White Oak Bayou BMP Demonstration Project – Cottage Grove Subdivision Quality Assurance Project Plan

City of Houston,
Department of Public Works and Engineering
Houston, Texas 77251-1562

Funding Source:

Nonpoint Source Protection Program CWA §319(h)
Prepared in cooperation with the Texas Commission on Environmental Quality
and the U.S. Environmental Protection Agency
Federal ID #99614614

Effective Period: One year from date of final approval

Questions concerning this quality assurance project plan should be directed to:

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611 Walker, Houston, TX 77002
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A1 APPROVAL PAGE

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Monitoring Division

Sharon Coleman, Acting QA Manager Date

Kyle Girten, Lead NPS QA Specialist Date
Quality Assurance Team

Water Quality Planning Division

Kerry Neimann, Team Leader Date
Nonpoint Source Program

Nancy Ragland, Team Leader Date
Data Management and Analysis

Anju Chalise, NPS QA Specialist Date
Nonpoint Source Program

Bill Carter, TCEQ NPS Project Manager Date
Project Manager, Nonpoint Source Program

City of Houston

Cheryl Harris, Sr. Project Manager Date
Storm Water Engineering

Gabriel Mussio, QA Officer Date
Energy and Environmental Management

City of Houston, Water Quality Laboratory

Dr. Ying Wei, Laboratory Manager Date

Dr. S. Thakur, Laboratory QA Officer Date

A1 APPROVAL PAGE

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

Monitoring Division

10/14/2012
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11/14/12
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11/13/12
Anju Chalise, NPS QA Specialist Date
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11/12/2012
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City of Houston

11/5/2012
Cheryl Harris, Sr. Project Manager Date
Storm Water Engineering

11/5/12
Gabriel Mussio, QA Officer Date
Energy and Environmental Management

City of Houston, Water Quality Laboratory

11/8/12
Dr. Ying Wei, Laboratory Manager Date

11/8/12
Dr. S. Thakur, Laboratory QA Officer Date

The City of Houston will secure written documentation from additional project participants (e.g., subcontractors, laboratories) stating the organization's awareness of and commitment to requirements contained in this quality assurance project plan and any amendments or revisions of this plan. The City of Houston will maintain this documentation as part of the project's quality assurance records. This documentation will be available for review. Copies of this documentation will also be submitted as deliverables to the TCEQ NPS Project Manager within 30 days of final TCEQ approval of the QAPP.

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A3 DISTRIBUTION LIST

The TCEQ QA Specialist will provide original versions of this project plan and any amendments or revisions of this plan to the TCEQ Project Manager and the City of Houston Project Manager. The TCEQ NPS Project Manager will provide copies to the TCEQ Data Management and Analysis Team Leader and EPA Project Officer within two weeks of approval. The TCEQ Project Manager will document receipt of the plan and maintain this documentation as part of the project's quality assurance records. This documentation will be available for review.

Nancy Ragland, Team Leader
Data Management and Analysis
MC-234
(512) 239-6546

U.S. Environmental Protection Agency Region 6
State/Tribal Section
1445 Ross Avenue
Suite # 1200
Dallas, TX 75202-2733
Leslie Rauscher, Project Officer
(214) 665-2773

The City of Houston will provide copies of this project plan and any amendments or revisions of this plan to each project participant defined in the list below. The City of Houston will document receipt of the plan by each participant and maintain this documentation as part of the project's quality assurance records. This documentation will be available for review.

City of Houston
611 Walker
Houston, TX 77020
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(832) 395-2284

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(832)-393-8079

Dr. Ying Wei, Laboratory Supervisor

(832)395-6012Dr. Shuba Thakur, Laboratory Quality Assurance Officer
(832)395-6010
Rice University
Dr. Phil Bedient
Rice University, Field Supervisor
(713) 348-4953

List of Acronyms *Edit and/or expand this list as appropriate*

AWRL	Ambient Water Reporting Limit
BMP	Best Management Practice
CAP	Corrective Action Plan
COC	Chain of Custody
CWA	Clean Water Act
DOC	Demonstration of Capability
DMP	Data Management Plan
DMRG	Data Management Reference Guide
DM&A	Data Management and Analysis
DQO	Data Quality Objective
EMC	Event Mean Concentration
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPS	Global Positioning System
IT	Information Technology
LCS	Laboratory Control Sample
LCSD	Laboratory Control Sample Duplicate
LID	Low Impact Development
LOD	Limit of Detection
LOQ	Limit of Quantitation
MS	Matrix Spike
NELAC	National Environmental Laboratory Accreditation Conference
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PM	Project Manager
PO	Project Officer
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manual
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
QMP	Quality Management Plan
RPD	Relative Percent Difference
SLOC	Station Location
SOP	Standard Operating Procedure
SWQM	Surface Water Quality Monitoring
SWQMIS	Surface Water Quality Monitoring Information System
TCEQ	Texas Commission on Environmental Quality
TKN	Total Kjeldahl N
TMDL	Total Maximum Daily Loads
TSS	Total Suspended Solids
TSWQS	Texas Surface Water Quality Standards
WQI	Water Quality Inventory

A4 PROJECT/TASK ORGANIZATION

TCEQ

Monitoring Division

Kyle Girten
Lead NPS QA Specialist

Assists the TCEQ Project Manager in QA related issues. Serves on planning team for NPS projects. Participates in the planning, development, approval, implementation, and maintenance of the QAPP. Determines conformance with program quality system requirements. Coordinates or performs audits, as deemed necessary and using a wide variety of assessment guidelines and tools. Concurs with proposed corrective actions and verifications. Monitors corrective action. Provides technical expertise and/or consultation on quality services. Provides a point of contact at the TCEQ to resolve QA issues. Recommends to TCEQ management that work be stopped in order to safe guard project and programmatic objectives, worker safety, public health, or environmental protection.

Water Quality Planning Division

Kerry Niemann, Team Leader
NPS Program

Responsible for management and oversight of the TCEQ NPS Program. Oversees the development of QA guidance for the NPS program to be sure it is within pertinent frameworks of the TCEQ. Monitors the effectiveness of the program quality system. Reviews and approves all NPS projects, internal QA audits, corrective actions, reports, work plans, and contracts. Enforces corrective action, as required. Ensures NPS personnel are fully trained and adequately staffed.

Bill Carter
TCEQ NPS Project Manager

Maintains a thorough knowledge of work activities, commitments, deliverables, and time frames associated with projects. Develops lines of communication and working relationships between the contractor, the TCEQ, and the EPA. Tracks deliverables to ensure that tasks are completed as specified in the contract. Responsible for ensuring that the project deliverables are submitted on time and are of acceptable quality and quantity to achieve project objectives. Serves on planning team for NPS projects. Participates in the development, approval, implementation, and maintenance of the QAPP. Assists the TCEQ QAS in technical review of the QAPP. Responsible for verifying that the QAPP is followed by the contractor. Notifies the TCEQ QAS of particular circumstances which may adversely affect the quality of data derived from the collection and analysis of samples. Enforces corrective action.

Anju Chalise
NPS Quality Assurance Specialist

Assists Lead QAS with NPS QA management. Serves as liaison between NPS management and Agency QA management. Responsible for NPS guidance development related to program quality assurance. Serves on planning team for NPS projects. Participates in the development, approval, implementation, and maintenance of the QAPP.

Rebecca Ross
NPS Data Manager

Responsible for coordination and tracking of NPS data sets from initial submittal through NPS Project Manager review and approval. Ensures that data is reported following instructions in the Surface Water Quality Monitoring Data Management Reference Guide (January 2012, or most current version). Runs automated data validation checks in SWQMIS and coordinates data verification and error correction with NPS Project Managers' data review. Generates SWQMIS summary reports to assist NPS Project Managers' data reviews. Provides training and guidance to NPS and Planning Agencies on technical data issues. Reviews QAPPs for valid monitoring stations. Checks validity of parameter codes, submitting entity code(s), collecting entity code(s), and monitoring type code(s). Develops and maintains data management-related standard operating procedures for NPS data management. Serves on planning team for NPS projects.

City of Houston

Cheryl Harris
City of Houston, Department of Public Works & Engineering, Project Manager

Responsible for ensuring tasks and other requirements in the contract are executed on time and are of acceptable quality. Monitors and assesses the quality of work. Coordinates attendance at conference calls, training, meetings, and related project activities with the TCEQ. Responsible for verifying the QAPP is followed and the project is producing data of known and acceptable quality. Ensures adequate training and supervision of all monitoring and data collection activities. Complies with corrective action requirements.

Responsible for the acquisition, verification, and transfer of data to the TCEQ. Oversees data management for the study. Performs data quality assurances prior to transfer of data to TCEQ. Responsible for transferring data to the TCEQ in the acceptable format. Ensures data are submitted according to work plan specifications. Provides the point of contact for the TCEQ Data Manager to resolve issues related to the data.

Gabriel Mussio
City of Houston, Energy and Environmental Management Division, QAO

Responsible for coordinating development and implementation of the QA program. Responsible for writing and maintaining the QAPP. Responsible for maintaining records of QAPP distribution, including appendices and amendments. Responsible for maintaining written records of sub-tier commitment to requirements specified in this QAPP. Responsible for identifying, receiving, and maintaining project quality assurance records. Responsible for coordinating with the TCEQ QAS to resolve QA- related issues. Notifies the contractor Project Manager and TCEQ Project Manager of particular circumstances which may adversely affect the quality of data. Responsible for validation and verification of all data collected according with Table 4 procedures and acquired data procedures after each task is performed. Coordinates the research and review of technical QA material and data related to water quality monitoring system design and analytical techniques. Conducts laboratory inspections. Develops, facilitates, and conducts monitoring systems audits.

Dr. Ying Wei
Laboratory Manager

Responsible for supervision of laboratory personnel involved in generating analytical data for this project. Responsible for ensuring that laboratory personnel involved in generating analytical data have adequate training and a thorough knowledge of the QAPP and all SOPs specific to the analyses or task performed and/or supervised. Responsible for oversight of all operations, ensuring that all QA/QC requirements are met, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates monitoring systems audits.

Dr. Ying Wei
Data Manager

Responsible for the acquisition, verification, and transfer of data to the TCEQ. Oversees data management for the study. Performs data quality assurances prior to transfer of data to TCEQ. Responsible for transferring data to the TCEQ in the Event/Result file format specified in the DMRG. Ensures data are submitted according to workplan specifications. Provides the point of contact for the TCEQ Data Manager to resolve issues related to the data.

Dr. Shuba Thakur
Laboratory QAO

Monitors the implementation of the QAM and the QAPP within the laboratory to ensure complete compliance with QA objectives as defined by the contract and in the QAPP. Conducts internal audits to identify potential problems and ensure compliance with written SOPs. Responsible for supervising and verifying all aspects of the QA/QC in the laboratory. Performs validation and verification of data before the report is sent to the contractor. Insures that all QA reviews are conducted in a timely manner from real-time review at the bench during analysis to final pass-off of data to the QA officer.

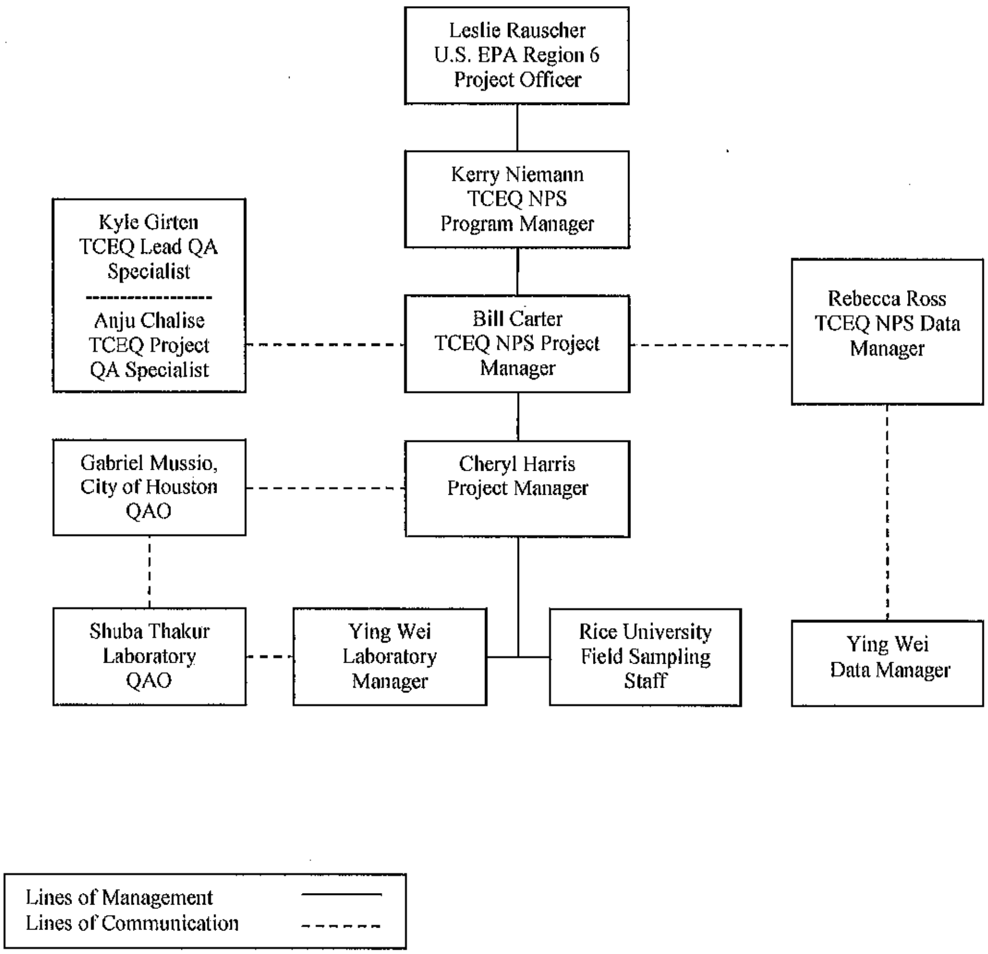
Dr. Phil Bedient
Rice University, Field Supervisor

Responsible for supervising all aspects of the sampling and measurement of surface waters and other parameters in the field. Responsible for the acquisition of water samples and field data measurements in a timely manner that meet the quality objectives specified in Section A7 (Table A.1), as well as the requirements of Sections B1 through B8. Responsible for field scheduling, staffing, and ensuring that staff is appropriately trained as specified in Sections A6 and A8.

U.S. EPA Region 6
Leslie Rauscher
EPA Project Officer

Responsible for managing the CWA Section 319 funded grant on the behalf on EPA. Assists the TCEQ in approving projects that are consistent with the management goals designated under the State's NPS management plan and meet federal guidance. Coordinates the review of project work plans, draft deliverables, and works with the State in making these items approvable. Meets with the State at least semi-annually to evaluate the progress of each project and when conditions permit, participate in a site visit on the project. Fosters communication within EPA by updating management and others, both verbally and in writing, on the progress of the State's program and on other issues as they arise. Assists the regional NPS coordinator in tracking a State's annual progress in its management of the NPS program. Assists in grant close-out procedures ensuring all deliverables have been satisfied prior to closing a grant.

Figure A4.1. Organization Chart - Lines of Communication



A5 PROBLEM DEFINITION/BACKGROUND

The White Oak Bayou watershed was identified as impaired for bacteria by TCEQ in the 2008 Texas Water Quality Inventory and 303(d) List. The Texas Coastal Nonpoint Source Pollution Control Program identifies urban pollution as the source of 43--85 percent 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 Whiteoak Bayou TMDL, the entire watershed is more than 50 percent impervious cover. The International Stormwater Database (www.bmpdatabase.org) has limited information describing the performance of porous pavement BMPs. The database does not characterize influent concentrations for porous pavement or provide any information regarding the effectiveness of porous pavement to reduce/remove bacteria. There is a need for more qualified data on the performance of porous paving for bacteria removal from runoff, particularly in an urban redevelopment context. The White Oak Bayou BMP Demonstration Project will construct porous pavement, bioswales, and filter tree boxes in a redeveloping sub-area of the City of Houston's (City) urban watershed. The project will evaluate 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 to preserve BMP objectives, and documenting findings in a final report. The project fulfills NPS Management Program long term goals to focus abatement efforts in watersheds (White Oak Bayou) identified as impaired by NPS pollution, to support local programs to prevent NPS pollution, and to support implementation of local programs to reduce NPS pollution. The project also develops partnerships and relationships to facilitate collective, cooperative approaches to manage NPS pollution and increase overall public awareness of NPS issues and prevention activities. This QAPP addresses the program developed between the City of Houston and the TCEQ to carry out the activities associated with this project.

