

Coastal Prairie Freshwater Wetland Function Project

Contract Number
582-7-77820

Quality Assurance Project Plan

Prepared by:

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Effective Date: December, 2007

A1 Approval Page

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A3 Distribution List

A final copy of this Quality Assurance Project Plan (QAPP) is to be received and retained by the following individuals:

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Dr. Margaret G. Forbes, Biology Department, co-PI, Baylor University

Ms. Helen E. Drummond, Program and Grant Manager, GBEP/ TCEQ
Mr. Steven R. Johnston, Project Manager, GBEP/TCEQ
Ms. Linsey Lippert, Quality Assurance Officer, GBEP/TCEQ

Mr. Tom Weber, Manager, Water Programs/Chief Engineer's Office/TCEQ
Mr. Stephen Stubbs, Quality Assurance Manager, TCEQ

Ms. Susan Branning, Chief of Assistance Programs Branch, EPA
Ms. Betty Ashley, Project Manager, EPA

A4 Project/Task Organization

We will conduct periodic sampling over a two-year period to describe the water quality and water storage functions of Coastal Prairie Freshwater Wetlands (CPFWS) in the Galveston Bay area. This work will be conducted at a minimum of nine wetland locations selected with assistance from the Wetland Advisory Group. This work will be carried out by faculty, researchers, students, and technicians based at Baylor University (herein referred to as Baylor), and the University of North Texas (UNT).

It is believed that most pollutants enter CPFWSs during precipitation events either from direct precipitation or from overland runoff. Our study defines water quality function as the capacity of the CPFWS to reduce aqueous levels of selected pollutants over time. We will characterize water quality as soon after a rainfall event as possible, and again approximately 7-10 days later. For example, after a rainfall event surface water grab samples will be taken from the wetland. Seven to ten days later, additional grab samples will be taken. Water samples will be transported to the Center for Reservoir and Aquatic Systems Research (CRASR) laboratory at Baylor for analyses. Water samples for heavy metal analyses will be preserved and shipped immediately to a commercial laboratory. Samples will be collected, preserved, and analyzed according to standard methods.

Water storage function will be measured by installing water level recorders at selected CPFWSs. Rain gages and piezometers will also be installed and monitored during site visits. Surface runoff and evapotranspiration will be calculated using appropriate models and precipitation will be measured with rain gages. We plan to produce a record of rainfall, evapotranspiration, groundwater movement, and wetland water levels for the study period. All collection procedures and equipment to be used are described below. Tabular and graphical presentations of these data will be submitted to GBEP, the scientific community, management agencies and the public. These data will also be used to modify conceptual models that assess CPFWS's capacity for water quality and water storage functions.

Functional assessment models will be applied using GIS mapping and available GIS databases (soil, National Wetland Inventory, land cover, topography, etc). A functional value will be calculated for each wetland based upon average values of cells within the boundary and this information will be displayed on maps.

Roles and Responsibilities of Key Organizations and Personnel

Baylor University

Robert. D. Doyle (Baylor Project Manager)

The Baylor Project Manager determines the priorities for the data collection and analysis for the project, and oversees the work of the Baylor Research Technicians and Analytical Technician. The Baylor Project Manager drafts work plans, writes quarterly progress

reports, and communicates with the Galveston Bay Estuary Program (GBEP) Program Manager and GBEP Project Manager. The Baylor Project Manager also oversees the final project report deliverables. The Project Manager will assist the QA Manager in performing routine QA/QC checks of data, deviations of sampling and chain of custody protocol, and field staff supervision, including audits.

Margaret G. Forbes (Baylor Co-PI, Quality Assurance Manager)

The Quality Assurance Manager works with the Project Manager to determine priorities for data collection and overseeing activities of Research Technician I. The co-PI will also contribute to development of the drafts work plans and quarterly progress reports. The co-PI will also work with the Baylor Project Manager in the development of the final project report deliverables. Baylor QA Manager is responsible for implementing the quality system as defined by the contract and in the QAPP. The QA Manager is responsible for writing, maintaining, and distributing the QAPP and ensuring the quality of data submitted to the Galveston Bay Estuary Program of the Texas Commission on Environmental Quality. The QA Manager also has the responsibility of maintaining records of QAPP distribution, including appendices and amendments. The QA Manager provides oversight of all sampling events, chain of custody, sample analysis, and data validation through systematic and routine paper and field audits. The QA Manager is responsible for compiling audit reviews, findings, and corrective actions taken for submission in reports to the GBEP.

Bryan W. Brooks (Baylor Research Associate I)

The Baylor Research Associate I (Brooks) works with the Project Manager to determine appropriate sampling approaches and overseeing activities of Research Technician II. This Research Associate will also contribute to development of the drafts work plans and quarterly progress reports. This Research Associate oversees collection and analyses of water samples for organic contaminants associated with the project. This Research Associate will assist the QA Manager in performing routine QA/QC checks of data, deviations of sampling and chain of custody protocol, and field staff supervision, including audits.

Joe C. Yelderman (Baylor Research Associate II)

This Baylor Research Associate II works with the Baylor Project Manager (Doyle) and co-PI (Forbes) to manage installation and monitoring of hydrologic monitoring devices. This Research Associate oversees collection of hydrologic field data required for the project. In particular, this Research Associate is responsible for collection and analysis of data on water storage in CPFWs.

Sascha Usenko (Baylor Research Technician I)

The Baylor Research Technician I works under the supervision of the TAMU Research Associate (Brooks) and Project Manager (Doyle) in the collection of field data for analyses of organic contaminants for the project. In particular, this technician is

responsible for collection and analysis of data on polycyclic aromatic hydrocarbons (PAHs) in precipitation and surface waters for the water quality portion of the project.

Melissa Mullins (Baylor Research Technician II)

The Baylor Research Technician II will work under the supervision of the Project Manager (Doyle) and the co-PI (Forbes). This Research Technician will be responsible for collection of all vegetation data, including aggregate measures such as percent cover. This Baylor Research Technician II will also assist with all field monitoring and data collection activities.

Jeff Back (Baylor Analytical Manager)

The Baylor Analytical Manager is the manager of the CRASR laboratory and will work under the supervision of the Project Manager (Doyle). The Analytical Manager will be responsible for analyses of all water samples for nutrient (nitrogen and phosphorus) content. The Baylor Analytical Manager follows analytical and QA procedures outlined in Appendix A.

University of North Texas

Bruce Hunter (UNT Research Associate)

The UNT Research Associate gathers appropriate GIS databases and aerial photography for the project. The Research Associate will also be responsible for applying the water quality and water function models in a GIS format. The Research Associate (Hunter) will obtain and manage GIS databases to be used for the project. The UNT Research Associate (Hunter) will direct the development of new GIS databases that will result from application of the functional assessment models. The UNT is the home of the Center for Spatial Analysis and Mapping (CSAM), a GIS and remote sensing research facility. The UNT/CSAM is a sub-contractor to Baylor for this project and is responsible for the GIS component of the project.

Galveston Bay Estuary Program Organization

GBEP Program Manager

The Program Manager guides and oversees the work of the GBEP Project Manager. The Program Manager will review projects developed each fiscal year for submission to the Budget & Priorities Workgroup (see description, page 9).

GBEP Project Manager

Regional Monitoring and Research Coordinator will function as Project Manager for the Loadings, Water Quality Mapping and Phytoplankton Project, which falls under the Regional Monitoring and Research program areas. In practice, the term Project Manager is used interchangeably with “TCEQ Project Representative”, “GBEP Project Representative” and “Contract Manager”. The Project Manager is responsible for:

- Maintaining necessary lines of communication and good working relationships between lead division staff, personnel of other divisions and organizations participating in a project;
- Ensuring the lead division administrative services coordinator or grant budget coordinator, and the TCEQ federal funds coordinator are informed of changes, revisions, or additions to the project;
- Elevating problems and issues requiring resolution to the Division Director, Policy and Regulation, or designee(s) for disposition, when appropriate; assist in preparing contracts and intergovernmental agreements;
- Reviewing the contractor's performance, including quality and timeliness of deliverables, reasonableness of expenditures, progress on meeting objectives/goals of the contract and enforce corrective action measures to assist contractors in meeting deadlines and scheduled commitments.

TCEQ Executive Director, Deputy Directors, Division Directors, and the quality assurance manager have delegated authority to develop and implement project-related quality systems, including development and maintenance of QAPPs, to Project Managers. These systems shall be developed with the concurrence and assistance of lead project quality assurance staff. GBEP Program Manager selects the GBEP Project Manager.

GBEP Quality Assurance Officer

The GBEP Quality Assurance (QA) Officer assists GBEP Project Managers in the development and review of Quality Assurance Project Plans and other QA/QC elements of projects as required by the U.S. Environmental Protection Agency (EPA) and the TCEQ.

GBEP Advisory Group

The GBEP advisory groups include the Galveston Bay Council (GBC), its subcommittees, task forces and workgroups. The advisory groups participate in project management as described below.

Galveston Bay Council

The GBC will:

- Provide an ongoing forum for technical and stakeholders review and involvement during *The Galveston Bay Plan (The Plan)* implementation;
- Contribute to assessments of Plan effectiveness and participate in periodic redirection of *The Plan* initiatives;
- Advise the TCEQ during consistency reviews of eligible federal projects;
- Maintain agency commitments to implement *The Plan*; assure efficient cross-jurisdictional coordination and, if necessary, facilitate resolution of disputes;
- Set annual priorities for the implementation of action plans.

The GBC reviews and approves the annual GBEP work plan during GBC meetings each April. The work plan contains the listing of projects developed through subcommittees and approved by the Budget and Priorities Workgroup.

Budget and Priorities Workgroup

The function of the Budget and Priorities Workgroup (B&P) of the GBC is to focus resources to accomplish major objectives in *The Plan* and advise on redirection of efforts where appropriate. B&P first reviews and approves the draft annual GBEP work plan before submission to the GBC. The B&P is also responsible for recommending resolutions of technical issues or conflicts to the program manager, regarding projects that are not resolvable by the respective subcommittee.

