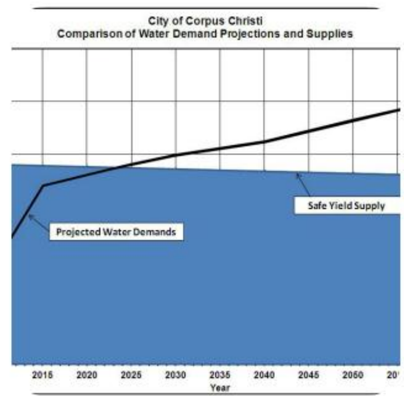
Nueces River and Corpus Christi and Baffin Bays
Basin and Bay Area Stakeholders Committee

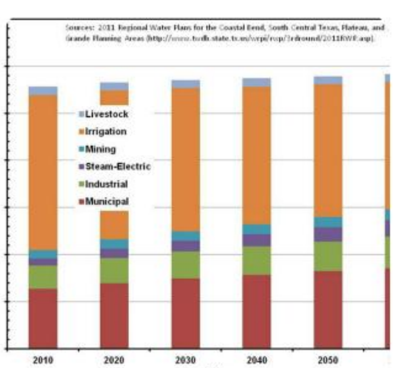
Work Plan for Adaptive Management

Submission to the Environmental Flows Advisory Group
and the Texas Commission on Environmental Quality










November 2012

Work Plan for Adaptive Management

Prepared by
Nueces River and Corpus Christi and Baffin Bays
Basin and Bay Area Stakeholders Committee
(Nueces BBASC)

With Technical Support from
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and the
Nueces River and Corpus Christi and Baffin Bays
Basin and Bay Expert Science Team
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November 2012

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Common Abbreviations

acft	acre-feet
acft/yr	acre-feet per year
BBASC	Basin and Bay Area Stakeholder Committee
BBEST	Basin and Bay Expert Science Team
BOR	Bureau of Reclamation
CBBEP	Coastal Bend Bays & Estuaries Program
CCWSM	Corpus Christi Water Supply Model
CRP	Clean Rivers Program
EFAG	Environmental Flows Advisory Group
EPA	Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
FRAT	Flow Regime Application Tool
GCD	Groundwater Conservation District
GAM	Groundwater Availability Model
GMA	Groundwater Management Area
HEFR	Hydrology-based Environmental Flow Regime
HRI	Harte Research Institute for the Gulf of Mexico Studies
IR	Infra-Red
MA-NERR	Mission Aransas – National Estuarine Research Reserve
MGD	Million Gallons per Day
MSL	Mean Sea Level
NEAC	Nueces Estuary Advisory Council
NOC	Nueces Overflow Channel
NRA	Nueces River Authority
ppt	Parts per thousand
ROC	Rincon Overflow Channel
RWP	Regional Water Planning Group
SAC	Science Advisory Committee
SB3	Senate Bill 3
SLR	Sea Level Rise
SMART	Salinity Monitoring And Real Time inflow management
SOW	Scope of Work
SWQM	Surface Water Quality Monitoring
TCEQ	Texas Commission on Environmental Quality
TIFP	Texas Instream Flow Program
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSS	Total Suspended Solids
TWDB	Texas Water Development Board
TXRR	Texas Rainfall-Runoff
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UT-BEG	University of Texas – Bureau of Economic Geology
WWTP	Waste Water Treatment Plant

Nueces BBASC Tier 1 Work Plan Recommendations

Priority	Pg #	Study Name
1	9	Salinity Monitoring and Real Time (SMART) inflow management study
2	10	Evaluate potential for Allison wastewater effluent with its nutrients and other return flows (e.g., Oso Bay returns) to improve environmental health of the Rincon Bayou delta
3	11	Describe relationships between flow and physical, chemical, and biological structure and function of the streams and how these relationships support ecological health
4	13	Re-examination of the 2001 Agreed Order monthly targets
5	15	Describe and design studies to address relationships between abundance of fish and shellfish in the bay and bay salinities
6	16	Improve salinity modeling methods for determining environmental inflow regimes
7	17	Explore landform modifications to Nueces Bay and Nueces Delta
8	19	Conduct additional modeling of relationships between in-stream habitat and flow

