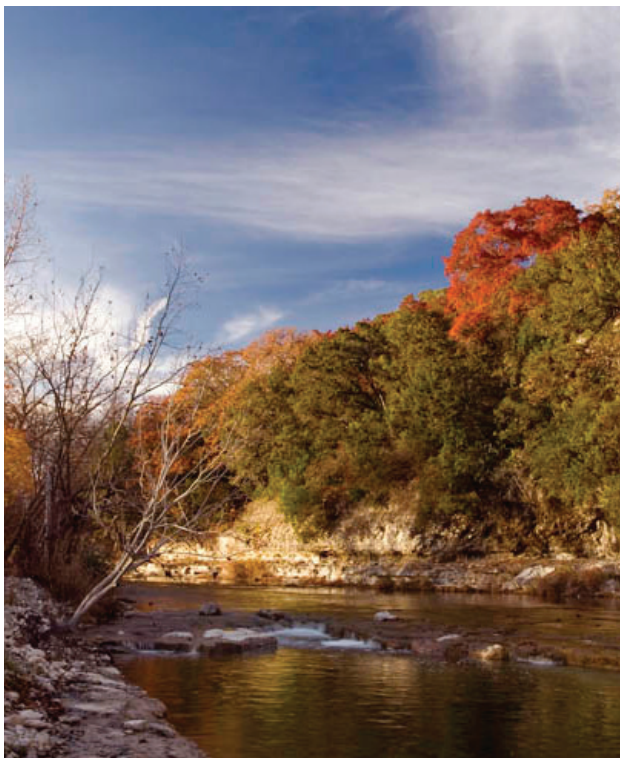
Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Area Stakeholders Committee

Work Plan for Adaptive Management



May 25, 2012

Guadalupe, San Antonio, Mission, & Aransas Rivers and
Mission, Copano, Aransas, & San Antonio Bays
Basin & Bay Area Stakeholders Committee (GSA BBASC)

Work Plan for Adaptive Management

Preliminary Scopes of Work
May 25, 2012

May 10, 2012

The Honorable Troy Fraser, Co-Presiding Officer
The Honorable Allan Ritter, Co-Presiding Officer
Environmental Flows Advisory Group (EFAG)

Mr. Zak Covar, Executive Director
Texas Commission on Environmental Quality (TCEQ)

Dear Chairman Fraser, Chairman Ritter and Mr. Covar:

Please accept this submittal of the Work Plan for Adaptive Management (Work Plan) from the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas and San Antonio Bays Basin and Bay Area Stakeholders Committee (BBASC). The BBASC has offered a comprehensive list of study efforts and activities that will provide additional information for future environmental flow rulemaking as well as expand knowledge on the ecosystems of the rivers and bays within our basin.

The BBASC Work Plan is prioritized in three tiers, with the Tier 1 recommendations listed in specific priority order. Study efforts and activities listed in Tier 2 are presented as a higher priority than those items listed in Tier 3; however, within the two tiers the efforts are not prioritized. The BBASC preferred to present prioritization in this manner to highlight the studies and activities it identified as most important in the immediate term without discouraging potential sponsoring or funding entities interested in advancing efforts within the other tiers.

As you review the plan, notice the prioritized Tier 1 efforts recommended by the GSA BBASC address specific information and data gaps that were recognized by both the BBASC and the Basin and Bay Expert Science Team (BBEST) in the previously submitted environmental flow recommendation reports. The BBASC has identified as its top priority in the Work Plan the completion of an Instream Flow study (in accordance with the SB2 Instream Flow guidelines) for the Lower Guadalupe River. The committee identified the lack of site specific biological information linked to historical flow data on the Guadalupe River as a significant limitation in the development of environmental flow recommendations for the Guadalupe River. In addition, the committee recommended two additional flow gages—one on the San Antonio River and one on the Guadalupe. The committee recommended conducting a synoptic flow study before finalizing the location of a new gage below Victoria on the Guadalupe River. The committee also prioritized studies within the bay and estuary system that will advance the level of scientific information on rangia clams; life cycle of key faunal species, particularly some of the mobile species like white shrimp and blue crab; and additional salinity studies to obtain information to better correlate freshwater inflow to salinity throughout the bay and estuary system.

The BBASC chose to devote a section of the Work Plan to addressing the importance of the Potential Strategies to Meet Environmental Flow standards as presented in Section 6 of its Environmental Flow Recommendation Report. Several of the recommended Work Plan elements will provide additional data and information to assess the application and benefit of specific strategies. The BBASC is acutely aware that new ideas and innovative approaches to allocation and management of water resources must be explored to balance diverse water uses and needs within the basin.

An obstacle that can't be overstated is the lack of funding to advance the body of science on the rivers and bay systems. We encourage the State of Texas to prioritize funding for the scientific studies and

activities presented in this Work Plan. As the state's population continues to grow, we are very aware that all natural resources will be stressed. It is important to have sound scientific data to assess and understand the benefits and detriments of each decision that is made. The State of Texas, river authorities and other natural resource managers are limited as stewards of these resources without access to thorough information and scientific data from which to evaluate decisions. The State of Texas continues to look at funding strategies to meet future water supply needs; we ask that as these discussions progress the State consider funding mechanisms to support the recommendation within this Work Plan. Funding will be critical to ensure that decisions related to the management of limited water supplies have the best available information to sustain the future well-being of the economy and natural resources of the State of Texas.

Lastly, the BBASC recommended a five-year review cycle for the environmental flow standards for this bay and basin area. In Section 2 of the report, we used our experience during this initial process to offer ideas for improving the timeline and effectiveness of the process for the next review cycle.

As the leadership of the BBASC, we make ourselves available to answer questions or provide more information on the recommendations within this Work Plan for Adaptive Management.

Respectfully submitted,

Suzanne B. Scott
GSA BBASC Chair

Dianne Wassenich
GSA BBASC Vice-Chair

Table of Contents

BBASC Tier 1 Work Plan Recommendations

Priority	Pg #	Study Name	Notes
1	10	Instream Flows - SB2 TIFP Guadalupe Study	
2	13	Instream Flows - Streamflow Gaging and Synoptic Flow Study	
2a	13	USGS Streamflow Gaging and Water Quality Monitoring	The gage location below Victoria is dependent upon the Synoptic Flow Study (2b)
2b	15	Synoptic Flow Measurements to Estimate Freshwater Inflow and Applicability of Lower River Gaging Stations	
3	16	Bays & Estuaries - *Rangia* Clam Investigations	
4	17	Bays & Estuaries - Life Cycle Habitat & Salinity Studies for Key Faunal Species	
5	19	Bays & Estuaries - Hydrodynamic & Salinity Model Improvements	Hydrodynamic & Salinity Model Improvements Study is dependent upon Synoptic Flow Study (2b)
6	20	Instream Flows - Full Accounting of Surface Water	

BBASC Tier 2 Work Plan Recommendations

***Disclaimer: Studies listed are grouped by type of study, not in any prioritized order**

	Pg #	
	23	Instream Flows - Riparian Assessment and Monitoring
	25	Instream Flows - Biological Sampling and Monitoring
	27	Instream Flows - Geomorphic Studies and Monitoring
	31	Bays & Estuaries - The Distribution and Abundance of Marsh Vegetation in Relation to Salinity and Elevation in the Guadalupe Estuary Delta
	33	Bays & Estuaries - Habitat Suitability Models for Eastern Oysters, Blue Crabs & White Shrimp
	34	Bays & Estuaries - Development of an Inundation and Salinity Model of the Guadalupe Estuary Lower Delta and Adjacent Bays

BBASC Tier 3 Work Plan Recommendations

***Disclaimer: Studies listed are grouped by type of study, not in any prioritized order**

	Pg #	
	36	Instream Flows - Groundwater Studies
	38	Instream Flows - Water Quality Monitoring
	41	Instream Flows - Invasives
	42	Bays & Estuaries - Nutrient Load & Concentration Monitoring
	43	Bays & Estuaries - Role of Cedar Bayou in the Exchange of Water and Meroplankton to the Guadalupe Estuary
	44	Bays & Estuaries - Evaluation of Sediment Transport Affecting the Guadalupe Estuary Delta
	46	Bays & Estuaries - Sea Level Rise Associated with Climate Change

Section 1 Legislative Mandate

Pursuant to SB3 of the 80th Texas Legislature the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Area Stakeholders Committee (GSA BBASC) was charged with development of a Work Plan to be submitted to the Environmental Flows Advisory Group (EFAG) for approval.

Section 11.02362(p) In recognition of the importance of adaptive management, after submitting its recommendations regarding environmental flow standards and strategies to meet the environmental flow standards to the commission, each basin and bay area stakeholders committee, with the assistance of the pertinent basin and bay expert science team, shall prepare and submit for approval by the advisory group a work plan. The work plan must:

(1) establish a periodic review of the basin and bay environmental flow analyses and environmental flow regime recommendations, environmental flow standards, and strategies, to occur at least once every 10 years;

(2) prescribe specific monitoring, studies, and activities; and

(3) establish a schedule for continuing the validation or refinement of the basin and bay environmental flow analyses and environmental flow regime recommendations, the environmental flow standards adopted by the commission, and the strategies to achieve those standards.

Section 2 GSA BBASC Recommended Timeline for Review of Standards and Standards Update and Review Recommendations

The GSA BBASC recommends a five year periodic review cycle as opposed to the default ten year review identified in SB3 for the review of the basin and bay environmental flow analysis and environmental flow regime recommendations, the environmental flow standards and BBASC recommended strategies. Further, the GSA BBASC recommends maintaining the same five year cycle for addressing the "validation or refinement of the basin and bay environmental flow analyses and environmental flow regime recommendations, the environmental flow standards adopted by the commission, and the strategies to achieve those standards." The tolling of the five year review clock shall commence upon the date the TCEQ formally adopts the environmental flow standards for this basin. This Work Plan was created and prioritized based upon the assumption TCEQ will adopt the GSA BBASCs recommendation to review the rulemaking process on a five year cycle.

During the GSA BBASC's deliberations over the Work Plan elements, the committee developed additional recommendations to improve the environmental flows recommendation process as it progresses to the review and update phase. The GSA BBASC recommends clearly defining the continuing technical advisory role of the BBESTs and adequately funding the BBESTs' continued support of the BBASCs during the required review processes. As future BBASCs are appointed, and as current

committees need to name new members to their BBESTs, the GSA BBASC recommends BBASCs consider the professional expertise of their BBEST teams, taking into consideration whether they have an appropriate balance of water resource engineers and academics. Lastly, the GSA BBASC recommends enhanced integration of the Texas Commission on Environmental Quality (TCEQ) Water Availability Department during the BBASC recommendation deliberations.

As BBASCs enter into the adaptive management phase of the environmental flows process, they will require their associated BBEST's scientific expertise and professional judgment. To our knowledge, BBESTs have not been funded beyond the initial round of recommendations. As the continued involvement of the BBESTs is critical to the success of the environmental flows process, the State should appropriately fund their participation to ensure the stakeholder groups and State agencies continue to receive the best available science as called for in the SB3 legislation. The GSA BBASC respectfully requests the 83rd Legislature address the funding needs of the environmental flows process to ensure the continued support of the appointed Basin and Bay Expert Science Teams.

The GSA BBASC also recommends that TCEQ, as the State's surface water permitting agency, should more actively support and participate in the BBEST and BBASC deliberations. Where the GSA BBASC and BBEST utilized present conditions and gage data to develop their recommendations, the TCEQ exclusively used WAM Run 3 to develop their proposed standards. These differences in methodology have led to confusion and dissatisfaction among stakeholders regarding how the proposed TCEQ standards were developed. To avoid similar situations in the future, the GSA BBASC recommends there be agreement on the models, technical tools, assumptions and data to be used for developing future standards prior to the BBEST, BBASC, and TCEQ staff entering into the first adaptive management and standards review phase. Additionally, the GSA BBASC recommends TCEQ conduct a workshop with the BBEST and BBASC during its technical analysis, thereby allowing all parties that have been intimately engaged in the environmental flows process to foster communication and support clearer understanding of the multiple layers of recommendations. The GSA BBASC believes the above outlined measures will improve communication and technical understanding by the stakeholders, which will benefit the environmental flows program in the future.

Section 3 Strategies to Meet Environmental Flow Standards; Identification, Quantification, Implementation and Measurement

In addition to requiring that each bay and basin area stakeholder committee develop recommendations for environmental flow standards, SB3 also mandates that each committee recommend strategies to meet these standards. In this context, "strategies" refers to the various ways the water needed to fulfill these recommended environmental flow protection standards could be made available for that purpose.

While the flow standards are only applicable to new water rights issued in the basin, "strategies" are distinct in that they have the potential to address environmental flow challenges that may already exist due to existing water use permits. The GSA BBEST report recognized that, based on the available science, with a few noted exceptions, a sound ecological environment exists in these rivers, bays and estuaries today. However, during the GSA BBASC deliberations, GSA BBEST members presented additional analysis regarding the potential impact that full utilization of existing water rights could have on flows. The additional information raised concerns among GSA BBASC members that the "sound ecological environment" found today could change, particularly during lower flow times of the year, as existing water rights are more fully utilized. For this reason, the identification, quantification and implementation of strategies to meet environmental flow standards is of particular interest to the GSA BBASC.

It is recognized that a robust effort to pursue strategies to meet environmental flow protection goals offers those within the watershed a unique opportunity to work collaboratively towards the goal of protecting a sound ecological environment while also meeting human water supply needs. For example, one piece of the stakeholder recommendations includes a dedication of the equivalent of 10 percent of the firm yield of a new water supply permit to the bay and estuary system. Because new permit-holders are able to provide the 10 percent dedication by implementation of strategies, there is significant flexibility in how this requirement can be met and can therefore catalyze creative solutions.

