Clean Water Act §319(h) Nonpoint Source Pollution Control Program

Development of a Watershed Protection Plan for Cedar Bayou

***TSSWCB Project* Number 10-08**
Revision No. 1

Modeling Quality Assurance Project Plan

Texas State Soil and Water Conservation Board

Prepared by:
Houston-Galveston Area Council
3555 Timmons Lane, Suite 120
Houston, TX 77027

Effective Period: Upon EPA Approval through August 31, 2015

(With annual revisions required)

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

Justin Bower
P.O. Box 22777
Houston, TX 77227-2777
(713) 499-6653
Justin.Bower@H-GAC.com

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A1 APPROVAL PAGE

Modeling Quality Assurance Project Plan (QAPP) for the *Development of a Watershed Protection Plan for Cedar Bayou.*

United States Environmental Protection Agency (EPA), Region VI

Name: Curry Jones
Title: USEPA Chief; State/Tribal Programs Section

Signature: ______________________________ Date: ____________________

Name: Henry Brewer
Title: USEPA Texas Nonpoint Source Project Officer

Signature: ______________________________ Date: ____________________

Texas State Soil and Water Conservation Board (TSSWCB)

Name: Ashley Wendt
Title: TSSWCB Project Manager (PM)

Signature: ________________________________ Date: ____________________

Name: Mitch Conine
Title: TSSWCB Quality Assurance Officer (QAO)

Signature: ________________________________ Date: ____________________

Houston-Galveston Area Council (H-GAC)

Name: Justin Bower
Title: H-GAC Senior Environmental Planner/ PM

Signature:____________________________________Date:____________________

Name: Jean Wright
Title: H-GAC QAO
Signature:____________________________________Date:____________________

CDM Smith, Inc.

Name: Tobin Maples
Title: CDM Smith Client Service Leader

Signature:____________________________________Date:____________________

Name: Tina Petersen
Title: CDM Smith PM
Signature:____________________________________Date:____________________

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Appendices

List of Acronyms

ARS	United States Department of Agriculture-Agricultural Research Service
BSLC	Bacteria Source Load Calculator
CADDIS	Causal Analysis/Diagnosis Decision Infomration System
CAR	Corrective Action Report
CDM	CDM Smith, Inc.
CRP	Clean Rivers Program
CWA	Clean Water Act
DQO	Data Quality Objectives
EPA	Environmental Protection Agency
FDC	Flow Duration Curve
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
LDC	Load Duration Curve
NLCD	National Land Cover Data Set
NOAA	National Oceanic and Atmospheric Administration
PM	Project Manager
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QAO	Quality Assurance Officer
QC	Quality Control
QPR	Quarterly Progress Report
SELECT	Spatially Explicit Load Enrichment Calculation Tool
SOP	Standard Operating Procedures
SSL	Spatial Sciences Laboratory
SSURGO	Soil Survey Geographic database
SWMM	Stormwater Management Model
SWAT	Soil and Water Assessment Tool
TAMU	Texas A&M University; College Station Campus
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TSSWCB	Texas State Soil and Water Conservation Board
USGS	United States Geological Survey
WWTF	Wastewater Treatment Facility

A3 DISTRIBUTION LIST

Organizations, and individuals within, which will receive copies of the approved QAPP and any subsequent revisions include:

U.S. Environmental Protection Agency, Region 6 (EPA)
1445 Ross Avenue, Suite # 1200; Dallas, TX 75202-2733

Name: Henry Brewer
Title: Texas NPS Project Officer

Texas State Soil and Water Conservation Board (TSSWCB)
P.O. Box 658; Temple, TX 76503

Name: Ashley Wendt
Title: TSSWCB PM

Name: Mitch Conine
Title: TSSWCB QAO

Houston-Galveston Area Council (H-GAC)
P.O. Box 22777 Houston, TX 77227-2777

Name: Justin Bower
Title: Senior Environmental Planner/ PM

Name: Jean Wright
Title: H-GAC QAO

CDM Smith, Inc. (CDM)
3050 Post Oak Boulevard, #300; Houston, TX 77056

Name: Tobin Maples
Title: CDM Smith Client Service Leader

Name: Tina Petersen
Title: CDM Smith PM

A4 PROJECT/TASK ORGANIZATION

The following is a list of individuals and organizations participating in the project with their specific roles and responsibilities:

EPA – U.S. Environmental Protection Agency, Region 6, Dallas, Texas. Provides project oversight and funding at the federal level.

Henry Brewer, EPA Project Officer

> Responsible for overall performance and direction of the project at the federal level. Ensures that the project assists in achieving the goals of the Clean Water Act (CWA). Reviews and approves the QAPP, project progress, and deliverables.

TSSWCB – Texas State Soil and Water Conservation Board, Temple, Texas. Provides project overview at the State level.

Ashley Wendt, TSSWCB PM

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

Mitch Conine, TSSWCB QAO

> Reviews and approves QAPP and any amendments or revisions and ensures distribution of approved/revised QAPPs to TSSWCB participants. Responsible for verifying that the QAPP is followed by project participants. Assists the TSSWCB PM on issues related to Quality Assurance (QA). Determines that the project meets the requirements for planning, QA/QC, and reporting under the CWA Section 319 NPS Grant program. Coordinates reviews and approvals of QAPPs and amendments or revisions. Monitors implementation of corrective actions. Coordinates and conducts audits of field and laboratory systems and procedures.

H-GAC – Houston-Galveston Area Council, Houston, Texas. Responsible for reporting and development of data quality objectives (DQOs) and a quality assurance project plan, developing geographic information system (GIS) inventory, classifying land use and land cover, and modeling the Cedar Bayou watershed for use in the watershed protection plan (WPP) development.

Justin Bower, H-GAC Senior Environmental Planner/PM

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 TSSWCB. Responsible for verifying the QAPP is followed and the project is producing data of known and acceptable quality. Ensures adequate training and a thorough knowledge of standard operating procedures specific to modeling activities. Responsible for oversight of all modeling activites and ensuring that all QA/QC requirements are met. Complies with corrective action requirements.

Jean Wright, H-GAC 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 TSSWCB QAO to resolve QA-related issues. Notifies the TSSWCB PM of particular circumstances which may adversely affect the quality of data. Responsible for validation and verification of all data collected according with procedures listed in this document and acquired data procedures after each task is performed. Coordinates the review of technical QA material.

William Hoffman, H-GAC Data Manager

Responsible for conducting the SWQMIS water quality data evaluation. Coordinates with the QAO and PM on developing and implementing data management-related aspects of the QAPP. Manages acquisition and transfer of SWQMIS and related Clean Rivers Program (CRP) data to other staff for modeling purposes.

Thushara Ranatunga, H-GAC Modeler

Responsible for conducting modeling efforts. Maintains primary documentation for modeling efforts. Provides preliminary data to H-GAC PM. Assists in model selection and assumption refinement. Notifies H-GAC PM of any issues related to model efforts or of any changes to methodologies discussed in the QAPP.

William Bass, H-GAC GIS Manager

Responsible for reviewing and maintaining spatial data resources and internal GIS. Manages acquisition or transfer of any external GIS or related spatial data. Provides GIS information and updates to H-GAC PM.

CDM – CDM Smith, Inc., Houston, Texas. Responsible for conducting SWMM5 and CADDIS efforts. Develops and operates SWMM5 model for Cedar Bayou Tidal Segment and conducts CADDIS evaluation for Cedar Bayou Above Tidal segment. Coordinates review of assumptions, results, and revisions with H-GAC PM and H-GAC Modeler.

Tobin Maples, CDM Smith Client Service Leader

Respponsible for overseeing contract relations with H-GAC and provides oversight for CDM Smith project work with CDM Smith PM.

Tina Petersen, CDM Smith PM

Responsible for overseeing all project work on the SWMM5 and CADDIS efforts. Coordinates efforts of CDM Smith_project team. Coordinates review of assumptions, results, and revisions with H-GAC PM and H-GAC modeler. Notifies H-GAC PM of any issues related to model efforts or of any changes to methodologies discussed in the QAPP.

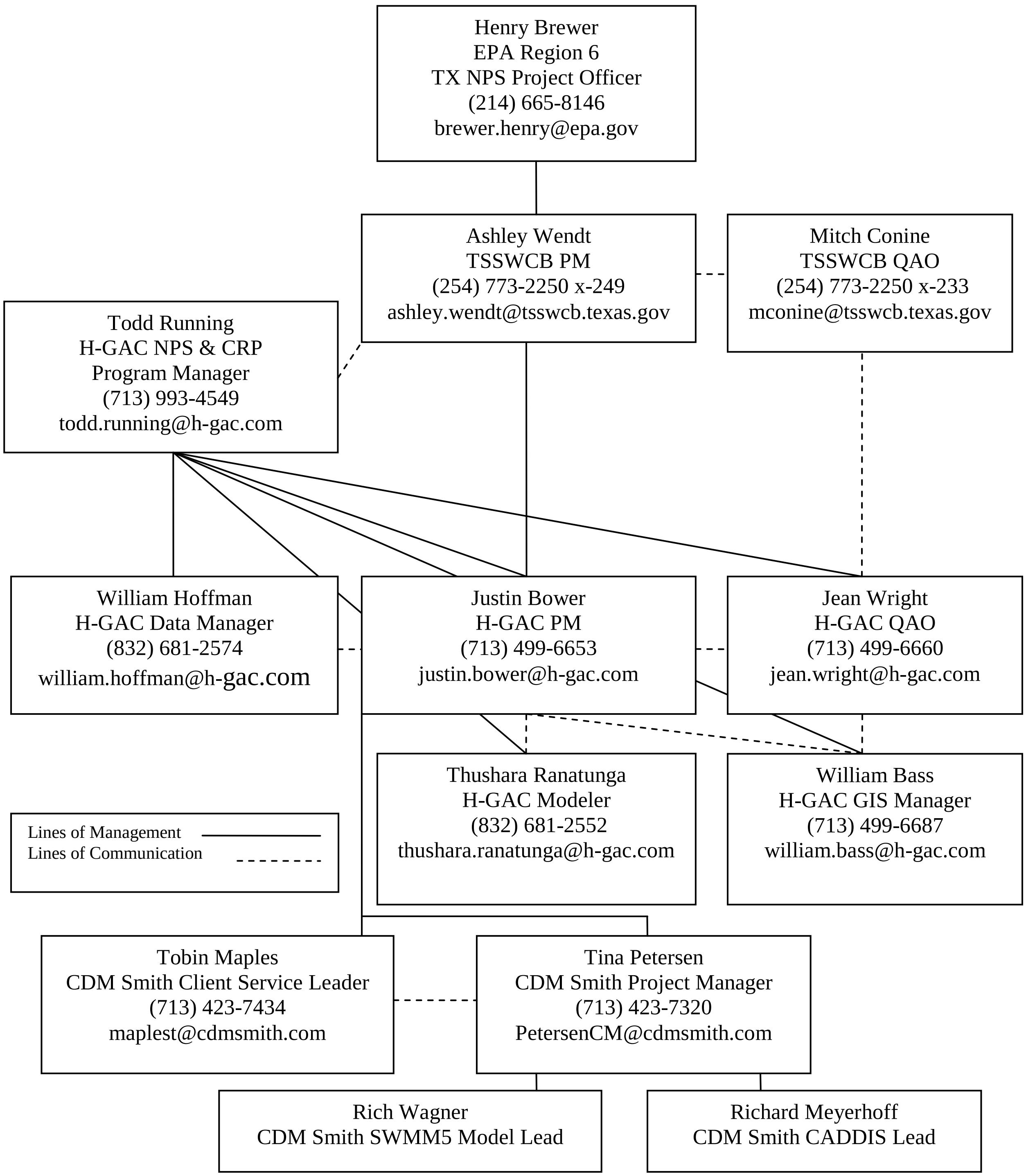
Rich Wagner, CDM Smith SWMM5 Modeling Lead

Responsible for overseeing the SWMM5 modeling effort. Coordinates with CDM Smith PM on all feedback from H-GAC and all assumptions, results and revisions related to the SWMM5 modeling effort for Cedar Bayou Tidal Segment. Notifies CDM Smith PM of any issues related to model efforts or of any changes to methodologies discussed in the QAPP.

