White Oak Bayou Cottage Grove Subdivision

Low Impact Development Demonstration Project

Project Final Report

NPS Water Pollution Management Program

Clean Water Act § 319(h) Grant

White Oak Watershed

TCEQ Contract No. 582-10-90464

City of Houston, Texas

Prepared for

Texas Commission on Environmental Quality

and the Environmental Protection Agency

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The Project Consultant Team consisting of Jones & Carter, Inc., Watearth, Inc., HVJ Associates, Inc., Berg-Oliver Associates, Inc., and KGA / DeForest Design, L.L.C.

Jones & Carter, Inc. was authorized by the City to supply qualified professional engineering services for the preliminary design, final design and construction phase services of the White Oak Bayou Cottage Grove Subdivision LID Demonstration Project.

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Table of Contents

Cover……..... 2
Acknowledgements..... 3
Background……..... 5
Executive Summary..... 7
Introduction..... 9
Task Summary..... 23
Task 1: Project Administratin.....23
Objective.....23
Task 2: Public Outreach……..... 24
Objective.....24
Task 3: Study Design (Water Quality Study Plan)…….....25
Objective.....25
Task 4: Quality Assurance Project Plan (QAPP) Development and Data Plan…… 27
Objective.....27
Task 5: BMP Design and Sub-Contactor Selection…….....28
Objective..... 28
Task 6: BMP Construction…….....28
Objective.....28
Task 7: BMP Performance Evaluation.....33
Objective.....33
Task 8: Final Report.....34
Objective.....34
Summary.....35

Background

White Oak Bayou above tidal (Segment 1017) was first identified as impaired for bacteria in 1996. The Texas Coastal Nonpoint Source Pollution Control Program identifies urban pollution as the source of 43%-85% of pollution (sediments, nutrients, fecal coliform, pesticides, and oil and grease) loadings to Galveston Bay. The Texas Water Quality Inventory and 303(d) List identifies the causes of the bacteria impairment as urban runoff / storm sewers and sanitary sewer overflows. According to the White Oak Bayou TMDL, the entire watershed is more than 50% impervious cover.

The White Oak Bayou BMP Demonstration Project purpose was to construct LID BMPs in a redeveloping sub-area of the Houston's urban watershed. The project's goals are to accomplish load reduction of NPS pollution discharge to White Oak Bayou while also evaluating BMP effectiveness in reducing pollutant loadings (bacteria and other water quality parameters), evaluating long term viability to construct and maintain BMPs, assessing construction cost and long term maintenance costs, assessing effectiveness of maintenance practices.

The project fulfills NPS Management Program long term goals to focus abatement efforts in watersheds (White Oak Bayou) identified as impaired by NPS pollution and to support implementation of local programs to reduce NPS pollution. The project also developed partnerships and relationships to facilitate collective, cooperative approaches to manage NPS pollution to increase overall public awareness of NPS issues and prevention activities.

Funding:

Congress amended the Clean Water Act in 1987 to establish grant funding to help states and localities to reduce nonpoint source (NPS) pollution of public waterways. NPS pollution is produced by diffuse sources, such as storm water that drains from parking lots and yards, which may be contaminated with petroleum substances, fertilizer and pesticides.

A Grant Agreement was approved between TCEQ and the City on May 5, 2010; Ordinance No. 2010-353 to provide Engineering, Construction and Monitoring for the selected LID demonstration project within the Cottage Grove Subdivision.

Significance of the project location:

The project selected is located in an urban area of the City described as Cottage Grove Subdivision, along Darling Street from T.C. Jester to Reinerman. The neighborhood is redeveloping from the original single family residential area (density of 2-6 dwelling units per acre) to high density townhomes (density of approximately 24 dwelling units per acre). The impervious cover ranges from approximately 50 percent per lot (original single family lots) to 90 percent per lot (new high density development). The change in impervious cover increases storm water runoff and NPS discharges to the White Oak Bayou watershed.

Project Scope:

The project consists of roadway reconstruction of approximately two blocks. The previous roadway section provided two narrow travel lanes with parallel open ditch drainage. The previous section had some drainage issues, substandard roadway widths and provided no pedestrian sidewalk. The improvements consist of standard two-lane with roadway for 50-ft right of way section, with curb and gutter section, sidewalks and LID features.

The project scope is to determine the effectiveness, the cost of installation, and the ongoing cost of maintenance of the installed LID features.

Objective:

If the proposed LID features prove effective for the soil types in Houston / Harris County, this will assist the City in expanding the Design Standards to include the studied LID features. Eventually this information will become available for new construction and redevelopment. If shown to be effective (low maintenance, durable, and competitive construction cost), developers may implement use of these pervious features as a method to offset the increase in impervious area. The City will also utilize this information in other Capital Improvement Projects.

Unlike traditional drainage infrastructure that relies on concrete and pipe, LID designs use natural features, pervious pavement or engineered swales covered with vegetation to reduce, contain, and manage runoff. The project will be monitored to document the effectiveness, the cost of installation, and the ongoing cost of maintenance of installed LID features in this project the LID features are rain gardens and tree boxes.

Executive Summary

The International Storm Water Database (www.bmpdatabase.org) has limited information describing the performance or effectiveness of LID features to remove/reduce bacteria. There is clearly a need for more qualified data on the performance of LID features for bacteria removal from runoff, particularly in an urban redevelopment context. Urban sources are the largest nonpoint source of pollution going to Galveston Bay.

- >85% of Bacteria, Pesticides, and Oil & Grease
- 55 - 65% of Nutrient loadings
- 43% of Sediment loading

On May 5, 2010 City Council passed an ordinance to authorize acceptance of TCEQ grant funds for the design and construction of White Oak Bayou LID Demonstration Project (Ordinance No. 2010-353, TCEQ Agreement No. 582-10-90464) to investigate and evaluate pollutant loadings, including bacteria, in the White Oak Bayou watershed. This project installed LID features in a targeted highly urbanized area of the White Oak Bayou watershed to evaluate performance; pollutant removal effectiveness, maintainability of infrastructure systems constructed, and cost feasibility.

The Project Team for this project is the City of Houston, TCEQ, Rice University, and Jones and Carter, Inc. Jones & Carter's design team included Watearth, Inc., HVJ Associates, Inc., Berg-Oliver Associates, Inc., and KGA / DeForest Design, L.L.C.

