The Georgia State University GIRAS (Green Infrastructure to Reduce Atlanta Stormwater) Initiative

D1 EPA Campus RainWorks Challenge

Team Members

Sharon Murphy, Project Manager –Geosciences

Jeff Pucciano – Art and Design

Ahmed Witwit – Public Health

Faculty Adviser

Dr. Jeremy E. Diem
Associate Professor, Department of Geosciences

Facilities Adviser

Ramesh Vakamudi
Associate Vice President for Facilities Management Service

ABSTRACT

Implementing green infrastructure to manage stormwater runoff in an urban setting can be problematic due to the lack of available space to effectively use low-impact development principles. The proposed project uses green roof in conjunction with a living wall and rain garden to achieve a 100% reduction in stormwater runoff from the Georgia State University Sports Arena from entering the Atlanta combined sewer system. The Sports Arena is currently responsible for over one million gallons of stormwater runoff annually, and this water directly enters the city's sewer system and is sent southward to a water-treatment facility. Roof runoff not contained by a 3-inch green roof covering approximately 75% of the roof would be diverted to a 165,848-gallon, above-ground cistern behind the building. Water harvested in the cistern would be used to irrigate the green roof and a 2,304 ft^2 living wall adjacent to the Sports Arena. Excess water would be diverted to an 856-ft^2 rain garden adjacent to the living wall; the average daily flow to the rain garden would be 2,000 gallons. The green roof also will reduce the sensible heat flux from the Sports Arena roof by 50% during the summer, thereby helping reduce GSU's contribution to Atlanta's heat island. The green roof also will remove approximately 57 pounds of criteria air pollutants annually. Finally, the proposed green infrastructure design will make the site more resilient to the projected increase in temperatures, decreased summer soil moisture, and increased heavy-rainfall events projected for the upcoming decades.

1. Introduction

Urban landscape design that incorporates “green” principles is essential to improving environmental conditions in urban areas now and especially in the future in the face of a changing climate. Urbanization leads to a reduction in vegetated land cover and thus increases stormwater runoff, the urban heat island effect, and other indicators of decreasing environmental quality (Hough 2004; Gill et al. 2008). Calling it one of the top reasons that water quality standards are not being met in urban areas, the U.S. Environmental Protection Agency (EPA) has deemed stormwater runoff as the biggest threat to water quality nationwide (Garrison & Horowitz 2012). Green infrastructure is a concept that comprises all types of ecosystems at a variety of spatial scales, where artificial landscapes are designed to mimic or restore the natural habitat that was replaced by impervious surfaces in the process of urbanization; it can increase biodiversity and provide physical and psychological health benefits to people and communities, increasing the overall health of the environment (Tzoulas et al 2007). In the context of stormwater runoff, green infrastructure supports the principles of low-impact development (LID) by increasing infiltration processes, evapotranspiration, and encouraging the reuse of stormwater runoff at the site where it is generated (U.S. EPA 2007). LID practices such as bioretention (i.e. rain gardens and bioswales), green roofs, and permeable pavements result in increased retention of stormwater and pollutants on site and also help mitigate the urban heat island (Dietz 2008).

Atlanta, Georgia is a city that has plentiful rainfall and frequent intense storms that result in excessive stormwater runoff that often overwhelms the city’s combined sewer system leading to raw sewage discharge into streams, thus the city is in desperate need of green infrastructure. The Atlanta climate is classified as humid subtropical according to the Köppen Climate System (Trewartha and Horn 1980) and thus the city receives an average of 50 inches of precipitation per year distributed relatively evenly throughout the year with no distinct dry months (Figure 1). But the region often does have a soil-water deficit during the summer season (Figure 2)[1]; therefore, irrigation is needed for landscaped areas. For comparison purposes, Chicago receives an average of 38 inches of precipitation per year with a one year storm producing 2.45 inches of precipitation in 24 hours, whereas a one year storm in Atlanta produces 3.32 inches of precipitation in 24 hours. Approximately 1.4 billion gallons of stormwater would naturally run off the footprint of Atlanta if the city

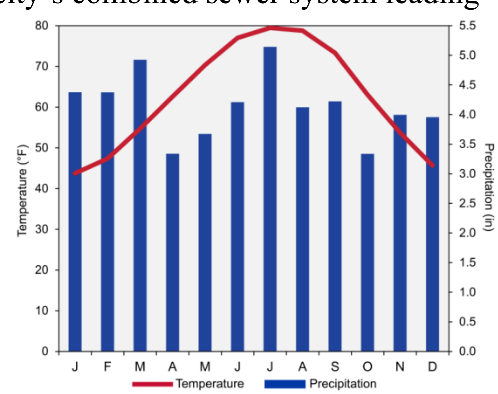

Figure 1. Climograph for downtown Atlanta, GA for 1985-2014. Data provided by the National Oceanic and Atmospheric Association.