Nueces BBASC Tier 2a Rivers and Streams Work Plan Recommendations

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

	Pg #	Study Name
	21	Describe the role of flow in the ecological health of the stream
	21	Identify stream locations and estuaries not included in the BBEST environmental flow regime report that should be analyzed for relationships between flow and environmental health
	22	Describe ecological services provided by perennial pools
	23	Identify flow regime components and quantities necessary to sustain mussels and compare to flow regimes identified necessary to sustain fish communities
	25	Describe how surface flow patterns and quantities are changing compared to the period of record patterns. Include consideration of possible future flows and diversions
	26	Describe groundwater flow into streams and how is it changing
	27	Describe relationships between benthic macroinvertebrates and flow
	27	Identify water development activities planned for the future, and how they might influence groundwater, river flows, and physical and hydrologic connections between the two
	28	Describe changes in geomorphology, i.e. trends in channel elevation, longitudinal profile, width, floodplain width, stream form, bed sediment size, and the role the flow regime contributes to those changes
	29	Identify the best period of record to use in deciding which hydrologic condition and hydrologic triggers should be used
	30	Identify key flow-dependent ecosystem functional (create ecological structure) processes associated with a sound ecological environment
	31	Develop sustainability boundary analysis

Nueces BBASC Tier 2b Bays Work Plan Recommendations

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

	Pg #	Study Name
	33	Relationship between freshwater inflow and ecological health
	34	Relationship between freshwater inflow and oyster reefs
	35	Identify vegetation/marsh changes occurring in the Rincon Bayou delta and relationship of those changes to freshwater inflow
	36	Define ecological effects of zero flow event duration, intervals between periods of zero flow, and long-term frequency of zero flow occurrences
	37	Continued monitoring of vegetative indicators
	39	Safe yield demand vs. current demand evaluation
	40	Ecologically sound environment strategy effectiveness program
	41	Evaluate probable effects of climate change (a greenhouse warmed future) on water resources including supply, demand, and the ecological condition of rivers and streams and associated bays in the Nueces Basin
	44	Nueces watershed pre- and post-development nutrient budgets
	46	Assessment of sediment transport and loadings into the Nueces Delta and estuary

1.0 Work Plan Purpose

Pursuant to Senate Bill 3 (SB3) of the 80th Texas Legislature the Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholders Committee (Nueces 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.*

2.0 Nueces BBASC Timeline for Standards and Recommendations Review

The Nueces BBASC recommends that a *periodic review of the basin and bay environmental flow analyses and environmental flow regime recommendations, environmental flow standards, and strategies occur at least once every 5 years.* Further, the Nueces 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 five year review period shall commence upon the date the Texas Commission on Environmental Quality (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 Nueces BBASCs recommendation to review the rulemaking process on a five year cycle.

3.0 Strategies to Meet Environmental Flow Standards

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.

It is important to note that a high priority strategy intended to facilitate meeting the environmental flow standards and to protect and improve the existing ecological condition of Nueces Bay and Delta is found in the Nueces BBASC Recommendations Report, as follows: "Recognizing the overall limited availability of surface water in the Nueces Basin, the Nueces BBASC wishes to stress, up front, that one of its most important conclusions and recommendations is that the TCEQ consult with the Nueces Estuary Advisory Council (NEAC) in TCEQ's evaluation of applications for new surface water appropriations in amounts of 500 acre-feet per year, or more, with NEAC's function being to consider and advise on how the new appropriations may affect the Nueces Bay and Delta." This recommendation is carried forward to the Nueces BBASC Work Plan for re-emphasis.