The GSA BBASC included a list of voluntary strategies in their Recommendations Report (see Strategy Options for Achieving Environmental Flow Standards listed below) as well as some initial work to quantify the potential of three of those strategies. Although this is a start, there is much more work that needs to be done in order to better understand which strategies might be most effective in helping to meet the environmental flow standards. For the next phase, a more extensive effort to determine, on a site-specific basis, which strategies can effectively be used to fulfill which parts of the flow regime recommendations is needed.

This next phase needs to include several steps:

1) Identifying potential strategies for evaluation to determine their ability to help meet the environmental flow standards,
2) Developing detailed plans for evaluating these strategies,
3) Performing evaluations to quantify the effects of identified strategies,
4) Preparing recommendations of strategies that should be pursued,
5) Working to implement recommended strategies, and
6) Performing measurements of strategies implementation

Data and Tools Needed for Achieving Environmental Flow Standards

In section 4.4 of the GSA BBASC Environmental Flows Recommendations Report, there are several items identified that will be critical in validating or refining the environmental flows standards and that pertain to the evaluation and implementation of strategies to meet the standards. These include:

• Data review and analysis - It is recommended that all relevant hydrological (surface water and groundwater), biological (instream and riparian), water quality, and geomorphologic data be collected and reviewed to the extent possible during each SB3 review cycle. This supplemental data could prove valuable when determining whether SB3 surface water environmental standards and rules are achievable as implemented. Additionally, this information could serve an important role in guiding any potential modifications to ongoing SB3 studies and monitoring.

• Evaluate additional support and funding for TCEQ South Texas Water Master Program

• Evaluate and advise on web-based technology to facilitate compliance with environmental flow permit conditions.

- **Secure agreement from TCEQ to perform a full accounting of all existing surface water use within the basin to allow for more accurate model projections of current and future water needs**
  - A more accurate accounting of actual surface water use, including an estimation of riparian and domestic and livestock (D&L) use will improve data used for water availability models while providing information to determine if existing water rights could be voluntarily repurposed to assist in meeting flow standards.
- **Improve access to and management of historical TCEQ data on wastewater return flows in order to improve understanding of the role wastewater return flows have in providing flows for environmental purposes**
- **Explore the addition of stream gages in the lower basin to increase data to more accurately measure the contribution of river flows to the bay and estuary system**
- **Update the Guadalupe – San Antonio Water Availability Model (GSA WAM) used by TCEQ for permitting**
  - The current period of record for the GSA WAM is 1934 through 1989 (56 years). The exclusion of the most recent 22 years of data in the model causes credibility issues with the data because many of the recent high flow and drought events are not included in the model. Furthermore, a longer period of record would provide more complete data for the next round of GSA BBASC Recommendations regarding the attainment frequencies associated with the Environmental Flow Standards Recommendations for the Guadalupe and Mission-Aransas Estuaries (Section 4.2).

<u>Strategy Options for Achieving Environmental Flow Standards</u>

- **Explore the donation, sale or lease of new or under-utilized water permits**
  - Willing water permit holders donate, sell or lease all or part of their permit so that water could stay in the stream for environmental flow protection. Permit would be changed to add instream and/or bay and estuary use. To be most effective, these permits would need to be firm water that is fairly senior.

- Use of a water trust can be helpful for keeping track of water dedicated for environmental flow purposes.

- **Dedication of wastewater return flows**
  - Dedication of permitted wastewater return flow toward environmental flow needs. The wastewater could be generated by a new permitted project, an existing project or through agreement or voluntary commitment of wastewater generated by a municipality. Water quality should be considered.

- **Dry Year Option (for Irrigation Permit)**
  - Agricultural water rights holders could be compensated for not diverting water during dry years. Priority should be given to agricultural water rights that have recent historical use. This approach reduces instream water use during critically dry periods in order to increase flows.

- **Increase storage of water for releases for environmental flows**
  - Additional storage could be added to projects to store water during higher flows to allow for releases to support the river/bay system during low flow periods when flow is needed.
  - Develop project to store surface water during higher flows (surface storage or aquifer storage and recovery) to have a solely dedicated source for environmental flows during drier times.

- **Dedication of Conserved Water from Current Permits to Environmental Flows**
  - Permit holders could voluntarily commit water that is saved through conservation methods to environmental flows. Most applicable to Agricultural or Municipal water permit holders.
  - Possible Environmental Quality Incentives Program (EQIP) funding for agricultural conservation practice/s and other available federal funding.

- **Facility Optimization to Enhance Environmental Flows**
  - Modifying a facility's operation and/or schedule of releases can help provide environmental flows. The amount and timing of releases can attempt to better mimic the natural flow patterns of the river system, thereby protecting environmental flows. This can be done to an individual facility or to multiple facilities in a watershed for an additive effect.

- **Water Rights Management**
  - The existing location and timing of diversions of water rights in the basin may inhibit opportunities for better resource management that could help support environmental flows.
  - Combinations of opportunities may exist whereby water right diversion points could be relocated, older rights used in conjunction with new water rights, or new water rights used

in conjunction with currently unused rights to improve delivery efficiencies to both water users and the environment. Contractual agreements will be necessary.

- **Set-asides of Unappropriated Water**
  - Some or all of unappropriated flow within the basins could be left in the river or removed from the amount of water available for future permitting. SB3 contemplates set-asides of unappropriated water by TCEQ.

- **Reduction of Groundwater Pumping**
  - Reducing groundwater pumping can allow springs to provide river baseflows.

- **Land Stewardship Programs**
  - Local, regional, state, and federal incentives for landowners to use good land management practices which will put more water into the water table.

  - ***Riparian Zone and Wetland Restoration and Stewardship***
    - Proper stewardship of riparian zones on the basin's creeks and rivers can build up the in-bank water holding capacities which serve to maintain base flows during dry periods and provide a healthy riparian habitat for both aquatic species and other wildlife. Flood attenuation and improved water quality are additional benefits resulting from proper stewardship of riparian zones.
    - Restored and healthy wetlands on the rivers or on the Gulf provide very productive wildlife habitat, filtering and cleansing actions desirable for inflows, and protection for inland communities from hurricanes.
  - ***Watershed or Catchment Stewardship***
    - A well-managed, healthy watershed not only provides a desirable livestock and wildlife environment, but increases groundwater penetration and recharge, reduces floods and provides other benefits.
    - Karst limestone watersheds are common across the Hill Country and Edwards Plateau, selective brush management and subsequent improved rangeland management has proven to sometimes increase ground recharge and springflows. Normally, Ashe juniper (cedar, mountain cedar) has been the target brush species, but in other cases mesquite control has produced desirable hydrological benefits.

- **Water Dedication from Existing Permits**
  - Some permit holders may be willing to have conditions placed on their permits, such as a certain percent or set amount of the water being dedicated to provide environmental flows.

- **Municipal, Industrial, Mining and Agricultural Conservation to reduce water use and demand**

- Each city, town and water utility, both large and small, should set goals to lower future surface and/or groundwater use using a conservation program which best fits their situation for both the utility and customers. The goal would be to reduce per capita water use and reduce demand for river diversions.
- Effective conservation programs/strategies include: stringent leak detection, low water use appliances, inverted pyramid rate structures, customer education program, rainwater harvesting, use of recycled water and gray water, and others.
- Agricultural irrigation conservation including installation of efficient of water delivery systems (canal, pipelines, etc.), improve center pivot systems, add in-ground moisture monitors, improve crop varieties and other farming methods.

- **Develop conjunctive use water projects**
  - To reduce reliance on surface water, water project developers should be encouraged to develop conjunctive use water projects using both groundwater and surface water. Better data on groundwater availability is now available for defined Groundwater Management Areas and modeled available groundwater reports to the TWDB increasing the certainty of groundwater use planning.

- **Develop alternate water supplies**
  - Alternative water supplies such as desalination of brackish groundwater or seawater desalination offer options to surface water usage and can provide additional water that could be stored and released for environmental flows.

- **Programs addressing logjam removal**

  - A logjam removal program could yield flow benefits to the bay and estuaries and improve stream bed conditions as well as riparian health in associated areas of the basin.

The GSA BBASC recognizes that voluntary implementation of water use and management strategies will improve the effective use of limited surface water within the basin particularly during the driest times when water is in its highest demand and flows are at their lowest. Implementation of strategies is also a vital component toward reaching recommended flow attainment targets while achieving a balance between water supply and environmental needs.

Section 4 Work Plan for Adaptive Management Elements

Pursuant to SB3 of the 80th Texas Legislature, as quoted below, the GSA BBASC was charged with development of a Work Plan to be submitted to the Environmental Flows Advisory Group (EFAG) for approval. With the assistance of the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Expert Science Team (GSA BBEST) the GSA BBASC began to identify subject areas deemed appropriate for monitoring, studies, and activities in their Recommendations Report submitted on September 1, 2011. Although the GSA BBASC

Recommendations Report provided a list of potential Work Plan activities, the list was neither complete nor prioritized. Similarly, Section 7 of the GSA BBEST Recommendations Report identified a developing list of monitoring, studies, and activities deemed appropriate to better inform, support, and adaptively manage environmental flow standards.

To begin addressing identified data gaps the GSA BBASC with the assistance of the GSA BBEST developed "scopes of work" for the monitoring, studies, and activities relevant to the subjects of interest in accordance with guidance from the Science Advisory Committee (SAC). These "scopes of work" focus on the what, why, where, when, who, and cost associated with each subject in order to facilitate these efforts being commenced. The scopes of work and identified strategies constitute the great majority of this Work Plan.

Work Plan subjects identified by the GSA BBASC and/or the GSA BBEST have been categorized based on relevance to instream flows and freshwater inflows to bays and estuaries are listed in Tables 6.0-1 and 6.0-2[1] of the GSA BBASC Recommendations Report. These Work Plan subjects have since been reviewed, revised, edited, and in some instances condensed and combined. The consolidation of some study scopes was accomplished in two workgroups with one focused on instream efforts and the other on bay and estuary issues.

The instream workgroup prioritized their top ten issues while the bay and estuary workgroup did the same for coastal inflow data gaps. The prioritization criteria considered by the instream workgroup included: required time to complete a study; significance of the data gap; connectivity to river/ bay; most influence on inflows; impact on aquatic, estuary, riparian; sequential nature of studies; urgency to address damage areas; and available funding opportunities and costs. The bay and estuary workgroup prioritization criteria considered whether the proposed studies will have a direct influence on the understanding of the current environmental-flow recommendations; promotion of understanding of e-flows and the role of freshwater inflows; availability of funding opportunities; the ability to complete the proposed projects within the planning process; and the potential for funding and resource partnerships. To finalize the Work Plan prioritization, the two workgroups held a joint meeting and agreed that a three-tiered prioritization approach was sufficient to fulfill their legislative mandate and would provide adequate notice to the scientific community which studies were most important to fill data gaps as long as the studies recommended in Tier 1 were numerically prioritized.

The GSA BBASC decided to prioritize the Work Plan elements into three tiers with only those study elements in Tier 1 being numerically prioritized. The GSA BBASC believes the most critical studies and efforts to address known data gaps have been identified and ranked in Tier 1. The studies and efforts in Tiers 2 and 3 were not individually ranked based on the belief that these items are relatively equal in importance. There was much discussion amongst the GSA BBASC regarding the potential for unintentionally diminishing the importance of the Tier 2 and 3 identified studies. Rather than

[1] See Appendix

sequentially ranking these remaining studies, the GSA BBASC chose to group them according to timeline considerations and data gap importance.

TIER 1 Priorities

SENATE BILL 2/TEXAS INSTREAM FLOW PROGRAM (SB2/TIFP) STUDIES ON REMAINING RIVERS IN BASIN

GSA BBASC Priority #1
Instream Flows – SB2/TIFP on Guadalupe

Dependencies/Links: Though not dependent upon, but linked to several recommended studies, the GSA BBASC recommends a Senate Bill 2 (SB2)/Texas Instream Flow Program (TIFP) Study on the Guadalupe River. The GSA BBASC recommends the study first focus on the lower Guadalupe River below Canyon Reservoir followed by a study of the Guadalupe River above Canyon Reservoir. Additionally, several recommended studies in the GSA Work Plan for Adaptive Management will contribute data to these SB2/TIFP studies.

What: In addition to the on-going collaborative efforts in the lower San Antonio sub-basin, the TIFP has the lower Guadalupe River below Canyon Reservoir listed as a primary priority site and the Guadalupe River above Canyon Reservoir listed as a secondary priority site. These rankings suggest the TIFP will be pursuing future studies in these river basins. The GSA BBASC benefited from the interim TIFP study report that provided the committee information connecting biological data to flow levels at specific sites along the Lower San Antonio River and Lower Cibolo Creek. The ability to tie biological data to observable flow levels was critical to the committee's environmental flow recommendations for the Lower San Antonio River and the GSA BBASC believes similar data on the Guadalupe will be equally beneficial for the next round of recommendations. As such, during BBASC Instream work group deliberations, the need for a SB2 study on the lower Guadalupe River was echoed and unanimously supported. To meet these ends, a SB2 study on the lower Guadalupe River below Canyon Reservoir is recommended as a Tier 1 priority. The GSA BBASC recommends the TIFP studies on the Guadalupe be conducted in accordance with the TIFP Technical Overview (TIFP 2008).