Richard Meyerhoff, CDM Smith CADDIS Evaluation Lead

Responsible for overseeing the CADDIS evaluation effort for Cedar Bayou Above Tidal segment. Coordinates with CDM Smith PM on all feedback from H-GAC and all assumptions, results and revisions related to CADDIS analysis activities. Notifies CDM Smith PM of any issues related to CADDIS evaluation efforts or of any changes to methodologies discussed in the QAPP.

Figure A4-1. Project Organization Chart



A5 PROBLEM DEFINITION/BACKGROUND

The purpose of this project is to work with federal, state and local agencies to coordinate a stakeholder driven process for development of a watershed protection plan for the Cedar Bayou watershed which will satisfy the EPA's nine element guidance for watershed-based plans.

The Cedar Bayou watershed drains approximately 200 square miles of the upper Gulf Coast area of Texas, east of the City of Houston. Cedar Bayou flows south from its headwaters in Liberty County to form the majority of the boundary between Harris and Liberty and Chambers Counties. Cedar Bayou comprises two stream segments as defined by TCEQ. Stream segment 0902 is Cedar Bayou Above Tidal, which flows from a point 7.4 kilometers (4.6 miles) upstream of FM 1960 in Liberty County (northwest of the City of Dayton) to a point 2.2 kilometers (1.4 miles) upstream of IH 10 in Chambers/Harris County (due west of the City of Mont Belvieu). Segment 0901 is Cedar Bayou Tidal, which flows from a point 2.2 kilometers (1.4 miles) upstream of IH 10 in Chambers/Harris County (due west of the City of Mont Belvieu) to the confluence with Galveston Bay 1.0 kilometer (0.6 mile) downstream of Tri-City Beach Road in Chambers County (southeast of the City of Baytown).

The top third of the watershed primarily comprises agricultural and low density residential uses. Most of the Bayou and its network of drainage tributaries are channelized or bermed in this area, and range in size from a small, ephemeral drainage ditch to a shallow creek. The middle third of the watershed includes large portions of undeveloped land, agricultural areas, and scattered industrial and residential uses. The Bayou in this section has a thick riparian buffer zone in many areas, widens and deepens, and contains consistent flow. The bottom third of the watershed includes suburban areas and dense urban and industrial uses. Historically, the lower portion of the watershed has been a locus for commodities and petrochemical industry activity. This section of the Bayou continues to widen, becoming a small river, and then a series of interconnected lakes prior to its confluence with Upper Galveston Bay.

Regional growth projections point to a continued rapid increase of population for Harris County and its adjacent counties through 2035. In the Cedar Bayou watershed, much of that growth is expected to occur in and adjacent to existing urban and suburban areas, and along major transportation corridors. Additionally, the lower reaches of Cedar Bayou serve a large volume of barge traffic, which is expected to increase with the proposed development of a barge terminal. In the upper portions of the watershed, significant portions of the Bayou and its tributaries have been modified in path and channel characteristics, and natural drainage has been replaced throughout much of the bayou with an intricate series of drainage ditches, canals, and channelized tributaries.

In the 2008 Texas Water Quality Inventory and 303(d) List, Cedar Bayou Above Tidal (0902) is listed as impaired for macrobenthic communities and Cedar Bayou Tidal (0901) is listed as non-supporting of the contact recreation standard due to elevated levels of indicator bacteria, and also impaired for PCBs and Dioxin in edible fish tissue. In the 2010 Integrated Report for Clean Water Act Sections 305(b) and 303(d), the same impairments exist, with the exception of a delisting of Segment 0902 for impaired macrobenthic communities. However, the 2010 Integrated Report also indicates that Segment 0902 has concerns for impaired macrobenthic communities and depressed dissolved oxygen, while Segment 0901 has concern for chlorophyll-*a*. In the 2012 Integrated Report, Segment 0901 is impaired for bacteria, and PCBs and Dioxins in edible fish tissue. Chlorophyll-a is listed as a concern for this segment. Segment 0902 is not listed for any impairments or concerns.

Cedar Bayou Tidal is part of the Houston Ship Channel and Upper Galveston Bay TMDL project for Dioxin and Polychlorinated Biphenyls (PCBs) in Fish Tissue. Additionally, the TMDL for Upper Galveston Bay (Segment 2421), currently being addressed in the Upper Gulf Coast Oyster Waters TMDL Implementation Plan, is potentially affected by flow from the Bayou. Some aspects of nonpoint source pollution are being addressed by the City of Baytown and the Joint Task Force (Harris County, Harris County Flood Control District, the City of Houston, and the Texas Department of Transportation (TxDOT) through their respective TPDES storm water permits, which include areas in the Harris County portions of the watershed. Cedar Bayou supports appreciable recreational activity, including boating, swimming, and fishing, which could be impacted by these water quality impairments. Cedar Bayou is also a tributary to the Galveston Bay system, thus these contaminants potentially impact a wide range of economic and ecological interests even beyond their watershed of origin. To that end, H-GAC sought §319(h) grant funding from the TSSWCB and the EPA for the development of a watershed protection plan for Cedar Bayou, resulting in this project.

H-GAC, through the Clean Rivers Program, has historical ambient monitoring data from six stations (11111, 11115, 11117, 11118, 11120, and 11123) in the watershed. Sites 11111 and 11120 have data from as early as 1995. Sites 11117 and 11123 have data starting from 2007. Currently, sites 11115, 11117, 11118, and 11123 are being monitored by H-GAC. Six additional sites are being monitored during the course of the Cedar Bayou project, which is covered under the TSSWCB project 10-08 Monitoring QAPP. This increased ambient monitoring, along with monitoring of storm flow events, monitoring of dissolved oxygen levels, and biological assessment of macrobenthic communities, will be conducted to support the development of the Cedar Bayou Watershed Protection Plan (WPP).

To provide information for local stakeholders in the development of the project, including loading estimates and necessary load reductions, H-GAC and the TSSWCB have identified a series of necessary modeling efforts. In order to characterize the spatial loading potential of the watershed and investigate probable causes of pollution, H-GAC will:

- Develop and implement a GIS-based land use/land cover (LULC) analysis to identify trends over time;
- Retrieve and evaluate all historical SWQMIS data for Cedar Bayou for trends and variability, both spatially and temporally;
- Conduct load duration curve (LDC) analysis of historic water quality data in the above-tidal (0902) segment

- Use the Spatially Explicit Load Enrichment Calculation Tool (SELECT) to evaluate the potential loadings from the land uses throughout the watershed and its subwatersheds; and
- Use the Soil and Water Assessment Tool (SWAT) to evaluate and quantify the impact of loadings from sources and potential reductions from management practices in the above-tidal (0902) segment of Cedar Bayou.
- Conduct SWMM5 modeling in the tidal (0901) segment of Cedar Bayou to evaluate the impacts of loadings on water quality, the impacts of tidal action on pollutant removal, and to identify necessary reductions.
- Conduct an evaluation of ecological communities in the above itdal (0902) segment using EPA's CADDIS.

These modeling efforts will provide valuable information in facilitating the development of a Watershed Protection Plan for Cedar Bayou.

A6 PROJECT GOALS AND DESCRIPTION

The overall goal of the Cedar Bayou WPP is to identify, evaluate and address sources of pollution in the Cedar Bayou watershed for the purpose of improving and maintaining water quality in Cedar Bayou (segments 0901 and 0902). The seven efforts discussed under this QAPP will support this overall goal by providing data analysis to guide the stakeholder-driven decision making process. Specifically, the modeling efforts will help stakeholders identify past water quality trends, compare past and current land use and land cover (to help identify trends and potential sources of contaminants), evaluate loadings in relation to flow conditions,evaluate the potential loadings from the various subwatersheds and sources, evaluate the impact of watershed processes on loadings in the waterway, and evaluate the impact of tidal action on pollutant removal. The modeling efforts will utilize existing geospatial data and existing water quality monitoring data in conjunction with data generated under current monitoring activities (described fully in the Monitoring QAPP for Cedar Bayou – TSSWCB project 10-08). To meet these tasks, as described in the following segments of the project scope of work, H-GAC will: 1) Evaluate trends in the existing water quality data in SWQMIS; 2) evaluate and update (as appropriate) the existing LULC data for the watershed; 3) develop and assess LDCs for contaminants related to impairments, 4) conduct SELECT modeling to establish loadings for contaminants, 5) conduct SWAT modeling in the above-tidal segment to evaluate the impact of source loadings and potential reductions from management practices, 6) retain a contractor to conduct SWMM5 modeling in the tidal segment to evaluate the impact of source loadings and potential reductions from management practices and the impact of tidal action on pollutant removal, and 7) conduct CADDIS evaluation of the above tidal segment to evaluate ecological communities

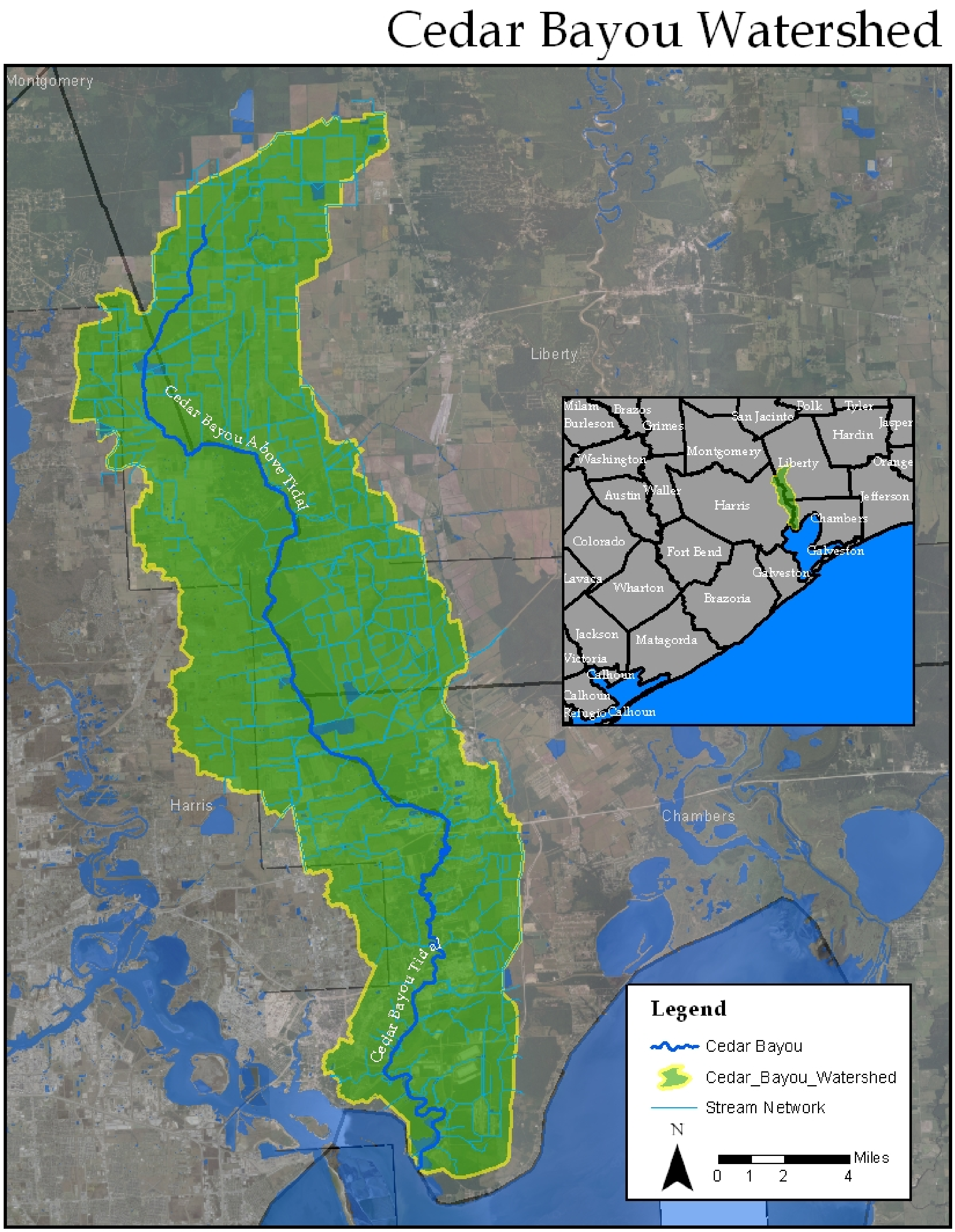


Figure A6-1 – The Cedar Bayou Watershed

The modeling efforts will be conducted by H-GAC (or their contractors) under the direction of the TSSWCB. The results of the modeling effort will be included in a technical report submitted to TSSWCB for inclusion in the Cedar Bayou WPP (TSSWCB Project 10-08).