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 project is located in an urban area of the City described as Cottage Grove subdivision. 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. The nonpoint pollutant sources that will be addressed by this project are described as runoff from urban and developing areas. Urban runoff may include significant loadings of nutrients, oxygen-demanding substances, pathogens, and toxic materials. Section 5.2 of the Texas Coastal NPS Pollution Control Program identifies runoff from urban land areas as "generating the highest loadings of NPS pollution to Galveston Bay." The report estimates that 43 percent of total NPS sediment loadings, 55--65 percent of NPS nutrient loadings, and over 85 percent of all the fecal coliform, pesticides, and oil and grease are from local NPSs of pollution. Subcategories of urban sources of NPS pollution that will be addressed include urban runoff (5.2.1.1), runoff from construction activities (5.2.1.2), and runoff from roads and bridges (5.2.1.4).

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 their infancy 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.

(Holman-Dodds, 2003; Williams, 2006; Harrell, 2003; Goff, 2006; Li, 2011; Brander, 2004).[1] LID design concepts utilize an integrated approach to stormwater management to maintain the hydrologic functions of storage, infiltration, as well as the volume and frequency of discharges. In addition to effectively managing stormwater and reducing runoff, infiltration-based development may also increase recharge of local ground water aquifers and streams, reduce erosion and stream widening, and improve steam water quality (Coffman, 1999).[2] LID practices have also been reported by the USEPA to be more cost effective and lower in maintenance than conventional, structural stormwater controls (USEPA, 2000).[3]

The project described in this QAPP will implement LID BMPs to reduce NPS pollution for selected locations within the Cottage Grove Subdivision. Street reconstruction of approximately two block lengths will be accomplished. The existing street section provides two narrow travel lanes with parallel open ditch drainage. The existing 50 foot (ft) right of way is not wide enough to accommodate on-street parallel parking or pedestrian sidewalks. The street section will be revised from the existing narrow travel lanes without parking to a one way travel lane with parallel on-street parking and sidewalks. The reconstructed street section(s) will include several LID BMPs.

The goals of this project are as follows:

- Evaluate the effectiveness of LID BMP's to reduce pollutant loadings and runoff volume
- Evaluate the cost of installation of LID BMP's in neighborhoods under redevelopment to townhomes
- Evaluate the ongoing cost of maintenance of LID technologies

If the proposed BMPs are effective for the soil types in Houston/Harris County, the list of existing BMPs in the City of Houston's Design Standards will be expanded to include the studied BMPs which will become available for application to new construction and redevelopment. If these LID technologies are shown to be effective (low maintenance, durable, and competitive construction cost), developers may implement use of these pervious surfaces as a method to offset the increase in impervious area.

The scope of work for this project includes collection of storm water quality data for the existing condition (pre-construction), collection of storm water quality data after construction of BMPs (post-construction), development of

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[1] Holman-Dodds, J. K., Bradley, A. A., & Potter, K. W. (2003). Evaluation of Hydrologic Benefits of Infiltration Based Urban Storm Water Management. *Journal of the American Water Resources Association, 39 (1)*, 205-215; Williams, E., & Wise, W. (2006). Hydrologic Impacts of Alternative Approaches to Storm Water Management and Land Development. *Journal of the American Water Resources Association, 42 (2)*, 443-455; Harrell, L., & Ranjithan, R. (2003). Detention Pond Design and Land Use Planning for Watershed Management. *Journal of Water Resources Planning and Management*, 98-106; Goff, K., & Gentry, R. (2006). Influence of Watershed and Development Characteristics on the Cumulative Impacts of Stormwater Detention Ponds. *Water Resources Management, 20*, 829-860; Li, Q., Cai, T., Yu, M., Lu, G., Xie, W., & Bai, X. (n.d.). Investigation into the impacts of land-use change on runoff generation characteristics in the upper Huaihe River basin, China. *Journal of Hydrologic Engineering*; Brander, K. E., E., O. K., & Potter, K. W. (2004). Modeled Impacts of Development Type on Runoff Volume and Infiltration Performance. *Journal of the American Water Resources Association, 40 (4)*, 961-969.

[2] Coffman, L. (1999). Low Impact Development Design Strategies: An Integrated Design Approach. Maryland, Prince George's County: Department of Natural Resources, Programs and Planning Division.

[3] United States Environmental Protection Agency. (2000). Low Impact Development (LID) A Literature Review. EPA-841-B-00-005.

maintenance activities, preparation of a scheduled maintenance program for each BMP, monitoring of storm water quality and maintenance activities for a two year period following construction, evaluation of construction cost and annual operation/maintenance costs, and documentation of project findings and conclusions in a final report. The project aims to achieve reductions in urban NPS pollutants and improve water quality in the White Oak Bayou watershed. Measures of success (other than pollutant load reductions) that will be considered include evaluation of maintenance feasibility, evaluation of first cost and long term maintenance costs, assessment of neighborhood impacts and public acceptance, and assessment of potential city wide application of BMP technologies for public construction and private development. Innovative features of the project include assessment of maintenance practices to achieve long term BMP effectiveness and evaluations of long term cost feasibility.

The experimental and control sites include two blocks on two different streets within the Cottage Grove Subdivision. The control street is Petty Street and the experimental site is Darling Street. The design of LID features and associated BMP's along Darling Street and implementation and sampling parameters for the site is as follows:

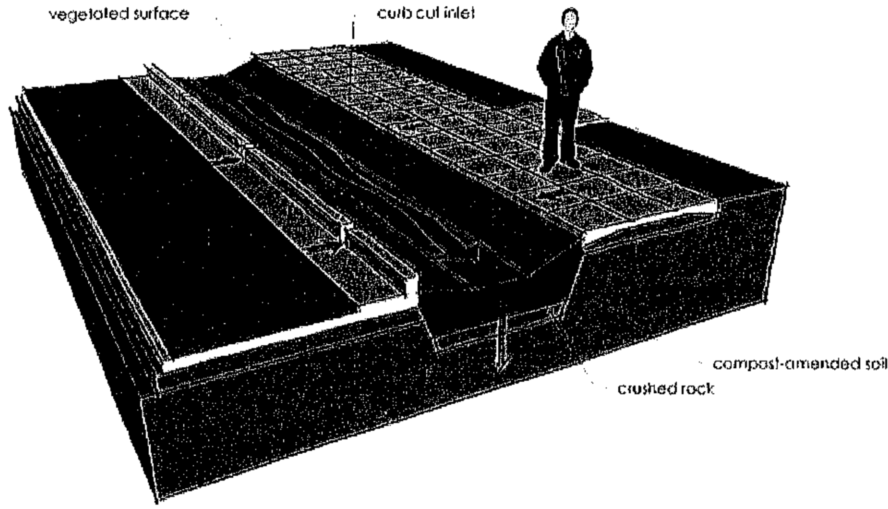
1. Rubber Pavement/Pavers

Rubber pavement or pavers will be placed as a sidewalk for non-road pedestrian use. A good alternative to porous concrete, it is better suited for areas where the soil is clay.

Rubber Pavers: http://www.creative-journeys.com/?p=139

2. Bioswales

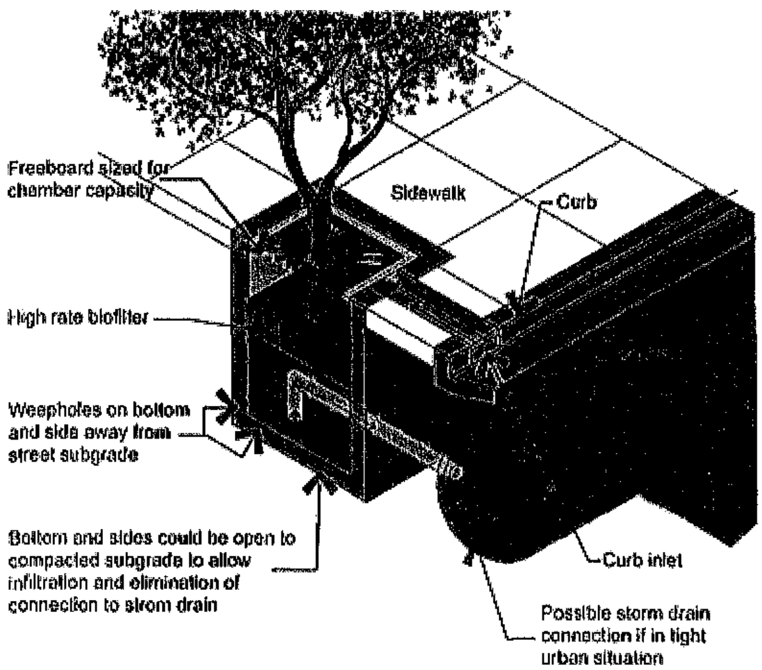
Bioswales, or grass swales, will be constructed along the roadside to collect excess runoff from the pavement. These open channel systems are appropriate for smaller drainage areas and are applicable to a variety of site conditions. They serve as a mechanism to reduce runoff volume through greater infiltration capabilities and also serve to reduce runoff velocity. In addition, bioswales effectively remove pollutants primarily through sedimentation, but also through infiltration and adsorption.



Constructed bioswale (www.greeninfrastructurewiki.com)

3. Tree box filters

Tree boxes are used to collect runoff beneath trees and/or other landscape plants. Stormwater drains into the filter box, infiltrates through a porous media, and flows out of the system through an under drain into the storm drain system or into the surrounding soil. Pollutants in the runoff are removed by the vegetation and soil media, while also irrigating the trees.



Manufactured Tree Box Filters (www.ladstudios.com)

A6 PROJECT/TASK DESCRIPTION

The City of Houston will design the reconstruction of two blocks in the Cottage Grove area (Appendix A and Appendix D) utilizing three LID technologies (vegetative swales, porous pavement, and filter tree boxes) to evaluate reductions in urban NPS pollutants and assess their ability to improve water quality in the White Oak Bayou watershed. 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 and for a two year period following construction.

This implementation assessment project will provide storm water data collection at four water-quality monitoring sites for up to three years. Two sites are located at the outfall of the proposed BMP implementation site at the intersection of Darling and Reinerman Streets, and two sites at the intersection of Darling and Detering Streets. Monitoring sites will be located on the north side of the streets. A second street, Petty Street, will be used as a control site for appropriate comparison purposes. Two monitoring sites will be located at the intersection of Darling and Reinerman Streets and at the intersection of Darling and Reinerman Streets. One monitoring site will be located near the intersection of Darling St. and TC Jester, one at Petty and TC Jester, as well as one at Darling and Reinerman and one at Petty and Reinerman. At each water quality monitoring site, ambient water DO, temperature and conductivity will be monitored. Water samples from each site will also be collected during three to six storm flow events as manual (grab) samples. Samples will be analyzed for TSS, TDS, nitrate and nitrite as N, total phosphorous, and E. coli. Water will be sampled in accordance with the latest version of the TCEQ guidance document, *Surface Water Quality Monitoring Procedures, Volume 1 (RG-415).*

Water quality data will be used to determine the amount of pollutant loads (nitrate/nitrite, phosphorus, E. coli and sediment) that are prevented from entering the White Oak Bayou by operation of the Darling Street LID BMPs. This will be accomplished by first calculating the amount of contaminants in the runoff from Darling Street during storm pulses with the existing land use conditions. Then, the amount of contaminants in the runoff will be calculated during storm pulses after construction of the LID BMPs. This data will be used to evaluate the amount of pollutants prevented from entering White Oak Bayou after the construction of the BMPs. Pollutant loading masses will be determined by taking water samples and measuring flow rate at the sampling locations on Darling and Petty Streets. The masses of nitrate/nitrite, phosphorous, and sediment will be calculated with the following formula:

$$Q * C(N,P,S,E) * T = M(N,P,S,E)$$

Where:

Q = Rate of flow out of the White Oak Bayou BMP demonstration site
C(N,P,S,E) = Concentration of N (nitrate/nitrite), P (phosphorous), S (sediment), or E (E. coli) during storm pulse
T = Duration of time step
M(N,P,S,E) = Mass of contaminant in runoff

The efficiency of the LID BMPs will be evaluated by: 1) computation of absolute load reduction (pre-construction loads – post construction loads) and percent load reduction (pre-construction loads – post construction loads)/pre-construction loads *100 and, 2) comparisons of event mean concentrations (pre-construction EMC – post-construction EMC) on both an event and project period basis.

Water flow will be determined at the weir described below for a specific amount of time (1 minute) at two separate occasions, before the 30 minute time step and at the end of the 30 minute time step. With the height of the water coming from the weir, flow can be determined using the weir equation for this specified weir (see section B1). Instantaneous flow rates will be added through the time steps until the end of the time step. This will give us volume during the time. With this information and concentrations we can find load concentration values by multiplying volume and concentration to get a mass/time value.

See Appendix B for the project-related work plan tasks related to data collection and schedule of deliverables for a description of work defined in this QAPP.

See Section B1 for monitoring to be conducted under this QAPP.

Revisions to the QAPP

Until the work described is completed, this QAPP shall be reissued annually on the anniversary date, or revised and reissued prior to any significant changes being made in activities, whichever is sooner. Reissuances and annual updates must be submitted to the TCEQ for approval at least 90 days before the last approved version has expired. If the QAPP expires, the QAPP is no longer in effect and the work covered by the QAPP must be halted. If the entire QAPP is current, valid, and accurately reflects the project goals and the organization's policy, the annual re-issuance may be done by a certification that the plan is current. This can be accomplished by submitting a cover letter stating the status of the QAPP and a copy of new, signed approval pages for the QAPP. If the QAPP needs to be updated to incorporate amendments made earlier in the year or to incorporate new changes, a full annual update is required. This is accomplished by submitting a cover letter, a document detailing changes made, and a full copy of the updated QAPP (including signature pages).

Amendments

Amendments to the QAPP may be necessary to reflect changes in project organization, tasks, schedules, objectives, and methods; address deficiencies and nonconformances; improve operational efficiency; and/or accommodate unique or unanticipated circumstances. Requests for amendments are directed from the contractor Project Manager to the TCEQ Project Manager in writing using the QAPP Amendment shell. The changes are effective immediately upon approval by the TCEQ NPS Project Manager and Quality Assurance Specialist, or their designees, and the EPA Project Officer (if necessary).

Amendments to the QAPP and the reasons for the changes will be documented, and revised pages will be forwarded to all persons on the QAPP distribution list by the Contractor QAO. Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.

A7 QUALITY OBJECTIVES AND CRITERIA

Only data collected that have a valid parameter code in Table A7.1 will be stored in SWQMIS. Any parameters listed in Table A7.1 that do not have a valid TCEQ parameter code assigned will not be stored in SWQMIS.

The White Oak Bayou BMP Demonstration Project will construct bioswales, rain gardens, and filter tree boxes in a redeveloping sub-area of the City of Houston's (City) urban watershed. The project will evaluate 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 to preserve BMP objectives, and documenting findings in a final report.

Quantitative and qualitative information regarding measurement data needed to measure water quality improvements are provided below.

Table A7.1 Measurement Performance Specifications for BMP Effectiveness Monitoring

PARAMETER	UNITS	MATRIX	METHOD	PARAMETER CODE	AWRL *	Limit of Quantitation (LOQ)	Recovery at LOQ (%)	PRECISION (RPD of LCS/LCSD)	BIAS %Rec. of LCS	Complete-ness (%)
Nitrate/Nitrite – N	mg/l	Water	EPA 300.0	00593	.05	.05	70-130	20	80-120	90
Residue, Total Nonfilterable, TSS	mg/L	Water	SM 2540 D	00530	4	1	NA	20	80-120	90
Total Phosphorus	mg/L	Water	EPA 365.3	00665	.06	.05	70-130	20	80-120	90
E. coli	MPN/100mL	Water	SM 9223-B	31699	1	1	NA	0.5***	NA	90
Rainfall**	inches from storm initiation	Water	NA	46530	NA	NA	NA	NA	NA	90
Instantaneous Flow	cfs	Water	TCEQ SOP, V1	00061	NA	NA	NA	NA	NA	90
Flow Method	NA	NA	TCEQ SOP, V1	89835	NA	NA	NA	NA	NA	90
pH	pH/units	Water	EPA 150.1 and TCEQ SOP, V1	00400	NA	NA	NA	NA	NA	90
DO	Mg/L	Water	SM 4500-O G and TCEQ SOP, V1	00300	NA	NA	NA	NA	NA	90
Specific Conductance	µS/cm	Water	EPA 120.1 and TCEQ SOP, V1	00094	NA	NA	NA	NA	NA	90
Temperature	°C	Water	SM2550 B and TCEQ SOP, V1	00010	NA	NA	NA	NA	NA	90

PARAMETER	UNITS	MATRIX	METHOD	PARAMETER CODE	AWRL *	Limit of Quantitation (LOQ)	Recovery at LOQ (%)	PRECISION (RPD of LCS/LCSD)	BIAS %Rec. of LCS	Completeness (%)
Turbidity, Observed	1-low 2-medium 3-high	Water	TCEQ SOP, V1	88842	NA	NA	NA	NA	NA	90

References: *US EPA Methods for Chemical Analysis of Water and Wastewater*, Manual #EPA-600/4-79-020. American Public Health Association, American Water Works Association and Water Environment Federation, *Standard Methods for the Examination of Water and Waste Water*, 20th Ed., Texas Commission on Environmental Quality *Surface Water Quality Monitoring Procedures*, Volume 1, October 2008.