As noted above, the TIFP along with SARA recently conducted a TIFP SB2 study on lower San Antonio River and lower Cibolo Creek. A detailed description of that study is presented in the interim progress report prepared by the TIFP (TIFP 2011). Importantly, the results from that study were integral to the GSA BBASC environmental flow recommendations and carried forward into TCEQ rulemaking. Table 1 provides an overview of 1) the SARA/TIFP sponsored SB2 component studies in the lower San Antonio sub-basin that are still in progress; 2) applied

research efforts that have been identified during that study which may improve the ecological understanding of the aquatic and riparian communities and their relationship to flow; and 3) specific long-term monitoring recommended. Individual scopes for SARA/TIFP activities are not presented in this BBASC report, but can be obtained by contacting project sponsors.

Finally, additional rivers for consideration by the GSA BBASC for potential instream flow program type studies include the lower San Marcos River, Blanco River, Medina River, and Mission River. Should future projects appear targeted for these river systems, it may be prudent for the GSA BBASC to consider and support TIFP related studies on these specific rivers, in order to fill data gaps on ecological knowledge and flow-ecology relationships within these systems.

Why: The GSA BBASC recognized the importance of tying site specific biological data to flow levels when they largely adopted the TIFP recommendations for the Lower San Antonio River. A similar level of study effort would beneficial to the understanding of the Guadalupe River Basin too.

Where: Guadalupe River below Canyon Reservoir is first priority however SB2 type studies are also recommended for the lower San Marcos River, Blanco River, Medina River and Mission River.

When: Begin on the Guadalupe River below Canyon Reservoir as soon as possible.

Who: TCEQ, TPWD, TWDB, GBRA, and stakeholders

Cost: $1,000,000 – $2,000,000

Table 1. Texas Instream Flow Program
Lower San Antonio River and Lower Cibolo Creek Ongoing Activities

COMPONENT		SUBJECT
BIOLOGY		
Instream	Studies	Life history research on focal species
		Macroinvertebrate community / substrate disturbance evaluation
		Seasonal fish sampling
	Monitoring	Specific flow/temperature driven sampling for fish and mussels
		Long-term annual fisheries sampling
Riparian	Studies	High flow pulse effects on riparian communities
		Development of a mechanistic ecosystem model of ecological interactions of high flow pulses and riparian communities
	Monitoring	Long-term annual monitoring of select riparian transects
		Long-term (every 10 years) limited tree-ring coring analysis to assess riparian productivity relative to total annual volume
WATER QUALITY		
	Studies	Water quality modeling for Cibolo Creek, if warranted
	Monitoring	Specific water temperature and dissolved monitoring at Cibolo Creek during subsistence flow conditions
GEOMORPHOLOGY		
	Studies	2D hydraulic modeling to evaluate channel change with discharge
	Monitoring	Long-term (every five years) select channel cross-sections within study sites to assess potential changes in channel configuration

GSA BBASC Priority #2
Instream Flows - Streamflow Gaging and Synoptic Flow Study

USGS Streamflow Gaging and Water Quality Monitoring

Dependencies: The location of the recommended gage below Victoria will be dependent on the Synoptic Flow Study; however, the Stream Flow Gaging will utilize existing gages that are in place the entire period of the study. Additionally, efforts might include sediment collection as described in Tier 3 Bay & Estuary study: Evaluation of Sediment Transport Affecting the Guadalupe Estuary Delta

What: The San Antonio River Authority and GBRA, U.S. Army Corps of Engineers (USACE), Edwards Aquifer Authority (EAA), CPSE, SAWS, and TWDB annually enter into a cooperative funding agreements with the U.S. Geological Survey (USGS) to support multi-purpose water quality and stream flow monitoring programs. The programs support the annual operation and maintenance of stream flow gages and water quality gages within the San Antonio, Guadalupe, and Mission River watersheds (Table 2). It is recommended that additional funding partners be identified, and cooperative funding agreements and monitoring programs be continued into the future. Additionally, it is recommended that a gage be installed on the Guadalupe River at SH 35 in Refugio County, downstream of the GBRA Salt Water Barrier and Diversion Canal, and a gage be installed on the San Antonio River upstream of the CPSE diversion. Funding partners need to be identified for the new sites. For the downstream Guadalupe River location, the synoptic flow measurements estimating freshwater inflow and applicability of lower river gaging stations is a prerequisite task for completion to this effort to inform the most efficient placement and design for this gage.

Why: Maintaining the existing network of stream flow gages at each monitoring site and establishing new sites as recommended above will provide water resource managers and agencies comprehensive flow records that can be compared with biological, habitat and water quality information into the future.

Where: San Antonio, Guadalupe and Mission River basins.

When: Contract annually over the next 10 years.

Who: USGS with funding support from SARA, GBRA, USACE, EAA, CPSE, SAWS, TWDB, TCEQ, TPWD, TSSWCB, and stakeholder agencies.

Cost: To be determined, for existing sites expected to be about $340,000 annually. The installation of a new gage site and operation and maintenance (O&M) for the first year is $25,000; annual O&M costs for subsequent years are $16,000.

Table 2. USGS gage stations and funding related to BBASC Recommendations

EXISTING Gage Location	Cooperator	Cooperator Funds	USGS Funds/ NSIP Funds	Total EXISTING Cost
Guadalupe River at Comfort	GBRA/USACE-FW	$1,545 $2,265	$13,900	$17,710
Guadalupe River near Spring Branch	GBRA/USACE-FW	$9,310 $2,265	$4,590	$16,165
Blanco River at Wimberley	USACE-FW	$1,545	$13,905	$15,450
San Marcos River at Luling	GBRA/USACE-FW	$1,545 $720	$14,730	$16,995
Plum Creek near Luling	NSIP		$15,450	$15,450
Guadalupe River at Gonzales	GBRA/USACE-FW	$5,925 $7,725	$1,800	$15,450
Sandies Creek near Westhoff	NSIP		$15,450	$15,450
Guadalupe River at Cuero	GBRA/USACE-FW	$9,310 $2,265	$4,590	$16,165
Guadalupe River at Victoria	GBRA/USACE-FW	$1,545 $720	$14,730	$16,995
Medina River at Bandera	EAA	$10,350	$5,100	$15,450
Medina River at San Antonio	SARA/NSIP	$41,230	$300 $13,600	$55,130
San Antonio River near Elmendorf	CPS/SAWS	$9,350 $49,280	$6,100 $0	$64,730
San Antonio River near Falls City	TWDB	$8,250	$7,200	$15,450
Cibolo Creek near Falls City	NSIP		$15,450	$15,450
San Antonio River at Goliad	TWDB/USACE-FW	$2,060 $11,590	$1,800	$15,450
Mission River at Refugio	TWDB	$8,250	$7,200	$15,450
Total Annual Existing Cost		$187,045	$157,115	$342,940
Proposed NEW Gages	Cooperator	Installation	Annual Maintenance	Total NEW Costs
San Antonio River upstream of the CPSE diversion	To be determined	$25,000	$16,000	$41,000
Downstream of the GBRA Salt Water Barrier and Diversion Canal	To be determined	$25,000	$16,000	$41,000
Total NEW Costs		$50,000	$32,000	$82,000
Total Annual Program Costs (Existing and New)				$374,940

Synoptic flow measurements to estimate freshwater inflow and applicability of lower river gaging stations

Dependencies: The Synoptic Flow Study could affect other recommended studies such as Riparian, Biological and Geomorphologic Monitoring as well as the Hydrodynamic Salinity Modeling and Marsh Inundation and Salinity Models.

What: Subject to high flow conditions in the Guadalupe River, flows may pass through cuts in the banks of the river and make their way into the Guadalupe Estuary via Schwings, Hog, and/or Goff Bayous passing near or through Green Lake. Hence, the streamflow gaging station on the Guadalupe River near Tivoli (USGS# 08188800) does not measure all Guadalupe River flows passing Victoria and Bloomington that contribute freshwater inflow to the estuary under high flow conditions. Subject to average and low flow conditions, however, this gage does provide a reasonably accurate measure of the combined flows of the Guadalupe and San Antonio Rivers, but diversions into the GBRA Calhoun County Rural Water Supply System (Calhoun Canal System) must be subtracted and discharges (return flows) into the Victoria Barge Canal must be added to calculate measured freshwater inflow to the Guadalupe Estuary. At the present time, diversions into the Calhoun Canal System are measured where the Main Canal passes under State Highway 185. While no water has been diverted for consumption by GBRA or its customers between the Guadalupe River and this measurement point, gravity diversions from the river have passed through gates on the left bank, a diversion canal west of Green Lake, Hog Bayou, a diversion canal south of Green Lake, Goff Bayou, inverted siphons under the Victoria Barge Canal, Dow's Main Pump Station, an above-grade canal and underground conduits on Dow property, and a short segment of the Main Canal. Although any water leaving the river and not measured at SH185 still contributes inflow to the Guadalupe Estuary and/or sustains delta area wetlands and riparian vegetation, improved understanding of the fate of such unaccounted water could lead to improved gaging methods, more accurate modeling of estuarine systems, and/or more efficient management for water supply and/or ecological purposes. Streamflows in the lower San Antonio River below McFaddin are split between the San Antonio River and Elm Bayou before discharging into the Guadalupe River a short distance upstream of the USGS streamflow gaging station identified as the Guadalupe River near Tivoli. Further investigation of this split in terms of variation with streamflow magnitude, floodplain inundation, geomorphology, and ecological effects may provide insights as to whether interventions (e.g., channel forming, bank stabilization, levee construction, etc.) would have associated benefits.

For a range of flows in the Guadalupe and San Antonio Rivers and in the Calhoun Canal System, this work item includes performing synoptic flow measurements at multiple locations in the rivers, bayous, and Calhoun Canal System to ascertain the course(s) of measured flows. Using the results of these synoptic flow measurements, an assessment of

the potential benefits of alternative or supplemental gaging stations and/or interventions will be conducted.

Why: Improve understanding of flow patterns in the lower Guadalupe – San Antonio River Basin and proximate bayous and water courses affecting riparian wetland habitats and freshwater inflows to the Guadalupe Estuary and to determine gage placement and design for GSA BBASC Priority #2, Instream Flows – Streamflow Gaging and Synoptic Flow Study, *USGS Streamflow Gaging and Water Quality Monitoring*.

Where: Guadalupe River below Victoria, San Antonio River below McFaddin, and proximate floodplain and delta areas

When: Two year study which will include at least four synoptic measurements with high and low river flows and high and low Calhoun Canal System flows.

Who: Flow measurements, hydraulic analyses, and gaging location assessments by USGS, River Authorities, State agencies, and/or technical consultants; geomorphological and ecological assessments by technical consultants and/or universities.

Cost: $25,000 per set of synoptic measurements; $50,000 for hydraulic analyses and gaging location assessments; and $25,000 for geomorphological and ecological assessments.

GSA BBASC Priority #3
Bays & Estuaries - *Rangia* Clam Investigations

What: *Rangia* Clam Investigations

Why: In Section 7.1.2.2 of the GSA BBEST Environmental Flows Recommendation Report, the BBEST recognized the need for additional efforts related to *Rangia* clams more specifically as follows:

1. Implement investigation of the location-specific reproductive requirements of *Rangia* clams. These requirements are the very core of the BBEST work with this species and were assumed equal to those found in literature derived from studies in other Gulf and Atlantic Seaboard states.
2. Develop a better assessment of the distribution and abundance patterns of *Rangia* in the Guadalupe and Mission-Aransas Estuaries via appropriate sampling design and field equipment. TPWD data was used by BBEST, but this data essentially reports incidental catch since TPWD and others do not sample specifically for *Rangia*.

Item (1) is partially covered in an ongoing investigation into salinity patterns as a driver of population spatial coverage, but that work assumes the reproductive requirements are consistent with existing literature. More specific information needs to be pursued via laboratory assessments or intensive field test and monitoring.

Additionally, information regarding the salinity suitability curve / habitat modeling approach for oysters referenced as part of GSA BBASC Tier 2 Priority, Bays & Estuaries – Habitat Suitability Models for Eastern Oysters, Blue Crabs, &White Shrimp would support refinements in the *Rangia* habitat modeling refinements

Where: Site specific studies in the upper brackish portions of the Guadalupe and Mission-Aransas Estuaries for *Rangia* items (1) and (2).

When[2]: 1) reproductive requirements of *Rangia*: 18-24 months from initiation
2) distribution and abundance patterns of *Rangia*: 2-4 months from initiation for each estuary

Who: Mission Aransas National Estuarine Research Reserve (NERR), additional field and/ or laboratory assessments by university private contractor(s) or university(ies)

Cost: 1) lab or field study probably in range of $80,000 -$90,000
[basis: 1 grad student full time employee (FTE) for 18 months at $20/hr. and ¼ FTE supervisory for 18 months at $35/hr.]

2) distribution and abundance patterns of *Rangia*: approximately $50-60,000 or $25,000-30,000 per estuary [basis: similar study performed by contractor on Sabine Lake during Sabine-Neches BBEST work]

GSA BBASC Priority #4
Bays & Estuaries - Life Cycle Habitat & Salinity Studies for Key Faunal Species

What: Life cycle habitat & salinity studies for key faunal species

Why: As described in sections 4.1.5 and 4.3.1 of the GSA BBEST Environmental Flows Recommendation Report, recruitment of post-larval and juvenile life history stages of many species may depend on freshwater inflows producing regions of reduced salinity within estuaries, and some species may derive enhanced benefit from these salinity reductions

[2] note these are study durations, not billable hour / cost estimates.

occurring during particular seasons. Spring rains may reduce salinities in coastal estuaries for several months due to the long turnover times of most bays on the south Texas coast. This freshwater inflow also provides nutrients that stimulate primary productivity that helps enhance the productivity of the entire food web. Although the BBEST originally planned to use the white shrimp (*Litopenaeus setiferus*) and blue crabs (*Callinectes sapidus*) as key species for characterizing freshwater inflow needs of the Mission-Aransas and Guadalupe estuaries, after review of available data from TPWD, review of the published scientific literature and consultation with local and national scientific experts, it was the consensus of the BBEST that the relationships between freshwater inflow and abundances of these key species were not direct, but included other complex factors that would require additional study.