The following elements of project tasks, as described in the project scope of work, are related to this QAPP:

H-GAC, in collaboration with other project partners, will develop a comprehensive GIS inventory of the Cedar Bayou watershed. This GIS will include the most recent information available on land use, elevation, soils, stream networks, reservoirs, roads, municipalities and satellite imagery or aerial photography. Locations of SWQM stations, USGS gages, public access points to the water bodies, floodwater-retarding structures, wetlands, TPDES permittees (including WWTFs, CAFOs and MS4s), and subdivisions should also be included. Locations of possible bacteria sources, identified during the source survey, should be incorporated. The cumulative impact of TSSWCB-certified WQMPs on the management of agricultural and silvicultural lands should be documented.

H-GAC will compile existing LULC datasets for the watershed from existing data. The current LULC data sources used in this project are the National Land Cover Dataset (NLCD) 2006 and National Oceanic and Atmospheric Administration (NOAA) C-CAP 2011 datasets. While the existing data is deemed current and accurate, H-GAC will work with local stakeholders to assess the degree to which existing datasets represent current watershed conditions on the local level. Additionally, H-GAC staff will identify any discrepancies noted in informal field reconnaissance activities. If existing LULC datasets do not represent current conditions on the local level, H-GAC will make localized updates utilizing the most current satellite or aerial imagery. The current aerial imagery source for the project area is 1-foot resolution H-GAC aerial data produced by H-GAC's vendor, Surdex in January 2012. Individual LULC classes will be comparable to NLCD and delineated in shapefile or ArcGIS grid format. H-GAC will provide an analysis of LULC changes and trends over time for use in watershed planning.

H-GAC will work with local stakeholders and technical experts to develop a source survey (also known as a sanitary survey) that characterizes the possible sources of pollutant loadings. The source survey should be developed so that it represents warm and cool seasons and low and high flow conditions. The source survey should evaluate sources like WWTFs, central sewage collection systems, OSSFs, and MS4s. TPDES compliance issues should be examined. Wildlife, livestock and non-domestic animal populations should be examined. H-GAC will conduct the source survey as designed.

H-GAC will retrieve all historic data in SWQMIS for the watershed. H-GAC will assess historic data for trends and variability, both spatially and temporally.

H-GAC will conduct a LDC analysis of historic and existing water quality data for the non-tidal portion of the watershed. LDCs will be developed for at least one critical index site per assessment unit to determine load reductions needed to achieve water quality standards. Using water quality data collected or compiled under the TSSWCB project 10-08 Monitoring QAPP, H-GAC will refine LDCs developed with historic data. LDCs shall be consistent with 1) EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs*, 2) EPA's *Options for Expressing Daily Loads in TMDLs*, and 3) EPA's *Development of Duration-Curve Based Methods for Quantifying Variability and Change in Watershed Hydrology and Water Quality*.

H-GAC will utilize SELECT to model pollutant loadings from across the watershed. Utilizing information from the GIS inventory, source survey, surface water quality monitoring, and LULC update; SELECT will be developed for the entire watershed, tidal and non-tidal portions. Modeling will be used to estimate loadings from various sources and to identify critical loading areas within the watersheds.

H-GAC will conduct SWAT modeling to evaluate and quantify loading from sources in the above tidal portion of the watershed, to evaluate the potential impact of management activities, and to serve as an input to future modeling in the tidal portion of the watershed.

H-GAC will retain the services of CDM Smith, Inc. to conduct SWMM5 modeling to evaluate the impact of watershed processes and tidal removal on instream concentrations in the tidal segment.

H-GAC will retain the services of CDM Smith, Inc. to conduct a CADDIS evaluation to evaluate the ecological communities of the above tidal segment.

Table A6.1 summarizes the project plan milestones for the seven modeling efforts represented in the tasks above.

Table A6.1 Project Milestones

Task	Project Milestones	Start	End
2.1	H-GAC will develop a QAPP for water quality monitoring activities in Task 5 and a QAPP for watershed modeling activities in Task 6 consistent with all applicable standards.	Nov. 10	Jul. 13
2.2	H-GAC will implement the approved QAPPs. H-GAC will submit revisions and necessary amendments to the QAPPs as needed.	Sept. 13	Aug. 15
4.1	H-GAC, in collaboration with other project partners, will develop a comprehensive GIS inventory of the Cedar Bayou watershed. This GIS will include the most recent information available on land use, elevation, soils, stream networks, reservoirs, roads, municipalities, points of interest (stream gauges, SWQM stations, potential bacteria sources, etc.) and satellite imagery or aerial photography.	Sept. 13	Aug.. 15
4.2	H-GAC will compile and evaluate existing land use/land cover data for the watershed and make changes as appropriate based on site reconnaisance and stakeholder input.	Sept. 13	Aug. 15
4.3	H-GAC will work with local stakeholders and technical experts to develop a source survey (also known as a sanitary survey) that characterizes the possible sources of pollutant loadings.	Sept. 13	Aug.. 15
4.4	H-GAC will retrieve all historic data in SWQMIS for the watershed. H-GAC will assess historic data for trends and variability, both spatially and temporally.	Sept. 13	Aug. 15
6.1	H-GAC will conduct a LDC analysis using historic data and refine it with data collected under this project's monitoring QAPP.	Sept. 13	Aug. 15
6.2	H-GAC will conduct SELECT modeling to establish contaminant loadings.	Sept. 13	Aug. 15
6.2	H-GAC will conduct SWAT modeling to evaluate and quantify loading from sources in the above tidal portion of the watershed, to evaluate the potential impact of management activities, and to serve as an input to future modeling in the tidal portion of the watershed.	Sept. 13	Aug. 15
6.3	H-GAC will contract with a consultant who will employ a model capable of quantifying pollutant loadings and needed load reductions in the tidal portion of the watershed (i.e., a simple tidal prism model, the complex EFDC model). The model will perform a quantitative analysis of the tidal mixing processes between Cedar Bayou and the Galveston Bay system. The model will be used to understand the exchange of pollutant loads each tidal cycle and the rate at which tidal mixing removes pollutants from the bayou.	Sept. 13	Aug. 15
6.4	H-GAC will employ EPA's Causal Analysis/Diagnosis Decision Information System (CADDIS) to conduct a causal evaluation of the macrobenthic invertebrate impairment in the non-tidal portion of the watershed. CADDIS, an online application, provides a pragmatic guide for determining the causes of detrimental changes and undesirable biological conditions observed in aquatic systems. CADDIS supports defensible causal analyses of the mechanisms, symptoms, and stressor-response relationships for various specific stressors in order to draw appropriate conclusions.	Sept. 13	Aug. 15

For the purpose of this QAPP, four of the modeling efforts will be conducted with named models (SELECT, LDCs, SWAT, SWMM5). The CADDIS evaluation will be completed with EPA's proprietary CADDIS evaluation process. The historical SWQMIS data analysis will be conducted directly with Statistical Analysis System (SAS), and the LULC analysis will be completed in ArcGIS 10 as an input for the SELECT model.

LULC Update

The project will utilize existing LULC datasets (NOAA C-CAP, NLCD), which may be updated based on feedback from stakeholders and discrepancies noted in informal field reconnaissance. Updates will utilize current aerial imagery (H-GAC/Surdex, 2012). The land use classification scheme to be used in updates or changes to the existing delineations will be based on the NOAA C-CAP 22 category classification system[1]:

Unclassified
- **Background (0)** – areas within the image file limits but containing no data values
- **Unclassified (1)** – areas in which land cover cannot be determined; these include clouds and deep shadow.

Developed Land
- **Developed, High Intensity (2)** – contains significant land area is covered by concrete, asphalt, and other constructed materials. Vegetation, if present, occupies < 20 percent of the landscape. Constructed materials account for 80 to 100 percent of the total cover. This class includes heavily built-up urban centers and large constructed surfaces in suburban and rural areas with a variety of land uses.
- **Developed, Medium Intensity (3)** – contains areas with a mixture of constructed materials and vegetation or other cover. Constructed materials account for 50 to 79 percent of total area. This class commonly includes multi- and single-family housing areas, especially in suburban neighborhoods, but may include all types of land use.
- **Developed, Low Intensity (4)** – contains areas with a mixture of constructed materials and substantial amounts of vegetation or other cover. Constructed materials account for 21 to 49 percent of total area. This subclass commonly includes single-family housing areas, especially in rural neighborhoods, but may include all types of land use.
- **Developed, Open Space (5)** – contains areas with a mixture of some constructed materials, but mostly managed grasses or low-lying vegetation planted in developed areas for recreation, erosion control, or aesthetic purposes. These areas are maintained by human activity such as fertilization and irrigation, are distinguished by enhanced biomass productivity, and can be recognized through vegetative indices based on spectral characteristics. Constructed surfaces account for less than 20 percent of total land cover.

Agricultural Land
- **Cultivated Crops (6)** – contains areas intensely managed for the production of annual crops. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.
- **Pasture/Hay (7)** – contains areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle and not tilled. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

Grassland
- **Grassland/Herbaceous (8)** – contains areas dominated by grammanoid or herbaceous vegetation, generally greater than 80 percent of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

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[1] The C-CAP data has 25 total categories; however the Tundra, Perrenial Ice/Snow, and Background categories are not utilized in our Region.

Forest Land

- **Deciduous Forest (9)** – contains areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
- **Evergreen Forest (10)** – contains areas dominated by trees generally greater than 5 meters tall and greater than 20 percent of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
- **Mixed Forest (11)** – contains areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover. *Both coniferous and broad-leaved evergreens are included in this category.*

Scrub Land

- **Scrub/Shrub (12) –** contains areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20 percent of total vegetation. This class includes tree shrubs, young trees in an early successional stage, or trees stunted from environmental conditions.

Palustrine Wetlands

- **Palustrine Forested Wetland (13)** – includes tidal and nontidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent.
- **Palustrine Scrub/Shrub Wetland (14) –** includes tidal and non tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation coverage is greater than 20 percent. *Species present could be true shrubs, young trees and shrubs, or trees that are small or stunted due to environmental conditions.*
- **Palustrine Emergent Wetland (Persistent) (15)** – includes tidal and nontidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is below 0.5 percent. Total vegetation cover is greater than 80 percent. *Plants generally remain standing until the next growing season.*

Estuarine Wetlands

- **Estuarine Forested Wetland (16)** – includes tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
- **Estuarine Scrub / Shrub Wetland (17)** – includes tidal wetlands dominated by woody vegetation less than 5 meters in height, and all such wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent. Total vegetation coverage is greater than 20 percent.
- **Estuarine Emergent Wetland (18)** – Includes all tidal wetlands dominated by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens). Wetlands that occur in tidal areas in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and that are present for most of the growing season in most years. Total vegetation cover is greater than 80 percent. *Perennial plants usually dominate these wetlands.*

Barren Land

- **Unconsolidated Shore (19) –** includes material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Substrates lack vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable.