GBC Subcommittees

The GBC Subcommittees advise and comment on, in concurrence with the needs of GBEP and the Subcommittee Coordinator, the Scope of Work, project goals and objectives, specification of deliverables and the review and approval of final deliverables. The breakdown of the subcommittees is as follows:

1. Natural Resource Uses Subcommittee

The Natural Resource Uses (NRU) Subcommittee of the GBC facilitates the implementation of the Habitat/Living Resource Conservation area and three of four components of the Balanced Human Uses area of *The Plan*. Annually, the subcommittee develops projects that implement the following action plans:

- Habitat protection;
- Species population protection;
- Freshwater inflow and bay circulation;
- Spills/dumping;
- Shoreline management.

2. Water and Sediment Quality Subcommittee

The Water and Sediment Quality (WSQ) Subcommittee of the GBC facilitates the implementation of the Water and Sediment Quality Improvement area and one component of the Balanced Human Uses area of *The Plan*. The subcommittee annually develops projects that implement the following action plans:

- Water and sediment quality;
- Non-point sources of pollution;
- Point sources of pollution;
- Public health protection.

3. Public Participation and Education Subcommittee

The Public Participation and Education (PPE) Subcommittee of the GBC facilitates the implementation of the Public Participation and Education Action Plan. The subcommittee

provides support for all other Plan actions; annual projects are developed in consideration of the other subcommittees' initiatives.

4. Monitoring and Research Subcommittee

The Regional Monitoring Subcommittee of the GBC facilitates the implementation of the Monitoring and Research Action Plans of *The Plan*. Like the PPE subcommittee, this group provides support for all other Plan actions; annual projects are developed in consideration of the other subcommittees' initiatives.

Wetlands Advisory Group, a subgroup of the Monitoring and Research Subcommittee, was formed to lend expertise from local, state and federal resource agencies to this project.

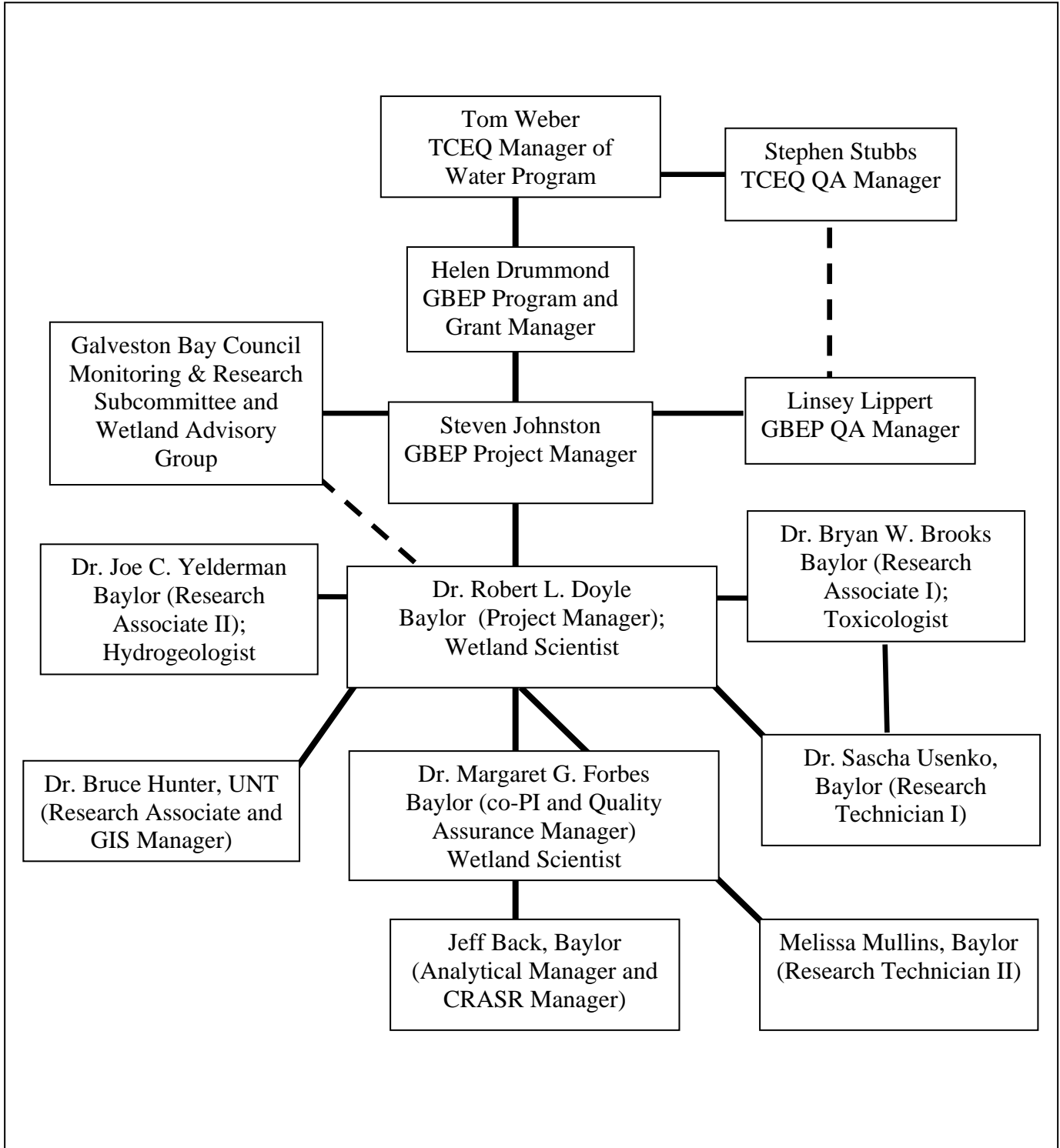
GBC Subcommittee Coordinators

Individuals from the GBEP staff are assigned by the GBEP Program Manager to facilitate and coordinate efforts of the following subset of GBC advisory groups:

- NRU Subcommittee
- WSQ Subcommittee
- PPE Subcommittee
- Monitoring and Research Subcommittee

As subcommittee coordinators, these individuals facilitate quarterly meetings of the advisory groups and develop the listing of annual projects that will be submitted through the GBEP hierarchy and ultimately approved by the GBC.

Figure 1. Organizational chart of project personnel



A5 Problem Definition/Background

In the Galveston Bay area, the most common type of freshwater wetlands are depressions and flats associated with the Coastal Prairie ecosystem that extends from southwestern Louisiana to the south Texas coastal plain. Studies estimate that between 1992 and 2002, over 9,000 acres of these Coastal Prairie Freshwater Wetlands (CPFWS) were lost, and there is no indication that the rate of wetland loss will slow in the near future (Jacob and Lopez 2005). The cumulative loss of water quality and flood storage function associated with the rapid disappearance of these wetlands will likely have detrimental effects on water quality and flood attenuation in the lower Galveston Bay watershed. Nationwide, there are few quantitative data available to estimate the pollutant reduction effectiveness and hydrologic processes of palustrine (freshwater) wetlands nationwide (Whigham and Jordan 2003), much less in the Texas Coastal Prairie region. In fact, there is little water quality data on CPFWS in general, and linkages between these functions and the environmental integrity of jurisdictional waters such as Galveston Bay have remained largely theoretical. Although there is recent evidence that CPFWS are periodically connected to receiving waters during runoff events (Sipocz 2002); there is currently insufficient data to estimate the cumulative water storage or water quality of these wetlands.

There is a need to quantify the water quality and water storage capacity of CPFWS in the Galveston Bay area and to provide a framework for evaluating the impacts of wetland losses on regional water quality and flooding. This study proposes to: (1) evaluate the capacity of freshwater wetlands to store water during storm events; (2) evaluate the role of freshwater wetlands in processing pollutants; and (3) develop water quality and flood storage functional assessment models.

The results of this study will provide a more comprehensive and quantitative understanding of how depressional wetlands attenuate pollutants and provide critical flood storage in the region.

A6 Project/Task Description

The proposed two-year study will focus on CPFWS within the Galveston Bay area. The study area shall be defined by the 30 USGS 7.5-minute quadrangle maps (Fig. 2) analyzed by White et al. (1993). This study focuses on palustrine wetlands that are not within the 100-year floodplain. With input from an advisory group, we will select six to nine wetlands that are characteristic of CPFWS within the study area, and describe their water quality and water storage functions.

Project objectives, tasks, and schedule of deliverables are described as follows:

Phase 1: Project Development (8/17/07 – 10/31/07)

Objective: Work with local and regional experts and survey the literature to develop the Project Work Plan, Quality Assurance Project Plan (QAPP), conceptual functional assessment models for CPFWS and a list of model variables for water storage and water quality functions.

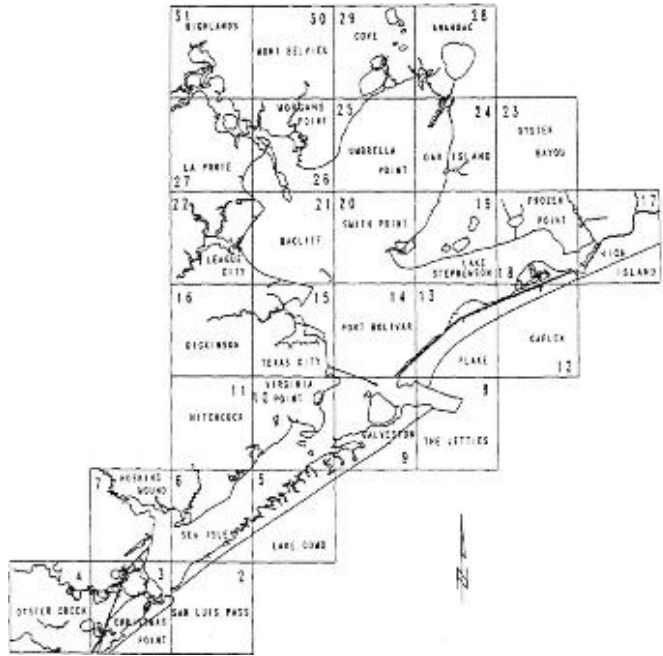


Figure 2. Project study area as defined by 30 USGS 7.5-minute quadrangle maps. Figure from White et al. (1993).

