POLYTECHNIC UNIVERSITY PUERTO RICO
GRADUATE SCHOOL

THE FEASIBILITY OF INSTALLING A GREEN ROOF SYSTEM TO MITIGATE LARGE WATER RUN-OFF

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ABSTRACT

The purpose of this project is to determine if it is economically and physically feasible to install a water management system that will help solve the flooding problem that the educational institution XYZ has been presenting over the years. It was determined that a combination of an extensive green roof system and a rainwater harvesting system could be used for this situation. The weight that would be exerted over the existing roof satisfies the permissible load. The cost was determined to be $41,000. Given this and the actual economic situation of the institution, it was determined that in order to continue with this project, donations or sponsorships would be required.

INTRODUCTION

XYZ is a public educational institution located in the west of Puerto Rico. The location of XYZ can be categorized as urban, which means that great amounts of stormwater runoff is generated from heavy rain events. XYZ has long been presenting flooding problems, with major consequences at one of its parking lots. The focus of this project is to find a feasible solution that will reduce the stormwater runoff in the adjacent areas, which will result in minimizing the effects of a flooding event.

Objectives

The objectives of these project are the following:

- Determine the physical feasibility of locating a green roof system in the building adjacent to the parking lot.
- Determine the economic viability of implementing this system.

Methodology

The following methodology was followed to complete the project:

- Determine the impact the impervious surfaces have on this area.
- Determine maximum load.
- Perform an economic analysis.

LITERATURE REVIEW

The growth of population has led to the development of civil infrastructure and many urbanized areas. Urbanized areas consist of areas with high concentration of impervious surfaces. This creates a problem in the event of heavy rainfalls, because the water runoff cannot infiltrate through the soil and absorbed to the underground water bodies, or because there is more water than the amount that the surrounding soil can absorb [1].

The optimal option to avoid stormwater runoff is to preserve the natural vegetation undisturbed, which results in a much more cost-effective alternative [2]. Some alternatives used to manage stormwater runoff are green roof systems, infiltration planters, swales, inlets, catch basins, water harvesting, porous pavements, among other methods [3].

A green roof is a green space created by adding layers of growing medium and plants on top of a traditional roofing system to help retain, absorb and filter storm water. Other than reducing the amount of storm water runoff, green roofs help moderate the temperature of the structure, reduce noise, improve air quality, increases the value of the property and can act as a recreational space or other amenity.

When a green roof system is implemented, a delay in the water runoff is experimented in comparison to a conventional roof. Therefore, a time gap between the peak runoff of a conventional roof and a green roof is created for the same rain event. This occurs because of the amount of water that is retained and absorbed by the green roof system. This is illustrated in Figure 1.

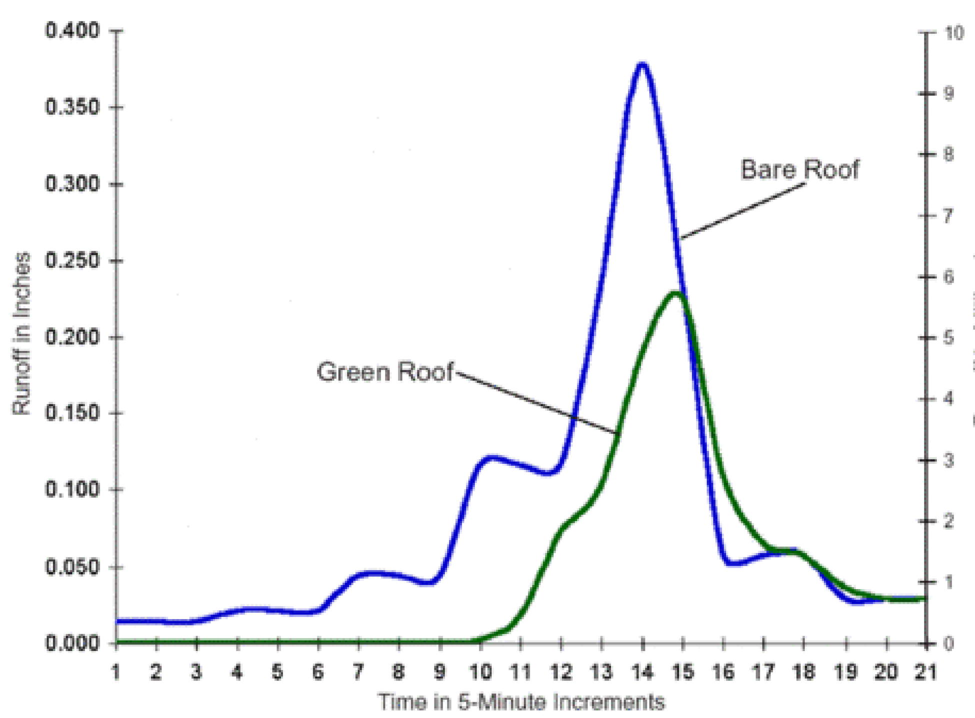

Figure 1
Peak Runoff Bare Roof vs Green Roof

Rainwater harvesting consists of collecting stormwater and storing it for later use. It is considered a small-scale best management practice and it is an economic solution for stormwater management [4].