How: An initial approach would include additional review of scientific literature and existing data sets to identify the most likely factors that complicate the relationships between salinity and the abundances of key species such as white shrimp and blue crabs. Once these factors are determined, field and/or laboratory studies can be designed to understand how these additional factors interact with salinity to affect the populations of these key species. Hopefully, these additional scientific studies will guide future efforts to determine environmental flow requirements of Texas estuaries based on the requirements of these valued key species.

Where: Entire basin, or initial study within San Antonio Bay, with its higher freshwater inflow and more consistent salinity gradient.

When: Six months for dedicated review of literature and available data. The results of the dedicated review of literature and additional data will assist in determining; recommended additional studies

Who: Literature review and data review by university investigator, RFP for additional studies issued through Sea Grant or comparable agency and Mission Aransas National Estuarine Research Reserve (NERR)

Cost: Literature and data review: $35,000 [basis 1 FTE for 6 months at $35 per hour]
Field/laboratory studies TBD. Additional costs could not be determined however costs could likely be significant.

GSA BBASC Priority #5
Bays & Estuaries – Hydrodynamic & Salinity Model Improvements

Dependencies: The Hydrodynamic & Salinity Modeling Improvements study could be dependent on the Synoptic Flow Study

What: Improvements to the TxBLEND Hydrodynamic and Salinity Transport Model (TxBLEND Model)

Why: As described in Section 4 of the GSA BBEST Recommendations Report and in two memos from the TWDB to the BBEST (described therein as TWDB 2010a, 2010b) there are certain inflow conditions and certain geographic areas of the Guadalupe and Mission-Aransas Estuaries that have proven difficult for the TxBLEND Model to predict salinity accurately. There is also new salinity monitoring data from fixed stations in the Mission-Aransas National Estuarine Research Reserve (NERR). Given this information, Section 7.1.2.1of the GSA BBEST Environmental Flows Recommendation Report recognized the need for additional efforts to calibrate and improve TxBLEND model performance. Possible model improvements include: (1) improving the model grid (*e.g*., update bathymetry, increase grid resolution, move the freshwater boundary upstream, or improve spatial representation of inflow points); (2) improving estimates of hydrology and freshwater inflows to the bay; (3) improving spatial representation of precipitation falling on the bay (through use of NEXRAD data); (4) improving spatial representation of evaporation from the bay; (5) and improving model coefficients.

During deliberations of the GSA BBASC, concerns were raised about the potential for some error in the technique of estimating inflows to the Guadalupe Estuary in particular. Because TxBLEND requires inflows to the bay as a principal model input, any recommendation or improvement to inflow estimates will be included for model calibration. The GSA BBASC has a proposed study (see the Instream Flows Workplan Synoptic Flow Study) to improve estimates of freshwater inflows. In addition, TWDB maintains estimates of freshwater inflows to the estuary and continually works towards improving datasets on diversions and return flows as well as estimates of rainfall-runoff in ungaged watersheds.

Where: This study proposes a systematic re-examination of the TxBLEND model domain across various inflow levels to identify underperforming spatial areas and inflow conditions. The previous TWDB and BBEST efforts identified problematic TxBLEND performance in the upper portion of the Guadalupe Estuary and in the Copano Bay portion of the Mission-Aransas Estuary. For the upper portion of the Guadalupe Estuary, the TWDB previously identified certain inflow-salinity characteristics that are more challenging for TxBLEND to predict.

When[3]**:** 12-20 months from initiation. 6-10 months for model reassessment, including incorporation of any improved inflow estimates, alterations of inflow locations, modification of model grid, evaporation or precipitation techniques and gathering additional inflow and salinity data for a longer period of record. 6-10 months to recalibrate and validate model, including an interactive feedback meeting with outside peer group.

Who: TWDB with potential support / data from other State agencies, Guadalupe-Blanco River Authority, and the Mission Aransas National Estuarine Research Reserve (NERR)

Cost: model refinements: $50,000 - $84,000
[basis: 1 FTE for 9-15 months at $35/hr.]

GSA BBASC Priority #6
Instream Flows - Full Accounting of Surface Water

Dependencies/Links: The Tier 3 Instream Flow – Groundwater Studies: Impacts of Groundwater Withdrawals on Upper Basin Streamflows

Exempt Uses of Surface Water

What: The common law, state statutory law and early Spanish and Mexican law recognize a landowners right to take water from a stream that abuts one's property for domestic and livestock use, and such right is excluded from the appropriation and permitting system. As far back as 1895, it was recognized that a landowner had the right to build a dam, reservoir or lake on his property and impound water for the landowner's drinking purposes and the watering of livestock. The law has continued to evolve and in 1971 the exemption was modified to allow broader uses of the water. The volume and size of the reservoir is governed by the construction date of the reservoir. Those reservoirs constructed after 1953 can impound no more than 200 acre-feet of water. These reservoirs can include vanity ponds, stock tanks and flood control structures. By the nature of their construction, these ponds impound water that would, without their presence, flow into the waters of the state; however, these impoundments are not subject to conservation or curtailment by the South Texas Water Master in times of drought. The impact of these ponds on the surface waters of the Guadalupe, San Antonio and Mission River basins has not been quantified. A study is recommended to quantify the number of exempt use reservoirs. This study would also quantify the amount of water impounded annually based on watershed size, and map the reservoirs using GIS or Google Earth. Additionally, the impact of domestic and livestock use uses on the surface waters of the Guadalupe, San Antonio and Mission River basins has not been quantified. These riparian uses are not presently subject to curtailment by the South

[3] note: these are study durations, not billable hour / cost estimates.

Texas Water Master in times of drought. This study would quantify the volume of domestic and livestock uses in each river basin by visibly inspecting the river channels for pumps and pipelines that remove water from the stream and create a map of these riparian diversions using GIS or Google Earth. The overall study including both the exempt reservoirs and domestic and livestock use components would be made available to TCEQ and the South Texas Water Master.

Why: The development of management strategies aimed at ensuring attainment of recommended flow regimes can be informed by understanding the number and location of exempt use reservoirs, the amount of water impounded annually based on watershed size, and the volume and location of domestic and livestock use in each river basin.

Where: Guadalupe, San Antonio and Mission River basins

When: Three year study

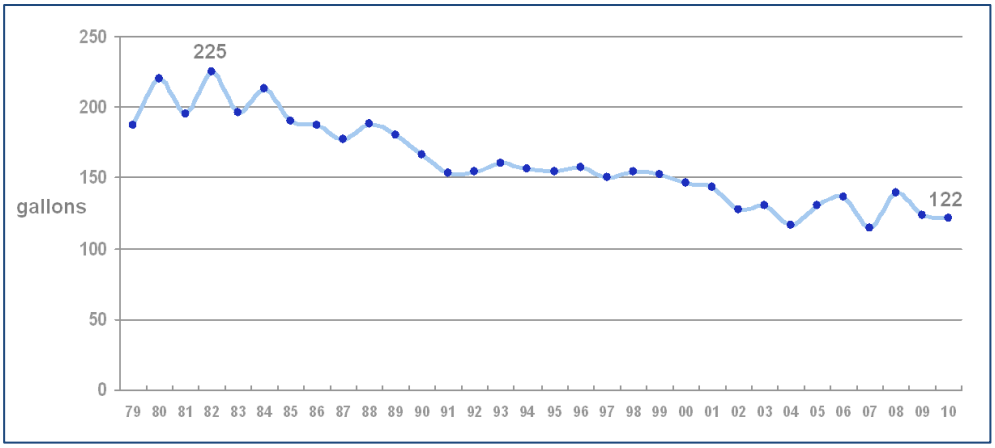
Who: Texas Water Development Board (TWDB), Texas Parks and Wildlife Department (TPWD), Texas State Soil & Water Conservation Board (TSSWCB), Texas Commission on Environmental Quality (TCEQ), Guadalupe-Blanco River Authority (GBRA), San Antonio River Authority (SARA), City Public Service (CPSE)/ San Antonio Water System (SAWS), Natural Resource Conservation Service (NRCS), Groundwater Conservation Districts (GCD) and Groundwater Management Areas (GMA), and other concerned stakeholder agencies.

Cost: To be determined, but expected to be approximately $200,000 split equally for the reservoirs and domestic and livestock components.

Effects of Conservation, Drought Management, and Reuse

What: In many streams in the Guadalupe/San Antonio basin, subsistence and base flows are dominated by return flows from wastewater treatment plants. As San Antonio has demonstrated, effective Conservation and Drought Management can have profound impacts on expected return flows of treated wastewaters to receiving streams. For example, previous estimates of year 2010 effluent production by San Antonio ranged as high as 380,000 acre-feet, but the actual production in 2010 was less than 150,000 acre-feet, largely owing to reductions in per capita water use resulting from aggressive conservation.

Figure 1
Daily Per Capita Water Use, SAWS Customers, 1979 to 2010



As San Antonio furthers its conservation efforts and as other cities begin to adopt similar conservation and reuse strategies, flows to receiving streams may be impacted. Additionally, as development in the oil and gas industry continues, an increased potential for direct reuse contracts exists. There is a need for a comprehensive evaluation of future return flows that can be expected considering growth in population and concomitant water demands, along with planned and potential conservation and reuse strategies.

Why: The development of management strategies aimed at ensuring attainment of recommended flow regimes can be informed by understanding the realized and potential impacts of Conservation and Drought Management.

Where: Guadalupe, San Antonio and Mission River basins.

When: One to two year study.

Who: River Authorities, Municipal service providers such as SAWS and City of New Braunfels, TWDB, TCEQ and technical consultants

Cost: To be refined, likely not to exceed $50,000 - $100,000

TIER 2 Priorities

***Disclaimer: Studies listed are grouped by type of study, not in any prioritized order.**

GSA BBASC Tier 2 Priority
Instream Flows - Riparian Assessment and Monitoring

Dependencies/Links: Riparian, Biological and Geomorphologic Monitoring, if linked would benefit from studies conducted at the same locations for use as input into future SB2 studies.

Riparian Vegetation Mapping and Long-Term Monitoring

What: The objective is to establish a comprehensive riparian vegetation mapping program in the Guadalupe San Antonio Mission Aransas (GSAMA) Basin. The TIFP has already conducted detailed field studies at selected gage locations in portions of the lower San Antonio Basin, and is currently analyzing this data in relation to geomorphologic data. Expansion of the geographic scope of this program should be supported to include Guadalupe and Mission-Aransas basins. Within Section 4.3.1 of the GSA BBASC Environmental Flows Recommendations Report the importance of high flow pulses and overbank flows on riparian vegetation is addressed. These types of flows are necessary in the riparian environment to provide channel and substrate maintenance, limitation of riparian vegetation encroachment, riparian vegetation diversity maintenance, conditions conductive to seedling development, floodplain connectivity, lateral channel movement, floodplain maintenance, recharge of floodplain water tables, flushing of organic material into the channel, nutrient deposition in the floodplain, and restoration of water quality in isolated floodplain water bodies. Flow alteration in magnitude, duration, or frequency, can substantially change riparian vegetation as the flow influences geomorphic features (Naiman et al. 2010), inundation (Auble et al. 1994; Naiman et al, 2010), and, ultimately, riparian vegetation succession (Day et al. 1988). However, the level of alteration that might cause such changes in the GSAMA basins is unknown at this time. That present day distribution of riparian vegetation is reflective of relative inundation duration is known (Auble et al. 1994), but again the basin specifics remain data gaps in our understanding. Data collected on woody vegetation density and basal area provides a dataset that can be assessed to determine current community structure and successional dynamics across the floodplain. Data should be analyzed and correlated to fine-resolution multi-spectral imagery to develop high-detail riparian community maps and datasets.

Additionally, long-term riparian transects will be established following the initial mapping efforts. The objective is to establish long-term riparian transects to track ecological condition of the riparian corridor over time. The TIFP has already established long-term riparian transects for the lower San Antonio River and lower Cibolo Creek basins. The intent is to extend a similar level of effort to the Guadalupe, Mission, and Aransas river basins.

Why: A comprehensive riparian mapping effort will provide the foundation for the selection of representative, long-term riparian monitoring locations. This comprehensive mapping will support future analysis of the effectiveness of high flow pulses (as recommended by TCEQ rules and implementation strategies) to sustain existing riparian communities over time. Long-term riparian transect data collection will be used to specifically track ecological condition of the system over time, and assess (validate) the Environmental Flow Recommendations and Implementation Strategies.

Where: Guadalupe and Mission-Aransas basins

When: Two to three years for sampling, mapping and analyses; annually for long-term transects during the growing season.