The City was the contracting agency handling the project lead and coordination effort for design and construction. The City Laboratory is responsible for providing the testing laboratory services for water testing. The TCEQ is a financial partner providing not only funding, but oversight and review of the testing and procedures used through the testing phase of the project. Rice University is providing sampling and flow measurement of not only the LID features along Darling Street, but also along Petty Street. Petty Street is the street immediately north of Darling Street and has been identified as an appropriate comparison street. Jones & Carter, Inc. provided the design and construction engineering services.

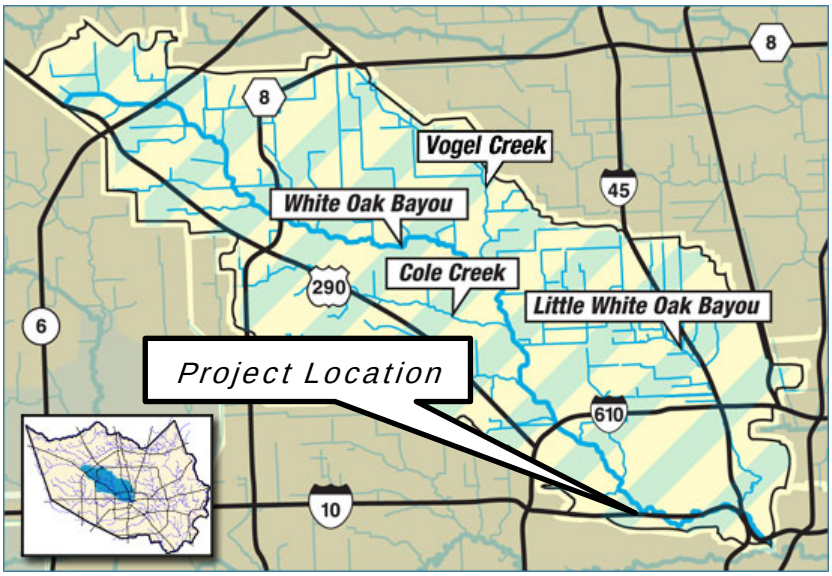
The final improvements include the construction of LID features along Darling Street between T.C. Jester Boulevard and Reinerman Street in the Cottage Grove Subdivision (approximately 1,425 linear feet). Construct a 28-foot (28') wide pavement section with sidewalks on both sides of the street. The pavement will narrow with modified curbs at the intersections to allow for more room for LID features at these locations. The features will be evaluated to determine their effectiveness from both a water quantity and water quality standpoint and the applicability of these features in other areas of the City.

Introduction

In recent years, Low Impact Development (LID) has been considered as an alternative approach to stormwater management. Today, LID practices are growing in popularity, but are not widespread largely due to the lack of documented effectiveness and lack of public understanding. Although numerous studies have analyzed different development scenarios that aim to manage runoff from impervious surfaces and to promote infiltration on site, more research is needed to quantify the effects and LID practices. The Cottage Grove LID design concepts utilized an integrated approach to stormwater management which includes quality and quantity. The general concept and criteria was to integrate LID while including principle design criteria such as alignment, right-of-way, environmental considerations, paving, drainage public and private utilities, vehicular and pedestrian traffic control and signage.

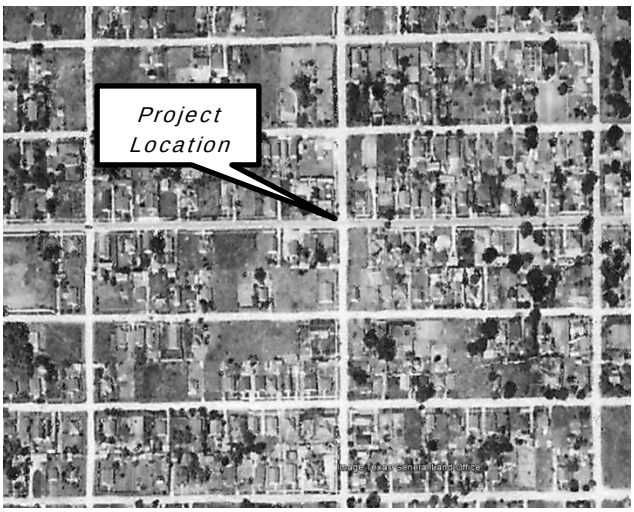
Project Location & General Information

The general location of the proposed project is in the near northwest side of the City and can be found on Key Map page 492C. The project will be constructed on Darling Street between T.C. Jester Boulevard and Reinerman Street. Darling Street is currently an asphalt road with roadside ditches. The LID and drainage features constructed for this project are intended to improve the storm water quality and the overall drainage in the area as well as the quality of the pavement.

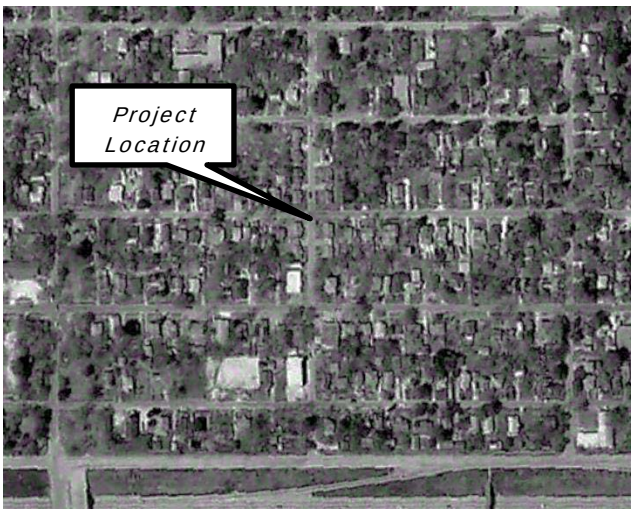


Cottage Grove is an area in transition. The original single family homes are gradually being replaced with multi-story townhomes. Single family residential development along the project limits began in the early 1900s and was mostly complete by the 1950s. Some commercial development began after the construction of IH-10 to the south in the 1970s and T.C. Jester Boulevard in the 1980s. Townhome developments began to replace the original single family residences at a steady rate in the last 10 to 15 years.

