators and seedeaters. The rain garden will also serve the purpose of providing a beautiful natural backdrop to the Early Childhood Center's playground adjacent to our project area. Viewing the interaction of butterflies and birds with the plants can be a springboard for hands-on education in a natural environment.

In planting a rain garden, it is crucial to consider the possible benefits and drawbacks of the flora used. In general, we are looking for plants that would have the least impact on the local animal and plant populations, while providing the most benefits. These plants would have to be native to the New York area, and be suitable for the soil conditions found in rain gardens. Additionally, the plants should be aesthetically pleasing and require minimal upkeep. We have found several plants that would fit these categories and would be suitable for our proposed garden.

- **Oxeye Sunflower (Heliopsis helianthoides)**

The Oxeye Sunflower is a plant featuring dark and reddish hued stems and foliage, with bright yellow flowers that bloom throughout the summer. It is relatively small, with an average height of around 1.5 to 2 feet, and a spread of 18 to 24 inches. It provides a seed source for small birds and animals, and the Oxeye's nectar attracts pollinating insects, such as butterflies. In the winter, the stems serve as a good housing source for insects beneficial to the area. The Oxeye works well in a rain garden setting due to the fact that while it prefers moist soil, it can tolerate drought without too much of an issue.

By Muller, Thomas L. Copyright 2012 Lady Bird Johnson Wildflower Center.

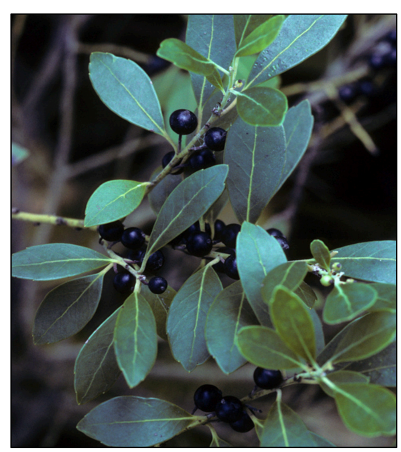
By Marcus, Joseph A. Copyright 2012 Lady Bird Johnson Wildflower Center.

- **Swamp Milkweed (Asclepias incarnata)**

The Swamp Milkweed is a plant that averages 3 to 4 feet in height and has very deep taproots, making it a good plant to reach deep soil. It has oval-shaped green leaves, and bright pink clusters of flowers that attract butterflies and other pollinators, in addition to emitting a distinct vanilla scent. It grows well in either moist or regular garden soil, making it great for a rain garden environment.

- **Inkberry (Lex glabra)**

The Inkberry plant is an evergreen Holly that is extremely resistant to weather changes, and is commonly used in urban areas. It is very resistant to pests and diseases. Starting in the fall, the Inkberry plant grows berries that are edible to birds, and last into the winter. Its average height is 3 to 4 feet, with a width of 4 to 5 feet.



By Wasowski, Andy, and Sally Wasowski. Copyright 2012 Lady Bird Johnson Wildflower Center.

By Bloodworth, Stefan. Copyright 2012 Lady Bird Johnson Wildflower Center.

- **New York Ironweed (Vernonia noveboracensis)**

The ironweed plant grows best in moist to normal soil that would be present in a rain garden setting. It provides plenty of nectar for supporting local pollinators, and does not require much maintenance. The Ironweed is a relatively tall and narrow plant, topped with fluffy purple flowers. It grows to an average height of 3 to 4 feet with a width of 1 to 2 feet.

