Designing Green Infrastructure for a Desert City: design experiment of hydro-ecological performance evaluation for biodetention details at Flood Control District of Maricopa County, Phoenix, Arizona

Chingwen Cheng[1], *Amanda Trakas[1], Paul Coseo[1], and Kristian Kelly[1].

1 Arizona State University, The Design School, 810 S. Forest Ave, Tempe, AZ 85281, *Graduate Student

Introduction

Green infrastructure (GI) design used for stormwater control has been widely studied in temperate and wet climate in cities such as Seattle for decades yet little research has been done in hot and arid environment (Sanchez 2019). Cities in the Phoenix metro area in recent years have recognized the potential multiple benefits of GI and developed design guidelines. However, one of the challenges for implementation is due to a lack of supporting evidence for alternative practices (McPhilips and Matsler 2018). To understand GI's hydrological performance and landscape design applications, the Hydro-GI Lab at The Design School collaborated with Flood Control District of Maricopa County (FCD) and conducted a field design experiment on FCD's Durango Campus. We aim to answer two key questions: 1) how effective does GI biodetention design control stormwater flow infiltration in hot and arid environment? 2) how do native plants perform within GI stormwater design in the Phoenix metro area.

Method

Three repeated samples of three different stormwater biodetention basin design details with identical planting design (Figure 1a, 1b) were installed and examined with three details: 1) Standard Basin with no soil amendment (Figure 1c), 2) Water Harvesting Basin with 4 inches of mulch (Figure 1d), and 3) Biodetention Basin with 16 inches of amended soils (Figure 1e). Monthly experiments to measure infiltration rates and canopy volume were performed from June to December 2019.

