

EA Project Summaries and Findings Report Project

Project 10 – Evaluation of the Vegetation Along Roadways in Edwards Aquifer Recharge and Contributing Zones for Storm Water Management and Water Quality Improvement

Project Summary

Author: UTSA

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Funding Amount

\$798,636

Stated objectives of the study – *This UTSA project will evaluate soil and vegetation composition and density along roadways in the Edwards Recharge and Contributing Zones of Bexar County for control of sediments, nutrients, and other pollutants and make recommendations of xeric species of vegetation most adaptable to roadway conditions.*

Justification for the study – *San Antonio experienced the highest per capita growth of any major city in 2017, and the population of Bexar County is estimated to reach 2.8 million by 2060 representing a 94% increase from 2000 to 2060 (TWDB, 2011). Increased population is characterized by loss of natural habitat, fragmented ecosystems, and impacts to environmental processes and ecosystems services. Development and habitat fragmentation result not only in increased stormwater runoff, but also loss of ecosystem services and declines in biodiversity which can impact water quality (Vitousek 1994, Walsh 2000). An increase in impervious surface, including roadways, is another factor that results from increased population growth and urbanization, with potential to impact the Edwards Aquifer. In arid and semi-arid regions such as central Texas, understanding vegetation composition and coverage will provide insight into which species are most efficient in trapping sediment and removing pollutants from stormwater runoff along roadways.*

1 Summary

This project evaluated vegetation and stormwater quality within two different types of low impact development (LID) systems, sand filtration basins¹ and vegetated swales, along major highways in the Edwards Aquifer recharge and contributing zones. Roadways increase stormwater runoff and enable mobilization of pollutants from vehicles and other sources. The researchers aimed to determine if the vegetation in the LID systems is effective in controlling and containing stormwater runoff from roadways and the associated sediment and pollutants. By evaluating the plant composition, soil types, stormwater pollutant levels, and microbial ecology at these sites, the researchers developed recommendations for improved management, such as identifying the best plants for use in these systems. A better understanding of how these systems function supports more effective treatment of runoff along roadways.

The project included a vegetation study and a water quality study, and soils analysis was done in both. Figure 1 shows the locations of the study sites. The vegetation study involved two phases including field observations and sampling as well as greenhouse studies. The results produced a list of recommended

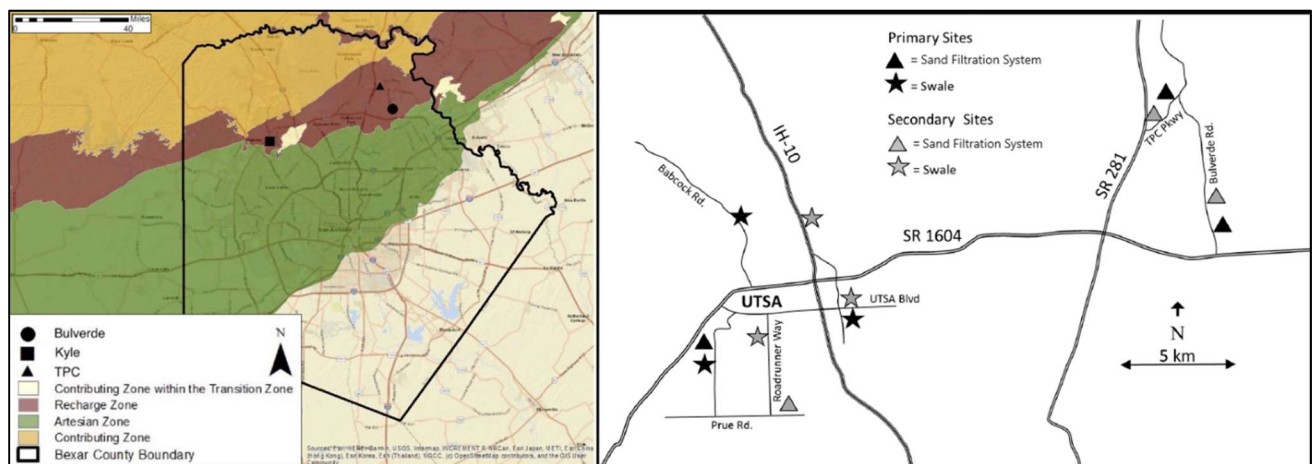
native species for planting in LID structures that can accommodate varying conditions and may be the most resilient to the impacts of climate change, included as Exhibit 1. Plants in the

