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SAN ANTONIO RIVER AUTHORITY
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CITY OF SAN ANTONIO TEXAS

Implementation of a Low Impact Development Testbed at The University of Texas at San Antonio Main Campus

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Project Scope, Cost and Schedule

- Goal: assess the stormwater treatment of bioretentions and sand filter basins
- $1,069,113
- Original Agreement: June 1st 2017 to May 31st 2020
- Two No-Cost Extension Amendments due to weather and construction delays

Activity/Task	2017		2018				2019				2020				2021				2022			
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Objective 1 - Column Experiments																						
1.1 - Design and Construction of Columns	x																					
1.2 - Water Quality Experiments		x	x	x			x															
1.3 - Identification of Best Parameters				x	x	x																
Objective 2 - Implementation of the BMP Test Bed																						
2.1 - Site Definition/Permiting	x																					
2.2 - Pre-Implementation Monitoring	x	x	x	x	x	x	x	x														
2.3 - Design		x	x	x																		
2.4 - Construction			x	x	x	x	x	x														
Objective 3 - BMP Test Bed Monitoring																						
3.1 - Monitoring Equipment Installation					x	x	x	x														
3.2 - Sample Collection and Laboratory Testing								x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.3 - Synthesis and Recommendations														x	x	x	x	x	x	x	x	x
Objective 4 - Education Program																						
4.1 - Water Sustainability and LID modules										x											x	x
4.2 - K-12 students/schools Tours									x				x			x			x			

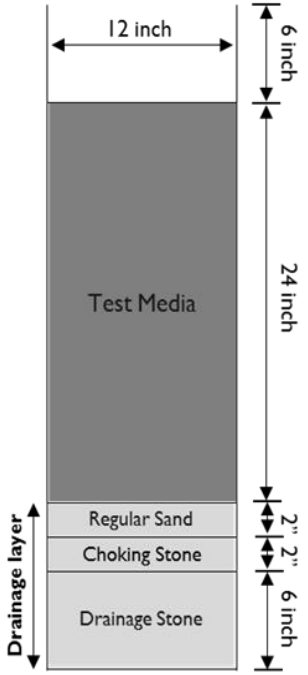
Project Deliverables and Questions

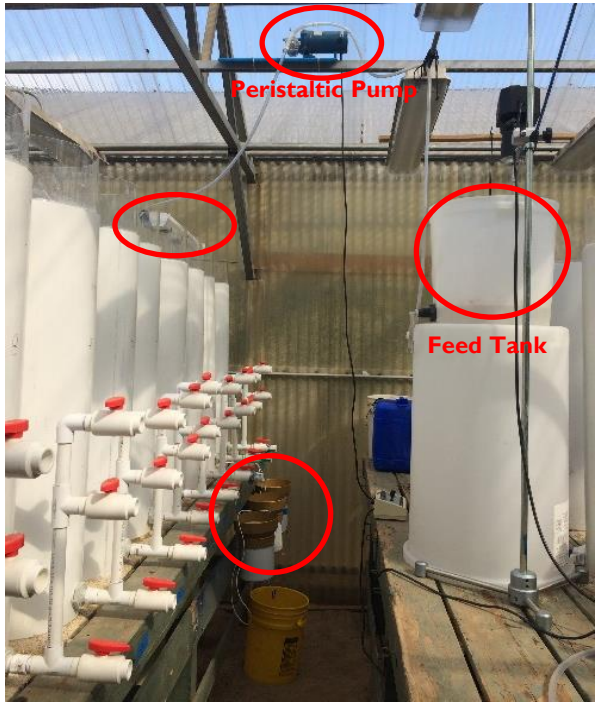
- COSA / UTSA Agreement signed on June 2017
  - *The Project shall produce the following deliverables:*
    - *a) Optimal bioretention design for San Antonio using bioretention columns experiments.*
    - *b) Full-scale BMP test bed, composed of a series of parallel bioretention and sand filter cells.*
    - *c) Monitoring before and after the implementation of the BMP LID test bed.*
    - *d) Education of the public and students about stormwater sustainability.*
  - *The Project shall answer the following questions:*
    - *a) What are the water quality differences between treating stormwater with sand filter and bioretention basins?*
    - *b) What are the water quality differences between treating stormwater with and without liners?*
    - *c) How much recharge can be generated in an unlined BMP?*
    - *d) What is the best design of bioretention basins in terms of soil and plants for the San Antonio region?*

Column Experiments

- 12 columns
- Nine media and three plants were tested:
  - Regular Sand
  - Limestone Sand
  - BioFilter 5-3-2 Sandy Loam
    - Biosolids from WWTP
  - Recycled Glass+BioMix
  - Lime-Mix Bioretention
    - media with **crushed limestone**
    - Developed at UTSA Lab

  - **Blend#1**: Blend of **limestone** sand, fines and organics provided by the Urban Land Clearing Soil & Compost Company;
  - **Blend#2**: Blend #1 with addition of **Iron**;
  - **BioFilter 4-3-3**: is the improved version of BioFilter 5-3-2 with **green-waste** instead of bio-solids;
  - **BioFilter 4-3-3MS**: similar composition of the BioFilter 4-3-3 with **limestone sand** instead of regular sand.

