Work Plan
For
Adaptive Management

Prepared for
Brazos River and Associated Bay and Estuary System
Basin and Bay Area Stakeholders Committee (BBASC)

July 2013
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List of Abbreviations

ALM	**Aquatic Life Measurement (Protocols)**
BRA	**Brazos River Authority**
COE	**U.S. Army Corps of Engineers**
CRP	**Clean Rivers Program**
DFC	**Desired Future Conditions**
EFR	**Environmental Flow Recommendations**
EQIP	**Environmental Quality Incentives Program**
GMA	**Groundwater Management Area**
HGAC	**Houston Galveston Area Council**
NRCS	**U.S. Department of Agriculture Natural Resources Conservation Service**
SAC	**Science Advisory Committee**
SOW	**Scope (s) of Work**
SWQM	**Surface Water Quality Monitoring (team)**
TCEQ	**Texas Commission on Environmental Quality**
TESCP	**Temporary Erosion and Sediment Control Plan**
TIFP	**Texas Instream Flow Program**
TPWD	**Texas Parks and Wildlife Department**
TSS	**Total Suspended Solids**
TWDB	**Texas Water Development Board**
USGS	**U. S. Geological Survey**

1.0 Work Plan Purpose

Senate Bill 3 (SB3) of the 80th Texas Legislature was written to create a basin-by-basin process for developing environmental flow standards. SB3 requires the creation of a "work plan" to facilitate the adaptive management of the environmental flow standards adopted. The SB3 offers the following language for timing of and what components should be incorporated in the work plan.

Section 11.02362 (p) In recognition of the importance of adaptive management, after submitting its recommendation 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 recommendation, environmental flow standards, and strategies, to occur at least once every 10 years;

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

(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 by the commission, and the strategies to achieve those standards.

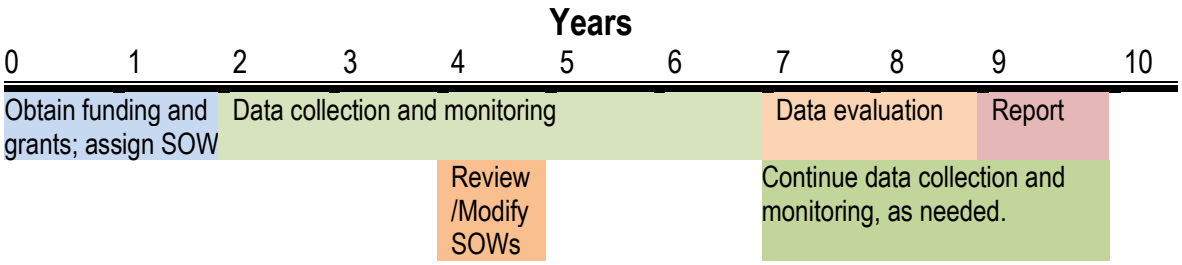
The Brazos River and Associated Bay and Estuary System Basin and Bay Area Stakeholders Committee worked (Brazos BBASC) to develop a Work Plan for Adaptive Management (work plan). After review by the BRAZOS BBASC and Brazos River and Associated Bay and Estuary System Expert Science Team (Brazos BBEST), a final Adaptive Work Plan will be prepared for submittal to the Environmental Flows Advisory Group (EFAG) for approval.

2.0 Brazos BBASC Timeline for Environmental Flow Recommendations

2.1 Periodic Review

Brazos BBASC recommends that the periodic review *"of the basin and bay environmental flow analyses and environmental flow regime (EFR) recommendation, environmental flow standards, and strategies"* **occurs at least once every 10 years**.

The Brazos BBASC has recommended the following time line for the periodic review:



1st and 2nd years
It is estimated that two years will be needed to evaluate recommendations in the work plan; obtain the necessary funding and grants for studies and monitoring; and to determine who will perform work.

2nd through 7th years
Begin studies and recommended monitoring in work plan. Based on the recommended seasonal collection of data for some of the studies included in the work plan, at least five years of data should be collected, thus, providing five data points for statistical analyses.

After the first two years of modeling and data collection, members of the BBASC and BBEST should reevaluate each recommended study and monitoring scope of work (SOW). This will allow modifications to be made to the SOW to ensure each item of concern, data gap, or data requirements for environmental flow regime models are adequately addressed.

7th through the 9th years
It is projected that two years will be required for evaluating data. Some additional monitoring may be necessary for validation or to fill any data gaps that may have occurred.

10th year
The last year of the review cycle will be used to prepare, review, and submit report summarizing the data evaluation, review the environmental flow regime recommendations, and address future environmental flow standards, and strategies.

2.2 Schedule for EFR validation

The Brazos BBASC further recommends maintaining a ten 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 by the commission, and the strategies to achieve those standards"*.

The ten year review cycle will begin at the TCEQ adoption of the environmental flow standards for the Brazos River Basin. The proposed ten year review period was incorporated into this Work Plan with the assumption that the TCEQ will approve the recommended review schedule.

In its Work Plan Guidance, the Science Advisory Committee for Environmental Flows (SAC) suggested this periodic process would *"confirm or refute that the recommended standards are protective of a sound ecological environment".* It is anticipated that new information may be evaluated for adaptive management as it becomes available, as stated in the SAC Work Plan Guidance, *"and evaluation of the standards and implementation strategies is anticipated to be a continuing process".*

Consideration shall be given to having an annual BBASC stakeholders' meeting to review status of projects and funding.

3.0 Monitoring and Research Recommendations for Adaptive Management

As required by the SB3 adaptive management directive the approved flow regime will be reassessed periodically and adjusted as needed in light of new data and improved understanding.

The Brazos BBEST report in Section 8 suggested that "A successful adaptive management process includes four basic steps, (1) identify data gaps and what studies are necessary to fill the data gaps, (2) secure funding and resources to implement research and monitoring, (3) conduct research and monitoring and assess results in relation to the environmental flow regime, (4) and develop mechanisms to refine the flow regime and associated implementation strategies."

A Work Plan was prepared to address the first step using Brazos BBEST recommended list of monitoring, studies, and activities deemed appropriate to better support, validate, and adaptively manage environmental flow standards in Section 8 of their Report; and the Brazos BBASC identified Work Plan Items areas deemed appropriate for monitoring, studies, and activities in Section 5, page 52, of their Recommendations Report.

The items addressed in this Work Plan are outlined in Table 1.

Table 1
Recommend Studies for Adaptive Management

Report	Item	Priority	Recommended Study
BBEST 8.1.1.1	3.1.1	1	Continue cooperative funding agreements for stream flow gauging stations into the future, especially for the 20 focal reaches evaluated in this report.
BBEST 8.1.3.1	3.1.2	1	Continue the on-going routine water quality monitoring at all locations that coincide with the focal reaches of the recommended flow regimes.
BBEST 8.1.2.1	3.1.3	1	Continue TSS data collection at routine water quality monitoring locations.
BBEST 8.1.1.3	3.1.4	1	Continue support for reservoir surveys and evaluate the latest reservoir capacity information during the adaptive management review processes.
BBASC Pg. 52	3.1.5	1	Conduct studies to evaluate the benefits of over-bank flows to help maintain a healthy river system, including sediment and nutrient transfer, moving the river channel, maintaining the riparian ecology, and maintenance of oxbows.
BBASC Pg. 52	3.1.6	2	Commission a long term study to monitor salinity, nutrient transport, and sediment transport and deposition, and associated estuarine health in order to detect any negative effects as upstream projects are implemented over the next few decades.
BBASC Pg. 52	3.1.7	2	Analyze the BBASC environmental flow recommendation at the Richmond gage and compare to the results of the BBEST analysis.
BBASC Pg. 52	3.1.8	2	Continue fish surveys (of all species) on the Middle Brazos Segments 1204 and 1206.
BBASC Pg. 52	3.1.9	2	Conduct additional studies for the area from Possum Kingdom to Whitney, including the golden algae issue.
BBEST 8.1.4.5	3.1.10	2	Conduct ALM assessments with expanded habitat data for the Salt, Double Mountain, and Clear Forks of the Brazos River and the river upstream of Possum Kingdom reservoir.
BBEST 8.1.4.2	3.1.11	3	Historical and current community analyses should include other taxonomic groups as well as fish, especially mussels and aquatic insects.

