# EA Project Summaries and Findings Report Project

# Project 7 – Water Quality in the Leon Creek Watershed Recharge Zone as a Function of Urban Development, and Community Education of the Threats and Conservation of the Edwards Aquifer

## Project Summary


Author: UTSA

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Funding Amount

$2,671,236

**Stated objectives of the study** - *This University of Texas at San Antonio project has three major components: Goal 1, Describing the Water Quality as a Function of Land Cover within the Edwards Aquifer Recharge Zone in Bexar County. Goal 2, Describing the Efficacy of Low Impact Developments on Water Quality. Goal 3, Community Outreach and the Development of a Living Laboratory.*

**Justification for the study** – *Goal 1 focuses on one of the fastest growing areas in Bexar County. The Leon Creek watershed in northern Bexar County is an urbanizing watershed with on-going development occurring in currently forested and low-density urban areas. Very little is known about how water quality is impacted by changes in land cover from forested areas of Ashe juniper to areas of urban development.*

*Goal 2 leverages a UTSA-funded development project (new parking lot) which is incorporating LID BMPs to assess the effects of these BMPs on water quality. In spite of the general understanding that BMPs improve water quality, the applicants could find no literature showing the effects of BMPs on water quality and quantity within the Edwards Aquifer Recharge Zone.*

*Goal 3 leverages existing outreach programs and formal partnerships with the US Forest Service and the US Fish and Wildlife Service and informal partnerships with other area entities to expand the University's outreach to include the Edwards Aquifer. It has been shown that individuals who participate in water-related education programs build a "water conscience." This component of the program will construct the Edwards Aquifer Recharge Living Laboratory where UTSA will deliver curriculum on Bexar County's water use, water conservation, and water quality.*

## 1 Summary


Green stormwater infrastructure (GSI), a type of low impact development (LID), in urbanized areas can help protect ecosystems, the community, and infrastructure by slowing down the routing of stormwater downstream, both mitigating flooding risks and reducing erosion. By improving the water quality of stormwater runoff before it enters streams or aquifers, LID systems also help protect aquatic species. This study was designed to provide a better understanding of LID performance in the San Antonio region including pollution and flood mitigation effectiveness relative to implementation and maintenance costs. The researchers also hoped to gain further understanding of the feasibility and benefits of implementing LID facilities for stormwater management in the Edwards Aquifer recharge zone.

Objective one was designed to help increase the project team's understanding of how areas experiencing rapid development, such as northwest San Antonio, are impacting the water quality and vegetation in receiving streams. By monitoring flow in 12 streams within watersheds with a range of impervious cover, researchers found further supporting evidence that the frequency of runoff events and the volume of runoff increased in watersheds containing a greater percentage of impervious cover. Results of surface water samples collected in the streams during rain events identified greater concentrations of nitrate and *E. coli* in the more urban watersheds. Last, the project team conduct surveys of the riparian vegetation, primarily

the woody plant species growing along the stream banks and in the adjacent floodplains. Survey results concluded that riparian communities were dominated by heat and drought tolerant species. Although all the sampled streams were dominated by native species, species diversity decreased when the area in the contributing watershed had more impervious cover.

Objective two investigated the impacts of three bioretention basins installed on the UTSA main campus. Researchers collected data on temperature and flow rate, in addition to collecting and analyzing stormwater samples for various pollutants, at the inlet and outlet of the bioretention systems. The same data and samples were collected from a natural channel in a vegetated area to be used as a control. The flow patterns and results of the water quality analysis were compared in the following configurations:

- runoff entering and exiting the bioretention basins,
- discharge from the bioretention systems and the runoff in the natural channel, and
- water discharging from parking lots (inlet to bioretention basins) and the natural channel.

Bioretention basins were also found to decrease the volume and flow rate of runoff by an average of 74% and 85% respectively, and reduced stormwater temperature spikes during the warmer months. Results also indicated that a few parameters, including several metals, were higher within the natural channel than from samples collected at the outlets of one or more bioretention basin outlets, while other metals and parameters were lower within the natural channel. More information is needed on potential sources of pollutants within the watershed drainage to the natural channel. Similarly, several constituents, including TDS and salinity, were higher at the bioretention basin outlets when compared to the inlet concentrations.

Objective three funded the construction and operation of the Mesquite Living Lab, a 2,000 square foot open-air classroom used to host a youth summer camp, site visits by local professional organizations, and provide research opportunities for UTSA students. The facility includes a cistern, a green roof, and a bioretention basin.