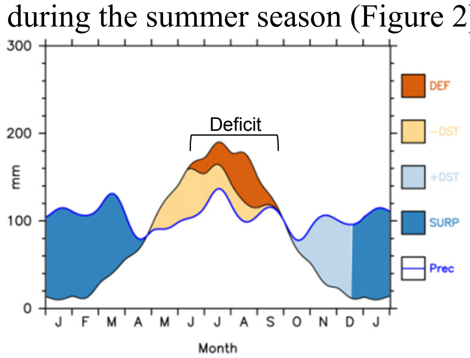

Figure 2. The annual soil water budget of Atlanta shows a soil moisture deficit in the summertime.

[1] The soil-water budget was calculated using the Web-based, Water-Budget, Interactive, Modeling Program (*Web*WIMP).

did not exist.[2] But Atlanta is actually comprised of 40% impervious surfaces, which are responsible for much of the 41 billion gallons of stormwater runoff annually (Murphy, 2015). And the percentage of impervious surfaces should increase with increased development of the city.

Located in the portion of Atlanta with the largest amount of stormwater runoff per unit area is the campus of Georgia State University (GSU) (Figure 3). GSU, which is a minority-serving institution with over 10,000 African-American students, is in the heart of downtown Atlanta. The campus consists of approximately 90% impervious surface (Murphy 2015). GSU is considered an open, urban campus meaning that the streets and sidewalks that transect the campus are public thoroughfares owned and maintained by the city of Atlanta. The roofs of GSU alone total 32 acres and generate about 38 million gallons of stormwater runoff annually (Murphy 2015). The entirety of this stormwater is directed into the municipal sewer system and is diverted to the Chattahoochee River and ultimately into the Gulf of Mexico. At this time there is no green infrastructure on the campus of GSU with a primary purpose to mitigate stormwater runoff.

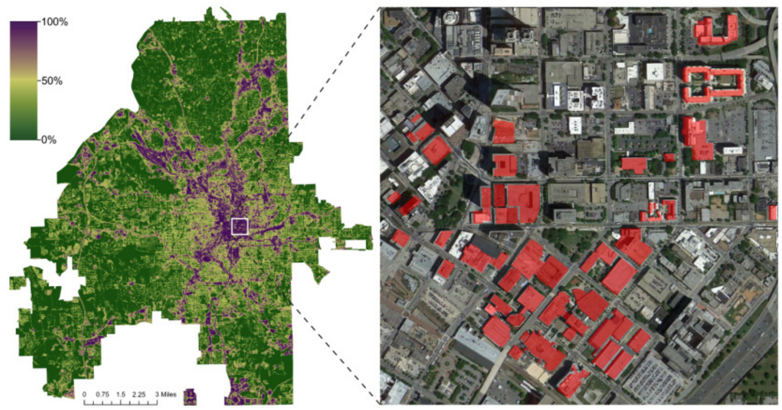

Figure 3. Percent impervious cover for the City of Atlanta (left). The GSU footprint (right panel) is a 1-km cell with the highest percentage of impervious cover. GSU buildings are shown in red.

As an urban campus, and as the fastest growing university in the University System of Georgia, GSU acquires classroom and office space by purchasing existing buildings and renovating them to suit the university's needs. Rarely is the university able to construct a building on its own due to the lack of available land in the urban core, and the high cost of purchasing land should it become available. This means that the majority of the campus buildings were not designed with green infrastructure in mind. Funding limits and the inability to afford building downtime prohibit the university from structurally reinforcing many of the existing buildings so that they can accommodate the saturated loading weight of a vegetated roof. Other barriers to instituting green infrastructure include lack of appropriate access for maintenance needs, the presence of fume exhaust systems on science buildings, safety concerns that come with public access to roofs, and ownership and zoning restrictions of the public throughways that intersect the campus.

The aim of this project is to examine the feasibility of using green infrastructure to prevent all stormwater runoff from the GSU Sports Arena from entering the city's combined sewer system while working within the constraints mentioned in the preceding paragraph. The goal is to use the processes of evapotranspiration and infiltration to manage the stormwater

[2] Calculated using the EPA's National Stormwater Calculator.

runoff, while also reducing the Atlanta urban heat island via the latent heat flux, and using the vegetation component of the proposed green infrastructure to remove atmospheric pollutants.

