URBAN WATER WORKS
QUALITY DESIGN IN URBAN WATER INFRASTRUCTURE

Innovative Urban Stormwater BMP

Mark Denn, Gabriela Ramos, and Joseph Yarosz

BAEN 480 – Spring 2020 Capstone

TEXAS A&M UNIVERSITY
Department of Biological and Agricultural Engineering

Motivation

According to the Fourth National Climate Assessment of 2018, changes in precipitation across regions show increased heavy downpours and decreased surface water quality. Heavy downpours are a growing threat to urban areas due city infrastructure which cannot absorb or manage heavy rainfall in comparison to rural areas. As a result there is frequent urban flooding, caused by rain that falls on impervious surfaces overwhelming local stormwater drainage capacity (NRDC 2019).

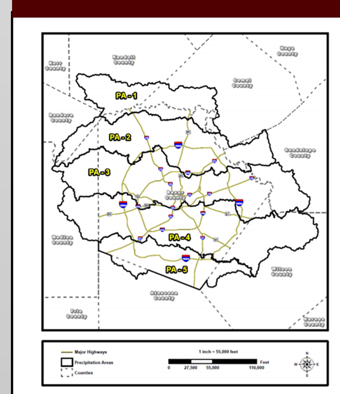
Low impact development (LID) and best management practices (BMP) are strategies which will be used to help reduce the present and future risk of water security and urban flooding.

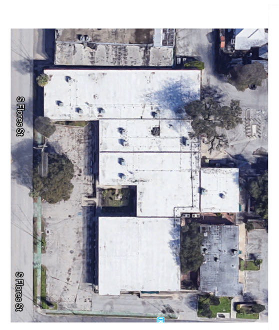
Design Objectives

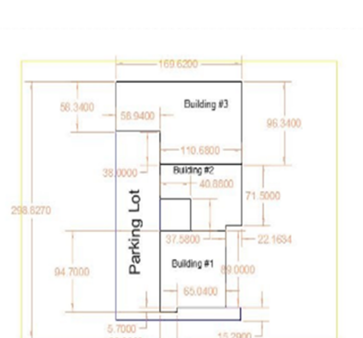
In particular to this project, LID and BMPs will be used to reduce urban stormwater rooftop runoff. Urban Water Works is working in part with the San Antonio River Authority to develop a stormwater BMP system to collect rooftop runoff from a high impervious area located downtown of San Antonio. The stormwater BMP incorporates the use of Bioretention and Greenwall designs at the desired location, capturing at least 0.5 inches of runoff produced from the site per storm event. The Greenwall and Bioretention BMP is designed to be easily implemented to various buildings within a highly urbanized area. The constraints of the recommended solution involves:

- limited 4ft width between the building and parking area
- vertical design
- no opportunity for infiltration to the city stormwater sewer system
- little customization
- easily installed
- produced from recycled material

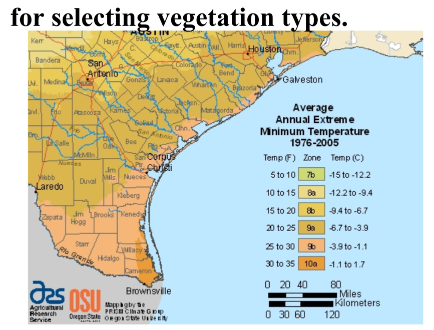
Location Analysis







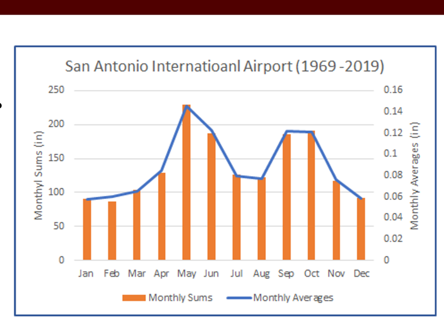
A plant hardiness map was used to select vegetation that would thrive within the climate of San Antonio. Based off location, zone 9a was chosen for selecting vegetation types.