Strategy Options for Achieving Environmental Flow Standards

In Section 5 of the Nueces 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:

Facility Operational Modification to Enhance Environmental Flows

- Modifying a facility's (e.g. a water treatment plant, a reservoir) operation and/or schedule of releases may help provide environmental flows to a river or bay. The amount and timing of releases from a facility or multiple facilities in a watershed could attempt to mimic natural flow patterns of the river system or inflow to a bay.

Water Right Management

- The existing location and timing of diversions of water rights in the basin may inhibit opportunities for better resource management. 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 and permit amendments may be necessary.

Reduction of Groundwater Pumping for Spring Flow Protection

- Reducing groundwater pumping where practical may enhance spring flows to provide river flows.

Land Stewardship Watershed or Catchment Stewardship

- Use land management practices demonstrated to put more water into the water table. Seek local, regional, state, and federal funding and tax incentives for landowners to voluntarily implement such practices. Possible examples include:

    a) A well-managed, healthy watershed can provide a desirable environment for livestock and wildlife and increase groundwater penetration and recharge. Flood attenuation and improved water quality are additional benefits resulting from proper watershed and riparian zone stewardship.

    b) Selective brush management and subsequent improved rangeland management can increase groundwater recharge and spring flows. Normally, Ashe juniper (cedar, mountain cedar) has been the target brush species, but in other cases mesquite control has produced desirable hydrological benefits. Similarly, removal of invasive plant species such as *Arundo donax* (Giant Cane) from riparian areas may increase water availability by reducing evapotranspiration.

    c) Restored and healthy wetlands on the rivers or on the Gulf coast provide very productive wildlife habitat, filtering and cleansing actions desirable for inflows, and can protect inland communities from hurricanes and flooding.

    d) Investigate removal of water hyacinth from Lake Corpus Christi.

Explore Dedication of Water from Existing, New, or Underutilized Permits to Environmental Flows

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

- Agricultural or municipal water permit holders could voluntarily commit water saved through conservation measures to environmental flows.

- Investigate the availability of funding for agricultural water conservation practices (i.e., United States Department of Agriculture (USDA) Environmental Quality Incentives Program (EQIP) and other federal funding sources).

- Willing water permit holders donate, sell, or lease all or part of their permit so that that water can stay in the stream for environmental flow protection. Permit may 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.

Municipal, Industrial, Mining, and Agricultural Conservation to Reduce Water use and Demand

- Water users within the Nueces River Basin, both large and small, should set goals to decrease future surface and/or groundwater use using the Water Smart Program by the Texas Water Development Board (TWDB) or other conservation programs which best fit the entity's situation.

- Conservation programs/strategies may include stringent leak detection, low water use appliances, increasing block rate structures, customer education programs, rainwater harvesting, use of recycled water and gray water, year round residential lawn watering schedules, xeriscaping, and others. Water harvesting projects can be eligible for state wide recognition from the TWDB water catchment awards program.

- Innovative technologies should be investigated and implemented to reduce evaporation from public water treatment plant reservoirs, i.e., physical covering of water holding basins with plastic balls or structural covering. Chemical covering maybe applicable in less windy environments.

- Implement advanced agricultural irrigation conservation strategies, including installation of more efficient water delivery systems (impervious canal liners, covered canals, pipelines, etc.), improved center pivot systems (i.e., Low Energy Precision Application systems), and in-ground moisture monitors, plus the planting of improved crop varieties and other farming methods.

Effluent Reuse

- The benefits of reuse of treated wastewater to the ecological and reservoir system yield in the Nueces Delta have been well documented. Beginning in the early 1990s and continuing through today, research findings, scientific monitoring studies, and engineering reports have all supported the diversion and use of Allison Waste Water Treatment Plan (WWTP) effluent for fresh water inflow purposes and the enhancement of productivity in the Nueces Delta (Region N RWP 2011, Section 4C.5.1 thru Section 4C.5.3). However, recent regulatory Texas Pollutant Discharge Elimination System (TPDES) permit limits require that the ammonia be reduced from the effluent, also reducing the ecological benefit to the estuaries. Discharges not meeting permitted levels currently required for discharge into the Delta are discharged to the river. Renewed efforts need to be made by the City of Corpus Christi, NEAC, and Nueces BBASC to work with TCEQ and the Environmental Protection Agency (EPA) to increase the permitted level for ammonia (NH_3 as N) to the current Allison WWTP design capabilities. Higher limits would allow for an increase of environmental flows to the Delta by 2 Million Gallons per Day (MGD) or a little under 2,245 acre-feet per year (acft/yr).