- Original Single Family Residences density, 2 to 6 dwelling units per acre
- Redeveloping to High Density Residences density, 24 dwelling units per acre
- Impervious cover increasing from 50% to 90%



Circa 1944 via Google Earth v7.1.2.2041



Circa 1978 via Google Earth v7.1.2.2041

Circa 2008 via Google Earth v7.1.2.2041

Circa 2014 via Google Earth v7.1.2.2041

Design

The general design of Darling Street with LID features is limited to the available existing right-of-way. The right-of-way is 50 feet wide throughout the project limits. The project is the reconstruction of the existing pavement and will involve widening the roadway, however, since

the existing right-of-way cannot be widened, all improvements were designed to fit in the existing right-of-way.

The project area is located within the White Oak Bayou watershed. The storm runoff from Darling Street is collected by the three (3) cross streets. All of the runoff eventually makes it way to the same point and discharges to White Oak Bayou (HCFCD Unit No. E100-00-00) through the same outfall. White Oak Bayou flows east/southeast to Buffalo Bayou, which drains to the San Jacinto River and then Galveston Bay.

The drainage systems were analyzed. The different paths the storm water takes are summarized below. The existing storm sewer was analyzed using EPA SWMM to determine if improvements are needed in order to conform to the current City standards. The improvements were designed within the City's design guidelines including a review of the risk of structural flooding in the community. The project's LID features were designed not to increase the risk of additional flooding in the area and to provide improvements to the drainage. Because the project affects only two blocks, it will not be likely to significantly influence the overall drainage of the area.

The project changed the typical section by adding LID features along its length along with concrete curb and gutter instead of asphalt with roadside ditch. The actual roadway section will be discussed in the "Roadway Section Design" of this report.

Low Impact Development (LID) Features

Addressing the Existing Street Right-of-Way Challenges

As discussed previously, Darling Street is located within a 50-foot wide right-of-way with existing utilities including water, sanitary sewer, electrical, natural gas, cable, and telephone. The neighborhood is predominately single family residential, but is being redeveloped into more townhome style development. It continues to be predominately residential and additional right-of-way acquisition is not considered a feasible option. The project team discussed several options to incorporate LID features into the roadway design. The following items were evaluated with respect to the control of traffic and adequate room to allow for LID features to be installed.

- **One way streets** – The use of one way streets could provide more room for LID features. It was decided that a one-way section was probably not feasible because of the street layouts in the surrounding neighborhood and the fact that the project is looking at only two blocks, not a full neighborhood reconstruction.
- **Chicanes** – The use of chicanes will provide a mid-block traffic calming area while providing space for additional LID features. It was decided that chicanes are probably not feasible for this project since the location of these features does not fit well with the existing development and on-going redevelopment in the area
- **Divided pavement** – One of the early concepts for LID in Cottage Grove was the use of divided pavement with LID features down the middle of the pavement. The limited right-of-way available for a divided pavement combined with reduced access to driveways and inadequate room for proper turning radii eliminated this as a viable option.
- **Modified curbs (Bulb-Outs) at intersections (T.C. Jester / Darling, Reinerman / Darling, and Detering / Darling)** – Modified curbs will allow room for rain garden features at the intersections and also will provide traffic control value.

Above and below are typical Existing Conditions of the 2-lane residential asphalt street with grass-lined roadside ditches

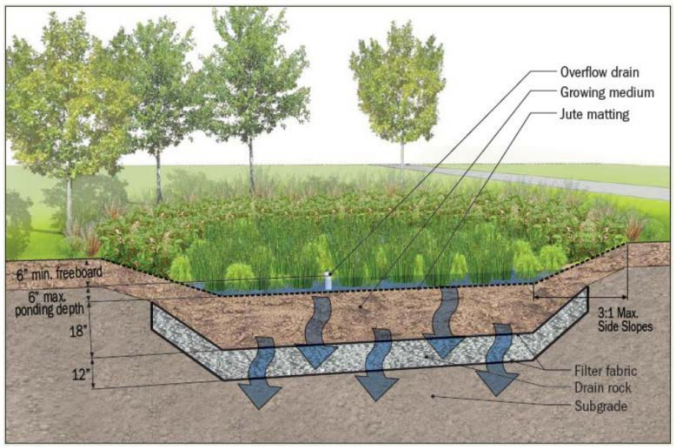
Evaluation of LID Features and Best Management Practices (BMPs)

One of the primary purposes of the Cottage Grove LID Demonstration Project is to develop a section of street improvements that utilizes LID components and to evaluate the functionality of the features to improve water quality while maintaining basic City Street and drainage criteria. This section of the report will discuss the advantages and disadvantages of various BMP features and provide background reasoning for each feature selected. Since all of the LID features evaluated have a proven history of providing some level of storm water quality improvement and a portion of the project requires monitoring and testing to evaluate functionality of the features, this section of the report does not consider any specific water quality justification for the recommended LID features.

The LID features researched and discussed with the project team included tree boxes, bio-swales, rain gardens, permeable pavement, bio-retention, porous pavers, and open graded asphalt. A brief description of each of the features and a summary of the advantages and disadvantages of each feature is listed below:

<u>Rain Gardens (Bioretention)</u>

Rain Gardens are typically planted, depressed areas that allow for the collection of stormwater runoff. It allows rainwater to soak into either native soil or an engineered soil mix which sometimes includes an under drain and/or pipe system. Plantings usually include native vegetation and provide proven water quality improvements.



From Low Impact Development Approaches Handbook by Clean Water Services, July 2009

Advantages

- Research shows good improvement in water quality, lower TSS, heavy metals and nutrients.
- Generally low maintenance cost.
- Provides a pocket garden area that is visually appealing and a valued asset to the neighborhood.
- Provides for an assortment of native type vegetation such as trees, shrubs and grasses that can be designed to suit each location.
- Many rain gardens encompass both public and private areas to allow for a more functional feature

Disadvantages

- Usually requires a relatively large area to be effective
- Does not fit well in a 50-foot right-of-way.
- Conflicts with other utilities and maintenance of those utilities (i.e. water, sewer, power) could damage the rain garden and its effectiveness.

Tree Boxes

Tree boxes are typically a container filled with a soil mix planted with small trees or shrubs that sit behind curb lines in typical curb and gutter street sections as shown in the tree box photograph recently taken at the Cottage Grove LID project location. They are as small as 4-foot by 4-foot and designed to function in more urban settings. Tree boxes can be installed on-grade or at low areas along the pavement. Storm water is directed into the features where it flows through a vegetated/landscaped area with a porous or other specially designed media.