¹ These stormwater treatment systems are dry basins consisting of a sand layer on top of gravel and underdrain pipes that discharge the filtered runoff downstream of the system. The study also refers to the sand filtration basins as detention ponds/basins and infiltration systems.

list can be selected based on the conditions of specific LID structures to increase plant survival and provide water quality benefits.

The water quality study involved stormwater and soil sampling to support the analysis of pollutant levels in runoff and determination of bacterial community composition. Researchers found that while solids were effectively removed in both swales and basins, nutrient and metal removal efficiency varied. In several sand filtration basins, some nutrient levels were higher in the discharge leaving the structure. This has been observed in other studies and warrants further investigation. A similar trend was noticed for metals. Most metals were detected at low concentrations and were either reduced or showed little change at the outlet. Magnesium consistently had the highest concentrations throughout the basins; in addition, higher concentrations were observed at the outlet than the inlet. The diversity and composition of bacterial communities, responsible for processes that may help enhance the performance and pollutant removal capabilities of LID structures, were analyzed based on their DNA to assess their impacts on vegetation and water quality.

Figure 1 – Project location and study sites



1.1 Methods

The vegetation study included field observations and sampling for multiple parameters, greenhouse studies, and a statistical analysis of the results. Vegetation and soil samples were collected at twelve sites (six sand filtration basins and six vegetated swales) adjacent to major roadways throughout the summers and winters of 2020 and 2021. The researchers recorded vegetation at each site along randomly placed transects to determine patterns including the amount of space each plant species was taking up within the structure, their abundance, and how many different species were present. They also classified the observed plants based on several characteristics and status as either a native or non-native species. Samples of the plants were then randomly selected and analyzed for their weight, organic matter content, organic carbon content, and metals. Three soil samples were collected at each site and then separated into three additional categories based on the depth the soil was taken from. The soil was weighed and analyzed for several parameters including organic carbon and organic matter content, metals, and density. Sediment from stormwater runoff was also captured at each site for oil and grease analysis.

Greenhouse studies focused on six species of native grasses collected locally on UTSA campus and from the swales in the study. The grasses were raised from seed for two to three months for use in three studies: 1) drought tolerance, 2) nutrient growth, and 3) metals uptake. To evaluate for drought tolerance, the plants were watered at varying intervals over three months, and then harvested and weighed. Plants were also potted in soils with four different concentrations of both nitrogen and phosphorus (key nutrients for plant growth), and then harvested and weighed after three months. In addition, five of the species of native grasses were grown for eight weeks in soil with added copper, lead, and chromium. The selected metals are pollutants of concern in runoff from roadways released by vehicle emissions and wear of automobile parts. The length, weight, and metal content of the plants' roots and shoots were then analyzed. Eight native species were also planted in the swales after being maintained in the greenhouse for three months. They were monitored for two growing seasons and then harvested and weighed. Statistical analysis was conducted for all the measured variables, and management recommendations were developed, based on the results.

The water quality study monitored three of the basins and three of the vegetated swales also evaluated in the vegetation study. All six of these systems were within the Edwards Aquifer recharge zone. All the selected basins allow stormwater filtration through a layer of sand and discharge filtered effluent through a perforated pipe. The researchers conducted stormwater sampling for a year at each location. For the sand filtration basins, stormwater was collected at the inlet and outlet of the structures using autosamplers. The samplers at the inlet were programmed to begin collecting the samples at 15-minute time intervals once stormflow reached a specific depth. The samplers at the outlet of the basins were programmed to begin collecting samples every 30 minutes starting 15 minutes after the inlet sampler was triggered. To perform sampling within the selected sections of the identified swales, the length of each was measured and then samplers containing a 1-liter amber glass bottle were placed at the beginning, middle, and end of each section.