Design Experiment Layout

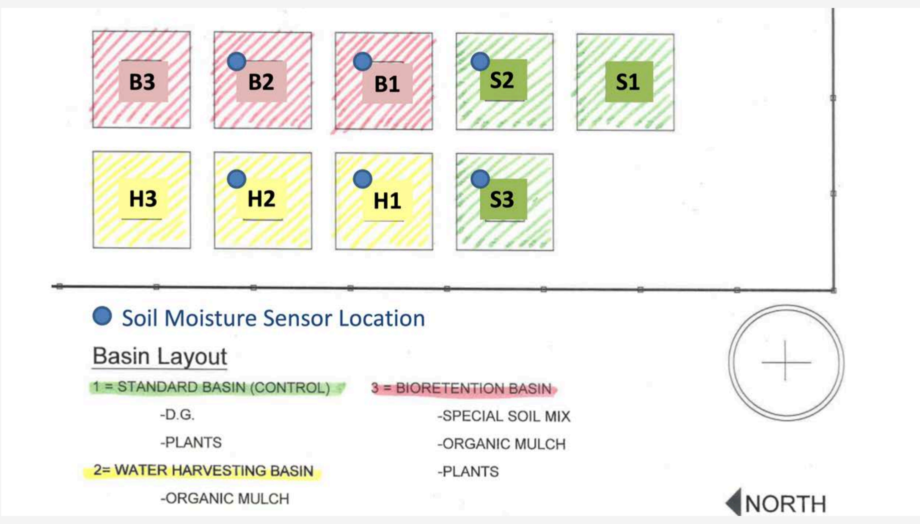

Figure 1a

Planting Plan

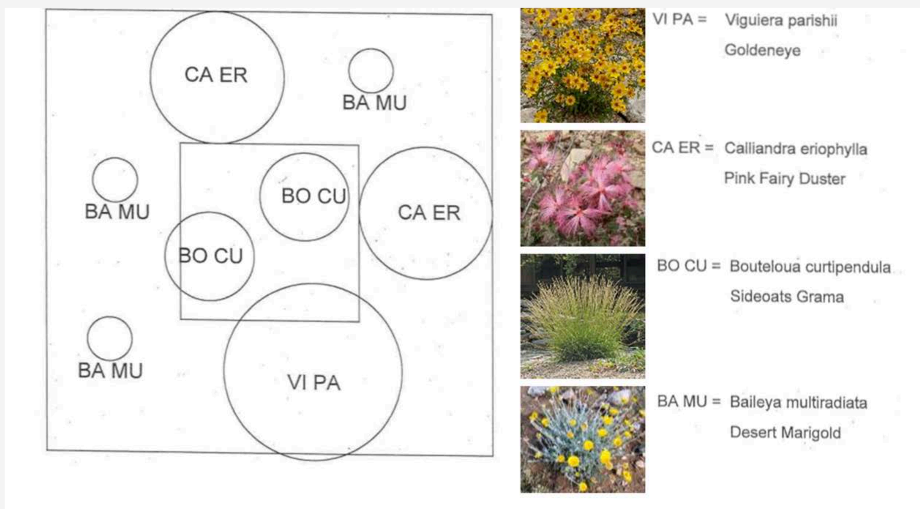

Figure 1b

Standard Basin - Section View

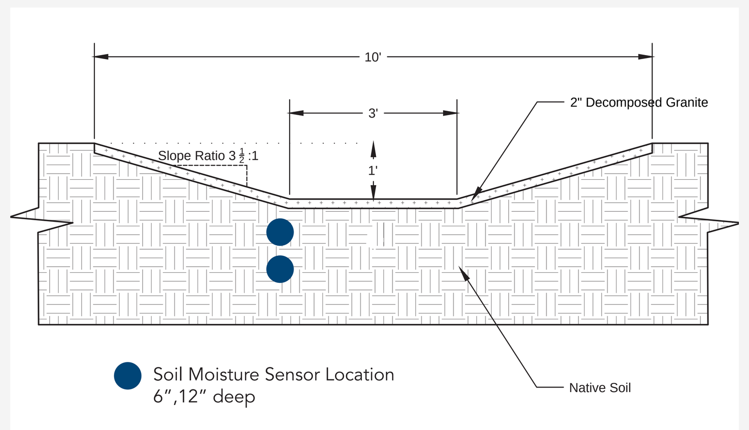

Figure 1c

Water Harvesting Basin - Section View

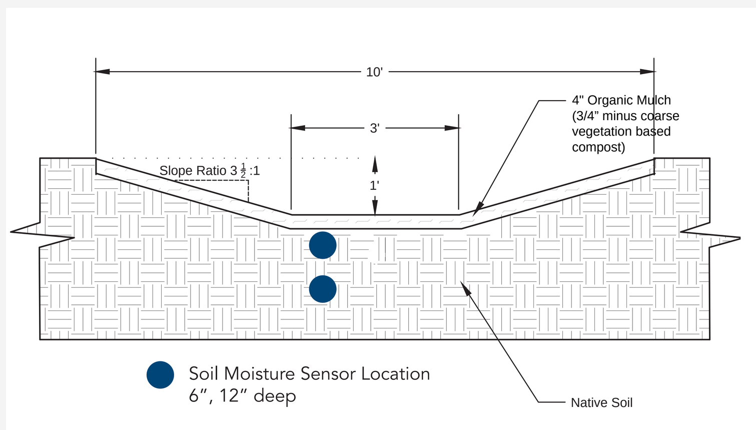

Figure 1d

Biodetention Basin - Section View

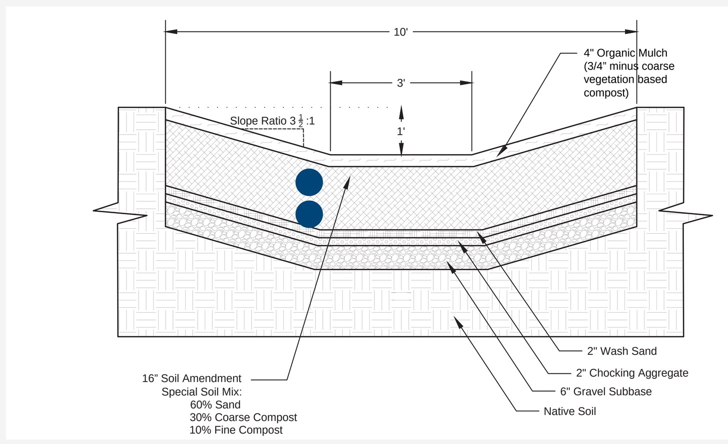

Figure 1e

Infiltration rate is measured in two ways: flooding experiments and soil moisture sensor. Infiltration rates were calculated by recording the depth of water ponding in the basin in every 5 minutes for 50 minutes. Soil moisture sensors were installed with two repeats in three types of basins (Figure 1a) and in 6" and 12" in depth. Soil water contents were recorded every 5 minutes and aggregated into every hour daily for analysis. Plants measured by canopy volume to track plant establishment and performance was calculated using the ellipsoid volume formula [2/3πH (A1/2 x B1/2)] for accommodating various plant shapes and sizes (Thorne et al. 2002).