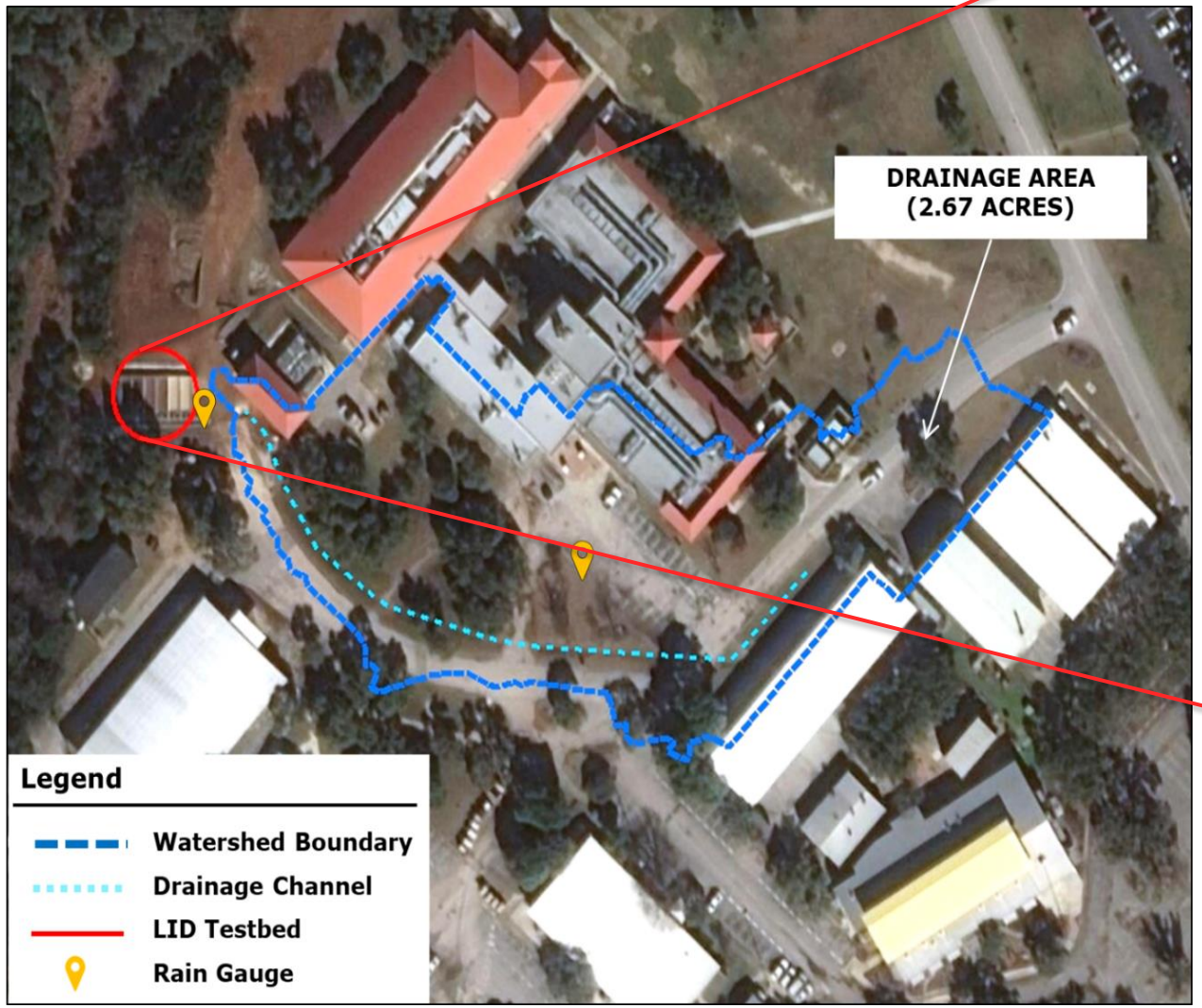




- Lessons Learned:
  - Quality control of media was challenging
    - Gradation, and Phosphorus & organic matter content
  - Close collaboration with Soil Media providers
  - Limestone sand improved results
    - High absorption capacity by Calcium and Magnesium
  - Plants enhanced treatment, but no difference between species