Tree Box at the Cottage Grove

Landscaping typically includes a tree and/or other landscaping. Shrubs or dwarf trees are also used depending on the location and desired look. There are two basic types of tree boxes, proprietary complete units such as "Filterra" or built in place boxes using filter fabric and select graded materials.

Advantages

- Can be located in some smaller open areas between driveways.
- Can be installed with vertical walls to increase possible location options.
- Cost close to inlet cost estimated at $3,000 per box.
- Research shows good improvement in water quality, lower TSS, heavy metals and nutrients.
- Preferred to Bioswales where leaching is a potential issue.
- Vegetation can be customized as best suited for the location.

Disadvantages

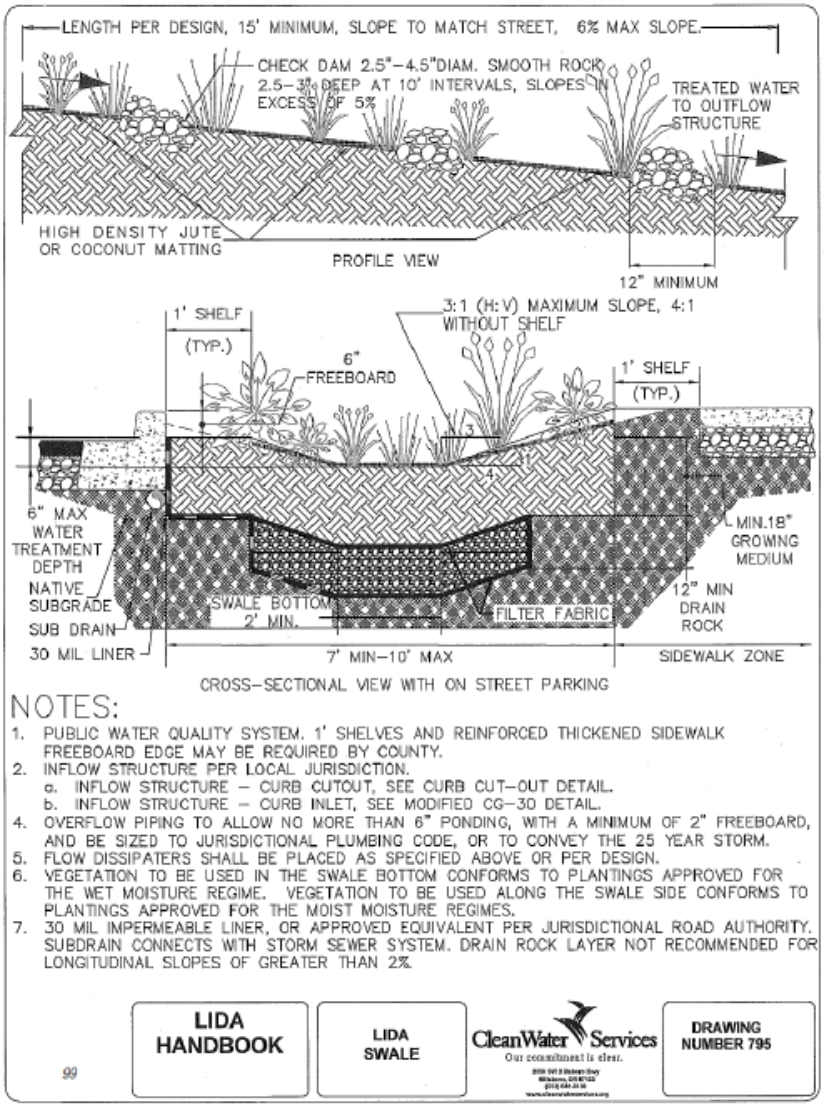
- Have limited hydrologic performance.
- Porous material must be maintained regularly.
- Trees may not fit with overhead power lines.
- Generally not compatible with the look of residential areas.
- Potential for trees to outgrow the box due to abundant watering

Bioswales

Bioswales are vegetated swales that are designed to remove silt and pollutants. When incorporated into a street or roadway design, they are typically shallow (less than 2-feet in most cases) swales with vegetation specifically selected to slow the rate of runoff. They may include under drain systems such as porous media or a small pipe system (similar to French drains). If an underdrain system is used, they typically require a geo-fabric and graded porous layer(s).

Advantages

- There is a defined storage volume available to control ponding locations. Typical storage expected for Darling Street is 9-inches to 1-foot of depth, based on the limited right-of-way available.
- Fit the existing look of the neighborhood with an open ditch drainage system.
- Effective in reduction of pollutants.
- The cost of swales and under drain system should be comparable or less cost than a typical storm sewer system.
- Can have a flexible design that can meet City Design Criteria.



From Low Impact Development Approaches Handbook by Clean Water Services, July 2009

Disadvantages

- The required vegetation height for proper function could be 18-inches tall or more, which could impact accessibility to residences from the street.
- Maintenance of a porous media in addition to pipe system.
- Not typically mowed often, which may not fit resident's expectations?
- May lose effectiveness with multiple driveways and redevelopment activities.
- Repair of other utilities (i.e. water, sewer, power) could damage the bioswale and the effectiveness of the feature.

Porous Pavement

Porous pavement is a permeable pavement surface which allows water to flow through the pavement to an underlying drainage layer and/or an under-drain system. While many manufacturers promote paving blocks backfilled with gravel or other porous media as porous pavement, the pavement discussed here is a concrete or asphalt pavement with less fine particles in the design mix and a more rounded aggregate with gradation to promote porosity.

Advantages

- Reduces the rate of runoff from the street or paved surface.
- Generally provides water quality improvement.
- Application provides a look consistent with existing streets
- Since sidewalks were being added anyway, would not require additional space

Disadvantages

- Installation of mix requires special knowledge or prior experience.
- Performance is tied to quality and effectiveness of the under drain system.
- The presence of and sediment on pavement reduces effectiveness
- High maintenance material requires vacuuming to remove silt and sediment
- Active redevelopment in the area presents the risk of repeated disturbance and possible damage to porous sidewalks
- Water quality benefits not well defined or documented

Several other items were discussed and vetted with the project team. These items included: open graded asphalt and alternative sidewalk materials.

Open Graded Asphalt

Open Graded Asphalt is an asphalt mix with 15 to 25 percent void space. It is primarily used as on overlay course on highways and other roadways. It allows water to drain through the pavement surface either onto the main pavement course or into an under drain system.