- **Barren Land (20)** – contains areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulations of earth material. Generally, vegetation accounts for less than 10 percent of total cover.

Water and Submerged Lands

- **Open Water (21)** – include areas of open water, generally with less than 25 percent cover of vegetation or soil.
- **Palustrine Aquatic Bed (22)** – includes tidal and nontidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is below 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, detached floating mats, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent.

Estuarine Aquatic Bed (23) – includes tidal wetlands and deepwater habitats in which salinity due to ocean-derived salts is equal to or greater than 0.5 percent and which are dominated by plants that grow and form a continuous cover principally on or at the surface of the water. These include algal mats, kelp beds, and rooted vascular plant assemblages. Total vegetation cover is greater than 80 percent.

Model descriptions

Spatially Explicit Load Enrichment Calculation Tool (SELECT)

The Center for TMDL and Watershed Studies at Virginia Tech has been involved in TMDL development for bacteria impairments. The Center personnel developed a systematic process for source characterization that includes the following steps:

- Inventorying bacterial sources (including livestock, wildlife, humans, and pets);
- Distributing estimated loads to the land as a function of land use and source type; and
- Generating bacterial load input parameters for watershed-scale simulation models.

This process provides a consistent approach that is necessary to develop comprehensive bacteria TMDLs. The Center personnel developed a software tool, the Bacteria Source Load Calculator (BSLC), to assist with the bacterial source characterization process and to automate the creation of input files for water quality modeling (Zeckoski, et al., 2005). But BSLC does not spatially reference the sources. A spatially-explicit tool, Spatially Explicit Load Enrichment Calculation Tool (SELECT) has been developed by Spatial Sciences Laboratory (SSL) and the Biological and Agricultural Engineering Department at Texas A&M University (TAMU), to calculate contaminant-loads resulting from various sources in a watershed. SELECT calculates and allocates pathogen loading to a stream from various sources in a watershed. All loads will be spatially referenced.

In order to allocate the bacteria load throughout the watershed, estimations of the source contributions will be made. This in turn allows the sources and locations to be ranked according to their potential contribution. The populations of agricultural animals, wildlife, and domestic pets are calculated and distributed throughout the watershed according to appropriate land use. Furthermore, point sources such as WWTF are identified and their contribution quantified based on flow and effluent concentrations. Septic system contribution is also estimated based on criteria such as failure rate and age of the system. Once the watershed profile is developed for each potential source, the information will be aggregated to the sub-watershed level to identify the top contributing areas.

Load Duration Curve (LDC)

This is a simple and an effective first-step methodology to obtain data-based evaluations of the general relationship of concentrations to flow conditions, and thence the potential dominance of point versus nonpoint sources. A duration curve is a graph that illustrates the percentage of time during which a given parameter's value is equaled or exceeded. For example, a flow duration curve (FDC) uses the hydrograph of the observed stream flows to calculate and depict the percentage of time the flows are equaled or exceeded.

A LDC, which is related to the FDC, shows the corresponding relationship between the contaminant loadings and stream flow conditions at the monitoring site. In this manner, it assists in determining patterns in pollution loading (point sources, nonpoint sources, erosion, etc.) depending on the streamflow conditions. Based on the observed patterns, specific management measures can be implemented that target a particular kind of pollutant source. Another main advantage of the LDC method is that it can also be used to evaluate the current impairment by determining the percent of samples that exceed the standard.

H-GAC will develop LDCs for *E. coli*, Entereococcus, Total Nitrogen, and Total Phosphorus[2].

Soil and Water Assessment Tool (SWAT) for Cedar Bayou Above Tidal Segment

SWAT is a public domain model that was developed in the early 1990s at Texas A&M University by the United States Department of Agriculture- Agricultural Research Service (ARS). Major components of the model include hydrology, weather, erosion, soil temperature, crop growth, nutrients, pesticides and agricultural management. SWAT has the ability to predict changes in sediment, nutrients (i.e. organic and inorganic nitrogen and organic and soluble phosphorus), pesticides, dissolved oxygen, bacteria and algae loadings from different management conditions in large un-gauged basins. SWAT operates on a daily time step and can be used for long-term simulations. The model output is available in daily, monthly and annual time scales. SWAT coding and subroutines are modular, allowing for addition of new subroutines when necessary. SWAT has been successfully applied to model flow and water quality issues including sediments, nutrients and pesticides in watersheds. Output from SWAT of simulated upstream boundary conditions, runoff flows and bacteria levels will be used as an input to future tidal modeling efforts.

[2] Additional contaminants may require LDCs, based on monitoring results and modeling efforts which may be amended to this QAPP at a later date (biological modeling activities, etc.). If this is the case, a future QAPP amendment will include a reference in this section to the additional parameters.

The ArcGIS interface version[3] (ArcSWAT 2012.10.8) of the SWAT model will be used as a watershed model and receiving water model for the freshwater (above-tidal) segments of Cedar Bayou. The simulated flow and constituent concentrations, such as bacteria (E. coli and Enterococcus), Total Nitrogen, and Total Phosphorus, will be calibrated to the available flow and constituent observations (historical field data). Model coefficients will be adjusted based on literature values and staff expertise to achieve a suitable model calibration.

H-GAC will compile and review available physical and water quality data for the system. This will include the water quality data at all ten monitoring sites (historical and current), flow data from the Cedar Bayou watershed, soils data, local meteorological data, land use data, and topographic information. With this information a period of up to two years will be selected with representative weather conditions that contain a reasonable amount of monitoring data that are consistent with the current bacteria attainment status.

With data compiled, H-GAC will set up the watershed model and the stream model using the available watershed information. The subwatershed delineation will be based on the delineation for the SELECT model. Monitoring station locations will be considered as the outlets of the sub-watersheds. The Hydrologic Response Unit (HRU) analysis will be conducted using soil type, LULC classification, and slope. The daily flow will be simulated by the SWAT watershed model and calibrated using event mean concentrations, and other information from the literature as appropriate. Flow data from the above-tidal portion of Cedar Bayou will be used as a reference to evaluate the reasonableness of the flows calculated from the watershed model. The model calibration will involve adjusting the various model parameters until an acceptable level of agreement between model and data is reached. It is an iterative procedure that is achieved using a combination of best professional judgment and quantitative comparison with a subset of the observed data. The indicator bacteria data will then be employed to develop an appropriate model calibration for bacteria levels in the streams. The bacteria simulation will incorporate runoff loads and background sources. The indicator bacteria data results for monitoring stations within the watershed along with available SELECT loading data as appropriate will then be employed to developing an appropriate model calibration. Sensitivity analysis will be performed for the adjusted model parameters for both flow and bacteria in order to deciding the model parameter sensitivity. Model validation will be performed for a separate subset of observed data to demonstrate that the calibrated model is capable of making sufficiently accurate simulations.

The SWAT model will be used to evaluate representative periods every 10 years through 2040. The model will be operated to simulate the conditions that might be expected with projected population growth. This will involve adjusting the SWAT runoff characteristics to represent additional development occurring in the areas of the watershed with current development. Projections of population growth would be used to adjust the watershed land use along with wastewater flows. This will allow explicit consideration of the changes

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[3] Throughout the QAPP, the term "SWAT" is used to refer in a general way to the model and modeling approach that will be used. ArcSWAT 2012.10.8 is the specific interface version of that base model that will be employed in place of the older 2009 base model.

normally resulting with population growth. The model will then be used to evaluate ways to manage changes in the watershed to avoid future water quality problems. The simulation of future conditions will be performed using meteorological data from 2009 or another year that is determined to be considered a representative year.

The final simulation to be performed is for a future where the LULC from the future conditions simulation is maintained, but watershed practices are adjusted to reflect anticipated BMPs to improve water quality, while still accommodating population growth. These measures will include BMPs selected by the stakeholders of the Cedar Bayou Watershed Partnership. The effectiveness of proposed BMPs including those addressing urban runoff, pets, education and outreach, agriculture, sanitary sewer plants, and OSSFs, will be based on literature values. This may include, but is not limited to, BMPs such as:

- Change in livestock grazing management practices;
- Change in livestock manure management practices including addition of grass filter strips;
- Adjustment of manure land application practices;
- Septic system repair/replacement, educational outreach, increased maintenance requirements;
- Pet waste clean-up; and
- Feral hog management.

Other BMPs may be added at a later time through discussions with stakeholders. These development policies would be reflected in the model and runs will be made to determine the effects on bacteria levels. BMP implementation will be modeled at the watershed scale; thus, only high level gross conditions will be modeled with no detailed projections performed. Adjustment to model inputs to reflect the effects of such measures will be based on professional judgment.

SWMM5 Watershed and Receiving Water Tidal Model for Cedar Bayou Tidal Segment

The Storm Water Management Model (SWMM5) was developed by USEPA in the early 1970s, with the most recent major release being SWMM5. CDM Smith collaborated with USEPA to complete the upgrade from SWMM4 to SWMM5. The SWMM5 model was developed initially to simulate storm events for watersheds with impervious surfaces such as urban environments (Rossman, 2007). Thus, it has the capability to model urban infrastructure in a very detailed manner by including the effects of drainage systems, detention basins, sewers and flow controls. This is of particularly interest in Cedar Bayou Tidal which encompasses several urban and highly industrialized regions. Although focused on urban areas, it should be noted that its functionality is not entirely limited to urban regions.

Additionally, the SWMM5 model has the capability to handle complex flow simulations, including tidal fluctuations and multiple outlets using the dynamic wave routing approach. The dynamic wave routing function in SWMM5 solves the Saint Venant equations, conserving mass and momentum that govern the unsteady flow of water through a drainage network of channels and pipes.

The SWMM5 model can use event mean concentrations, build-up and washoff or other water quality algorithms to simulate pollutant accumulation and runoff, including that of bacteria. SWMM5 routes flow and water quality loading to provide a simple receiving water model that can simulate first order instream loss processes.

The SWMM5 model (Version 5.0.022) will be used to simulate the tidal segments of Cedar Bayou. Subcatchment delineations were based on the SELECT boundaries and further defined using catchment delineations developed by Harris County Flood Control District. It is expected that time step of one minute (60 seconds) or less will be used to ensure proper continuity for the dynamic wave simulate that will be used for SWMM5 routing.

Model calibration will focus on matching observed data within the receiving water through adjusting various model parameters until an acceptable level of agreement between model and data is reached (discussed in more detail in Section B7). Model coefficients will be adjusted based on literature values and staff expertise to achieve a suitable model calibration. This is an iterative procedure that requires a combination of best professional judgement and quantitative comparison with the observed data. Calibration of the SWMM5 model will start with examination of salinity concentrations to confirm that proper flushing, water rights pumping/discharges, and tidal fluctuation is achieved with the model. Next, indicator bacteria (enterococci) will be calibrated. The bacteria simulations will incorporate bacteria sources from runoff and point source loads from wastewater treatment facilities and sanitary sewer overflows as well as other sources identified in SELECT modeling. Model validation will be performed for a separate subset of observed data to demonstrate that the calibrated model is capable of reproducing observed datasets consistently.

The SWMM5 model will be also be used to evaluate future land use conditions and a total of five (5) different scenarios that will evaluate a combination of future land use and BMP implementation. BMP scenarios will be modeled at the watershed scale; thus, only high level gross conditions will be modeled with no detailed projections performed. Adjustment to model inputs to reflect the effects of such measures will be based on professional judgment.