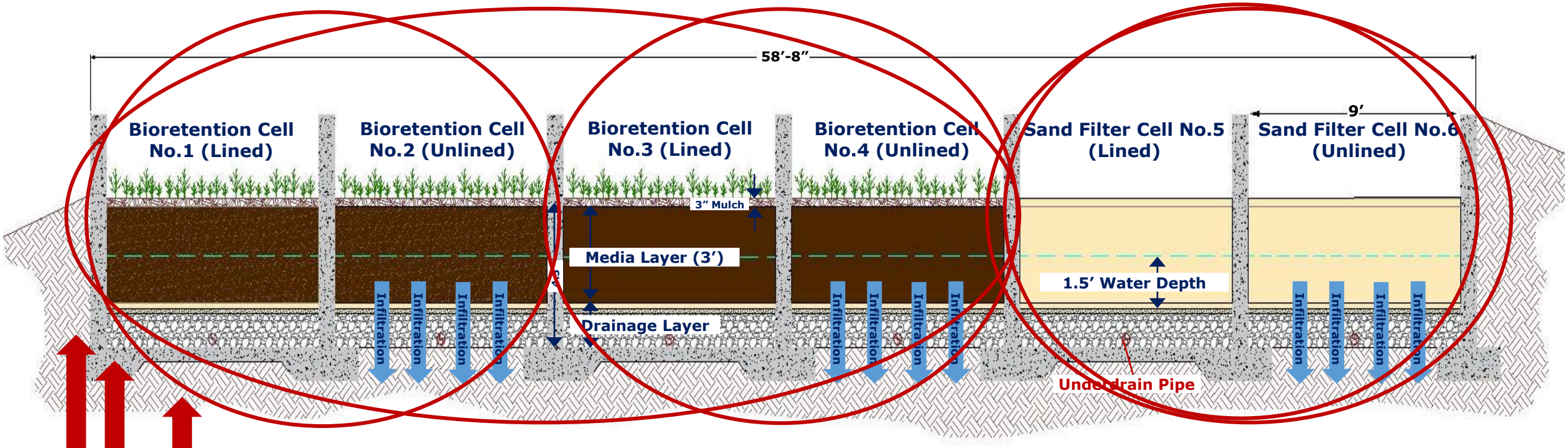
Pollutant	Target Concentration C_{in}^{Target} (mg/L)
TSS	100
Nitrate (NOX) as N	0.3
Total Kjeldhal Nitrogen (TKN) (Org N + NH3-N)	1.85
Total Phosphorus (TP)	0.2
Total Copper (TCu)	0.02
Total Zinc (TZn)	0.13
Total Lead (TPb)	0.08

The LID Testbed



Six parallel cells (9 ft x 30 ft x 4.5 ft) filled with:

- Custom limestone mixture (Cells 1 & 2)
- Regular bioretention mixture (Cells 3 & 4)
- Limestone sand (Cells 5 & 6)



- ✓ Compare the performance of Bioretention basins vs Sand filter basins
- ✓ Compare the impact of filtration media composition in two bioretention designs
- ✓ Compare the performance of Lined vs Unlined cells to evaluate the impact of liners

Monitoring the LID Testbed

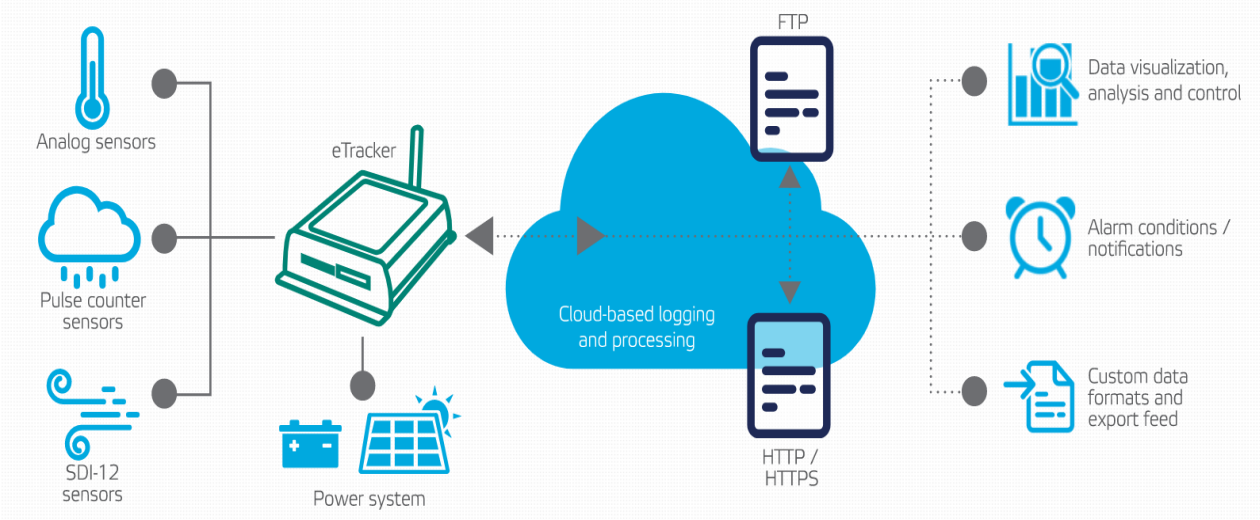
Stormwater Quantity:

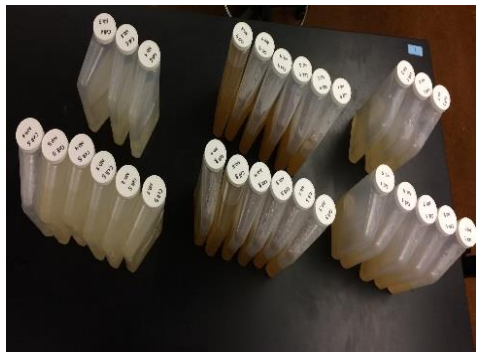
5-min interval

Rainfall, flowrate, water level and soil moisture content

Stormwater Quality:

- Flow-paced sampling at the inlet and six outlets
- Total and volatile suspended solids
- Nitrate and total nitrogen
- Phosphate and total phosphorus
- Dissolved and total heavy metals (lead, copper and zinc)
- Total and E. coli coliform bacteria
- pH, DO and conductivity





