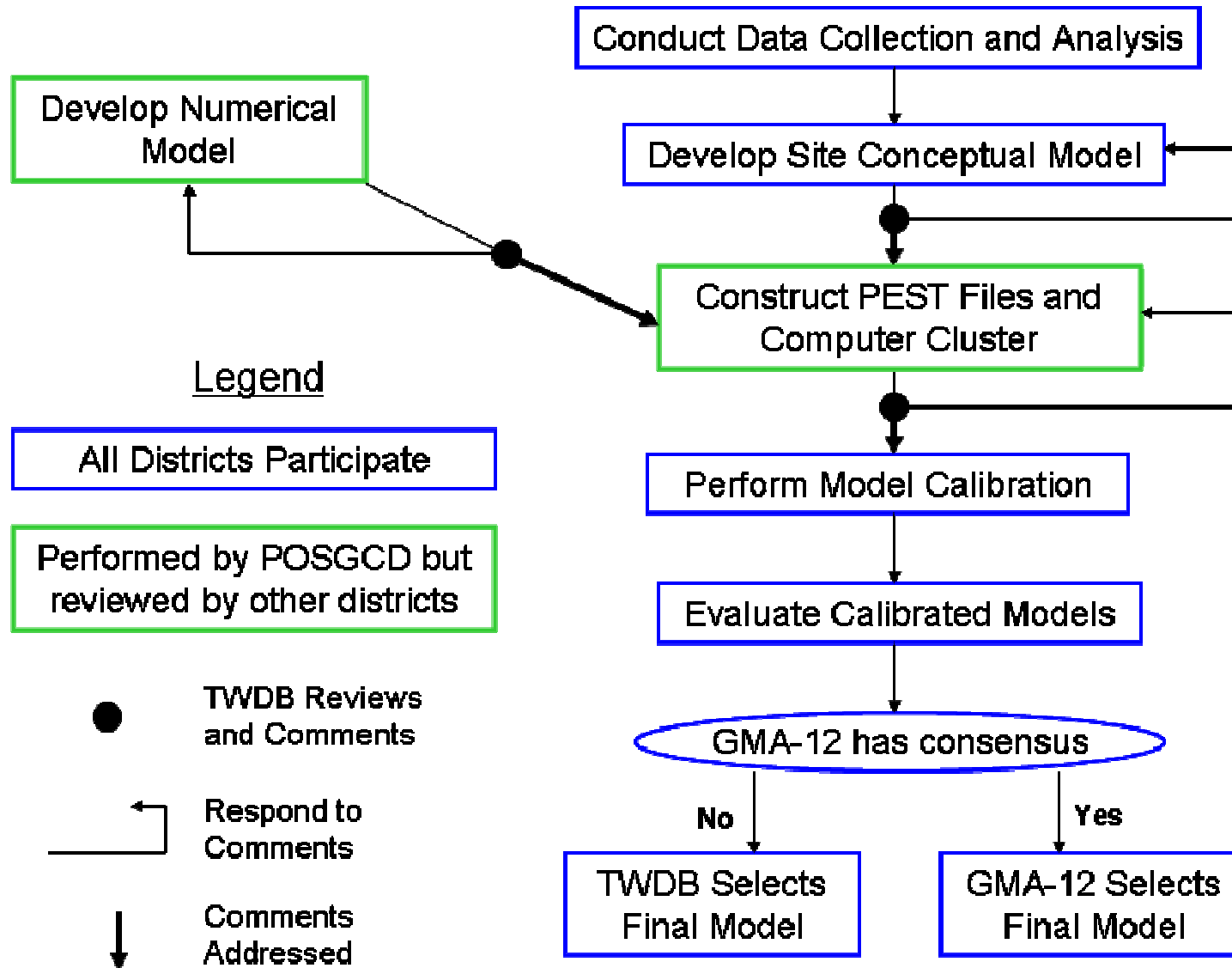


Generalized Flowchart of Proposed Project Activities



Development of Groundwater Model for GMA-12
Using a Participatory Framework
for Data Collection and Model Calibration

Submitted to:



Texas Water Development Board

Submitted by the Member Districts of
Groundwater Management Area 12:

Brazos Valley Groundwater Conservation District
Far West Groundwater Conservation District
Fayette County Conservation District
Lost Pines Groundwater Conservation District
Post Oak Savannah Groundwater Conservation District