- Task 1.1 Develop the Project Work Plan to include a detailed description of all work to be carried out, a schedule for deliverables, and a time-line for all related tasks (Table 1).
- Task 1.2 Prepare the QAPP for approval by the TCEQ Project Representative in accordance with the EPA's G-5/R-5 document guidelines. The QAPP shall be updated annually.
- Task 1.3 With input from the Galveston Bay Estuary Program (GBEP) personnel, create an advisory Wetland Workgroup composed of wetland scientists and appropriate resource managers to guide the project and review deliverables. Interactions with the workgroups include attendance of selected meetings and visits to one or more wetland sites that will be used for field assessment.
- Task 1.4 Survey and review available literature on CPFWs and existing wetland functional assessment models to create an annotated bibliography.

- Task 1.5 Develop conceptual assessment models to be evaluated during Phase 2 field assessments. The conceptual models will be based on available literature and knowledge of the physical, chemical, hydrologic, and biological characteristics of CPFWs. Models will be developed for water storage and water quality functions. Separate water quality functional models will be developed for distinct classes of pollutants (e.g. phosphorus, nitrogen, petroleum by products, heavy metals) depending on their prevalence in the study area and the pollution attenuation pathways believed to be present in CPFWs.
- Task 1.6 Obtain most recent geographic base maps of the Galveston Bay area and create a GIS database. These should include the most recent digital National Wetland Inventory maps, soil maps, and land use covers.

Phase 2: Field Assessment (11/1/07 – 6/30/08)

Objectives: Test utility and accuracy of conceptual models by collecting and analyzing water storage and water quality data and CPFW characteristics. With input from the Wetland Workgroup, six to nine CPFWs will be selected that include undisturbed (reference) and disturbed wetlands.

- Task 2.1 Meet with Wetland Workgroup and review conceptual models, site selection, and approach to field assessment.
- Task 2.2 Present progress report to Estuary Program Subcommittee.
- Task 2.3 Conduct field assessment and laboratory analyses on selected wetlands. Field assessment activities will measure the necessary physical, chemical, and biological characteristics, or their indicators, for each wetland appropriate to the assessment models. For example, if the functional model for heavy metal removal indicates that soil clay content and pH are the primary variables contributing to high function, soil clay content and pH will be determined at each wetland.

To characterize site hydrology, we plan to install rain gages, piezometers, and water level recorders in selected wetlands to estimate precipitation, groundwater exchange, and evapotranspiration. Evapotranspiration may also be calculated using PET models. Water storage will be based on the change in volume of the wetland under wet and dry conditions. This may be determined by field indicators (e.g. soil characteristics, vegetation, wrack deposits) as well as hydrologic and site topographical measurements.

Because atmospheric deposition is believed to be a major pathway for input of pollutants to CPFWs, we will sample for selected regional air pollutants such as polycyclic aromatic hydrocarbons (PAHs), and heavy metals. Water quality

function in CPFWs will be demonstrated by decreases in contaminant concentrations over time. Pollution attenuation most likely occurs via degradation (e.g. photolysis, hydrolysis, microbial action), long-term storage (e.g. burial in sediments, sorption to sediment, uptake by plants), or other mechanisms. Therefore the sampling objective will be to quantify pollutant levels in the wetland water column immediately following a deposition event and again in one to two weeks. The change in aquatic concentrations of the pollutant represents the quantity of pollutant removed per area and per unit time.

Site selection, selection of pollutants, and detailed assessment methodologies will be determined with input from the Wetland Workgroup and therefore are not included in this work plan.

Task 2.4 Finalize assessment models based on the results of field assessment conducted in Task 2.3. The variables, their weighting, and possible mathematical relationships used in the functional assessment models will be adjusted based on the results of the data collected during the field assessment.

Task 2.5 Apply functional indices to GIS geodatabases for use in spatial analyses, mapping and other forms of visual display. GIS data layers will be constructed in raster format at a scale suitable to optimize input layers; one example potentially being Landsat imagery for land cover analysis. Mathematical indices, or qualitative categories, will be calculated for each raster cell that falls within the boundaries of a wetland as outlined above. A total value or category will be calculated for each wetland based upon average values of cells within the boundary.

For wetlands located in Harris County, LIDAR information will be used to delineate watershed boundaries. In areas without LIDAR data, or other high resolution elevation data, watershed boundaries will be determined using available topographic information. Land cover types will be classified to simple categories that reflect runoff coefficients. This analysis, coupled with precipitation data, can provide a volumetric estimate of surface and atmospheric contributions to the wetlands. Delivery products will consist of paper maps, digital maps, and a geodatabase.

Task 2.6 Provide report and presentation to summarize year-one project methods, results, data and analysis, and suggestions for changes to work plan and QAPP.

Phase 3: Field Verification and Dissemination of Results (7/1/08 – 7/31/09)

Objectives: To evaluate the accuracy of the conceptual models, field assessments will be repeated on a new set of CPFWs. The finalized models will be applied to selected wetlands and

field assessments will be conducted for the same parameters to develop a measure of model error. Draft and final results, including data and maps, will be disseminated.

- Task 3.1 Select additional wetland sites during meeting with Wetland Workgroup
- Task 3.2 Conduct water quality and flood storage field assessments and compare results to model predictions.
- Task 3.3 Dissemination of final results including presentation to GBEP, delivery of final GIS maps, draft and final project report, and submission of manuscripts to scientific journals for peer review.

A7 Quality Objectives and Performance Criteria

Currently, little is known about water quality and water storage in CPFWs. Budget constraints often force scientists and regulators to infer conclusions based on data that are collected at a limited number of sites for short periods of time. Lack of temporal replication, particularly for water quality parameters, will be a significant limitation of this study. We are not aware of previous attempts to calibrate or verify functional assessment models for water quality or water storage. Therefore this study represents an important step toward improving on functional assessment modeling.

Although data results may be highly variable, an important objective of this study is to provide consistent data quality. Data collected during project activities will be recorded and analyzed according to accepted standard methods for water collection and preservation (APHA 1998), the Quality Control/Quality Assurance (QA/QC) procedures established and specified in the QAPP and in Baylor's Center for Reservoir and Aquatic System Research's Standard Operating Procedures (SOPs). Any updates or changes to these Quality Assurance procedures will be coordinated with the GBEP Project Manager.

This project will make qualitative statements describing data confidence based on the existence and availability of the following documentation:

- Approved QAPP
- Established QA/QC procedures
- Agency-specific procedural documentation
- Metadata in a standard format

Performance criteria for the project will involve data acquisition, processing, maintenance, analysis and presentation of results. Data will be acquired from field and laboratory analyses made from monthly samplings. These datasets must be summarized in tabular format and stored in Baylor/UNT computers. This information will be made available on a quarterly basis to the GBEP Project Manager and will be maintained without corruption or data loss for the entire

contract period and summarized in the final project report. Evaluation of the data will be delivered in a draft final report for review by GBEP Project Manager and GBC subcommittees. Following review and incorporation of any comments a final report will be submitted to GBEP Project Manager.

Baylor maintains a Quality Management Plan (QMP) that documents how researchers structure their quality system and describes their quality policies and procedures. The Baylor QMP was prepared according to the EPA QA/R-2 manual (EPA/240/B-01/002, March 2001). The most recent QMP was prepared by the CRASR Director and peer-reviewed by the Quality Assurance Management (QAM) Committee in conjunction with all PI's and reviewed and approved by the Baylor Vice Provost for Research. The most recent QMP was approved by Region 6 EPA Quality Assurance Staff on December 3, 2007 (EPA QTRAK number 08-015).

A8 Special Training/Certification

This project requires staff with experience in hydrology, water sample/data collection, nutrient and PAH analysis, database management, statistical analysis, and development of GIS-based maps of water quality. The Baylor Project Manager, co-PI, Research Associates, and Research Technicians have several years of experience in hydrology or water quality data collection and database management. Our researchers have several ongoing projects that use similar sampling methods. UNT Research Associate (Hunter) has extensive experience developing maps in GIS and using GIS-based applications. All project staff are qualified to perform his/her individual tasks and capable of producing visualizations of analytical results based on experience or classroom training. Students that will participate in the project will be trained appropriately prior to conducting field work or laboratory analyses. Students will be supervised by listed project personnel.

A9 Documents and Records

The Baylor Project Manager will be responsible for archiving the QAPP for the Project. When revisions become necessary to the QAPP, he will apply a new version number to the document, call a meeting of project personnel and distribute the new version, and reclaim the old versions for destruction. The archive folder for the Project will contain all approved versions of the Project's QAPP.

Records produced by this project will consist of raw data acquired from the lab and field progressing through various stages of compilation of data into summarized tabular format. The raw data will consist of all data collected from the various monthly samplings in the Galveston Bay project area. An example of a data tracking sheet used to record data collected from water samples or other field measurements can be found in Appendix B.

All data reports, summaries, and other project documentation will be retained in a specially designated folder on individual Baylor desk top computers and backed up on compact disks (CDs) on a quarterly basis by Baylor project personnel. Only Baylor project staff will have access to this documentation. The Baylor Project Manager and co-PIs will retain all original data reports, summaries, and other project documentation for one year after completion of the project. At the end of that one-year period, all data reports, summaries and documentation will be transferred to the GBEP Project Manager. The GBEP Project Manager will retain project document, records, and raw data for a minimum of 10 years. Baylor Project Manager will retain backed-up copies of these documents, records, and data for a minimum of 5 years.

The final data report will be organized according to data type. Quarterly summaries of the data processed will be maintained and recorded in a project file. At the end of the project all data will be submitted to GBEP Project Manager as requested. All hard copies of tracking sheets and field data sheets, laboratory data sheets, GIS data files, etc. will remain at Baylor University.

II. Data Acquisition

B1 Sampling Process Design

This project was designed in an attempt to quantify freshwater wetland water quality and water storage functions in the Galveston Bay study area. Site selection will be guided by the following criteria: (1) wetlands should be characteristic of the those in the study area (i.e. coastal prairie freshwater depressions or flats); (2) wetlands should be located so as to provide adequate geographic coverage (i.e. not all sites located in the same county or quadrangles); and (3) wetlands be selected so as to provide a range of model variable values, particularly with respect to soils and vegetation. Sites will be sampled for water quality condition at least twice in order to determine changes in pollutant concentrations. Additional sampling may occur, however the overall numbers of sampling events will be limited by funding constraints.