* The most up-to-date AWRL is located at http://www.tceq.state.tx.us/compliance/monitoring/nps/grants/NPS-QAPP.html

** Rainfall data will be acquired indirectly as radar rainfall and will not be submitted to SWQMIS

*** Based on a range statistic as described in Standard Methods, 20th Edition, Section 9020-B, A Quality Assurance/Quality Control - Intralaboratory Quality Control Guidelines. This criterion applies to bacteriological duplicates with concentrations >10 MPN/100mL or >10 organisms/100mL.

Precision

Precision is the degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. It is a measure of agreement among replicate measurements of the same property, under prescribed similar conditions, and is an indication of random error.

Field splits are used to assess the variability of sample handling, preservation, and storage, as well as the analytical process, and are prepared by splitting samples in the field. Control limits for field splits are defined in Section B5.

Laboratory precision is assessed by comparing replicate analyses of laboratory control samples in the sample matrix (e.g. deionized water, sand, commercially available tissue) or sample/duplicate pairs in the case of bacterial analysis. Precision results are compared against measurement performance specifications and used during evaluation of analytical performance. Program-defined measurement performance specifications for precision are defined in Table A7.1.

Bias

Bias is a statistical measurement of correctness and includes multiple components of systematic error. A measurement is considered unbiased when the value reported does not differ from the true value. Bias is determined through the analysis of laboratory control samples and LOQ Check Standards prepared with verified and known amounts of all target analytes in the sample matrix (e.g. deionized water, sand, commercially available tissue) and by calculating percent recovery. Results are compared against measurement performance specifications and used during evaluation of analytical performance. Program-defined measurement performance specifications for bias are specified in Table A7.1.

Representativeness

Site selection, the appropriate sampling regime, the sampling of all pertinent media according to TCEQ SOPs, and use of only approved analytical methods will assure that the measurement data represents the conditions at the site. We anticipate a minimum of 4 storm events will be sampled per year, contingent on weather patterns. An appropriate storm event is any storm that yields more than 0.1 inches of rainfall and occurs at least 72 hours from the previously measurable (greater than 0.1 inch rainfall) storm event.

Each sampling event will consist of water quality samples collected at each sampling station (BMP outlets and control site outlets) at equal time intervals throughout the entire event. Water quality samples will be collected as grab samples and flow velocity measurements will be calculated. In this manner, representative samples will be collected, which will retain the characteristics of the first flush as well as characteristics from the entire hydrograph. See section B1 for more details about sampling procedures. In order to assess effectiveness of the BMPs, data will be collected for storms of varying size and intensity throughout the year, representing typical conditions of the site.

Completeness

The completeness of the data is basically a relationship of how much of the data is available for use compared to the total potential data. Ideally, 100% of the data should be available. However, the possibility of unavailable data due to accidents, insufficient sample volume, broken or lost samples, etc. is to be expected. Therefore, it will be a general goal of the project(s) that 90% data completion is achieved.

Comparability

Confidence in the comparability of routine data sets for this project and for water quality assessments is based on the commitment of project staff to use only approved sampling and analysis methods and QA/QC protocols in accordance with quality system requirements and as described in this QAPP and in TCEQ SOPs. Comparability is also guaranteed by reporting data in standard units, by using accepted rules for rounding figures, and by reporting data in a standard format as specified in Section B10.

Limit of Quantitation

AWRLs (Table A7.1) are used in this project as the limit of quantitation specification, so data collected under this QAPP can be compared against the TSWQS. Laboratory limits of quantitation (Table A7.1) must be at or below the AWRL for each applicable parameter.

Laboratory Measurement Quality Control Requirements and Acceptability Criteria are provided in Section B5.

Analytical Quantitation

To demonstrate the ability to recover at the limit of quantitation, the laboratory will analyze an LOQ check standard for each batch of samples run.

Laboratory Measurement Quality Control Requirements and Acceptability Criteria are provided in Section B5

A8 SPECIAL TRAINING/CERTIFICATION

Field personnel will receive training in proper sampling and field analysis. Before actual sampling or field analysis occurs, they will demonstrate to the QA officer (in the field), their ability to properly operate the automatic samplers and retrieve the samples. The QA officer will sign off each field staff in their field logbooks.

Global Positioning System (GPS) equipment may be used as a component of the information required by the Station Location (SLOC) request process for creating the certified positional data that will ultimately be entered into the TCEQ's SWQMIS database. Any positional data obtained by Nonpoint Source Program grantees using a Global Positioning System will follow the TCEQ's OPP 8.11 and 8.12 policy regarding the collection and management of positional data.

Positional data entered into SWQMIS will be collected by a GPS certified individual with an agency approved GPS device to ensure that the agency receives reliable and accurate positional data. Certification can be obtained in any of three ways: completing a TCEQ training class, completing a suitable training class offered by an outside vendor, or by providing documentation of sufficient GPS expertise and experience. Contractors must agree to adhere to relevant TCEQ policies when entering GPS-collected data.

In lieu of entering certified GPS Coordinates, positional data may be acquired with a GPS and verified with photo interpolation using a certified source, such as Google Earth or Google Map. The verified coordinates and map interface can then be used to develop a new SLOC.

Contractors and subcontractors must ensure that laboratories analyzing samples under this QAPP meet the requirements contained in TNI Volume 1 Module 2, Section 4.5.5 (concerning Review of Requests, Tenders, and Contracts).

A9 DOCUMENTS AND RECORDS

Laboratory Test Reports

Test/data reports from the laboratory must document the test results clearly and accurately. Routine data reports should be consistent with the TNI standards (Volume 1, Module 2, Section 5.10) and include the information necessary for the interpretation and validation of data. The requirements for reporting data and the procedures are provided.

- Sample results
- Units of measurement
- Sample matrix
- Dry weight or Wet Weight (as applicable)
- Location information
- Date and time of collection
- Sample depth
- LOQ and LOD (formerly referred to as the reporting limit and the method detection limit, respectively), and qualifications of results outside the working ranch (if applicable)
- Certification of NELAC compliance on a result by result basis
- Title of report and unique identifiers on each page
- Name/address of the laboratory
- Name/address of the client
- A clear indication of the sample(s) analyzed
- Date and time of sample receipt
- Identification of method used

- Identification of samples that did not meet QA requirements and why (e.g. holding times exceeded)
- Clearly Identified subcontract laboratory results (as applicable)
- Name/title of person accepting responsibility for the report
- Project-specific quality control results to include field split results (as applicable); equipment, trip, and field blank results (as applicable); and precision, bias, and LOQ check standard results
- Narrative information QC failures or derivation from requirements that may affect the quality of results or is necessary for verification and validation of data

Reports will be consistent with the NELAC standards and should include any additional information critical to the review, verification, validation, and interpretation of data. This should be based on the process that has been worked out with the contractor and is documented in Section D1 and D2 of this document.

The NELAC certified laboratory's process for reporting data or relevant portions of the laboratory's SOP or quality manual will be submitted as a separate file with the QAPP.

Electronic Data

Data will be submitted to the TCEQ in the event/result format specified in the TCEQ Data Management Reference Guide (DMRG; January 2012) for upload to the Surface Water Quality Monitoring Information System (SWQMIS). The Data Review Checklist and Summary as contained in Appendix C of this document will be submitted with the data.

A submitting entity will submit a station location request (SLOC) directly to the TCEQ Data Manager through SWQMIS for each sampling site to obtain a station identification number. If submitting entity does not have access to the SWQMIS, TCEQ Project Manager will assist the submitting entity to get the access. TCEQ Project Manager should be copied on all the correspondence throughout the process. The TCEQ Project Manager will ensure that submitting entity actually requests SLOCS before submitting any data to the TCEQ.

All reported Events will have a unique TagID (see DMRG). A Tag Prefix must be requested from the TCEQ in accordance with the DMRG where the Submitting Entity does not already have one. TagIDs used in this project will be seven-character alphanumerics with the structure of the two-letter Tag prefix followed by a four digit number and ending with the character "N": for example - KI1234N, KI1235N, etc.

Submitting Entity, Collecting Entity, and Monitoring Type codes will reflect the project organization and monitoring type in accordance with the DMRG. The proper coding of Monitoring Type is essential to accurately capture any bias toward certain environmental condition (for example, high flow events). The Project Manager should be consulted to assure proper use of the Monitoring Type code.

Name of Monitoring Entity	**Tag Prefix**	**Submitting Entity**	**Collecting Entity**	**Monitoring Type**
City of Houston	***HP***	***HO***	***RU****	***BF***

*The Rice University Collecting Entity Code Request has been approved as of July 20th 2012

Records and Documents Retention Requirements

Document/Record	Location	Retention	Form
QAPP, amendments, and appendices	Rice Univ.	5 years	Paper
QAPP distribution documentation	Rice Univ.	5 years	Paper
Training records	Rice Univ.	5 years	Paper
Field notebooks or field data sheets	Rice Univ.	5 years	Paper
Field equipment calibration/maintenance l	Rice Univ.	5 years	Paper
Chain of custody records	Rice Univ.	5 years	Paper
Field SOPs	Rice Univ.	5 years	Paper
Laboratory QA manuals	Lab	5 years	Paper
Laboratory SOPs	Lab	5 years	Paper
Laboratory procedures	Lab	5 years	Paper
Instrument readings/printouts	Lab	5 years	Paper
Laboratory data reports/results	Lab	5 years	Paper
Laboratory equipment maintenance logs	Lab	5 years	Paper
Corrective action documentation	Lab	5 years	Paper

B1 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The experimental design for the study is based on the intent to demonstrate removal of nutrients, E. coli and TSS by BMP practices in the Cottage Grove subdivision prior to discharge into White Oak Bayou (Appendix D).

The three LID BMP practices that will be assessed in this study are rain gardens, bioswales, and tree boxes. The bioswale, tree box and rain garden areas will be vegetated BMPs that collects excess runoff and treats it by filtration through the soil media into the underground storage. Sampling will be conducted at the outlets of the site to evaluate the cumulative runoff volume reduction and pollutant removal of the practices. Reported pollutant removal efficiency of selected BMPs is listed in Appendix J. Monitoring sites are specified in Table B1.1. The sampling locations were chosen to correspond to the runoff outflow from the BMPs installed on Darling Street, and to correspond to the runoff outflow from a control site on Petty Street. The control site has similar hydrologic characteristics as well as traditional urban street characteristics. Sample collection will commence with the rain event and continue in order to collect representative samples at regular intervals throughout the runoff event. Samples will be collected from multiple storm events that are greater than 0.1 inches of rain and that occurs at least 72 hours from the previously measurable (greater than 0.1 inch rainfall) storm event.

During a rainfall event, grab samples will be taken throughout the event and corresponding flow velocities will be measured. Runoff samples will be collected at the outlet of each block in 30 minute intervals. Field personnel will be set up on site within 30 minutes of initial rainfall, and sampling will begin as soon as the whole team is on site. Sampling will start with the first observation of measurable flow. The rainfall data will be obtained from NEXRAD which covers the study area with an optimal radius. Radar accuracy is more reliable than gauge rainfall and allows for rainfall data to be obtained in locations where there might not be gauges data. Radar rainfall allows for this method to be applied in other various locations which would be ideal if these sorts of projects are to be replicated in other areas. Due to the small size of the study area, three separate rain gauges will be used to verify the radar data. These three gauges are located at 530 E100 White Oak Bayou at Ella Boulevard, 1000 Houston Transtar, and 520 White Oak Bayou at Heights Boulevard. These rain gauges were chosen due to their proximity to the site according to the Harris County Flood Warning System (http://www.harriscountyfws.org/)

After the initiation of sampling, the four samples on each of the streets will be collected in 30 minute intervals for the duration of the storm. Flow will be measured in an installed weir structure that has a known flow rate corresponding to flow level. An illustration of a Triangular Weir is shown in Figure B1.2 and follows the equation Q = 2.5H^2.5 to determine the flow rate. Instantaneous flow will be determined twice using the previously mentioned weir equation at the beginning of the 30 minute period and at the end of the 30 minute period. It will be assumed that flow will remain relatively constant during the 30 minute interval but an average will be taken of the beginning and ending flow to account for any major changes. With this information we can find volume, as mentioned previously, and with concentration values known we can multiply these 2 values to get us a load of mass/time.

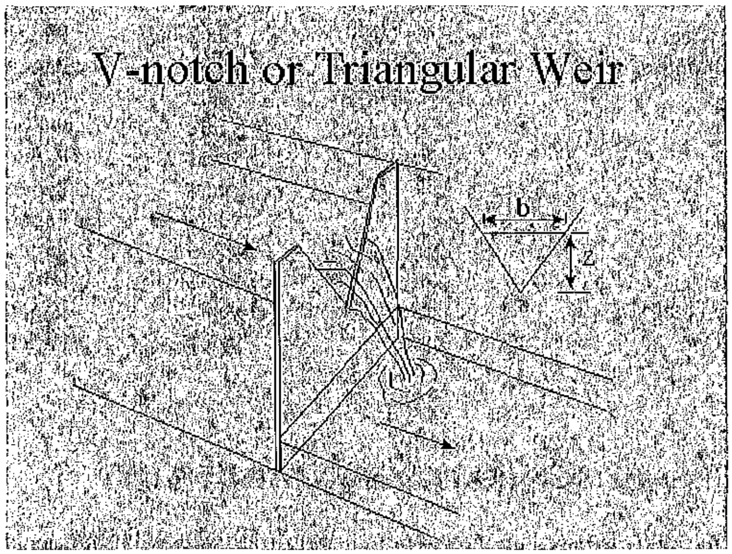


Figure B1.2. Illustration of a triangular weir structure (www.csus.edu)

The analytical results from the Darling Street location will be evaluated against runoff data from post-BMP construction and from Petty Street to determine if there is an improvement in water quality. Field data and samples will be collected following guidance of the EPA Urban Stormwater BMP Monitoring Manual (October 2009) Section 4.7.2, Grab Sample Collection Techniques. The type of flow (moderate, low, high) will determine how we approach the sampling site. Most will be moderate and thus samples will be grabbed directly from the sampling locations.

The coarse sampling interval may be necessary due to the labor intensive sampling procedures occurring at eight locations. However, varying of sampling intervals may be necessary during the early portion of events to gain a greater resolution of data during the first flush period, where there is a higher variability of pollutant loading. Typical rainfall runoff events have a duration of about 3-5 hours, meaning the total number of samples collected during an event would likely be between 28-48 samples. With pollutant concentrations and flow data, the pollutant loads in the runoff can be calculated for multiple time-steps throughout the event in order to estimate a load for the storm. The equation described in section A6 will be used to calculate pollutant loads. The time step for calculation will be considered the time between sampling events, i.e. the duration of time since the previous sample was collected at that location. The flow value will be measured in 30 minute intervals once at the beginning of the sampling period (where 4 samples will be collected on the control street and another 4 on the experimental street) and once at the end of the sampling period., allowing for calculation of pollutant loads.

The sampling event protocol will be adjusted as needed after the first sample storm event or subsequently, after written concurrence of the TCEQ project manager. Such adjustments will be done to avoid sampling trivial storms of 0.1 inches or smaller, as mentioned above. The adjustments would also be done to ensure an adequate number of sampling across a defined portion of the hydrograph, centered around the peak, are taken with each significant storm event. Outflow from the project site will be collected via grab samples at eight locations. The sampling procedure will collect three 450 ml samples and one 100 ml bacteria sample every 30 minutes (on both streets), starting at the beginning of the storm event. This will provide a representative sample from all parts of the hydrograph.

Monitoring will encompass evaluating the following water quantity and quality parameters for the BMP implementation:

- Event Mean Concentration (EMC)
- Peak flow rate
- pH
- Electrolytic Conductivity
- Total Kjeldahl N (TKN)
- NO_3/NO_2
- Total Phosphorus
- Total Suspended Sediments (TSS)

The U.S. EPA began using Event Mean Concentrations in the Nationwide Urban Runoff Program in 1983 to serve as a national measure of the magnitude of urban runoff and pollutant loadings. EMC is defined as the total pollutant mass discharged divided by the total runoff volume. 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.