Who: TPWD, TWDB, River Authorities, universities and technical consultants

Cost: To be determined, anticipated at $250,000 followed by $75,000 annually

Water table monitoring in the Riparian Corridor

What: The objective of groundwater monitoring stations at key USGS gage stations in the GSA Basin is to provide groundwater discharge and recharge data at various flow regimes. The GSA BBEST report highlights that hydrologic connectivity between the channel, floodplain, and terrace features is not well understood. Therefore, a basin-wide groundwater monitoring program would begin to address the data gaps associated with hydrologic connectivity in the basins. Availability of shallow groundwater resources is essential in maintaining a sound ecological environment within the riparian corridor (Stromberg et al. 1996). Availability is dependent on geology, topography, soils, and hydrologic regimes among ecoregions in the GSA basins as well as distance from the river to upland in the riparian corridor. Therefore sites should be located in areas that are representative of ecoregions, as well as where existing and proposed information are generated from the SB2 program, USGS gage locations, and long-term riparian monitoring sites. Shallow water wells should be positioned perpendicular to the stream course and data correlated to riparian vegetation community structure as well as hydrologic regimes in the stream channel. This baseline data can be used to develop depth-to-groundwater ranges for individual woody and herbaceous species and characterize the present groundwater-surface water-riparian community structure. Additional data can be generated in models to determine if proposed alterations to environmental flow regimes would change riparian community structure (Franz and Bazzaz 1977) and affect ecosystem functions the community provides to the stream and downstream estuary.

SARA with the USGS and others has conducted surface / groundwater studies on the Lower San Antonio River and Cibolo Creek.

Why: In order to validate the environmental flow regime and investigate implementation strategies, it will be essential to understand the interactions of water table and riparian corridor health. This study is designed to address this data gap, and provide ecological linkage information that will support the assessment of high-flow pulses, and on-going assessment of riparian corridor health and productivity.

Where: San Antonio, Guadalupe, Mission and Aransas River basins (Lower San Antonio River and Cibolo Creek have had studies conducted)

When: One to two years for identification of sites, data collection and processing, and model development; annual long-term monitoring at select locations.

Who: USGS, TPWD, GCDs, River Authorities, universities and technical consultants

Cost: To be determined, anticipated to be $200,000 for one to two year study and $50,000 per year to monitoring long-term sites (dependent on the number of sites selected for long-term monitoring).

GSA BBASC Tier 2 Priority
Instream Flows - Biological Sampling and Monitoring

Dependencies/Links: Riparian, Biological and Geomorphologic Monitoring, if linked would benefit from studies conducted at the same locations for use as input into future SB2 studies.

What: Section 7.1.1.3 of the GSA BBEST Environmental Flows Recommendations Report recognized three biology-related limitations to their recommendations: 1) sound ecological environments were based exclusively on fish communities; 2) fish habitats were used primarily in the assessment of instream flow needs; and 3) flow recommendations are not validated.

The TIFP Technical Overview (TIFP 2008) and Lower San Antonio River Basin Study Design (TIFP 2010) outline four major study components including hydrology and hydraulics, biology, physical processes, and water quality. Adhering to the guidance provided by TIFP (2008 and 2010), a methodology to determine Habitat Suitability Criteria (HSC) was developed and applied for the Lower San Antonio River Instream Flow Study (TIFP / SARA 2011). A suitability criterion for depth, velocity, substrate, and cover was developed for various species and/or guilds of species within the fish community of the lower San Antonio

River and Cibolo Creek. These criteria were used in conjunction with hydrodynamic models to model fish habitat at various flows.

The GSA BBASC Environmental Flows Recommendation Report also recognized limitations in available information regarding fish use of floodplain environments during overbank flows. In general, dependence between floodplain habitats and fluvial specialist fishes is not demonstrated in western gulf slope drainages and interdependency with other taxonomic groups is not known. Studies conducted in a nearby basin (Zeug et al. 2005) demonstrate uniqueness of floodplain environments and their contribution to maintaining fish diversity within the basin. As biological and habitat data collections are being planned, monitoring regimes should be developed to include sampling in floodplains during overbank flows.

Since biological sampling and monitoring data collection efforts are anticipated to involve personnel from State agencies, River Authorities, Universities, Stakeholder organizations, technical consultants and possibly volunteers, it is imperative that very specific quality assurance and quality control protocols for biological sampling, data collection, mapping, data submittal, data processing and data storage be developed and adhered to. Once qualified and verified, all data and information should be posted to a database and made available to the public via the internet. Developing specific protocols, quality assurance and quality control procedures will allow resource managers to consistently track the ecological condition of the system over time, and assess / validate the Environmental Flow Recommendations and Implementation Strategies. It is recommended that a sampling and monitoring regime with approved quality assurance protocols targeted at providing data and information to develop HSC be implemented.

Why: Long-term biological data collection will be used to specifically track ecological condition of the system over time, and assess the Environmental Flow Recommendations and Implementation Strategies. Collecting information on the floodplain usage of fishes in the lower basins will provide valuable information on high-flow pulses and resulting floodplain connectivity effects on the fisheries community. This information will be valuable in assessing the effectiveness of the implemented rules and resulting environmental flow regimes.

Where: San Antonio, Guadalupe and Mission River basins

When: One to two years for assessment of ecological soundness in Guadalupe, Mission, and upper San Antonio river basins. Annual monitoring is recommended in all basins for evaluation of floodplain usage, seasonal differences, and to track ecological condition over time.

Who: TPWD, TCEQ, TWDB, River Authorities, universities, stakeholder organizations, and technical consultants

Cost: Assessment of ecological soundness: $75,000 to $175,000 per basin (Guadalupe, Mission, and upper San Antonio). Taxonomic priorities should be established after determination of flow-sensitive taxa and long-term annual monitoring $150,000 per year for all three basins.

GSA BBASC Tier 2 Priority
Instream Flows – Geomorphic Studies and Monitoring

Dependencies/Links: Riparian, Biological and Geomorphologic Monitoring, if linked would benefit from studies conducted at the same locations for use as input into future SB2 studies.

Instream and Riparian Sediment Deposition

What: A geomorphic linkage to ecological health is a major data gap in BBEST analysis to date for both riparian communities and instream aquatic organisms. This study will help define the ecological linkage of sediment deposition in both riparian and instream habitats. Inherent in the geomorphic monitoring approach described above is the collection of channel elevation data at each planar surface corresponding to riparian sediment deposition areas and substrate characteristics. The basic channel topographic survey and analysis will also yield the requisite instream depositional or aggregation characteristics. Within each monitoring site, the distribution of mesohabitat types (i.e., run, pool, riffle, backwater, lateral habitats) will be mapped each year. Within each mesohabitat, the maximum depth, average and maximum width, and length should be noted. Also, within each mesohabitat, a minimum of nine randomly selected points should be selected where depth, velocity, substrate, and cover should be collected. As noted in GSA BBASC Tier 2 Priority, Instream Flows - Riparian Assessment and Monitoring, it is anticipated that along each cross section within the monitoring reach, a riparian line transect methodology will be utilized to characterize the species and age composition for trend analyses each year. It is also anticipated that the fish community will be sampled by mesohabitat unit during the annual monitoring activities of GSA BBASC Tier 2 Priority, Instream Flows – Biological Sampling and Monitoring. The mesohabitat mapping (plan view polygons, width, depth, velocity, substrate and cover should be accomplished by a two person crew in two field days. Analysis of data and comparison of trends should be accomplished by three person weeks of effort.

Why: Understanding the linkage of geomorphic changes to both the riparian and instream communities will be vital in tracking the ecological condition of the system over time, and assessing (validate) the Environmental Flow Recommendations and Implementation Strategies.

Where: Guadalupe, San Antonio and Mission River basins. At locations that have long-term biological monitoring and long-term riparian transects as noted and referenced during studies GSA BBASC Tier 2 Priority, Instream Flows – Riparian Assessment Monitoring and Biological Sampling and Monitoring.

When: Two to three year study

Who: TWDB, TPWD, River authorities, universities and technical consultants

Cost: To be refined, anticipated to be $250,000 for two to three year study

Geomorphic Studies and Monitoring

What: For this work plan element, a parsimonious approach is proposed that attempts to balance the cost-benefit tradeoffs between the high cost of site-specific studies that are not likely to be transferable between quantification sites and collection of quantitative data within the framework of a monitoring program that can provide inference on the efficacy of adopted environmental flow regimes. The following monitoring program is designed to be applied at each quantification reach on an annual basis and is an integral part of the monitoring program for other resource elements such as the aquatic and riparian resources. Each monitoring site should be at least ~300 mean channel widths and centered on the quantification gage location. Starting at either the upstream or downstream boundary, the channel topography should be measured perpendicular the stream at established locations approximately every 15 mean channel widths. Cross section profiles should be measured from an established bench mark(s) tied to the gage elevation and verticals placed at each break in channel topography (cuts, flat depositional areas, thalweg) and at a minimum of 20 locations or more to adequately define the channel topography. Sampling should be conducted in the early fall to minimize variation in flow regimes and increase sampling efficiency at lower flows for other monitoring activities such as fisheries collections. The right and left headpins that demark each cross section should be located a few feet into the upland vegetation zone. At each vertical across each cross section, the substrate characteristic based on a modified Wentworth scale should be noted in addition to the x-distance and bed elevation. In addition, at each cross section within the active channel, Wolman Pebble counts (a technique for measuring the size of particles on the river bottom) should be collected. These data should be analyzed to generate particle size duration curves for both longitudinal and temporal (year-to-year) changes. Cross section geometry in conjunction with bed material particle size distributions will show if large changes in channel bottom sediment characteristics or channel shape are evident in river channel characteristics. In addition, the slope of planar depositional features throughout the longitudinal profile of the channel should be plotted and compared against each sampling period.

Why: Understanding the linkage between the flow regime, channel change, streambank stability, effects on instream and riparian habitat and resulting affects biological processes is essential to track the ecological condition of the system over time, and fully assess (validate) the Environmental Flow Recommendations and Implementation Strategies.

Where: Guadalupe, San Antonio and Mission River basins. At locations that have long-term biological monitoring and long-term riparian transects as noted and referenced during studies GSA BBASC Tier 2 Priority, Instream Flows – Riparian Assessment Monitoring and Biological Sampling and Monitoring.

When: Annual monitoring to track channel changes over time

Who: TWDB, TPWD, River Authorities, universities and technical consultants

Cost: To be refined, anticipated to be $150,000 per year

Effects of Logjams on Habitat, Flooding, and Sediment Transport

What: Modern instream flow studies recognize the ecological role of high flow pulses and overbanking events though they are sporadic. In addition, a bulk of the current literature and associated practice works with the definition of an "overbank episode" duration as medium-term on the order of weeks to a month. However, very long-term overbank flows are associated with logjams and the associated reduced hydraulic capacity of the channels on both the lower San Antonio and Guadalupe Rivers. Some observers note increased flooding durations in the lower stretches of the San Antonio and Guadalupe Rivers (Womack, pers. comm.) over the last few decades which may not be fully explained by storm magnitudes. These episodes surpass standard definitions of overbank flows as described by the TIFP. During these events, riparian areas remain flooded for durations ranging from a few weeks to months and even years in select locations. There is little or no data on the riparian and instream effects of these extended durations of inundation caused by logjams on these lower river segments.

Additionally, it is highly probable that these logjams are acting as a substantial "sink" for river-borne sediment. If so, this impediment to sediment movement may have deleterious effects on the downstream river reaches as well as delta and wetland maintenance in the riverine-estuary boundary. Historical evidence from the nearby Colorado River would indicate that lower river logjams can have an enormous effect on sediment delivery to the estuary[4].

Why: The objective is to examine and understand the effects of logjams on: instream flows, sediment deposition onto riparian lands, sediment transfer to bays, freshwater surges to bays, indicator species guilds (especially riparian species), erosion from extensive channeling cut by water forced overbank.

Where: Lower Guadalupe River below Bloomington and lower San Antonio below Highway 77. Both on-site and comparative studies are likely needed to examine instream biotic and riparian

[4] as documented in "1.4.3 Historical Changes in Inflows" in LCRA et al. 2006 "Matagorda Bay - Freshwater Inflow Needs Study"

conditions on streams with and without logjams. Thus, this may necessitate examination of a nearby large-channel river (such as the Lavaca or Colorado). Alternatively, a comparative study could be accomplished via limited logjam removal in some portion of the lower San Antonio and/or Guadalupe Rivers.

When[5]: a) 8-12 months for a three-component simultaneous assessment of current conditions with regard to instream biota, riparian composition, and sediment retention.

b1) [after a] 12-18 months for comparative studies to analogous stream reach(s) without logjam and synthesis of results.

b2) [after a] if limited logjam removal is necessary to mount the studies, 24-36 months, with first 12 months for site selection and channel clearance operations; then 12-18 months for comparative studies and synthesis of results.

Who: Assessment and comparative studies and synthesis: River Authorities, TWDB, universities and technical consultants. Logjam removal as necessary: River Authority contracts for removal and maintenance.

Cost: a) current condition assessments: $113,000
[basis: instream biotic - 2 FTE university or agency investigator, 4 months at $35 / hr (= $45,000); riparian - 1 FTE university or agency investigator, 6 months at $35 / hr (= $34,000); sediment - 1 FTE university or agency investigator, 6 months at $35 / hr (= $34,000)]

b1) comparative studies & synthesis, nearby stream(s): $168,000
[basis: instream biotic - 2 FTE university or agency investigator, 6 months at $35 / hr (= $68,000); riparian - 1 FTE university or agency investigator, 9 months at $35 / hr (= $50,000); sediment - 1 FTE university or agency investigator, 9 months at $35 / hr (= $50,000)]

b2) additional cost for potential limited removal of logjams. additional $100,000.
[basis: discussions with GBRA on approximate cost for 1-mile removal.]