Sampling is divided into three categories: water quality, hydrology, and site characterization. Water quality sampling will occur at least twice at each wetland, once immediately following a rainfall event, when precipitation and inflow will also be sampled, and once seven to ten days later. Hydrology monitoring will be begin as soon as the equipment can be installed and continue for at least twelve months. Site characterization involves describing the site in terms of the model variable and will be accomplished during any site visit. Additional details of these sampling events are provided in the following sections. Sampling process design is the responsibility of Baylor Project Manager and co-PIs and will follow widely-accepted, standard procedures for sample collection, preservation, calibration, and analyses.

B2 Sampling Methods

Water Quality

At each wetland site, three surface water locations will be established for water quality monitoring and sample collection. At each sampling location, temperature, pH, dissolved oxygen, and conductivity will be measured using a YSI 600 XLM® multiparameter datasonde configured with a YSI 650 MDS® multiparameter display system.

A surface water grab samples will be collected from each sampling location. Water samples for nutrient analysis will be collected in 1-L acid-washed bottles and placed on ice. Samples will be collected at least twice from each sampling site, once following precipitation and again 7-10 days later. All samples will be kept at or just below 4°C until analyzed for nutrient content. On each sampling trip, a “trip blank” will be prepared in the field using deionized water and transported with the actual samples. Samples will be preserved or stored according to standard procedures (APHA 1988). Sample holding times will be no greater than four weeks.

Rainwater and surface runoff samples will be collected at a minimum of three selected wetlands to quantify the pollutant load entering the wetland. Rainwater samples will be collected as follows: a Teflon bag will be placed in a steel drum and each drum will be secured to the ground. A cooler with a small hole in the top will be placed in the bottom of the drum. The bottom half of the Teflon bag will be placed in the cooler, which will contain dry ice and blue ice. The remainder of the Teflon bag will extend out of the cooler through the small opening and wrap around the opening of the drum, acting as a funnel. The resulting sample will be retrieved immediately following the rain event. Samples will be sealed in the Teflon bags using zip ties, then transported back to the laboratory on blue ice and split for analysis. Runoff samples will be collected from small in-ground interceptors that allow surface runoff to enter. These storm interceptor boxes will be lined with small Teflon bags, with collection and storage methods identical to rainwater samples.

Immediately upon return to the lab from the field, a portion of each water sample will be vacuum-filtered through a 0.45 µm glass fiber filter (GF/F). The filtrate will be analyzed for dissolved ammonium (NH_4^+), dissolved nitrate+nitrite ($\text{NO}_2^- + \text{NO}_3^-$) and soluble reactive phosphorus ($\sim \text{PO}_4^{3-}$). The remaining unfiltered water samples will be analyzed for turbidity, conductivity, total nitrogen, and total phosphorus. For all analytes, every ninth sample will be split for duplicate analyses.

All nutrient analyses will be performed in the Center for Reservoir and Aquatic Systems Research (CRASR) Laboratory of Baylor using a Lachat QuickChem 8500 Flow Injection Autoanalyzer. Ammonia-nitrogen will be analyzed using the phenolate method (EPA 350.1); nitrite+nitrate concentrations will be determined using the cadmium reduction method (EPA 353.2); and soluble reactive phosphorus will be measured using the molybdate-blue method (EPA 365.1). Total phosphorus (EPA method 365.1) will be determined on persulfate digested samples using the molybdate-blue method. For total phosphorus, 250 ml unfiltered samples are preserved with two drops of concentrated H_2SO_4 and stored in the refrigerator for a period no

longer than 28 days. Total nitrogen will be determined by analysis of nitrate plus nitrite-nitrogen in persulfate-digested samples using the cadmium reduction method. Additional details are provided in Appendix A.

Accepted standard procedures will be utilized in the analysis of each sample (APHA 1998). Additionally, all analyses will be done in accordance with standard QA/QC protocols for sample collection, receiving, storage, and calibration/standardization. The CRASR maintains SOPs for sample collection, multiparameter probe use, and nutrient analyses included in this QAPP.

Briefly, PAHs will be extracted from the aqueous samples using a modified Speedisk. The modified Speedisks will be prepared in the laboratory by combining a 1-g hydrophobic DVB Speedisk with a 1-g hydrophilic DVB Speedisk. Aqueous samples will be pulled from the Teflon bags onto the Speedisk using Teflon tubing and a vacuum manifold. Target compounds will be eluted off the Speedisk using ethyl acetate and dichloromethane. Eluate will be concentrated and then analyzed by gas chromatographic mass spectrometry with electron impact ionization (Usenko et al. 2005).

Samples for metal analyses will be collected in plastic 250-ml bottles and immediately shipped to a commercial laboratory where they will be preserved with HNO₃. Total metal analyses for Pb, Be, Sb, Se, Zn will be performed by a commercial laboratory that is NELAC certified. Analyses will be conducted by inductively coupled plasma-mass spectrometry (ICP-MS). Separate method blanks will be submitted with each sampling event.

Water Storage (Hydrology)

Water storage is an important wetland function because it has the potential to reduce flooding by dampening peak flood flows. The temporal pattern of water storage also has an important influence on other wetland functions such as providing habitat for native flora and fauna, cycling elements, and improving water quality. We plan to use two methods to estimate wetland water storage; the first relies on topographic measurements and the second uses *in situ* monitoring equipment to characterize the wetland's hydroperiod and water balance.

The topographic method calculates water storage volume of the wetland by multiplying the wetland area by the average wetland flood storage depth. The wetland area will be delineated by walking with a hand-held GPS unit (Trimble GeoExplorer) around the wetland-upland boundary. Wetland indicators such as high water marks, drift lines, and vegetation changes may be used to determine the location of the wetland-upland boundary. Average flood storage depth is defined as the surface water elevation range within the wetland multiplied by 0.5. The elevation range is the difference in elevation between the seasonally lowest surface water boundary and the wetland-upland boundary, as determined by a hand held level and stadia rod.

Wetland water balance and hydroperiod will be determined by developing a continuous record of surface water elevations in three selected wetlands. The water balance formula is shown below (Equation 1).

$$\Delta S = [(PPT - EVPT) \times A] + Inflow - Outflow \pm GW \quad \text{Eq. 1}$$

Where: ΔS is the change in water volume or water storage (m^3)
PPT is precipitation (m)
EVPT is evapotranspiration (m)
A is the wetland surface area (m^2)
Inflow is the volume of water entering the wetland via overland flow (m^3)
Outflow is the volume of water leaving the wetland through an outlet (m^3)
GW is groundwater recharge and discharges (m^3)

Precipitation will be measured using a Data Logging Rain Gauge (Onset RG2-M). Evapotranspiration will be calculated using the Mather-Thornthwaite equation with latitude correction (Rosenberry et al. 2004) and compared to daily reductions in water level. Inflow will be estimated using an appropriate runoff equations (e.g. SWAT). Wetland water level will be measured with pressure transducers (Global Water WL 16 Level Logger). In wetlands with a discrete outflow area, outflow will be determined by installing a weir or flume and the pressure transducer will be installed near the weir or flume. Although most of the wetlands are believed to have limited groundwater interactions, if groundwater exchange is suspected, we will also place a pressure transducer in the piezometer to measure groundwater fluctuations and calculate gains and losses. The equipment will be installed after site selection has been completed and data will be measured and recorded on an hourly basis. Data will be downloaded monthly. Hourly changes in water level will be compared to evapotranspiration calculations. The wetland hydroperiod (record of water level over time) will be developed and used to estimate water storage for a range of rainfall events.

Site Characterization / Functional Assessment Model Variables

Functional assessment models include variables that describe particular characteristics of the individual wetland and its watershed. Although functional assessment models have not been finalized, the draft models have identified the following variables:

1. Wetland Volume
2. Wetland Outlet
3. Wetland Area to Catchment Area Ratio
4. Macrophyte Density
5. Wetland Hydroperiod
6. Wet-dry Potential
7. Wetland Buffer

8. Soil Organic Matter
9. Wetland and Catchment Land Use
10. Soil Clay Content
11. Soil pH

The details regarding how each of these variables is defined and will be measured or estimated, is included in Appendix C. The determination of some variables made be made by both a field/laboratory method or an aerial photography/GIS database method. This is necessary because the finalized assessment models will be applied to wetlands outside the study area using GIS-based methods and databases. Four variables will also be determined using field or laboratory measurements (macrophyte density, soil organic matter, soil clay content and soil pH). Both GIS approaches and field/laboratory methods are described in Appendix C.

B3 Sample Handling and Custody

Sample handling and chain of custody records, as noted in A9, will be the responsibility of Baylor project staff and will follow widely accepted standards allowing for the tracking and history of each sample collected in this study. These records will be stored on computer as well as on hard copy printouts to be kept in the laboratory. Should a review or QA audit note an error in sample handling or chain of custody, corrective action will be taken as described in section III, C1.

B4 Analytical Methods

Analytical methods for nutrients will be the responsibility of Baylor Analytical Technician and will be performed according to procedures specified in CRASR SOPs and QA/QC Protocol (Appendix A). Analytical methods for PAHs will be the responsibility of the Baylor Research Associate I. Analytical methods for metals analyses will be the responsibility of the selected commercial laboratory.

Redundant electronic back-up systems and access to multiple analytical systems to process the samples will minimize the potential for analytical failures. Collection of excess sample from the field will also minimize risk of sample loss in the lab. Baylor sample preservation procedures in the field and in the lab also allow for long-term sample viability.

B5 Quality Control

Quality control measures for sampling methods, sample handling, chain of custody records, analytical methods, instrument/equipment testing, inspection, maintenance, calibration, and frequency of calibration will be implemented according to Standard Methods (APHA 1998) and Appendix A. The QA Manager with co-Project Managers, review and conduct QC audits to

determine if errors or anomalies are present and if corrective action is needed as described in section III, C1.

B6 Instrument/Equipment Testing, Inspection, and Maintenance

All instrumentation and equipment used on the project will be the responsibility of Baylor project personnel. Testing, inspection and maintenance of instruments and equipment used on the project will be performed regularly by Baylor project personnel according to manufacturer's recommendations and CRASR SOPs and QA/QC Protocol, Appendix A. The QA Manager with co-Project Managers, review and conduct QC audits to ensure all project staff are following manufactures recommendations and CRASR SOPs and QA/QC Protocol, Appendix A.