Establishing flow rate

Measuring water ponding

Measuring canopy volume

Results

Figure 2 and 3 show the progression of plant growth by volume over the study period for each basin type during the summer (June, August), fall (September, October), and winter (December) months. The Standard Basins (S) demonstrated the slowest infiltration rate during the flooding experiments (Figure 4 and 5). These basins also demonstrated the highest total plant volume, including multiple volunteer species recorded over the course of the experiments. The Water Harvesting Basins (H) demonstrated a faster infiltration rate (.07cm/min) than the Standard Basins (.03cm/min) along with the second highest total plant volume with fewer additional volunteers. The Biodetention Basins (B) demonstrated the fastest infiltration rate, assuming comparable to the water flow rate (.36cm/min); however, they supported the lowest total canopy volume of all the basins. The soil water content at 6" in depth has higher water volume than the ones at 12" in depth in S and H Basins validate their lower infiltration rates than that in B basins.

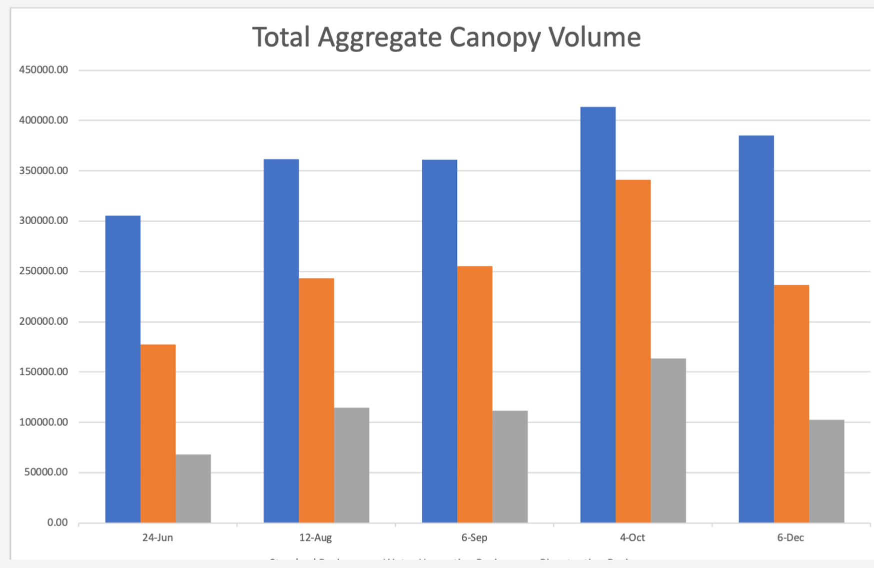

Figure 2

Figure 3

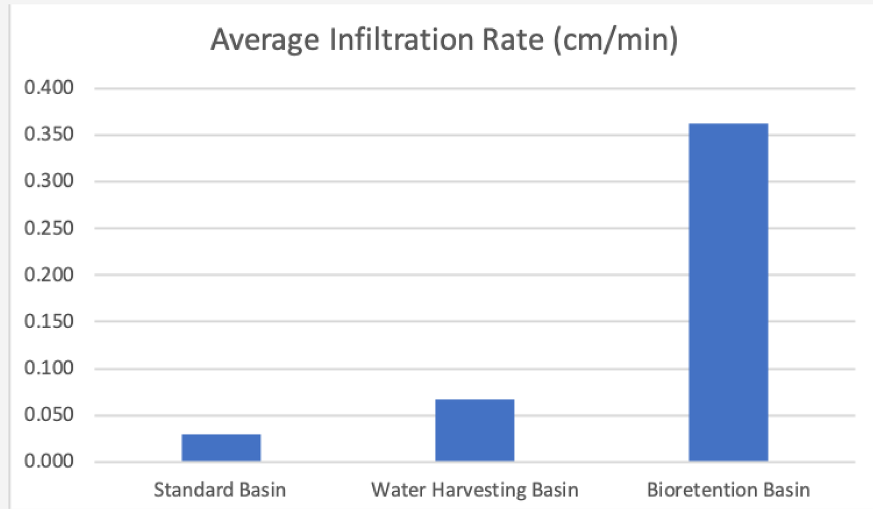

Figure 4

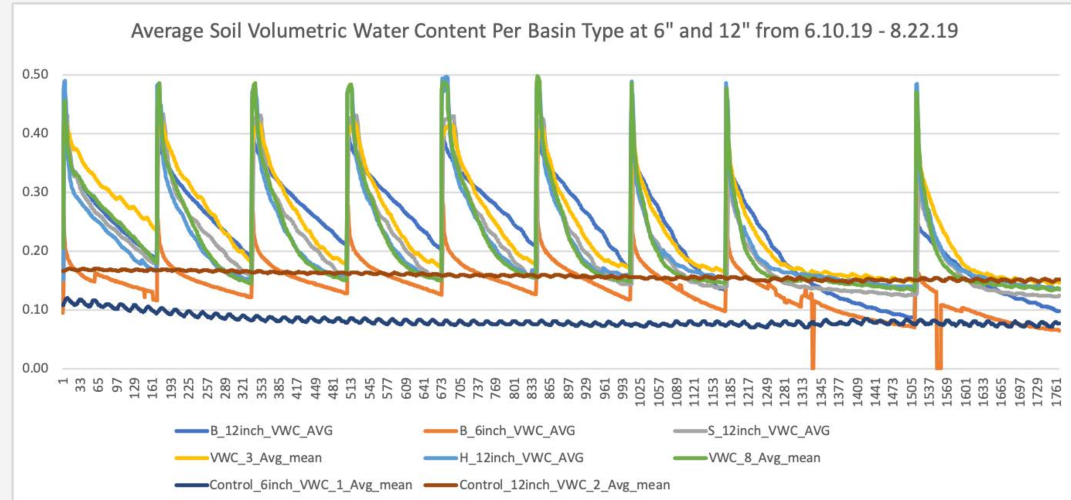

Figure 5

Discussion

The preliminary results show promising trends of increased infiltration rates and stormwater holding capacity with additional soil amendment. Since native soil in the valley is clay-rich and not well drained, adding sand and organic matters can improve its infiltration and increased soil water capacity.