Total cost: $281,000 - 381,000

[5] note these are study durations, not billable hour / cost estimates.

GSA BBASC Tier 2 Priority
Bays & Estuaries - The Distribution and Abundance of Marsh Vegetation in Relation to Salinity and Elevation in the Guadalupe Estuary Delta

What: The purpose of this study is to determine distribution and abundance of salinity-sensitive wetland plants in the Guadalupe Estuary delta below the southern fork of the Guadalupe River in Refugio County and to monitor the associated salinity regimes. From this data, quantitative status and trends of low-salinity tolerant plants and their salinity tolerance limits would be assessed. This project builds on previous qualitative work by Benton et al. (1984) under TWDB contract, and by the Bureau of Economic Geology, University of Texas at Austin, that reported on wetland plant occurrence/distributions in the Submerged Lands of Texas series for Guadalupe and San Antonio Bay (White et al. 1987). The proposed project would also overlap with the work to be performed in GSA BBASC Tier 2 Priority, Bays & Estuaries – Development of an Inundation and Salinity Model of the Guadalupe Estuary Lower Delta and Adjacent Bays. The objectives of this project are:

1. Determine distribution/ abundance of dominant, wetland vascular plant species along elevation transects in the Guadalupe Delta interior below the south fork of the Guadalupe River, and along the shorelines of Guadalupe and Hynes Bay.
2. Monitor the salinity and inundation (water level) regimes which are associated with these dominant wetland species occurrence and abundance.
3. Develop regression models that correlate dominant wetland plant abundance (production) with inundation and salinity variables so that the plants could be used as focal species to assess freshwater inflow (FWI) needs for the Guadalupe/San Antonio Estuary.

Why: The lower Guadalupe Delta (including Guadalupe Bay) is known to contain a variety of low-salinity sensitive, wetland vegetation (i.e. plant species such as arrowhead, bulrushes, sedges, and aquatic grasses). Because these species are restricted to growth salinities below 2 – 4 psu and represent fixed, stationary habitats, they would comprise good candidates for low-salinity tolerant (so-called oligohaline) focal species in fresh water inflow (FWI) analysis for the Estuary. However, information from Texas on these plants' distribution and productivity, especially in relation to the salinity gradient in the Delta area, is poorly known, making them difficult at this time to analyze as focal species in quantitative freshwater inflow regime assessments (similar to oysters). This Guadalupe Estuary Delta survey to assess the distribution and abundance of marsh vegetation in relation to salinity and elevation is recommended as part of the GSA BBEST Environmental Flows Recommendation Report.

Where: The project area comprises the Guadalupe Delta region below south fork of the Guadalupe River, and also includes Guadalupe and Hynes Bays shorelines. A dynamic salinity gradient in

this region produces the narrow salinity range required by the oligohaline vegetation under certain limited inflow regimes.

How: Project includes three tasks:

1. Surveys of wetland plant distribution on a monthly basis (or bimonthly from November to March), using fixed, defined transects along a tidal elevation gradient. Identify dominant species.
2. Monitoring dominant plant seasonal abundance (biomass) and physico-chemical parameters associated with their occurrence. This project will employ standard plant monitoring methodology at transect sampling sites and should use automated recording instruments for salinity and water levels. Primary locations for bay tide levels and discharge measurements will provide open-bay salinity and water levels during flood periods, as compared to base or low flow periods.
3. Integrating these field-collected data into regression models that relate dominant plant production to freshwater inflow related factors including back-bay salinity and inundation regimes, and corresponding data from the open Guadalupe Bay .

Who: Study to be performed by trained wetlands biologist or botanist (university researcher or consultant/contractor), Mission Aransas National Estuarine Research Reserve (NERR)

When: Two year field study and one year overlapping statistical analysis work (two years total).

Cost: This project could be funded through a joint funding agreement between the TWDB and the Coastal Management Program. The work requires 2-3 trained quantitative ecologists to survey/collect plants, process biomass samples, and maintain water level and salinity meters. Water quality monitoring meters (e.g. datasondes) and water level gages must be maintained, thus this project would best be performed as part of the GSA BBASC Tier 2 Priority, Bays & Estuaries – Development of an Inundation and Salinity Model of the Guadalupe Estuary Lower Delta and Adjacent Bays. Total required funds for the project is $105,000.

TASK	DESCRIPTION	AMOUNT
1.	Field Surveys and Water Level/Salinity Monitoring (2 yrs)	$75,000
2.	Regression Analysis of Plant Production/Inundation/ Salinity	$30,000
3.	Data and Calculations of Plant vs. Salinity Tolerance Limits	
	TOTAL COST	**$105,000**

GSA BBASC Tier 2 Priority
Bays & Estuaries - Habitat Suitability Models for Eastern Oysters, Blue Crabs & White Shrimp

Dependencies: The Habitat Suitability Models is dependent on the Life Cycle Habitat & Salinity Studies for Key Faunal Species

What: Habitat Suitability Models for Oysters, Blue Crabs, & White Shrimp

Why: As identified by the GSA BBEST:

1. Develop basin-wide, multi-parameter Habitat Suitability Models for:
   a) eastern oysters
   b) blue crabs
   c) white shrimp
2. Implement investigation of the location specific requirements of eastern oysters with regard to avoiding the dermo parasite (Dermo).

Part (1a) would be a refinement for the oyster modeling already performed. The salinity suitability curve utilized by BBEST was for whole year average salinity from literature. It may need to be refined for summer and geographic specificity. Other refinements could include additional parameters such as substrate and time-specific curves based on 6-24 months antecedent conditions as indicated by literature addressing cumulative effects of dermo and checks on dermo due to low salinity and low temperature episodes. Parts (1b) and (1c) may be better as a separate undertaking because of still unresolved conceptual issues related to motile species. Studies should involve a principal investigator and expert panel/workshop for conceptual model development.

This Workplan Task would also be heavily informed by results of Tier 1 Priorities: GSA BBASC Priority #3, Bays & Estuaries – *Rangia* Clam Investigations and GSA BBASC Priority #4, Bays & Estuaries – Life Cycle Habitat & Salinity Studies for Key Faunal Species.

Where: Guadalupe and Mission-Aransas Estuaries

When[6]: 1a) Easter Oysters: 18-24 months to complete
1b) Blue Crabs: 9-12 months to complete; not contingent upon 1a
1c) White Shrimp: 9-12 months to complete, not contingent upon 1a
1d) Oysters - Dermo: 12-18 months from initiation

Who: 1) contractor, or university with agency support

[6] note these are study durations, not billable hour / cost estimates.

2) dermo data from TPWD and and university researchers synthesized with salinity and salinity-duration
information based on TPWD, TWDB, GBRA, Mission-Aransas NERR and other sonde data. Synthesis by university or contractor with support from TPWD and Dr. Ray

Cost: 1a) oyster habitat suitability model refinement: $11,000 - $22,000
[basis: 1 FTE university investigator / contractor level for 2-4 months, depending upon scope, at $35 / hr]

1b and c) motile species (blue crab, white shrimp) habitat suitability model development: $33,000
[basis: 1 FTE university investigator / contractor level for 4 months at $35 / hr;
1 FTE agency personnel for1 months at $35 / hr; $5,000 travel & stipends]

1d) Dermo synthesis in range of $67,000 -$100,000
[basis: contractor or university investigator, 1 FTE for range of 12-18 months at $35 / hr]

GSA BBASC Tier 2 Priority
Bays & Estuaries - Development of an Inundation and Salinity Model of the Guadalupe Estuary Lower Delta and Adjacent Bays

Dependencies: The Inundation and Salinity Model of the Guadalupe Estuary Lower Delta and Adjacent Bays study could be dependent on Stream Flow Gaging, Hydrodynamic & Salinity Studies for Key Faunal Species and Distribution and Abundance of Marsh Vegetation in Relation to Salinity and Elevation in the Guadalupe Estuary Delta studies recommended.

What: The purpose of this study is to evaluate inundation and salinity dynamics of the lower portion of the Guadalupe Estuary Delta over a range of hydrologic conditions. Based on land surface topography and water monitoring data, an inundation and salinity model would be developed. This project builds on previous work by the TWDB that evaluated salinity exchange and water level changes in Texas Bays. The objectives of this work are:

1. Collect flow and water level data at control points in the lower Delta lakes and interior marshes, and in the open part of Guadalupe and Hynes Bay above San Antonio Bay proper. Obtain and analyze Light Detection and Ranging (LIDAR) elevation data.
2. Evaluate exchange of water using monitored water level and salinity measurements over tidal cycles and inflow pulses.

3. Modify and apply a suitable model (perhaps TxBLEND or SELFE[7]) that correlates inflow from the Guadalupe River, with salinities and water levels between the open Guadalupe Bay and the interior regions of the lower Guadalupe Delta.

Why: The lower Guadalupe Delta consists of the old distributary portions below the South fork of the Guadalupe River. This portion of the Guadalupe Delta has been gradually cut off from the main flow of the Guadalupe River since Traylor Cut was formed in 1935. Freshwater inflows (also containing nutrients and suspended sediment) have been deprived from this lower delta region, and it has been eroding and subsiding since. Although this lower Delta interior contains considerable low salinity wetlands, and is thought to function as nursery habitat for estuarine organisms, hydrologic dynamics remain poorly defined, and the tidal inundation of this backmarsh area has not been characterized. If a shallow marsh inundation model is developed, the need for freshwater inflows in supporting the biological productivity of such wetland areas can be included in BBASC adaptive management of the Guadalupe/San Antonio Bay system, as well as other Texas estuaries. Currently, this important lower Delta area is not included in assessing freshwater inflow needs of estuaries as part of the SB3 process.

Where: The lower Guadalupe Delta consists of the old distributary channels and interior lakes below the South fork of the Guadalupe River. This portion of the Guadalupe Delta has been cut off from the main flow of the Guadalupe River, which now empties inflows and sediments primarily into Mission Lake.

When: 30 months from project initiation; 18 months for model design and development, analysis of LIDAR data, and gathering of sufficient up-to-date water level and salinity data; 12 months to calibrate and validate model.

Who: This project may require multiple entities working in collaboration on various aspects of the project. Based on previous experience modeling coastal wetland areas and estuaries, the Texas Water Development Board (TWDB) is the logical candidate to carry-out the project or, if necessary, coordinate with collaborating subcontractor(s). A few groups (e.g. Harte Research Inst., UT-Bureau of Economic Geology) have considerable expertise in the area of LIDAR data analysis. GCD's or GMAs may also be likely partners.

Cost: This project requires three distinct phases: (1) Acquiring LIDAR data of land surface topography/elevation within the lower Guadalupe Delta; (2) Monitoring of salinity and water levels within the Guadalupe Deltic Marsh and nearby upper Guadalupe and Hynes Bays; and, (3) Development of an inundation and hydrodynamic model which includes the Guadalupe Delta.

[7] SELFE: A semi-implicit Eulerian-Lagrangian finite-element model for cross-scale ocean circulation

It may be possible to obtain existing LIDAR data for use in development of the model collection effort could be significant. The study will require one- to two-years of field data collection for salinity and water surface elevation in the study area. This effort will require instruments to be purchased (or borrowed) for long-term deployment at strategic locations and to be serviced and maintained by field staff. Data collection also will require processing and quality assurance. An estimated cost for this portion of the project is $75,000.

Development of a model of wetland inundation will require extending an existing bay hydrodynamic and salinity transport model (*e.g.*, TxBLEND) to include the delta area *or* developing a new bay-delta model using another hydrodynamic model (*e.g.*, SELFE). The estimated cost for this effort is $125,000.

TASK	DESCRIPTION	AMOUNT
1.	Obtain Lidar Data for Study Area	
2.	Salinity Collection and Water level Measurements	$75,000
3.	Model Development	$125,000
	TOTAL COST (min)	**$200,000**

TIER 3 Priorities

***Disclaimer: Studies listed are grouped by type of study, not in any prioritized order.**

GSA BBASC Tier 3 Priority
Instream Flows – Groundwater Studies

Impacts of Groundwater Withdrawals on Upper Basin Streamflows

What: Streamflows in the Guadalupe/San Antonio basin are impacted by complex and poorly understood connections between groundwater systems and surface water, and these groundwater systems are under increasing pressure from expanding uses for commercial, industrial, and domestic activities. The primary groundwater system in the upper basin is the Edwards-Trinity (Plateau) Aquifer, which is projected to be one of the most stressed aquifers in the State over the next 50 years, with large areas seeing steep drops in water levels (TWDB Report 353). Numerous springs and seeps that emerge from the Trinity Aquifer feed Hill Country streams and form a component of base and subsistence flows, or they may contribute to Edwards Aquifer recharge and in turn becomes Edwards Aquifer springflow, one of the most important components of instream flows downstream of the Balcones escarpment. There is also significant recharge to the Edwards Aquifer from the Trinity by interformational flow, with estimates ranging from 59,000 af/yr to over 300,000 af/yr. At the same time, GCDs in the Upper Basin are working to develop management plans for their Modeled Available Groundwater (MAG), which are quantities derived from

consideration of the District's Desired Future Conditions (DFCs) in the TWDB's Groundwater Availability Models.

In the river valleys of the Guadalupe/San Antonio basin, two types of sedimentary deposits influence instream flows by acting as a mechanism for significant flow to and from the river channel. Alluvial deposits are recent or Holocene age deposits associated with floodplains of streams and tributaries, composed of unconsolidated material that is chiefly gravel, sand, and silt, and they yield small to large quantities of fresh to slightly saline groundwater. Terrace deposits are scattered remnants of Pleistocene age that occur at higher elevations than alluvial deposits, usually 20 to 50 feet thick and composed of gravel, sand, silt, and clay, sometimes cemented with calcium carbonate, and yield small to moderate amounts of fresh to moderately saline groundwater.