3.1 Scopes of Work

The Work Plan Items and associated SOWs have been developed from the recommended items from the BBASC report and Priority 1 items from BBEST report. Those are listed here by priority assigned in Table 1. Each SOW will include a discussion of the item and why monitoring and studies are needed, what kind of the monitoring and/or studies would be required, frequency and longevity of each study, existing project (available) funding and approximated associated costs.

3.1.1 Priority 1

It is recommended that support for cooperative funding agreements for the stream flow gauging stations are continued into the future, especially for the 20 focal reaches evaluated in this report. The BBEST report also prioritized this as a priority 1.

The stream flow gages give valuable information needed to assess recommended environmental flows and validate transport models.

TWDB, BRA, US-COE, municipalities, etc. annually enter into a cooperative funding agreement with the USGS to support the annual operation and maintenance of stream flow gages in the Brazos Basin.

The BBEST report indicated that this was an on-going maintenance program that would most likely continue to be performed and partially funded by the above-referenced agencies. Total costs for annual operation and maintenance of gages are anticipated to be $500,000 per year.

3.1.2 Priority 1

The BBEST report recommended that the routine water quality monitoring should be continued at all locations that coincide with the focal reaches of the recommended flow regimes. BBEST classified this item as a priority 1.

Per Senate Bill 818 and under contract with the TCEQ, BRA, and Houston-Galveston Area Council (HGAC), administer and execute the Clean Rivers Program for their respective basins. The program is designed to monitor general water quality, compile a long-term comprehensive database, detect trends, identify pollutant sources, and aid in water quality planning and watershed management. Additionally, the TCEQ Surface Water Quality Monitoring Program performs routine water quality monitoring at specified sites throughout both river basins. Currently, water quality monitoring stations are established at or near all of the locations where the BBEST had recommended an instream flow regime. Physico-chemical data are gathered on a regular basis at selected locations.

The BBEST report indicated that this was an on-going monitoring program that would most likely continue to be performed and partially funded by the above-referenced agencies.

The Clean Rivers Program funds much of the water quality data collection in the State. The Program has not had any funding increase since its inception more than 15 years ago. BBASC recommends increasing the state-wide funding for the Clean Rivers Program from $5 million to $7.5 million. Therefore, BBASC anticipates that the total costs for the monitoring at 20 gages would be approximately $1 million per year. However, these costs could vary depending on frequency and type of parameters monitored.

3.1.3 Priority 1

The BBEST Report recommends that TSS data collection be continued at routine water quality monitoring locations that coincide with the locations of the recommended flow regimes.

Because of time restraints only two locations were selected for geomorphology analyses. Continuing data collection of TSS will allow comparison to historical data and will enable real time data to add validity to geomorphology transport formulas and to further determine what effects the BBASC recommended environmental flows will have to annual average sediment yield.

Item 3.1.3 is linked with Item 3.1.2. Collection of TSS concentrations may be a part of some or all of the routine water quality monitoring conducted by the TCEQ, BRA, and HGAC.

Currently, this monitoring is partially funded and is an ongoing task that most likely will continue to be performed by the above-referenced agencies. Estimated costs for adding TSS analyses to Water Quality Monitoring already established, but not performing TSS collection, is $20,000 per year per site. Estimated total costs for conducting TSS monitoring separately is $400,000 per year. These costs could vary depending on monitoring frequency.

3.1.4 Priority 1

The BBEST Report recommends that support for reservoir volumetric surveys be continued and that the latest reservoir capacity information be evaluated during the adaptive management review process.

The Brazos Basin reservoirs accumulate sediment from upstream catchments. Sediment deposition reduces water storage capacity of reservoirs and water availability. Sediment accumulation has been faster in some reservoirs of the

basin (e.g. Lake Granger and Lake Aquilla) and is slower than anticipated by dam engineers in other reservoirs (e.g. Lake Georgetown).

The Texas Water Code (TWC) authorizes the TWBD to perform surveys, under their Hydrographic Survey Program, to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability. In the Brazos Basin, reservoirs are surveyed approximately every ten years. Continuing data collection of TSS will also be useful for comparison to historical data to determine what effects of the recommended environmental flows will have to reservoir sediment accumulation.

This monitoring is currently partially funded and is an ongoing task that will most likely continue to be performed by the TWDB. Estimated costs are $200,000 per reservoir.

3.1.5 Priority 1

The BBASC recommended that studies be conducted to evaluate the benefits of over-bank flows to help maintain a healthy river system.

The BBASC report did recognize *the importance of over-bank flows for sediment and nutrient transfer, for moving the river channel, for maintaining the riparian ecology and for the maintenance of oxbows,* but did not include over-bank flows as potential flow standards for the Brazos and San Bernard River basins, for the following reasons:

- *The potential for flood damage to both property and human life;*
- *Time constraints imposed by Senate Bill 3 do not allow for sufficient consideration;*
- *The history of TCEQ not approving over-bank flows in previously submitted BBASC Environmental Recommendations Reports; and*
- *Over-bank flows are likely to continue to occur naturally.*

The BBEST used a study conducted in 2003 by the TWBD, TPWD, TCEQ, Texas State University, and Texas A&M University that quantified the flows needed to make connections with six Oxbow lakes located in the Brazos River floodplains between Bryan and Lake Jackson. Daily flow data were recorded during the study, and were used to determine the frequency of connections of the Oxbow lakes to the river channels.

To ensure that natural over-bank flows are occurring and maintaining connectivity to oxbow lakes, water quality, flow, and groundwater elevations should be monitored. Flow meters should be installed to quantify future connection occurrences for comparison to previous studies. Water quality meters also could be used to illustrate changes in temperature, oxygen (optical dissolved oxygen probes), pH, and conductivity within selected oxbow lakes. Water level recorder

set to record high water elevations also could be used to quantify over-bank events. They should be placed near connection points between stream bank and oxbow lake. The selected oxbow lakes should be visited monthly in order to download data and ensure meters are calibrated and collecting valid data. Satellite imagery should be used to observe increases in areal extent of the lakes to see if the increases calibrate with the recorded over-bank events.

To determine sediment transfer, this project could employ a methodology similar to that developed for the project completed on the Trinity River titled, "Evaluating the Variability of Sediment and Nutrient Loading from Riverine Systems into Texas Estuaries and Bays" (USGS April 2011, Fact Sheet 2011-3036), and would identify changes in sediment concentrations during over-bank flows, as compared to base or low flow periods. This task should follow USGS procedures for discharge measurements, and sediment (TSS and size fractionation) collection that currently exist. Emphasis would be placed on over-bank or 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 selected sampling locations at oxbow lakes connections, adjacent to flood plain areas, and in areas of active geomorphology.

Additional riparian studies in flood plains areas would provide information on changes in floodplain ecological diversity.

Estimated costs for these studies are $700,000 over five years.

3.1.6 Priority 2

A long term study will be commissioned to monitor salinity, nutrient transport, sediment transport and deposition, and associated estuarine health in order to detect any negative effects as upstream projects are implemented over the next few decades.

The BBEST used a Hydrological-based approach to develop time series of monthly inflows to the Gulf of Mexico from the Brazos River Basin, reflecting several different scenarios involving hypothetical new projects subject to the recommended in stream flow regimes. The BBEST report stated that "The general conclusion was that using varying amounts of diversion/impoundment infrastructure development beyond that which is currently authorized in the basin (scenarios deemed realistic at the present time) would have minimal to moderate effects on sediment yields, lateral connectivity in support of fish populations and ecosystem productivity, and salinity regimes in support of estuarine biodiversity and productivity."

However, the BBEST report also cautions that if upstream projects reduce stream flows to EFRs only, there could be damage to the current ecological systems. The damage would occur mostly from reduced high flow pluses that aid in

geomorphological dynamics, ensure ecological dynamics within riparian corridors, help with lateral connectivity, and maintain balance of salinity regimes in estuaries.