October 2009

1. A brief description of the research proposal (not to exceed 1 page).

POSGCD will work with other GMA-12 member districts to update and improve datasets and groundwater models used by GMA-12 districts to manage and develop groundwater resources. The proposed project will focus on developing a single groundwater model for GMA-12 that does the following:

- Includes the Sparta, Queen City, Carrizo, Calvert Bluff, Simsboro, Hooper, Yegua, Jackson, and the Brazos Alluvium Aquifers;
- Incorporates pumping and hydrogeological information assembled by GMA-12 districts for their respective counties and by the Railroad Commission for six coal mines located within the GMA;
- Addresses specific concerns that districts have regarding the current set of GMA-12 models;
- Is developed through a highly transparent process that explicitly documents the assumptions and constraints used to develop a calibrated model; and,
- Is developed using participatory framework that provides each district with the capability and opportunity to help develop the calibrated model.

An innovative aspect of the project is using a computer software called PEST as the basis for the model calibration methodology. PEST is a parameter estimation software that offers capabilities above and beyond conventional trial-and-error methods for matching calibration targets (e.g., water levels and surface water base flows) to model simulated results. PEST also provides an architecture for quantifying uncertainty estimates of the model predictions and a streamlined process for developing calibrated models by multiple developers (i.e., the GMA member districts, TWDB, etc.). PEST uses a single input file that contains the constraints and assumptions used by PEST to estimate a set model parameters for the GAM. This file is called the PEST control file.

After the development of the conceptual model and PEST control file, the districts will be instructed how to investigate different model calibration possibilities independently of each other using the PEST framework. For approximately eight months, the districts will work to develop their own calibrated models and to review those of other districts. At the end of this period, each district will submit their preferred calibrated GMA-12 GAM and associated PEST control file to GMA-12 for consideration. After receipt of calibrated models from each district, GMA-12 will jointly select a final model. If GMA-12 cannot reach a consensus on the final model selection within two months, GMA-12 will ask the TWDB to make the final model selection for the GMA.

2. Explanation of why the research is needed (not to exceed 1 page).

The research described in this proposal is needed to provide GMA-12 districts with a modeling tool that can be used with confidence to help manage and develop groundwater resources. Among the key issues that need to be addressed are:

The Simsboro Aquifer – A majority of the future pumping in GMA-12 will occur across Lee, Burleson, and Brazos Counties in the Simsboro aquifer. Unfortunately, the current Queen City/Sparta GAM model calibration did not include any reported data from various pumping tests or measured water levels from Lee and Burleson Counties and includes relatively little information from Brazos County. Results from this project will provide a model that has been calibrated with an extensive Simsboro dataset that extends across GMA-12 and addresses many of the areas of concerns for the GCDs.

Location of Low-Permeability (or sealing) Faults – The current Queen City/Sparta GAM (Kelley and others, 2004) includes a series of sealing faults that can significantly affect flow in the Carrizo and Simsboro aquifers. Results from sensitivity analysis on GMA-12 model DFC simulations show that the predicted average drawdown in Lee and Burleson Counties changes between 40 and 60 feet if these faults are omitted. However, the GAM report does not provide any evidence that the faults are sealing. Results from this proposed project will be used to investigate the rationale for either maintaining or changing the properties of these faults based on an analysis of hydrogeological information and modeling results.

Groundwater Surface Water Interaction – At the DFC stakeholder meetings for GMA-12 and POSGCD, attendees have expressed concerns about impacts of groundwater pumping on spring and stream flows. To address this concern, the proposed project will evaluate USGS and other studies regarding the Brazos River, the Colorado River, and springs to improve GMA-12 understanding of groundwater-surface water interactions. Among the concerns of the districts is that the vertical grid spacing may need to be more refined at some locations in the GAMs to accurately simulate groundwater-surface water interactions. To address the latter concern, the project will implement an approach for numerically representing the local groundwater system similar to the approach used by the Lower Colorado River Basin model (Young and Kelley, 2007).

Extensive Information Available – A review of GMA-12 GAMs indicates that a significant amount of information is not included in their final calibration. This information includes hydrogeological data from the Wilcox formation at six coal mine sites and the last 10 years of information collected by the districts. As part of the proposed project, the datasets available from the Railroad Commission and the GCDs will be assembled, organized, documented, and used to calibrate the GMA-12 model.