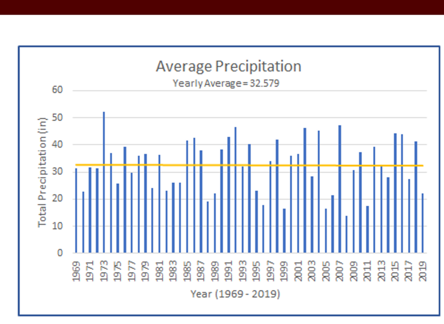
Using a precipitation area map provided by the city of San Antonio Storm Water Design Criteria Manual, intensity-duration-frequency curves (IDF) and depth-duration-frequency curves (DDF) were selected to represent precipitation data used in hydraulic modeling. For this project, the PA-3 region was used.

Weather Analysis

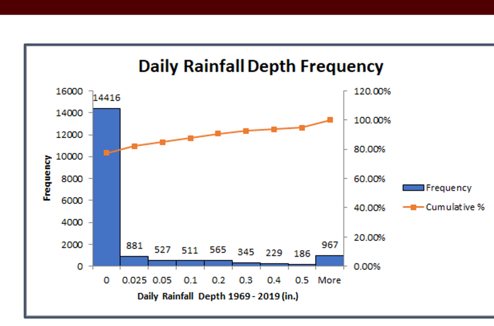
1.



2.



3.



- Highest Daily Rainfall On Record = 11.26 in (1998)
- 1. Months May, June, September, and October having the greatest average daily rainfall, with 0.15, 0.12, 0.12, 0.12 inches respectively
  2. Yearly average precipitation being 32.6 inches
  3. 77% predicted rainfall depth to be 0 inches and 5.2% of rainfall depth predicted to be above 0.5 inches

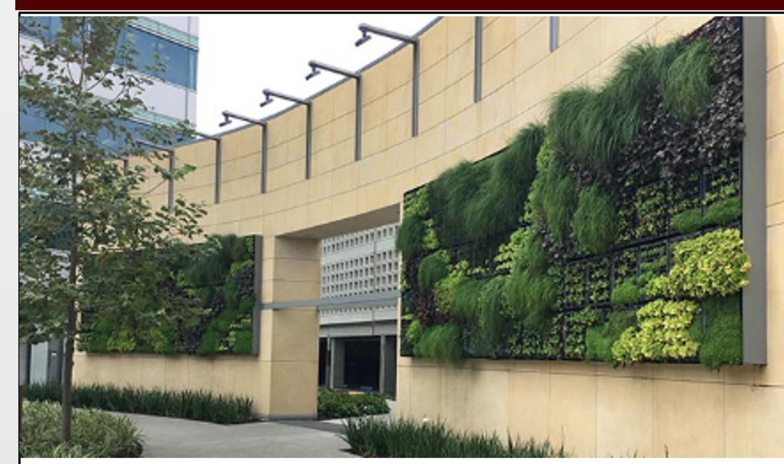
Table 1. Peak runoff rates

Rainfall Depth P (in)	Roof Area 1 (gpm)	Roof Area 2 (gpm)
0.1	3.39	2.88
0.2	6.78	5.76
0.5	16.94	14.39
1	33.89	28.79
5	169.43	143.93
9	304.98	259.07
10	338.87	287.85
11	372.75	316.64

Peak Rooftop Runoff Flow rates:

From Table 1, for a 0.5 inch storm event the peak flow rate in gallons per minute is predicted to be 17 for building one and 14 for building two. The peak flow rates are used to estimate volumes of runoff for a 24 hour storm event, in which the green wall and bioretention areas will need to capture.

Green Wall



A component of the BMP system includes a modular green wall system. The function of this design is to reduce the total runoff exiting the roof by storing and using the runoff simultaneously. The greenwall design is easily modifiable through the addition or subtraction modules from the wall frame and can be adjusted to various sized buildings. Another purpose of the greenwall is to increase the visual appeal of building it is being applied to.