CADDIS for Cedar Bayou Above Tidal Segment

CADDIS or the Causal Analysis/Diagnostic and Decision Information System is a guide or process developed by USEPA to identify causes of existing biological impairments in aquatic systems through an organized framework of analysis. The evaluation has been structured as a five step process:

- Step 1: Define the Case
- Step 2: List Candidate Causes

- Step 3: Evaluate Data from the Case
- Step 4: Evaluate Date form Elsewhere
- Step 5: Identify Probable Cause

TCEQ no longer considers the Above Tidal Segment of Cedar Bayou impaired; therefore a strict application of the CADDIS process will not be possible. Instead, CDM Smith will apply the general steps and principles associated with the CADDIS process to evaluate the basis for and potential causes of the historical macrobenthic community impairment that was previously documented in the segment.

A7 QUALITY OBJECTIVES AND CRITERIA

H-GAC will conduct a phased modeling effort to develop pollutant source and loading information and estimates of needed pollutant reductions. The objectives of the water quality modeling for this project are as follows:

1) Develop and obtain approval for a QAPP
2) Evaluate existing historical data SWQMIS data for the watershed
3) Conduct a GIS-based analysis of LULC over time
4) Develop LDCs to analyze the temporal trends in the observed water quantity and quality data for the watershed. The LDCs will be developed using currently existing water quality and flow data available from SWQMIS, collected under the Clean Rivers Program and supplemented with USGS flow gage data. Obtain an interpolated model to simulate the trends of the monitored data. Evaluate the trends and the required load-reductions of bacteria and nutrients for different flow-rate regimes (low, medium, and high flow) using LDC and interpolated model.
5) Spatially characterize and rank sources of bacteria within the watershed using SELECT, a spatially-explicit GIS methodology. Use subwatershed areas and identify, quantify and rank pollutant loads from various sources, i.e. agriculture, urban/human, wildlife, and other sources in the study area.
6) Evaluate and quantify the impact of sources on water quality in the above-tidal portion of the watershed using SWAT. Model the impact of proposed management strategies on loading and water quality impact. Utilize the SWAT results as an input for future modeling in the tidal portion of the watershed.
7) Conduct SWMM5 modeling to evaluate the impacts of tidal proceses on pollutant loads in the tidal segment and identify necessary load reductions to meet water quality standards.
8) Conduct CADDIS evaluation of the macrobenthic communities of the above tidal segment.

Historical SWQMIS analysis

Historical data from the Clean Rivers Program's monitoring locations in the watershed will be evaluated using SAS for trends and variability, both spatially and temporally between sampling locations and for the watershed as a whole. Historical Clean Rivers Program data was collected under the corresponding Clean Rivers Program Monitoring QAPP active at the respective time the data was collected.

LULC analyses

The existing LULC datasets are deemed to meet project quality goals. The criteria for any changes or updates based on stakeholder input and field verification include that changes be verified by a staff member with experience in the land use classification categories of the dataset. A field visit will be required to verify the recommended change.

LDC

Load duration curves show the relationship between flow and water quality. They are used as a tool to quantify pollutant loads and load reductions by comparing stream flow and pollutant concentrations. They identify critical hydrological conditions in which the waterbody does not meet the standard for any specific pollutant. In cases of exceedances of the standard, it is necessary to determine the required load reduction in that region near the monitoring station.

SELECT

The SELECT approach was developed by SSL and the Biological and Agricultural Engineering Department at TAMU to characterize potential bacteria loading on the ground surface of a watershed. It is similar to BSCL (Zeckoski, et al. 2005) in TMDL development. Since SELECT predicts fecal bacteria loading to land areas, which cannot be representatively sampled, there are no calibration parameters in SELECT. To assist in assessment of most likely bacteria sources, SELECT calculates potential (not actual) bacteria loading to the ground surface (not into a waterbody). Distributions for input parameters for SELECT will be created based on literature values and expert knowledge. Loads from each land use will be generated by SELECT.

SWAT for Cedar Bayou Above Tidal

SWAT is a water quality model package that was developed in the early 1990's at TAMU by ARS. It can simulate flow and numerous water quality parameters including temperature, DO, nitrogen species (organic, ammonium, nitrate), phosphorus species (organic and orthophosphate), indicator bacteria and two parameters to be designated such as salinity and TSS. The model can also represent the effects of attached macrophytes on DO and nutrient uptake. The model is capable of simulating effects of land management practices on water, sediment and agricultural chemical yields for large-scale complex watersheds or river basins. During this modeling effort, current conditions, future conditions without BMPs, and future conditions with BMPs simulations will be completed.

With both average bacterial, nitrogen, and phosphorus loads and average flows defined for the current condition, a calculation will be made by dividing the loads (constituent units/time) by the flows (volume/time) to obtain a concentration measure (constituent unit/volume) that can be compared with applicable criteria for contact recreation. SELECT calculates potential bacteria loading to the ground surface, not into a waterbody. Therefore, the measure calculated this way will give a potential upper limit of the concentration assuming all the loading is washed off into the stream. The concentrations for both present and future conditions will be calculated.

SWMM5 Watershed/Receiving Water Tidal Model for Cedar Bayou Tidal Segment

The SWMM5 water quality watershed/receiving water model will be used to generate watershed flow and loading information for the Cedar Bayou tidal segment using the one-dimensional dynamic wave flow routing module in SWMM5. Watershed loading will be estimated using a combination of typical observed event mean concentrations for Texas as well as bacteria loading specified in the SELECT model described previously. The SWMM5 model will then be used, in conjunction with tidal elevation information, to establish the tidal receiving water model. The SWMM5 model will be used to simulate the fate and transport of indicator bacteria in the tidal segment of Cedar Bayou.

The instream enterococci concentrations for the Cedar Bayou tidal segment can be compared with applicable criteria for contact recreation. The model will be calibrated for the present condition to be consistent with available data. For future conditions, projected land use change for the catchment will be used to adjust the watershed impervious cover and runoff characteristics along with wastewater flows. The instream concentrations for both present and future conditions will be calculated as well as for up to five future condition/best management practice scenarios.

CADDIS for Cedar Bayou Above Tidal Segment

CADDIS or the Causal Analysis/Diagnostic and Decision Information System is a guide or process developed by USEPA to identify causes of existing biological impairments in aquatic systems through an organized framework of analysis.

The CADDIS analysis will be conducted based on available information from SWQMIS and H-GAC macrobenthic monitoring events. These data will be compiled and potential data gaps identified. CDM Smith will review the available biological, physical and chemical data, first by reviewing what is available in SWQMIS and from H-GAC. In some cases, if further clarification or information is required, the original field and benthic sample data sheets may be reviewed if available. The data will then be evaluated in conjunction with information such as land uses, water quality data and any other relevant data to determine if there is a reason for the historical water quality impairment.

A8 SPECIAL TRAINING/CERTIFICATION

All personnel involved in model calibration, validation, and development will have the appropriate education and training required to adequately perform their duties. No special certifications are required.

A9 DOCUMENTATION AND RECORDS

All records, including modeler's notebooks and electronic files, will be archived by H-GAC for at least five years. These records will document model testing, calibration, and evaluation and will include documentation of written rationale for selection of models, record of code verification (hand-calculation checks, comparison to other models), source of historical data, and source of new theory, calibration and sensitivity analyses results, and documentation of adjustments to parameter values due to calibration. Electronic data on the project computers and the network server are backed up daily to the network drive and weekly to an external hard drive and the PI's computer. In the event of a catastrophic systems failure, the tapes can be used to restore the data in less than one day's time. Data generated on the day of the failure may be lost, but can be reproduced from raw data in most cases.

H-GAC's QAO will produce an annual QA/QC report, which will be kept on file at H-GAC with copies distributed to individuals listed in section A3. Any items or areas identified as potential problems and any variations or supplements to QAPP procedures noted in the QA/QC report will be made known to pertinent project personnel and included in an update or amendment to the QAPP. Individuals listed in Section A3 will be notified of approval of the most current copy of the QAPP by the H-GAC PM. The H-GAC PM will make the most recent version of the QAPP available to all entities listed in Section A3 of this QAPP. Current copies of the QAPP will be kept on file for all individuals on the distribution list.

Quarterly progress reports disseminated to the individuals listed in section A3 will note activities conducted in connection with the water quality modeling project, items or areas identified as potential problems, and any variations or supplements to the QAPP.

Technical reports on the historical SWQMIS data analysis, LULC analyses, SELECT modeling analysis, LDC analysis, SWAT modeling, SWMM5 Watershed and Receiving Water Tidal Modeling, and CADDIS evaluation will be developed. Outcomes will be discussed with the Cedar Bayou WPP stakeholder group and utilized in the development of the WPP. All files used to produce the technical reports will be saved electronically by H-GAC for at least five years.

Corrective Action Reports (CARs) will be utilized when necessary (Appendix A). CARs will be maintained in an accessible location for reference at H-GAC and will be disseminated to the individuals listed in section A3. CARs resulting in any changes or variations from the QAPP will be made known to pertinent project personnel and documented in updates or amendments to the QAPP when appropriate.

Table A9.1 Project Documents and Records

Document/Record	Location	Retention[a]	Form[b]
QAPPs, amendments, and appendices	H-GAC	5 years	Paper/Electronic
QAPP distribution documentation	H-GAC	5 years	Paper/Electronic
Corrective Action Reports (CARs)	H-GAC	5 years	Paper/Electronic
Modeler Notebook	H-GAC	5 years	Paper
Model Input Files	H-GAC	5 years	Electronic
Model Output Files	H-GAC	5 years	Paper/Electronic
Model Calibration Documentation	H-GAC	5 years	Paper/Electronic
Model Validation Documentation	H-GAC	5 years	Paper/Electronic
Progress Report/ Final Report/Data	H-GAC, TSSWCB	5 years	Paper/Electronic

[a] After the close of the project
[b] Electronic files should be ASCII (DOS) pipe delimited text files or MS Word/Excel; model input and output files can be archived in the format used by the modeling software, provided the capability of conversion to ASCII (DOS) pipe delimited text files or MS Word/Excel is maintained over the time of retention.

Digital files of land cover data for each watershed will be produced in shapefile or ArcGIS grid format and stored on CD-ROM disks. Multi-color hard copy maps of land cover can be produced at various geographic scales from these digital files.

The TSSWCB may elect to take possession of records at the conclusion of the specified retention period. Further, as requested, the model and its inputs and outputs will be delivered to the TSSWCB.

QAPP Revision and Amendments

Until the work described is completed, this QAPP shall be revised as necessary and reissued annually on the anniversary date, or revised and reissued within 120 days of significant changes, whichever is sooner. The last approved versions of QAPPs shall remain in effect until revised versions have been fully approved; the revision must be submitted to the TSSWCB for approval before the last approved version has expired. 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 will be accomplished by submitting a cover letter stating the status of the QAPP and a copy of new, signed approval pages for the QAPP.

QAPP amendments may be necessary to reflect changes in project organization, tasks, schedules, objectives and methods; address deficiencies and nonconformance; improve operational efficiency; and/or accommodate unique or unanticipated circumstances. Written requests for amendments are directed from the H-GAC PM to the TSSWCB PM and are effective immediately upon approval by the TSSWCB PM and QAO, and EPA Project Officer. Amendments to the QAPP and the reasons for the changes will be documented and distributed to all individuals on the QAPP distribution list by the H-GAC PM or designee.

Amendments shall be reviewed, approved, and incorporated into a revised QAPP during the annual revision process.

B1 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

LULC analyses

The evaluation of existing LULC analyses is an iterative process based on data from aerial imagery, existing LULC datasets, stakeholder input, and field reconnaissance as needed. Existing LULC data and any revisions or updates will be assigned to categories according to the category descriptions provided in Section A6. Updates will be made by GIS and modeling staff after consultation with the PM. The most current aerial imagery will be compared with field observations and existing LU/LC data. Depending on the nature of the potential change and land use/cover involved, input from local officials or project stakeholders may be sought to provide historical information or other relevant perspective to bear. The H-GAC PM will utilize best professional judgement in making a final determination based on consideration of all available information.