Interaction Among Aquifer Systems – The GMA-12 model will provide the capability to model the flow within several groundwater systems that otherwise would need to be simulated using multiple GAMs. The inclusion of the aquifers into a single model would reduce the complexity and uncertainty associated with predicting how groundwater flow among these aquifers would affect water levels.

3. A detailed scope of work describing each task and a time schedule for each (not to exceed 5 pages).

Table 1 lists nine tasks that comprise the proposed project. For each of the tasks, Table 1 provides a key objective.

Table 1. Project Tasks and their Objectives

Task Name	Key Objective(s)
Task 1. Data Collection and Analysis	Assemble information that can be used to improve GMA-12's ability to accurately predict future groundwater conditions
Task 2. Site Conceptual Model	Document the current understanding of GMA-12's aquifer and establish guidelines for the model calibration
Task 3. Numerical Flow Model	Develop a numerical grid that has the resolution needed and select a groundwater flow code to accurately simulate groundwater flow, recharge, and groundwater interactions with surface water
Task 4. PEST Files and Computer Cluster	Develop a calibration methodology that can be easily executed by modifying a few files, and retain the necessary computer resources to perform the PEST calibration runs in a timely manner
Task 5. Model Calibration	Districts develop their own calibrated models and review those of other districts. GMA-12 or TWDB select the final model
Task 6. Workshops	Explain project findings, solicit feedback from stakeholders, and demonstrate how to calibrate the GMA-12 model using PEST
Task 7. Reports	Document the project findings
Task 8. Project Management	Manage project schedule, budget, and deliverables

The project will last four years. Exhibit 1 gives a timeline for the major activities and milestones. The first 2.5 years the project focuses on developing a numerical model and the PEST methodology for model calibration. The last 1.5 years of the project focuses on making the refinements to the numerical model and performing the model calibrations. The timetable reflects the need to create a working model for use in the next DFC planning process scheduled for September 2015.

A description of each task listed in Table 1 is as follows:

Task 1. Data Collection and Analysis – The overall goal of this task is to collect information for constructing and calibrating the GMA-12 model. During the first project year, GMA-12 districts will assemble hydrogeological and groundwater use information pertinent to the model calibration. The hydrogeologic information will be consolidated into a central GMA-12 database that will contain water level data, water quality data, and

results from pumping test analyses. One of the objectives is to improve the current characterization of the Simsboro aquifer. Currently, most of the districts have an active monitoring program in the Simsboro and have collected pumping test data over the last five years. In addition, the Simsboro is one of the aquifers that is a part of the site characterization studies performed at the six mining sites within GMA-12. Table 2 lists some of the information that is available from the Railroad commission for these mining sites.

Table 2. Summary of Data Available from Six Coal Mine Sites in GMA-12

Data Assessed	Sandow	Three Oaks	Calvert	Twin Oak	Kosse	Jewett
County Location	Milam, Lee and Williamson	Milam, Lee and Bastrop	Robertson	Robertson	Robertson and Limestone	Leon, Limestone and Freestone
Number of Wells	166	77	22	28	42	200-300
Baseline Data Year(s)	1997	1999, 2001	1986, 1993	1986, 2000	1987, 2004	1995 to 2000
Number of Slug/Pump Tests	30	20	7	6	12	40
Model Results	Yes	Yes	Yes	Yes	No	Yes
Groundwater Production Reporting	Annual	Quarterly	Annual	NA	NA	Annual
No. of Monitoring Wells	50	48	30	NA	NA	80
Monitored Locations	Underburden	Overburden/Underburden	Underburden	NA	NA	Overburden/Underburden

Another objective is to investigate how the Karnes-Milano-Mexia-Talco Fault Zone impacts groundwater flow. The investigation will include an analysis of geophysical logs, water level data, water quality data, and pumping test results. A third objective is to estimate groundwater pumping rates across GMA-12 from 2000 to 2009, and to review the TWDB estimates of pumping rates from 1980 to 2000. If appropriate, the project will also assemble water use information relevant to estimating pumping prior to 1980 for the situation in which the model calibration includes a transient simulation prior to 1980.