## 1.1 Methods

**Objective One**

The project team monitored the flow, collected water quality samples, and surveyed the stream bank vegetation at 12 ephemeral streams, which only flow during and after rain events. The sites were divided into two watershed classifications – rural, where the impervious cover in the contributing drainage area was less than 3%, or urban, where the impervious cover was greater than 18%. The impervious cover for all the watersheds ranged from 0% to 45%. They then compared the results between the two categories to see how a watershed's level of impervious cover impacted the response of the metrics.

Water quality samples were collected from a minimum of five storm events at each site using a combination of autosamplers, flow meters, and publicly available United States Geological Survey (USGS) gauge data. Parameters are listed in Figure 1. Surveys of each site's riparian vegetation were conducted within identified areas extending across the stream channel. The researchers identified the vegetation species, percent canopy cover, basal area, and stem density to then compare if the vegetation communities differed based on proximity to the stream, flood frequency, and the watersheds level of impervious cover or land use. They also evaluated the results for other external factors, such as high temperatures, and drought conditions, that may have impacted the plant communities.

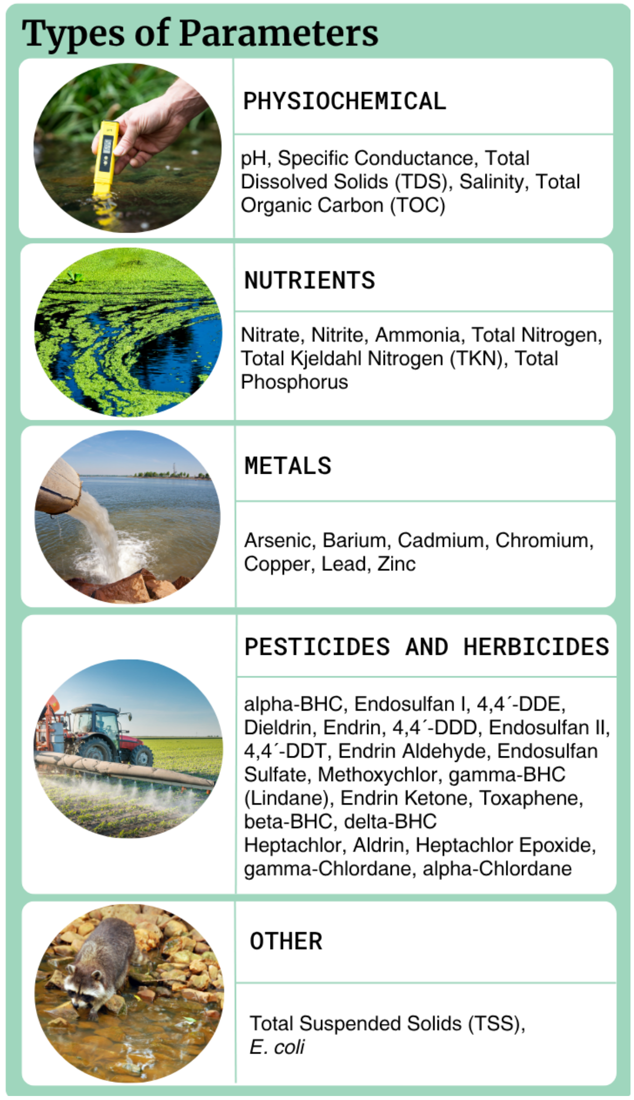


Figure 1 – Ephemeral stream water quality sampling parameters.

**Objective Two**

The primary goal was to investigate the impacts of converting natural, vegetated areas into parking lots on runoff volume, peak flow, and water quality. The researchers measured the water quality of runoff entering three bioretention basins (EC 1, EC2, and Living Lab) and compared it against the water quality of runoff in a natural channel receiving runoff from a vegetated area (EC Natural. They also calculated various flow metrics based on data from flow meters, including the peak flow rate, defined as the maximum rate of discharge during a rain event, and the rain event's duration. The bioretention lots were all constructed to the San Antonio River Authority standards, with impermeable liners, gravel storage layers, underdrains, engineered soil media, and stabilized with either vegetation or cobbles. Researchers collected between 25 and 68 samples using a combination of autosamplers and grab samples at each of the seven sampling locations (inlets, outlets, and in-channel). The inlet and outlet values were compared to determine the bioretention basins' pollutant removal efficiency. Water quality results of the bioretention basin outlets were also compared against the natural channel to evaluate if the bioretention basins could return runoff to pre-development conditions. Water temperatures were monitored at the inlet and outlets of two of the bioretention basins to determine if there were spikes in runoff temperatures as they flowed into the system, and if the basins were able to attenuate these fluctuations.

