FUNDING OPPORTUNITY for CL BBASC CYCLE 2

To Improve the Groundwater Availability Model for the Carrizo-Wilcox Aquifer in Central Texas to include a robust groundwater-surface water package

A. Colorado Lavaca Basin BBASC Work Plan: Groundwater-Surface Water Tasks

Environmental Stewardship and INTERA believe that the improvement projects described in B. below facilitate the initial phase of work described in the main task and priority task #3. To understand and model the relationships between groundwater and surface water the models used need to be adequately designed to meet that objective. The Gulf Coast model was improved during the LCRA-SAWS project. This is an opportunity to update the Central Carrizo-Wilcox model.

WORK PLAN (See Tables 1 and 2):

Main Task: Describe relationships between groundwater and stream flow (Table 2 of Work Plan): This may require creation of long-term groundwater monitoring locations combined with special studies analyzing relationships between groundwater levels, stream flows, groundwater withdrawals, land cover/use patterns, and meteorological conditions for specific streams. Monitoring should be designed to last preferably until at least 2071. Special studies analyzing relationships between groundwater levels, stream flows, and groundwater withdrawals, combined with a review of monitoring data should be conducted every 10 years. These studies should be conducted on a minimum of two representative watersheds in each of the upper Colorado and Lavaca-Navidad river basins and on at least one watershed in the lower Colorado basin. Lack of rainfall monitoring in specific areas combined with inadequate information about runoff rates, plant uptake rates, and interception of runoff before it infiltrates the ground will complicate this analysis. Coordinating Agency: TWDB.

- Priority Task #3 (Table 1): **Determine relationships between groundwater withdrawals from the Carrizo-Wilcox and the Gulf Coast aquifers, and flows to rivers** (estimated at $300,000 to $400,000). These studies would start as desk-top analysis but additional field work should be conducted if more data are needed. *These studies should be conducted on tributaries in addition to the main rivers or streams. Studies should be designed to help provide data suitable for use in both WAM and GAM modeling efforts, including efforts to understand historical and current relationships and to facilitate predictions of future relationships.*
- Priority Task #6 (Table 1): **Determine how groundwater development activities, as listed in the then current State and relevant Regional Water Plans, might influence river flows and the physical and hydrologic connections between surface and groundwater** (estimated at $50,000).

B. GMA-12 GAM Improvements

Environmental Stewardship and INTERA are requesting funding to accomplish Proposal 1 option 1a or 1b and Proposal 2 which are incremental to the GW-SW basic package and would enable the development of a robust groundwater-surface water component in the GMA-12 Groundwater Availability Model (GAM) as a part of the TWDB and INTERA contract.

Budget:			
	Fault Development	$520,000	Funded by TWDB & GCDs
	GW-SW basic package	$200,000	Funded by GCDs, LCRA & BRA
	Proposal 1a - River Grids Only	$ 30,000	Request CL BBASC (Cycle 2)
	Proposal 1b - River + Tribs Grids	$ 50,000	Request CL BBASC (Cycle 2)
	Proposal 2 - Paired Gages-Wells	$ 10,000	Request CL BBASC (Cycle 2)

Proposal 1:
Improve the Central Queen-City/Sparta/Carrizo/Wilcox (QCSPCZWX) Groundwater Availability Model Ability to Simulate Groundwater-Surface Water Interaction

Background: The Central Sparta-Queen City-Carrizo-Wilcox Groundwater Availability Model (GAM) includes the Simsboro aquifer formation in Groundwater Management Area 12 which is projected to become a major water supply aquifer for Central Texas and the I-35 corridor. The GAM simulates the interactions of the Carrizo-Wilcox aquifer with the Queen City and the Sparta aquifers during the period from 1975 to 1999. Among the concerns with the predictive accuracy of the GAM is that limited aquifer test data from all aquifers and very limited water level data from the Simsboro aquifer in Lee and Burleson counties were used to develop the GAM. In addition, the GAM was developed using a simplified approach to simulate the impact of the Mexia-Talco fault zone on groundwater flow and the interaction between groundwater and surface water flow.