GIS Inventory

A high quality GIS inventory will be produced by compiling the most recent information from local, state and federal agencies (Table B1.1 reflects current data sources). All datasets will be projected using NAD 1983 StatePlane Texas South Central FIPS. To the greatest extent practicable, data will be compiled from data resources currently compiled under H-GAC's agency-wide GIS. Original data sources are indicated in the Table B1.1 below. Additional information needed will be collected as needed, and the QAPP will be updated.

Table B1.1 Datasets Included in GIS Inventory and Sources of Each

Data	Source	Website
Land Use/Land Cover	NOAA C-CAP 2011, NLCD 2006	http://www.h-gac.com/community/gis/gis-data.aspx
Elevation	USGS-NED	http://www.h-gac.com/community/gis/gis-data.aspx
Soils	USDA SSURGO	http://soils.usda.gov/survey/geography/ssurgo/
Water Features	H-GAC	http://www.h-gac.com/community/gis/gis-data.aspx
Roads	H-GAC-Starmap	http://www.h-gac.com/community/gis/gis-data.aspx
Political Boundaries	H-GAC	http://www.h-gac.com/community/gis/gis-data.aspx
Aerial Imagery	H-GAC 2012 (Surdex)	http://www.h-gac.com/community/gis/gis-data.aspx
Water Quality Monitoring Stations	H-GAC/TCEQ	http://www.h-gac.com/community/gis/gis-data.aspx
USGS Gauges	USGS	http://waterdata.usgs.gov/tx/nwis/rt
TPDES Permittee Outfalls	H-GAC/TCEQ	http://www.h-gac.com/community/gis/gis-data.aspx
OSSFs	H-GAC	http://www.h-gac.com/community/gis/gis-

		data.aspx
Potential Bacteria Sources	H-GAC	http://www.h-gac.com/community/gis/gis-data.aspx
Public Access Points to Waterways	H-GAC	http://www.h-gac.com/community/gis/gis-data.aspx
Impoundments	H-GAC/TCEQ	http://www.h-gac.com/community/gis/gis-data.aspx
Parcels (where available)	H-GAC	http://www.h-gac.com/community/gis/gis-data.aspx
Census data	US Census	http://www.h-gac.com/community/gis/gis-data.aspx

SELECT

High quality spatial data will be utilized in the SELECT modeling approach (Table B1.2). The source code 'F' signifies that the input can be measured directly from the field while the code 'L' signifies the input is taken from literature. Distributions for input parameters for SELECT will be created based on literature values, expert knowledge and stakeholder input (as applicable).

Since SELECT predicts fecal bacteria loading to land areas, which cannot be representatively sampled, there are no calibration parameters in SELECT. To assist in assessment of most likely bacteria sources, SELECT calculates potential (not actual) bacteria loading to the ground surface (not into a waterbody). Since data is not available to determine actual fecal bacteria loading to the ground surface across a watershed, calibration of SELECT predictions to field data is not possible and will not be performed. A qualitative assessment of model outputs will evaluate appropriate incorporation of data inputs; results of the assessment will be reported in the project-associated reports (Cedar Bayou WPP).

Table B1.2 SELECT Model Inputs[4]

Name	Source	Date	Description
Land Cover	NOAA C-CAP 2011, NLCD 2006	2011	GIS Shapefiles
Watershed	TCEQ	2003	GIS Shapefiles
Coastal Preserve	GLO\USGS	2000	GIS Shapefiles
County	TXDOT	2000	GIS Shapefiles
Urban Centers	Census Bureau	2000	GIS Shapefiles
Roads	H-GAC-Starmap	2007	GIS Shapefiles
Water Quality (incl. ambient)	H-GAC	2007	GIS Shapefiles

[4] The dates assigned to these data sources represent the most currently available data at the time of submission of this QAPP. Many of these data sources are iterative, and it is expected that during the course of this effort, new versions of the same datasets may become available. H-GAC will use the most current version of these identified datasets.

Wastewater SA	H-GAC	2007	GIS Shapefiles
WWTP Outfalls	TCEQ	2007	GIS Shapefiles
Soil	NRCS	2000	GIS Shapefiles
Potential Septic System	H-GAC	2010	Interpolated Data
Flood Zones	FEMA	2000	GIS Shapefiles
Population	Census Bureau	2006	Tabular, Estimate
Housing Units	Appraisal District	2006	Tabular
Inventory of Buildings	Appraisal District	2006	Tabular
Livestock population	NASS	2008	Tabular
Wildlife population	TPWD	2008	Tabular
Fecal production rates	USEPA	2004	Tabular
Pet population	AVMA	2001	Tabular

Table B1.3 Source of SELECT Inputs

Source of SELECT Inputs	Units	Source
Soils data (SSURGO) coverage		F
Land Use/Land Cover (NLCD) coverage		F
Digital Elevation Model (USGS-NHD) coverage	m (elevation)	F
Curve number lookup table (NRCS)		L
Livestock population (NASS) coverage	number / county	F
Wildlife population (TPWD) coverage	number / area	F
Fecal production rates (USEPA)	cfu/day	L
Septic system age (health districts) coverage	age/subdivision	F
Population (US Census) coverage	number / area	F
Pet population (AVMA)	pets/household	L
WWTP location and permits (TCEQ) coverage	TCEQ	F

SWAT for Cedar Bayou Above Tidal Segment

The Soil and Water Assessment Tool (SWAT) was developed in the early 1990's at Texas A&M University by the USDA Agricultural Research Service. The SWAT model is public domain, well-regarded internationally, and has an active users group, online forum, and website. SWAT is a continuous model that simulates the effects of land management practices on water, sediment and agricultural chemical yields for large-scale complex watersheds or river basins. Additional capability for including impervious cover can be accomplished by activating urban buildup/wash-off equations that are from the Storm Water Management Model (SWMM).

SWAT will be used to model current and future impacts of watershed processes on bacteria loads in the Above Tidal segment, and the potential impact of BMPs. The SWAT model upstream and runoff loadings will be incorporated into the Tidal segment SWMM5 Model as an input. A summary of SWAT model inputs is presented in **Table B1.4**

Table B1.4 SWAT Inputs

SWAT Inputs
Soils data (SSURGO) coverage
Land Use/Land Cover (NLCD) coverage
Digital Elevation Model (USGS-NED) coverage
Precipitation (NCDC)
Stream flow data (USGS flow gauge 08067500)
Current and future BMPs (based on literature values)
Wastewater treatment facility discharges (flow and bacteria concentrations based on DMRs)
OSSF flow and bacteria concentrations (H-GAC OSSF location dataset)
Concentrations and loadings associated with bacteria sources in the watershed (SELECT and literature values)

SWMM5 Watershed and Receiving Water Tidal Model for Cedar Bayou Tidal Segment

The SWMM5 model will simulate watershed and tidal receiving water processes. Additionally, direct flow from WWTPs will be used as a point source input into the SWMM5 model. A summary of SWMM5 watershed and receiving water tidal model inputs are presented in **Table B1.4**.

Table B1.4 Source of SWMM5 Inputs

Name	Source	Date	Description
Land Cover	NOAA C-CAP 2011, NLCD 2006	2011	GIS Shapefiles
Watershed	Combination of Harris County Flood Control, H-GAC and NHD Watershed Boundaries	Various	GIS Shapefiles
Soils data (SSURGO) coverage	Natural Resource Conservation Service	Various	GIS Shapefiles
Upstream boundary conditions for flow, bacteria concentration	SWAT model of above tidal Cedar Bayou	n/a	Tabular data
Downstream boundary conditions for bacteria, salinity concentration	TCEQ SWQMIS data	Various	Tabular data
Elevation datasets	Digital Elevation Model (USGS-NHD) coverage supplemented with information from 2006 FEMA LiDAR data for Chambers Count and 2009 USACE Post Ike & Gustav from Coastal Mapping Program	Various	GIS Shapefiles
Precipitation	National Climatic Data Center (NCDC)	Various	Tabular Data
Domestic wastewater treatment facilities flow and bacteria concentrations (if appropriate)	TCEQ and USEPA	Various	Tabular Data
Bacteria sources in Cedar Bayou Tidal watershed	SELECT model and other sources (e.g., HGAC septic system data, SSO data from TCEQ)	Various	Tabular Data and GIS shapefiles
Water surface elevations at mouth of Cedar Bayou Tidal	Morgan's Point Tide Gage maintained by Texas Coastal Ocean Observation Network (TCOON)	Various	Tabular Data and GIS shapefiles
Water rights information (pumping, discharge, frequency)	TCEQ	Various	Tabular Data and GIS shapefiles
Bathymetry	US Army Corps Enginers and others	Various	Tabular Data and GIS shapefiles
Climate data (Evaporation)	Calculated based on daily max/min air temperature from NCDC)	Various	Tabular Data
Runoff event mean concentrations	Literature values	Various	Tabular Data

CADDIS Evaluation for Cedar Bayou Above Tidal Segment

The CADDIS evaluation for above tidal Cedar Bayou will be based on available data from H-GAC and TCEQ regarding water quality, macrobenthic assessments, as well as other watershed characteristics such as land use data and wastewater treatment facility locations and discharge water quality. A summary of key CADDIS evaluation data needs are presented in Table B1.5.

Table B1.5 Source of CADDIS Evaluation Data Needs

Name	Source	Date	Description
Land Cover	NOAA C-CAP 2011, NLCD 2006	2011	GIS Shapefiles
Biological data, including sample locations, macrobenthic and fish survey results, and any associated site location and habitat data	TCEQ SWQMIS database and H-GAC	Various	Tabular Data; GIS Coordinates
Sampling and analysis methods used to collect biological data over the data period of record	TCEQ and H-GAC	Various	Procedures; Guidance
Biological assessment methods employed by TCEQ over the data period of record	TCEQ	Various	Procedures; Guidance
Domestic wastewater treatment facility locations; effluent flow volume and water quality (as appropriate)	TCEQ and USEPA	Various	Tabular Data
Water quality data	TCEQ SWQMIS database and H-GAC observations as well as field data sheets if necessary	Various	Tabular Data and GIS shapefiles

B2 SAMPLING METHOD REQUIREMENTS

Not applicable.

B3 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

Not applicable.

B4 ANALYTICAL METHODS

Not applicable.

B5 QUALITY CONTROL REQUIREMENTS

The existing data being used in the LULC analyses will be collected from agencies that use their own quality control protocol. These agencies provide metadata for all the data collected. All data is collected from a public domain from federal, state, and regional sources.

Revisions to existing LULC datasets will be based on the categories utilized by those datasets, as interpreted by staff with knowledge of the proper classification of land cover. Verification of stakeholder input or informal field reconnaissance will be made with additional field visits or through evaluation of the most current aerial imagery (currently 2012 H-GAC aerial imagery) by staff members with knowledge of LULC classifications specific to the dataset being revised.

B6 EQUIPMENT TESTING, INSPECTION, & MAINTENANCE REQUIREMENTS

Not applicable.

B7 INSTRUMENT CALIBRATION AND FREQUENCY

No instrument calibration is conducted or required for the GIS Inventory, LULC analyses, LDC analyses, SELECT, or CADDIS analyses.

Model calibration is the process where the model input parameters are adjusted until the simulated data from the model match with observed data. Model parameters related to watershed/landscape processes will be adjusted to match the measured and simulated flow, sediment, and nutrients at key locations in the watershed. During the calibration process, model parameters will be adjusted within literature recommended ranges or based on site-specific considerations as appropriate. Model calibration is an iterative procedure that is achieved using a combination of best professional judgment and quantitative comparison with a subset of the measured data (Section A7). The SWAT and SWMM5 models will be calibrated with data from the Clean Rivers Program and data collected under the monitoring QAPP for this project.