Monitoring the LID Testbed

Phase I – without Internal Water Storage

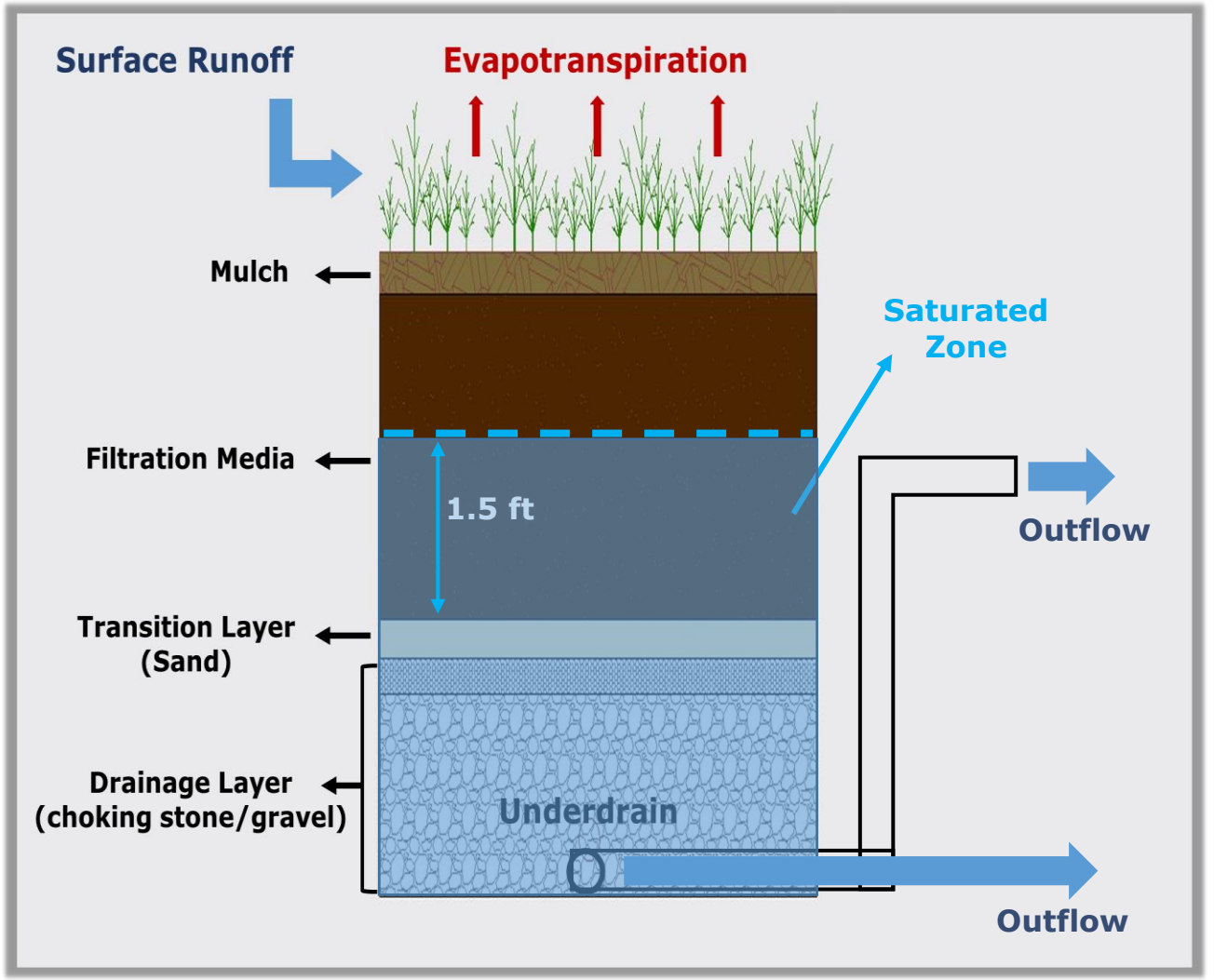
21 months of monitoring: June 2019- April 2021