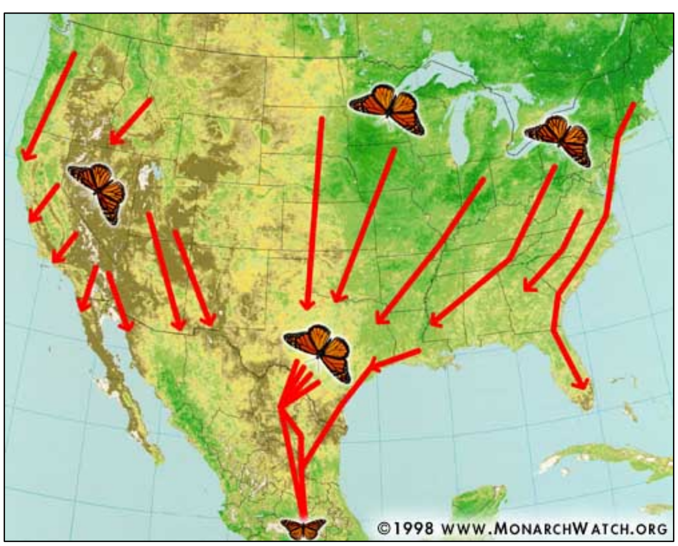
- **Tall White Beardtongue (Penstemon digitalis)**

The Tall White Beardtongue features wide leaves and bundles of white flowers atop reddish stems. Its nectar supports pollinators, and its seeds support local birds. The average height ranges from 24 to 30 inches and the average width is 18 to 24 inches.

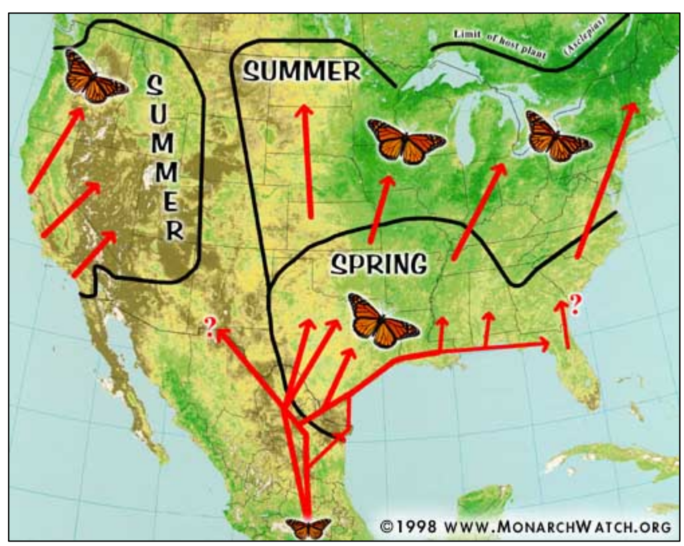
By Wasowski, Andy, and Sally Wasowski. Copyright 2012 Lady Bird Johnson Wildflower Center.

This garden also has an added animal (or more specifically, insect) benefit. All of the above plants have the effect of providing sources of pollination to local pollinators, but milkweed in particular is known to be a host for Monarch butterflies, which are appropriately considered members of the tropical milkweed butterfly subfamily (http://www.bbg.org/gardening/article/milkweeds). Monarch butterflies travel along a pathway through the general New York area in their migration patterns in both the spring and the fall as seen in maps on www.monarchwatch.org. In recent times, however, plants used by butterflies as they travel have been disappearing as a result of industrial, commercial, and residential land use. By planting milkweeds in our rain garden, it may be possible to assist Monarch Butterflies on their journey. The Brooklyn College campus can then reap the benefits and enjoy an increased presence of the beautiful orange and black butterflies.

Fall Migration Pathway:



Spring/Summer Migration Pathway:



SECTION FOUR:
SIDEWALK RENOVATION AND
GREEN INFRASTRUCTURE IMPLEMANTAION

Currently, there are rows and rows of sidewalk planting areas along Campus Road that are filled with cement, concrete bricks, and dry soil. These materials make the sidewalk planter spaces totally useless to Brooklyn College. The sidewalks are already very wide, and no one even walks on the aforementioned space because there are small trees and dead tree stumps there.