To fully understand the relationship to fresh water flows and the estuarine environment and to verify the EFR models, a multi-disciplinary approach is required and will involve experts in hydrology, modeling, geology, geochemistry, biology, and estuarine ecology. The procedures to estimate negative effect from upstream projects and the amount of freshwater inflow to maintain a sound ecological environment should be based on some, if not all of, the following methods:

- Continue research to verify historical patterns of hydrology, nutrient loading, sediment transport and deposition, salinity, and flow to determine the relationship between inflow and estuarine health;

- Review published studies and research conducted on the importance of periodic connections and maintenance of fish population and ecological balance in the lower Brazos River;

- Monitor sediment load to ensure long-term maintenance of the river delta and associated wetlands;

- Water quality data collected should include salinity, nutrients, TSS, pH, temperature, and dissolved oxygen.

- Due to the lack of paired long-term biological, water quality, and hydrological data, fish assemblage studies should be initiated within the Brazos and the San Bernard Rivers estuaries and compared to water quality and hydrological data.

- These studies should also be compared to historical studies and models to discover differences, to identify focal species, and develop quantitative metrics between freshwater inflow and estuarine health; these models can be adapted for additional projects;

- Identify any major data gaps for further recommendation during the five year review.

Experts would typically be university scientists with expertise in the key areas described above. However, there are scientists from TPWD, TWBD, and other groups that would have the capacity to substantially contribute. In addition, the Coastal Bend Bay and Estuary Program (CBBEP) would be a key organization to help lead this effort. Request for proposals for the work could be requested through groups such as Texas Sea Grant, and the CBBEP.

The study should also include flow measurement and water quality monitoring collected pre- and post-projects, at locations upstream and downstream in the basin for which water supply projects are being considered to verify whether or not the project was the cause of the inflow fluctuation.

The timing and frequency of the studies would be based on the type of project. Estimated costs for these studies are $3,000,000 over five years.

3.1.7 Priority 2

An analysis of BBASC environmental flow recommendation at the Richmond gage be evaluated and compared to the results of the BBEST analysis. Initiate estuarine studies to supplement existing 40-year old assessments of sediment and nutrient inflows, and delta formation on the aquatic community under EFR flows.

BBASC did not have the opportunity to fully vet and analyze what potential impacts on the estuary may result from BBASC modifications of the EFR at Richmond, specifically, not adopting high flow pulses, annual pulses, on level of seasonal pulse. The BBASC believes that short of development of an on-channel reservoir upon the main stem of the Lower Brazos or several on-channel reservoirs upon the main tributaries of the Lower Brazos, it is expected that some pulses will continue to occur and sufficient sediment and nutrient delivery will be available into the foreseeable future.

Thus, while these high magnitude pulses are not specifically prescribed in the BBASC recommendation for the Richmond gage, the group anticipates that these high flow pulses will likely continue to maintain the health of the Brazos and San Bernard estuaries.

To compare the BBASC to the BBEST flow recommendations, the flow regime application tool (FRAT) can be used to estimate firm yields.

Estuarine studies needed to supplement 40-year old assessments of sediment and nutrient inflows, and delta formation on the aquatic community under EFR can be combined with studies recommended in Items 3.1.6 and 3.1.5.

Cost for these studies and monitoring is estimated to be $500,000 over three years.

3.1.8 Priority 2

The Brazos BBACS report recommends that fish surveys (of all species) on the Middle Brazos Segments 1204 and 1206.

Until the TCEQ defines Aquatic Life Measurement protocols to include habitat to improve applicability to instream assessment, the fish surveys could be completed

using the same methodology used by Dr. Tim Bonner, Dr. Weston Nowlin, and Dr. Yixin Zhang and the Texas State University-San Marcos Department of Biology/Aquatic Station when completing their study *Ecological Characterization of the lower Brazos River*.

"Geomorphic units (e.g., riffle, pool, and run) were sampled and processed independently to address species-habitat associations at time of capture. Physical habitat surveyed includes habitat length, width, water depth, current velocity, percent substrate, percent woody debris, percent aquatic vegetation, and percent canopy cover.

Fish were collected using a combination of seines, a backpack electrofisher, and a boat-mounted electrofisher. The fish were collected from geomorphic units until few individuals and no additional species were collected following several successive seine hauls or electrofishing passes. Fishes were identified and enumerated in the field according to Hubbs et al. 2008.

Physicochemical parameters including temperature (°C), dissolved oxygen concentration (mg/L), conductivity (mS/cm), and pH were measured once on each site-date using an YSI-Model 650 multiprobe meter. Mean annual flow and cumulative drainage were determined for each site using the USGS National Hydrography Dataset Plus."

Statistical analyses then can be completed and compared to historical data to determine effects of the recommended EFR.

The BBASC recommends that these surveys be taken once per season as defined in the BBEST report. The BBEST Report defined three seasons as follows:

- Winter duration is November through February:
- Spring duration is March through June; and
- Summer duration is June through October.

The cost for the surveys is approximately $1,500,000 over a five year period.

3.1.9 Priority 2

The Brazos BBASC report recommended additional studies for the area from Possum Kingdom to Whitney, including the golden algae issue.

According to the BBEST Report, "Under certain environmental conditions golden alga can produce toxins that can cause massive fish and bivalve kills." Additionally, "golden alga blooms are complex and involve changing water flow, salinity, nutrient concentration, light intensity, and temperature, various combinations of which may increase or decrease a golden alga bloom." (Brooks et. al. 2011).

A study that included a flow rate in which no toxins blooms occurred was reviewed during the BBEST research. The BBEST believed that their recommended pulse

flow rates were consistent with the pulse flow rates that would prevent toxic blooms. The BBASC recommended environmental flow rates also need to be compared to the "no toxic bloom published flow rates".

The BBEST Report also stated, "Currently, the precise combination of factors that initiate or terminate a toxic bloom is not fully understood". A study should be conducted to evaluate other factors that may produce toxic blooms. The study should include monitoring for salinity, nutrients, and temperature seasonally and during times of alga blooms for comparison. Also, flows should be gauged both upstream and downstream of bloom areas in order to further understand the relationship between stream flow regime and alga toxic blooms.

Additionally, along with a rigorous and thorough review of scientific literature, the results of the recommended studies could be used to develop a model to demonstrate how the golden alga responds to different combination of all the factors listed above. This would help predict future toxic blooms and develop minimum environmental flow recommendations to prevent toxic blooms.

This item is linked to Items 3.1.2, 3.1.3, and 3.1.8. Collection of chloride, nutrient, total suspended solids (TSS), and water temperature is currently a part of routine water quality monitoring conducted by the TCEQ, BRA, and HGAC. Continuing data light intensity can be estimated using meteorological data and recorded TSS measurements. The data collected should also be compared to other similar studies on golden alga blooms in an attempt to identify factors that are favorable for a toxic bloom.

Texas Water Development Board (TWDB), BRA, US Army Corps of Engineers (US-COE), municipalities, etc. annually enter into a cooperative funding agreement with the U.S Geological Survey (USGS) to support the annual operation and maintenance of stream flow gages in the Brazos Basin (3.1.1). Additionally, laboratory species studies concentrating on environmental conditions optimal for a toxic bloom could be performed by university scientists or students with expertise in the golden alga species. These studies could be funded by state, federal, or private donors.

It is estimated that the cost for these studies will be $1,000,000 over five years.

3.1.10 Priority 2

No ALM assessments have been performed in the Salt Fork of the Brazos, the Double Mountain Fork of the Brazos, the Clear Fork of the Brazos, or the Brazos River upstream from Possum Kingdom reservoir. The BBEST recommends that ALM monitoring with expanded habitat data collection be performed in these reaches.

The BBEST identified several tasks or studies related to ALM activities and the need to have an expanded ALM protocol(s). BBASC recommends performing

ALM assessments to gather data to define the Aquatic Life Uses in the Salt Fork, Double Mountain Fork and Upper Brazos or Clear Fork of the Brazos River. It is estimated that the cost will be $1.5 million over five years. This task is associated with the BBEST 8.1.4.5 and other tasks prioritized in this work plan.

3.1.11 Priority 3

Historical and current community analyses should be conducted on other taxonomic groups as well as fish, especially mussels and aquatic insects.