A combination of LID practices will be installed along the two block segment of Darling St to evaluate the reduction of runoff pollutants and runoff volume. The goal is to assess the BMPs as an entire treatment train with the opportunity to test different combinations of BMPs. The design will allow for a comparison of flow and parameter concentrations for runoff entering and leaving (so sampling will be done upstream and downstream of set of BMPs). The samples during pre-construction will represent initial conditions of parameter concentrations. The post-construction samples will represent the flow and parameter concentrations before and after they have run through each set of BMPs. Manual grab samples will be collected at four locations along Darling Street and four locations along Petty Street during the course of storm events pre-construction and post-construction. Location of sampling point is intended to capture the outfall of each block, allowing total runoff to be assessed along the block. Because the LID BMP runoff will be evaluated against pre-construction conditions and a control site, inflow measurements are not required for this study. Rather a total reduction in runoff volume and runoff pollutant loadings will be assessed for LID BMP practices versus typical residential development.

Dr. P. Bedient, with Rice University, will supervise the field sampling teams. He will oversee the determination of the portion of the flow event that is most appropriate for sampling as well as the interval of grab samples.

Table B1.1 Monitoring Sites

TCEQ Station ID	Site Description	Latitude Longitude	Start Date	End Date	Sample Matrix	Approx. Annual Monitoring Freq. (TSS, Nutrients, E. coli)	Comments
21251	Effluent Point north, Darling Street and T.C. Jester Boulevard	29.779875 N -95.417739 W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall
21252	Effluent Point north, Darling Street and Detering Street (west)	29.779894 N -95.415975W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall
21253	Effluent Point north, Darling Street and Detering Street (east)	29.779894 N -95.415878 W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall
21254	Effluent Point north, Darling Street and Reinerman Street	29.779931 N -95.413692 W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall
21255	Effluent point north, Petty Street and T.C. Jester Boulevard	29.780597 N -95.417822 W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall
21256	Effluent point north, Petty Street and Detering Street (west)	29.780625 N -95.415983 W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall
21257	Effluent point north, Petty Street and Detering Street (east)	29.780625 N -95.415889 W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall
21258	Effluent point north, Petty Street and Reinerman Street	29.780678 N -95.413703 W	TBD	TBD	water	Between 4 and 6	Sampling tied to rainfall

B2 SAMPLING METHODS

Field Sampling Procedures

A SOP for the grab sampling procedures is attached as Appendix E. Storm water sample collection will follow the field sampling procedures for conventional and microbiological parameters documented in the TCEQ Surface Water Quality Monitoring Procedures Manual (August 2012 or most recent version) and also from recommendations from the EPA Urban Storm Water BMP Performance Manual, as applicable. The sampling is being performed in drainage ditches rather than a larger body of water such as a river. Therefore special considerations will need to be made to avoid the introduction of any extraneous dirt debris or vegetation. Procedures specific to sampling storm water to address these special considerations (debris in small bodies of water) will follow the EPA manual, in other cases the SWQM will be followed. Also, low flow conditions might require that sampling location be changed within a few feet to allow for a complete sampling. This would be for the same effluent point and thus do not think that new station location requests would be necessary.

The sample container types, minimum sample volume, preservation requirements, and holding time requirements are specified in table B2.1. Preservation of all samples is performed in the field immediately upon collection, within 15 minutes.

Table B2.1 BMP Effectiveness Monitoring

Parameter	Matrix	Sample Type	Container*	Preservation	Minimum Sample Volume	Holding Time
Nitrite+nitrate-N	Water	Grab	250 mL Polyethylene Bottle	ice, dark	250 mL	28 days
Total Phosphorus-P	Water	Grab	250 mL Polyethylene Bottle	ice, dark, pH <2 with H_2SO_4	250 mL	28 days
E. coli	Water	Grab	100 mL Polyethylene Bottle	Ice, 0.008% $Na_2S_2O_3$	100mL, Sterilized bottle	6 hrs*
Total Suspended Solids	Water	Grab	250 mL Polyethylene Bottle	ice, dark	250 mL	7 days

* The six hour holding time will be followed when all possible, but in the case of infrequent rain events and necessary samples of E. coli are collected late in the evening or on weekends, the 24 hour holding time used by the City of Houston's Water Quality Laboratory at 2300 Federal Road may be followed. COH lab personnel are not commonly present at the facility on weekends, inhibiting the delivery and testing of water quality samples before the six hour holding time. In some cases a COH lab employee may agree to meet field sampling crew at the lab, otherwise the extended holding time may have to be used.

Processes to Prevent Cross Contamination

Procedures outlined in the TCEQ Surface Water Quality Procedures outline the necessary steps to prevent cross-contamination of samples. These include such things as direct collection into sample containers and the use of commercially pre-cleaned sample containers.

Documentation of Field Sampling Activities

Field sampling activities are documented on the Field Data Reporting Form as presented in Appendix F. For all visits, station ID, location, sampling time, sampling date, sampling depth, preservatives added to samples, and sample collector's name/signature are recorded. Values for all measured field parameters are recorded. Detailed observational data are recorded including water appearance, weather, biological activity, unusual odors, specific sample information, missing parameters, days since last significant rainfall, and flow severity.

Recording Data

For the purposes of this section and subsequent sections, all personnel follow the basic rules for recording information as documented below:

1. Legible writing in indelible, waterproof ink with no modifications, write-overs or cross-outs;
2. Changes should be made by crossing out original entries with a single line, entering the changes, and initialing and dating the corrections.
3. Close-outs on incomplete pages with an initialed and dated diagonal line.
4. Sample Type (i.e. analyses) to be performed.

Sampling Method Requirement or Sampling Process Design Deficiencies and Corrective Action

Examples of sampling method requirement or sample design deficiencies include but are not limited to such things as inadequate sample volume due to spillage or container leaks, failure to preserve samples appropriately, contamination of a sample bottle during collection, storage temperature and holding time exceedance, sampling at the wrong site, etc. Any deviations from the QAPP and appropriate sampling procedures may invalidate resulting data and may require corrective action. Corrective action may include for samples to be discarded and re-collected. It is the responsibility of the City of Houston Project Manager, in consultation with the City of Houston QAO, to ensure that the actions and resolutions to the problems are documented and that records are maintained in accordance with this QAPP. In addition, these actions and resolutions will be conveyed to the NPS Project Manager both verbally and in writing in the project progress reports and by completion of a corrective action plan (CAP).

The definition of and process for handling deficiencies and corrective actions are defined in Section C1.

B3 SAMPLE HANDLING AND CUSTODY

Sample Labeling

Samples from the field are labeled on the container with an indelible marker. Label information includes:

1. Site identification
2. Date and time of collection
3. Preservative added, if applicable
4. Sample Type (i.e. analyses) to be performed

Sample Handling

Samples collected in the field will be preserved as applicable, labeled, and transported in a cooler at the specified temperature. The samples will be transported to the City of Houston, Water Quality Laboratory within the required handling time, Table B.2. At the COH, Water Quality Laboratory, the Chain of Custody forms will be used to document the transfer (Appendix G). The field data sheets and sample labels will be scrutinized by laboratory staff to ensure the proper preservation of the samples as well as to ensure the samples will be processed within the specified holding time.

Sample Tracking

Proper sample handling and custody procedures ensure the custody and integrity of samples beginning at the time of sampling and continuing through transport, sample receipt, preparation, and analysis.

A sample is in custody if it is in actual physical possession or in a secured area that is restricted to authorized personnel. The COC form is used to document sample handling during transfer from the field to the laboratory and among contractors. The following information concerning the sample is recorded on the COC form (See Appendix G).

1. Date and time of collection
2. Site identification
3. Sample matrix
4. Number of containers
5. Preservative used
6. Was the sample filtered
7. Analyses required
8. Name of collector
9. Custody transfer signatures and dates and time of transfer
10. Bill of lading (*if applicable*)

Sample Tracking Procedure Deficiencies and Corrective Action

All deficiencies associated with chain-of-custody procedures as described in this QAPP are immediately reported to the Contractor Project Manager. These include such items as delays in transfer, resulting in holding time violations; violations of sample preservation requirements; incomplete documentation, including signatures; possible tampering of samples; broken or spilled samples, etc. The City of Houston Project Manager in consultation with the City of Houston QAO will determine if the procedural violation may have compromised the validity of the resulting data. Any failures that have reasonable potential to compromise data validity will invalidate data, and the sampling event should be repeated. The resolution of the situation will be reported to the TCEQ NPS Project Manager in the project progress report. Corrective Action Plans will be prepared by the Contractor QAO and submitted to TCEQ NPS Project Manager along with project progress report.

The definition of and process for handling deficiencies and deficiencies, nonconformances, and corrective action are defined in Section C1.

B4 ANALYTICAL METHODS

The analytical methods are listed in Table A.1 of Section A7. Laboratories collecting data under this QAPP are compliant with the TNI Standards.

Copies of laboratory SOPs are retained by the contractor and are available for review by the TCEQ. Laboratory SOPs are consistent with EPA requirements as specified in the method.

Standards Traceability

All standards used in the field and laboratory are traceable to certified reference materials. Standards and reagent preparation is fully documented and maintained in a standards log book. Each documentation includes information concerning the standard or reagent identification, starting materials, including concentration, amount used and lot number; date prepared, expiration date and preparer=s initials/signature. The bottle is labeled in a way that will trace the standard or reagent back to preparation. Standards or reagents used are documented each day samples are prepared or analyzed.

Analytical Method Deficiencies and Corrective Actions

Deficiencies in field and laboratory measurement systems involve, but are not limited to such things as instrument malfunctions, failures in calibration, blank contamination, quality control samples outside QAPP defined limits, etc. In many cases, the field technician or lab analyst will be able to correct the problem. If the problem is resolvable by the field technician or lab analyst, then they will document the problem on the field data sheet or laboratory record and complete the analysis. If the problem is not resolvable, then it is conveyed to the City of Houston Laboratory Supervisor, who will make the determination and notify the City of Houston QAO. If the analytical system failure may compromise the sample results, the resulting data will not be reported to the TCEQ. The nature and disposition of the problem is reported on the data report which is sent to the City of Houston Manager. The City of Houston Project Manager will include this information in the CAP and submit with the Progress Report which is sent to the TCEQ NPS Project Manager.

The definition of and process for handling deficiencies and deficiencies, nonconformances, and corrective action are defined in Section C1.

The TCEQ has determined that analyses associated with the qualifier codes holding time exceedance, sample received unpreserved, estimated value, etc. may have unacceptable measurement uncertainty associated with them. This will immediately disqualify analyses from submittal to SWQMIS. Therefore, data with these types of problems should not be reported to the TCEQ. Additionally, any data collected or analyzed by means other than those stated in the QAPP, or data suspect for any reason should not be submitted for loading and storage in SWQMIS.

B5 QUALITY CONTROL

Sampling Quality Control Requirements and Acceptability Criteria

Field Split - A field split is a single sample subdivided by field staff immediately following collection and submitted to the laboratory as two separately identified samples according to procedures specified in the *SWQM Procedures*. Split samples are preserved, handled, shipped, and analyzed identically and are used to assess variability in all of these processes. Field splits apply to conventional samples only. At each sampling location the frequency of the split will be 2 per event per location to confirm a minimum 5% of dup analysis. The precision of field split results is calculated by relative percent difference (RPD) using the following equation:

$$RPD = [(X_1-X_2)/\{(X_1+X_2)/2\} * 100]$$

A 30% RPD criteria will be used to screen field split results as a possible indicator of excessive variability in the sample handling and analytical system. If it is determined that elevated quantities of analyte (i.e., > 5 times the LOQ) were measured and analytical variability can be eliminated as a factor, than variability in field split results will primarily be used as a trigger for discussion with field staff to ensure samples are being handled in the field correctly. Some individual sample results may be invalidated based on the examination of all extenuating information. The information derived from field splits is generally considered to be event specific and would not normally be used to determine the validity of an entire batch; however, some batches of samples may be invalidated depending on the situation. Professional judgment during data validation will be relied upon to interpret the results and take appropriate action. The qualification (i.e., invalidation) of data will be documented on the Data Review Checklist and Summary. Deficiencies will be addressed as specified in this section under Quality Control or Acceptability Requirement Deficiencies and Corrective Actions.

Laboratory Measurement Quality Control Requirements and Acceptability Criteria

Batch – A batch is defined as environmental samples that are prepared and/or analyzed together with the same process and personnel, using the same lot(s) of reagents. A **preparation batch** is composed of one to 20 environmental samples of the same NELAC-defined matrix, meeting the above mentioned criteria and with a maximum time between the start of processing of the first and last sample in the batch to be 25 hours. An **analytical batch** is composed of prepared environmental samples (extract, digestates or concentrates) which are analyzed together as a group. An analytical batch can include prepared samples originating from various environmental matrices and can exceed 20 samples.

Method Specific QC requirements – QC samples, other than those specified later this section, are run (e.g., sample duplicates, surrogates, internal standards, continuing calibration samples, interference check samples, positive control, negative control, and media blank) as specified in the methods. The requirements for these samples, their acceptance criteria or instructions for establishing criteria, and corrective actions are method-specific.

Detailed laboratory QC requirements and corrective action procedures are contained within the individual laboratory quality manuals (QMs). The minimum requirements that all participants abide by are stated below.

Limit of Quantitation (LOQ) – The laboratory will analyze a calibration standard (if applicable) at the LOQ on each day calibrations are performed. In addition, an LOQ check standard will be analyzed with each analytical batch. Calibrations including the standard at the LOQ will meet the calibration requirements of the analytical method or corrective action will be implemented.

> LOQ Sediment and Tissue Samples – When considering LOQs for solid samples and how they apply to results, two aspects of the analysis are considered: (1) the LOQ of the sample, based on the real-world in which moisture content and interferences affect the result and (2) the LOQ in the QAPP which is a value less than or equal to the AWRL based on an idealized sample with zero % moisture.
>
> The LOQ for a solid sample is based on the lowest non-zero calibration standard (as are those for water samples), the moisture content of the solid sample, and any sample concentration or dilution factors resulting from sample preparation or clean-up.
>
> To establish solid-phase LOQs to be listed in Table A7.1 of the QAPP, the laboratory will adjust the concentration of the lowest non-zero calibration standard for the amount of sample extracted, the final extract volume, and moisture content (assumed to be zero % moisture). Each calculated LOQ will be less than or equal to the AWRL on the dry-weight basis to satisfy the AWRL requirement for sediment and tissue analyses. When data are reviewed for consistency with the QAPP, they are evaluated based on this requirement. Results may not appear to meet the AWRL requirement due to high moisture content, high concentrations of non-target analytes necessitating sample dilution, etc. These sample results will be submitted to the TCEQ with an explanation on the Data Review Checklist and Summary as to why results do not appear to meet the AWRL requirement.

LOQ Check Standard – An LOQ check standard consists of a sample matrix (e.g., deionized water, sand, commercially available tissue) free from the analytes of interest spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes. It is used to establish intra-laboratory bias to assess the performance of the measurement system at the lower limits of analysis. The LOQ check standard is spiked into the sample matrix at a level less than or near the LOQ for each analyte for each analytical batch of samples run.

The LOQ check standard is carried through the complete preparation and analytical process. LOQ Check Standards are run at a rate of one per analytical batch.

The percent recovery of the LOQ check standard is calculated using the following equation in which %R is percent recovery, SR is the sample result, and SA is the reference concentration for the check standard:

$$\%R = SR/SA * 100$$

Measurement performance specifications are used to determine the acceptability of LOQ Check Standard analyses as specified in Table A7.1.

Laboratory Control Sample (LCS) – An LCS consists of a sample matrix (e.g., deionized water, sand, commercially available tissue) free from the analytes of interest spiked with verified known amounts of analytes or a material containing known and verified amounts of analytes. It is used to establish intra-laboratory bias to assess the performance of the measurement system. The LCS is spiked into the sample matrix at a level less than or near the midpoint of the calibration for each analyte. In cases of test methods with very long lists of analytes, LCSs are prepared with all the target analytes and not just a representative number, except in cases of organic analytes with multipeak responses.

The LCS is carried through the complete preparation and analytical process. LCSs are run at a rate of one per preparation batch.

Results of LCSs are calculated by percent recovery (%R), which is defined as 100 times the measured concentration, divided by the true concentration of the spiked sample.

The following formula is used to calculate percent recovery, where %R is percent recovery; SR is the measured result; and SA is the true result:

$$\%R = SR/SA * 100$$

Measurement performance specifications are used to determine the acceptability of LCS analyses as specified in Table A7.1.