Total of **9 storm events** captured
Total treated volume ≈ 40,000 cf

Phase II – with Internal Water Storage

20 months of monitoring: April 2021- January 2023

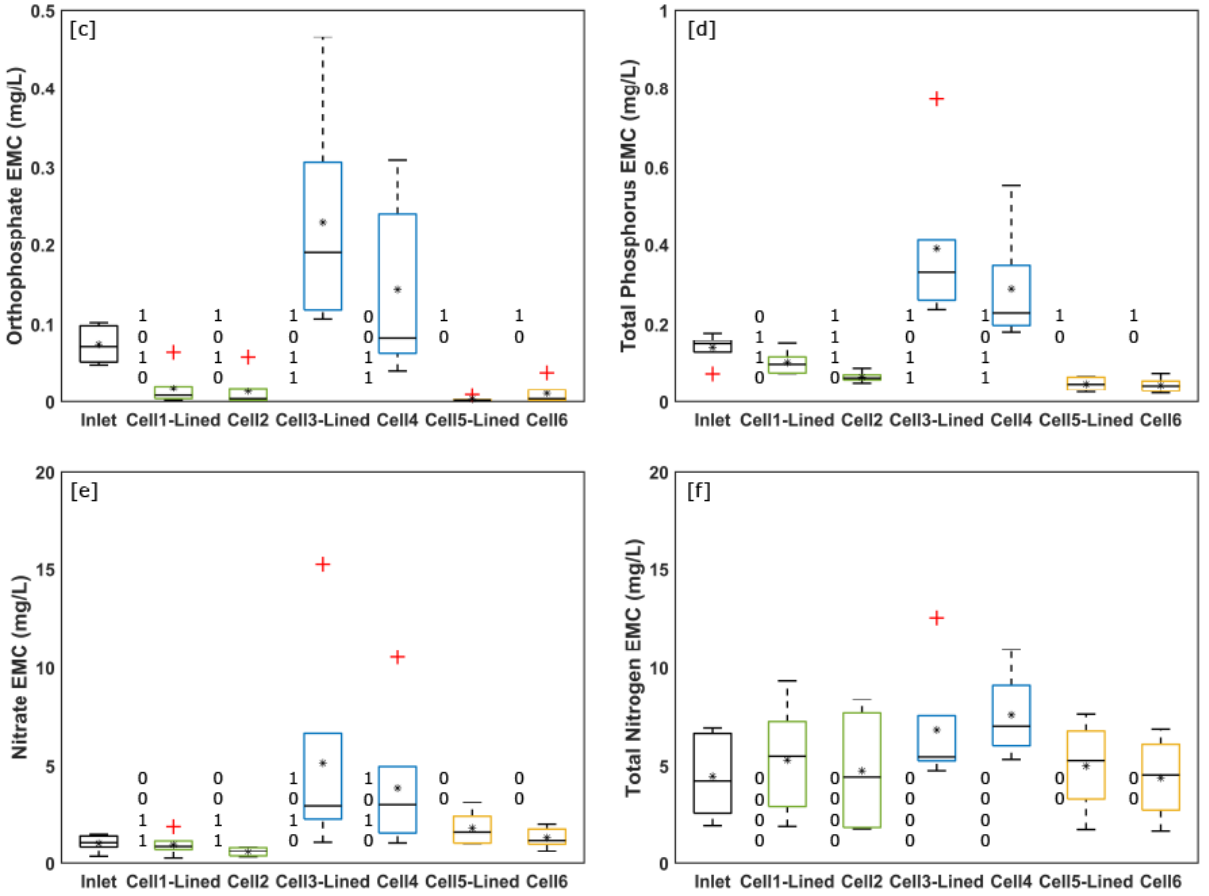
Total of **6 storm events** captured so far
Total treated volume ≈ 80,000 cf



Water Quality Results

- What are the water quality differences between treating stormwater with sand filter and bioretention basins?
  - No statistical difference at 95% confidence interval was found between sand filter basins and bioretention basins for most parameters
    - Our sand filter basin used limestone sand
  - Regular bioretention-mix leached most pollutants due to its high nutrient and organic matter content

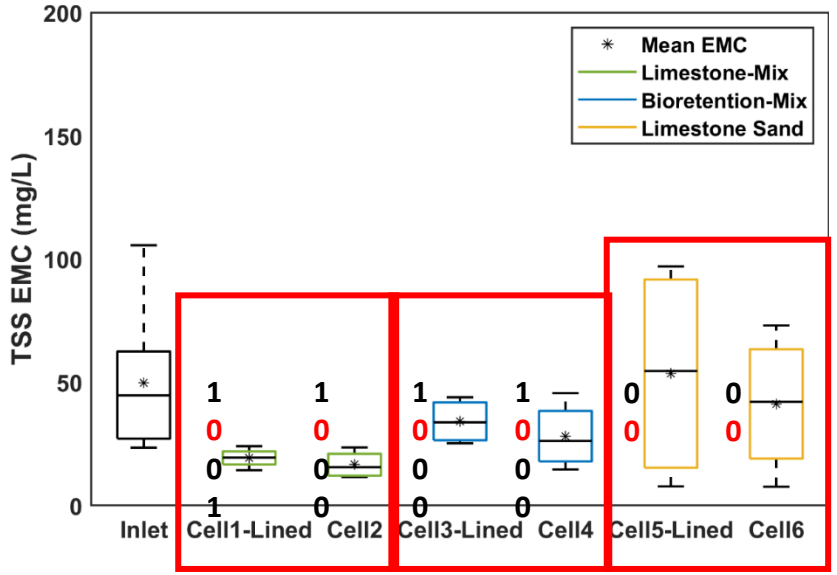
Significance of Difference at 95% (α=0.05)	
Inlet vs outlets	h=1 or 0
Lined vs unlined	h=1 or 0
Limestone-mix vs Bioretention-mix	h=1 or 0
Limestone-mix & Bioretention-mix vs Limestone Sand	h=1 or 0