Task 2. Site Conceptual Model – The major objective of this task is to create a conceptual framework of the groundwater flow system to support the numerical model. The task will be used to review and evaluate site conceptual models developed for the coal mines and for the TWDB GAMs. The GAMs include the Yegua-Jackson aquifer (Deeds and others, in preparation) the Carrizo-Wilcox aquifers (Dutton and others, 2002) and the Sparta -Queen City aquifers (Kelley and others, 2004). In addition, the

tasks will be used to review reports associated with groundwater flow in the alluvium of the Colorado and the Brazos Rivers. This evaluation will provide groundwater contours for each aquifer, a discussion of the geohydrology of each aquifer, and a summary of relevant studies concerning recharge and interaction between surface water and groundwater.

Task 3. Numerical Flow Model – A main objective of this task is to develop a numerical model that has sufficient grid resolution to adequately simulate the local, regional, and deep groundwater flow systems. Without a sufficient level of resolution, inaccurate simulations of groundwater contributions to surface water can occur (Young and others, 2008). A sufficient level of grid resolution will be achieved by using the gridding technique developed by Young and others (2008) for the Lower Colorado River Basin model. This technique involves creating a separate model layer for the shallow aquifer system and assigning elevations for streams and rivers based on elevations extracted from USGS 10-meter digital elevation models or grids from HEC-RAS models of major rivers. A second major objective is to develop a numerical model that can provide a robust and stable solution to the rewetting of dry cells and thereby overcome the convergence and accuracy problems that can plague MODFLOW96 (Harbaugh and MacDonald, 1996). The second objective will be achieved by using a version of MODFLOW 2005 (Panday, personal conversation) that has been developed using the type of pseudo-soil function to help the numerical solution converge to a water table location.

Task 4. PEST Files and High Performance Computer Cluster – The major objective of this task is to develop a calibration methodology that is transparent and can be easily executed by each district. To accomplish this objective, the project will use PEST to calibrate the model. PEST is a parameter estimation software that can be used with MODFLOW to perform model calibration. PEST achieves model calibration by performing numerous model simulations and tracking how changes in the input parameters affect the model calibration. Demonstrations of PEST's ability to calibrate regional groundwater models that surpass the TWDB calibration standards for GAMs is demonstrated by the work of Young and others (2008) in the Gulf Coast aquifer and by Young and others (2009) in the Edwards-Trinity Plateau and Pecos Valley aquifers.

Although considerable expertise and effort is required to set up the PEST files, the instructions for the final model calibration run are contained within a single PEST control file. Among the important instructions in the PEST control file are the constraints placed on the model input parameters and the selection of the calibration targets. Thus, after the PEST files are created, the different model calibrations can be investigated by anyone who is capable of modifying the PEST control file and running PEST.

Because numerous model simulations will be required as part of the model calibration process, the project requires options for distributing a PEST run over multiple computers so that a calibration run can be completed in several days or less. To perform some of the larger PEST calibration runs, a computer cluster will be built for the project and options will be investigated to purchase computer computational time over the internet or from an existing computer cluster.

Task 5. Model Calibration – A major objective of this task is to have all districts actively engage in the modeling calibration process to the extent that is beneficial for achieving consensus on selecting a final model calibration. The model calibration task begins after a working set of PEST files have been generated and thoroughly tested on a high performance computer cluster. At that time, a workshop will be held to instruct the other districts on how to run a PEST calibration. To augment the time the districts will have to run PEST calibration, the project will seek to find options for running the PEST calibration over the internet in addition to running it on the project’s computer cluster. Approximately eight months will be allocated for the districts to develop their preferred calibrated model. During this period, the districts will meet at least every two months to discuss progress and comment on the most current set of calibrated models. At the end of the eight-month period, each district will submit their preferred calibrated model and associated PEST control file to GMA-12 for consideration for the final GMA-12 model. If after two-months, GMA-12 cannot develop a consensus on the final model, then the TWDB will be ask to make the final decision.

Task 6. Workshops – A major objective of this task is provide a public forum where individuals and groups can monitor and provide feedback regarding the development and calibration of the GMA-12 model. At least one major workshop will be held each year. The workshops will be coordinated with the TWDB and be conducted according to the rules governing the stakeholder forums for the GAM program.

Task 7. Reports – A list of anticipated reports is provided in Section 13.

Task 8. Project Management – The project will be administrated by POSGCD. The project manager will be Gary Westbrook. Mr. Westbrook will delegate tasks to the other districts as appropriate. The districts will in turn work with their consultants to perform the work.