Laboratory Duplicates – A laboratory duplicate is prepared by taking aliquots of a sample from the same container under laboratory conditions and processed and analyzed independently. A laboratory control sample duplicate (LCSD) is prepared in the laboratory by splitting aliquots of an LCS. Both samples are carried through the entire preparation and analytical process. LCSDs are used to assess precision and are performed at a rate of one per preparation batch.

For most parameters, precision is calculated by the relative percent difference (RPD) of LCS duplicate results as defined by 100 times the difference (range) of each duplicate set, divided by the average value (mean) of the set. For duplicate results, X_1 and X_2, the RPD is calculated from the following equation: *(If other formulas apply, adjust appropriately.)*

$$RPD = [(X_1 - X_2)/\{(X_1+X_2)/2\} * 100]$$

A bacteriological duplicate is considered to be a special type of laboratory duplicate and applies when bacteriological samples are run in the field as well as in the lab. Bacteriological duplicate analyses are performed on samples from the sample bottle on a 10% basis. Results of bacteriological duplicates are evaluated by calculating the logarithm of each result and determining the range of each pair.

Measurement performance specifications are used to determine the acceptability of duplicate analyses-as specified in Table A7.1. The specifications for bacteriological duplicates in Table A7.1 apply to samples with concentrations > 10 org./100mL.

Laboratory equipment blank – Laboratory equipment blanks are prepared at the laboratory where collection materials for metals sampling equipment are cleaned between uses. These blanks document that the materials provided by the laboratory are free of contamination. The QC check is performed before the metals sampling equipment is sent to the field. The analysis of laboratory equipment blanks should yield values less than the LOQ. Otherwise, the equipment should not be used.

Matrix spike (MS) – Matrix spikes are prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available. Matrix spikes are used, for example, to determine the effect of the matrix on a method's recovery efficiency.

Percent recovery of the known concentration of added analyte is used to assess accuracy of the analytical process. The spiking occurs prior to sample preparation and analysis. Spiked samples are routinely prepared and analyzed at a rate of 10% of samples processed, or one per preparation batch whichever is greater. The information from these controls is sample/matrix specific and is not used to determine the validity of the entire batch. The MS is spiked at a level less than or equal to the midpoint of the calibration or analysis range for each analyte. Percent recovery (%R) is defined as 100 times the observed concentration, minus the sample concentration, divided by the true concentration of the spike.

The results from matrix spikes are primarily designed to assess the validity of analytical results in a given matrix and are expressed as percent recovery (%R). The laboratory shall document the calculation for %R. The percent recovery of the matrix spike is calculated using the following equation in which %R is percent recovery, SSR is the observed spiked sample concentration, SR is the sample result, and SA is the reference concentration of the spike added:

$$\%R = (SSR - SR)/SA * 100$$

Measurement performance specifications for matrix spikes are not specified in this document.

The results are compared to the acceptance criteria as published in the mandated test method. Where there are no established criteria, the laboratory shall determine the internal criteria and document the method used to establish the limits. For matrix spike results outside established criteria, corrective action shall be documented or the data reported with appropriate data qualifying codes.

Method blank – A method blank is a sample of matrix similar to the batch of associated samples (when available) that is free from the analytes of interest and is processed simultaneously with and under the same conditions as the samples through all steps of the analytical procedures, and in which no target analytes or interferences are present at concentrations that impact the analytical results for sample analyses. The method blanks are performed at a rate of once per preparation batch. The method blank is used to document contamination from the analytical process. The analysis of method blanks should yield values less than the LOQ. In all cases the corrective action must be documented.

The method blank shall be analyzed at a minimum of once per preparation batch. In those instances for which no separate preparation method is used (example: volatiles in water) the batch shall be defined as environmental samples that are analyzed together with the same method and personnel, using the same lots of reagents, not to exceed the analysis of 20 environmental samples.

Quality Control or Acceptability Requirement Deficiencies and Corrective Actions

Sampling QC excursions are evaluated by the Contractor Project Manager, in consultation with the Contractor QAO. In that differences in sample results are used to assess the entire sampling process, including environmental variability, the arbitrary rejection of results based on pre-determined limits is not practical. Therefore, the professional judgment of the City of Houston Project Manager and QAO will be relied upon in evaluating results. Rejecting sample results based on wide variability is a possibility. Field blanks for trace elements and trace organics are scrutinized very closely. Field blank values exceeding the acceptability criteria may automatically invalidate the sample, especially in cases where high blank values may be indicative of contamination which may be causal in putting a value above the standard. Notations of field split excursions and blank contamination are noted in the quarterly report and the final QC Report. Equipment blanks for metals analysis are also scrutinized very closely.

Laboratory measurement quality control failures are evaluated by the laboratory staff. The disposition of such failures and the nature and disposition of the problem is reported to the City of Houston Laboratory QAO. The Laboratory QAO will discuss with the City of Houston Project Manager. If applicable, the City of Houston Project Manager will include this information in the CAP and submit with the Progress Report which is sent to the TCEQ NPS Project Manager.

The definition of and process for handling deficiencies and deficiencies, nonconformances, and corrective action are defined in Section C1.

B6 INSTRUMENT/EQUIPMENT TESTING, INSPECTION AND MAINTENANCE

All in-stream field sampling equipment testing and maintenance requirements are detailed in the *TCEQ Surface Water Quality Monitoring Procedures, Volume 1*. Equipment records are kept on all field equipment and a supply of critical spare parts is maintained by the Contractor Field Supervisor.

All laboratory tools, gauges, instrument, and equipment testing and maintenance requirements are contained within laboratory QAM(s). Testing and maintenance records are maintained and are available for inspection by the TCEQ. Instruments requiring daily or in-use testing may include, but are not limited to, water baths, ovens, autoclaves, incubators, refrigerators, and laboratory pure water. Critical spare parts for essential equipment are maintained to prevent downtime. Maintenance records are available for inspection by the TCEQ.

B7 INSTRUMENT/EQUIPMENT CALIBRATION AND FREQUENCY

Field Equipment calibration requirements are contained in the TCEQ *Surface Water Quality Monitoring Procedures Manual*. Post calibration error limits and the disposition resulting from error are adhered to. Data not meeting post-error limit requirements invalidates associated data collected subsequent to the pre-calibration and are not submitted to the TCEQ.

Detailed laboratory calibrations are contained within the QAM(s).

B8 INSPECTION/ACCEPTANCE OF SUPPLIES AND CONSUMABLES

New batches of supplies are tested before use to verify that they function properly and are not contaminated. The laboratory QAM provides additional details on acceptance requirements for laboratory supplies and consumables.

B9 NON-DIRECT MEASUREMENTS

Directly collected data collected under this QAPP will be submitted to the TCEQ for storage in SWQMIS. This project will not submit any acquired or non-direct measurement data to SWQMIS that has been or is going to be collected under another QAPP. All data collected under this QAPP and any acquired or non-direct measurements will comply with all requirements/guidance of the project. Rainfall data will be collected using NEXRAD radar rainfall to calculate the input volume of rainfall in the project site. NEXRAD rainfall covers the site at an optimum radius and is the most accurate for rainfall information, if needed three rain gauges (520, 530, 1000) that are mentioned in section B1 will be used to verify the radar data. Indirect measurements will also result from analysis of elevation data either from Lidar elevation dataset collected as part of the Tropical Storm Allison Recovery Project (TSARP) or from the Field Survey collected by the City of

Houston. Elevation data will be used to determine the area draining to the sampling locations. This will be used to account for any runoff that does not originate in the BMP study area or the comparison study area. Elevation data can be modeled (using GIS) to determine the general flow patterns of the streets and surrounding areas. This information will also be verified by the surveying done by Jones and Carter. With flow pattern information we can find the sources of the water that end up in the drainage ditches that are monitored. Knowing the sources of water, runoff not originating from the BMP site can be taken into account.

B10 DATA MANAGEMENT

Field Collection and Management of Routine Samples

Field staff will visit the site within 30 minutes of start of rainfall events to collect water samples and measure flow velocities. Site identification, date, time, personnel, water depth, measurements of field parameters, and any comment concerning weather or conditions at the site are noted in the field notebook. A field notebook is filled out in the field for each site visit.

Samples collected at the site will be labeled for transportation to the laboratory. Site name, time of collection, comments, and other pertinent data are copied from the field notebook to the COC. The COC and accompanying sample bags/bottles are submitted to laboratory analyst.

Laboratory Data

All field samples will be logged upon receipt, COC's (if applicable) will be checked for number of samples, proper and exact I.D. number, signatures, dates, and type of analysis specified. The field technician will be notified if any discrepancy is found and proper corrections made. All samples will be stored at 4°C until analysis.

Personnel

Section A4 lists responsibilities and lines of communication for data management personnel.

Data Management Process

Samples are collected by Rice University field staff and transferred to the City of Houston laboratory for analyses as described in Sections B1 and B2. Sampling information (e.g. site location, date, time, sampling depth, etc.) is used to generate a unique sampling event in an interim database built on an autogenerated alphanumeric key field. Measurement results 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 facilitate accurate data entry. Following data verification and validation, the data are exported from the interim database into the Event/Result format required for submission to TCEQ's SWQMIS (as described in the SWQM DMRG January 2012). Once TCEQ approval of the data is obtained, the data are loaded into SWQMIS by TCEQ data managers.

See Appendix K for the Data Management Process Flow Chart.

Record-keeping and Data Storage

City of Houston record keeping and document control procedures are contained in the water quality sampling and laboratory standard operating procedures (SOPs) and this QAPP. Original field and laboratory data sheets are stored in the City of Houston offices in accordance with the record-retention schedule in Section A9.

Archives/Data Retention

Complete original data sets are archived on permanent media and retained on-site by the Contractor for a retention period specified in section A9.

Data Verification/Validation

The control mechanisms for detecting and correcting errors and for preventing loss of data during data reduction, data reporting, and data entry are contained in Sections D1, D2, and D3.

Forms and Checklists

See Appendix J for the Field and Laboratory Data Sheets.

See Appendix C for the Data Review Checklist and Summary.

Data Dictionary

Terminology and field descriptions are included in the SWQM DMRG (January 2012). For the purposes of verifying which entity codes are included in this QAPP, a table outlining the entities that will be used when submitting data under this QAPP is included below.

Name of Monitoring Entity	Tag Prefix	Submitting Entity	Collecting Entity	Monitoring Type Code
City of Houston	*HP*	*HO*	*RU**	*BF*

*The collection Entity Code for Rice University has been approved as of July 20th 2012

Data Handling

Data are processed using the Microsoft suite of tools and applications. Data integrity is maintained by the implementation of password protections which control access to the database and by limiting update rights to a select user group. No data from external sources are maintained in the database. The database administrator is responsible for assigning user rights and assuring database integrity.

Hardware and Software Requirements

Hardware configurations are sufficient to run Microsoft under the Windows operating system in a networked environment. Information Resources staff are responsible for assuring hardware configurations meet the requirements for running current and future data management/database software as well as providing technical support. Software development and database administration are also the responsibility of the information resources department. Information Resources develops applications based on user requests and assures full system compatibility prior to implementation.

Information Resource Management Requirements

City of Houston information technology (IT) policy is contained in IT SOPs which are available for review at City of Houston offices.

Quality Assurance/Control

See Section D of this QAPP.

C1 Assessments and Response Actions

Table C1.1 Assessments and Response Requirements

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Status Monitoring Oversight, etc.	Continuous	Contractor Project Manager	Monitoring of the project status and records to ensure requirements are being fulfilled.	Report to TCEQ in Quarterly Report
Laboratory Inspections	Dates to be determined by the TCEQ lab inspector	TCEQ Lab Inspector	Analytical and quality control procedures employed at the laboratory and the contract laboratory	30 days to respond in writing to the TCEQ to address corrective actions
Monitoring Systems Audit	Dates to be determined by TCEQ	TCEQ QAS	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP. Field sampling, handling and measurement; facility review; and data management as they relate to the NPS Project	30 days to respond in writing to the TCEQ to address corrective actions
Laboratory Inspection	Based on work plan and or discretion of contractor	Contractor QAO	Analytical and quality control procedures employed at the laboratory and the contract laboratory	30 days to respond in writing to the contractor QAO to address corrective actions
Monitoring Systems Audit	Based on work plan and or discretion of contractor	Contractor QAO	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP. Field sampling, handling and measurement; facility review; and data management as they relate to the NPS Project	30 days to respond in writing to the contractor QAO to address corrective actions
Site Visit	Dates to be determined by TCEQ	TCEQ PM	Status of activities. Overall compliance with work plan and QAPP	As needed

Corrective Action Process for Deficiencies

Deficiencies are any deviation from the QAPP, SWQM Procedures Manual, SOPs, or Data Management Reference Guide. Deficiencies may invalidate resulting data and may require corrective action. Corrective action may include for samples to be discarded and re-collected. Deficiencies are documented in logbooks, field data sheets, etc. by field or laboratory staff. It is the responsibility of the City of Houston Project Manager, in consultation with the City of Houston QAO, to ensure that the actions and resolutions to the problems are documented and that records are maintained in accordance with this QAPP. In addition, these actions and resolutions will be conveyed to the NPS Project Manager both verbally and in writing in the project progress reports and by completion of a corrective action plan (CAP).

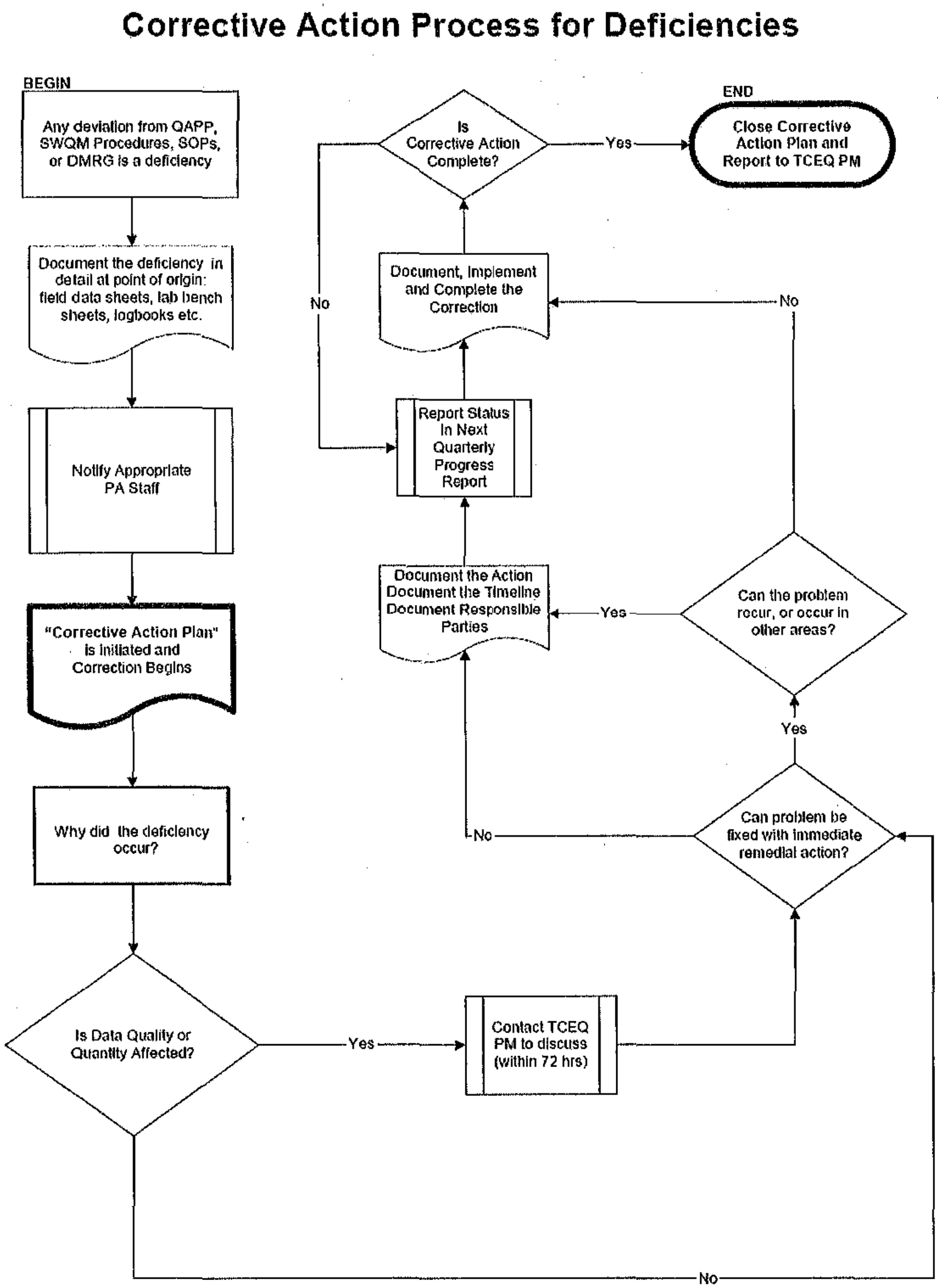
Corrective Action

CAPs should:

- Identify the problem, nonconformity, or undesirable situation
- Identify immediate remedial actions if possible
- Identify the underlying cause(s) of the problem
- Identify whether the problem is likely to recur, or occur in other areas
- Evaluate the need for Corrective Action
- Use problem-solving techniques to verify causes, determine solution, and develop an action plan
- Identify personnel responsible for action
- Establish timelines and provide a schedule
- Document the corrective action

To facilitate the process a flow chart has been developed (see figure C1.1: Corrective Action Process for Deficiencies).