2. Proposed Green Infrastructure Approach

With guidance from the GSU Facilities administration, the roof of the GSU Sports Arena was identified as being the leading candidate for a green-roof study due to its age, size, and accessibility (Figure 4). Total square footage of the portion of the roof designated for a green roof is approximately 32,300 ft^2, or about 0.74 acre; this area is separated into three sections by expansion joints. The total area of the Sports Arena roof is approximately 39,000 ft^2. In 1995 the roof was refurbished using a dark, coal tar pitch technology. According to the GSU Facilities Administration, the roof is in very good condition and is not scheduled for replacement or renovation at this time. Access to the roof is provided by two stairwells located on the northeast and northwest corners of the roof. There is no mechanical or venting equipment infringing on the central portion of the roof, creating a large expanse of usable surface area. The roof decking consists of 3-inch concrete with a flat surface across the extent of the roof making the Sports Arena an ideal roof for a case-study analysis of green roofs and green infrastructure on the GSU campus. In addition to having a roof that can feasibly host a green roof, the exterior of the Sports Arena has an under-utilized park space that has the potential to become a very popular spot on campus for students to relax while also functioning as a stormwater sink if designed well (see Section 2.2).

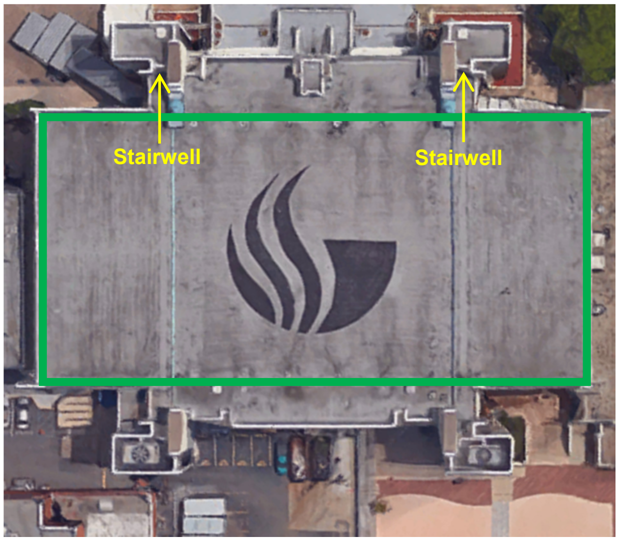

Figure 4. The roof of the GSU Sports Arena. The portion bounded by the green rectangle, which is 32,300 ft^2, can be converted into a green roof.

Creating a space that invites the student body to escape the urban concrete jungle while also allowing them to see green infrastructure design elements in a real-world application is accomplished through the use of green-roof technology, a cistern for storing excess stormwater, a living wall, and a rain garden. To maximize the park space as a respite from the built environment of the campus, principles of biophilic design will guide the execution of the LID features. The frontline of this approach will be an extensive green roof located on the Sports Arena. An extensive green roof cannot capture all the stormwater from a precipitation event; therefore, the excess runoff will be diverted into a cistern where it will be stored for use for irrigating the roof primarily during the summer months. A large above-ground cistern is required to store the runoff. Cistern water will be continuously diverted to the park space to be used to support a living wall and rain garden.

2.1. Phase One: Green Roof

A structural analysis performed by Palmer Engineering Company in October, 2015 found that the roof of the Sports Arena is capable of supporting the saturated loading weight of an extensive green roof (Figure 5) with a maximum weight of 15 lbs ft^2. Irrigation is recommended on extensive green roofs in the southeastern U.S. during summer months due to the deficit in soil moisture (price et al. 2011; Hardin et al. 2012). Irrigating the vegetated roof helps to increase the plant selection palette beyond sedums(Price et al., 2011), and it also increases the latent heat flux that is so effective at cooling land surface temperatures (Yang et al. 2015). Green roofs have been shown to reduce the kinetic temperature of roofs by about 18 °C, or more if kept sufficiently irrigated (Nardini et al. 2012; Dvorak & Volder 2013). This plan calls for a 3-inch inch substrate, which should reduce stormwater runoff by about 12%.[3] The green roof also will help remove common urban atmospheric pollutants that are of prime importance to public health and quality of life measures (Calderón-Garcidueñas et al. 2015).

Rooftops present a challenge for successfully growing vegetation due to the harsh conditions that occur with changes in elevation. Raising the elevation increases the plants exposure to solar radiation and wind and care must be taken to select plants that are able to tolerate these conditions. A focus on native plants, particularly CAM4 grasses, will provide a suitable habitat for local insects and birds (Van Mechelen et al. 2015). Native plants proven to survive winter and summer under irrigated conditions include pussytoes (*Antennaria plantaginifolia*), mouse-ear tickseed (*Coreopsis auriculata*), eastern bottlebrush grass (*Elymus hystrix*), glade cleft phlox (*Phlox bifida stellaria*), and eggleston's violet (*Viola egglestonii*) (Price et al. 2011).