**Objective Three**

The third objective included the construction of the Mesquite Living Lab, the demonstration LID features, and a commitment to using the facility for water resources related education (see Figure 2). The cistern can hold 2,700 gallons and collects roof runoff. There is also a green roof over the restroom, and a bioretention system which captures an acre of parking lot runoff. This bioretention system was part of the monitoring effort in objective two.

In addition to the educational opportunities hosted at the lab, the green roof was also incorporated into a study to investigate a potential reduction in cooling costs. Temperatures were measured in the restroom, at the ground surface, and seven inches below the bioretention soil surface. The temperature of the green roof was not measured due to access challenges.

Figure 2 – The Mesquite Living Lab facility.

## 1.2 Findings

**Objective One**

| HIGHER IN URBAN SITES | LOWER IN URBAN SITES |
|---|---|
| Cadmium, Copper, TKN, Total Phosphorus, Total Nitrogen, Nitrate, Nitrite, TOC, *E. coli*, 2,4 dichlorophenylacetic acid | pH, Specific Conductance, TDS, TSS, Arsenic, Barium, Chromium, Zinc, Salinity |

Figure 3 –Comparison of water quality sampling results by watershed classification. Based on analysis of first flush samples. Parameters in green were found to have concentrations significantly higher in urban sites vs. rural sites, and values in red were found to have concentrations significantly lower in urban sites vs. rural sites.

When the researchers compared the water quality results of the first flush samples, they found that 10 out of the 22 pollutants sampled were higher in the urban sites than in rural sites, while four were lower in the urban sites (see Figure 3). It is worth noting that *E. coli* levels in the 1st flush samples from the watersheds classified as urban were above the Texas Commission on Environmental Quality's recommended value for primary contract recreation. Elevated nitrogen levels, also observed in urban sites, can lead to detrimental eutrophication in streams or negatively impact the water quality in the Edwards Aquifer. The project team also analyzed the water quality sampling results for changes in concentrations between the 1st and 2nd flush, and between the different watershed classifications. The results from comparing the 1st to 2nd flush samples in urban and rural sites were mixed.

The vegetation survey identified 43 different species of shrubs and trees across all eight locations. Non-native species were uncommon across all the sites, with only 5 species documented. Native species represented 98% of the total canopy composition, and drought tolerant species were abundant at all the sites, representing 99% of the canopy composition. Site-level species diversity was found to be negatively correlated with a watershed's level of impervious cover.

**Objective Two**

Hydrology measurements were averaged across all the events, and outflow volume was calculated to be approximately 74% of the inflow volume with an 85% flow rate reduction. The inlet flow duration averaged 90 minutes, while the outflow duration was 245 minutes, indicating that the bioretention basins were facilitating water storage, infiltration, evaporation, and plant uptake.

The water quality analysis results provided insight to both the pollutant removal efficiency of bioretention basins as well as differences in water quality between runoff within the natural channel and the runoff being discharged from parking lots on UTSA campus. Evaluation of the bioretention basins' pollutant removal efficiency revealed several constituents that had higher concentrations in the discharge, including salinity and TDS. The increase in TDS is consistent with previous, similar research. The sample results of two additional analytes, arsenic and barium, were also elevated in the discharge from the East Campus 2 bioretention basin; however, this may have been a result of the basin's construction issues. Although the project team did not report any significant reductions in pollutant concentrations based on the sampling results, the approximately 26% reduction in outflow volume suggests that there was likely a reduction in pollutant loads leaving the system. The study also noted that the pollutant levels in the runoff entering the bioretention basins were relatively low and comparable to the runoff in the natural channel. As a result, while there may not have been an opportunity for significant concentration reductions, there may have been valuable reductions in the pollutant loads.