Advantages

- Keeps water off surface

- Reduces sound

Disadvantages

- Additional cost for a street section may not be justified
- Maintenance such as vacuuming is needed to keep surface functioning as intended

Alternatives for Sidewalks

The project team discussed several alternatives for sidewalk construction; including porous pavement material, rubber fiber and rubber mat as alternative materials. These materials work well in areas with trees and other vegetation with root systems than need expansive areas. It was determined that the ability of these type features to meet ADA requirements, high maintenance costs if used as part of the LID features in the public right-of-way, uncertain service life and the complexity of LID features it would add to the demonstration and control project were sufficient reasons to remove them from consideration in this project.

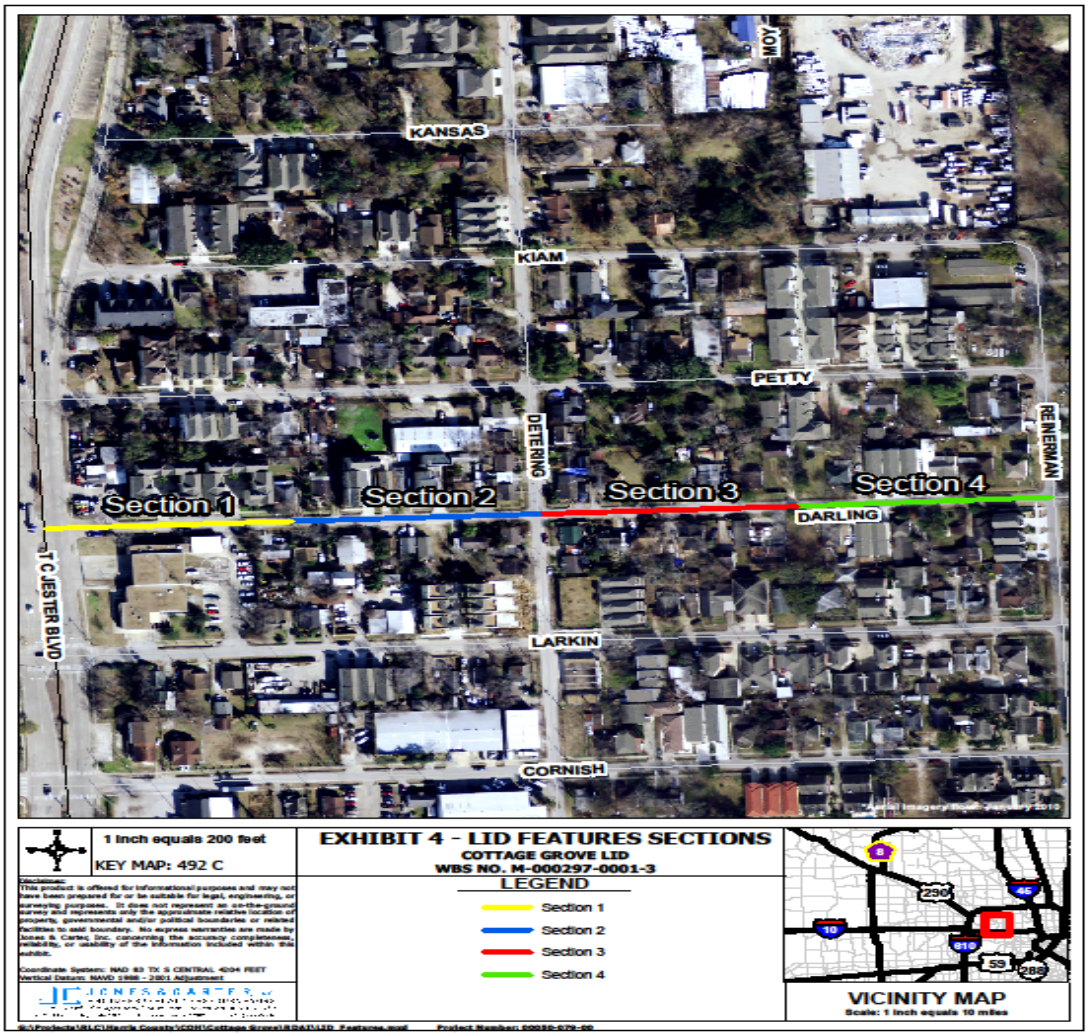
General

Below are project evaluations and recommendations included in the project. These recommendations were reached by applying requirements of the stated design criteria, existing field conditions, objectives and directions of the City, and the LID features that will function in this area. These evaluations combine to form the proposed design parameters for Final Design.

LID Features

The recommended design for LID features on Darling Street include a standard 28-foot (28') wide pavement section with 5-foot (5') sidewalks on both sides of the street. The pavement will narrow with modified curb at the intersections to allow for more room for rain gardens at these locations. Based on the drainage area plan for the Cottage Grove Subdivision, there are drainage breaks near mid-block between T.C. Jester Boulevard and Detering Street and another break near mid-block between Detering Street and Reinerman Street. These drainage breaks allow for four (4) logical break points in LID features proposed along Darling Street as follows

- Section 1 - From T.C. Jester Boulevard east to mid-block.
- Section 2 – From mid-block east to Detering Street.
- Section 3 – From Detering Street east to mid-block.
- Section 4 – From mid-block east to Reinerman Street