B7 Instrument/Equipment Calibration and Frequency of Calibration

All instrumentation and equipment calibration used on the project will be the responsibility of Baylor project personnel and will be performed each time the equipment is to be used (whether in the field or in the lab). The QA Manager with co-Project Managers, review and conduct QC audits to ensure all project staff are following and documenting calibration procedures based on manufactures recommendations CRASR SOPs and QA/QC Protocol, Appendix A.

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

Detailed laboratory calibrations are contained within the Baylor QMP. The QMP identifies all tools, gauges, instruments, and other sampling, measuring, and test equipment used for data collection activities affecting quality that must be controlled and, at specified periods, calibrated to maintain bias within specified limits. Calibration records are maintained and are available for inspection by the TCEQ.

B8 Inspection/Acceptance of Supplies and Consumables

Supplies and consumables purchased for this project will be used for laboratory analyses, field data collection, equipment, document preparation and report generation. Purchasing procedures will adhere to Baylor mandates and policies. The QA Manager with co-Project Managers, review and conduct QC audits to ensure all supplies and consumables are handled according to CRASR SOPs and QA/QC Protocol, Appendix A.

B9 Non-direct Measurements

Most data gathered throughout this project will be through direct measurements in the field, wet chemistry in the lab, or continuous measurements (e.g. water level recorders) from fixed sampling stations. Some data, however, will result from databases that are obtained from external sources. These databases are primarily geodatabases from government entities such as U.S. Fish and Wildlife Service, U.S. Geological Survey, U.S. Department of Agriculture – Natural Resource Conservation Service, Texas Natural Resource Information Service, Texas Parks and Wildlife, and Houston-Galveston Area Council of Governments.

Although GIS data from governmental sources are being used, it is not uncommon to detect positional errors when overlaid with each other due to a variety of reasons. For example, the scale at which data were originally obtained may vary, creating coarser resolution for vector or raster based data. This is often evident in line work hydrology data, where streams representing lines may not exactly overlay streams in aerial photography obtained at a much finer scale. Another common problem is registration error where one dataset is registered within its initially defined tolerances, but when overlaid upon a second dataset that also is registered within originally defined tolerances, exhibits some shift. A third example is land cover conditions based upon seasonal variability as captured in aerial photography. Municipal governments often obtain aerial photography during “leaf-off” winter conditions in order to better identify structures, whereas agricultural land cover data (e.g. NAIP) records data during peak growing season. In both cases, climatic conditions might be either wet or dry, thus changing the presence of surface water and vegetation conditions, as captured by imagery.

All datasets from State and Federal agencies are accompanied by metadata. These metadata will be kept with the datasets. Metadata for subsets of the geodatasets, such as, for example, “emergent wetlands” from NWI data, or specific soil characteristics from NRCS data, will be created in order to clarify the origin and purpose for extraction or exclusion. Metadata will also accompany GIS files that are created onsite for this project. Model input, construction and output will be checked by UNT and Baylor research staff for logical consistency.

All datasets will be archived in CD format in an ESRI based geodatabase. The geodatabase will be developed in State Plane, feet, NAD83, Texas South Central Zone. This coordinate system is commonly used by local government GIS managers in Houston-Galveston area and easily meshes with extant geodatabases from the area. Duplication of the geodatabase into additional coordinate systems can be made available, if required. Output measurements from the GIS model will be provided in feet and acres by default; metric system measurements will be provided if needed. Datasets for the project will be housed on one primary computer in the GIS research laboratory at UNT, a second dataset will be located on a local server within the laboratory and a backup copy will be housed on a university network drive which has daily backups. Dataset access will be limited to faculty, staff and graduate students conducting the research. Paper based logs of tasks and personnel will be recorded throughout the research period for documentation and archival purposes.

B10 Data Management

The use of computing and electronic communications resources for the transfer, processing and maintenance of data will be the responsibility of Baylor, and redundant systems are already in place at Baylor. Data will be backed up on CDs on a quarterly basis and stored in fire safe and in redundant locations. Emergency power supply systems are utilized to insure uninterrupted access to data.

Baylor will use Microsoft software packages for processing and maintaining data. ArcGIS software will be used for GIS applications. SAS or equivalent software will be used to perform statistical analyses. Datasets processed by personnel not directly involved in data management or analysis will be provided with read-only permission. Changes made to the sample database or GIS files will be kept as notes or additions within the database framework. Notes will be made available to GBEP Project Manager during site visits.

Data Management Flow Chart

Collection of Direct Field Data

- Collect surface water grab samples, rainwater and runoff samples
- Measure YSI parameters and record data
- Record readings or download data from hydrologic equipment
- Record site characteristics (vegetation cover, presence of outflow modifications, etc.) as described in Appendix D.

Collection of Direct Laboratory Data

- Analyze water samples for nutrients using methods and QA/QC protocols described in Appendix A. Transfer data to project database.
- Transfer data from water level recorders to desktop computer and enter into project database.
- Analyze soils for organic matter, clay content, pH in laboratory.
- Analyze PAHs using Speedisk extraction methods described previously.
- Request total metals results from commercial laboratory.

Quality Control of Original Data

- Review of all original data for errors.
- Potential errors are reviewed by Project Manager and co-PIs
- When verified, errors are noted on in database and corrected, if possible.
- Maintain updated QAPP information and documentation on any data acquisition methodologies.

Transfer of Original Data to Electronic Data

- Secure original data sheets, and transfer verified data to computers with adequate server space with necessary data duplication and firewalls at Baylor facilities.

Quality Control of Electronic Data Entry

- Analyze data and check for data entry errors by comparing with original data sheets.
- Correct any verified errors in electronic database.
- Maintain updated QAPP information and documentation on any data acquisition methodologies.

Analysis of Data

- Analyze hydrologic data by type and sampling station to determine wetland water budget.
- Analyze water quality parameters, calculating amount of pollutant concentration change in surface water immediately following precipitation event and 7 to 10 days later.
- Analyze water quality parameters, calculating amount of pollutant load in runoff and precipitation.
- Analyze percent removal of metals, PAH, and nutrients as predicted by conceptual models and modify models to reflect differences in removal.

Dissemination of Data

- Provide graphical and tabular analyses to GBEP Project Manager in quarterly progress reports
- Provide graphical and tabular analyses to GBEP Project Manager in a final report.
- Work with GBEP Project Manager to develop a report summarizing the findings of this inflows study.
- Provide graphs and interpretations of information to the GBEP Project Manager and GBC Subcommittees for use in assessing the importance of freshwater wetlands in water storage and water quality.
- Provide GIS-based maps to GBEP Project Manager and GBC Subcommittees that indicate the relative value of freshwater wetlands within the study area.

III. Assessment and Oversight

C1 Assessments and Response Actions

Baylor Project/Quality Manager and co-PIs will conduct routine data audits on quarterly datasets before final analyses are performed. Data quality control measures will be a critical part of these audits. See B10 for oversight of data management and D2 for quality control. QA Manager will decide when samples need to be re-run or thrown out. This will occur when results pass analytical QA/QC standards used in Appendix A, but the results indicate contamination of some

sort. These data will be flagged in the database and the remaining sample will be thrown out. In some cases where there appears to be no contamination, samples will be re-run and marked as such in the database.

C2 Quarterly Reports to GBEP Project Management

Quarterly reports will include updates on sampling efforts during the previous period, including observations made during field sampling, as well as a summary of data to date and any updated analyses that may have been completed. Any minor deviation from the sampling protocol will be included in any progress and final reports with appropriate documentation to the GBEP Project Manager. Should any change or needed changes impact the quality of the data, major changes to analytical or sampling procedures, deviations from the QAPP, tasks or Scope of Work, Baylor Project Manager will contact GBEP Project Manager to discuss response, which could include revision of the QAPP, amendment to the contract or termination of contract. GBEP Project Manager will determine if and when TCEQ management staff are to be informed of minor or major changes. Data audit results and corrective actions taken will also be included in progress/final reports to the GBEP Project Manager.

IV. Data Validation and Usability

D1 Data Review, Verification, and Validation

All water quality data obtained for this project will have completed a chain of custody approved by Baylor researchers. Project management will have control over all data collected and custodians handling the data. All data, whether collected or following sample analysis, will be reviewed against Data Quality Objectives, instrumentation limits, and professional judgment to determine if errors, including transcription, are present before summary analysis begins, see section IV, D2. If a data error is suspected the Baylor Project Manager and co-PIs will be notified and will determine if possible, the likely cause and what corrective action is needed, see section III Assessment and Oversight and section IV, D2. Any changes to data sheets will be noted in the database.

D2 Verification and Validation Methods

Data will be reviewed and validated in a stepwise process to exclude from the database all questionable values. First, values will be eliminated that cannot be precisely identified. Second, values will be eliminated that cannot be precisely located to a latitude and longitude or landmark in the Galveston Bay system. Third, values will be eliminated that cannot be verified according to the QAPP and lack documentation on how the value was obtained. Finally, values for a particular parameter and method will be reviewed to question the validity of outliers. Extreme values will be excluded if it is determined that it is physically or biologically impossible for the parameter to obtain that value. Outliers that pass the test of impossibility, but are still an order of

magnitude or one standard deviation greater or less than the next closest value, will be referred to the Baylor Project Manager and Baylor co-PIs for determination of inclusion or exclusion.

D3 Reconciliation with User Requirements

The requirements for data management and analysis have been and will be defined by the management structure of the GBEP and the *Galveston Bay Plan*. The GBEP and Baylor project management planned this freshwater wetland functional assessment study. However, Baylor is responsible for the collection of the data and will provide opinions on the appropriate usage of their data for the final report to GBEP.

Determination of which scientific questions to analyze is derived from the needs of the agencies responsible for data collection and the planning process of the GBEP. The Baylor project management will work with the data users who participate in the GBEP management structure on interpretation of the analytical results. The Baylor Project Manager will review specific requests for changes to interpretations of analytical results, if the request is made through the GBEP Project Manager.

The Baylor project management is aware of the limitations of this study and will report on these limitations to decision makers. Cautions about these limitations will also be included in all documents and reports.