Exhibit 1. Major task activities for the first three years

	Year 1	Year 2	Year 3
Task 1. Data Collection And Analysis	<ul style="list-style-type: none"> • Estimate pumping rates for 2000 to 2009 • Assemble and evaluate water levels, water quality data, and aquifer test results • Assemble historical information on spring, lakes, and streams • Identify faults that merit further characterization 	<ul style="list-style-type: none"> • Assemble and evaluate geophysical logs for water quality, faults offset, and sand percentages for selected aquifers • Estimate historical pumping prior to 1980 and after 2000 • Review TWDB pumping estimate from 1980 to 2000 • Develop estimates for pumping prior to 1980 • Finalize pumping files from 1980 to 2009 	<ul style="list-style-type: none"> • Continue assembling and evaluating aquifer information • Revisit pumping estimates, if needed
Task 2. Site Conceptual Model	<ul style="list-style-type: none"> • Review existing RRC and TWDB reports regarding site conceptual models and aquifer properties • Review information regarding groundwater-surface water interaction and recharge • Review Brazos alluvium study 	<ul style="list-style-type: none"> • Revise characterization of faults, aquifer properties, and water quality • Develop a site conceptual model • Update representation of faults, aquifer properties and boundaries 	<ul style="list-style-type: none"> • Finalize site conceptual model
Task 3. Numerical Flow Model	<ul style="list-style-type: none"> • Estimate land topography and river bottom elevations • Construct surface layer model (layer 1) based on stream information • Develop model grid to combine Brazos Alluvium, Yegua/ Jackson, and Queen City/ Sparta/Carrizo/Simsboro deposits 	<ul style="list-style-type: none"> • Select final MODFLOW code • Finalize numerical grid to account for estimates of updip and downdip location • Enhance algorithms to generate aquifer properties and recharge based on site conceptual model and pilot points 	<ul style="list-style-type: none"> • Update model files to insure consistency with the site conceptual model

	<ul style="list-style-type: none"> • Evaluate MODFLOW 2005 capability for rewetting of grid cell 		
Task 4. PEST Files and High Performance Computer Cluster	<ul style="list-style-type: none"> • Investigate options for constructing computer cluster and buying computer time on-line • Develop a simple set of PEST files file for 1980 to 2000 to benchmark model runs 	<ul style="list-style-type: none"> • Develop a comprehensive set of PEST files to construct and calibrate a model run from 1980 to 2010 • Select preliminary calibration targets • Construct computer cluster for GMA-12 • Benchmark preliminary PEST runs 	<ul style="list-style-type: none"> • Develop final set of PEST calibration targets • Finalize and implement strategy for supporting PEST runs by different districts
Task 5. Model Calibration	No Work Planned	No Work Planned	<ul style="list-style-type: none"> • Submit a set of PEST files to TWDB for review
Task 6. Workshops	<ul style="list-style-type: none"> • Introduce project goals and approach 	<ul style="list-style-type: none"> • Present results from data collection and analysis and current site conceptual model • Explain and demonstrate a PEST calibration simulation 	<ul style="list-style-type: none"> • Develop a calibrated GMA-12 model using PEST
Task 7. Reports		<ul style="list-style-type: none"> • Submit a final data report 	<ul style="list-style-type: none"> • Submit a final site conceptual report
Task 8. Program Management	<ul style="list-style-type: none"> • Conduct kickoff meeting with TWDB • Set up initial contracts • Conduct district meetings 	<ul style="list-style-type: none"> • Conduct semi-annual TWDB meetings • Conduct district meetings 	<ul style="list-style-type: none"> • Conduct semi-annual TWDB meetings • Conduct district meetings

4. A list of products (reports, plans, or other products) that the Board will receive as a result of this research

Table 3 lists the deliverables by year.

Table 3. List of Deliverable by Year

Year	Deliverable
Year 1	No Deliverables
Year 2	<ul style="list-style-type: none">• Draft Data Report• Final Data Report• Draft Conceptual Model Report
Year 3	<ul style="list-style-type: none">• Final Conceptual Model Report• Draft PEST Application Report
Year 4	<ul style="list-style-type: none">• Final PEST Application Report• Draft GMA-12 Model Report• Final GMA-12 Model Report• Updated Data Report• GMA-12 Model Files