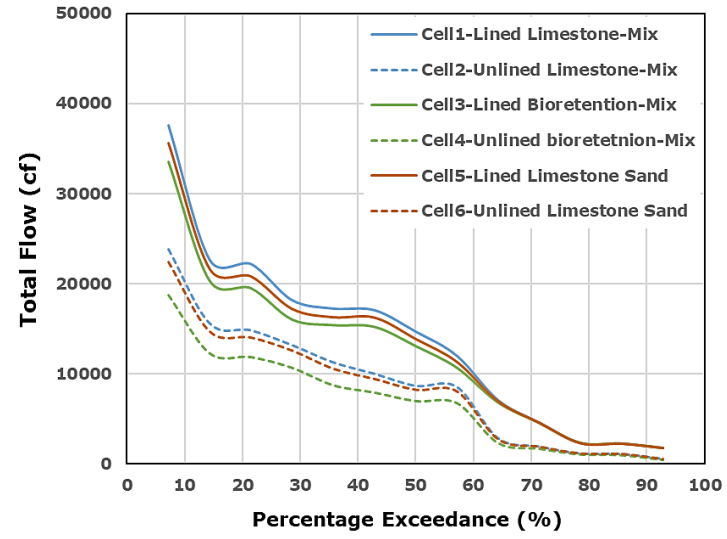


Water Quality Results

- What are the water quality differences between treating stormwater with and without liners?
  - No statistical difference at 95% confidence in water quality was observed between lined and unlined cells
- How much recharge can be generated in an unlined BMP?
  - Unlined cells showed approximately 20% reduced outflow compared to lined cells without IWS
  - The potential for infiltration is higher if no underdrain is used.

Significance of Difference at 95% (α=0.05)	
Inlet vs outlets	h=1 or 0
Lined vs unlined	h=1 or 0
Limestone-mix vs Bioretention-mix	h=1 or 0
Limestone-mix & Bioretention-mix vs Limestone Sand	h=1 or 0