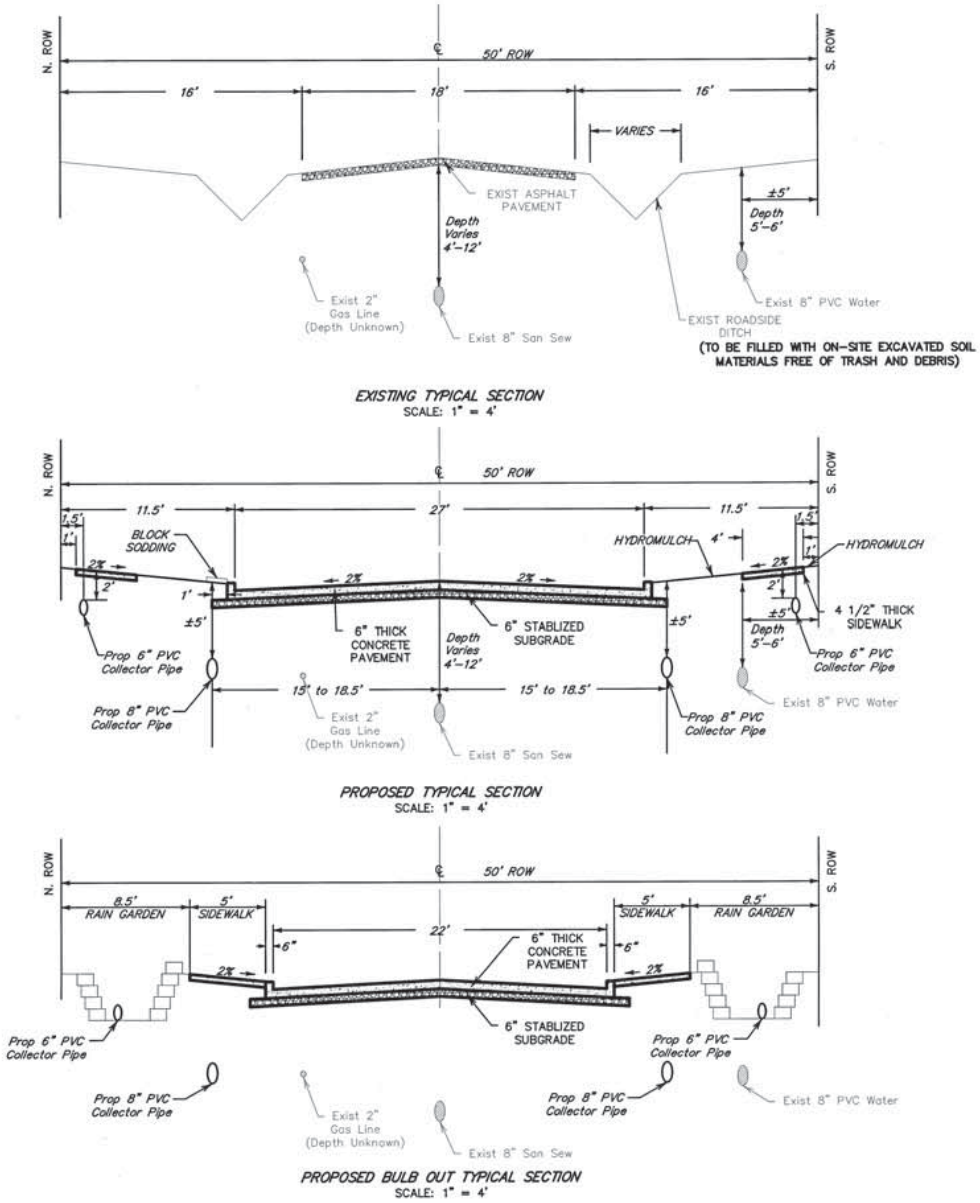


With the urban look at T.C. Jester Boulevard near the fire station it was determined that Section 1 is a prime location for tree box features. Section 2 and 3 are very conducive to rain gardens in the proposed modified curbs at Detering Street and Darling Street. Section 4 has a number of closely spaced driveways that are more conducive to tree box features, but with a bulb-out at Reinerman to allow a rain garden feature.

This provides for a layout that begins with tree box features at the TC Jester to mid-block transitioning to bioswales and rain gardens through mid-block between Detering and Reinerman and ending with rain gardens at the Darling and Reinerman Street. This layout allows sufficient LID features without creating an over complicated matrix of features that could not easily be monitored or compared for their effectiveness.

Roadway Section Design

The recommended roadway section for Darling Street is generally a 28-foot (28') wide back-of-curb to back-of-curb reinforced concrete section with curb and gutter. At the intersection of Darling Street and Detering Street, modified curb was constructed on all four corners to narrow the pavement width to 23 feet (23') back-of-curb to back-of-curb. At the intersection of Darling Street and Reinerman Street, modified curb was constructed on the northwest and southwest corners. As discussed previously, this allowed for more room to construct a LID feature, such as a rain garden. The modified curb also acts as a traffic calming device and shortens the distance a pedestrian has to travel to cross the street.



Before construction, many residents and visitors parked along the street, often partially within the roadside ditch. The wider pavement section will allow for on-street parking while providing adequate width for traffic flow.

Drainage

The LID features are an integral part of the drainage facilities. The existing storm sewer along T.C. Jester Boulevard will be utilized for Section 1. The existing storm sewer along Reinerman Street will be utilized for Section 4. Sections 2 and 3 drain towards Detering Street, which previously had no underground storm sewer. A storm sewer was installed along Detering Street from Darling Street to the existing storm sewer along Kiam Street. This storm sewer is shown as a storm sewer line in the construction plans for T.C. Jester Boulevard, so constructing the Detering Street storm sewer is consistent with the original drainage plan for the area. The Detering Street storm sewer offers two main advantages:

- It would provide sufficient depth to drain the LID features in which he LID features proposed for this area typically need at least three to four feet (3'-4') of depth to function properly.
- It would intercept runoff from areas south of Darling Street.

One of the main goals of the overall project is to determine if the LID features function well enough to be used in other areas. After construction, runoff from Darling Street will be measured and compared with the runoff from the Pre Construction Data.

Floodplain

According to the Harris County Flood Control District's Flood Education Mapping Tool, the project is within 0.2% (500-year) Floodplain, defined as floodplain is an area at risk for flooding from a bayou, creek or other waterway overflowing during a 0.2% (500-year) flood. Since Darling Street is not in the 100-year floodplain, we do not anticipate any impacts to the floodplain as a result of the construction.

Property Acquisition

The City did not acquire property as part of this project. All improvements was made within the established right-of-way.

Estimated Construction Cost

The below table is the preliminary estimated construction cost.

Cottage Grove LID Demonstration Project	Estimate Construction Cost (ECC)	20% Contingency	Final ECC
Storm	$ 81,635	$ 16,327	$ 97,962
Paving	$ 518,280	$ 103,656	$ 621,936
Water	$ 83,075	$ 16,615	$ 99,690
Wastewater	$ 5,400	$ 1,080	$ 6,480
LID Features	$ 204,290	$ 40,858	$ 245,148
Total ECC	$ 892,680	$ 178,536	**$ 1,071,216**

Task Summary

A synopsis of the project is listed on the following pages as it was outlined by task in the Grant. Where discussion is warranted a paragraph will follow the project activities description.

Task 1: Project Management

Objective: To effectively administer, coordinate and monitor all work performed under this project including technical and financial supervision and preparation of status reports. To

effectively administer, coordinate and monitor all work performed under this project including technical and financial Supervision and preparation of status reports.