Ecological soundness of stream reaches within the BBEST report was based primarily on fish community analyses. Some portions of the Brazos basin have diverse mussel communities with at least two of the documented species currently on the Federal Endangered Species Candidate List. To gain a better understanding of current ecological soundness and to determine legacy effects that might constrain environmental flow recommendations other taxonomic groups should be considered.

Freshwater Mussels
Because freshwater mussels are the most threatened and rapidly declining group of freshwater organisms in North America, a study of how the recommended EFR affects the presence, distribution, and life cycles of mussels (spawning period, host fish) should be one focus of the study.

These two species were selected for study inclusion as target organisms based on the following:

- The existing knowledge of the distribution and population status of mussels in the Brazos system;
- Their importance as an ecosystem component; and
- Their known sensitivity to instream flow patterns.

The BBEST proposed two mussel species for target studies. The Smooth Pimpleback is proposed as a focal species for the middle Brazos, lower Brazos, Little Navasota, and Leon Rivers due to its limited geographical range and imperiled status.

The Pistolgrip is proposed as a focal species for the Navasota River due to its peripheral occurrence in the Brazos system, apparent geographical restriction there among Brazos streams and speciose nature of the Navasota mussel fauna.

Surveys and studies should be focused on fundamental information about the life cycle of these two mussels to further understand the relationship between environmental flows and mussel health. Areas of emphasis should include the ecological conditions (flow, temperature, season, bottom conditions) required for mussel spawning, releasing parasitic larvae, attaching to the bottom, and for

growth and survival, as well as the ecological conditions required by the fish species that host parasitic larval mussels.

Insects

Insect studies were not included in the BBEST evaluation. The report states that "historically, instream flow studies have placed little emphasis on non-fish elements, and their relationships to stream flow are poorly known". They assumed that meeting the ecological requirements of fish will produce ecological conditions and dynamics protective of riparian plants, aquatic invertebrates, and other aquatic and riparian vertebrates.

However, if aquatic insect studies are initiated, they should focus on published studies regarding Brazos River species including distribution, life cycles, habitats, and preferred geomorphology, as well as how the insects react to variable water qualities and sediment loads. If studies are not available, private funding and grants for Universities could be considered.

Biological monitoring of fish, as well as macro-invertebrates, and instream habitats should be performed quarterly according to TIFP protocols. Currently the BRA and the TCEQ SWQM staff conducts ALM, which consists of fish and benthic macro-invertebrate collections and basic habitat assessment. Portion of these data may be useful in the mussel and insect assessments.

These studies should be conducted over a three year period at an estimated cost of $900,000.

4.0 Strategies to Meet Environmental Flow Standards

After the development of the recommended environmental flow standards, SB3 mandates that each bay and basin area stakeholder committee also develop recommendation for strategies to meet these standards.

> *"..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 by the commission, and the* ***strategies to achieve those standards****"*

In the Brazos BBASC Brazos *Environmental Flow Standards and Strategies Recommendations Report* Section 4.0 titled Strategies to Meet Environmental Flow Standards, a list of voluntary or incentive- based measures strategies were developed. These strategies include:

- Consider the use of incentives, such as tax incentives to encourage donation of water rights for environmental flows. Rights could be dedicated to the Texas Water Trust or private water trusts.

- Explore opportunities for individuals to obtain grants, donations, or state or federal funding to purchase or lease water rights for use in dedicating such water for environmental flows through the Texas Water Trust or private water trusts.

- Promote the beneficial reuse of treated wastewater effluent for uses such as irrigation of large landscaped area (golf courses, parks, etc.) to reduce the demand of potable water, thereby reducing or delaying the need for future raw water supplies.

- Consider developing cost incentive programs for entities that promote conservation and dedicate conserved water to environmental flows. This would encourage entities to implement specialized and targeted conservation measures and dedicate all or a portion of the savings experienced to environmental flows. It would need to be clear that the entities would not be subject to water right cancellation for non-use if they are saving water for the purpose of environmental flows.

- Explore conjunctive use of groundwater and surface water to determine whether such conjunctive use would benefit environmental flows. Conjunctive use allows a water use to toggle back and forth between surface and groundwater depending on conditions. In some cases, during dry times, a water user could rely more heavily on groundwater so as to protect river environmental flows.

- Explore the benefits for graywater use in reducing the use of potable water for uses such as lawn irrigation and other innovative uses which could use graywater rather than potable water. Graywater shall mean wastewater from showers, bathtubs, hand washing lavatories, sinks not used for food preparation or disposal, and clothes washing machines. Graywater does not include wastewater from the washing of material, including diapers,

soiled with human excreta or wastewater that has come in contact with toilet waste. Use of graywater shall be in accordance with Title 30 Texas Administrative Code, Chapter 285.

- Provide information to and support the Groundwater Management Area (GMA) process so that the establishment or consideration of Desired Future Conditions (DFC) takes into account any potential impact that DFCs may have on environmental flows, particularly spring-flow, and how groundwater could be used to benefit environmental flows.

- Encourage stewardship activities on private lands by providing incentives or funding to landowners who engage in land management practices that benefit water quality and environmental flows. These could include activities such as riparian protection or wetlands restoration that have a proven benefit to environmental flows.

- Encourage stewardship activities on public lands that benefit water quality and environmental flows. Where possible, public entities with landholdings could engage in activities on those lands such as riparian protection, invasive species control, wetlands restoration, etc that provide a benefit to environmental flows.

- Increase Environmental Quality Incentives Program (EQIP) contract awards for water conservation and water quality improvement. The EQIP is a voluntary program that provides financial and technical assistance to agricultural producers through contracts up to a maximum term of ten years in length. To increase available water supply, increase the federal cost share paid under EQIP contracts for control of invasive water-robbing species such as juniper, mesquite, salt cedar, and others. These contracts provide financial assistance to help plan and implement conservation practices that address natural resource concerns and for opportunities to improve soil, water, plant, animal, air and related resources on agricultural land and non-industrial private forestland.

- Encourage and increase public acceptance of prescribed burning as a rangeland management tool. Reduce legal and regulatory hurdles to prescribed burning. Consider a government-subsidized liability insurance program for trained prescribed burners who are affiliated with an established prescribed burn organization. Increase application of prescribed burning under EQIP contracts. Prescribed fire has been shown to control the spread of woody invasive species, provide improved water quality to rivers and streams, improve wildlife habitat, and increase available forage.

- Evaluate additional strategies to control invasive species such as salt cedar, mesquite, the giant cane *Arundo donax* and juniper. Seek state funding, tax incentives, or similar monetary incentives to support evaluations and implement recommended eradication/control strategies. Removal of invasive species, particularly those that are heavy water users has been shown over time to increase flows and such removal should be encouraged or incentivized where possible.

- Consider forming a group of reservoir owners (such as those that operate more than one reservoir, various owners for several reservoirs, etc.) to periodically review ways and means to improve reservoir operations to enhance both environmental flows and water

supply. This could include scheduling releases to better mimic natural flow patterns and could be done for individual dams or multiple dams. It may also include consideration of attenuation and travel time for downstream water supply releases. For example, in some cases water supply releases may be scheduled at different flow rates and times while still delivering the same volume of water to the downstream location. In some instances, this flexibility might better provide for environmental flow needs.

- Consider a voluntary dry-year option program for irrigators in the Brazos basin like the Voluntary Irrigation Suspension Program Option in the Edwards Aquifer area. This program is a voluntary program open to participation to eligible holders of irrigation water rights from the Edwards Aquifer Authority (EAA) in Atascosa, Bexar, Comal, Hays, Medina and Uvalde counties who are willing to suspend exercising all or a portion of their authorized withdrawal rights in exchange for financial compensation.

- Explore water right management options to look for efficiencies that could benefit environmental flows. This could include finding opportunities where water right diversion points could be relocated to improve delivery efficiencies to both water users and the environment.

- Consider the construction of a saltwater barrier to prevent saltwater intrusion in the lower basin. During periods of low-flow in the river, saltwater can intrude into the mouth of the Brazos, at times reaching as far as forty miles upstream. Constructing a saltwater barrier, which could take the form of a passable dam structure, could prevent this intrusion and improve water quality in that area of the basin.

- Consider creating opportunities to educate the public, including creating school curriculum, regarding water conservation, land and water stewardship, and other issues related to environmental flows.