APPENDIX A: NUTRIENT ANALYSIS AT CRASR, BAYLOR UNIVERSITY

Determination of Total and Dissolved Nutrients with Lachat

Currently we are analyzing water samples with the Lachat QuickChem 8500 Flow Injection Autoanalyzer. Dissolved nutrients are determined on samples that have been filtered through a 0.45 micron glass fiber filter and total nutrients are determined on unfiltered samples. Ammonia-nitrogen (NH_4^+) will be analyzed using the phenolate method (EPA 350.1); nitrite+nitrate (NO_3^- NO_2^-) concentrations will be determined on filtered samples using the cadmium reduction method (EPA 353.2); and soluble reactive phosphorus will be determined using the molybdate-blue method (EPA 365.1). Analyses of total phosphorus (TP) will be determined on persulfate digested samples using the molybdate-blue method (EPA 365.1). Total nitrogen (TN) will be determined by analysis of nitrate plus nitrite in persulfate-digested samples using the cadmium reduction method. The method detection limits and ranges are provided below.

Analyte	EPA Method	QuikChem Method	Method Detection Limit (mg/L)	Standard Range (mg/L)
NO_3^- NO_2^-	353.2	10-107-04-1-C	0.01	0.01 – 2.0
PO_4^{3-}	365.1	10-115-01-1-M	0.001	0.001 – 0.100
NH_4^+	350.1	10-107-06-1-B	0.05	0.05 – 5.00
TP	365.1	10-115-01-1-F	0.003	0.003 – 0.200
TN	353.2	10-107-04-1-C	0.01	0.01 – 2.0

Quality Assurance/Quality Control Procedures

Sample Receiving

Upon collecting samples, each sample container is logged in a chain of custody form and appropriate information is recorded to insure proper analytical parameters. Samples are either preserved (acidified) or kept frozen at -20°C until analyzed. Samples are generally not thawed until reliable instrument operation is determined.

Sample requirement and analysis

Approximately 20 mls of sample is required to determine the three dissolved analytes (NO_3^- NO_2^- , NH_4^+ , PO_4^{3-}) in the current configuration of the Lachat autoanalyzer. Sample injection occurs over 120 seconds with 60 second wash in between. In order to conduct duplicate analysis of one sample a volume of 30 mls is necessary. Samples are run in batches of 15.

Calibration/Standardization

Standard ranges are given in the table above. Currently five standards are run in duplicate at the beginning of each day. Linear regression calculations are conducted to generate conversion equations. Generally, correlation coefficients of 0.999 or better are achieved. At the end of each days run all standards are analyzed again and regression analysis is conducted. The results of these regression analyses are compared to the initial determinations and adjustments can be made for instrument drift.

Baseline and Instrument Drift and Matrix Considerations

A Certified Reference Material (CRM) is also analyzed between each batch of 15 samples with blank determination before and after each standard check. Blanks are also analyzed after each calibration in order to bracket each batch of 15 samples. These blanks are used to adjust the baseline and to monitor drift. A CRM and a replicate sample are utilized to determine percent spike recovery and relative percent difference. Previous determinations of these values have produced values of <5 % variation in percent spike recovery and, <10 % RPD.

Determination of Total Nitrogen and Phosphorus with Persulfate Digestion.

The elements nitrogen and phosphorus can also be incorporated in organic material as particulates in living material or organic matter transported to aquatic environments. In order to make determinations of the quantity of these materials incorporated as particulate matter a decomposition technique must be employed to convert the elements to a detectable component. Decomposition techniques generally employ a strong oxidizing agent to ensure quantitative recovery. The proposed method utilizes potassium persulfate ($K_2S_2O_8$) with pressure and heating to accomplish the complete decomposition and oxidation of elemental components in organic matter to a detectable form. This is followed by determination of soluble reactive phosphorus (EPA Method 361.5) and nitrate + nitrite (EPA Method 353.2) as described in Appendix A.

Method

Samples designated for total nitrogen and phosphorus determination are not filtered but collected in a clean fashion free of potential contamination. Sample volumes are transferred gravimetrically after vigorously shaking and resuspended any settled material. Sample volumes of approximately 30 grams are transferred into 40 ml borosilicate sample vials (Note, total weight of sample and sample vial should be recorded upon completion of all additions and will be compared with post measurement to determine if leakage has occurred). Persulfate is added in a 5-ml quantity and the sample vials are then sealed with septum caps (Teflon septa) and prepared for autoclaving. The autoclaving step must include a 25-minute cycle at 18 psi and 121°C temperature.

After cooling the sample containers are weighed and compared to pre-autoclave values. Leakage is easily identified through this step. In addition, spike controls of known quantities are run in the form of CRMs with sample runs. At least one spike recovery should be run per 15-sample batch. From these spiked samples recovery analysis is performed and reported.

Total nitrogen is determined by digestion with a similar alkaline persulfate solution, followed by measurement of nitrite+nitrate in the Lachat autoanalyzer (EPA 353.2).

Quality Assurance/Quality Control Procedures

Receiving

Upon receiving samples, each container is logged in a chain of custody form and appropriate information is recorded to insure proper analytical parameters (e.g. salinity values). Samples are logged and stored at either -20°C until analyzed. Samples are generally not thawed until reliable instrument operation is determined.

Sample requirement and analysis

Approximately 30 mls of sample is required to determine the Total Nitrogen and Phosphorous in the current configuration of the Technicon Autoanalyzer. Sample injection occurs over 120 seconds with 60 second wash in between. Samples are run in batches of 15. A CRM and a blank are autoclaved for each batch of 15.

Calibration/Standardization

Standard ranges are given in the table above. Currently four standards are run in duplicate at the beginning of each day. Line regression calculations are conducted to generate conversion equations. Generally, correlation coefficients of 0.999 or better are achieved. At the end of each days run all standards are analyzed again and regression analysis is conducted. The results of these regression analyses are compared to the initial determinations and adjustments can be made for instrument drift.

Baseline and Instrument Drift

A non-autoclaved CRM is also analyzed between each batch of 15 samples with blank determination before and after each calibration check. Blanks are also analyzed after each calibration in order to bracket each batch of 15 samples. These blanks are used to adjust the baseline and to monitor drift. The CRM is utilized to determine percent spike recovery and relative percent difference. Previous determinations of these values have produced values of $<5\%$ variation in percent spike recovery and, $<10\%$ RPD.

APPENDIX B: SAMPLE DATA COLLECTION FORM

Wetland ID:	Date:	Time:	Personnel:																																																																																										
Air Temp (C):	Weather:		Days since rain:																																																																																										
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APPENDIX C: MODEL VARIABLES

Wetland Volume (V_{vol})

Definition: The wetland volume refers to the storage volume capacity of the wetland that is typically available (i.e. empty) at the onset of precipitation events.

Rationale: The wetland volume is an important predictor of the wetland's capacity to attenuate flooding of downstream areas. Wetlands with a large volume that are permanently flooded may have limited available storage capacity for precipitation and runoff.

Measure/Units: Cubic meters, ac-ft, or other appropriate volume units.

Field Measurement: The water storage volume of the wetland is calculated by multiplying the wetland area by the average wetland flood storage depth. Average flood storage depth is defined as the elevation range within the wetland multiplied by 0.5. The elevation range is the difference in elevation between the open water boundary and the wetland-upland boundary, as determined by a hand held level and stadia rod to the nearest tenth of a foot. Field indicators such as high water marks, drift lines, and vegetation changes may be used to determine the location of the wetland-upland boundary. The wetland area shall be delineated using a hand-held GPS unit.

GIS Measurement: The elevation of the open water boundary of the wetland will be taken as the elevation of the wetland boundary on the NWI map. Where possible, the open water perimeter of the wetland, and the upland-wetland boundary, will be determined using aerial photography. The elevations of these locations will be determined using topographic or LIDAR databases.

Wetland Outlet (V_{outlet})

Definition: This variable refers to the presence or absence of hydrologic alterations such as dikes, water control structures, artificial water inputs, ditching, or water removal by pumping (Table 2). The effect the alterations have on the wetland's ability to store water is determined from categories.

Rationale: Wetland outlet modifications tend to prevent the wetland from storing water during precipitation events by either lowering the elevation of the natural outlet and thereby reducing storage capacity, or by preventing the outflow of water between precipitation events and thereby reducing the available storage volume. This variable is relative to the natural condition of the wetland.

Measure/Units: The variable is indexed based on Table 2 below.

Field Measurement: Note the presence of dikes, artificial outlets, fill material, irrigation pipes, artificial pumps, ditches or other wetland modifications.

GIS Measurement: Using aerial photography, USGS maps, NWI maps or other resources, note the presence of dikes or other water control structures.

Table 2. Subindex values for V_{out} based on observations of various wetland outlet modifications (from Stutheit et al. 2004).

Alterations	Sub index Value
Natural conditions present, no dikes or fill within the wetland that restrict or redirect flow or change the wetland water regime class, no pumping or groundwater inputs -OR- wetland has been fully restored.	1.0
Dike(s) or fill bisects the wetland area and the amount of isolated wetland is proportional to the amount of the isolated catchment area -OR- dike has an unrestricted culvert(s) with the invert at or below natural grade.	0.9
Dike(s) with water control capability keep water on a wetland and does not change the wetland water regime class -OR- increased flows to the wetland supplement or correct altered hydrology.	0.6
Dike(s) or fill bisect and change the wetland water regime class -OR- groundwater presence has altered the natural wetland water regime class and soil characteristics -OR- sediment/soil ridge ponds shallow water outside of the wetland..	0.3
Dike(s) or artificial pumping keep the wetland drained -OR- land leveling or fill has raised the elevation of the bottom of the wetland above the temporary zone.	0.0

Wetland Area to Catchment Area Ratio (V_{catch})

Definition: The ratio of the wetland surface area to the surface area of that wetland’s catchment (watershed). The catchment area includes the wetland.

Rationale: The ratio of watershed size to wetland size provides an estimate for relative hydraulic retention time. The retention time of water in a wetland is an important consideration for pollutant removal/retention processes, particularly those that rely on biological activity. Longer retention times generally result in greater pollutant removal or retention.

Measure/Units: This variable is a unitless ratio.