Along Campus Road (from Whitehead Hall to James Hall), there are many in-ground planter areas. Each individual one of these areas along Campus Road measures 46 feet long by 4.5 feet wide. Each section has approximately 80 concrete tiles, plus certain areas where tree stumps were replaced with varying amounts of poured concrete. The main bricks measure out to be one foot by one foot, and the smaller bricks around the trees are about 10 inches by 2 inches.

One of the sidewalk planter spaces along Campus Road (the pictured space is located right outside Boylan Hall). Not only is this a misuse of available green space, but it's aesthetically unappealing and doesn't provide the best image for Brooklyn College.

Besides these spaces, there is another 175 foot by 4.5 foot space that's filled with concrete right outside of the exit of Whitehead Hall. This means that the area that we are planning to change totals right around 7,000 square feet.

An easy solution to this unusable space is to take out the cement and bricks and grow plants or grass to absorb the rain, improve the environment, and give the college a healthier and more vibrant look. Currently, rainwater is being wasted—it flows right over these large concrete spaces and onto the streets. It takes a long time for all the water to be dried up, it sometimes leads to clogs in the gutter systems outside of the campus, and it is not used in any way at all. Taking out the concrete tiles, bricks and cement patches is a good way to fix this.

The removal of these things will require a labor fee. Depending on the company/contractor hired, the cost could be around $1,000 at the most. As for new plants and grass, volunteers and students can plant them and use it as a case study for a project. The price of the new plants and/or grass is dependent on the types that are used. If one assumes that grass is $0.30 per square foot, the total price for planting grass on the designated area is $2,099.25. Brooklyn College will ultimately decide the amount of area permitted for student usage, but this is something that should be highly encouraged. Students will have the opportunity to learn while promoting a greener campus when allowed to use space like this for research projects and things of that nature.

A close-up of the current materials that clog the sidewalk planter spaces along Campus Road. One foot by one-foot concrete tiles and sloppily poured cement are not what these spaces need.

One of the dead tree stumps that can be found along the planter spaces along Campus Road (the pictured tree stump is located outside the side Bedford Avenue exit of James Hall).

The depth of the cement is about three inches deep. If the soil costs $8 per cubic yard, the total price of soil would end up being approximately $6,220. Students will have the opportunity to add the soil, and Brooklyn College can hold an event for families of the surrounding neighborhoods and communities to add the soil and grow plants. This will increase community activity and save on the labor for adding soil. Materials and tools used for planting can be borrowed or recycled.

This will be very cost-effective and perfect in promoting and teaching everyone about the benefits of recycling and green infrastructure techniques.

CONCLUSION:

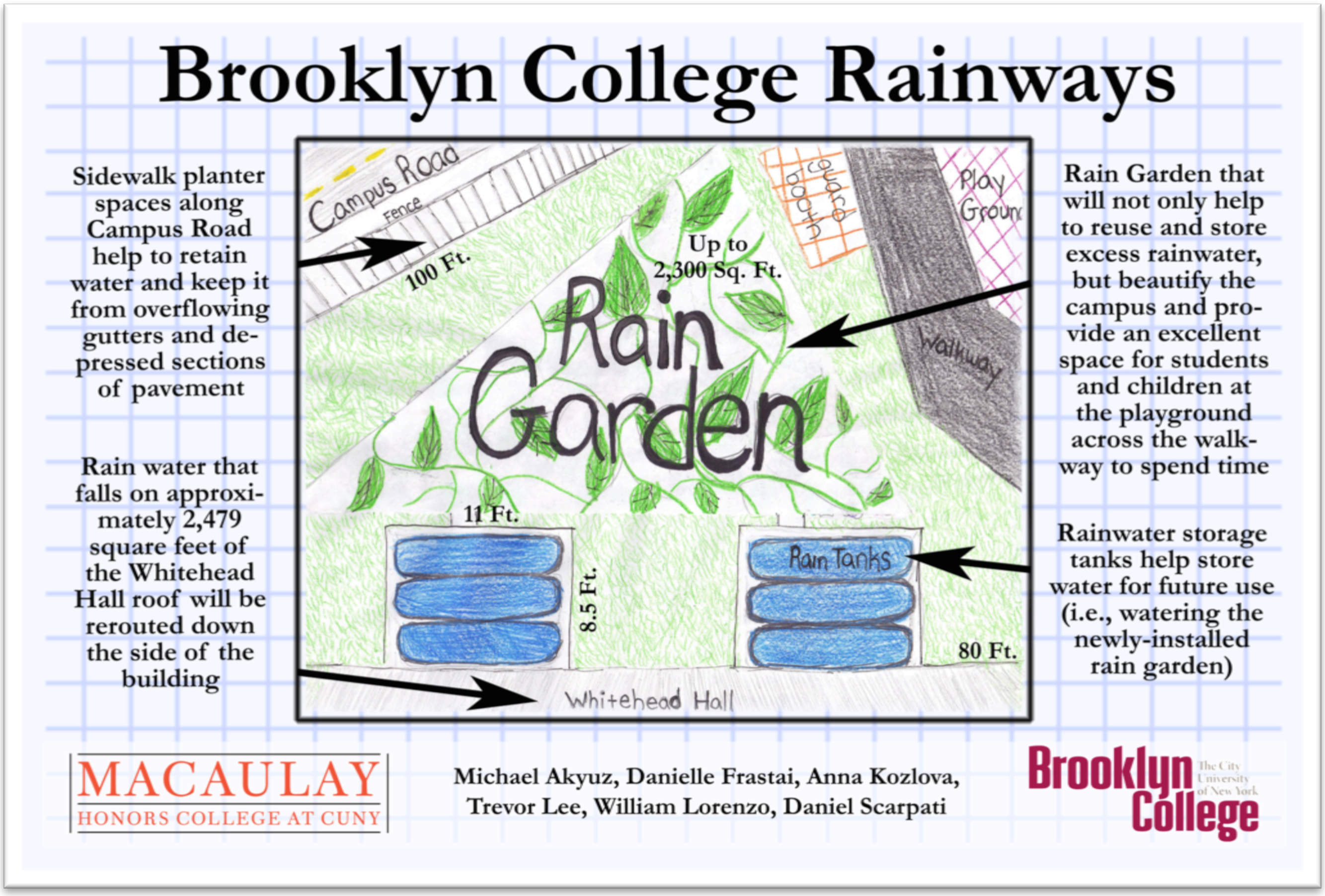
The four aspects of our project balance not only renovating and beautifying various parts of the Brooklyn College campus, but finding unique and creative ways to deal with excess rainwater and improving the overall green infrastructure of the site. From installing new gutter systems and rain tanks and designing and planting a picturesque rain garden to installing an energy-efficient charging station and redesigning the sidewalk planter spaces along Campus Road, our group focuses on a wide variety of green infrastructure implementation techniques and designs.