The City provided technical and fiscal oversight of the City project staff and / or subgrantee(s) / subcontractor(s) to ensure Tasks and Deliverables are acceptable, and are completed as scheduled and within budget. The City Public Works and Engineering, Engineering and Construction Division was designated to oversee the Grant for compliance.

Task 2: Public Outreach

Objective: To develop an information and communication process that informs the public. The process will be used to enhance partnerships with stakeholders, foster a public understanding of project goals and objectives, and encourage participation in maintaining appropriate BMPs. The process also helped the public achieve a better understanding of land use activities and their impact on water quality.

Communication Plan

Public Outreach was governed by the Communication Plan prepared by the City. The Goal was to develop an information and communication process that informs the public. The process was used to enhance partnerships with stakeholders, foster public understanding of the project goals and objectives and encourage participation in maintaining appropriate BMPs. The process also helped the public achieve a better understanding of land use activities and their impact on water quality. To accomplish this goal the City engaged stakeholder participation by facilitating Public Outreach Meetings, posting updates and pertinent status information on the City's website. The City's Process identifies groups: Stakeholders Group (Public/Private entities in the community) and Focus Group (Public/Private Partnerships for the project).

Stakeholder / Focus Group Participation:

The City hosted several stakeholder / Focus Group meetings. Attendees included the Council Member, neighborhood representatives and Association Conferences. The meetings gave the attendees an opportunity to ask questions and become informed on the BMP's. The meetings often included a Power Point presentation with the aid of renderings to provide hands on visual layout of the project.

- April 15, 2009 – Focus Group Meeting, HCEC, presented by Richard Chapin, City
- February 22, 2011 – Stake Holder Meeting presented by Richard Chapin, City
- April, 29, 2013 – Stake Holder Meeting presented by Cheryl Harris, City

Public Outreach: The City added a summary of the Cottage Grove project on the website, http://www.greenhoustontx.gov/). The goal was to inform and educate the public on BMP development and the City's commitment to water quality for future use.

Task 3: Water Quality Study Plan

This study plan proposed water quality monitoring for the implementation of LID Best Management Practices (BMPs) to reduce Non-Point Source (NPS) pollution in a redeveloping area of one of the City urban watersheds that has been identified as impaired for bacteria. The project will document the water quality benefits of the LID features through collection of storm water quality data prior to and after redevelopment, establish and conduct a scheduled maintenance program for each BMP and document and assess the construction costs and annual operation/maintenance costs for the LID BMPs for possible city-wide application in public construction and private development.

The Water Quality Study Plan identified the following:

Sampling Equipment and Methods: Samples are being collected by Rice University field staff and transferred to the City laboratory for analyses. Sampling information (e.g. site location, date, time, etc.) is used to generate a unique sampling event in an interim database built on an auto generated alphanumeric key field. Measurements from both the field data sheets and laboratory data sheets are manually entered (by field and laboratory staff, respectively) into the interim database for their corresponding event. Customized data entry forms will facilitate accurate data entry. Field data will be collected using a multi-probe sensor for field tests and a handheld flow meter for flow measurements in the outfall pipes. The method of collection is manual grab samples. The samples are being collected throughout the runoff events, at designated time intervals to establish event concentration mean of inflow and outflow concentrations within the BMPs. Samples will be taken at the time intervals at the inflow portion of the BMP and the outflow pipe in the

sampling well. Comparison of the concentrations of pollutant between the inflow and outflow will yield an effectiveness ratio for each BMP for each constituent, shown in the equation below.

Reduction of pollutant loads will be calculated in a straight forward method, as follows:

$$Reduction = (1 - {C_{out}}/{C_{in}}) * 100$$

Where C_{out} is the concentration of contaminant leaving Darling Street at the end of the BMP train, and C_{in} is the concentration of contaminant at the start of the BMP train on Darling Street.

Sampling Time Periods: The study was designed to collect data representative of long-term storm water quality conditions. Data collection was planned to extend over at least two seasons (to include inter-seasonal variation in storm patterns) and over two years (to include inter-year variation) and include some data collected during an index period (March 2014 - October 2014). However due to very dry weather conditions and some unforeseen design and construction delays, the City was unable to achieve the two year monitoring period as planned. Sampling events are dependent on rainfall; the sampling time window is currently Monday through Friday during lab business hours. Any rainfall event that falls out of this window will not be sampled.

Analytical Methods: Redeveloping urban areas increase the amount of impervious cover which increases the volume and peak flow of storm water runoff and the associated pollutants. The pollutants that are likely to be found in urban runoff will be analyzed during this study. These pollutants may include sediment, nutrients, oxygen-demanding substances, pathogens, and toxic materials. The pollutants being analyzed by the laboratory and field measurements include the following: pH, Total Suspended Solids (TSS), Total Phosphorous, Orthophosphate, Nitrate/Nitrite, Ammonia, Conductivity, Turbidity, flow rate, and E. coli Most Probable Number (MPN). Roads and parking lots are major sources of sediment, trash, hydrocarbons and the heavy metals, copper, zinc, and lead. Residential lawns, parks and golf courses can be a significant source of sediment, fertilizer, pesticide, and pathogens. The LID BMPs chosen for this study are

control measures that will mitigate changes to both quantity and quality of urban runoff typical in areas with significant increases in impervious cover.

EMCs will be calculated for this study using the following formula:

$$EMC = \Sigma(Q_i*C_i*T_i)/\Sigma(Q_i*T_i)$$

Where:

Q_i = Discharge flow rate at time i
C_i = Concentration of constituent at time i
T_i = Duration of time from previously collected sample

Additionally, the peak flow rate will be determined from the highest flow rate measured during the sampling event.

Task 4 Quality Assurance Project Plan (QAPP) Development and Data Collection

Objective: To develop and implement a plan to collect storm water volume and quality data for the existing condition (pre-construction) and storm water volume and quality data after construction of BMPs (post-construction) sufficient to meet the objectives developed under Objective 3 – to determine the effects of BMP installation and maintenance on storm water volume and quality for a two year period following construction.

Purpose of QAPP: The purpose of this QAPP is to clearly define the City's QA policy, management structure, and procedures which will be used to implement the QA requirements necessary to verify and validate the surface water quality data collected. The QAPP is reviewed by the TCEQ to help ensure that data generated for the purposes described above are scientifically valid and legally defensible. This process will ensure that all data submitted to SWQMIS have been collected and analyzed in a way that guarantees their reliability and therefore can be used in programs deemed appropriate by the TCEQ.