The researchers also compared the water quality at the inlet of the three bioretention basins against water quality within the natural channel to characterize the changes from replacing natural areas with impervious cover. Both barium and TSS were higher within the natural channel, while the bioretention basin inlets had lower copper and increased nitrite levels. The project team then compared the water quality of the bioretention basins' outlets to the runoff within the natural channel to determine if the bioretention basins could improve runoff to a natural-level equivalent. Results indicated that concentrations of several analytes, including five metals, calcium, pH, and TSS were higher within the natural channel than were measured at the outlet of at least one of the bioretention basins. Additional research could help determine if the elevated results in the natural channel are due to external factors, such as pollutant deposition from a nearby highway. The concentrations of TKN, selenium, nitrate, and TDS were significantly lower in the natural channel than at least one of the bioretention basin outlets.

Another important finding from this objective pertains to bioretention basin maintenance costs. The annual routine maintenance cost was calculated to be less than a manicured lawn, based on hourly rates and staff time for the three years of the study.

**Annual Maintenance Cost of Central Campus Lawn Before and After Conversion to Bioretention**

| TURF-GRASS LAWN | BIORETENTION BASIN |
|---|---|
| **$18,720 / YEAR** | **$13,200 / YEAR** |

One bioretention basin faced issues during construction resulting in poor performance, which will require a more extensive remediation to repair the scour and revegetate. It is estimated to cost $50,000, which is comparable to the university's annual costs for the maintenance of eight existing sand filters.  It should be noted that Typical bioretention basins do not require this level of intensive maintenance on such a short frequency.

**Objective Three**

The Mesquite Living Lab facility has hosted summer camps every year starting in 2022, focused on pollinators & hydrology. The facility has also hosted educational visits and tours from local water resources focused professional groups. Undergraduate & graduate students have gained outreach and public education experience while helping with the camps, as well as having access to the facility for research projects both related to this project and independently.

The analysis of the green roof as a potential insulation source for the facility's restroom indicated that the soil temperatures were lower than both the ground surface and air temperatures during the hottest part of the day. However, the soil temperatures were higher during the coolest part of the day. Thus, although the system is thought to be providing insulation for the building, it is unknown if it translates to significant energy savings.

### 1.3 Challenges and Limitations

As is commonly experienced, unpredictable rain patterns and drought conditions make it difficult to evaluate flow and collect runoff samples. Two of the streams studied in Objective One did not see any flow events over the one-year monitoring period, and as a result the project team was required to select substitutions. Access to two of the original streams selected for vegetation surveys also were inaccessible due to restricted access via private land, a challenge across Texas.

In addition to unpredictable precipitation patterns, the sampling and analysis of stormwater is also challenging. If an automated sampler failed to collect a sample, the project team would attempt to manually collect grab samples if flow was still occurring. As a result, some of the samples are not representative of the first flush. Other parameters, such as *E. coli*, require time sensitive analysis. If analyzed outside of the recommended hold time, the results may be inaccurate.

Last, although the construction issues with one of the bioretention basins proved to be a costly challenge, they also provided lessons learned. For example, it is important to minimize the time between a bioretention basin's excavation and the addition of aggregate or media. This should not be performed until the proper temporary erosion and sedimentation controls are installed to prevent construction sediment or debris from entering the system and clogging the underdrain pipe. A summary of the recommendations learned can be found in Exhibit A.

## 2 Benefits

The study provides multiple benefits for our understanding of the impacts of urbanization on stream water quality, hydrology, and vegetation. It also provides valuable data about pollutant treatment efficiencies of bioretention basins.

The overall contributions of the study are as follows:

- The project characterized pollutant levels in runoff from both urban and rural watersheds. Results could be used to inform the future implementation of LID features to ensure the selected feature will effectively reduce the target watershed's primary pollutant(s) of concern.
- The project provided lessons learned on bioretention basin construction to advise future implementation.

- The project increased the understanding of plant communities and mechanisms within riparian areas.
- The researchers expanded the local dataset of pollutant removal effectiveness for bioretention basins. This is a valuable dataset available for additional statistical analysis.
- The project provided additional supporting evidence that bioretention basins are effective in reducing the volume and peak flow of runoff during most rain events.
- The study revealed valuable insights into BMP pollutant removal efficiencies.
- The project team is continuing to provide natural resources and pollinator-related educational opportunities to the community. The Living Lab also provides opportunities for future research.

## Project Deliverable:

Laub, B.G., Garcia, M., Pardoe, A., May, L., Villanueva, F. (2024). Water quality of the Leon Creek watershed recharge zone as a function of urban development, and community education of the threats and conservation of the Edwards Aquifer. The University of Texas at San Antonio.