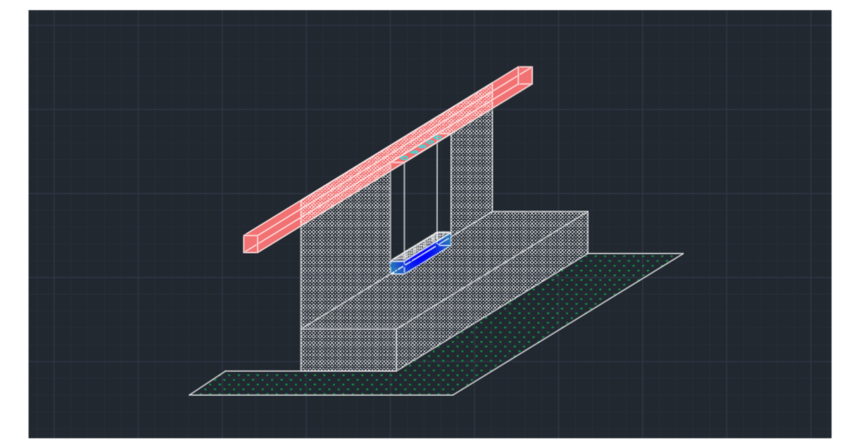


Figure 1.1: A preliminary 3D view of the modular green wall; blue highlight is the irrigation tank; red highlight is the building gutter system; grey highlight is the building infrastructure; dark area is the predicted green wall

Specifications of the Tournesol Modular Green wall System include:

- 1 module will hold 13 lbs of water (1.557 gallons)
- Each constructed frame will support a 250 lb load
- VGM-10 Module dimensions: 18.75''x 10''x 22''
- Gives an 8'' planting depth
- Modules will contain 100% post-consumer recycled black polypropylene

Building two is the focus area of the modular green wall. The best wall space is approximately 250 square feet. From Figure 1.2 the green wall arrangement best suited for the given area was approximated to be 11 modules per row and 4 modules per column. This arrangement will give enough space at the bottom for an irrigation tank, which will collect remaining green wall and gutter runoff.

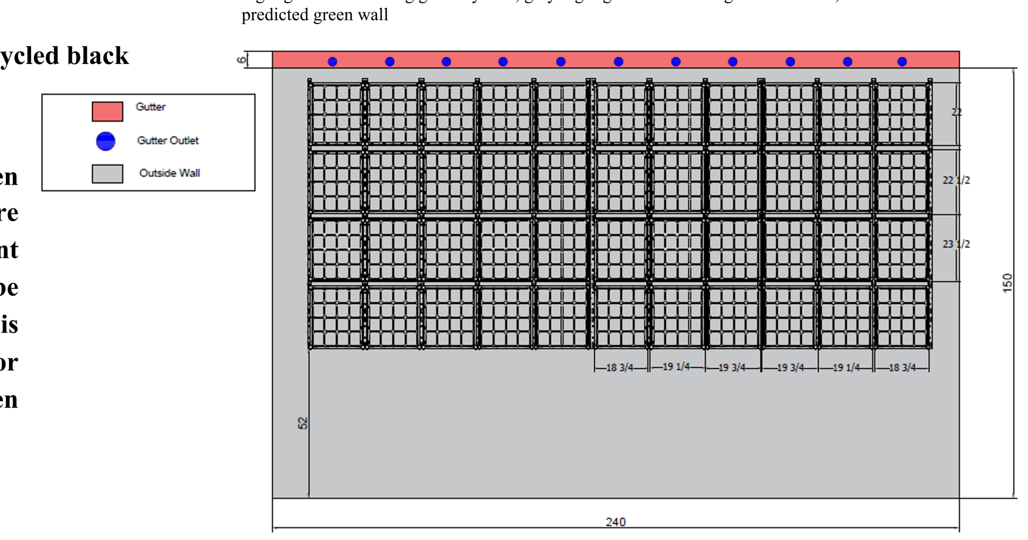


Figure 1.2: An AutoCAD sketch of the green wall design with measurements shown in inches

Irrigation System

Irrigation System was designed to sustain the greenwall design through an automated drip line irrigation system. Since the bioretention system has been designed to retain and use expected water discharges, no subsurface drainage is needed.

Irrigation pipeline will run vertically behind greenwall system. Irrigation tubes will run along module levels from sections of the irrigation piping, allowing drip irrigation to span across the top of each modular level.