The native plants, however, do not perform well in the basins with soil amendment since they are adaptive to native soils. This finding raises the question of balancing the hydrological and ecological performances with the selection of native plants or choices of soil amendment material that can best leverage using plants for additive effects for hydrological functions.

Further analyses will include climatic effects on infiltration and plant growth. Future experiments may include testing different types of plants and measure the interactions between water and heat exchange.

Conclusion

This pilot GI stormwater design experiment demonstrated the positive effects of using landscape design strategies in managing stormwater onsite. The findings can help to inform urban design and GI policy-making to allow alternative stormwater design using nature-based solutions in hot arid regions.

References

McPhillips, L. E. & A. M. Matsler. (2018). Temporal Evolution of Green Stormwater Infrastructure Strategies in Three US Cities. Frontiers in Built Environment, Vol.4.

Sanchez, C. (2019). Designing and Implementing Ecological Monitoring of Aridland Urban Ecological Infrastructure (UEI): A Case-Study of Design Process and Outcomes. Master of Science in Sustainability Thesis. Arizona State University.

Thorne, M.S., Skinner, Q.D., Smith, M.A., Rodgers, J.D., Laycock, W.A. , & Cerekci, S.A. (2002). Evaluation of a technique for measuring canopy. volume of shrubs. Journal of Range Management, 55: 235–241.

NSF · Central Arizona-Phoenix Long-Term Ecological Research CAP LTER · The Design School, Herberger Institute for Design and the Arts, Arizona State University · Hydro-GI LAB · Flood Control District of Maricopa County