Figure C1.1 Corrective Action Process for Deficiencies



Status of CAPs will be documented on the Corrective Action Status Table (See Appendix L) and included with Quarterly Progress Reports. In addition, significant conditions (i.e., situations which, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to the TCEQ immediately.

The City of Houston Project Manager is responsible for implementing and tracking corrective actions. Corrective action plans will be documented on the Corrective Action Plan Form (See Appendix M) and submitted, when complete, to the TCEQ Project Manager. Records of audit findings and corrective actions are maintained by both the TCEQ and the City of Houston QAO. Audit reports and corrective action documentation will be submitted to the TCEQ with the Quarterly Progress Report.

If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work are specified in the TCEQ QMP and in agreements in contracts between participating organizations.

C2 REPORTS TO MANAGEMENT

Contractor Evaluation and the Final Project Report detailed in this section are contract deliverables and are transferred to the TCEQ in accordance with contract requirements. Other reports detailed in this section are added by reference as contract deliverables.

Quarterly Progress Report - Summarizes the Contractor's activities for each task; reports monitoring status, problems, delays, and corrective actions; and outlines the status of each task's deliverables. Contractor to submit Quarterly Progress Report on the 15th of the month following each state fiscal quarter.

Monitoring Systems Audit Report and Response – Following any audit performed by the Contractor, a report of findings, recommendations and response is sent to the TCEQ in the quarterly progress report

Contractor Evaluation - The Contractor participates in a Contractor Evaluation by the TCEQ annually for compliance with administrative and programmatic standards.

Final Project Report - Summarizes the Contractor's activities for the entire project period including a description and documentation of major project activities; evaluation of the project results and environmental benefits; and a conclusion.

Reports by TCEQ Project Management

Contractor Evaluation - The Contractor participates in a Contractor Evaluation by the TCEQ annually for compliance with administrative and programmatic standards. Results of the evaluation are submitted to the TCEQ Financial Administration Division, Procurement and Contracts Section.

D1 DATA REVIEW, VERIFICATION, AND VALIDATION

For the purposes of this document, data verification is a systematic process for evaluating performance and compliance of a set of data to ascertain its completeness, correctness, and consistency using the methods and criteria defined in the QAPP. Validation means those processes taken independently of the data-generation processes to evaluate the technical usability of the verified data with respect to the planned objectives or intention of the project. Additionally, validation can provide a level of overall confidence in the reporting of the data based on the methods used.

All data obtained from field and laboratory measurements will be reviewed and verified for conformance to project requirements, and then validated against the data quality objectives which are listed in Section A7. Only those data which are supported by appropriate quality control data and meet the measurement performance specification defined for this project will be considered acceptable and submitted to the TCEQ for entry into SWQMIS.

The procedures for verification and validation of data are described in Section D2, below. The City of Houston Field Supervisor is responsible for ensuring that field data are properly reviewed and verified for integrity. The Laboratory Supervisor is responsible for ensuring that laboratory data are scientifically valid, defensible, of acceptable precision and bias, and reviewed for integrity. The City of Houston Data Manager will be responsible for ensuring that all data are properly reviewed and verified, and submitted in the required format to be loaded into SWQMIS.The Contractor QAO is responsible for validating a minimum of 10% of the data produced in each task. Finally, the City of Houston Project Manager, with the concurrence of the City of Houston QAO, is responsible for validating that all data to be reported meet the objectives of the project and are suitable for reporting to TCEQ.

D2 VERIFICATION AND VALIDATION METHODS

All data will be verified to ensure they are representative of the samples analyzed and locations where measurements were made, and that the data and associated quality control data conform to project specifications. The staff and management of the respective field, laboratory, and data management tasks are responsible for the integrity, validation and verification of the data each task generates or handles throughout each process. The field and laboratory tasks ensure the verification of raw data, electronically generated data, and data on chain-of-custody forms and hard copy output from instruments.

Verification, validation and integrity review of data will be performed using self-assessments and peer review, as appropriate to the project task, followed by technical review by the manager of the task. The data to be verified (listed in table D2.1) are evaluated against project performance specifications (Section A7) and are checked for errors, especially errors in transcription, calculations, and data input. If a question arises or an error is identified, the manager of the task responsible for generating the data is contacted to resolve the issue. Issues which can be corrected are corrected and documented electronically or by initialing and dating the associated paperwork. If an issue cannot be corrected, the task manager consults with the higher level project management to establish the appropriate course of action, or the data associated with the issue are rejected and not reported to the TCEQ for storage in SWQMIS. The performance of these tasks is documented by completion of the Data Review Checklist and Summary (Appendix C).

The City of Houston Project Manager and QAO are each responsible for validating that the verified data are scientifically valid, defensible, of known precision, bias, integrity, meet the data quality objectives of the project, and are reportable to TCEQ. One element of the validation process involves evaluating the data again for anomalies. Any suspected errors or anomalous data must be addressed by the manager of the task associated with the data, before data validation can be completed.

A second element of the validation process is consideration of any findings identified during the monitoring systems audit conducted by the TCEQ QAS assigned to the project. Any issues requiring corrective action must be addressed, and the potential impact of these issues on previously collected data will be assessed. Finally, the City of Houston Project Manager, with the concurrence of the QAO validates that the data meet the data quality objectives of the project and are suitable for reporting to TCEQ.

Table D2.1. Data Verification Procedures

Data to be Verified	Field Task	Laboratory Task	Lead Organization Data Manager Task
Sample documentation complete; samples labeled, sites identified	Y	Y	
Field QC samples collected for all analytes as prescribed in the TCEQ *SWQM Procedures Manual*	Y		
Standards and reagents traceable	Y	Y	
Chain of custody complete/acceptable	Y	Y	
Sample preservation and handling acceptable	Y	Y	
Holding times not exceeded	Y	Y	
Collection, preparation, and analysis consistent with SOPs and QAPP	Y	Y	Y
Field documentation (e.g., biological, odors) complete	Y		
Instrument calibration data complete	Y	Y	
Bacteriological records complete	Y	Y	
QC samples analyzed at required frequency	Y	Y	Y
QC results meet performance and program specifications	Y	Y	Y
Analytical sensitivity (Minimum Analytical Levels/Ambient Water Reporting Limits) consistent with QAPP		Y	Y
Results, calculations, transcriptions checked	Y	Y	
Laboratory bench-level review performed		Y	
All laboratory samples analyzed for all parameters		Y	
Corollary data agree	Y	Y	Y
Nonconforming activities documented	Y	Y	Y
Outliers confirmed and documented; reasonableness check performed			Y
Dates formatted correctly			Y
Depth reported correctly			Y
TAG IDs correct			Y
TCEQ ID number assigned			Y
Valid parameter codes			Y
Codes for submitting entity(ies), collecting entity(ies), and monitoring type(s) used correctly			Y
Time based on 24-hour clock			Y
Absence of transcription error confirmed	Y	Y	Y
Absence of electronic errors confirmed	Y	Y	Y
Sampling and analytical data gaps checked (e.g., all sites for which data are reported are on the coordinated monitoring schedule)	Y	Y	Y
Field QC results attached to data review checklist			Y
Verified data log submitted			Y
10% of data manually reviewed			Y

D3 RECONCILIATION WITH USER REQUIREMENTS

Data collected from this project will be analyzed by the Rice University and the City of Houston in order to report the performance of the BMPs and the measured reductions in NPS loadings. Load reduction will be calculated for each pollutant at the end of the BMP train at the outlet of the street by using the following equation for all storm events during that monitoring period. Since the BMPs do not use automatic samplers, a representative portion of the entire storm will be captured. Grab samples from these would be analyzed for pollutant concentrations. Load reduction will be calculated between pre and post construction not inflow to outflow. There are two load reduction conditions that will be calculated. Load reduction during the rain event (Reduction 1) and load reduction from pre-BMP to post-BMP (Reduction 2). This will allow us to show not only the decrease in pollutant loading for each storm event, but the decrease that occurs from installing BMPs in the Cottage Grove area.

Reduction 1 will be calculated in a straight forward method, as follows:

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

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.

Reduction 2 will be calculated using a more complex method. In order to control for confounding factors, Petty Street to the north will be used as a control street. During pre-BMP sampling, a correction factor (CF) will be calculated that will allow a correlation between concentration changes from water entering the west side of the street to water exiting on the east side between Petty and Darling Street.

$$CF = \frac{Percent\ Change\ Petty}{Percent\ Change\ Darling}$$

With the CF value, we will be able to determine, based on C_{in} for both Darling and Petty Streets and the C_{out} from Petty Street, what the expected effluent concentration for Darling Street (C_{exp}) should be for a given rainfall. We will use C_{exp} to estimate the percent reduction (Reduction 2) for pre-BMP to post-BMP, as follows:

$$Reduction\ 2 = (1 - {}^{C_{out}}/_{C_{exp}}) * 100$$

The sampling of concentrations of runoff from the pre-construction experimental street serve as the baseline to assess the success and rate of pollutant removal from the LID tools. In order to control for potential confounding from other unknown variables which may impact the trend or magnitude of pollution in the post construction time period, which would not be attributable to the LID tools, the control street pollution profile is used. The control street pollution profile will be statistically compared with the preconstruction street pollution profile and the baseline of both established. For example, we will explore relating the pollution profiles to each other via statistical regression. LID effectiveness will then be quantified in a change in the relationship between not just pre and post construction but also, post construction and control. In this way potential confounding is controlled. Calculations will be conducted in SAS statistical software. See section A6, pp. 16-17 for a detailed discussion of the of pollutant load calculation. We aim to see a reduction in pollutant load that is considered to be the standard for these technologies. These standards were developed in the Prince George's County Bioretention Manual (2001) and were cited in the US Department of Housing and Urban Development's The Practice of Low Impact Development

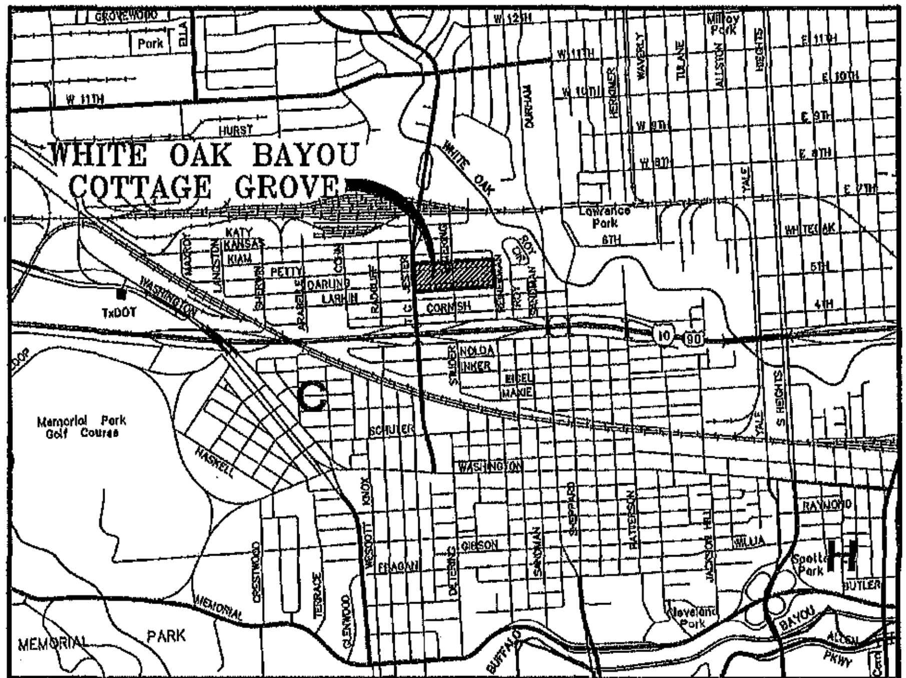
Manual (2003). For the bioswale and rain gardens, anticipated removal rates are approximately 80% or higher for both TSS and bacteria. For the treeboxes, anticipated removal rates are approximately 90% for bacteria and 85% for TSS.

The combination and placement of LID tools were chosen based on the drainage area maps. They were chosen to have the optimal water runoff removal. Rainfall data will be used to assess the capacity of the treatment system by comparing the success of LID during storms of similar magnitudes before and after construction. For example, pre-construction 1" storms will be compared to post construction 1" storm. It is expected that as the magnitude of the storm increases, efficiency of LID will decrease. The decrease in efficiency will be quantitatively measured and assessed.

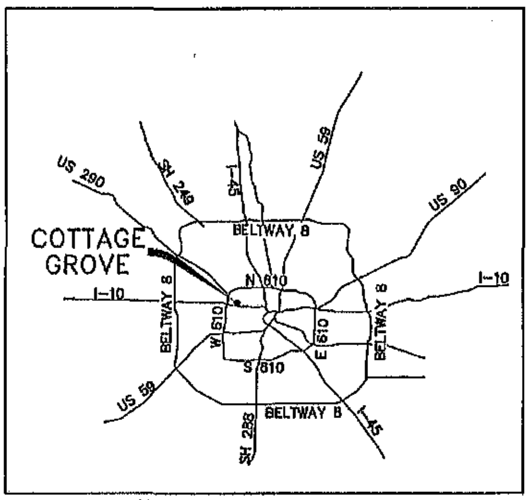
The percentage of pollutant removal achieved as a result of the BMP's performance will be one of several criteria reported by the City for the design and sizing of similar BMPs throughout the Gulf Coast region. The data and calculations will be used to help the city of Houston design further BMP because the data and calculations can be used as a standard to possibly predict the efficiency of other possible systems and allow for more thorough evaluation of sites and BMP technologies. Since there isn't a standard for LID implementation for the City of Houston the data and calculations obtained here will allow comparisons with future sites.

Monitoring data that do not meet data quality objectives will not be used in the project or submitted to SWQMIS. All monitoring data and/or performance calculations will be presented to stakeholders, at public meetings, and/or on a website.