When calibration standards are not obtained, H-GAC will check data for deficiencies and correct them. If steps outlined below do not bring predicted values within calibration standards, the H-GAC PM and/or the QAO will work with TSSWCB, EPA and stakeholders to arrive at an agreeable compromise.

Model parameters will be adjusted to minimize differences between measured and simulated flow and water quality trends at key locations. All model parameters will be adjusted within reasonable ranges recommended in published literature or based on site-specific considerations. Calibration will be done to represent normal, wet, and dry years. Time series plots and standard statistical measures such as mean, standard deviation, coefficient of determination and Nash-Suttcliffe simulation efficiency will be used to evaluate the performance of models during calibration and validation. Calibration is done systematically, first for flow, then for sediment and followed by organic and mineral nutrients (Santhi et al., 2001).

The USEPA Modeling QAPP Guidance (USEPA, 2002) specifically emphasizes model performance criteria, which are the basis by which judgments will be made on whether the model results are adequate to support the decisions required to address the study objectives. Therefore, the quality assurance on calibration expected accomplishments of the calibration and how the predictive quality of the model might be improved as a result of implementing the calibration procedures. The specific limits, standards, goodness-of-fit, or other criteria on which a model will be judged as being properly calibrated will be assessed (e.g. the percentage difference between measured data and predicted model results). Initially, time series plots are generally evaluated visually as to the agreement, or lack thereof, between the simulated and observed values. Subsequent statistical tests, discussed below, are used to further quantify the calibration fit.

Scatter plots usually include calculation of a correlation coefficient, along with the slope and intercept of the linear regression line; thus, the graphical and statistical assessments are combined. When observed data are adequate, confidence intervals for the observed data will be calculated so they can be considered in the model performance evaluation. There are a variety of ways to compare simulated and observed mean values. For example, the sporadic observed data can be aggregated over annual, seasonal, or monthly timeframes and compared to the full range of simulated values. The hydrodynamic and water quality components of the modeling framework for the Cedar Bayou will include one or more of the following types of graphical and statistical procedures:

Graphical comparisons may include:

- Time series plots of observed and simulated values for flow and total-P concentrations.
- Observed versus simulated scatter plots, with a best-fit linear regression line displayed.
- Cumulative frequency distributions of observed and simulated flows.
- Box & Whisker Plots of observed and simulated concentrations.

Statistical tests may include:

- Annual and seasonal flow volume comparisons;
- Nash-Sutcliffe Model Efficiency Criteria;
- Error statistics (e.g., mean error, absolute mean error, relative error, relative bias, and standard error of estimate);
- Correlation tests (e.g., linear correlation coefficient, coefficient for goodness-of-fit);
- Cumulative distribution tests.

Typical calibration guidelines for water quality modeling can be found in Donigian et al. (2002):

	Very Good	Good	Fair
Hydrology/hydraulics	<10%	10-15%	15-25%
Sediment	<15%	15-25%	25-35%
Water quality	<20%	20-30%	30-40%

These guidelines apply to annual and long-term monthly values ("long-term" monthly values, because it is easy to be off by more than this in a given month). Also, these targets are more appropriate in average and wet years. During dry years, with much lower streamflow, the relative percent difference tends to be higher.

In comparing measured and modeled loads, there are a number of potential sources of error even in locations with abundant flow and water quality measurement data. These include:

1. Watershed size with a limited flow and water quality data sets available for calibration;

2. Combined observation errors on the order of 10-20% for streamflow and precipitation measurements are not unreasonable; and

3. Inaccuracies in sample collection and laboratory analyses for water quality data may be as high as 20%.

These errors, compounded, could result in error of 30 to 40% even in areas with spatially and temporally abundant data. When the "observed" load used for calibration is calculated based on grab sampling data with daily flows, the load could be off by 40% or more because of the errors described above.

Therefore, applications of absolute criteria for model acceptance or rejection based on rigorous comparisons with the observed data are not appropriate for this effort. Final calibration acceptance will take into consideration these uncertainties, as well as the quality of the final measured data set and budget constraints. In the instance that calibration standards are not obtained, the following actions will be taken:

- Check data for deficiencies and correct any that are found,
- Check model algorithms for deficiencies and correct any that are found, and
- Re-calibrate the model after corrections of deficiencies

SWAT for Cedar Bayou Above Tidal Segment

For the SWAT model, annual flow will be calibrated so that predicted values agree to measured values within 15%. Partitioning of stream flow between surface and subsurface flows (as defined by base flow filter) will be calibrated so that predicted values agree to measured values within 15%. Sediment (where sedimentation survey or other data is available) will be calibrated so that predicted values also agree to measured values within 20%. Finally, nutrients and BOD (where in-stream data is available) will be calibrated so that the mean of the predicted values falls within 20% of the measured values.

Calibration of a SWAT model for the watershed will begin after QAPP approval. After collecting all available data for the watershed, the SWAT model will be calibrated to measured stream flow. All model parameters will be adjusted within ranges recommended in published literature. Then the model will be validated without adjusting any parameters. The calibration period will be from 2000-2005 (with 2000 as preparation period) and the validation period will be from 2006-2008. Time series plots and standard statistical measures will be used to evaluate the performance of modeling during calibration and validation. After calibration, the existing condition will be simulated for a 30-year period to determine time series of average daily flow at key sampling locations in the above tidal segment of Cedar Bayou watershed.

SWMM5 Watershed and Receiving Water Model for Cedar Bayou Tidal Segment

For the SWMM5 model, salinity concentrations will be calibrated first so that predicted mean values agree to measured values within 20%, assuming adequate data are available. This will provide a calibration of the model mixing and hydraulics. Bacteria concentrations (enterococci) will also be calibrated so that the geometric mean of the predicted values falls within 30% of the measured values.

Like the SWAT model, calibration of a SWMM5 model will begin after QAPP approval. After collecting all available data for the watershed, the SWMM5 model will be calibrated to measured salinity data in the tidal segment. All model parameters will be adjusted within ranges recommended in published literature. Then the model will be validated without adjusting any parameters. The calibration period will be from 2006-2013 (with 2006 as preparation period) and the validation period will be from 2001-2006. These periods were selected based on available data for both salinity and bacteria. Time series plots and standard statistical measures will be used to evaluate the performance of modeling during calibration and validation. After calibration and validation, the existing condition will be simulated for a 20-year period to determine time series of average bacteria concentrations at key sampling locations in the tidal segment of Cedar Bayou watershed.

B8 INSPECTION/ACCEPTANCE FOR SUPPLIES AND CONSUMABLES

Not applicable.

B9 DATA ACQUISITION REQUIREMENTS (NON-DIRECT MEASUREMENTS)

Water quality data collected by the Clean Rivers Program, specifically *E. coli*, nutrients and flow, will be used along with data collected under the Development of a Watershed Protection Plan for Cedar Bayou project (TSSWCB project 10-08) modeling and the historical SWQMIS data analysis. The LULC analyses will be conducted with existing GIS data. H-GAC is a partner in the Clean Rivers Program for the state of Texas. As such, they and their regional affiliates collect data on a regular basis for routine water quality assessment as part of the state's mandate for CWA §305(b) – Water Quality Inventory Report. These data also are used by Texas for consideration of water bodies to be added to their list of impaired waterbody segments, as described in CWA §303(d). Additional data obtained from the TCEQ are from the SWQMIS database. Data collected by the CRP is quality assured under the H-GAC's CRP QAPP. Data collected by the CRP, along with other sources as submitted and compiled in SWQMIS by various other quality-assured monitoring activities, will be compiled and analyzed as part of subtask 4.4 of the project (as described in A6 and A7 of this document). These data will also be used to develop SELECT, LDC, SWAT, and SWMM5 Cedar Bayou tidal segment watershed and receiving water tidal model analyses. These data were taken in accordance with the approved QAPP (the then-current *H-GAC's Texas Clean Rivers Program Regional Monitoring Activities QAPP* for CRP data, and the applicable QAPP for other SWQMIS data) for the project and encompasses all applicable data in SWQMIS for monitoring sites in the Cedar Bayou watershed. Data analyzed from these sources include water quality data and flow parameters.

The GIS will include the most recent information available on land use, elevation, soils, stream networks, reservoirs, roads, municipalities and satellite imagery or aerial photography. Locations of SWQM stations, USGS gages, public access points to the water bodies, floodwater-retarding structures, wetlands, TPDES permittees (including WWTFs, CAFOs and MS4s) and subdivisions should also be included. Locations of possible bacteria sources, identified during the source survey should be incorporated. The cumulative impact of TSSWCB-certified WQMPs on the management of agricultural and silvicultural lands should be documented.

Data collected under the *Development of a Watershed Protection Plan for Cedar Bayou* (TSSWCB Project 10-08) will also be used to develop and refine SELECT, LDC, SWAT, and SWMM5 Cedar Bayou tidal segment watershed and receiving water Tidal analyses. These data were taken in accordance with the approved Monitoring QAPP for the project and *H-GAC's Texas Clean Rivers Program Regional Monitoring Activities QAPP*, together encompassing data collected from November, 1 2010 to October 31, 2014. Data that may be used from this project include water quality and streamflow information.

LULC analyses conducted as part of the *Development of a Watershed Protection Plan for Cedar Bayou* (TSSWCB Project 10-08) will be developed in accordance with this QAPP.. Data to be used from this effort include existing LULC datasets, as potentially revised by stakeholders and field observations. These datasets will be used to create the developed analyses of LULC change over time for the watershed and its subwatersheds. Data developed under this project will serve as an input to SELECT and to inform stakeholder decisions.

All data used in the modeling procedures for this project are collected in accordance with approved quality assurance measures under the state's Clean Rivers Program, TCEQ, Texas Water Development Board, USDA, National Weather Service, USGS, or other applicable state, regional, or federal agency.

GIS data to be used are contained in Table B1.1. Measured precipitation and temperature will be collected from National Weather Service climate stations for input into the models. Quality assured stream flow measurements will be collected from the USGS stream gauge station as available.

Because most historical data is of known and acceptable quality and were collected and analyzed in a manner comparable and consistent with needs for this project, no limitations will be placed on their use, except where known deviations have occurred.

B10 DATA MANAGEMENT

Systems Design

H-GAC and CDM use laptop personal computers and desktop personal computers. The computers run Windows XP or Windows 7 operating systems. Software includes Microsoft® Word, Microsoft® Excel, Microsoft® Access, and a Statistical Analysis System database management system run through Windows XP operating system. All GIS analysis will be performed using ArcGIS 10x. The SELECT, SWAT, SWMM5 Cedar Bayou tidal segment watershed and receiving water model, and CADDIS evaluation efforts will involve the use of their proprietary software.

Backup and Disaster Recovery

All work and file storage takes place on a shared network drive(s) which are continuously backed up on the network servers and archived on a regular basis. In the event of a catastrophic systems failure, the archival backups can be used to restore the data in less than one day's time. Data generated on the day of the failure may be lost, but can be reproduced from raw data in most cases.

Archives and Data Retention

Original data recorded on paper files are stored for at least five years. Data in electronic format are stored on tape drives in a climate controlled, fire-resistant storage area in the H-GAC offices.

C1 ASSESSMENTS AND RESPONSE ACTIONS

Table C1.1 presents the types of assessments and response actions for activities applicable to the QAPP.