5.0 BBEST supplemental items in the Work Plan.

8.1.1.2
Some water rights holders are not currently diverting to the maximum amount allowable in their water right; assessment of the status of usage patterns by water rights holders could provide information useful for modifying EFR and implementation guidelines.

BBASC did not think that assessment of usage patterns would be reliable to use for EFRs. The water right holder may be unwilling to allow use of a portion of their allocated water for EFRs especially in light of the expanding Texas population and drought conditions. The BBASC recommended encouraging voluntary or incentive based programs to dedicate conserved water to environmental flows. This would encourage entities to implement specialized and targeted conservation measures and dedicate all or a portion of the savings experienced to environmental flows. It would need to be clear that the entities would not be subject to water right cancellation for non-use if they are saving water for the purpose of environmental flows.

8.1.1.4
Clearly, demand for water will increase in the near future. This increased demand has the potential to impact flows that support of the state's diverse ecological systems. Our BBEST did not attempt to address changes in future supplies because of our SB3 directive as well as basin-specific water availability estimates are lacking under climate-change scenarios. The BBEST recommends that studies be performed to assess future water supplies in terms of new water conservation practices, alternative water supplies, relationships between groundwater and surface waters, desalination potential, and other methods to maintain water, both for human use and for instream and riparian needs to maintain a sound environment.

The BBASC agrees that this is a good suggestion to take into consideration for future water needs and planning; however, the recommended EFRs have yet to be adopted and validated. This research may be more helpful after the first ten year review period and the biological, geomorphology, and water quality studies and monitoring have been completed.

8.1.2.2
Collection of additional sediment parameters (such as suspended bed material load, bedload, and bed material gradations) should also be added at our focal gauging stations in the basin. Unfortunately, these additional parameters cannot be easily incorporated into routine water quality sampling activity, and it is cost prohibitive to collect these parameters near all of the gauging stations in the basin. In 2007, the TWDB contracted with a consulting firm to perform this type of data collection and analysis in the Brazos River reach downstream from the Navasota River confluence. The BBEST recommends that five stations, one in the San Bernard Basin and four in the Brazos Basin above College Station, should be selected for a special sediment data collection effort. This will allow comparison with historical records.

This recommendation requires additional resources and funding not yet identified.

8.1.2.3

The BBEST recommends a monitoring program to evaluate channel evolution in the lower Brazos River in response to water management following provisions of the new environmental flow regimes. Monitoring should include surveying at the sites selected for recommendation 8.1.2.2, which would be permanently mounted and resurveyed at a prescribed time interval. For example, surveying a specific site annually during the winter (when sight obstruction by vegetation is minimized) is one way to collect data that may, over time, allow development of an understanding of the scour-fill cycle of the stream. Data collected at each site should allow for analysis of changes in cross-section and thalweg shape, berm formation, bank failure, and vegetation changes. Photo documentation should be part of the data set. Each segment-assessed site should be a minimum of one meander wavelength in length and cross sections should be taken along the entire length of the site at an interval of 5 to 10 channel widths apart. This will allow for identification of changes in the characteristics of channel geomorphology and riparian vegetation at the selected sites.

This could be coordinated with 8.1.2.2, as the recommendation will be labor-intensive.

8.1.3.2

During periods of extended drought, water temperature, dissolved oxygen, and pH should be recorded hourly (i.e., ever hour over a 24-hr period) whenever flows fall below subsistence flow levels and especially if a reach is reduced to disconnected pools (typically a situation encountered in the upper basin). This would facilitate assessment of effects of extended periods of subsistence flows on water quality and aquatic life use criteria.

This will have unique conditions for implementation.

8.1.4.1

BBEST flow recommendations are hypotheses and need to be validated with properly designed and replicated studies. Therefore, we recommend testing community and population responses to components of environmental flow regimes. For example, population-level responses of biota (i.e., population indices, nutrient uptake, growth, condition, reproductive success, and habitat use and selection) would be assessed during and after subsistence, dry/normal/wet base flows, high flow, and over-bank flow events. Specific questions should be directed at assumptions of the natural flow paradigm, such as "do the recommended subsistence flows sufficiently ensure survival for transient periods?" and "what are the ecological benefits of high flow pulses as recommended to the biological community?"

This item is a broad study. Specific studies have been recommended in items 3.1.5, 3.1.8, and 3.1.11 that would help validate the recommended EFRs also.

8.1.4.3

Biomonitoring protocols for macroinvertebrates and fishes should be developed prior to the implementation of the environmental flow recommendations. Biological Condition Gradient (BCG; Davies and Jackson 2006) is the recommended model for biomonitoring, but the model needs to be developed for the Brazos River Basin.

Currently, the BRA and TCEQ SWQM staff conducts aquatic life monitoring (ALM), which consist of fish and benthic macroinvertebrate collections and basic habitat assessment. This ALM is conducted in accordance with TCEQ Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data and provides TCEQ baseline data on environmental conditions and data to determine if aquatic life use criteria are being attained. Although these data meet the data quality requirements for their intended use and were useful for our effort, there are some limitations in the collection methodology that limit their suitability for instream flow evaluations.

Specifically, the SWQM ALM procedure has insufficient documentation of instream habitat, substrate types, and associated species for development of habitat suitability criteria for fish and invertebrate species and/or habitat guilds. The BBEST recommends that TCEQ's SWQM Program consider incorporating increased habitat and species use documentation into Volume 2 as an optional task for ALM procedures. These optional procedures would only be used when ALM assessments are conducted at or near sites where flow regime recommendations have been developed. This would provide increased flexibility to the ALM data collected as part of the CRP by allowing it to be used for refinement of instream flow recommendations yet still meet the SWQM Program's needs for data to establish baselines and to assess attainment of aquatic life use criteria.

This was a Priority 2 in the BBEST Report.

8.1.4.4
When ALM assessments are going to be performed at, or near, locations where the BBEST has recommended an instream flow regime, expanded data on habitat types and species use should be included in the assessment process.

This correlates with recommendation 3.1.8, and 3.1.10.

8.1.4.5 – This has been included as 3.1.10, Priority 2.

8.1.4.6
Currently, the TIFP is using a multi-disciplinary approach to generate habitat suitability criteria and to determine flow regimes that support a sound environment for the middle and lower Brazos. The TIFP's efforts have involved state agencies (TCEQ, TWDB, TPWD), BRA, private consultants, and universities to achieve biological, riparian, water quality, geomorphological, hydrological, and hydraulics studies. Data generated by these studies will be used to identify relationships between flow and ecological processes and to generate flow recommendations. Instead of TIFP developing flow recommendations independent of this BBEST, we encourage TIFP to use the hypotheses generated herein, which will be a more efficient and cost-effective method of validating and refining our flow regime recommendations. Consequently, TIFP efforts merit continued support and funding by the state and its participating agencies.

The BBASC does concur with the BBEST that the TIFP should be encouraged to focus their efforts on refining the recommended EFRs instead of developing new ones. However, this was a Priority 2 in the BBEST Report. Outside funding should be investigated.

8.1.4.7
The BBEST was unable to identify any documentation of the location, composition, or quantity of mussel beds in the San Bernard Basin. The BBEST recommends a comprehensive mussel survey in the San Bernard Basin.

This was a Priority 2 in the BBEST Report and correlates with several recommendations, including 3.1.10. Funding has not been identified.

8.1.5.1
Relationships among riparian plants and their responses to flow regimes were necessarily based on the application of fundamental understanding of responses to pulse and over-bank flows, which are based on the extensive scientific literature on the subject. Site-specific studies assessing the composition, coverage, and status of the riparian corridors in the Brazos and San Bernard River basins were generally lacking. The SB2 TIFP Riparian Monitoring Protocol implements a comprehensive, standardized data collection process within riparian corridors. The BBEST recommends extending the TIFP riparian assessments to include assessments near our 20 focal reaches associated with gage stations. These data could then be used as a baseline to track future changes in riparian communities and their relations to flow regime alterations.

The BBEST further recommends that these riparian corridors be assessed every 10 years to evaluate the degree to which recommended flow regimes and implementation strategies maintain riparian vegetation communities characteristic of a sound ecological environment.