ANALYSIS

For this project there are two areas of interest: the area where the flooding occurs (271,477 ft^2) and the area where the green roof and where the rainwater harvesting will be installed on (5,985 ft^2). In order to complete the runoff analysis, a data was collected from a field visit in which actual readings were obtained. The amount of rainfall and estimated retention is summarized in Table 1.

Table 1
Rainwater Retention Estimate for Harvesting System

Time	Recipient	Volume	Rainfall	Retention
2 hrs	729.2 cm^2	325 mL	0.2 cm/hr	105.6 gal/hr

A rainwater harvesting system is proposed to catch and store the remaining 50% of stormwater that will not be absorbed by the green rooftop. A 1,000-gallon HDPE tank is being recommended to store the water and use for irrigation purposes, shown in Figure 2.

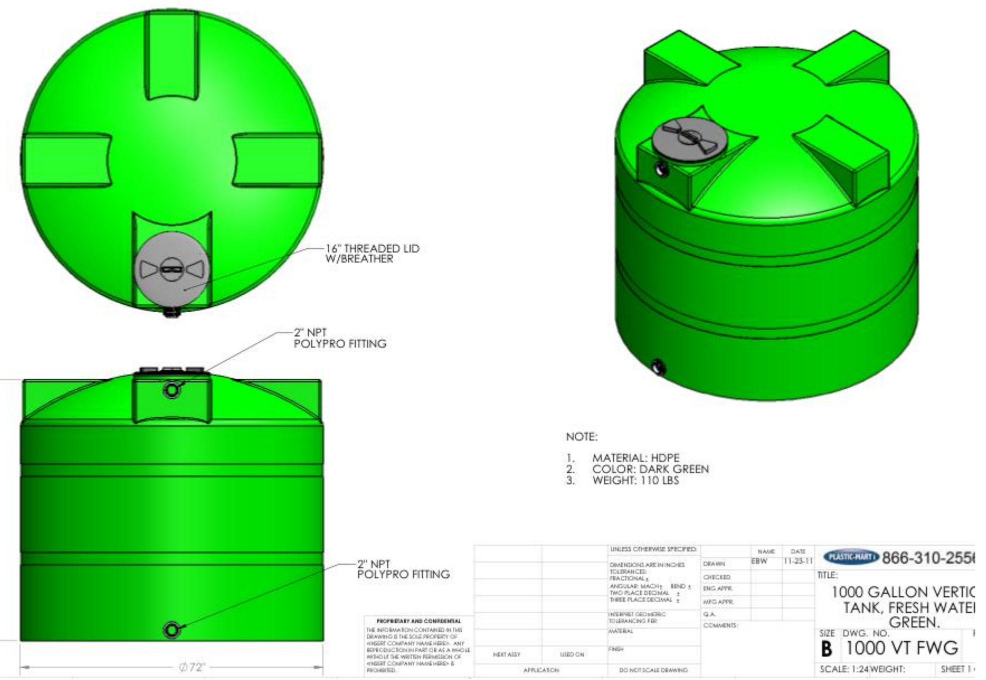

Figure 2
Recommended Tank for Rainwater Harvesting System

The weight of a green roof has great variety that depends on the depth, the materials and other components. The important measurement is wet weight because that is when fully saturated fabrics and plants are at their heaviest. The saturated weight (*q*) of 23 psf taken from the Conservation Technology website [4], was used to perform the roof load capacity analysis.