Appendix A. Area Location Map



VICINITY MAP
Scale: 1" = 2640' (0.5 MILES)



HARRIS COUNTY AREA MAP

White Oak Bayou/Cottage Grove
Subdivision LID Demonstration Project
M-0286
WBS NO. M-000297-0001-3
MAY 2012

JONES & CARTER, INC.
ENGINEERS • PLANNERS • SURVEYORS
Texas Board of Professional Engineers Registration No. F-439
6335 Gulfton Dr., Suite 100 Houston, Texas 77081 (713) 777-5337

P:\PROJECTS\00050 City of Houston\079 Cottage Grove LID Demonstration Project\Civil\Exhibits\WHITEOAKBAYOULID Vic Map.dwg May 11,2012 - 9:19am RLC

Appendix B. Work Plan

Table Appendix B.1 *Contract Scope of Work and Schedule of Deliverables*

Task 1	**Project Administration**
Objective	To effectively administer, coordinate and monitor all work performed under this project including technical and financial supervision and preparation of status reports.
Subtask 1.1	Project Oversight – The City of Houston will provide technical and fiscal oversight of the City of Houston project staff and/or subgrantee(s)/subcontractor(s) to ensure Tasks and Deliverables are acceptable, and are completed as schedule and within budget. With the TCEQ Project Manager's authorization, the City of Houston may secure the services of subgrantees(s)/subcontractor(s) as necessary to perform or assist in performance of the tasks under Objectives 2 and 3. Project oversight status will be provided to the TCEQ with the Quarterly Progress Reports (QPRs).
Subtask 1.2	QPRs –The City of Houston will submit QPRs to the TCEQ by the 15th of the month following each state fiscal quarter for incorporation into the Grant Reporting and Tracking System (GRTS). Progress reports will contain a level of detail sufficient to document the activities that occurred under each task during the quarter, and will contain a comprehensive tracking of deliverable status under each task. Progress reports will be distributed to all project partners.
Subtask 1.3:	Reimbursement Forms – The City of Houston will submit Reimbursement Forms to the TCEQ by the last day of the month following each state fiscal quarter.
Subtask 1.4:	**Contract Communication** – The City of Houston will participate in a post-award orientation meeting with TCEQ within 60 days of contract execution. The City of Houston will maintain regular telephone and/or email communication with the TCEQ Project Manager regarding the status and progress of the project in regard to any matters that require attention between QPRs. This will include a call or meeting each January, April, July, and October. Minutes recording the important items discussed and decisions made during each call will be attached to each QPR. Matters that must be communicated to the TCEQ Project Manager in the interim between QPRs include the following: • Requests for prior approval of activities or expenditures for which the contract requires advance approval or that are not specifically included in the scope of work. • Submission of work products funded by or referencing this contract to the TCEQ Project Manager prior to distribution to other parties, including the Project Fact Sheet and other publications. • Notification in advance when City of Houston has scheduled public meetings or events, initiation of construction, or other major task activities under this contract Information regarding events or circumstances that may require changes to the budget, scope of work, or schedule of deliverables. Such information must be reported within 48 hours of discovering these events or circumstances

Subtask 1.5:	Contractor Evaluation – The City of Houston will participate in an annual Contractor Evaluation.
Subtask 1.6:	Project Fact Sheet – The City of Houston will develop a one-page fact sheet of the project using the TCEQ NPS Projects Template. The fact sheet will briefly describe what the project is going to accomplish, and will provide background information on why the project is being conducted, the current status of the project, and who is involved in the project. The project fact sheet will be submitted to the TCEQ within 60 days after contract initiation. The fact sheet will be updated once at the end of the project to reflect the final results. The fact sheet will be published on the City of Houston website after approval from the TCEQ Project Manager.
Subtask 1.7:	Annual Report Article – The City of Houston will provide an article for the Nonpoint Source Annual Report upon request by the TCEQ. This report is produced annually in accordance with Section 319(h) of the Clean Water Act (CWA), and is used to report Texas' progress toward meeting the CWA § 319 goals and objectives, and toward implementing it's strategies as defined in the Texas Nonpoint Source Management Program. The article will include a brief summary of the project and describe the activities of the past fiscal year.
Deliverables	• Minutes of Post-Award Orientation Meeting • QPRs • Reimbursement Forms • Minutes of Quarterly Contract Conference Calls • Contractor Self-Evaluation • Responses to Contractor Evaluation • Project Fact Sheet • Annual Report Article
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 will also help the public achieve a better understanding of land use activities and their impact on water quality.
Subtask 2.1	Prepare a Communication Plan – The City's Community Relations staff, in coordination with project partners, will prepare an effective communication plan to inform and educate the public about NPS pollution and solicit their input. The communication plan will be implemented through a series of public meetings.
Subtask 2.2	Stakeholder Participation – The City will engage stakeholder participation in one design phase meeting, one preconstruction meeting, one meeting during construction, one post construction meeting, and quarterly conference calls hosted by the project's Focus Group. These meetings/conference calls will provide an opportunity to transmit study goals, activities, and results to the stakeholders in the Planning Area.
Subtask 2.3	Public Outreach – The City will engage additional activities to disseminate information about the project to the public. Updates will be provided for inclusion on the TCEQ web site and the City's web site (http://www.greenhoustontx.gov/). It is expected that periodic

	newspaper articles may be published.
Subtask 2.4	Public Coordination – The City will coordinate with project partners to solicit input, participate in public meetings, and provide information and input on project development.
Subtask 2.5	Program Coordination – The City will coordinate with ongoing outreach programs (e.g., Texas Watershed Steward Program and Texas Stream Team) to inform and educate the public and solicit their input on BMP development.
Subtask 2.6	Web Site Updates – The City will update web pages to include project information.
Deliverables	• List/database of identified stakeholders – with QPR • Updates to stakeholder list/database – with QPRs • Draft and Final Communication Plan • Public meeting notices, agendas, handouts, meeting materials, attendee lists, and record of public input • Web site update
Task 3	**Study Design**
Objective	To develop study objectives and data analysis procedures for testing the preliminary pollutant load reduction estimates for the project that were derived from published data as presented under Objective 7.
Subtask 3.1	Data Quality Objectives (DQOs) – The City will establish specific research objectives for determining runoff pollutant loads before and after BMP construction, and will follow the TCEQ protocols for storm water data collection, sampling, and laboratory analysis.
Subtask 3.2	Conduct a Data Review – The City will conduct a data review to identify data gaps and to determine the types of additional data needed to achieve the DQOs.
Subtask 3.3	Develop a Water Quality Study Plan – The City will summarize the specific objectives of the project's monitoring effort, the data requirements of the study or other data analysis and interpretation to be used in the project, the preliminary locations, times, and other details of planned monitoring activities. The City will demonstrate how the planned activities support the DQOs.
Deliverables	Draft and Final Water Quality Study Plan, including DQOs, analysis of data gaps, and procedures for data review
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.

Subtask 4.1	QAPP Planning Meetings – The City will schedule QAPP planning meetings with the TCEQ Project Manager, Quality Assurance staff, technical staff, management, and contractors, to implement a systematic planning process, based on the elements of the TCEQ NPS QAPP Shell. The information developed during the planning meetings will be incorporated into a QAPP. Additional planning meetings may also be conducted to determine if any changes need to be made to an existing QAPP. The determination of where the data ends up (and how it should be coded) will be determined during the QAPP planning meeting.
Subtask 4.2	QAPP for Monitoring – The City will develop and submit to the TCEQ a QAPP with project specific DQOs consistent with the *EPA Requirements for Quality Assurance Project Plans (QA/R5)* format and the TCEQ NPS QAPP Shell 120 days prior to the initiation of any data collection. All of the monitoring procedures and methods prescribed in the QAPP will be consistent with the guidelines detailed in the TCEQ Surface Water Quality Monitoring Procedures, Volume 1 and 2. The QAPP will be developed by the City with technical assistance from TCEQ Project Manager, Quality Assurance staff, technical staff, management, and contractors. The QAPP will be approved by the TCEQ.
Subtask 4.3	Data Collection – The City, with the Project Partners (Rice University), will develop a monitoring program for storm water quality data for the existing condition and after selected BMPs have been constructed. The Project Partners will conduct monitoring for six (6) pre-construction stormwater events in study year one, and six (6) post construction storm water events in study years two and three. Stormwater monitoring is tied to rainfall. All monitoring will be conducted as outlined in the QAPP, to achieve DQOs.
Subtask 4.4	QAPP Update –The City will provide input to TCEQ 60 days prior to the end of the effective period of the QAPP and will develop annual QAPP revisions no less than 45 days prior to the end of the effective period of the QAPP.
Subtask 4.5	QAPP Amendments – Amendments to the QAPP and the reasons for the changes will be documented by the City and revised pages will be forwarded to all persons on the QAPP distribution list by the Contractor QAO. Amendments shall be reviewed, approved, and incorporated by the City into a revised QAPP during the annual revision process or within 120 days of the initial approval in cases of significant changes.
Subtask 4.6	Data Submittals – The City will review, verify, and validate water quality monitoring data before it is submitted to the TCEQ. The City will submit to the TCEQ quarterly and at least one month prior to use, or prior to presenting to stakeholders. The City will submit a semi-annual report of water quality data consistent with TCEQ formatting requirements for upload into the Surface Water Quality Monitoring Information System (SWQMIS).
Deliverables	• QAPP Planning Meeting • Draft and Final QAPP • Draft and Final QAPP Annual Updates • Draft and Final QAPP Amendments • Data Submittals Water quality monitoring non-conformances will be reported to TCEQ Project Manager and included in QPRs
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. Choose the subcontractors and complete the Engineering Design to

	utilize LID technologies.
Subtask 5.1	Design Sub-Contractor Selection – The City will choose a design engineering firm and a geotechnical engineering firm for the design and bidding phases of the project.
Subtask 5.2	Design – The City, with their chosen design engineering firm, will perform engineering analysis to assess BMP effectiveness from literature resources; BMPs that will be considered for implementation include porous pavers, pervious concrete, vegetated swale, bio-retention swale, and other LEED certified products; prepare calculations of pollutant load reductions (estimated), meet with LEED certified manufacturer's and material suppliers to discuss potential third party contributions from manufacturing vendors and suppliers, design roadway sections implementing Low Impact Development technologies, and prepare bid documents.
Subtask 5.3	Construction Sub-Contractor Selection – Sub-contractors for construction activities will be selected by the City using the City's procurement processes. The City will bid construction sub-contractor activities to include: clearing, earth moving, channeling, installation of flow conduits and flow measuring devices, planting, and leveling.
Deliverables	• Brief minutes of draft and final design plan meetings with the TCEQ prior to initiation of construction activities • Draft and final certified engineering design plans for the LID facilities prior to initiation of construction activities Copy of executed subcontract
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 (e.g., vegetative swales, porous pavement/parking and porous sidewalk) along two blocks (5.17 acres) in the Cottage Grove subdivision to test the effectiveness and long term maintenance needs of the BMPs. Prepare a scheduled maintenance program for each BMP, initiate maintenance activities, evaluate construction cost and annual operation/maintenance costs, and document project findings and conclusions for the final report.
Subtask 6.1	Construction Activities – The construction phase of this project will be closely monitored by the City Project Manager and City staff to ensure that the product meets the specifications set forth in the engineering plans.
Subtask 6.2	Construction Meetings – The City will hold weekly meetings with construction contractors that focus on safety and minimizing the temporary negative environmental impacts from construction activities. Equipment used in construction will be as small a scale as possible to accomplish each given task in a timely manner.
Subtask 6.3	Maintenance Plan and Activities – The City will prepare a scheduled maintenance guide for the installations and document implementation of upkeep procedures.
Deliverables	Update and final documentation of construction progress and completion, and construction meetings, including pictures
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 costs, neighborhood impacts, and public acceptance, and an assessment of city-wide application of the BMPs in public construction and private development.
Subtask 7.1	Data Compilation – The City will present the runoff volume and water quality study results Compile the storm water quality data for the pre- and post-construction of the BMPs Compare the construction costs for the different BMPs Prepare calculations of pollutant load reductions (achieved) Prepare an analysis of maintenance costs Assess BMP effectiveness for initial operation and extended operational period
Subtask 7.2	Data Evaluation – The City will document the cost. The City will analyze BMP effectiveness using the study design. Pollutant load reductions; maintenance requirements and other applicable findings.
Deliverables	Draft and Final BMP Evaluation Report that includes the calculation of pollutant loads removed.
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.
Subtask 8.1	Draft Final Report – The City will provide a draft final report summarizing all project activities, findings, and the contents of all previous deliverables, referencing and/or attaching them as web links or appendices. This comprehensive, technical report will provide analysis of all activities and deliverables under this scope of work.
Subtask 8.2:	Final Report – The City will revise the Draft report to address all comments provided by the TCEQ Project Manager.
Deliverables	• Draft Final Report • Final Report

Schedule of Deliverables

Task No.	Task Description	Due Date*
1	Minutes of Post-Award Orientation Meeting	*6/24/2010*
	QPRs	Quarterly 15th of the month following each state fiscal quarter
	Reimbursements Forms	By the last day of the month following each state fiscal quarter
	Minutes of Quarterly Contract Conference Calls	Quarterly - include with QPRs
	Contractor Self-Evaluation	Annual
	Responses to Contractor Evaluation	Annual
	Project Fact Sheet	*7/24/2010*
	Annual Report Article	Annual
2	List/database of identified Stakeholders -with QPR	*7/15/2010*
	Updates to Stakeholder List/Database - With QPRs	Quarterly with QPRs
	Draft and Final Communication Plan	*12/31/10*
	Public meeting notices, agendas, handouts, meeting materials, attendee lists, and record of public input	5/29/2012
	Web site update	On Going
3	Draft and Final Water Quality Study Plan, including DQOs, Analysis of data gaps, and procedures for data review	*3/3/2011*
4		*8/7/2010*
	Draft and Final QAPP	5/18/12 and 6/18/12
	Draft and Final QAPP Annual Updates	Annual
	Draft and Final QAPP Amendments	On Going
	Data Submittals	Quarterly and at least one month prior to use, or prior to presenting to stakeholders
5	Brief minutes of draft and final design plan meetings with the TCEQ prior to initiation of construction activities	9/1/2013
	Draft and final certified engineering design plans for the LID facilities prior to initiation of construction activities	10/1/12 and 11/1/2012
	Copy of executed subcontract	1/30/2013
6	Update and final documentation of construction progress and completion, and construction meetings, including pictures	8/2/2013
	Maintenance Guide	11/1/2012
7	Draft and Final BMP Evaluation Report that includes the calculation of Pollutant Loads Removed	11/28/2013
8	Draft Final Report	11/28/2013
	Final Report	11/28/2013

** Dates in italics indicate deliverable dates already met.*

1Q = Sept, Oct, Nov   3Q = Mar, April, May
2Q = Dec, Jan, Feb   4Q = June, July, Aug

Appendix C. Data Review Checklist and Summary

NPS DATA REVIEW CHECKLIST AND SUMMARY

A completed checklist must accompany all data sets submitted to the TCEQ by the Contractor.

Data Format and Structure		**Y, N, or N/A**
A.	Are there any duplicate *Tag_Ids* in the *Events* file?	______
B.	Do the *Tag* prefixes correctly represent the entity providing the data?	______
C.	Have any *Tag Id* numbers been used in previous data submissions?	______
D.	Are TCEQ station location (SLOC) numbers assigned?	______
E.	Are sampling *Dates* in the correct format, MM/DD/YYYY with leading zeros?	______
F.	Are the sampling *Times* based on the 24 hour clock (e.g. 13:04) with leading zeros?	______
G.	Is the *Comment* field filled in where appropriate (e.g. unusual occurrence, sampling problems)?	______
H.	Are *Submitting Entity*, *Collecting Entity*, and *Monitoring Type* codes used correctly?	______
I.	Do the *Enddates* in the *Results* file match those in the *Events* file for each *Tag_Id*?	______
J.	Are values represented by a valid parameter code with the correct units?	______
K.	Are there any duplicate parameter codes for the same *Tag Id*?	______
L.	Are there any invalid symbols in the Greater Than/Less Than (*Gt/lt*) field?	______
M.	Are there any tag numbers in the *Result* file that are not in the *Event* file?	______
N.	Have verified outliers been identified with a "1" in the *Remark* field?	______

Data Quality Review

A.	Are all the "less-than" values reported at or below the specified reporting limit?	______
B.	Have checks on correctness of analysis or data reasonableness performed?	______
	e.g.: Is ortho-phosphorus less than total phosphorus?	______
	Are dissolved metal concentrations less than or equal to total metals?	______

C. Have at least 10% of the data in the data set been reviewed against the field and laboratory data sheets? __________

D. Are all *parameter codes* in the data set listed in the QAPP? __________

E. Are all *StationIds* in the data set listed in the QAPP? __________

Documentation Review

A. Are blank results acceptable as specified in the QAPP? __________

B. Was documentation of any unusual occurrences that may affect water quality included in the *Event* table's *Comments* field? __________

C. Were there any failures in sampling methods and/or deviations from sample design requirements that resulted in unreportable data? If yes, explain on next page. __________

D. Were there any failures in field and laboratory measurement systems that were not resolvable and resulted in unreportable data? If yes, explain on next page. __________

E. Were there any failures in field and/or laboratory measurement systems that were not resolvable and resulted in unreportable data? **If yes, explain on next page.** __________

F. Was the laboratory's NELAC Accreditation current for analysis conducted? __________

Describe any data reporting inconsistencies with performance specifications. Explain failures in sampling methods and field and laboratory measurement systems that resulted in data that could not be reported to the TCEQ. (attach another page if necessary):

Date Submitted to TCEQ: ________________________________

TAG Series: ________________________________

Date Range: ________________________________

Data Source: ________________________________

Comments (attach file if necessary): ________________________________

____

____

____

____

□ I certify that all data in this data set meets the requirements specified in Texas Water Code Chapter 5, Subchapter R (TWC §5.801 et seq) and Title 30 Texas Administrative Code Chapter 25, Subchapters A & B.

□ This data set has been reviewed using the Data Review Checklist.