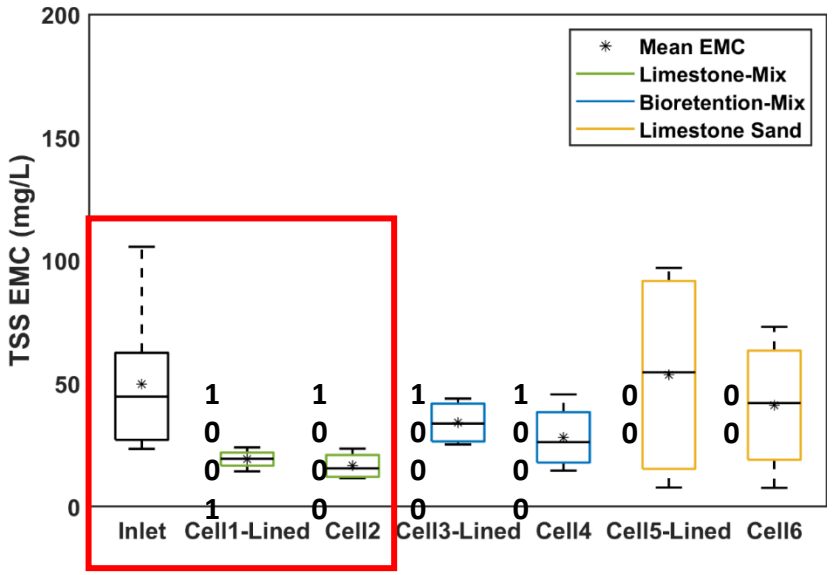


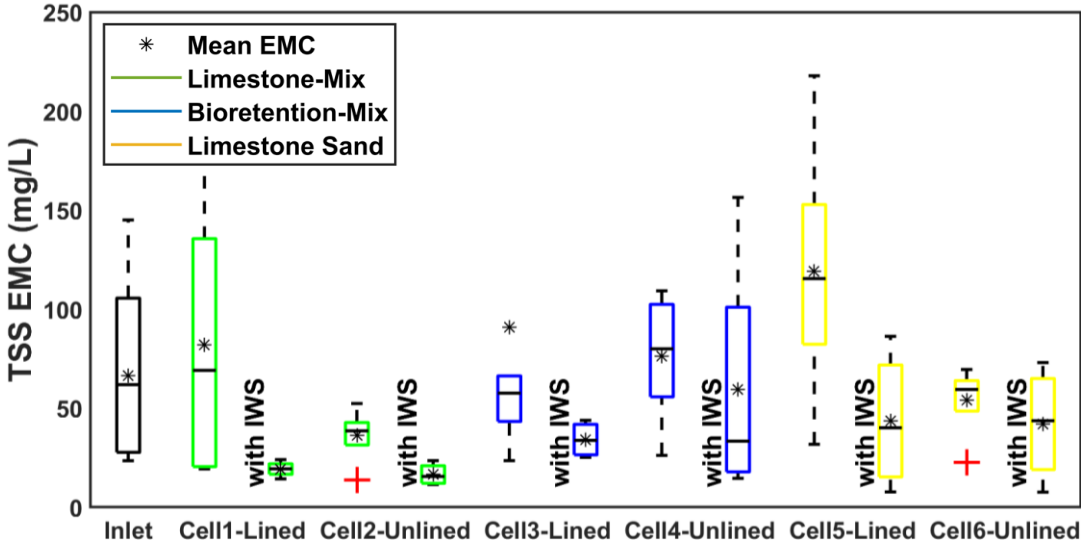


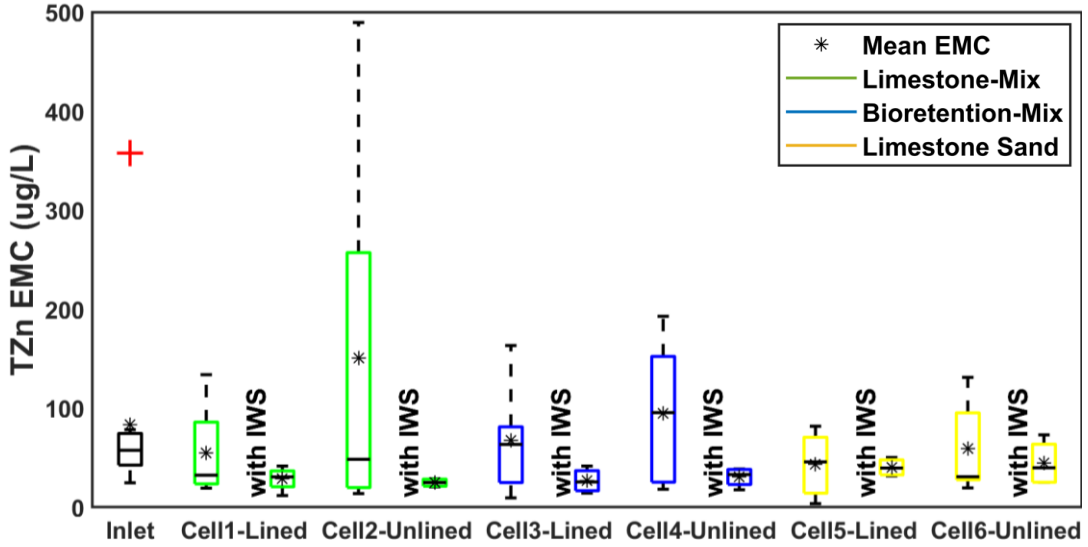
Significance of Difference at 95% (α=0.05)	
Inlet vs outlets	h=1 or 0
Lined vs unlined	h=1 or 0
Limestone-mix vs Bioretention-mix	h=1 or 0
Limestone-mix & Bioretention-mix vs Limestone Sand	h=1 or 0

Water Quality Results

- What is the best design of bioretention basins in terms of soil and plants for the San Antonio region?
  - Limestone mix media provided overall best results
  - Internal water storage operation enhanced pollutant removal, particularly for TSS and heavy metals (TZn)



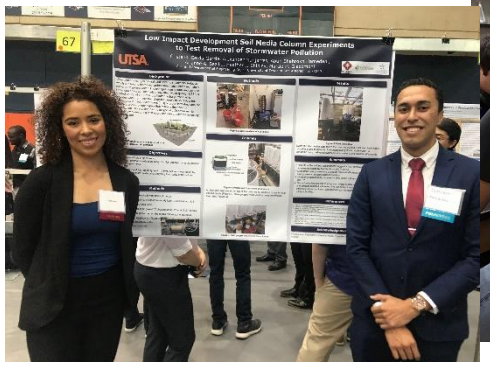




Educational Program Outcomes

- **K-12 students/school tours:**
  - ✓ 2019 - hosted total of 179 middle/high school students for the UTSA engineering summer camps
  - ✓ 2020 - we prepared videos of the LID testbed and filtration lab experiment for the virtual engineering summer camp
  - ✓ 2021 - hosted 6 undergraduate students for the STIR-UP student cohort
  - ✓ 2022 - hosted total of 160 middle/high school students for the Engineering week Lab Exhibit

- **Three education signages** were designed and implemented at the LID testbed



- **UTSA Undergraduate Research Showcase**
  - ✓Participated in 2018, 2019 and 2022

  Vida Mohagheghpour, our undergrad research assistant won the second place for best oral presentation