In August 2015, the TWDB hired INTERA to update the Central QCSPCZWX Model (GAM). INTERA scope-of-work includes:

- Improve the historical estimate of pumping in GMA 12 from pre-pumping conditions to 2010
- Assemble and analyze the large amount of aquifer pumping test data that has been performed in GMA 12 to determine the hydraulic properties of the aquifer formations and the impacts of geological faults on groundwater flow conditions
- Assemble and analyze the water level information from 1900 to 2010 with an emphasis of large-scale pumping tests to help evaluate the location and impacts of geological faults on groundwater flow
- Assemble and analyze geophysical well logs to help evaluate the location and impacts of the geological faults and the regions of thick sand units on groundwater flow
- Assemble and analyze well pumping information from GMA 12 from 1900 to 2010
- Develop a steady-state condition for the GAM that represents pre-pumping condition where no pumping occurred from the aquifer and the simulated water levels represents conditions where

Because of their limited funding, the TWDB did not fund a task to improve the GAM's capability to simulate groundwater-surface water interaction despite the fact that the GAM is known to contain potentially significant error in predicting the exchange of water between the major rivers and the underlying aquifers they intersect. As a result of this concern, several GCDs, the LCRA, and the BRA has committed $200,000 to improve the GW-SW capability. For this work, INTERA will implement a similar type of grid cell refinement and model calibration used to develop the Lower Colorado River Basin Model in Wharton, Colorado, and Matagorda counties.

One reason the LCRB model was developed is because the GMA 15 GAM used by the GCDs to guide the groundwater management does not accurately simulate model groundwater-surface water interaction. Among the known limitations of the GMA 15 GAM and most other GAMs is that they lack the vertical resolution in the model layers to represent a shallow groundwater flow zone. To develop a groundwater flow zone in the LCRB model, the LCRB modelers added model layers near the ground surface and decreased the size of the grid cells near the rivers to allow the model to better simulate shallow groundwater flow near the rivers. The approach used by the LCRB modelers to improve simulation of groundwater-surface water interaction has been documented in conferences and peer-reviewed articles. Figure 1 and 2 summarizes the significant

differences in predicted GW-SW interaction between the GMA 15 GAM and the LCRB model. Based on current funding for the SW-GW improvement, the following work will be completed:

- Convert the GMA 12 GAM from a MODFLOW 96 model to a MODFLOW-USG model so that localize grid refinement around rivers and tributaries can be done more efficiently
- Add a shallow layer to the model to represent the shallow flow zone as done in the LCRB model
- Refine the grid cells containing the Colorado and Brazos River and the tributaries of the two rives from a 1-mile grid to a 0.5-mile grid

Proposed Work. There are two proposals provided that will improve the Central QCSPCZWX GAM to better simulate GW-SW interaction in the Colorado River Basin. The two options are are called: Options 1a and Option 1b.

Proposal Option 1a: The proposed project will improve the simulation of GW-SW interaction along the Colorado River. The project will accomplish this objective by performing the following four tasks;

1.) Reduce the grid cell spacing from 0.5-miles to 0.25-miles for the grid cells representing the Colorado River. .
2.) Perform a literature search on hydrogeological studies for the Colorado alluvium and estimate transmissive and storage properties of the Colorado alluvium
3.) Represent the Colorado alluvium as a separate model layer in the GMA 12 GAM model
4.) Meet with the Colorado-Lavaca BBASC group at least one every six months to provide an update on model and to address questions related to SW-GW interaction

The cost for Proposal Option 1a is $30,000.

Proposed Work (Option 1b): The proposed project will improve the simulation of GW-SW interaction along the Colorado River and the tributaries of the Colorado River. The project will accomplish this objective by performing the following five tasks;

1.) Add an additional shallow layer to the GMA 12 GAM
2.) Reduce the grid cell spacing from 0.5-miles to 0.25-miles for the grid cells representing the Colorado River and the tributaries of the Colorado River. .
3.) Perform a literature search on hydrogeological studies for the Colorado alluvium and estimate transmissive and storage properties of the Colorado alluvium
4.) Represent the Colorado alluvium as a separate model layer in the GMA 12 GAM model
5.) Meet with the Colorado-Lavaca BBASC group at least one every six months to provide an update on model and to address questions related to SW-GW interaction

The proposed work will provide the GMA 12 GAM with a capability to simulate GW-SW interaction at the same level, if not better, than the LCRB model. The cost for Proposal Option 1b is $50,000.