Results from sampling in the basins were used to calculate the event mean concentration (EMC) of each storm event, which is a weighted average based on flow during the entire storm event that allows comparison between storm events of different sizes. The average concentrations of pollutants were also compared at locations identified as the beginning, middle, and end of the swales. The samples were analyzed for several common pollutants including nutrients, metals, fecal coliform, and oil and grease. Three additional soil samples were also collected at each basin in both the summer and winter of 2020. These samples were collected separately from the samples collected as part of the vegetation study. The researchers then extracted DNA from the soil to investigate the diversity and composition of bacterial communities.

1.2 Findings

The vegetation study identified a total of 154 different plant types, the majority of which were native species that occur naturally in the region and have adapted to local environmental conditions. The analysis led to the recommendation of 56 native species for planting in LID structures that allow plant selections based on desirable traits for individual features and resulting in increased resilience to changing environmental conditions such as temperature changes, flooding, and extended droughts. The recommendations included native grasses alongside herbs and herbaceous plants to increase plant diversity. Included in the suggestions are four native plants which exhibited uptake of several metals, including frog-fruit

demonstrating the highest overall uptake. White tridens, a native grass, was also found to be highly successful with a survival rate of 88%.

Many of the recommended native plants are easily grown from seeds, rhizomes, or bare root stock and appeared to occur spontaneously in LID features. Other management recommendations include limiting vegetation management during the growing season and disposing of the mowed plants in landfills to prevent the recycling of nutrients and metals back into the environment. Mowing swales and basins once at the end of the growing season may also promote a mixture of both annuals and perennials during the next season. The resulting high diversity of plants with different traits will result in greater resilience to environmental conditions.

The researchers found that soils were more compact and less porous not far from the surface. This can inhibit root growth of native plants and slow the infiltration of water through the soil. The features were also more successful at capturing sediment when there was increased vegetation cover, and when vegetation was allowed to grow higher. The promotion of a dense buffer zone of vegetation at the inlet will also reduce the sediment and pollutant loads from being distributed throughout the LID system. Although the identified vegetation contained many different species of native plants, the basins and swales were overall dominated by only a few non-native grasses. Observational evidence indicated that the plant communities in the LID structures are changing frequently due to management activities and extreme environmental conditions.

The greenhouse studies determined that growth of native grasses is greater with increased nutrient levels; however, it is likely that their growth will be more impacted by competition with non-native grasses than nutrient availability. Silver bluestem, White tridens, and Sideoats grama were also observed to exhibit the greatest drought tolerance and had moderate to high survival rates.

The water quality study observed that while solids were effectively removed in both swales and sand filtration basins, nutrient and metal removal efficiency varied. In several basins some nutrient levels, including nitrate and phosphorus, were higher in the discharge. These nutrients are potentially being leached from either the soil media or from decomposing organic matter, such as leaves and grass clippings. Swales, however, were demonstrated to be effective for nutrient removal. Most metals were detected at relatively low concentrations and were either reduced or showed little change at the outlet. The three sand filter sites showed a similar trend, with magnesium concentrations substantially higher than the other metals measured and with higher concentrations at the outlet than at the inlet. Building materials and automobile-related sources, such as roads and parking lots, are thought to contribute to higher metal concentrations in urban stormwater.

DNA of bacteria found in soil samples were also analyzed to evaluate the diversity and composition of bacterial communities in the LID structures. It was observed that the diversity of microbial communities increased during summer samples, which is consistent with the knowledge that microbes are impacted by seasons and weather. The most abundant bacteria found, Actinobacteria, is known for its role in several processes that increase the availability of nutrients for plant use. These processes help enable plants to utilize pollutants transported by stormwater runoff, such as nitrogen and phosphorus.