Field Measurement: The watershed (catchment) and wetland sizes may be determined using GPS and survey techniques where possible. In larger catchments, topographical maps or LIDAR will be used, in conjunction with field verification, to estimate catchment size. A mean ratio will be determined for the study area based on 80 to 120 CPFWs. An index will then be developed based on the sample distribution.

GIS Measurement: Topographical maps or aerial photography will be used to delineate and measure catchment and wetland area.

Emergent Macrophytic Vegetation (V_{mac})

Definition: The relative coverage of the wetland area by erect vegetation. Submersed vegetation is not included.

Rationale: High densities of emergent wetland vegetation are associated with abundant dissolved and particulate organic matter and the buildup of litter and peat substrates. Abundant plant matter also indicates that microbial activity is high and reducing conditions would be likely. These qualities are predictive of long-term phosphorus storage, sequestration of metals, partitioning of organic contaminants, and denitrification.

Measure/Units: percent cover.

Field Measurement: A 0.25-m² quadrat will be used to determine percent cover in the wetland. Transects will be laid out approximately 10 m apart and one quadrat analyzed every 10 m along that transect.

GIS Measurement: Percent of open water within each wetland will be determined and the percent cover of emergent vegetation will be calculated as follows:

$$V_{mac} = (100 - \text{percent open water}).$$

Wetland Hydroperiod (V_{hydro})

Definition: The frequency and duration of inundation that a wetland experiences in a typical year according to the Cowardin classification as shown on National Wetland Inventory maps. This variable is for use with Equation 2A.

Rationale: The wetland hydroperiod indicates the frequency and duration of inundation and therefore is associated with the extent of oxidation and reducing conditions in wetland soils. Reducing conditions are necessary to transform nitrate to nitrogen gas via denitrification.

Therefore wetlands with longer periods of inundation are expected to have a higher potential for removing high nitrate loads (Table 3).

Measure/Units: The categorical hydroperiods as described by Cowardin et al. (1979) are assigned arbitrary values according to the duration of inundation (Table 3).

Field Measurement: Water level recorders will operate continuously and indicate the frequency and duration of inundation in selected wetlands.

GIS Measurement: Cowardin classifications and values assigned in Table 3.

Table 3. V_{hydro} and V_{wetdry} values based on Cowardin classification of water regimes.

Water Regime	Weeks Flooded	Description of Surface Water	NWI symbol	V_{hydro} Eq. 2A	V_{wetdry} Eq. 2B
Permanently flooded	52	Present year round	H	1.0	0.1
Intermittently exposed	41 – 51	Present except during extreme drought	G	0.8	0.4
Semipermanently flooded	18 - 40	Present most of year, when absent, very shallow water table	F	0.6	0.8
Seasonally flooded	5 - 17	Wet during growing season, typically exposed during some period of each year	C	0.4	1.0
Saturated	seldom	Seldom present but soils saturated for extended periods	B	0.2	0.8
Temporarily flooded	1 – 4	Present for brief periods, lower water table, facultative vegetation	A	0.1	0.4
Intermittently flooded	seldom	If present, no seasonal pattern, hydric soils unlikely	J	0.05	0.1

Wet-dry Potential (V_{wetdry})

Definition: The potential frequency of water level fluctuations that a wetland experiences in a typical year based on the Cowardin classifications as listed on National Wetland Inventory maps. This variable is for use with Equation 2B.

Rationale: The wetland hydroperiod indicates the frequency and duration of inundation and therefore is associated with the extent of oxidation and reducing conditions in wetland soils. Oxidizing conditions are necessary to transform organic and ammonium nitrogen to nitrate before denitrification can proceed. Therefore wetlands with wet-dry hydrologic regimes have a higher potential for removing organic-nitrogen, ammonium and nitrate loads (Table 3).

Measure/Units: The categorical hydroperiods as described by Cowardin et al. (1979) are assigned arbitrary values according to the duration of inundation (Table 3).

Buffer Density (V_{buff})

Definition: The extent to which the area immediately adjacent to the wetland (30 m from wetland perimeter) is vegetated.

Rationale: High density of vegetation within the buffer area around the wetland contributes to filtration of particulate matter that carries pollutants. During runoff events, these moist soil areas may also contribute to transformation and sequestration of nitrogen, phosphorus, metals, and organics through microbial and sorption processes. The buffer area can be thought of as an extension of the wetland ecosystem, particularly during wet periods, during which the buffer areas may exhibit wetland characteristics such as hydric soils and vegetation.

Measure/Units: percent cover of vegetation within a 30 m zone perpendicular to the perimeter of the wetland.

Field Measurement: A 0.25-m² quadrat will be used to determine average percent cover in the wetland. Transects will be laid out perpendicular to the perimeter every 20 m. Along each transect, one quadrat will be analyzed every 10 m.

GIS Measurement: Percent of area that is vegetated within the 30-m wide buffer around the wetland determined using raster, digitized aerial photography.

Soil Organic Matter (V_{som})

Definition: The percent by weight of a soil sample that is comprised of organically derived matter.

Rationale: High soil organic matter has been described as the most important property for assessment of soil quality. Sufficient soil organic matter indicates that microbial activity and sequestration of metals, partitioning of organic contaminants, and denitrification are favored.

Measure/Units: Percent of soil organic matter in samples taken from the top 30 cm.

Field Measurement: Soil samples will be taken from a subset of locations that are sampled for vegetation composition (quadrats). Samples will be collected with a soil boring tool and placed in centrifuge tubes and placed on ice. In the laboratory, wet weight, dry weight and volatile solids weight will be determined on samples. Volatile solids provide an estimate of organic matter in solids (APHA 1998).

GIS Measurement: Percent of soil organic matter will be derived from SSURGO database. If more than one soil type occurs within the wetland, a weighted average will be calculated.

Land Use (V_{LU})

Definition: The dominant land use in the catchment area (including the wetland) based on categories defined in the National Land Cover Database.

Rationale: Land uses in the catchment predict the quality and quantity of runoff that will enter the wetland. This variable is used only to determine whether high levels of nitrate will be likely to enter the wetland during runoff events.

Measure/Units: a weighted average of pollution associated with various land uses (Table 4), multiplied by the percentage of that land use present in the wetland catchment.

Field Measurement: Direct observation will confirm the predominant land uses in the area for comparison to aerial photography. The delineation of catchment boundaries will be determined using standard surveying equipment, LIDAR (where available), or topographic maps.

GIS Measurement: Land use will be obtained from the 2001 National Land Cover Database.

Table 4. Mean runoff concentrations from selected land use types (from Adamus and Bergman 1995).

Land Use Category	Total Nitrogen (mg L ⁻¹)
Low Density Residential	1.77
Medium Density Residential	2.29
High Density Residential	2.22
Low Intensity Commercial	1.18
High Intensity Commercial	2.83

Industrial	1.79
Agriculture - Pasture	2.48
Agriculture - Crops	2.68
Agriculture - Other	2.32
Mining	1.18
Recreation, Open Space, Range	1.25
Natural Areas ^a	0.00

a. These numbers were set to zero to indicate no additional pollution loading from natural lands.

Soil Clay Content (V_{clay})

Definition: The percentage of a soil sample, by weight, that is comprised of material classified as <0.002 mm in size.

Rationale: Clay particles in soil have very high surface areas as well as a surface chemistry that enhance the sorption of polar molecules such as ammonium, heavy metals, some organics, and phosphates. Soils with high clay contents are likely to retain these contaminants.

Measure/Units: This measurement yield categorical values based on the surface texture of subsamples and is unitless.

Field Measurement: Soil samples are taken from a subset of locations and the “Texture-by-feel” method (Figure 2) is used to determine the soil textural class (clay, silt, sand, etc.). The class is then used to determine the average clay content as indicated by the soil pyramid (Figure 3.). The textural class of soil is indexed to provide values between 0.0 and 1.0 (Table 5).

GIS Measurement: Soil clay content will be estimated from surface texture (SURFTEX) attribute data from the Soil Survey Geographic (SSURGO) database. The conventional definitions for soil textural classes of clay (material below 0.002 mm), silt (0.002 to 0.05 mm), and sand (0.05 to 2.0 mm) are used to define the different soil types. The database classifications are ranked and assigned values from 0.0 to 1.0 for GIS application. If more than one soil type occurs within the wetland, a weighted average will be calculated.

Table 5. V_{clay} subindex values based on soil surface texture and clay content.

Textural Classification	Range of Clay Content (%)	FCI Value
Clay	56-100	1.00
Silty clay	40-60	0.64
Sandy clay	38-56	0.60
Silty clay loam	28-40	0.44
Clay loam	28-40	0.44
Sandy clay loam	20-38	0.37
Loamy sand	10-15	0.23
Sandy loam	15-20	0.22
Loam	8-28	0.18
Silt loam	0-28	0.16
Silt	0-12	0.08
Sand	0-10	0.06