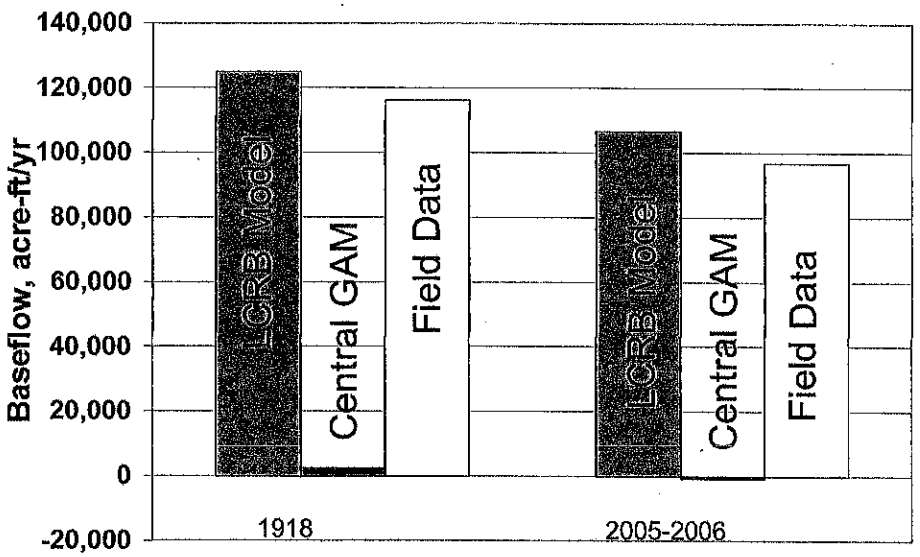

Figure 1 Comparison of predicted groundwater contribution to surface water baseline by the LCRAB model and GMA 15 GAM (Central GAM) to measured baseflow calculated from field data (stream gain-loss studies)

	Sources of Groundwater For Pumping for Wharton, Colorado, & Matagorda Counties from 1980 to 1999			
	Recharge	Storage	Inflow from Adjacent Counties	Leakage from Surface Water
Central GAM	0%	13%	12%	75%
LCRB Model	66%	28%	7%	0%

Figure 2 Comparison of predicted sources of groundwater that supplied pumping for Wharton, Colorado, and Matagorda Counties from the LCRB model and the GMA 15 GAM (Central GAM)

Proposal 2:
Development of a Work plan to Install Paired Surface Water Gage and Groundwater Well to Estimate GW-SW Interaction and to Quantity the Effects of Bank Flow on Hydrograph Analysis

Background: In Texas there is relatively little field data regarding the interaction of stream flow and groundwater. The most common type of data is gain-loss studies but these are difficult to perform and to analyze because of the difficulty with properly accounting for unsteady flow effects, losses to diversions, and return flows. As a result, of the few gain-loss studies that have been done, there are only a few of them that contain all of the data and appropriate analysis to provide reliable findings. In addition, the findings from these studies may be limited to the environmental conditions under which the study was performed. Another potentially useful type of GW-SW interaction information is from paired stream gages and groundwater wells. This type of information (see Figures 1 and 2) was collected on the Colorado River as part of the LCRA-SAWS Water Project. The hydrographs in Figure 1 show a dynamic GW-SW interaction with strongly correlated water elevation in both the groundwater well and the surface water gage. Preliminary analyses suggest that this type of data would provide useful insight into possible biases in commonly accepted approaches for calculating groundwater baseflow from river gage hydrographs. However, no work was done on quantifying these biases before the LCRA-SAWS Water Project was terminated.