1.3 Challenges and Limitations

Routine maintenance of stormwater features including the replacement of sand filters and mowing can make it difficult to identify the vegetation within a system. The use of heavy equipment when conducting maintenance, as well as smaller particles entering the features and settling over time, can also lead to compaction and clogged pore space which increases the difficulty in collecting soil cores to the desired depth. Limestone fragments in the soil, potentially from fill used during construction, also present a challenge when collecting soil samples. During the later portions of the study, Central Texas was experiencing a drought. Not only did this make it more challenging to collect storm event samples, it also may have altered the growth patterns of the vegetation present in the surveyed swales and basins. Therefore, the results may not be representative of plant growth during a typical growing season.

2 Benefits

This study provides multiple benefits for our understanding of vegetation and its role within stormwater treatment. The study also provides valuable data about pollutants and levels in discharge from high traffic roadways.

The overall contributions of the study are as follows:

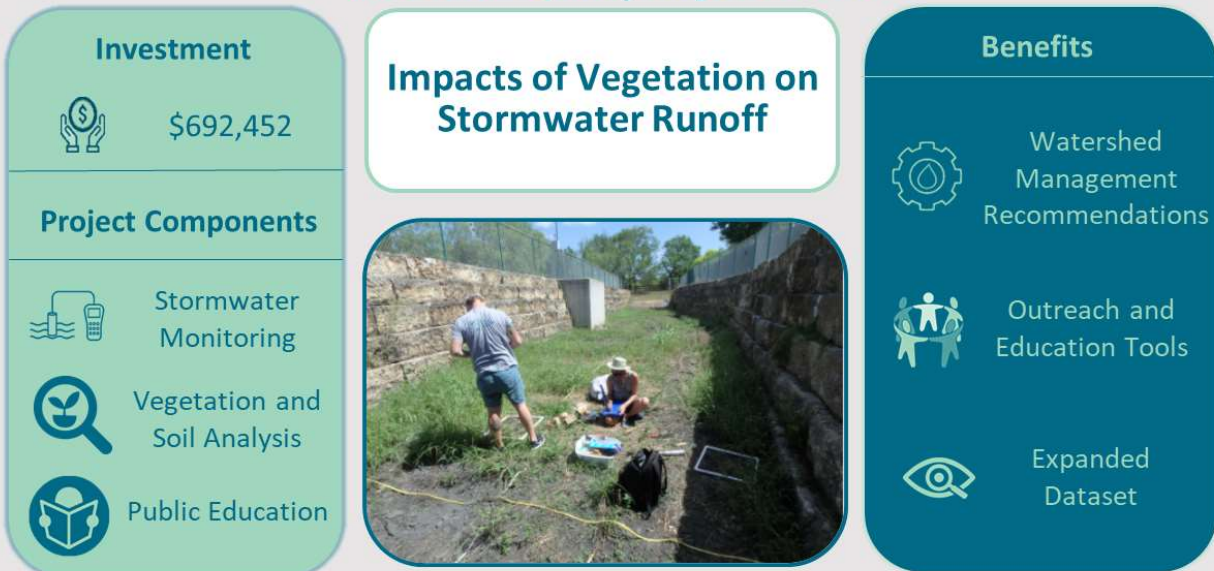
- The project provided management recommendations to maximize the water quality benefits from vegetated low impact development features along roadways.
- The project increased the understanding of plant succession and establishment trends within LID features.
- The researchers provided recommendations on native plant species for use by designers and maintenance teams to improve the effectiveness and resilience of vegetated low impact development features.
- The researchers expanded the local dataset of pollutant removal effectiveness for sand filtration basins and vegetated swales.
- The study suggests that some nutrient levels are higher at the outlet than inlets of BMPs. The authors identified the importance of maintenance, soil media composition, and vegetation recommendations to mitigate nutrients.

Project Deliverables:

Hutchinson, J.T., Kapoor, V., Dessouky, S. (2023). Evaluation of the vegetation along roadways in Edwards aquifer recharge and contributing zones for storm water management and water quality improvement. The University of Texas at San Antonio.