Harvesting stormwater runoff throughout the year can provide enough water to irrigate the green roof during the summer months. Based on the findings of Hardin et al. (2012) for 4-inch green roofs in the southern United States, a cistern with a minimum capacity of 100,000 gallons and an associated irrigation system are needed to ensure that substrate-moisture levels remain optimal for vegetative growth and health throughout the year in Atlanta. Since we will have a 3-inch substrate that will probably require more irrigation, we have decided to use a 165,000-gallon cistern, which will be approximately 31 ft. high and have a diameter of 36 ft. (i.e., footprint of 1,018 ft^2). Even if the cistern is nearly three-quarters full at the onset of a one-year storm, it is large enough to handle the 52,000 gallons of runoff from the Sports Arena roof from that storm. Stormwater that is not used for green-roof irrigation will be

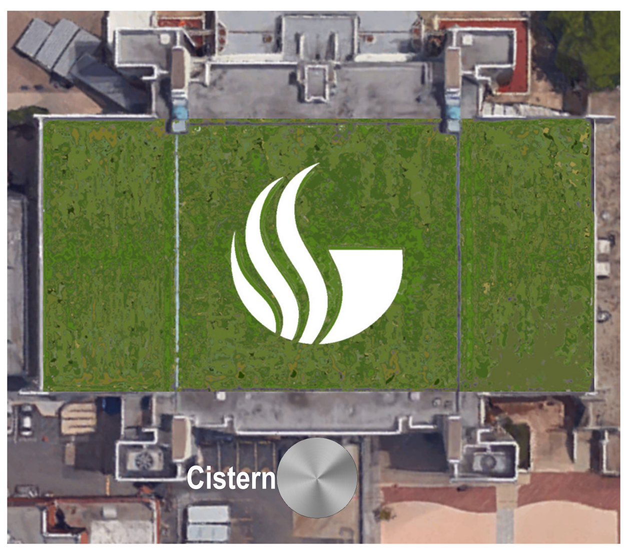

Figure 5. The Sports Arena roof with a 3-inch green roof supporting native plant species. The "G" in the center is designed to be illuminated at night.

[3] Calculated using the EPA's National Stormwater Calculator.

diverted/pumped to the living wall and rain garden described in Section 2.2. GSU facilities has asked that the cistern be located at ground level to the rear of the Sports Arena in order to accommodate its size and full-capacity weight. Green roofs are designed to function best when irrigated from above so the associated irrigation system that has been chosen is an overhead sprinkler system rather than a drip irrigation system.

2.2. Phase Two: Street Level Park Incorporating LID and Biophilic Design Principles
Taking advantage of an existing but underutilized park space that abuts the northeastern corner of the Sports Arena (Figure 6), we have designed a public space to act as a catchment for the remaining stormwater runoff and to also function as a place of respite and refuge for the student body. This park design will increase on-site stormwater retention to 100% by using water not used for green-roof irrigation to irrigate a living wall and to also discharge into a rain garden. As it exists, the park is unwelcoming in both design and function.

The north wall of the Aquatics building that serves as the south border of the park is an unsightly, concrete behemoth that is a harsh backdrop for a park where people should be able to relax. In order to soften the ambience of the park and to provide natural elements proven to speed recovery from stress (Ulrich et al. 1991) the north wall will support a living wall (i.e., vegetated wall). The living wall will serve multiple purposes: it will help remove excess stormwater runoff through irrigation, it will remove pollutants from the air, and it will hide an unsightly landscape element.

Figure 6. Rarely used park space adjacent to the northeastern corner of the Sports Arena.

Another design element that is both beautiful and functional is the inclusion of a rain garden to catch surface runoff from within the park boundaries. (Figure 7). The rain garden will include native plants and ornamental flowers capable of tolerating moist conditions. The goals for the rain garden are to not only remove stormwater, but also to provide habitat for pollinators and to provide a visually soft and inviting element that draws students and the public into the park space. It is estimated that the maximum daily discharge rate from the cistern into the garden would be approximately 2,000 gallons, and a rain garden as small as 214 ft^2 is designed to drain that amount of water. We have designed our rain garden to be five times as large (856 ft^2) to be able