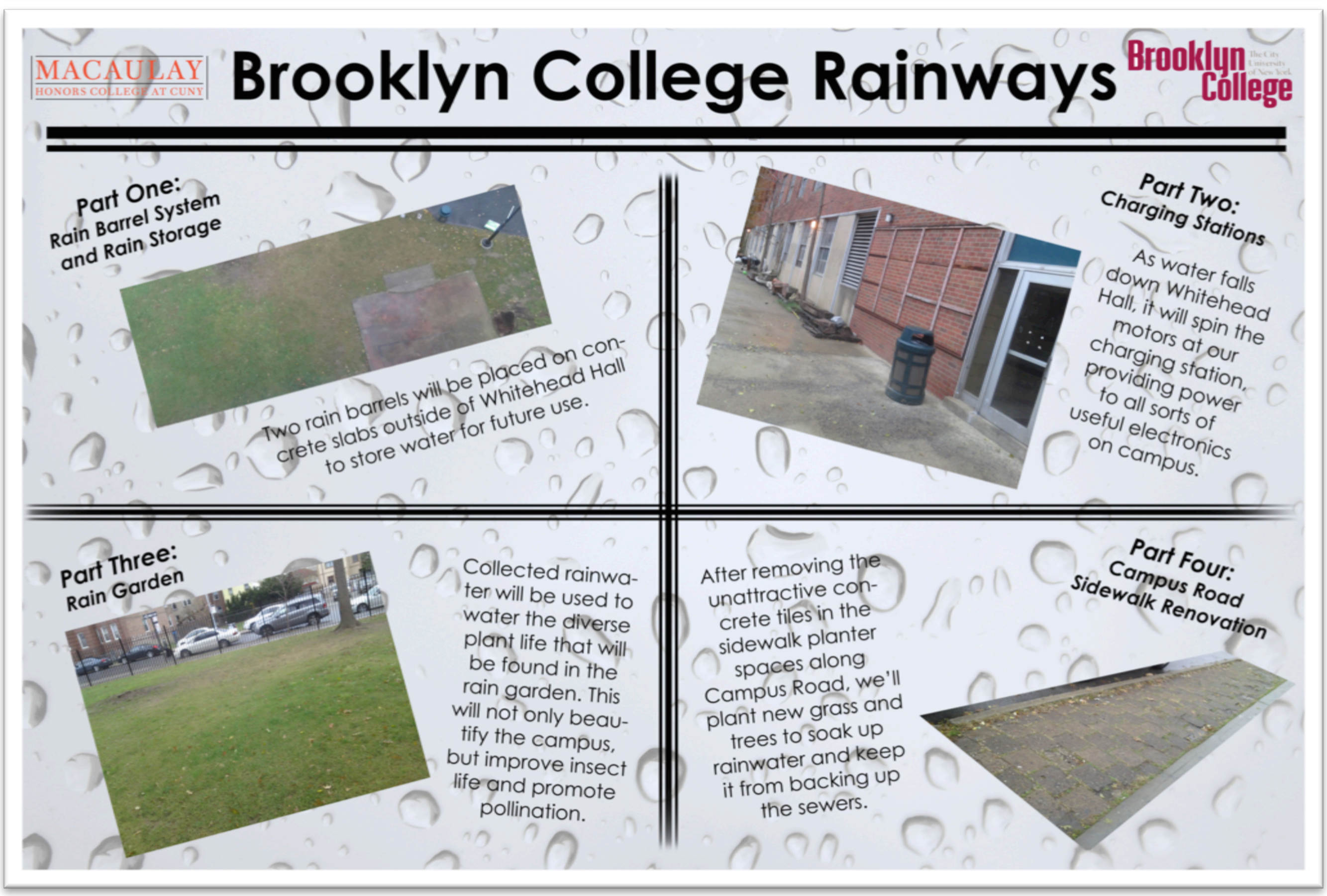
The heat island effect is another major problem addressed by our group. The sidewalk renovation takes a significant step in decreasing heat levels, especially during the summer time. With more plants and grass and less cement, more evapotranspiration will occur. The plants and grass will use the heat from the surrounding air to evaporate the water collected through our rain tanks and sidewalk planter spaces. There will be less air pollution, and the vegetation will absorb and lower carbon dioxide levels for photosynthesis, while churning out much needed oxygen.

The final cost of the entire project depends greatly on student volunteerism and faculty and administration assistance, but we can safely estimate somewhere in the $20,000 range for a total renovation. The EPA Campus RainWorks challenge provides a $46,000 grant to the first and second place winners, meaning that our group would put the money to excellent use and not go over-budget by any amount.

Original concept art of the gutter/drainage system on the sidewall of Whitehead Hall. As water falls, it turns the pinwheels on the building's wall, which in turn spins the motors at out charging station. The water then collects in the rain tanks at the base of the wall and is stores for use in the rain garden.

PROJECT POSTER DESIGNS:





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