- Industry also needs the flexibility to reuse effluent to reduce water demands. Reuse would allow for more fresh water to remain in the reservoirs, at times leading to increased flows to the bay and estuary. (Region N RWP 2011, Section 4C.6.3). The Nueces BBASC encourages industry to re-examine their current water conservation and reuse practices for possible improvements.

Develop Conjunctive Use Water Projects

- To reduce reliance on surface water, particularly during drought conditions, water providers should be encouraged to develop conjunctive use water projects using both groundwater and surface water. Better data on groundwater availability is now readily available for local groundwater conservation districts (GCDs) and Groundwater Management Areas (GMAs) within the Nueces River Basin, including modeled available groundwater reports from the TWDB, increasing the certainty of groundwater use planning.

Develop Alternative Water Supplies to Increase Availability of Water for Environmental Flows

- Alternative water supplies, such as desalination of brackish groundwater or seawater desalination, can provide additional water for human uses as well as for environmental flows.

- Additional water supply projects could be developed to capture water during higher flows events to allow for releases to support the river/bay system during no or low flow periods or when needed. The projects could be off-channel surface water storage, aquifer storage and recovery (ASR), or a combination of off-channel storage and ASR.

- Explore potential for direct reuse of municipal and industrial wastewater (e.g. by reverse osmosis treatment) for potable or other surface water supplies in some areas of the basins, where there is a net benefit to environmental flows.

Drought Contingency Plan Triggers

- Evaluate potential changes in the current City of Corpus Christi Water Conservation and Drought Contingency Plan to determine the impact on water supply, supply infrastructure and environmental flows. Consideration should be given to moving some measures now contained in the Drought Contingency portion of the plan into the Water Conservation section (i.e., implement year-round lawn watering schedules designed to minimize evaporation losses). Care should be exercised, however, to retain drought management measures which have the ability to significantly reduce water demand, on a temporary basis, during more critical stages of a drought so as to protect water supplies for both human and environmental needs.

Re-examination of the 2001 Agreed Order Monthly Targets

- The monthly targets that are in the 2001 Agreed Order were established about 20 years ago. A preliminary assessment of 20 years of inflow data shows that there is no longer a peak in inflow during the months of May and June for either the reservoirs or the bay. The data suggests that a redistribution of monthly targets to months when natural hydrological peaks occur might benefit both the public water supply in the form of salinity credits, as well as the bay. This strategy is the focus of the work plan study prioritized number four by the Nueces BBASC.

Salinity Monitoring and Real Time (SMART) Inflow Management

- Obtaining environmental enhancements based on a desired salinity range may be achieved through seasonal timing of releases made available from reservoir inflow passage, combined with real-time knowledge of the current bay salinity condition and near- and long-term weather and climate forecasting. SMART Inflow Management may include some or all of these considerations and may be specified for year-round or by season. The Nueces BBASC has initiated some preliminary modeling work on banking water (storing in the reservoir system) for later release when conditions in the bay and/or delta might benefit more from a pulsed event, and the results look promising. Further analysis should be conducted to determine full impact on reservoir operations, system storage, water supply, and bay enhancements by incorporating ungaged flow data and analysis from the Texas Rainfall-Runoff (TXRR) model. This strategy is the focus of the work plan study prioritized number one by the Nueces BBASC.