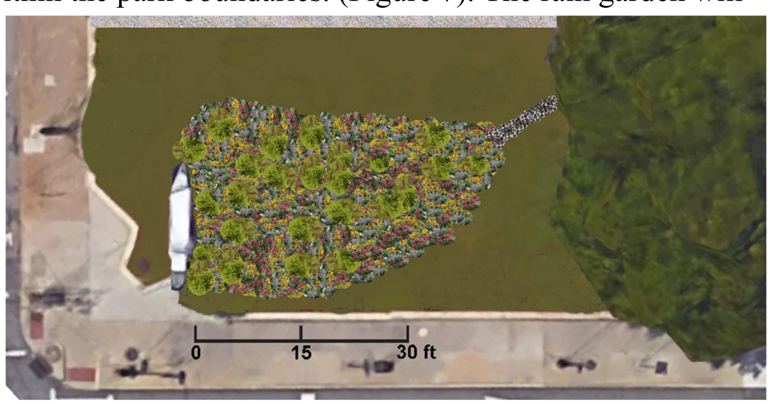

Figure 7. Aerial view of the proposed rain garden showing existing trees and sign and a proposed granite sitting ledge next to the living wall (not shown).

to handle the 10,000 gallons of runoff that might arise from a full cistern coupled with a modest storm.

3. Resiliency

The Atlanta region, much like the rest of the globe, is projected to become warmer over coming decades. Near-term climate projections indicate that temperatures will increase in all seasons, with the summer experiencing an increase of about 1°C and winter months increasing by 0.75°C (Kirtman et al. 2013). Located in the warmest portion of Atlanta, the area surrounding the GSU Sports Arena has a mean land surface temperature of 35 °C at 11 A.M. in summer, much warmer than the vegetated areas nearby (Figure 8). Green roofs can effectively cool the roof surface, thus reducing a major contributor to the urban heat island by directly reducing the roof temperature and indirectly by reducing the heat produced from air conditioning units (Akbari et al. 2001). In addition, extreme heat events are expected to increase in both frequency and intensity due to climate change, with urban areas experiencing a faster rate of increase than rural areas (Stone & Rodgers 2001; Meehl & Tebaldi 2004). If just 20% of the GSU campus had green roofs, the surface temperature of the campus would drop by 0.25 °C, and with 100% of the campus roofs vegetated the surface temperature would drop by 2.6 °C (Murphy 2015).

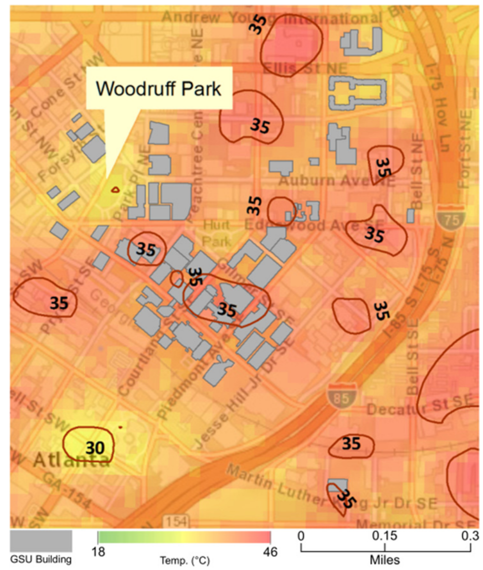

Figure 8. Land surface temperatures of the GSU campus and surrounding area at 11 A.M. during the summer.

Precipitation is projected to increase in the in the near-term future, yet soil moisture is projected to decrease. Atlanta-region precipitation is predicted to increase by 10% and there should be an increase in the percentage of precipitation occurring during heavy-rainfall events (Kirtman et al. 2013). Even if the Sports Arena green roof were able to remove 100% of stormwater at this time, it is unlikely that it would be able to do so in the future, making the rain garden and living wall essential elements of resiliency in the face of a changing climate. If just 20% of GSU roofs were vegetated, stormwater runoff for the campus could be reduced by 6.86%, but if all the roofs on campus were vegetated then stormwater could be reduced by 32.3% which translates into a prevention of over 68 million gallons of stormwater from entering the municipal sewer system (Murphy 2015). This increase in precipitation will not lead to an increase in soil-moisture due to the increase in evapotranspiration from

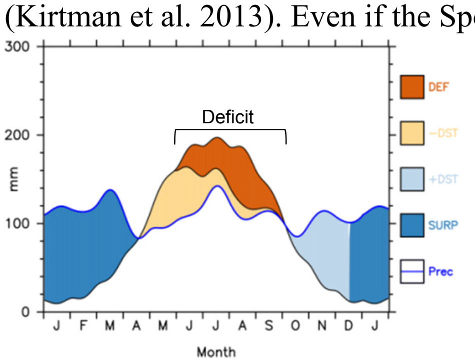

Figure 9. Projected annual soil water balance of Atlanta for 2016-2035.

rising temperatures. It is likely that the Atlanta summer soil-moisture deficit will last longer (Figure 9),[4] necessitating stormwater harvesting strategies for irrigation purposes.