In order to ensure that the installation of this system is feasible and safe, the deflection of the roof was computed. The slab thickness was assumed as a solid, one-way slab with both ends continuous. Based on these assumptions, and a span length (*L*) of 258 inches, equation (1) was used and the slab resulted in 10 inches.

$$\text{Slab Thickness } (h) = L / 28 \quad (1)$$

The deflection needs to be computed for the roof as is, without load, and also applying the load of the green rooftop system. The maximum permissible computed deflection (ΔMAX) without load was calculated with equation (2) and resulted in 1.43 in.

$$\Delta MAX = L / 180 \quad (2)$$

The deflection after the load is applied was computed with equation (3) and resulted in 0.0056 in. The coefficients used were the aspect ratio (γ) of 2.04, the deflection coefficient (*k*) of 0.0018 and the modulus of elasticity (*E*) of 4×10^6 psi.

$$\Delta = k\,(qa^4 / Eh^3) \quad (3)$$

Given that the deflection of the roof does not exceed the maximum permissible deflection, it is feasible to locate the green roof system in the selected roof.

RESULTS AND DISCUSSION

The proposed design follows a granular drainage system described in the Conservation Technology website [4]. These types of layouts were designed to maximize the water retention, while minimizing the weight they exert over the roof. The proposed design will consist of the characteristics described in Table 2.

Table 2
Characteristics of the Proposed Green Roof System

Extensive Soil Mix	2 in
Soil Mix Types	e.g. Horticultural pumice or scoria mix, cinder sand, peat moss
Granular Drainage Media	2 in
Protection Fabric	0.25 in
Separation Fabric	0.125 in
Separation Fabric Type	Polypropylene
Total Nominal Thickness	4 in

The selected plant for this project is the sanseviera trifasciata, also known as golden hahnii and colloquially known as "lengua de vaca". The caracteristics of the sanseviera trifasciata are shown in Table 3 and an image is shown in Figure 3.

Table 3
Characteristics of Sansevieria Trifasciata

Typical Height	5 in
Typical Width	5 in
Light Requirement	Full Sunlight
Water Requirement	Dry Tolerant
Soil Requirement	Sandy soil
Maintenance	Low
Irrigation Frequency	Weekly
Growth Speed	Slow

Figure 3
Sansevieria Trifasciata (Golden Hahnii)

The sanseviera trifasciata tend to propagate abundantly, therefore for this design it is recommended to plant them leaving a 2-foot distance between plants. Given this specification, a total of 963 plants will be required.

Using average costs provided by local vendors the total project cost was estimated as follows:

Total Cost = Plants + Green Roof System + Water Tank
= $1,610.62 + $38,778.15 + $599.99 = $40,988.76

Figure 4 shows a representation generated in Google Sketchup of how the roof would look like after the green roof system is installed.

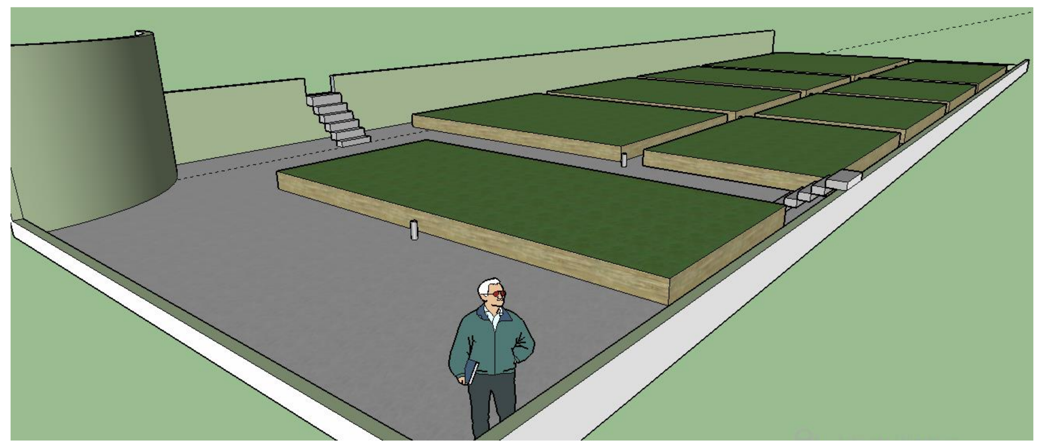

Figure 4
Proposed Green Roof Layout

CONCLUSION

From the load analysis it was determined that the physical implementation of this system is feasible, since the load it exerts is almost negligible. The total cost to implement a system that would reduce the stormwater runoff was calculated to be approximately $41,000.00 Given the fact that XYZ has a very limited budget, the only way it would be economically feasible to construct would be if it sponsored externally.

If the project is to be constructed, plants would need maintenance. Therefore, a plan can be arranged so that students can work with wage labor or as part of an engineering or agricultural sciences class or investigations.

REFERENCES

[1] National Geographic Society. Runoff [website]. Available: https://www.nationalgeographic.org/encyclopedia/runoff/.
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