Explore Landform Modifications to Nueces Bay and Nueces Delta

- Throughout the world, construction of water control structures has been used for effective management of fish and wildlife habitat and protection of preferred natural resources. Maximizing the benefits of available freshwater inflows from managed events such as pumped discharge, low volume natural or induced "overbank", and/or reuse of effluent, will likely require earthwork and related facilities of landscape scale within the Delta. Similarly, construction of appropriate design facilities in Nueces Bay proper to ensure longer retention of desired salinity levels at Salt 3 (the official salinity monitoring station located in Nueces Bay near Whites Point) from spills or pass-through events should be explored. Preliminary modeling performed by the TWDB for a hypothetical structure in Nueces Bay indicated a potential for salinity reduction benefits. These landforms can also provide erosion protection and serve as platforms for wetland and reef habitat development and they should be reinvestigated. This strategy is the focus of the work plan study prioritized number seven by the Nueces BBASC.

- A large scale earthwork project in the mid 1980s and early 1990s in the Nueces Delta intentionally created conditions suitable for the survival and continued persistence of *Spartina alterniflora* (smooth cordgrass). The results were achieved without requirement for freshwater to ameliorate hypersaline soil conditions. The mechanics of this large scale project are known and can be adapted for application within the Delta.

Use of Oil Spill Restoration and Other Mitigation Funds for Water Use Efficiency and Conservation

- Use oil spill restoration (e.g., Early Restoration Funds, Natural Resources Damage Assessment Funds, and/or Clean Water Act Funds from Restore Act), Supplemental Environmental Program (SEP), and other fund sources such as from in-lieu mitigation, to develop proposals for current senior water right owners to convert to other less water intensive business uses and/or dedicate water for environmental flows. This concept of funding use could be applied, as examples, to convert small to large private or public urban landscapes that depend on heavy water use to xeriscape and/or implement projects that improve quantity or utilization of inflows to Nueces Delta and Bay.

4.0 Work Plan for Adaptive Management Elements

Pursuant to SB3 of the 80th Texas Legislature, the Nueces BBASC was charged with development of a Work Plan to be submitted to the EFAG for approval. With the assistance of the Nueces Basin and Bays Expert Science Team (BBEST), the Nueces BBASC began to identify subject areas deemed appropriate for monitoring, studies, and activities in their Recommendations Report submitted in August 2012. Although the Nueces BBASC Recommendations Report provided a list of potential Work Plan activities, the list was neither complete nor prioritized. Similarly, Section 7 of the Nueces 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 Nueces BBASC, with the assistance of the Nueces 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 undertaken. The scopes of work (SOWs) and identified strategies constitute the great majority of this Work Plan.

Work Plan items identified by the Nueces BBASC and/or the Nueces BBEST have been categorized based on relevance to rivers and streams and bay issues, and are listed in Section 6 of the Nueces BBASC Recommendations Report. These Work Plan subjects have since been reviewed and refined. A Work Plan Workgroup was established to draft, review, categorize, and complete a preliminary prioritization of the SOWs. A draft Work Plan was then distributed to the full Nueces BBASC for review and refinement. Through this process, a final Work Plan was developed.

The prioritization criteria considered by the Workgroup included:

- direct influence of studies on understanding of the current environmental flow recommendations;
- significance of data gap(s);
- connectivity to river/ bay;
- promotion of understanding of environmental flows and the role of freshwater inflows;
- urgency to address damage areas;
- impact on aquatic, estuarine, and/or riparian systems;
- sequential nature of studies;
- required time to complete a study; and
- available funding opportunities, partnerships, and costs.