Table C1.1 Assessments and Response Actions

Assessment Activity	Approximate Schedule	Responsible Party(ies)	Scope	Response Requirements
Status Monitoring Oversight, etc.	Continuous	H-GAC	Monitoring of the project status and records to ensure requirements are being fulfilled. Monitoring and review of performance and data quality.	Report to project lead in Quarterly Report
Technical Systems Audit	Minimum of one during the course of this project.	TSSWCB QAO	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP. Facility review and data management as they relate to the project.	30 days to respond in writing to the TSSWCB QAO to address corrective actions
Model Input Evaluation	Minimum of once during model development per model	H-GAC, CDM	Modelling staff will evaluate existing data to ensure quality objectives for modeling will be supported by the data.	Report to TSSWCB in Quarterly Report.
Model Calibration/Validation Assessment	Minimum of once during model development per model	H-GAC, CDM	Modelling staff will evaluate model calibration outcome to ensure data quality objectives are supported by calibration status.	Report to TSSWCB in Quarterly Report. 30 days to respond in writing to the TSSWCB QAO to address corrective actions.
Model Outcome Assessment	Minimum of once during model development per model	H-GAC, CDM	Modelling staff will evaluate modeling outcomes to ensure results meet data quality objectives.	Report to TSSWCB in Quarterly Report. 30 days to respond in writing to the TSSWCB QAO to address corrective actions.

In addition to those listed above, the following assessment and response actions will be applied to modeling activities. As described in Section B9 (Non-direct Measurements), modeling staff will evaluate data to be used in calibration and as model input according to criteria discussed in Section A7 (Quality Objectives and Criteria) and will follow-up with the various data sources on any concerns that may arise.

The model calibration procedure is discussed in Section D2 and criteria for acceptable outcomes are provided in Section A7.

Results will be reported to the project QAO in the format provided in Section A9. If agreement is not achieved between the calibration standards and the predictive values, corrective action will be taken by the H-GAC PM to assure that the correct files are read appropriately and the test is repeated to document compliance. Corrective action is required to ensure that conditions adverse to quality data are identified promptly and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem. CARs (Appendix A) will be filled out to document the problems and the remedial action taken. Copies of CARs will be included in QPRs and will discuss any problems encountered and solutions made.. These CARs are the responsibility of the H-GAC QAO and PM, in conjunction with CDM project staff, and they will be disseminated to individuals listed in section A3. If the predicted value cannot be brought within calibration standards, the QAO will work with TSSWCB to arrive at an agreeable compromise.

Software requirements, software design, or code are examined to detect faults, programming errors, violations of development standards, or other problems. All errors found are recorded at the time of inspection, with later verification that all errors found have been successfully corrected. Software used to compute model predictions are tested to assess its performance relative to specific response times, computer processing usage, run time, convergence to solution, stability of the solution algorithms, the absence of terminal failures, and other quantitative aspects of computer operation.

Checks are made to ensure that the computer code for each module is computing module outputs accurately and within any specific time constraints. The full model framework is tested as the ultimate level of integration testing to verify that all project-specific requirements have been implemented as intended. All testing performed on the original version of the module or linked modules is repeated to detect new “bugs” introduced by changes made in the code to correct a model.

Modeling data and project deliverables will be quality controlled by the TSSWCB PM in-house review. The TSSWCB PM will maintain overall responsibility for examining H-GAC’s work to ensure methodologies and processes are consistent with the procedures outlined in this QAPP.

The TSSWCB QAO (or designee) may conduct an audit of the field or technical systems activities for this project as needed. The H-GAC PM will have the responsibility for initiating and implementing response actions associated with findings identified during the on-site audit. Once the response actions have been implemented, the TSSWCB QAO (or designee) may perform a follow-up audit to verify and document that the response actions were implemented effectively. Records of audit findings and corrective actions are maintained by the TSSWCB PM and H-GAC QAO. Corrective action documentation will be submitted to the TSSWCB PM with the progress report. If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in agreements or contracts between participating organizations.

C2 REPORTS TO MANAGEMENT

Quarterly Progress Report

The quarterly progress report summarizes H-GAC activities for each task; reports problems, delays, and corrective actions; and outlines the status of each tasks deliverables. Report written by the H-GAC project manager. CAR forms will be utilized when necessary (Appendix A). CARs will be maintained in an accessible location for reference at H-GAC and disseminated to individuals listed in section A3. CARs that result in any changes or variations from the QAPP will be made known to pertinent project personnel and documented in an update or amendment to the QAPP.

Audit Response

H-GAC will respond in writing to the TSSWCB within 30 days upon receipt of a audit report to address corrective actions. The response will be written by the H-GAC QAO.

Technical Reports

Technical reports summarize H-GAC's activities for the major project tasks (LULC Update, Modeling Analyses, and Historical Water Quality Monitoring Data). These individual technical reports will be compiled and used to develop the "Cedar Bayou Watershed Protection Plan", which will serve as the project's final report. The WPP and technical reports will be submitted as final project deliverables. Modeling reports, including model data input assessments, model calibration/validation assessments, and model outcome assessments, will be made available to the H-GAC PM and QAO by modeling staff and made available to TSSWCB as stand-alone deliverables. Reports will be written by or under the guidance of the H-GAC PM with assistance from other staff members.

D1 DATA REVIEW, VALIDATION AND VERIFICATION

All data obtained will be reviewed, validated, and verified against the data quality objects outlined in Section A7 (Quality Objectives and Criteria). Only those data that are supported by appropriate QC will be considered acceptable for use.

The procedures for verification and validation are described in Section D2, below. The H-GAC PM is responsible for ensuring that data are properly reviewed, verified, and submitted in the required format for the project database. Finally, the H-GAC QAO is responsible for validating that all data collected meet the DQOs of the project and are suitable for reporting.

D2 VALIDATION METHODS

There is no validation and calibration for either the historical SWQMIS data analysis, LULC analyses, or the SELECT model or LDC (as they are data processors).

SWAT for Cedar Bayou Above Tidal Segment

In the validation process for SWAT, the model is operated with input parameters set during the calibration process, as described in Section B7, without any change and the results are compared to the measured for the period of 2000-2008 to evaluate the model prediction. The same evaluation measures will be used for assessing the performance of the model during validation. In case the matching between simulated and observed data is not to the standard, the calibration process will be revisited until a best fit between simulated and observed data is obtained. The validation and verification process will be conducted by H-GAC.

SWAT is built with state-of-the-art components with an attempt to simulate the processes physically and realistically. Most of the model inputs are physically based (that is, based on readily available information). It is important to understand that SWAT is not a parametric model with a formal optimization procedure (as part of the calibration process) to fit any data. Instead, a few input variables that are not well defined physically such as runoff curve number and Universal Soil Loss Equation's cover and management factor (C factor) may be adjusted to provide a better fit. Moreover, these model parameters are adjusted within literature recommended values so that the results are scientifically valid and defensible. In addition, statistical measures used for evaluating the model's predicted data using the observed data during calibration and validation help to maintain the quality of the model simulation processes and the model results reliable.

SWMM5 Watershed and Receiving Water Model for for Cedar Bayou Tidal Segment

Like the SWAT model developed for the above tidal segment in Cedar Bayou, the SWMM5 watershed and receiving water model for the tidal segment of Cedar Bayou will be validated, as described in Section B7, without any change and the results are compared to the measured for the period of 2001-2008 to evaluate the model prediction. The same evaluation measures will be used for assessing the performance of the model during validation. In case the matching between simulated and observed data is not to the standard, the calibration process will be revisited until a best fit between simulated and observed data is obtained. The validation and verification process will be conducted by CDM Smith.

SWMM5 is built with state-of-the-art components with an attempt to simulate the processes physically and realistically. Most of the model inputs are physically based (that is, based on readily available information). It is important to understand that SWMM5 is not a parametric model with a formal optimization procedure (as part of the calibration process) to fit any data.

Instead, a few input variables that are not well defined physically, such as EMCs and instream first order loss rate, may be adjusted to provide a better fit. Moreover, these model parameters are adjusted within literature recommended values so that the results are scientifically valid and defensible. In addition, statistical measures used for evaluating the model's predicted data using the observed data during calibration and validation help to maintain the quality of the model simulation processes and the model results reliable.

D3 RECONCILIATION WITH USER REQUIREMENTS

The modeling framework developed for this project will be used to evaluate contaminant loading in the Cedar Bayou watershed. It will provide information pertaining to historical trends in water quality, trends in LULC change, relationship of pollutant loads to flow regimes,potential loading from areas within the watershed, the impacts of watershed processes on loads in the above tidal segment, the impact of tidal processes in the tidal segment, and an evaluation of the ecological communities of the above tidal segment. These seven analyses will provide critical information to the stakeholders for evaluating potential sources of contamination and selecting management measures to improve and maintain water quality in Cedar Bayou. The overall aim of these efforts is to support the development of the Cedar Bayou WPP (TSSWCB Project 10-08).

The final data will be reviewed to ensure that it meets the requirements as described in this QAPP. CARs will be initiated in cases where invalid or incorrect data have been detected. Data that have been reviewed, verified, and validated will be summarized for their ability to meet the DQOs of the project and the informational needs of water quality agency decision-makers. These summaries, along with a description of any limitations on data use, will be included in the final report.

LULC

Once the final version of the LULC map is produced, the TSSWCB PM will review the product to determine if the results meet the quality objectives of this QAPP..If data quality indicators do not meet the project's requirements as outlined in this QAPP the revised dataset may be returned for revisions.

These data, and data collected by other organizations, will subsequently be analyzed and used for watershed assessment, watershed plan development, and modeling activities. Thus, data which do not meet requirements will not be submitted to the TSSWCB nor will be considered appropriate for any of the uses noted above.

SELECT and LDC

The SELECT modeling framework developed for this project will be used to evaluate bacteria loading in the Cedar Bayou watershed. It will provide information pertaining to watershed characteristics and to the prediction of possible pollution, the sources of this pollution, and will provide critical information to assist in identifying management practices to prevent pollution loading in area streams. This, in turn, will be useful for incorporation in the WPP being developed under TSSWCB Project 10-08.

The LDC framework utilized for this project will be used to evaluate *E. coli*, Entereococcus, Total Nitrogen, and Total Phosphorus loading in relation to flow regimes in Cedar Bayou. These analyses will aid in targeting water quality best management practices recommendations to the most likely areas of *E. coli*, Entereococcus, Total Nitrogen, and Total Phosphorus impairment.

SWAT for Above Tidal Segment of Cedar Bayou

The SWAT modeling framework developed for this project will be used to evaluate flow contributions in the Cedar Bayou Above Tidal segment watershed. Model results may be incorporated into LDC analyses conducted by H-GAC, as a secondary source of flow data. The final data will be reviewed to ensure that it meets the requirements as described in this QAPP. CARs will be initiated in cases where invalid or incorrect data have been detected. Data that have been reviewed, verified, and validated will be summarized for their ability to meet the DQOs of the project and the informational needs of water quality agency decision-makers. These summaries, along with a description of any limitations on data use, will be included in the final report.

SWMM5 watershed and receiving water tidal model for Tidal Segment of Cedar Bayou

The SWMM5 watershed and receiving water modeling framework developed for this project will be used to evaluate the impact of watershed processes, tidal process and the impact of BMPs on in-stream concentrations in the Tidal segment. Model results will be used to guide stakeholder decisions and link selected BMPs to water quality impacts. The final data will be reviewed to ensure that it meets the requirements as described in this QAPP. CARs will be initiated in cases where invalid or incorrect data have been detected. Data that have been reviewed, verified, and validated will be summarized for their ability to meet the DQOs of the project and the informational needs of water quality agency decision-makers. These summaries, along with a description of any limitations on data use, will be included in the final report.

CADDIS Evaluation for Above Tidal Cedar Bayou

The CADDIS framework developed for this project will be used to evaluate the factors impacting macrobenthic communities of the Above Tidal segment. Results from the evaluation will be used to guide stakeholder decisions. The final data will be reviewed to ensure that it meets the requirements as described in this QAPP. CARs will be initiated in cases where invalid or incorrect data have been detected. Data that have been reviewed, verified, and validated will be summarized for their ability to meet the DQOs of the project and the informational needs of water quality agency decision-makers. These summaries, along with a description of any limitations on data use, will be included in the final report.

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Appendix A.

Corrective Action Plan Form

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?