This was a Priority 4 in the BBEST Report, and correlates with several recommendations, particularly 3.1.5.

8.1.5.2
Given the large amount of disturbance experienced by riparian vegetation communities in the basins of the Study Area (see Temporary Erosion and Sedimentation Control Plan (TESCP)), it is recommended that a survey of both the Brazos and San Bernard rivers and their major tributaries be performed to quantify the locations and extent of damage. This information could then be provided to federal and state agencies and non-profit organizations that educate, sponsor, and/or conduct riparian enhancement and reforestation projects.

This was a Priority 3 in the BBEST Report and could be associated with ALM or sediment transport recommendations. Funding sources have not been identified.

8.1.5.3
Portions of the Brazos River Basin are being overrun by the non-native, invasive shrub saltcedar (Tamarix spp.) that is outcompeting native riparian vegetation in many areas. Saltcedar now dominates the riparian community in the upper Brazos floodplain and has been identified in other parts of the Brazos Basin. Currently, there is not a thorough accounting of the extent of saltcedar encroachment in the basin. The BBEST recommends working with USGS to complete a study to locate and quantify saltcedar encroachments into the Brazos River riparian corridor and to identify changes in channel morphology associated with saltcedar encroachment.

Based on the results of a saltcedar survey, the BBASC may choose, during a subsequent adaptive management review, to recommend a control strategy for situations in which saltcedar is causing impairment to the native vegetation, degradation to the river channel, and reduction in available surface water (Chew 2009; Shafroth et al. 2008; Stromberg et al. 2009).

This was a Priority 5 in the BBEST Report. The BBASC recommended, in Section 4, a voluntary or incentive-based measure which would include "seeking funding, tax incentives, or similar monetary incentives to support evaluations and implement recommended eradication/control strategies."

8.1.5.4
Currently, not all portions of the Brazos are covered by the TESCP project. The BBEST recommends that as additional phases of the TESCP are completed, the portions of the Brazos not currently covered be mapped and assessed following the protocol documented in Section 4.4 Riparian Vegetation Communities.

This was a Priority 2 in the BBEST Report; unless funded by an outside resource, implementing this recommendation may be deferred to the second data collection period.

8.1.6.1
Sediments transported from the river system to the estuary reduce erosion and land subsidence in coastal zones; however, this process may be lessened in the Brazos River Basin by sediment capture in upstream reservoirs. The BBEST recommends that sediment discharge loads carried by freshwater inflows should be calculated in relation to flow regimes to determine the contribution of these sediments in moderating erosion and accretion rates along the coast.

This was a Priority 3 in the BBEST Report and correlates with several other recommendations. However, SOWs for studies for sediment transfer have been recommended in sections 3.1.5 and 3.1.6. The data recorded may be useful to determine transported sediments to coastal zones.

8.1.6.2
Marine dead zones can be caused by an increase in dissolved and particulate nutrient delivery (particularly nitrogen and phosphorus) in river discharge. These nutrients can lead to increases in the density of certain types of phytoplankton and subsequent hypoxia caused by both respiration and decomposition. In 2007 high rainfall resulted in twice the average discharge of the Brazos River into the Gulf of Mexico as normal. This stormwater carried a high nutrient load from urban and rural runoff. The rapid influx of nutrients into the Gulf of Mexico created a temporary dead zone. Currently, the CRP collects nutrient samples in freshwater throughout the Brazos and San Bernard basins. The BBEST believes it would be beneficial to also routinely monitor the Brazos and San Bernard estuaries and adjacent coastal wetlands for nutrient concentrations, which would permit evaluation of nutrient dynamics in relation to flows.

This was a Priority 4 in the BBEST Report, but could be included in the SOWs of recommendations like 3.1.3, 3.1.6, etc.

Table 2
Summarized Proposed Scopes of Work

Recommend Priority	Report Number	Recommendation	Current Funding	Agencies/ Organizations	Duration	Anticipated costs*
1	3.1.1	Maintenance of USGS gages	YP	USGS, USCOE, TWDB, BRA	O	$500,000 per year
1	3.1.2	Continue routine water quality monitoring at all locations that coincide with the focal reaches of the recommended EFRs.	YP	TCEQ, BRA, HGAC	O	$1,000,000 per year
1	3.1.3	Continue TSS data collection at routine water quality monitoring locations.	YP	TCEQ, BRA, HGAC	O	$400,000 per year
1	3.1.4	Continue reservoir surveys	YP	TWDB, University	O	$200,000 per reservoir
1	3.1.5	Conduct studies to evaluate the benefits of overbank flows	N	TWDB, TCEQ, TPWD, University	2015 – 2020	$700,000 over 5 years
2	3.1.6	Begin monitoring for parameters to detect negative affects in estuarine as upstream projects are implemented.	N	TWDB, TPWD, University	2015 – 2020	$3,000,000 over 5 years
2	3.1.7	Analyze BBASC EFR at Richmond gage and compare to the BBEST results.	N	BRA, TCEQ, TWDB	2015 – 2018	$500,000 over 3 years
2	3.1.8	Middle Brazos Fish Studies.	N	TCEQ, TPWD, University	2015 – 2020	$1,500,000 over 5 years
2	3.1.9	Golden Algae studies.	N	TCEQ, BRA, TPWD, University	2015 – 2020	$1,000,000 over 5 years
2	3.1.10	Conduct ALM assessments with expanded habitat data for the Salt, Double Mountain, and Clear Forks of the Brazos River and the river upstream of Possum Kingdom reservoir.	N	TCEQ, BRA, TPWD, University	2015-2020	$1,500,000 over 5 years
3	3.1.11	Mussel and aquatic insect studies.	N	TCEQ, BRA, TPWD, University	2017 – 2020	$900,000 over 3 years

O - Ongoing task that will most likely continue to be performed by respective agencies in perpetuity
Y/P – Yes, Partial Funding
N – No Funding
*All costs may be revised as the scopes of work are finalized

Table 3 (Table 8.2 in BBEST Report)
Summarized Potential Funding Sources

Table 8.2. Potential funding sources.

Program Name	Primary Focus	Funding Type	Funding Organization Type	Eligible Applicants	Potential Limited to a Specific Watershed or Recommendation
USCOE- Project Modifications for Improvement of the Environments	Ecosystem restoration with emphasis on fish and wildlife where a COE Project has contributed to degradation	Cost-Share	F	State or Local Government	Little River
USCOE - Aquatic Ecosystem Restoration	Aquatic ecosystem restoration	Cost-share	F	State or Local Government	
USEPA - Greater Research Opportunities Fellowships for Undergraduate Environmental Study	Environmental Study	Cost-share	F	Undergraduate Students	
USEPA - Science to Achieve Results Fellowships for Graduate Environmental Study	Environmental Study	Cost-share	F	Graduate Level Students	
USFWS - Cooperative Endangered Species Conservation Fund	Conservation projects for candidate, proposed, and listed species	Cost-share	F	State	mussels, smalleye shiner, sharpnose shiner, Brazos water snake
USFWS - Fisheries Conservation Management	Evaluating water quality, assessment of in-stream and riparian habitat, introduced species	Cost-share	F	State, Local Government, Non-profits, Universities	
USNSF - Doctoral Dissertation Research	Environmental sciences	Grants	F	Universities	Life history investigations
USNSF - Exploratory Research	Exploratory work on untested, but potentially transformative, research ideas or approaches; must involve radically different approaches, apply new expertise or engage interdisciplinary perspectives	Grants	F	State, Local Government, Universities, Scientists	
USNSF - Hydrologic Science Grant	Aqueous geochemistry, physical, chemical, and biological processes within water bodies	Cost-share	F	Not specified	Sediment and Channel response assessment
USNSF - Long-term Research in Environmental Biology	Generating long time series of biological and environmental data that address particular ecological and evolutionary processes	Grants	F	Universities	Life history investigations

Table 8.2. (Continued).