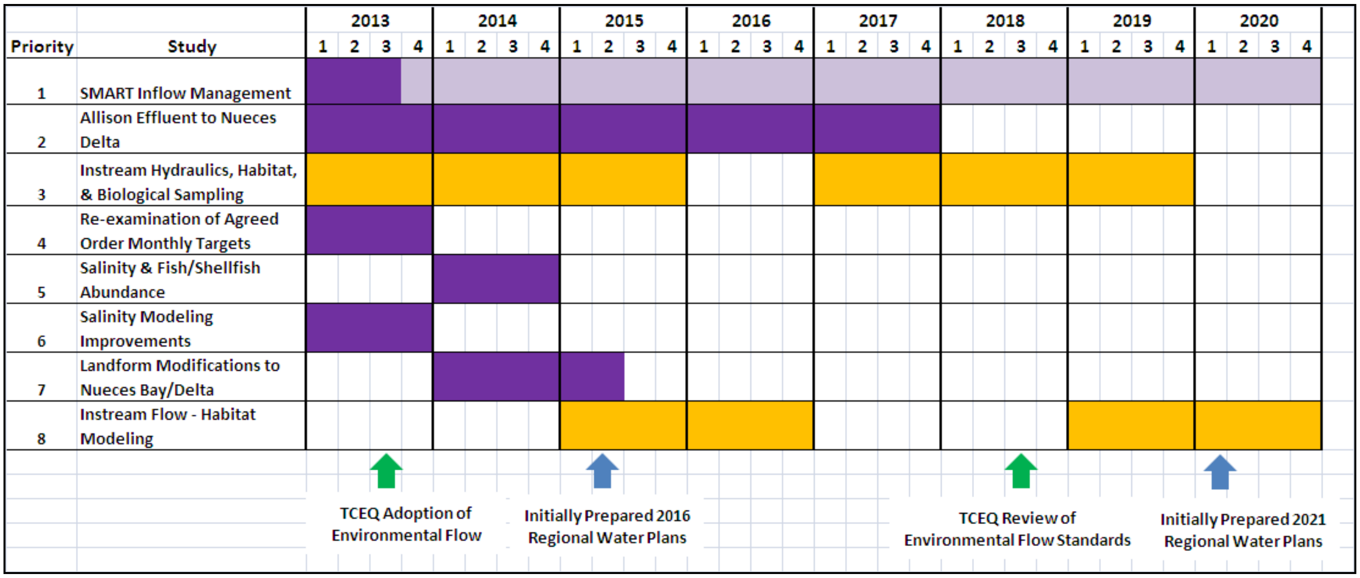
To finalize the Work Plan prioritization, the Nueces BBASC Workgroup held a meeting and agreed that a three-tiered prioritization approach is sufficient to fulfill legislative direction and provide adequate notice to the scientific community regarding which studies are most important to fill data gaps.

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 2a and 2b are not individually ranked based on the perception that these items are relatively equal in importance. Tiers 2a and 2b are simply grouped according to relevance to rivers and streams or bays.

Assuming the availability of funding sources, Table 1 is a proposed integrated schedule for performance of the eight prioritized work plan studies in the coming years. This schedule illustrates the prerequisite linkages among prioritized studies as well as the duration of each study. Also shown in Table 1 are the approximate points in time at which environmental flow standards for the Nueces River Basin and Bay Area are expected to be adopted and reviewed and the approximate publication dates for the initially prepared regional water plans. As is apparent, the five-year cycles for environmental flow standards and regional water plans are offset by about two years allowing sufficient time for the technical evaluation of water management strategies comprising the regional water plan to be based on current environmental flow standards.

While potential sources of funding are to be determined, agencies and entities with relevant technical expertise are listed for each work plan element. It is understood that the direct technical support of state and federal agency personnel and the indirect funding support (through project allocations or agency appropriations) of the Texas Legislature and U.S. Congress are essential to the successful implementation of this work plan and long-term administration of an effective adaptive management process.

Table 1. Preliminary schedule for performance of Nueces BBASC Tier 1 Work Plan studies. The yellow cells indicate River and Steam studies and the purple indicates Bay study work items. Green arrows show years of when TCEQ will adopt environmental flow standards and blue arrows show when the Regional Water Plans are initially prepared.



Tier 1 Priorities

Priority #1. Salinity Monitoring and Real Time (SMART) inflow management study

Linkages: This study is linked to the Priority #4 study focused on re-evaluating the 2001 Agreed Order to ensure environmental flows to the Nueces Estuary. This study is also linked to the Priority #6 study directing improvements to salinity modeling methods for determining environmental flow regimes. Both of these projects would enhance the applicability of SMART Inflow Management and create a tool for predicting changes in salinity regimes to make better management decisions.