Proposal 2: The proposal is to develop a work plan for collection, analyzing, and modeling water elevation data at paired groundwater wells and surface water gages at four location on the Colorado River and tributaries to the Colorado River. At each groundwater well and surface water gage, not only will water elevation be continuously collected but total dissolved solids (TDS) concentrations and temperature will also be continuously collected. The analysis will evaluate methods for performing hydrograph separation for estimating groundwater baseflow and identify potential biases/errors and approaches for correcting those biases/errors. The proposed analysis will include groundwater modeling and will be based on a review of the literature related to applications of groundwater and surface water modeling to determine baseflow and groundwater-surface exchange . INTERA staff will meet with BBASC committee prior to the start of the work to clarify work plan objectives and the amount of anticipate funding for a multi-year study. The work plan will provide the following:

- Evaluation of multiple river gage sites on the Colorado River and tributaries for placing one or more groundwater wells adjacent to an existing river gage
- Selection of the top four locations within the GMA 12 area (Bastrop and Fayette counties and could include tributaries) for pairing a river gage with a groundwater well(s)
- Proposed data collection approach
- Estimated costs for drilling and instrumenting the groundwater wells
- Proposed approach for performing hydrograph separation for estimating groundwater baseflow and identify potential biases/errors and approaches for correcting those biases/errors. This approach will use measurements of TDS concentrations, elevations, and temperature.
- Options for joint funding for the project.

The cost for performing Proposal 2 is $10,000.

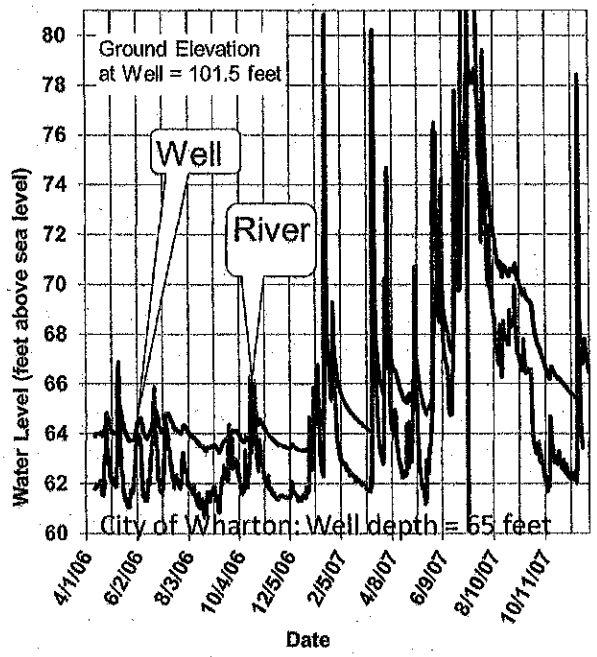

Figure 1 Comparisons of water elevation in a paired shallow groundwater well and a Colorado river gage near the City of Wharton

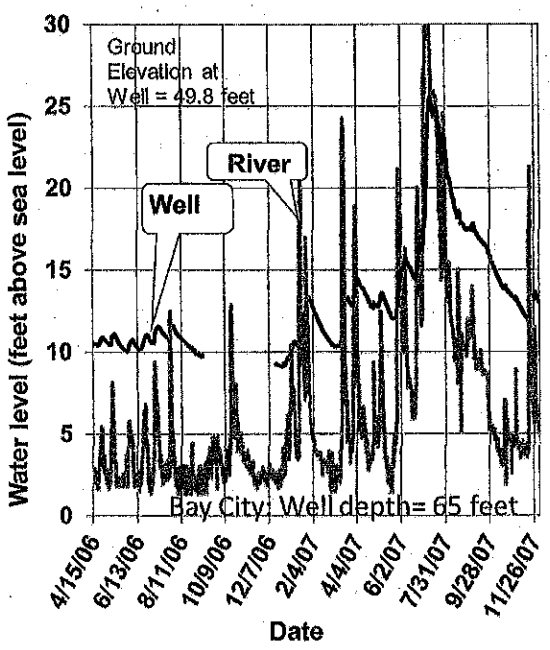

Figure 2 Comparison of water elevations in a paired shallow groundwater well and a Colorado river gage near the Bay City