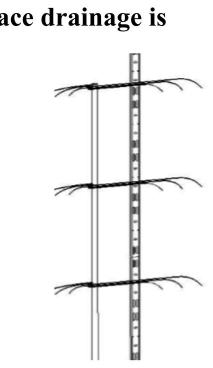


Figure 1.4: Water Distribution nodes

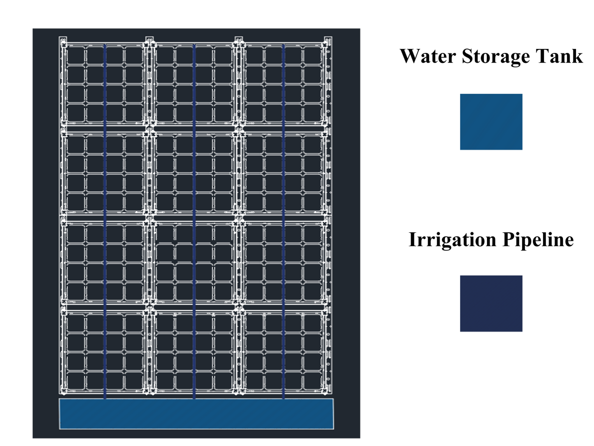


Figure 1.3: An AutoCAD sketch of the water distribution system for the greenwall

Bioretention Areas

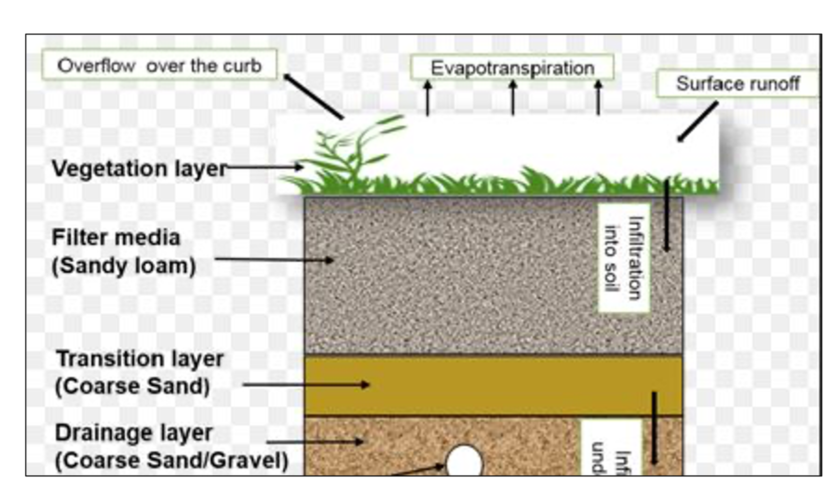
Bioretention has proven to be an extremely effective method for the catchment of stormwater runoff. The proposed plan will include 1300 sq. feet of bioretention along the sides of buildings one and two. This suggested design is estimated to capture stormwater runoff up to a 1.5" storm event based on average storm event of the surrounding region. The design will consist of four different media layers, with the top layer containing vegetation native to Texas. Installation and associated costs for the proposed design were calculated at $1200.

Vegetation Types (Zones 8-9)

- Salvia greggii
- Snake herb
- Spiderwort
- Prairie verbena

Layer Types:

- Filter Media (50% native/50% compost)
- Transition Layer (sand/gravel mix)
- Drainage Layer (sand/gravel mix)



Economic Analysis

From the estimated design costs the predicted installment and material value for the overall design, bioretention, green wall, and irrigation system, is $22,429. The predicted operations and maintenance cost of the bioretention area is approximately $4,940 /year/acre. The green wall design should be maintained 1 to 2 times per week and costs depends on the types of plants and irrigation system implemented. With dry resistant plants and an automatic drip irrigation system, the design will not need to be maintained daily but rather 1 to 2 times per week as stated before. If perennial or annual plants were to be used, the green wall should be maintained daily for the first growing months of the plants.