Program Name	Primary Focus	Funding Type	Funding Organization Type	Eligible Applicants	Potential Limited to a Specific Watershed or Recommendation
USNSF - Science, Engineering and Education Sustainability Fellows	Investigation that cross traditional disciplinary boundaries and address issues of sustainability through a systems approach	Grants	F	Post-Doctoral Fellow	
NOAA - Sea Grant Community Climate Adaptation Initiative	Climate adaptation efforts to enhance climate adaptation in coastal communities	Grants	F	Sea Grant College Programs - Texas A&M	Lower Brazos, San Bernard
TCEQ - Supplemental Environmental Project Program	Investing penalty dollars towards environmentally beneficial uses; must define a project and have accepted into program	Grants	S	Local Government, NPOs	
TCEQ - Clean River Program	Water quality monitoring, ALM and data assessment; current funding inadequate to cover Brazos Basin	Contract	S	BRA, HGAC	
Texas Sea Grant	Sustainable coastal communities, ecosystems, and habitats	Grants	S	Marine Researchers	Lower Brazos, San Bernard
TWDB - TIFP Studies	Supports data collection and modeling efforts required by SB2	Contract	S	TPWD, TCEQ, BRA, Researchers	SB2 Study Area
BRA - Water Quality Initiatives	Augments TCEQ's CRP funding to meet the requirements of the CRP for the entire basin	Self-funded	S	NA	
Doris Duke Charitable Foundation	Wildlife conservation, climate change, land stewardship and sustainability	Grants	NPO	Not specified	
Ducks Unlimited	Wildlife and habitat conservation; also runs projects directly	Grants	NPO	Not specified	
National Fish and Wildlife Foundation	Fish conservation, wildlife and habitat conservation	Grants	NPO	Not specified	
Turner Foundation	Biodiversity, protect functioning ecosystems, create buffer zones and wildlife corridors	Grants	NPO	Not specified	
The Nature Conservancy	Conservation, restoration, and sustainable development practices; runs projects directly		NPO	NA	Lower Brazos, San Bernard

Table 8.2. (Continued).

Program Name	Primary Focus	Funding Type	Funding Organization Type	Eligible Applicants	Potential Limited to a Specific Watershed or Recommendation
North American Native Fishes Association Conservation Research Grant	Research on vulnerable North American fish species	Grants	NPO	Student, Researcher, Conservation Group	Smallnose and/or sharpnose shiners
FishAmerica Fisheries Research Grant	Research projects to further the Nation Fish Habitat Plan	Grants	NPO	Government, Local Communities	Brazos Below Waco, Navasota, Little River, San Bernard
ALCOA Foundation - Advancing Sustainability Research Initiative	Natural resource management, sustainable design, environmental economics	Grants	C	Universities, NPOs	
Sea World & Busch Gardens Conservation Fund	Species research, habitat protection, animal rescue and rehabilitation	Grants	C	NPOs, Government, Universities, Research Centers	
Shell Oil Company	Threatened wildlife and/ or habitats, water quality research, ecosystems restoration	Grants	C	NPOs	

F - Federal Government, S - State Government, NPO - Non-profit Organization, C - Corporate

ATTACHMENT

DRAFT
Brazos BBASC Work Plan
Recommendations and Comments from the Brazos BBEST
August 29, 2013

DRAFT

Brazos BBASC Work Plan
Recommendations and Comments from the Brazos BBEST
August 29, 2013

Requested elements of the Brazos BBASC work plan are:

1. Establish a review of assessment of sound ecological environments with respect to flows

2. Prescribe monitoring, studies, and other activities for the purpose of validating and refining environmental flow standards and recommendations

Basin and bay environmental flow analyses and environmental flow regime (EFR) recommendations will be reviewed once every 10 years to "confirm or refute that the recommended standards are protective of a sound ecological environment".

Therefore, the Brazos BBEST herein reassesses BBEST and BBASC recommended work plan studies (Table 1 of the BBASC Work Plan). We reviewed and considered goals of each study, grouping them into two categories: 1) Research Goals, directly linked to "confirming or refuting" ERA recommendations and 2) Monitoring Goals, supporting and indirectly linked to "confirming or refuting" ERA recommendations (Section I).

Research Goals were further refined and developed into hypotheses that can be tested with the results of specific study activities (Section II). This effort clearly states the intended objectives of each study, a necessary step in the development of Request for Proposals (RFP) and funding. Our approach here is consistent with BBEST Work Plan recommendations 8.1.4.1 and 8.1.4.2.

Monitoring Goals might be paramount to the success of the Research Goals. For example, objectives of our Research Goals cannot be tested in the context of the EFR unless USGS Gauging Stations are operating. However, this and other monitoring goals are typically funded by programs outside of the Environmental Flow Program and should not be high priorities for funding under the Work Plan unless absolutely necessary.

I. Assessment of Prioritized Studies of the BBASC Work Plan

3.1.1: Continue cooperative funding agreements for stream flow gauging stations into the future, especially for the 20 focal reaches evaluated in this report.

Monitoring Goal

3.1.2: Continue the on-going routine water quality monitoring at all locations that coincide with the focal reaches of the recommended flow regimes.

As stated, a Monitoring Goal. See Section II for revision into a Research Goal.

3.1.3: Continue TSS data collection at routine water quality monitoring locations.

As stated, a Monitoring Goal. See Section II for revision into a Research Goal.

3.1.4: Continue support for reservoir surveys and evaluate the latest reservoir capacity information during the adaptive management review processes.

Monitoring Goal. These surveys are less crucial for environmental flow studies than other studies of the work plan, and can probably be removed from the recommendations. We realize that they are important for other purposes and support their continuation with funding provided by local reservoir owners.

3.1.5: Conduct studies to evaluate the benefits of over-bank flows to help maintain a healthy river system, including sediment and nutrient transfer, moving the river channel, maintaining the riparian ecology, and maintenance of oxbows.

Research Goal. See Section II for refinement and hypothesis development.

3.1.6: A long term study will be commissioned to monitor salinity, nutrient transport, sediment transport and deposition, and associated estuarine health in order to detect any negative effects as upstream projects are implemented over the next few decades.

As stated, a Monitoring Goal. See Section II for revision into a Research Goal.

3.1.7: An analysis of BBASC environmental flow recommendation at the Richmond gage be evaluated and compared to the results of the BBEST analysis. Initiate estuarine studies to supplement existing 40-year old assessments of sediment and nutrient inflows, and delta formation on the aquatic community under EFR flows.

Research Goal. See Section II for refinement and hypothesis development. We note that Rosharon is the most downstream gage for which flow standards have been recommended and might be substituted for Richmond.

3.1.8: The Brazos BBASC report recommends fish surveys (of all species) on the Middle Brazos Segments 1204 and 1206.

Research Goal. See Section II for refinement and hypothesis development. The BBEST recommends testing ecology–flow hypotheses throughout the drainage (perhaps 3-4 sites

strategically chosen for their value to represent ecological conditions of other locations) and not restricting to one or more reaches.

3.1.9: The Brazos BBASC report recommended additional studies for the area from Possum Kingdom to Whitney, including the golden algae issue.

As stated, a Monitoring Goal. See Section II for revision into a Research Goal.

3.1.10: No ALM assessments have been performed in the Salt Fork of the Brazos, the Double Mountain Fork of the Brazos, the Clear Fork of the Brazos, or the Brazos River upstream from Possum Kingdom reservoir. The BBEST recommends that ALM monitoring with expanded habitat data collection be performed in these reaches.

As stated, a Monitoring Goal. See Section II for revision into a Research Goal.

3.1.11: Historical and current community analyses should be conducted on other taxonomic groups as well as fish, especially mussels and aquatic insects.

Research Goal. See Section II for refinement and hypothesis development.

II. Suggested Revisions to Research Goals:

We revised Research Goals using a scientific method framework that develops testable hypotheses with regard to the influence of variation among flow regime components on key elements and indicators of a sound ecological environment.

A. Theory

1. Natural Flow Paradigm (Poff et al. 1997): "The ecological integrity of river ecosystems depends on the natural dynamic character" (i.e., magnitude, frequency, duration, timing and rate of change of hydrologic conditions).