Educational Program Outcomes

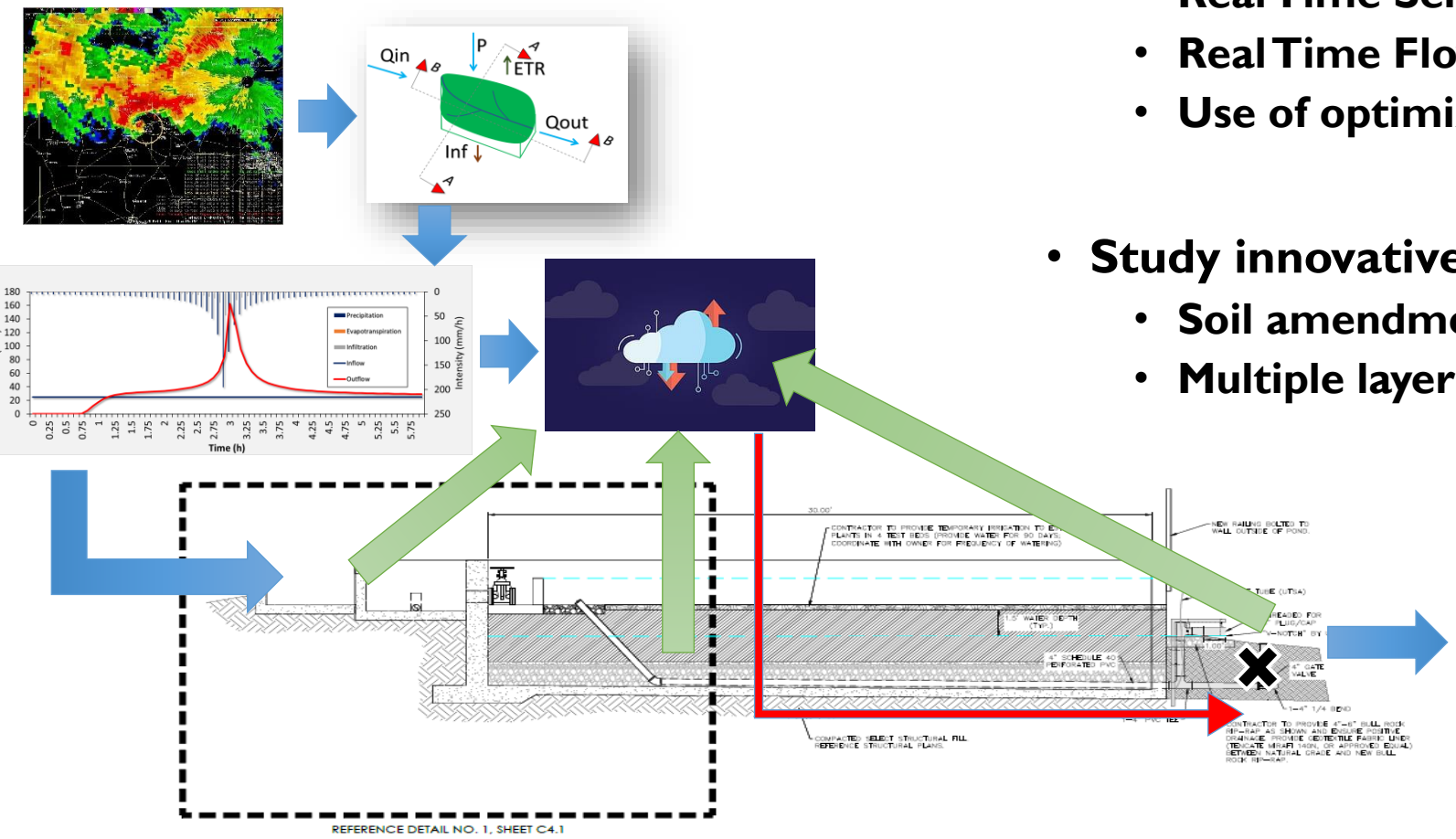
- Students involved in the LID testbed project (9 undergraduate, 1 MS, 2 PhDs, 2 Post-Docs)
  - Crista Cerda, Undergraduate research assistant 2017-2019
  - Aldo Hernandez, Undergraduate research assistant 2017-2018
  - Alexander Manjarres, Undergraduate research assistant 2017-2018
  - Armando Montante, Undergraduate research assistant 2018-2019
  - Alani Hall, Undergraduate research assistant 2018-2019
  - Akanksha Matta, Postdoctoral fellow 2019
  - Maya Abounasr, Undergraduate research assistant 2019-2020
  - Michelle Barkley, Undergraduate research assistant 2019-2021
  - Hanieh Soleimanifar, Postdoctoral fellow 2020
  - Marissa Lopez, Undergraduate research assistant 2021
  - Vida Mohagheghpour, Undergraduate research assistant 2021-2022
  - Ivan Cuervo, Graduate research assistant 2021-2022
  - Cesar do Lago, Graduate research assistant 2021-2022
  - Abtin Shahrokh Hamedani, Graduate research assistant 2018-2022

- Educational Modules were Developed:
  - Chap. 1) Water Resources Sustainability
  - Chap. 2) Low Impact Development
  - Chap. 3) LID Design
  - Chap. 4) LID Modeling
  - Chap. 5) Sand Filter Basins
  - Chap. 6) Bioretentions
  - Chap. 7) LID Testbed
- Audiences:
  - Engineering and environmental students at UTSA,
  - Summer field trips for k-12 students interested in engineering and environmental sciences.

Recommendations

- The results support the following:
  1. The need for impermeable liner in BMPs is likely unnecessary since it didn't add any observed water quality benefits
     - This requirement could be removed from TCEQ Manual, especially for low concentration watersheds (e.g. residential areas)
  2. The operation of cells with Internal Water Storage enhanced the quality of effluents for many parameters in comparison to bottom underdrain operation
  3. Limestone-based media could be incorporated/incentivized into LID/BMP Manuals
  4. The treatment performance of sand filter basins (with limestone sand) was equivalent to bioretention systems
  5. Maintenance has shown to be key for good performance of the treatments

Future of the LID Testbed



- **Enhance the LID Testbed Operation**
  - **Real Time Sensing**
  - **Real Time Flow and Water Quality Forecast**
  - **Use of optimization algorithms for Optimal Control**

- **Study innovative stormwater treatment techniques**
  - **Soil amendments**
  - **Multiple layers with different media**

Thank you. Questions?

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