4. Innovation and Value to Campus

This project design addresses environmental, social, and energy situations simultaneously. Environmentally, directly connected impervious surface will be reduced by 26,992 ft^2 (i.e., the 32,300 ft^2 green-roof portion of the roof minus the 5,308 ft^2 "G") and will eliminate stormwater runoff into the Atlanta sewer system potentially during all years. Stormwater will be harvested, evaporated, and infiltrated on site with no potable water used for irrigation. Should there not be sufficient stormwater for either purpose, gray water from the Sports Arena or aquatics building can be diverted to the park and to the green roof to ensure drought resistance. The rain garden will aid groundwater by recharging up to 730,000 gallons annually (~2,000 gallons day^{-1}). Because the structural loading capacity of the Sports Arena limits the use of larger vegetation, and the existing trees in the park will be retained, the tree canopy will not be increased beyond what currently exists. Finally, the green roof, living wall, and rain garden combined will remove over 60 lbs. of criteria pollutants from the urban atmosphere annually, with the expansive green roof responsible for more than 90% of the pollutant removal (Table 1).[5] Therefore, the new green infrastructure will remove roughly 15 times more air pollution than what the park currently does.

Table 1. Pounds of pollutants removed by the green roof, living wall, and rain garden annually.

Criteria Pollutant	Green Roof	Living Wall	Rain Garden	Total
O_3	29.7	2.7	0.4	32.9
NO_2	15.4	1.4	0.2	17.0
SO_2	4.3	0.4	0.1	4.8
PM_{10}	7.4	0.7	0.1	8.2
Sum	56.8	5.2	0.8	62.8

As it currently exists, the park is rarely used by students or by the public, in contrast to other urban parks adjacent to campus that are heavily used. There is nothing about this park that invites a person in, and it is entirely possible that the design of the park repels people with its unwelcoming design elements. Our plan is to create a space that is a showpiece for the university with its beauty, biophilic design elements, and as a demonstration space of urban green infrastructure potential. Students will have a place of respite from the onslaught of noise and concrete that accompany the urban landscape. A survey distributed to the university faculty regarding the desire and potential usage of the green roof and park for instructional and research purposes revealed a surprisingly strong interest in this project across academic disciplines. Favorable responses came from disciplines as diverse as neuroscience, psychology, geosciences,

---

[4] The projected soil-water budget was calculated using the Web-based, Water-Budget, Interactive, Modeling Program (*Web*WIMP).

[5] Estimated using removal rates in Yang et al. (2008)

economics, communications, and art. Potential uses included using the vegetated wall as a living art installation, using the green roof to grow plants for fibers and dyes in art projects, studying the impact of this type of greenspace on student well-being, and studying the impact of green infrastructure on the environment of downtown Atlanta. Finally, the park will serve as an excellent on-campus site for the hundreds of pre-K students at GSU's two child-development centers – located just two blocks from the park – to engage in STEM activities.

Being a truly urban and open campus, the park – which is located one block from a Metropolitan Atlanta Rapid Transit Authority (MARTA) light rail station and has a MARTA bus stop in front of it – will benefit not just students but the general public as well. The southern portion of the GSU campus lacks green space so the addition of a functional and inviting green space will be a welcome addition to the community.

The GSU community benefits from this green infrastructure design in multiple ways, but the university also benefits financially because of the increased energy efficiency of the Sports Arena resulting from the latent heat flux and insulating capacity of the green roof. Compared to the existing conventional roof, the addition of a green roof should result in a savings in energy expenditures of about $3,000 annually.

5. Likelihood of Implementation

The project team worked in collaboration with the Associate Vice President of GSU Facilities Management in developing a design with a high likelihood of being implemented. GSU Facilities supported this project by sponsoring the structural analysis of the Sports Arena roof by Palmer Engineering Company, and by providing guidance on the limitations facing green-infrastructure initiatives on an urban campus. The team maintained contact with the A.V.P. of Facilities throughout the conception and design process to ensure that all aspects of the plan could be funded and installed in reality. The Turner Foundation, a philanthropic funding organization, has shown strong interest in funding environmentally beneficial projects that benefit the Atlanta urban core. Such funding would be administered by the GSU Foundation to ensure continuity of the project as student leaders matriculate. The GSU Office of Sustainability has offered to fund the maintenance costs associated with the green roof through student fees that are earmarked for sustainability initiatives.

This green infrastructure initiative will complement the proposed campus greenway that will connect the campus core to the Petit Science Center complex (Figure 10).[6] The design concepts presented in this project, especially the green roof on the Sports Arena, serve as a demonstration of the potential that urban green infrastructure has despite restrictions presented by the built environment and lack of available space. In fact, the Sports Arena roof will be the second largest greenspace on campus.