EA Project Summaries and Findings Report Project
Project 10 – Evaluation of the Vegetation Along Roadways in
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Fact Sheet

Project 10: Evaluation of the Vegetation along Roadways in Edwards Aquifer Recharge and Contributing Zones for Storm Water Management and Water Quality Improvement



UTSA
The University of Texas at San Antonio

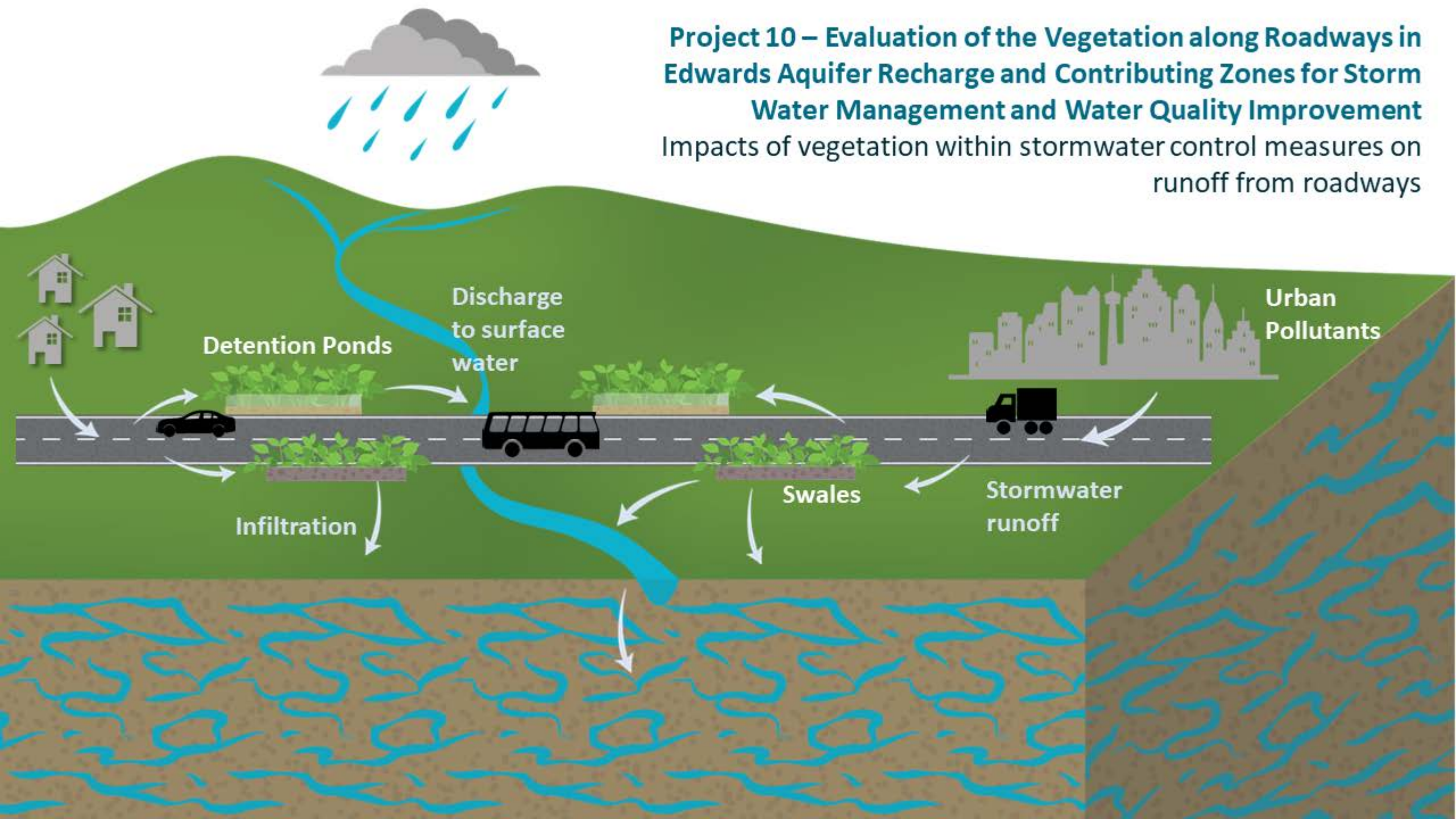
Benefits

- The project provided management recommendations to maximize the water quality benefits from vegetated low impact development features along roadways.
- The project increased the understanding of plant succession and establishment trends within LID features.
- The researchers provided recommendations on native plant species for use by designers and maintenance teams to improve the effectiveness and resilience of vegetated low impact development features.
- The researchers expanded the local dataset of pollutant removal effectiveness for sand filtration basins and vegetated swales.
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Project Graphic

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Impacts of vegetation within stormwater control measures on runoff from roadways



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Exhibit 1

Appendix 4. Native plant species suggested for planting in Low Impact Development Structures in Bexar County.