2. An example of BBASC's definition of "natural dynamic character" is below (1 of 22 reaches; using Rosharon as a specific example):

Gage Number 19- USGS Gage 8116650 Brazos River near Rosharon

Season	Subsistence	Hydrological conditions	Base	High Flow Pulses	Dry Hydrological Conditions Pulse per Season	Average Hydrological Conditions Pulse per Season	Wet Hydrological Conditions Pulse per Season
Winter	430cfs	Dry	1,140cfs		Pulse(s) 1 Qp:9,090 Volume 94,700 Duration 12	Pulse(s) 3 Qp:9,090 Volume 94,700 Duration 12	Pulse(s) 2 Qp:13,600 Volume 168,000 Duration 16
		Average	2,090cfs				
		Wet	4.700cfs				
Spring	430cfs	Dry	1,250cfs		Pulse(s) 1 Qp:6,580 Volume 58,500 Duration 10	Pulse(s)3 Qp:6,580 Volume 58,500 Duration 10	Pulse(s) 2 Qp:14,200 Volume 184,000 Duration 18
		Average	2,570cfs				
		Wet	4,740cfs				
Summer	430cfs	Dry	930cfs		Pulse(s) 1 Qp:2,490 Volume 14,900 Duration 6	Pulse(s) 3 Qp:2,490 Volume 14,900 Duration 6	Pulse(s) 2 Qp:4,980 Volume 39,100 Duration9
		Average	1,420cfs				
		Wet	2,630cfs				

Hydrological conditions based on the Palmer Index, 25%ile Dry, 50%ile Average, 75%ile Wet
50% Rule applies for Dry conditions Base Flow
Over-bank flows not adopted
Qp is in Cubic Feet per Second Volume is in ac/ft Duration is in Days

3. If these conditions are met at Rosharon, this EFR recommendation will maintain a sound ecological environment. If true, then we can make the following predictions.

B. Hypotheses for Rosharon (but should be expanded to other reaches; not an exhaustive list)

Subsistence flows (430 cfs)

Hypothesis: Subsistence flows of 430 CFS are sufficient to maintain dissolved oxygen, temperature, and other water quality parameters for a limited period of time. Revision of 3.1.2

Hypothesis: Subsistence flows are sufficient to allow natural structuring (richness, diversity, evenness, biomass, relative abundances, etc.) of biotic communities (algae, macroinvertebrate, mussels, fish, etc.) for a limited period of time. (Revision of 3.1.8, 3.1.9, 3.1.10, 3.1.11)

Base flows (930 to 4,750 cfs, depending on season and hydrological condition)

Hypothesis: Base flows are sufficient to allow natural structuring of biotic communities (algae, macroinvertebrate, mussels, fish, etc.). What is the quantitative relationship between flow variation (EFR components) and availability of essential habitat for the various types of organisms? What is this relationship with regard to long-term trends with regards to biotic indicators of a sound ecological environment? Revision of 3.1.8, 3.1.9, 3.1.10, 3.1.11

High Flow Pulses (2,490 to 14,200, depending on seasons and hydrological condition)

Hypothesis: Flow pulses will maintain sufficient rates of sediment transport to maintain a channel geomorphology that provides suitable habitat for the biota. Revision of 3.1.3

Hypothesis: Pulse flows will allow natural structuring of biotic communities (algae, macroinvertebrate, mussels, fish, etc.). Mechanisms that directly influence this structure include reproduction, early life stage survival and recruitment, habitat availability, and habitat connectivity. How does the flow regime influence these mechanisms? Revision to 3.1.8, 3.1.9, 3.1.10, 3.1.11

Overbank Flows

Though not recommended by BBASC, we can validate their importance in maintaining a healthy river.

Hypothesis: Overbank flows (BBEST: 60,600 at Rosharon) will maintain natural rates of stream mobility, sediment and nutrient transfer, riparian vegetation, and connectivity to oxbows (Revision of 3.1.5).

Estuarine Environments: Similar hypotheses as above can be generated to validate whether or not Rosharon's EFR are sufficient for the estuarine ecosystem, in terms of suitable salinity dynamics, marsh vegetation, productivity, long-term trends for biotic indicators, etc. (Revision of 3.1.6 and 3.1.7).

C. Conduct Experiments

Prioritize hypotheses

1st Priority - Hypotheses relating to flow pulses. Justification: The flow pulse components of EFRs present us with the largest gaps in ecological information and likely are the components most susceptible to water appropriations (storage and diversions) associated with future water rights permitting.

2nd Priority -Hypotheses relating to subsistence flows.

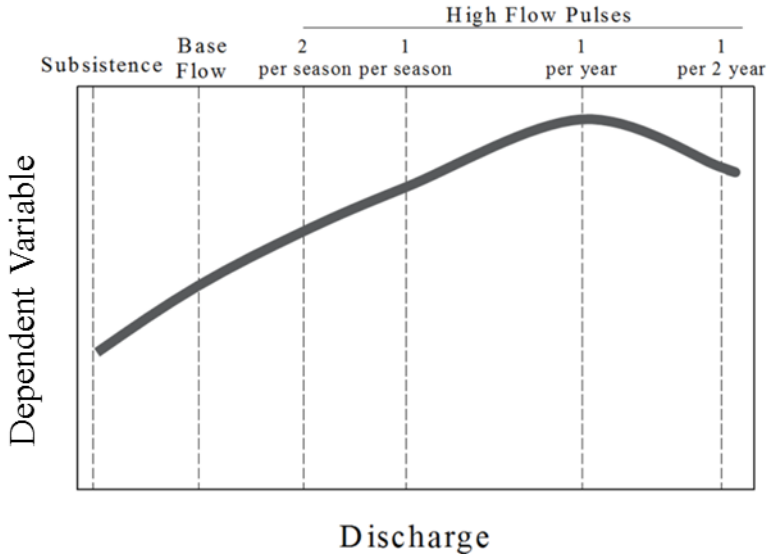
3rd Priority – Hypotheses relating to base flows, overbank flows, and estuarine environments.

Caveat: We cannot predict hydrologic condition in coming years. Therefore, we recommend moving to the next step and develop hypotheses and experimental designs for all flow tiers. In doing so, we would be prepared to validate all flow tiers opportunistically.

Refine hypotheses and develop experimental designs.

BBEST recommends hosting an expert workshop to establish conceptual models, specific null hypotheses, alternative hypotheses, and experimental designs. This workshop could (and probably should) involve scientists and a few key stakeholders who are involved in EFR research and/or deliberations in basins throughout the state. This would not be a large number of individuals, because many individuals have served on multiple BBESTs. This workshop would develop generalized concepts and experimental designs applicable statewide to most, if not all, basins. A subsequent BBEST and BBASC meeting would be held to apply those concepts and experimental designs to specific representative reaches in the Brazos Basin and develop an overall research plan for the Brazos Basin.

Example: The relationship between coarse particulate organic matter (CPOM; a major source of nutrients in flowing waters), larval fish abundance, or other response variables with flow tiers (EFR components) would be discussed and developed during the workshop (see graph below depicting an expected relationship). The next step would be to develop adequate experimental design, including sampling methodologies, to validate the expected relationship relative to flow tiers.



Another example is the flow dependency of reproduction and survival by certain fishes and macroinvertebrates (mussels are receiving increasing attention). The research conducted by Dr. Gene Wilde at Texas Tech University on fish population responses to flow variation in rivers of the upper Brazos and Canadian basins exemplifies the kinds of research that would be most useful for validating, refuting, or refining EFR recommendations and standards. Other university and agency scientists are currently conducting similar kind of research projects in other regions of the state.

Brazos BBEST members have considerable experience with this area of research, but there is insufficient time for us to propose a set of detailed studies for the BBASC to consider. We also are aware that a long list of proposed studies is unwarranted, because funding in the near term will undoubtedly support only a handful of new studies within the basin. Instead, we feel the best course of action would be to propose a smaller set of studies focused on the priority topics we have identified, and to recommend that, prior to issuing any RFP (should funds become available for research), a workshop be organized to **develop specific research priorities that stress hypothesis testing**. Only in this manner can we truly make informed recommendations about revising EFR standards. Please note that we are referring to new research initiatives focused on validation, refutation, or revision of EFR recommendations and standards. We again recognize the value of ongoing monitoring efforts (flow gages, water quality programs, etc.) that are currently funded by other sources. These efforts certainly support EFR research and deliberations indirectly, and in some cases very directly, but the limited funds available for EFR studies should be utilized to support the research priorities we have identified.