[6] http://facilities.gsu.edu/files/2013/07/Physical-Master-Plan-7-9-2013.pdf

Figure 10. The portion of the GSU master plan focusing on the core portion of the campus. The Sports Arena green roof is shown, but it is not part of the master plan.

6. Maintenance

The green roof, cistern, living wall, and rain garden all will require periodic maintenance. At the present time, maintenance of the green roof can only be performed by GSU Facilities staff. Student groups such as the Sustainability Tribe, fraternities, and sororities have offered to help with general maintenance of the park, such as weeding and plugging; this demonstrates another avenue that the project improves student engagement in "green" processes. Inspection and maintenance of the integrity of the roof system will be handled by GSU Facilities staff whose experience and knowledge of building systems will identify any problems or issues with the roof that may escape the eye of a volunteer. The park will be maintained by the GSU grounds crews that manage the campus greenspaces and trained in appropriate care for the rain garden and living wall.

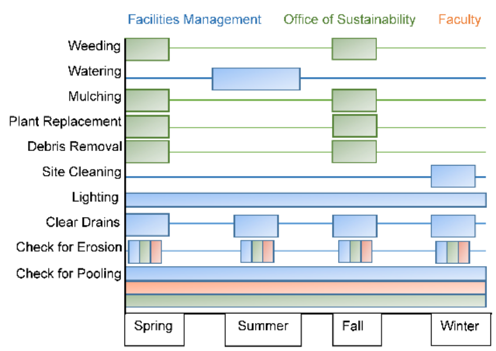

Figure 11. Maintenance schedule for the green roof.

7. Budget

The cost estimate for the project is subject to change due to the competitive bidding process that the university must adhere to for projects such as these. The costs associated with this project reflect a best guess estimate based on information gathered from green roof professionals, professional roofers, and local landscapers. It is estimated that costs for both phases of the project will total approximately $997,939 (Table 2). This total assumes that the current roof on the Sports Arena will not be replaced due to the confidence that GSU Facilities has in the integrity of the existing roof. In light of the age of the roof, a modular green roof system has been selected that will allow for easy access and repair should a leak occur. The addition of a vegetated roof over the existing roof should extend the life of the current roof, but to what extent remains unknown so calculating the net present value is problematic.

Table 2. Estimated expenses associated with the proposed project.

Item	Amount	Cost per Unit	Cost	Notes
Extensive Green Roof	29,804 ft^{-2}	$11.42 ft^{-2}	$340,536	Includes materials, installation, and shipping.
Cistern	165,848 gallons	$0.65 $gallon^{-1}$	$107,801	Does not include installation
Living Wall	2,304 ft^{-2}	$100 ft^{-2}	$230,400	Includes materials and labor
Rain Garden	342 ft^{-2}	$15 ft^{-2}	$5,130	Includes materials and labor
Boulders	11 tons	$300 ton^{-1}	$3,300	Boulders would be in the southwestern corner of the park where water enters from the cistern
Creek rock	1 ton	$120 ton^{-1}	$120	The creek rock is needed for the artificial stream going from the boulders to the rain garden
Granite slabs		Repurposed granite from the Campus Courtyard renovation	$0	The slabs would provide a seating area next to the living wall
Site preparation and misc. costs			$68,728	
Design Fee		Estimated 10% of total	$75,601	
Project Contingency Fund		Estimated 20% of total	$166,323	
Initial Budget Estimate			**$997,939**	

8. Timeline

This proposal is designed to be implemented in two phases (Figure 12). The first phase is the installation of the green roof and cistern, and the second phase is the renovation of the park. Phase one should begin in the fall so that the green-roof vegetation has time to establish a strong root system and recover from transplant shock before the stress of summer temperatures arrives. Phase two should begin in late winter with site preparation and the installation of piping to carry water from the cistern to the water feature and the living wall. Once the site has been prepared and the rain garden soil appropriately amended, the plants should be installed once the last chance of frost has passed in the spring. At this time the plants will have time to establish their root systems before the high summer temperatures occur.

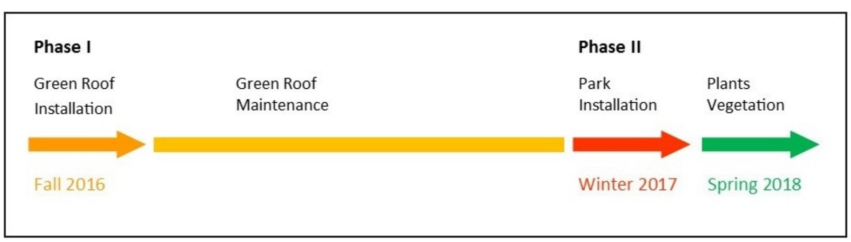

Figure 12. Timeline of the proposed project.