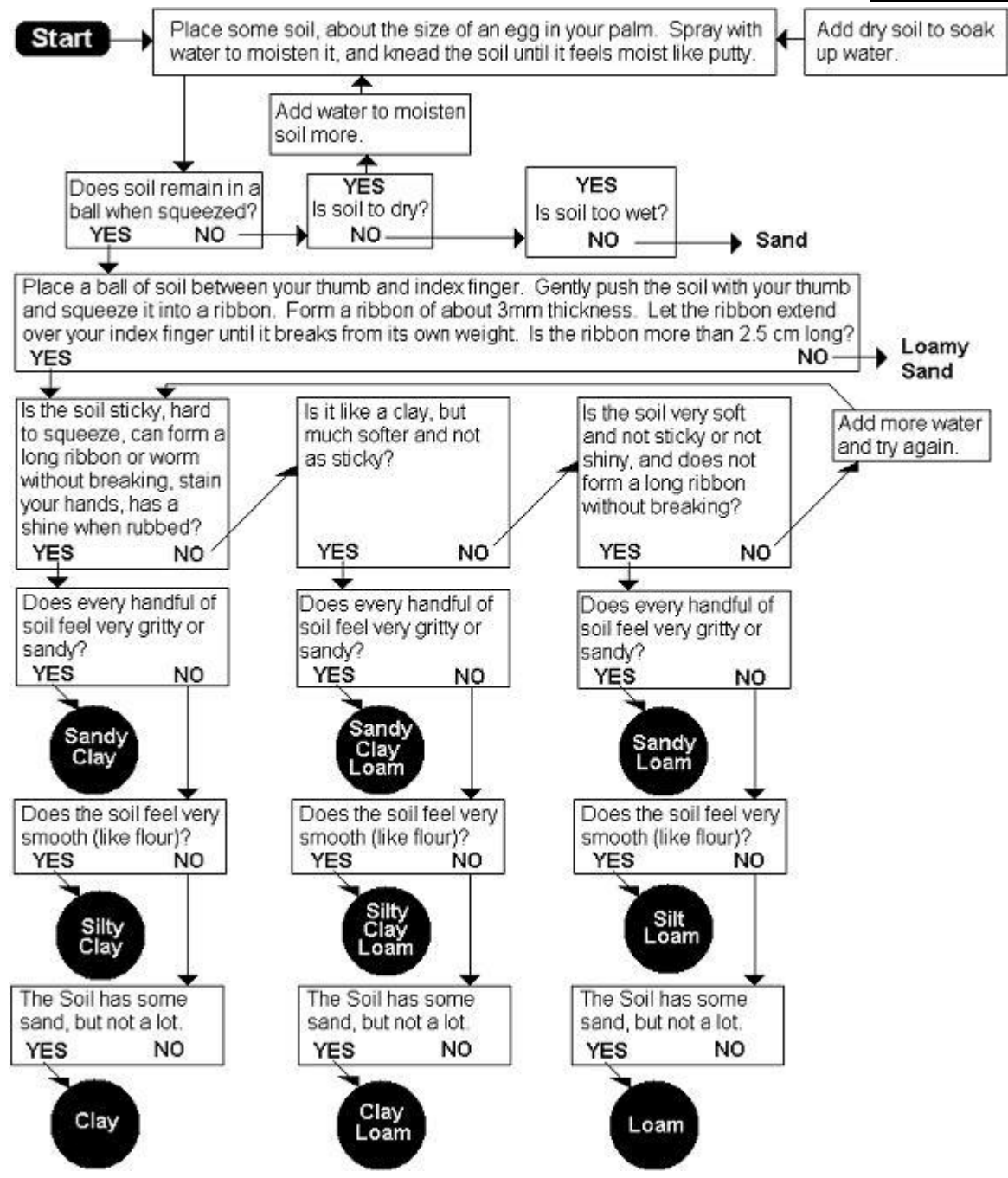


Figure 2. Method for determining soil class by surface texture. Modified from S.J. Thien. 1979. A flow diagram for teaching texture by feel analysis. *Journal of Agronomic Education* 8:54-55. Also at: http://soils.usda.gov/education/resources/k_12/lessons/texture/

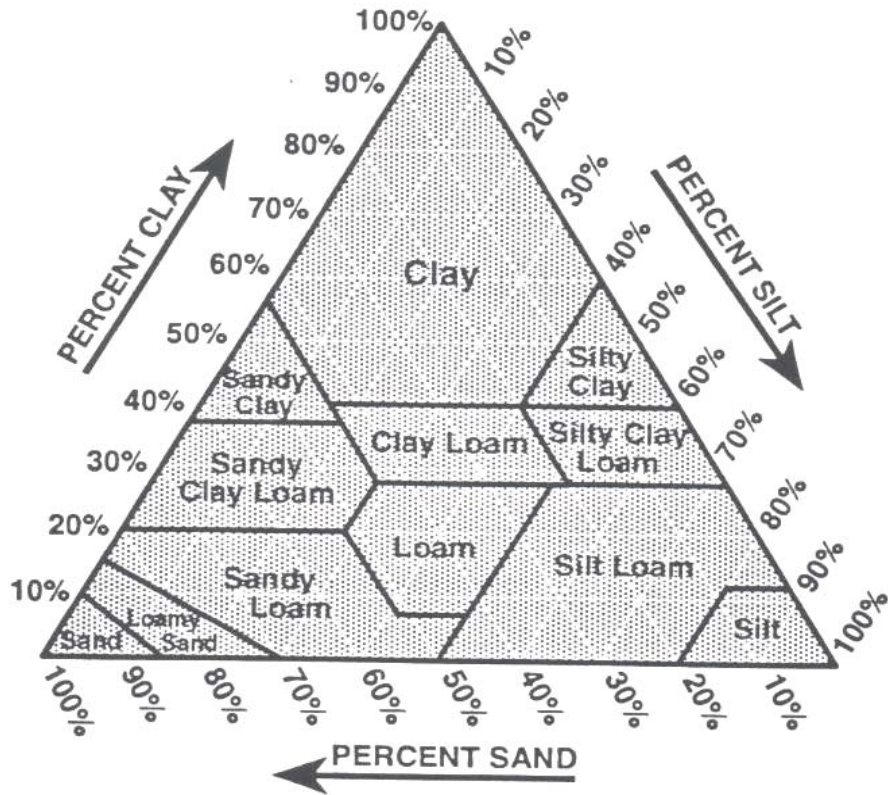


Figure 3. Soil pyramid for textural classifications.

Soil pH (V_{soilpH})

Definition: The pH (acidity) of a soil-water mixture on a scale of 0 to 14 with 7.0 being neutral.

Rationale: Soil pH influences water quality and sorption/precipitation mechanisms. Many pollutants are more soluble in acidic conditions. In alkaline soils, calcium and magnesium will form insoluble precipitates with many pollutants, especially phosphates and metals.

Measure/Units: Soil pH ranges and categories are included in USDA Soil Survey Manuals for each mapped soil type. The pH ranges are converted to index values as shown in Table 5.

Field Measurement: Soil collected for determination of soil organic matter, and textural analysis will be used for determination of soil pH. After determination of soil dry weight, 40 grams of dried soil will be added to an equal weight of distilled water and mixed. A pH probe

will be used to determine the pH of the supernatant. Three replicates will be analyzed for pH. Soil pH classes and FCI values are shown in Table 6.

GIS Measurement: Soil pH descriptions will be obtained from the SSURGO database and converted to FCI values according to Table 6. If more than one soil type occurs within the wetland, a weighted average will be calculated.

Table 6. Soil pH classes, associated pH values, and indices values for V_{soilpH} .

Soil pH Class	Soil pH range ^a	FCI Value
Ultra acid	< 3.5	0.0
Extremely acid	3.5 – 4.4	0.1
Very strongly acid	4.5 – 5.0	0.2
Strongly acid	5.1 – 5.5	0.3
Moderately acid	5.6 – 6.0	0.4
Slightly acid	6.1 – 6.5	0.5
Neutral	6.6 – 7.3	0.6
Slightly alkaline	7.4 – 7.8	0.7
Moderately alkaline	7.9 – 8.4	0.8
Strongly alkaline	8.5 – 9.0	0.9
Very strongly alkaline	> 9.0	1.0

a. From the National Soil Survey Handbook (USDA 193).

APPENDIX D: DATA MANAGEMENT PLAN

Data Management Process

Field data will be recorded on field data reporting forms and then entered into a database file. Field data forms will be maintained for five years. If any calculations are made, at least 10% will be checked by hand for accuracy. At least 10% of all electronic entries will be verified for accuracy. After each data entry session, accuracy will be verified by the Project Quality Assurance Manager (Forbes) and updated databases will be sent to the Project Manager (Doyle) as a back-up repository.

Data generated by CRASR laboratory will be first quality checked by the Analytical Manager (Back) for compliance with QA/QC procedures described in Appendix A. Data that are not consistent with QC standards will be flagged and this information will be provided to the Project QA Manager (Forbes). The data will then be sent to the Project QA Manager (Forbes) for entry into the project databases. Data generated by commercial laboratory and by Baylor Research Technician I will also be provided to the Project QA Manager for entry into the project databases. These data will include results of spikes, calibrations, method blanks, and other QC steps described in Appendix A.

Data that pass QC standards but have values that are biologically impossible will be flagged for further examination and discussion between the project personnel. These data will be eliminated if it is determined that they are statistical outliers according to criteria outlined in Standard Methods (APHA 1998).

Approved data will also be entered into the project database and a minimum of 10% of samples will be checked for accuracy. After each data entry session, accuracy will be verified by the Project Quality Assurance Manager and updated databases will be sent to the Project Manager as a back-up repository.

Aerial photography and GIS databases will be maintained by the Research Associate and GIOS Manager at the University of North Texas. These databases will also be stored on CDs or separate hard drives at Baylor along with the project databases described above. At least quarterly, these GIS databases will be updated at the Baylor site.

Data generated from the above activities will be organized in tabular and graphical forms for delivery to the GBEP Project Manager. Descriptions of QC procedure results, flagged data, eliminated data, and other important qualifying information will accompany the data.

Quality Assurance/Control - See Section D of this QAPP.

Migration/Transfer/Conversion - The Project Team's data manager is Thad Scott of Baylor University. He is responsible for the acquisition, verification, and transfer of data to the TCEQ TMDL Project Manager. Mr. Scott oversees data management for the project by performing data quality assurances prior to transfer of data to TCEQ in the format specified in the *SWQM Data Management Reference Guide* (2003) or most recent version. Mr. Scott transfers the laboratory results into the Baylor RTA database. After ensuring the data are free of transcription errors, he converts the database into an ACSII pipe delimited format. He ensures that the data review checklist is completed and data are submitted with appropriate codes. All migration, transfer, and conversion of data, as well as data history will accompany his final submission.

Backup/Disaster Recovery – Data files stored on the network servers at Baylor University and TCEQ computer systems are routinely backed up. The data files will be saved to a CD-ROM for distribution and archived. Copies of the field data reporting forms will be maintained at Baylor University for a period of five years as additional insurance against data loss.

Archives/Data Retention - Complete original data sets are archived on permanent media (zip disk or CD-ROM) and retained on-site by Baylor University for a retention period specified in the original QAPP approved by the TCEQ Project Manager.

Information Dissemination - Project updates will be provided to the TMDL Project Manager in quarterly progress reports and the information will be made available at stakeholder meetings. Environmental data collected as part of the project described in this QAPP will be accessible to the general public from the GBEP database once the data has undergone the QA/QC protocol described herein.

APPENDIX E: REFERENCES

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