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Fact Sheet

## Project 7 – Water Quality in the Leon Creek Watershed Recharge Zone as a Function of Urban Development, and Community Education of the Threats and Conservation of the Edwards Aquifer

**Investment**

$2,671,236

**Project Components**

- Surface Water and Stormwater Monitoring
- Stormwater BMP Construction
- Maintenance
- Public Education
- Vegetation Analysis

**Opportunities for Green Infrastructure to Mitigate Urbanization**

**Benefits**

- Supports Future Construction Projects
- Improved Water Quality
- Maintenance Pricing
- Outreach and Education Tools
- Expanded Local Dataset

UTSA
The University of Texas at San Antonio

# Benefits

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- The project provided lessons learned on bioretention basin construction to advise future implementation.
- The project increased the understanding of plant communities and mechanisms within riparian areas.
- The researchers expanded the local dataset of pollutant removal effectiveness for bioretention basins. This is a valuable dataset available for additional statistical analysis.
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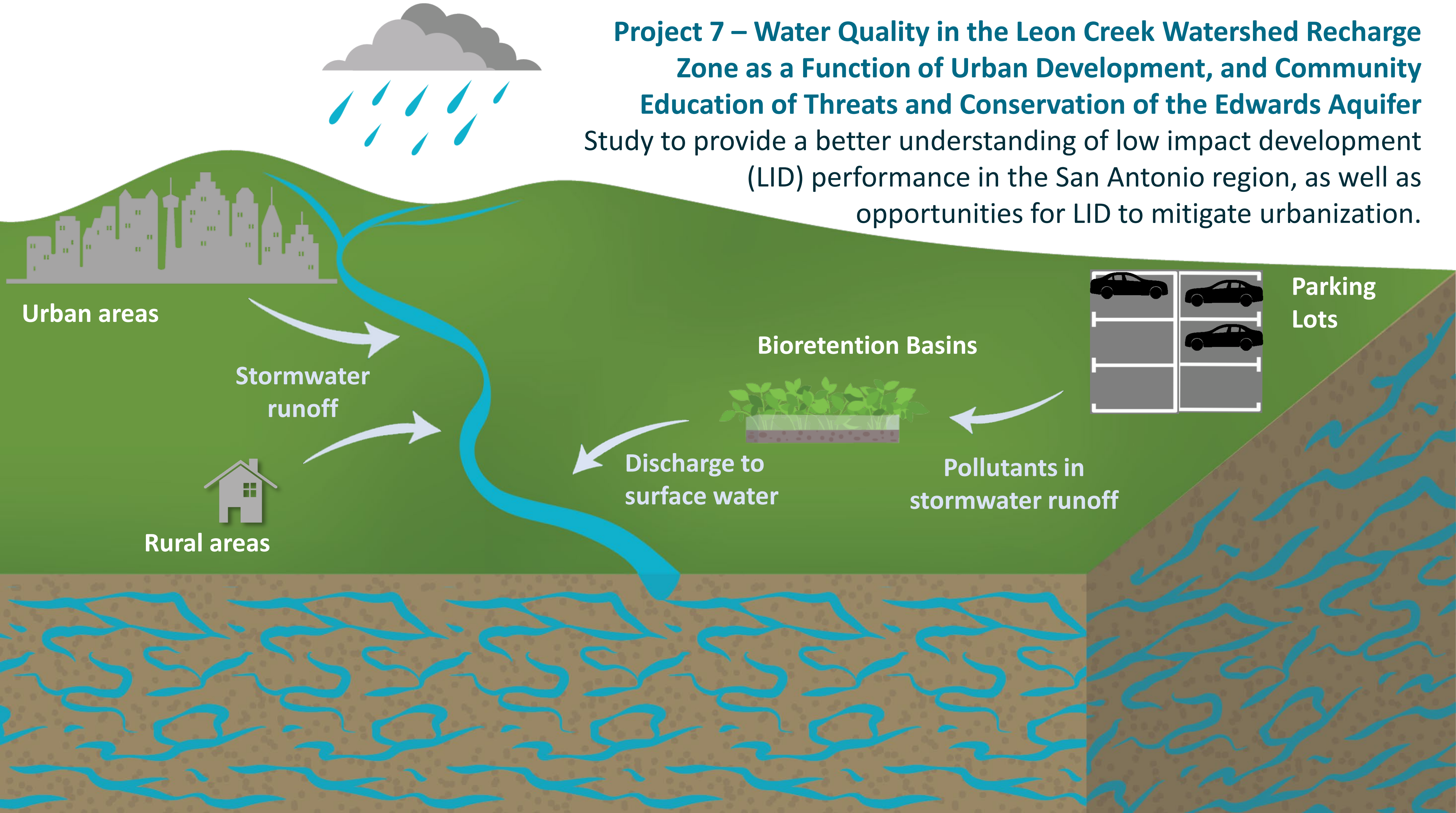
Project Graphic