References

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*, *70*(3), 295–310. http://doi.org/10.1016/S0038-092X(00)00089-X

Calderón-Garcidueñas, L., Calderón-Garcidueñas, A., Torres-Jardón, R., Avila-Ramírez, J., Kulesza, R. J., & Angiulli, A. D. (2015). Air pollution and your brain: what do you need to know right now. *Primary Health Care Research & Development*, *16*(04), 329–345. http://doi.org/10.1017/S146342361400036X

Dietz, M. E. (2007). Low impact development practices: A review of current research and recommendations for future directions. *Water, Air, and Soil Pollution, 186*(1-4), 351–363.

Dvorak, B., & Volder, A. (2013). Rooftop temperature reduction from unirrigated modular green roofs in south-central Texas. *Urban Forestry & Urban Greening*, *12*, 28–35. http://doi.org/10.1016/j.ufug.2012.05.004

Gill, S. E., Handley, J. F., Ennos, A. R., Pauleit, S., Theuray, N., & Lindley, S. J. (2008). Characterising the urban environment of UK cities and towns: A template for landscape planning. *Landscape and Urban Planning, 87*(3), 210–222.

Hardin, M., Wanielista, M., & Chopra, M. (2012). A Mass Balance Model for Designing Green Roof Systems that Incorporate a Cistern for Re-Use. *Water*, *4*(4), 914–931. http://doi.org/10.3390/w4040914

Hough, Michael. (2004). Cities and Natural Process: A Basis for Sustainability. Taylor and Francis.

Kirtman, B., S.B. Power, J.A. Adedoyin, G.J. Boer, R. Bojariu, I. Camilloni, F.J. Doblas-Reyes, A.M. Fiore, M. Kimoto, G.A. Meehl, M. Prather, A. Sarr, C. Schär, R. Sutton, G.J. van Oldenborgh, G. Vecchi and H.J. Wang, 2013: Near-term Climate Change: Projections and Predictability. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Meehl, G. A., & Tebaldi, C. (2004). More intense, more frequent, and longer lasting heat waves in the 21st century. *Science*, *305*(5686), 994–997. http://doi.org/10.1126/science.1098704

Murphy, Sharon, "Assessing the Effectiveness of Extensive Green Roofs at Improving Environmental Conditions in Atlanta, Georgia." Thesis, Georgia State University, 2015. http://scholarworks.gsu.edu/geosciences_theses/87

Nardini, A., Andri, S., & Crasso, M. (2012). Influence of substrate depth and vegetation type on temperature and water runoff mitigation by extensive green roofs: shrubs versus herbaceous plants. *Urban Ecosystems*, *15*(3), 697–708. http://doi.org/10.1007/s11252-011-0220-5

Price, J. G., Watts, S. A., Wright, A. N., Peters, R. W., & Kirby, J. T. (2011). Irrigation lowers substrate temperature and enhances survival of plants on green roofs in the southeastern United States. *HortTechnology, 21*(5), 586–592.

Stone, B., & Rodgers, M. O. (2001). Urban form and thermal efficiency - How the design of cities influences the urban heat island effect. *Journal of the American Planning Association*, *67*(2), 186–198. http://doi.org/10.1080/01944360108976228

Targino, A. C., Krecl, P., & Coraiola, G. C. (2014). Effects of the large-scale atmospheric circulation on the onset and strength of urban heat islands: a case study. *Theoretical and Applied Climatology*, *117*(1-2), 73–87. http://doi.org/10.1007/s00704-013-0989-7

Trewartha, G. T., and L. H. Horn (1980). An Introduction to Climate. McGraw-Hill, 416 pp.

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning, 81*(3), 167–178.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201–230. http://doi.org/10.1016/S0272-4944(05)80184-7

U.S. EPA (2007). Green Infrastructure Statement of Intent. http://www.epa.gov/sites/production/files/2015-10/documents/gi_intentstatement.pdf

Van Mechelen, C., Van Meerbeek, K., Dutoit, T., & Hermy, M. (2015). Functional diversity as a framework for novel ecosystem design: The example of extensive green roofs. *Landscape and Urban Planning*, *136*, 165–173. http://doi.org/10.1016/j.landurbplan.2014.11.022

Yang, W., Wang, Z., Cui, J., Zhu, Z., & Zhao, X. (2015). Comparative study of the thermal performance of the novel green (planting) roofs against other existing roofs. *Sustainable Cities and Society*, *16*, 1–12. http://doi.org/10.1016/j.scs.2015.01.002