Best Management Practice	Activity/Material	Unit	Unit Cost Estimate	Design Measurement	Estimated Design Cost
Green Wall Frame	VGM-10 Module	Module	$123	44	$5,412
	Planting Media	Module	$31	176	$5,456
	VGMR-3 railing	Rail	$139	12	$1,668
	VGMR-2 railing	Rail	$99	12	$1,188
	VGM3 Living Wall Anti Lift Arm	Arm	$12.00	44	$528.00
	VGM-10 Living Wall Module Right Bracket	Bracket	$37	88	$3,256
	VGM-10 Living Wall Module Left Bracket	Bracket	$37	88	$3,256
Total:					**$20,764**
Drip Irrigation System	Installation	Linear foot	$3.20	100	$320.00
	Irrigation Kit	Linear foot	$0.15	100	$15.00
	Mainline Tubing	Linear foot	$0.60	100	$60.00
	Pressure Reg.	Item	$20	-	20
	Accessories	Item	$10	-	10
	Timer	Item	$40	-	40
Total:					**$465**
Bioretention	Excavation/Hauling	Cubic yard	$6.30	24	$150
	Soil Installation	Cubic foot	$0.50	400	$200
	Gravel Installation	Cubic foot	$0.50	300	$150
	Filter Fabric	Square foot	$0.50	200	$100
	Mulch	Square foot	$0.50	200	$100
	Perforated Pipe	Linear foot	$2	50	$100
	Overflow Drop Box	1 box	$50	-	$50
	Plants	square foot	$2	200	$400
Total:					**$1,200**

Results and Discussions

The results produced has shown the bioretention and green wall designs to be very effective in managing runoff at the site location. The proposed design has the capacity to hold stormwater runoff up to a 1.5 inch storm event with the 1300 sq. foot bioretention and 130 square foot green wall.

The green wall design is predicted to store a maximum of 274 gallons per continuous storm event. With the additional irrigation storage system, the wall will be able to at least hold an additional 225 gallons. The combination of green wall and irrigation will be able to hold about 500 gallons. Extra runoff will be redirected to the bioretention area. The bioretention area will maximize the area of water catchment.

The system is able to store large volumes of water for an extended period of time, and will require very little maintenance. The overall design can be implemented into the existing site by the end of the calendar year, with the ability to be upscaled as desired. This design will be able to accommodate all the needs of stormwater catchment and mitigation, while also improving the site location with more green infrastructure and adding to the visual appeal to the area.

Table 2: The total average rainfall in gallons each month is expected to receive

Month	Average Rainfall (in.)	Total Monthly Yield of Harvested Water (Gallons)	Area 1 Monthly Yield of Harvested Water (Gallons)	Area 2 Monthly Yield of Harvested Water (Gallons)
January	0.06	537.68	290.72	246.96
February	0.06	561.74	303.73	258.01
March	0.07	614.04	332.01	282.03
April	0.08	792.30	428.40	363.91
May	0.15	1362.81	736.87	625.94
June	0.12	1149.28	621.42	527.87
July	0.08	746.40	403.58	342.82
August	0.08	726.17	392.64	333.53
September	0.12	1141.01	616.94	524.06
October	0.12	1133.63	612.95	520.68
November	0.08	715.43	386.83	328.60
December	0.06	549.43	297.08	252.35
Annual		10029.90	5423.16	4606.74

Conclusions and Future Work

Final Design:
The BMP design has been organized in a manner that can easily scaled up or down based on building size, with the current design falling well within the given budget of $25,000 - 100,000. Total runoff in gallons can be held and dissipated with the design.

Future Work:
The future work for this project will consist of redirecting connections from the roof gutters to bioretention area, the addition of gutter outlets on building 2, and producing more areas of green walls of different sizes with other other alternative designs such as cisterns.

References

1. Weber, A.. 2019. "What is Urban Flooding". The National Resources Defense Council. Retrieved April 9, 2020. (https://www.nrdc.org/experts/anna-weber/what-urban-flooding)

1. National Climate Assessment. 2018. "Fourth National Climate Assessment, v2." Impacts, Risks, and Adaptation in the United States. Summary Findings. Retrieved April 9, 2020. (https://nca2018.globalchange.gov/)

1. Dorman, T., M. Frey, J. Wright, B. Wardynski, J. Smith, B. Tucker, J. Riverson, A. Teague, and K. Bishop. 2013. "San Antonio River Basin Low Impact Development Technical Design Guidance Manual, v1." San Antonio River Authority. San Antonio, TX.