# Project 7 – Water Quality in the Leon Creek Watershed Recharge Zone as a Function of Urban Development, and Community Education of Threats and Conservation of the Edwards Aquifer

Study to provide a better understanding of low impact development (LID) performance in the San Antonio region, as well as opportunities for LID to mitigate urbanization.



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Project 7 – Water Quality in the Leon Creek Watershed Recharge Zone as a Function of Urban Development, and Community Education of the Threats and Conservation of the Edwards Aquifer

Exhibit A

# Recommendations from Lessons Learned

| | |
|---|---|
| 1 | Selecting experienced contractors (in bioswale or bioretention) construction methods, provides cost benefits. Contractors with experience results in lower overall construction cost by reduced timeline delays, ability to identify subpar materials ultimately results in lower operational cost because of better construction. |
| 2 | Additional oversight may be needed to assist with installation with underexperienced contractors. |
| 3 | Pre-construction meetings should review the project strategies to ensure contractor has reviewed specifications for the basin and idenify items that help with timely installation. |
| 4 | Our contractor ordered material and stored on sight. Staging the material resulted in degration of quality. To install a quality basin, the contractor should have as tight a timeline for installation coordinated with all subs to minimize exposure of lines, degration of materials, and weather related delays. |
| 5 | Ensure the construction specifications and drawings align. Civil, Plumbing, and Landscape plans should match in details and design. All plans should reference the same specification, such as distinguishing washed, double washed or triple washed stone. |
| 6 | Excavation and construction of facilities should not begin until the project has all materials on site and all trades have timeline for installation. |
| 7 | The excavated facility should not be used as a temporary BMP during construction. The faciliy should not be used to dewater the site after rain events. Do not value engineer (VE) requirements to clean, or scour, facility at project completion. |
| 8 | Ensure adequate soil and irrigation is specified around the basin. No part of stabilization should be removed as cost saving measure. |
| 9 | Install BMPs around the facility during construction to minimize silt entering the basin during rain events. |
| 10 | Delivery tickets should be reviewed by inspectors to confirm the right size and condition of materials. |
| 11 | Discuss wtith the contractor means and methods to install biomedia in lifts to ensure materials are not excessively compacted. |
| 12 | If possible, do not accept the biomedia test specification without a date. Ensure the vendor provides recent soil testing results. We learned the specified soil testing may be several months old. If possible, in construction documents, specify independent testing. |
| 13 | Specify in construction documents for bid, a minimum number of in place soil tests i.e. Infiltration testing. |
| 14 | Ensure terms are well defined and understood by the contractors: what is meant by "until established", how do you define "washed", acceptance of materials as "specified". |
| 15 | Specify contingency and require minimums if construction is delayed and define what is acceptable regarding item such as: condition of the liner, biomedia, and underpiping. Define rain days. Discuss possible delays resulting to unprotected materials during rain events. Ask contractor to consider a plan of action to prevent degration of the facility due to weather conditions i.e. sun, temperature, wind, rain, freezing mid way through constructiokn. Consider requesting a weather plan in bid documents specifically for the facility. Agree to maximum number of delay days for the facility due to weather to ensure the facility is protected. |
| 16 | Specify materials, for example, perforated pipe. Engineer will specify hole size. Ensure this is met. We had contractors drilling holes into PVC on site. |
| 17 | Ensure plant material is inspected and that they are planted adequately. Plants were not installed to the minimum depth and then covered with the mulch layer. Most of them floated and were lost at the first event. |
| 18 | Operational cost will be lower if the bioretention is vegetated. Un-vegetated facilities seem to have more scouring. Vegetation seems to anchor the media. |
| 19 | Define testing in terms of where, when, how recent. Vendors provided material test results for media but the testing occurred months before delivery. Consider funding additional tests to assist with longevity of the facility during operational phase. |