Contractor's Signature: ________________________________

Date: ________________________________

Appendix D. Detailed Site Location Map

= LID BMP experimental site and sampling locations

= Control site and sampling locations

Appendix E: Field Standard Operating Procedures

Water Quality Sampling Standard Operating Procedures

Sampling Locations:

Cottage Grove Subdivision: Darling St. and Petty St. Park on Reinerman St.
For Directions to sampling locations see Appendix C

Checklist for the Field:

Blue Ice
Ice Chest
Bottle of DI water

18 sampling bottle packets
Each packet should have;
 -4 standard 200mL plastic bottles
 -1 120 mL polyethylene bottle with Na_2SO_3
pH Meter
DO Meter
TSS Meter
CND Meter
Backup Batteries for meters
Bottle of 11N-19N of H_2SO_4

Log Book
Pencils
Sharpies

Paper Towels/towels
Gloves
Rain Gear (Poncho, boots etc.)
Bottled Water

Reminders:

Try to keep the meters in their Ziploc bags in order to prevent them from getting wet

Before entering the field:

1. Calibrate meters, record readings from pH 4, 7, 10, and Conductivity for 100 and 1000mmol for TSS.

2. E-mail or call lab to inform them you are sampling and will be dropping off samples. Mention that Rice University is dropping off samples taken for the City of Houston and tell them who will be dropping off the samples.

To drop sample off at the lab:
Call lab (713-330-2501)

Anyone who is dropping off samples **MUST have filled out a clearance form (See Appendix A)**

At each station (4 on each street)

Begin sampling procedure on 30 minute intervals (for each St)

Notes:
1. Check area for other individuals and safety concerns. Be aware of surroundings at all times. Note that surfaces will be slippery and water levels may be rising.

2. One person should be taking the samples and one person should record measurements and be a lookout to ensure safety.

3. Be mindful of the probes and equipment and avoid getting them wet as much as possible.

Collecting Samples Procedure:

Start upstream and move downstream. W→E

1. Put in one of the sampling bottle in the middle of the channel.

2. Once the sampling bottle is completely full take out bottle to take measurements

3. Wash off DO Probe with DI water

4. Immediately use DO meter to measure the DO. It will fluctuate wildly, take measurement at point where the DO is a steady maximum.
Note: Measurements should be taken in less than a minute

5. Record measurement of both the DO and the temperature of the water.

6. Rinse probe with DI water.

7. Repeat steps 3-6 for pH probe.

8. Repeat steps 3-6 for TSS probe

9. Repeat steps 3-6 for CND probe

10. Collect samples with the remaining 200mL sampling bottles. Make sure that there is no headspace and that there are no bubbles.
11. With 1 of the 200 mL bottles, add H2SO4 until pH is less than 2. Label bottle as pH<2.

12. Be sure that lid is tighten.

13. Use 120 mL polyethylene bottle with Na2SO3 to collect sample for E coli. Submerse bottle in water, do not let the water bubble. Leave ½ inch headspace.
NOTE: There is a pill in this bottle so it cannot be lost or sample will be invalid.

14. Label ALL bottles with Station #, time, date, sample number and initial. (See Appendix B for naming nomenclature)

15. Be sure that all equipment has been rinsed and check area for all material.

16. Put samples in ice chest with ice immediately once at the car.

17. Fill out Lab Documentation (See Appendix C)

Repeat every half hour at each street. Depending on the severity of the storm the process may be repeat on both streets.

18. Drop off sampling at City Lab
FOR directions to Lab See Appendix D

SAMPLES NEED TO BE DROPPED OFF AT THE LAB WITHIN 6 HOURS OF COLLECTION.

After sampling

1. Record standard measurements for each probe.
2. The probes should have been cleaned after all sampling but if not done be sure that the probes have been rinsed with DI water.
3. Replace supplies as needed

IMPORTANT:

Drink water as needed to avoid dehydration.
Do not sample at a site where individuals are loitering, continue to next location.
If an accident occurs and someone gets hurt call emergency numbers and seek medical attention if necessary.
If equipment is lost, continue on with the sampling, and replace as needed.

IN CASE OF EMERGENCY notify:
Dr. Bedient: Cell 713-303-0266
Sandra Baylor: Cell 713-408-9960

IMPORTANT NUMBERS
Dr. Ying Wei- City Lab Contact 832-395-6012 (Alternate number: 713-305-9014 yingwei@houstonTX.gov)
City Lab 832-395-6032
George Doubleday: 713-515-7374
Tatyana Luttenschlager: 832-528-3034
Mike Burcham: 321-960-9789

Appendix F. Field Data Reporting Form

Field Data Reporting Form

RTAG# | REGION | EMAIL-ID: COLLECTOR

STATION ID | SEGMENT | SEQUENCE | DATA SOURCE

Station Description

GRAB SAMPLE

M M D D Y Y Y Y — DATE

H H M M — TIME

X — DEPTH

M = meters

COMPOSITE SAMPLE

COMPOSITE CATEGORY: T = TIME S = SPACE (i.e. Depth) B = BOTH F = FLOW WEIGHT

M M D D Y Y Y Y — START DATE

H H M M — START TIME

START DEPTH (SURFACE) M = Meters F = Feet

M M D D Y Y Y Y — END DATE

H H M M — END TIME

END DEPTH (DEEPEST) M = Meters F = Feet

COMPOSITE TYPE : ## = Number of Grabs in Composite CN = Continuous

00010		WATER TEMP (EC only)
00400		pH (s.u)
00300		D.O. (mg/L)
00094		SPECIFIC COND (Φmhos/cm)
00480		SALINITY (ppt, marine only)
50060		CHLORINE RESIDUAL (mg/L)
00078		SECCHI DISK (meters)
82078		TURBIDITY-FIELD (NTU)
31616		FECAL COLIFORM (#/100 ml)
31699		E. coli (#/100 ml) (Colilert Method)
31701		Enterococci (#/100 ml) (Enterolert Method)

72053		DAYS SINCE LAST SIGNIFICANT PRECIPITATION			
01351		FLOW SEVERITY		1-no flow	2-low
		3-normal	5-high	4-flood	6-dry
00061		INSTANTANEOUS STREAM FLOW (ft^3/sec)			
89835		FLOW MEASUREMENT METHOD 1- Flow Gage Station 2- Electric 3- Mechanical 4- Weir/Flume			
74069		FLOW ESTIMATE (ft^3/sec)			
82903		TOTAL WATER DEPTH (meters)			
00055		WATER VELOCITY (maximum)(ft/sec)			
89864		MAXIMUM POOL WIDTH (meters) *			
89869		POOL LENGTH (meters) *			
89865		MAXIMUM POOL DEPTH (meters) *			
89870		% POOL COVERAGE IN 500 M REACH *			

*Parameters related to data collection in perennial pools; i.e., Flow Severity of 1 and Flow of zero reported.

Measurement Comments and Field Observations:

Appendix G. Chain-of-Custody Form

Water Quality Laboratory 2300 Federal Road, Houston, Tx.77015 713-330-2501 Chain of Custody (Special Project)					
Effective	Applied Area	Document Type	Document ID	Version	Document Page
01/01/08	***Laboratory***	***Form***	***144***	***1.01***	**1 *of* 1**

Lab Use Only	Item	Sample ID /Description	Sampling		Depth(s) (ft)	Sample Type		Matrix			No. Of Containers	Type of Container/ Preservation	Requested Analysis						
			Date	Time		Comp.	Grab	Water	Soil	Other									

Comments: ____

Collected By: ________________

Relinquished By: ______________ Relinquished Date and Time: ________________

Received By: ______________ Received Date & Time: ________________

Appendix H. Automated Sampler Testing and Maintenance Requirements

Not applicable to project, for in-stream sampling refer to the TCEQ: Surface Water Quality Monitoring Procedures, Volume 1.

Appendix I Automated Sampler Calibration Requirements

Not applicable to project, for in-stream samples refer to: TCEQ Surface Water Quality Monitoring Procedures, Volume 1.

Appendix J Field and Laboratory Data Sheets

Reported pollutant removal efficiency of BMPs

BMP	TSS	Total P	Total N	Bacteria
Bioretention	-	81	43	-
Dry Well	80-100	40-60	40-60	60-80
Infiltration Trench	80-100	40-60	40-60	60-80
Filter Strip	20-100	0-60	0-60	-
Vegetated Swale	30-65	10-25	0-15	Neg.
Infiltration Swale	90	65	50	-
Wet Swale	80	20	40	-

TCEQ Surface Water Quality Monitoring Calibration and Maintenance Log

Date: Time: Employee name:

Calibration

Function	Temp. of Standard	Value of Standard	Initial Reading	Calibrated to	Comments
Specific conductance (high) ∃1,000 ΦS/cm					
Conductivity cell constant					Range 5.0 ∀ 0.5
pH calibrated (~7)					
pH mv for pH 7 solution					Range 0 ∀ 50 mv
pH slope (~ 4/10)					
pH mv for pH 10 pH mv for pH 4					Range: -130 to -230 mv Range: 130 to 230 mv
Dissolved oxygen (%sat) *					
Dissolved oxygen charge					Range 25 to 75
Dissolved oxygen gain					Range 0.7 to 1.4
Optional Sensors (include parameter: turbidity, etc.)					

DATA NEEDED FOR DISSOLVED OXYGEN CALIBRATION

Altitude (A) =_____________feet above msl . Barometric pressure _________ inches _______________ mm

Barometric Pressure (BP) Options	Barometric Pressure Formulas
Barometer	Barometric pressure (inches) ________ x 25.4 = BP _______mm
From local source after correction (CBP)	BP _________ mm = CBP _______ mm - 2.5 (altitude ____/100)
Estimated from altitude only	BP _________ mm= 760 mm - 2.5 (altitude _____/100)
DO % saturation standard calculation *	**DO% sat Standard = Absolute BP mmHg/760 x 100**

Deployment Checklist (required for data logging only)

Logging interval: Yes No	SDI-12 Autosleep enabled: Yes No	RS 232 autosleep enabled: Yes No	DO warm-up time:	Battery volts in Sonde (days):	Available memory in Sonde (days):

Post-Calibration Check

Date: Time: Employee Name:
Battery Voltage: Sonde Type and Serial No.

Function	Temp. of Standard	Value of Standard	Initial Reading	Pass Post-Cal?	Comments
Specific conductance				☐Yes ☐No	
pH calibrated (~7)				☐Yes ☐No	
pH slope (~ 4/10)				☐Yes ☐No	
Dissolved oxygen (%sat) *				☐Yes ☐No	
Optional Sensors (include parameter: turbidity, etc.)				☐Yes ☐No	
				☐Yes ☐No	

Location of Deployment, Routine Run, or Special Study: Date/Time Deployed: Date/Time Retrieved:

Use(circle one): 24-hour Continuous Grab Referee

MAINTENANCE
(Refer to Chapter 8 for maintenance requirements)

Sensor	**Date**	**Initials**	**Maintenance Completed**
pH			
DO			
Specific Conductance			

Perform temperature check along with regular maintenance. The laboratory thermometer must be checked against NIST traceable thermometer annually.

Annual NIST traceable check	Date:	NIST Temp:	Lab Thermometer Temp:	Correction Factor:
Maintenance temperature check	Date:	Sonde Temp:	Lab Thermometer Temp:	

Factory maintenance/repair notes:

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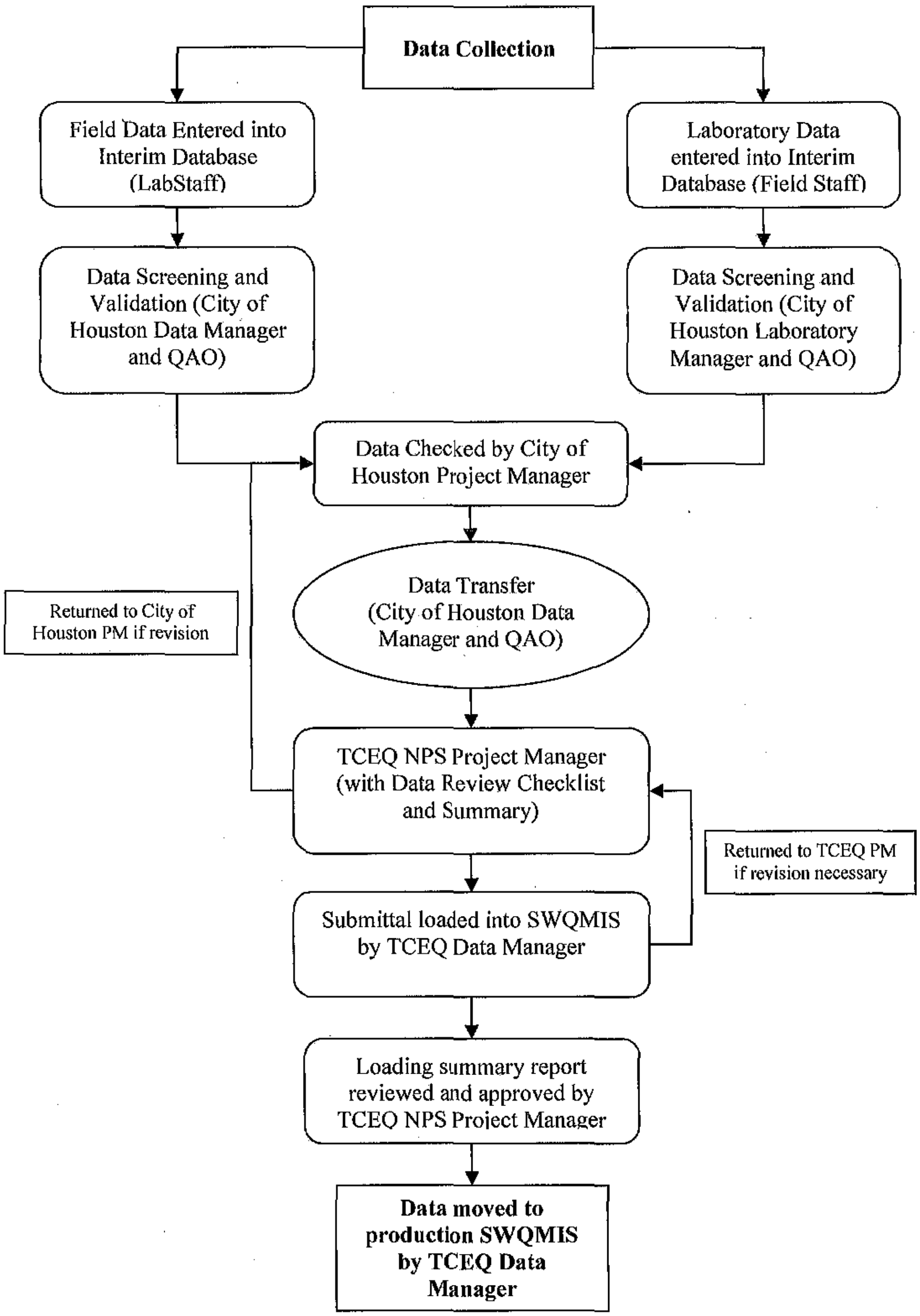
				In Situ Measurements						
	Matrix	Description	# of containers	DO (mg/L)	Temperat ure (deg	Conducti vity (uS)	pH	TDS (ppm)	Notes on Samples	Sample ID

						Field Remarks:
						Lab log #
	Date	**Time**		Page #/ Total Pages		**Laboratory Name:**

Appendix K. Data Management Flow Chart

Draft NPS Data Management Process Flow Chart



Appendix L: Corrective Action Status Table

Appendix L - Corrective Action Status Table

Corrective Action #	Date Issued	Description of Deficiency	Action Taken	Date Closed

Appendix M: Corrective Action Plan Form

Corrective Action Plan
Issued by:________________ **Date Issued**________________ **Report No.**________________
Description of deficiency
Root Cause of deficiency
Programmatic Impact of deficiency
Does the seriousness of the deficiency require immediate reporting to the TCEQ? If so, when was it?
Corrective Action to address the deficiency and prevent its recurrence
Proposed Completion Date for Each Action
Individual(s) Responsible for Each Action
Method of Verification
Date Corrective Action Plan Closed?

ATTACHMENT 1

Example Letter to Document Adherence to the QAPP

TO: (name)

TCEQ

FROM: Cheryl Harris

City of Houston

RE: City of Houston, White Oak Bayou BMP Demonstration QAPP

Please sign and return this form by (date) to:

(address)

I acknowledge receipt of the "White Oak Bayou BMP Demonstration QAPP , September 16, 2010". I understand that the document describes quality assurance, quality control, data management and reporting, and other technical activities that must be implemented to ensure the results of work performed will satisfy stated performance criteria.

My signature on this document signifies that I have read and approved the document contents. Furthermore, I will ensure that all staff members participating in activities covered under this QAPP will be required to familiarize themselves with the document contents and adhere to the contents as well.

____

Signature Date

Copies of the signed forms should be sent by the Contractor to the TCEQ NPS Project Manager within 60 days of TCEQ approval of the QAPP.