Given all of these complex factors and uncertainties, it may be difficult to gage the potential effectiveness of BBASC strategies to protect environmental flows and expected attainment frequencies for such flows unless predictions can be made regarding the impacts of groundwater use. This will likely involve hydrologic data collection and a modeling approach, in which a number of scenarios are evaluated to estimate the resulting contribution to upper basin streamflows from groundwater systems when various permutations of the factors described above are taken into account. For the hydrologic data collection, it will be imperative to understand spring discharge from minor springs in the upper basin. As such, it is anticipated that gages at select upper basin locations will be implemented to monitoring spring flow over time. In addition to hydrologic studies, it will be necessary to inventory and/or estimate current and future withdrawal volumes from these formations, evaluate regulatory constraints, and construct a more complete picture of instream flows that will result from the interaction of all factors. Finally, in an attempt to evaluate all water uses, this study would quantify the volume of domestic and livestock groundwater use in each river basin.

Why: In order to devise and implement effective management strategies aimed at ensuring attainment of recommended flow regimes, it will be necessary to gain a better understanding and a predictive capability regarding 1) the interplay and impacts of hydrologic factors; and 2) the impact of alluvial gravels on instream flows, along with current and potential withdrawals of water.

Where: Portions of the Upper Basin where groundwater use may impact streamflows (mostly north of the Edwards Aquifer recharge and artesian zones) and where groundwater drawn from alluvial aquifers may impact streamflows.

When: One year study to evaluate existing data. Two to three year study if new hydrologic studies are commissioned.

Who: River Authorities, USGS, Southwest Research Institute, GMA's, GCD's, universities, and technical consultants

Cost: To be determined, and will be variable depending on the extent and complexity of the desired analysis. For example, a low-dollar approach might involve using only existing reports and data on connectivity and water transfer between groundwater systems, or if funding is available it might be preferable to conduct a fresh evaluation and narrow down the range of volumes estimated by previous studies.

GSA BBASC Tier 3 Priority
Instream Flows – Water Quality Monitoring

TCEQ Clean Rivers Program Water Quality Monitoring

What: Per Senate Bill 818 and under contract with the TCEQ, SARA and GBRA administer and execute the Clean Rivers Program (CRP) Monitoring for their respective basins. The program has been in place since 1991 and is designed to monitor general water quality, compile a long term comprehensive data base, detect trends, identify pollutant sources and aid in water quality planning. The CRP is funded by fees charged to wastewater dischargers by the TCEQ. Due to the long history of the CRP, its excellent quality assurance / quality control protocols, extensive and accessible data base, and consistency across the State, it is recommended that the CRP be continued. However, it is also recommended that the CRP monitoring regime be adjusted as necessary to follow the guidance provided in the TIFP Technical Overview (TIFP 2008). Sampling sites should include all 16 stream locations that were evaluated by the BBEST and adjust biological collection protocols to support the development of Habitat Suitability Criteria (HSC).

In order to augment the CRP monitoring and data base, SARA and GBRA conduct supplemental stream monitoring programs. These programs include long-term monitoring of established sites to identify areas of concern and intensive surveys that focus on identifying potential sources contributing to elevated bacteria levels. In addition to water quality and bacterial monitoring, SARA and GBRA conduct biological monitoring with routine fish and benthic macroinvertebrate collections as well as an annual habitat assessment at each monitoring site. The biological data collected by SARA and GBRA provides fish and benthic macroinvertebrate community composition data that can be analyzed to identify aquatic ecosystem trends and document changes. It is recommended that biological monitoring in the San Antonio and Guadalupe River basins be adjusted to include all 16 sites analyzed by the BBEST, and that similar water quality and biological monitoring be initiated in the Mission River. By building upon an already successful monitoring program, the BBASC will be able to take advantage of existing funding sources, experienced personnel, quality assurance protocols, standard operating procedures, established databases and in kind

services. The resulting effort would be a very comprehensive monitoring program that can be adjusted and implemented without unnecessary delays. The biological sampling component of the CRP will be closely coordinated with the biological monitoring proposed in GSA BBASC Tier 2 Priority, Instream Flows – Biological Sampling and Monitoring. To the degree practicable, CRP fish collections will include a mesohabitat component in order to use this data to supplement HSC development described in GSA BBASC Tier 2 Priority, Instream Flows – Biological Sampling and Monitoring.

Why: Application of the CRP monitoring augmented with biological collections and habitat assessments provides a comprehensive data base that can support HSC. Data can be evaluated to track the ecological condition of the system over time to document potential ecosystem trends and changes that would support adaptive management.

Where: San Antonio, Guadalupe and Mission River Basins at all 16 stations with BBASC environmental flow recommendations.

When: To begin September 2013 to coincide with the CRP biannual contracting period and continue for six years. It is recommended that water quality sampling occur at all 16 sites bimonthly, and biological collections at all 16 sites be conducted twice per year during the index period (March through October).

Who: SARA, GBRA, TPWD, TCEQ, TWDB, and technical consultants

Cost: FY2012 and 2013 CRP funding from the TCEQ is $ 418,806 for SARA and $286,682 for GBRA for the two year contracting period. The CRP is augmented with additional river authority funded monitoring; SARA provides $139,761 towards additional support monitoring and GBRA provides an additional $71,360 per two year contracting period. The estimated cost for biological collections and habitat assessment at 16 sites twice per year is $153,600 over a two year period. The total estimated cost for the water quality and biological monitoring is approximately $1,070,209 per two year period. The total estimated cost for the recommended six year study period is $3,210,627.

If the CRP is funded and continues until 2019, it is assumed that CRP monitoring can be adjusted to support the work plan for adaptive management and CRP funding would defray some of the monitoring costs. Traditionally both SARA and GBRA have contributed funds and in kind support towards additional monitoring and studies; however there are no assurances that additional SARA and GBRA funding will be available in the future. In order to accomplish the water quality and biological sampling outlined in this scope, additional funds or in kind support from TCEQ, TPWD, TWDB, TSSWCB, municipalities and stakeholder agencies will need to be identified.

Real-time Monitoring System

What: The San Antonio and Guadalupe River Basin Real Time Monitoring (RTM) Network was developed by the TCEQ in cooperation with SARA, GBRA, CPSE, SAWS, and other local government entities and businesses to provide near-real time monitoring of water quality and enable users to identify, manage and minimize pollutants. This network was established for monitoring water quality concerns due to: point and non-point source pollution carried in storm water runoff, point source discharges, sewer overflows, accidental toxic spills, growth and development of industrial complexes, urbanization and other impacts to the environment. The parameters measured and recorded are dissolved oxygen, temperature, pH, and conductivity, (and turbidity in the Guadalupe River Basin). The main objective is to monitor normal conditions of the receiving streams and collect data to document long term trends in the water quality. The goal is to develop a RTM system that traces the continuity of water quality from ground water through spring emergences, through the Metropolitan areas, and includes tributaries that contribute flow towards San Antonio Bay. Currently there are 14 established surface water RTM sites within the Guadalupe and San Antonio basins, however only three RTM sites (Sandies Creek near Westhoff, Medina River at San Antonio, and San Antonio River near Elmendorf) are located where the BBEST analysis was conducted. It is recommended that the RTM system be expanded to include all 16 sites that were analyzed by the BBEST to develop their Instream flow recommendations.

Why: To provide near-real time water quality data online to water resource agencies, water managers, utility operators and the public in an effort to identify, manage and minimize pollutants. The RTM network serves as an online sentinel that can alert agency scientists of developing water quality problems.

Where: Guadalupe, San Antonio and Mission River basins

When: To begin in October 2013 and continue for 10 years

Who: By cooperative agreements with the USGS and funding support from TWDB, TPWD, TSSWCB, TCEQ, GBRA, SARA, CPSE / SAWS, and other concerned stakeholder agencies

Cost: Installation per RTM site $35,000 (FY2012), annual per site maintenance cost $44,000 (FY2012). Therefore, the cost of installing an additional 13 sites would be $455,000, and annual maintenance costs for all 16 sites would be $704,000.

GSA BBASC Tier 3 Priority
Instream Flows – Invasives

Impacts of Invasive Species

What: Ecohydrological data is limited for riparian communities within the GSA Basin; therefore, evapotranspiration (ET) rates for native and non-native riparian vegetation need to be researched in locations that represent the ecoregional diversity of the basins and where other riparian, hydrologic, and geomorphic data are being collected. The GSA BBEST and SB2 Interim Progress reports address riparian community water needs; however, water use by riparian communities is minimally discussed. Additionally, the influence of non-native vegetation on the regional water budget is difficult to quantify due to limited information on the annual rates of ET in native and non-native riparian communities in the GSA basin. Development of invasive species within riparian corridors has been documented to have ecohydrologic consequences, including a decrease in the water table as well as reduction in water yields (Huddle et al. 2011). The temporal, spatial, and total volume of water used by riparian vegetation varies depending on species composition, ecotype, and age as well as underlying biotic and abiotic factors (Friedman et al. 2005). Non-native woody species alters native riparian composition, which ultimately influences the site water balance and the amount of water available to native riparian vegetation (Huddle et al. 2011).

Evapotranspiration varies by riparian structure and composition, especially with increases or decreases in species density and invasive species. An understanding of both native and invasive species is necessary to quantify benefits of management strategies. Study sites should be located along the riparian corridor and at representative locations within the watershed at a scale that is representative of each ecoregion in the basin. Models should be developed that estimate the ET rates based on plant functional type (obligate wetland, shallow-rooted riparian, deep-rooted riparian, transitional riparian, upland) and water table depth can potentially integrate physiological measurements across larger scales (Baird and Maddock 2005). This effort will be closely coordinated with recommended GSA BBASC Tier 3 Priority, Instream Flows – Groundwater Studies: *Impacts of Groundwater Withdrawals (from Alluvial Gravels and on Upper Basin Streamflows* and GSA BBASC Tier 3 Priority, Instream Flows – Water Quality Monitoring, to maximize data collected during those riparian focused efforts.

Why: The development of management strategies aimed at ensuring attainment of recommended flow regimes can be informed by understanding the hydrologic budget of riparian communities. Recognized water use by native and non-native riparian communities should be understood as a key component for improving water management options and/or restoration efforts.

Where: San Antonio, Guadalupe, Mission and Aransas River basins

When: Two to four years

Who: TWDB, TPWD, universities and technical consultants

Cost: To be determined

GSA BBASC Tier 3 Priority
Bays & Estuaries – Nutrient Load & Concentration Monitoring

What: Nutrient load and concentration monitoring

Why: As described in Section 4 of the GSA BBEST Environmental Flows Recommendation Report and Section 7.1.2.3 an increased nutrient load that may accompany freshwater inflows can result in serious degradation of the estuarine environment through the increase in the frequency of hypoxic (low oxygen) events and through the stimulation of harmful algal blooms that may result on fish kills. In addition, increased inputs of major nutrients (mainly Nitrogen, but also Phosphorous) may result in increased algal growth which decreases water clarity and reduces the amount of seagrasses in these estuaries.

Where: The Mission-Aransas Estuary is monitored for nutrients on a monthly basis at 5 locations by the Mission-Aransas National Estuarine Research Reserve (NERR), as part of their standard System-Wide Monitoring Program. The reserve staff is also measuring nutrient load from the Mission and Aransas Rivers with funding from the US Environmental Protection Agency. Similar monitoring in San Antonio Bay is needed. An intensive study of freshwater inflows, nutrient concentrations and biological responses in San Antonio Bay was carried out during 1987-88 by the University of Texas Marine Science Institute with funding from the TWDB. The study period included a period with a large pulse of freshwater into the bay. The data from the proposed study would provide a useful comparison to current conditions.

How: Water samples for nutrient analysis should be collected on a monthly basis from the combined flow of the San Antonio and Guadalupe Rivers that enters the head of San Antonio Bay, and from a minimum of an additional three sites along the salinity gradient of San Antonio Bay. When water samples are collected, profiles of water column temperature, salinity, oxygen concentration and chlorophyll concentration should also be collected at each site.

When: Nutrient collection should occur over at least a 12 month period, but if funds allow, a 2 year study would be preferable.

Who: Samples could be collected by TPWD, staff of the Mission-Aransas NERR or GBRA under the CRP. Sample analysis can be performed by the Mission-Aransas NERR, who already performs analysis of nutrient samples from Aransas and Copano Bays.

Cost: If samples can be collected by TPWD or other agency without cost, nutrient analysis for four locations would cost $180 per month (three replicates per station x 4 stations x $15 per sample), or $2,160 per year. If Mission-Aransas NERR collects samples, additional costs of $250 per month would be needed to cover the cost of boat use fees and fuel, or an additional $3,000 per year. Personnel costs would be covered by TPWD and/or Mission-Aransas NERR personnel.

GSA BBASC Tier 3 Priority
Bays & Estuaries - Role of Cedar Bayou in the Exchange of Water and Meroplankton to the Guadalupe Estuary

Dependencies: The Role of Cedar Bayou in the Exchange of Water and Meroplankton to the Guadalupe Estuary study could be dependent on the Hydrodynamic & Salinity Modeling Improvements study.