Common name	Taxonomic name	USDA Symbol	Group	Duration	Growth Habit	Wetland Status ¹
Silver bluestem	<i>Bothriochloa laguroides</i>	BOLA2	Monocot	Perennial	Graminoid	FACU
Sideoats Grama	<i>Bouteloua curtipendula</i>	BOCU	Monocot	Perennial	Graminoid	Upland
Buffalograss	<i>Bouteloua dactyloides</i>	BODA2	Monocot	Perennial	Graminoid	FACU
Texas grama	<i>Bouteloua rigidiseta</i>	BORI	Monocot	Perennial	Graminoid	Upland
Indian paintbrush	<i>Castilleja indivisa</i>	CAIN13	Dicot	Annual	Forb/Herb	FAC
American star-thistle	<i>Centaurea americana</i>	CEAM2	Dicot	Annual	Forb/Herb	Upland
Lady Bird's centaury	<i>Centaureum texense</i>	CETE2	Dicot	Annual	Forb/Herb	Upland
Sorrelvine	<i>Cissus trifoliata</i>	CITR2	Dicot	Perennial	Vine	FACU
Drummond's clematis	<i>Clematis drummondii</i>	CLDR	Dicot	Perennial	Vine	FACU
Whitemouth Dayflower	<i>Commelina communis</i>	COER	Monocot	Perennial	Forb/Herb	FACU
Goldenmane tickseed	<i>Coreopsis basalis</i>	COBA2	Dicot	Annual	Forb/Herb	FACU
Bush croton	<i>Croton fruticosus</i>	CRFR	Dicot	Perennial	Forb/Herb	Upland
Fragrant flatsedge	<i>Cyperus odoratus</i>	CYOD	Monocot	Ann/Per	Graminoid	FACW ¹
Bentawn flatsedge	<i>Cyperus reflexus</i>	CYRE2	Monocot	Perennial	Graminoid	FAC ¹
Tropical flatsedge	<i>Cyperus surinamensis</i>	CYSU	Monocot	Perennial	Graminoid	FACW ¹
Carolina ponyfoot	<i>Dichondra carolinensis</i> Michx.	DICA3	Dicot	Perennial	Forb/Herb	FAC ¹
Common spikerush	<i>Eleocharis palustris</i>	ELPA3	Monocot	Perennial	Graminoid	Obligate ¹
Indian blanket	<i>Gaillardia pulchella</i>	GAPU	Dicot	An/Bi/Pr	Forb/Herb	Upland
Dakota mock vervain	<i>Glandularia bipinnatifida</i>	GLBI2	Dicot	Ann/Per	Forb/Herb	Upland
Longdisk sneezeweed	<i>Helenium quadridentatum</i>	HEQU	Dicot	Annual	Forb/Herb	FAC ¹
Common sunflower	<i>Helianthus annuus</i>	HEAN3	Dicot	Annual	Forb/Herb	FACU
Little barley	<i>Hordeum pusillum</i>	HOPU	Monocot	Annual	Graminoid	FAC ¹
Carolina woolywhite	<i>Hymenopappus scabiosaeus</i>	HYSC	Dicot	Biennial	Forb/Herb	Upland
Tievine	<i>Ipomoea cordatotriloba</i>	IPCOC2	Dicot	Perennial	Vine	Upland
American water-willow	<i>Justicia americana</i>	JUAM	Dicot	Perennial	Forb/Herb	Obligate ¹
Ozark grass	<i>Limnodea arkansana</i>	LIAR	Monocot	Annual	Graminoid	FAC ¹
Texas yellowstar	<i>Lindheimera texana</i>	LITE3	Dicot	Annual	Forb/Herb	Upland
Texas lupine	<i>Lupinus texensis</i>	LUTE	Dicot	Annual	Forb/Herb	Upland