The water quality pollutants to be analyzed in this study include suspended solids, nitrate, phosphorus, and E. coli. In order to estimate load reductions resulting from the installed

practices, pre-construction and post-construction monitoring data will be compiled and evaluated. This data will be used to determine the effectiveness of the installed BMPs. Storm water flow and quality data for existing and post-construction conditions will also be collected via grab samples to determine the effects of BMP installation and maintenance on storm water volume and quality prior to construction. Pre-Construction data was entered into SWQMIS.
The post construction data is yet to be determined.

Task 5: BMP Design and Sub-Contractor Selection

Objective: To design the reconstruction of two blocks in the Cottage Grove area utilizing LID technologies (e.g., vegetative swales, porous pavement/parking and porous sidewalk) to achieve reductions in urban NPS pollutants and improve water quality in the White Oak Bayou watershed.

Jones & Carter, Inc. was authorized by the City to supply qualified professional engineering services for the preliminary design, final design and construction phase services of the White Oak Bayou Cottage Grove Subdivision LID Demonstration Project.

The Project consultant team consisting of Jones & Carter, Inc., Watearth, Inc., HVJ Associates, Inc., Berg-Oliver Associates, Inc., and KGA / DeForest Design, L.L.C.

Jones & Carter, Inc. is being assisted by the firm of Watearth, Inc., which is providing technical knowledge of LID features and hydrology and hydraulics modeling of the proposed features. Also Rice University Department of Civil and Environmental Engineering, in particular Dr. Philip Bedient and his graduate assistants provided a sounding board for the LID features during design.

Task 6 BMP Construction

Objective: To complete the construction of the street and storm water LID BMPs and test the effectiveness of BMPs in decreasing potential constituent sources. Construct several types of BMPs (tree boxes and rain gardens) along two blocks (draining 5.17 acres) in the Cottage Grove subdivision to test the effectiveness and long term maintenance needs of the BMPs.

The City Advertised for Bid Solicitation on April 19, 2013. The Construction schedule was 135 Days. The Pre-Bid Meeting was held at the City on April 30, 2013. Due to the construction of the LID features TCEQ and the City agreed upon a mandatory Pre-Bid Meeting.
On May 9, 2013, the City opened Bids. The Low Bidder was Metro City Construction, L.P. with a bid of $1,675,737.50 which was 4.78% below the Engineers Estimate Construction Cost of $1,759,780.70.

The City proceeded with the recommendation to award the contract to the Low Bidder and issued a Notice of Intent to Award on May 14, 2013. City Council Passed an Ordinance to enter in to the Construction Contract with Metro City Construction June 19, 2013, for the construction of White Oak Bayou Cottage Grove Subdivision LID Demonstration Project.

Construction Phase:

The Contractor received Notice to Proceed on January 6, 2014 with a duration time of 135 days. There were several delays and unforeseen issues during construction. Substantial Completion

Construction Placement of the Tree Box

Construction Placement of the Tree Box

was granted to the Contractor on October 9, 2014 approximately 150 days over schedule. Some of the delays were due to unexpected utility relocations, driveway adjustments, traffic control re-design/relocation of LID features that were impacted by private development and long lead delivery of the Tree Boxes.

Construction Placement of the Tree Box

Construction Placement of the Tree Box

Above is a Rain Gardens at the Northwest intersection of Darling and Detering Street

Above is a Rain Gardens at the Southwest intersection of Darling and Detering Street and Below is a Rain Garden Northwest Corner of Darling Street and Reinerman Street

Above and below are Tree Boxes at the Westside of Darling Street

Task 7: BMP Performance Evaluation

Objective: To estimate pollutant load reductions resulting from the installed practices. Compile and evaluate the pre-construction and post construction monitoring data and apply the research design to determine the effectiveness of the installed BMPs, particularly in regard to pollutant load reductions. The BMPs will also be evaluated in regard to maintenance feasibility, life cycle cost, neighborhood impacts and public acceptance, and an assessment of city-wide application of the BMPs in public construction and private development.

Data Compilation –

The city conducted pre construction of the project area for storm water quality data. The results are recorded in the TCEQ database. Due to the delay in the completion of the construction and pending favorable rain event, the post data is still pending. The City is committed to compiling the data and evaluating the results. The Contractor as part of his contract will continue to maintain the LID features in accordance with the maintenance plan. The city will be able to evaluate the cost effectiveness of maintaining both LID features in an urban environment.

Task 8: Final Report

Objective: To provide the TCEQ and the EPA with a comprehensive report on the activities and success of the pilot project conducted by the City during the course of this project. The City will also conduct an assessment of the data for this report.

Summary

Section 319 of the Clean Water Act provides grant funding to help states and localities to reduce nonpoint source pollution of public waterways. Nonpoint source pollution is produced by diffuse sources, such as storm water that drains from parking lots and yards, which may be contaminated with petroleum substances, fertilizer, pesticides and bacteria.

The Nonpoint Source Management Program supports a wide variety of activities including education, demonstration projects, and monitoring to assess the success of specific projects that potentially prevent or reduce nonpoint source pollution. The Texas Commission on Environmental Quality (TCEQ) administers these reimbursement grants for the EPA.
This NPS Grant provided the City of Houston with the opportunity to participate in a program that supports activities including education, demonstration projects, monitoring and the evaluation of BMPs that prevent or reduces pollutants entering the waterways.

The Cottage Grove Demonstration Project is projected to have impacts not only on the selected two block project area but throughout the City in terms of the application of LID features in other projects. The project's goal was to install and evaluate the effectiveness of the LID within an urban and redeveloping area. Although this project was only able to install and evaluate two LID features, due to existing conditions, this may expand into the evaluation of other BMPs such as porous pavement, sidewalks, alternative pavers and others. The success of Cottage Grove will be measured by effectiveness, durability, and feasible O&M. If proven feasible the list of LIDs in the City of Houston Design Standards may be expanded to include Tree Boxes and Rain Gardens and made available for application to new construction and other city projects. The City will also begin to incorporate LID features in its Capital Improvement Projects. At this time the City has two other major projects with LID features and is using some of the design and O&M ideas from Cottage Grove.

Darling Street Before

Darling Street After