What: Scouring of Passes

Why: The coastline of Texas has a nearly continuous set of barrier islands that separate the coastal bays and estuaries from the open Gulf of Mexico. The number of passes or points of seawater exchange between coastal bays and the open Gulf are limited. These passes are maintained by the natural exchanges of water between the bays and Gulf that result from freshwater inflows and tidal exchange. This water movement removes sediments from the passes to allow for the free exchange of water. Since the construction of several deep water passes that are dredged and maintained to depths needed by large sea-going vessels, the number of natural passes have decreased, since most of the water exchange tends to occur through the path of least resistance in the deeper channels rather than traveling across broad bays and through shallower natural passes. Many estuarine species of finfish, shellfish and other ecologically important species move between the bays and the Gulf of Mexico through these passes, and their life-cycles are dependent on these points of exchange.

Where: The best known example of a natural pass that remains within the Guadalupe-San Antonio Bay and Basin region is Cedar Bayou, a natural pass that has historically separated San Jose and Matagorda Islands. This pass has been closed by natural sedimentation several times, and has been re-opened through manmade and natural processes on several occasions. The pass closed in early 2008 and has remained closed since. The Army Corp of Engineers has

recently issued a permit that would allow for re-opening of Cedar Bayou once a funding source has been found.

How: When Cedar Bayou is re-opened, a study is needed to determine the rates of water exchange through the opening, the ability of this flow to remove sand at the Gulf exchange point to keep the pass open, and to quantify the exchange of early life history stages of fish and shellfish through this pass, to help quantify its value to the regional estuarine ecology.

Who: Studies could be carried out by state agencies (TPWD, TWDB) and/or university/state partnerships such as the Mission-Aransas NERR, or through an RFP through Texas Sea Grant to university investigators.

Cost: $75,000 [basis: 1 FTE for 12 months over 2 years plus field work expenses]

GSA BBASC Tier 3 Priority
Bays & Estuaries – Evaluation of Sediment Transport Affecting the Guadalupe Estuary Delta

What: This study aims to evaluate sediment transport and loading entering the Guadalupe Estuary, primarily into Mission Lake, over a range of hydrologic conditions. This is particularly important during peak inflow periods, when the largest pulses of sediments are brought in that contribute to accretion of a prograding delta system in Mission Lake. This new sediment accretion should offset the potential sediment that is lost to the lower, older Delta which is undergoing subsidence and decay. This project builds on previous work in Guadalupe Estuary by TWDB and the Bureau of Economic Geology, University of Texas at Austin, and a current joint project by the USGS /TWDB that is evaluating sediment input of the Trinity River into Trinity Bay. The objectives of this work are:

1. Collect flow and sediment transport data in the Guadalupe River above Mission Lake, and calculate loadings to Mission Lake proper with its prograding delta.
2. Evaluate the range in sediment concentrations over major inflow hydrographs to determine inflow vs. sediment loading relationships.
3. Determine from in situ field measurements, the current rate of subsidence occurring in the lower (older) portion of the Guadalupe Delta, and calculate whether current sediment diversion into Mission Lake offsets this subsidence.

Why: Sediment delivery from the Guadalupe River to the estuary is necessary to maintain the shallow-water marshes, especially in the upper estuary, deltaic reaches. Concentrations of riverborne suspended sediment are affected by natural conditions (soil erosion and streambed re-suspension) and can also be affected by upstream human activities (construction, timber harvesting, certain agricultural practices, and hydraulic alteration). The

lower Guadalupe Delta consists of abandoned distributary channels and lakes below the South fork of the Guadalupe River. This portion of the Guadalupe Delta has been gradually cut off from the main flow of the Guadalupe River since Traylor Cut was formed in 1935. Freshwater inflow (also containing nutrients and suspended sediment) has thus been deprived from this lower delta region and emergent marshes have been eroding and subsiding. Sediment input from Traylor Cut now empties into Mission Lake, where a new delta is prograding. Although the lower, old Delta contains considerable low salinity wetlands in the interior area, which are thought to function as important nursery habitat for estuarine organisms, sedimentation dynamics remain poorly defined. This area is steadily being lost as marshlands become submerged, and the amount of sediment deposition required to maintain shallow-water backmarsh areas has not been characterized. Because these loadings are unknown, freshwater inflow estimates to satisfy sediment loading requirements have not been accurately included in the current SB3 inflow regimes.

Where: The lower Guadalupe delta consists of the old distributary channels and interior lakes below the South fork of the Guadalupe River. This portion of the Guadalupe Delta has been cut off from the main flow of the Guadalupe River since inflows and sediments now empty primarily into Mission Lake. Sediment input into Mission Lake via Traylor Cut is contributing to a new prograding delta there.

How: Sediment Collection and Discharge Measurements: USGS stream gage No. 8188800 on the Guadalupe River near Tivoli, TX would be the primary location for suspended sediment sample collection and discharge measurements. This project could employ a methodology similar to that developed for the project completed on the Trinity River titled, *An Evaluation of the Variability of Trinity River Nutrient and Sediment Concentration into Galveston Bay during High Flow*, and would identify changes in sediment concentrations during flood periods, as compared to base or low flow periods. This task should follow USGS procedures for discharge measurements, and sediment (total suspended and size fractionation) collection that exist at the commencement of this study. Emphasis would be placed on high-flow events. The attenuation/backscatter signal of an acoustic Doppler velocity meter (ADVM) could be used to evaluate the relation between backscatter and sediment concentration. An option is that an Optical Backscatter Sensor (OBS) turbidity probe could be installed with the instrumentation at Tivoli. This would include a recording current meter, so the gage is set up for digital measurement and data logging. Blucher Inst/TCOON has had much experience with OBS technology for measuring Total Suspended Solids (TSS) in the Coastal Bend bays. An automatic measurement would greatly relieve the problem of analyzing water-sample determinations, especially sample collection during floods.

Subsidence measurements in the old Delta would be performed according to methods in earlier studies by University of Texas-Bureau of Economic Geology (UT-BEG) or by Harte Research Institute (HRI).

When: This would be a 6 year study, done in 2 phases. The first phase would be 3 years with at least 3 years of actual in situ field sampling of sediment inputs, plus subsidence measurements during 2 of these years. The second phase would be another 2-3 years, including field sampling and development of a numerical sediment transport model.

Who: The sediment transport/loading project would need to be funded through a joint funding agreement between the USGS and the TWDB, as currently performed in Trinity and Matagorda Bays. The sampling and measurement of sediment discharge requires a crew of 2-3 trained Hydrologists (or Hydrographers) to operate machinery, process samples, and measure stream flow. Analytical services for sediment sampling could be provided by the USGS National Water Quality Lab. Blucher Institute should be part of the automated recording measurements.

A Subsidence analysis project in the old Delta could be conducted by an experienced contractor such as University of Texas Bureau of Economic Geology or the Harte Research Institute at Texas A&M University-Corpus Christi.

Cost: Total cost is $650,000 over 6 years. Required funds for the sediment transport project are estimated at $500,000 total with USGS contributing Cooperative Water Program funding and the TWDB contributing from its Research and Planning Fund. This funding is divided up into 2 phases. Subsidence study costs are estimated at $125,000 and a contractor (e.g. HRI, UT-BEG) would need outside funding to support their work.

TASK	DESCRIPTION	AMOUNT
1.	Sediment Transportation	$500,000
	Phase 1 – Three Years	$250,000
	Phase 2 – Three Years	$250,000
2.	Subsidence Study	$150,000
	TOTAL COST	**$650,000**

GSA BBASC Tier 3 Priority
Bays & Estuaries – Sea Level Rise Associated with Climate Change

What: Sea Level Rise Associated with Climate Change

Why: Identified by the GSA BBASC. Threats to the estuaries are predominantly in form of:

1. Threats to barrier islands integrity with implications for large changes in circulation and salinity;
2. Potential inundation and loss of wetlands

How: 1a) synthesis of existing information on range of predicted sea level rise;
1b) assessment of vulnerability / development of scenarios of change;
1c) applications of hydrodynamic circulation-salinity models;
2a) assessment of vulnerability via field assessment of vegetation species and communities GSA BBASC Tier 2 Priority, Bays & Estuaries – Development of an Inundation and Salinity Model of the Guadalupe Estuary Lower Delta and Adjacent Bays
2b) literature synthesis of salinity/inundation requirements and tolerances of vegetation species GSA BBASC Tier 2 Priority, Bays & Estuaries – The Distribution and Abundance of Marsh Vegetation in Relation to Salinity and Elevation in the Guadalupe Estuary Delta
2c) predictions by coupling 2a & b with insights and predictions from 1.

When[8]: 1a) 4-6 months to complete
1b) 2-3 months after 1a;
1c) 6-8 months after 1b
2a) 4-6 months to complete
2b) 4-6 months after 2a;
2c) 6-8 months after 2b

Who: 1a) literature synthesis by university investigator;
1b) workshop with experts, convened by TPWD or TWDB;
1c) TWDB or contractor
2a) field investigations by private contractor(s) or university(ies);
2b) same as 2a);
2c) TWDB or contractor

Cost: 1a) literature synthesis $17,000
[basis: 1 FTE university investigator for 3 months at $35 / hr]
1b) vulnerability assessment / scenario workshop- $11,000
[basis: 1 FTE agency personnel for1 months at $35 / hr; $5,000 travel & stipends]
1c) model applications - $34,000
[basis: 1 FTE agency or contractor for 6 months at $35 / hr]
2a) field vegetation assessment $26,000
[basis: 1 grad student FTE for 3 months at $20/hr and 1 FTE supervisory level for 3 months at $35 / hr]
2b) literature synthesis -$17,000
[basis: 1 FTE university investigator or contractor for 3 months at $35 / hr]
2c) wetlands change predictions - $25,000
[basis: 1 FTE university or contractor for 4 months at $35 / hr

[8] note these are study durations, not billable hour / cost estimates.

Section 5 Appendix

Table 6.0-1. Work Plan Subjects for Adaptive Management – Instream Flows (Rivers, Streams, Tributaries, and Riparian Zones)

ID#	Subject	Primary BBEST Member(s)	Flow Regime Component			Hydrology	Source(s)
			Subsistence	Base	Pulse		
1	Impacts of Groundwater Use on Upper Basin Streamflows	Eckhardt				X	BBASC
2	Exempt Uses of Surface Water	Magin, Gonzales				X	BBASC
3	Riparian Diversions for Domestic & Livestock (D&L) Uses	Magin, Gonzales				X	BBASC
4	Effects of Conservation & Drought Management	Eckhardt				X	BBASC
5	Predictability in Surface Water Permitting	Vaugh				X	BBASC
6	Logjams & Related Flooding, Durations & Effects on Habitat	Vaugh			X		BBASC
7	Impacts of Invasive Species	Smith			X	X	BBASC
8	Impacts of Groundwater Withdrawn from Alluvial Gravels	Eckhardt	X	X		X	BBASC
9	Instream & Riparian Sediment Deposition	Hardy			X	X	BBASC
10	USGS Streamflow Gaging & Water Quality Monitoring	Magin, Gonzales	X	X	X	X	BBEST
11	TCEQ Clean Rivers Program Water Quality Monitoring	Gonzales, Magin	X	X	X		BBEST
12	Real Time Water Quality Monitoring System	Gonzales, Magin	X	X	X		BBEST
13	Biological Sampling & Monitoring	Bonner	X	X	X		BBEST
14	Texas Instream Flows Program	Vaugh	X	X	X	X	BBEST
15	Edwards Aquifer Recovery Implementation Program	Vaugh	X	X		X	BBASC/BBEST
16	Environmental Flow Collaboration Forum	Smith	X	X	X	X	BBEST
17	Geomorphic Studies & Monitoring	Hardy			X	X	BBEST
18	Riparian Vegetation Mapping & Monitoring	Smith			X		BBEST
19	Groundwater Monitoring in the Riparian Corridor	Smith	X	X	X	X	BBEST
20	Fish Community Use of Floodplain Environments	Bonner			X		BBEST
21	Expanded Gauge and Onsite Studies to Improve Understanding of Lowest Stretches of San Antonio and Guadalupe Rivers		X	X	X		BBASC

Table 6.0-2. Work Plan Subjects for Adaptive Management – Bays and Estuaries

ID#	Subject	Primary BBEST Member(s)	Flora/Fauna	Sediment	Nutrients	Inflow	Source(s)
1	Scouring of Passes & Impacts on Estuarine Ecology	Buskey	X				BBASC
2	Marine Wetland Effects on Commercial & Recreational Fishing	Pulich	X				BBASC
3	Impacts of Levees	Vaugh		X		X	BBASC
4	Impacts of Saltwater Barrier	Vaugh		X		X	BBASC
5	Sediment Transport Affecting Guadalupe Delta	Pulich		X		X	BBASC/BBEST
6	Sea Level Rise Associated with Climate Change	Johns				X	BBASC
7	Hydrodynamic & Salinity Modeling Improvements	Johns				X	BBEST
8	Bay & Marsh Salinity & Water Level Data Collection & Monitoring	Johns				X	BBEST
9	Diversion & Return Flow Data for Freshwater Inflow Estimates	Vaugh				X	BBEST
10	Rangia Clam & Eastern Oyster Investigations	Johns, Buskey, Holt	X				BBEST
11	Delta Inundation & Salinity Modeling	Pulich				X	BBEST
12	Life Cycle Habitat & Salinity Studies for Key Faunal Species	Buskey, Pulich, Holt	X				BBEST
13	Salinity Sensitive Plant Monitoring	Pulich	X				BBEST
14	Habitat Suitability Models for Oysters, Blue Crabs, & White Shrimp	Johns	X				BBEST
15	Nutrient Load & Concentration Monitoring	Buskey			X		BBEST