Algerita	<i>Mahonia trifoliolata</i>	MATR3	Dicot	Perennial	Shrub	Upland
Bigfoot waterclover	<i>Marsilea macropoda</i>	MAMA9	Fern	Perennial	Forb/Herb	Obligate ¹
Lemon beebalm	<i>Monarda citriodora</i>	MOCI	Dicot	An/Bi/Pr	Forb/Herb	Upland
Texas wintergrass	<i>Nassella leucotricha</i>	NALE3	Monocot	Perennial	Graminoid	FACU
Yellow-puff	<i>Neptunia lutea</i>	NELU2	Dicot	Perennial	Forb/Herb	FACU
Pinkladies	<i>Oenothera speciosa</i>	OESP2	Dicot	Perennial	Forb/Herb	Upland
Scarlet beeblossom	<i>Oenothera suffrutescens</i>	OESU3	Dicot	Perennial	Forb/Herb	Upland
Slender yellow woodsorrel	<i>Oxalis dillenii</i>	OXDI2	Dicot	Perennial	Forb/Herb	FACU
Drummond's woodsorrel	<i>Oxalis drummondii</i>	OXDR	Dicot	Perennial	Forb/Herb	FACU
Western wheatgrass	<i>Pascopyrum smithii</i>	PASM	Monocot	Perennial	Graminoid	FACU
Carolina canarygrass	<i>Phalaris caroliniana</i>	PHCA6	Monocot	Annual	Graminoid	FACW ¹
Turkey tangle fogfruit	<i>Phyla nodiflora</i>	PHNO2	Dicot	Perennial	Forb/Herb	FAC
Sweetscent	<i>Pluchea odorata</i>	PLODO	Dicot	Ann/Per	Forb/Herb	FAC ¹
Denseflower knotweed	<i>Polygonum glabrum</i>	POGL10	Dicot	Ann/Per	Forb/Herb	Obligate ¹
Upright prairie coneflower	<i>Ratibida columnifera</i>	RACO3	Dicot	Perennial	Forb/Herb	Upland
Blackeyed Susan	<i>Rudbeckia hirta</i>	RUHI2	Dicot	An/Bi/Pr	Forb/Herb	FACU
Violet wild petunia	<i>Ruellia nudiflora</i>	RUNU	Dicot	Perennial	Forb/Herb	Upland
Little bluestem	<i>Schizachyrium scoparium</i>	SCSC	Monocot	Perennial	Graminoid	FACU
Southwestern bristlegrass	<i>Setaria scheelei</i>	SESC2	Monocot	Perennial	Graminoid	FACU
Swordleaf blue-eyed grass	<i>Sisyrinchium chilense</i>	SICH2	Monocot	Perennial	Forb/Herb	Upland
Saw greenbrier	<i>Smilax bona-nox</i>	SMBO2	Monocot	Perennial	Vine	FACU
Silverleaf nightshade	<i>Solanum elaeagnifolium</i>	SOEL	Dicot	Perennial	Forb/Herb	Upland
Buffalobur nightshade	<i>Solanum rostratum</i>	SORO	Dicot	Annual	Forb/Herb	Upland
Stiff greenthread	<i>Thelesperma filifolium</i>	THFI	Dicot	Ann/Per	Forb/Herb	FACU
White tridens	<i>Tridens albescens</i>	TRAL2	Monocot	Perennial	Graminoid	FAC
Texas signalgrass	<i>Urochloa texana</i>	URTE2	Monocot	Annual	Graminoid	Upland
Golden crownbeard	<i>Verbesina encelioides</i>	VEEN	Dicot	Annual	Forb/Herb	FAC
Louisiana vetch	<i>Vicia ludoviciana</i>	VILU	Dicot	Annual	Forb/Herb	Upland

¹ - Recommended for LID structures that have longer hydroperiods and higher soil moisture.