What: The SMART Inflow Management strategy pulses water to the estuary as needed based on salinity conditions in the bay and delta, rather than through a schedule of monthly target volumes. The strategy seeks multiple goals: 1) to assure adequate environmental flows to Nueces Bay and Delta that creates measureable ecological benefits, 2) provides connectivity between Bay and Delta while also providing for a reduced variance in salinities, and 3) helps to maintain recreational and economic values within the reservoirs for longer periods of time.

Why: The Nueces BBEST reports that there is a loss of salinity gradient in the Nueces Bay and Delta that influences a zonation of communities found within the bay system. Connectivity of freshwater is another issue within the delta, and high salinity variance is found both in the delta and the bay. The salinity gradient between the bay and delta are compromised due to both the connectivity and high salinity variance. Through modeling exercises, the SMART Inflow Management concept appears to be a viable strategy for efficiently utilizing the limited freshwater resource available to create bay and delta conditions that have a salinity gradient, connectivity, and a reduction in the salinity extremes that have a negative impact on estuarine productivity. In order to validate the preliminary modeling efforts conducted to date that show an improvement to managing freshwater inflows into the bay, it will be essential to understand the long term ecological and economical benefits.

Where: The Reservoir System to Nueces Bay and Delta.

How: Since preliminary modeling work has already been completed and shows positive results, the next initial step could be to begin implementing the SMART Inflow Management on a trial basis over a period of years. A small advisory group could be formed from members on the NEAC to help monitor when freshwater inflows are needed into the bay and to establish criteria for storing (i.e. water banking) and releasing water. In order for SMART Inflow Management to be implemented under the current Agreed Order, a water "banking" concept would need to be created where any required monthly pass through water could be stored in the reservoir until a later date pending either: 1) bay and/or delta conditions need freshwater (i.e. salinities are increasing above a certain threshold), or 2) a large enough volume of water has been banked over time in order to create significant changes in salinities for the bay. The small advisory group would work under the guidance of the NEAC and be communicating with reservoir operators and TCEQ on how and when to best send water to the bay, with the idea being to develop an operational plan for SMART Inflow Management. The Corpus Christi Water Supply Model (CCWSM) should be run to insure safe yield is not negatively impacted.

When: A 10 year pilot project could be initiated beginning September 1, 2013, allowing the NEAC time to organize a committee and lay the framework for implementing the project.

Who: The NEAC, which is chaired by TCEQ, would be the overall guidance for the pilot project. The NEAC would create the advisory group from its list of members, establishing a balanced group of stakeholders to lead the project. The City of Corpus Christi (City) is the operator of the reservoirs and is a member of the NEAC, so the City would be an integral part of the projects success. The TWDB has expressed interest in modifying the TxBLEND model to be a possible tool for knowing when and how much freshwater to release in order to meet the desired conditions in Nueces Bay. In coordination with TxBLEND should be the use of the CCWSM by consultants familiar with its capabilities.

Cost: $40,000 to $75,000 to initiate model runs insuring no negative impacts on safe yield. It is anticipated to be $0 for initiating the 10 yr pilot project. Texas Parks and Wildlife Department (TPWD) samples Nueces Bay with routine trawls and bag seine efforts. Additional sampling efforts for measuring success would be scoped out through the NEAC prior to September 1, 2013.

Priority #2. Evaluate potential for Allison wastewater effluent with its nutrients and other return flows (e.g., Oso Bay returns) to improve environmental health of the Rincon Bayou delta

Linkages: This study is linked to the un-prioritized Bays study focused on evaluating changes in nutrient loads within the Nueces Watershed. An evaluation of nutrient loads pre- vs. post-reservoir construction might indicate a change in management decisions on effluent releases to the Nueces Delta and Bay.

What: The City of Corpus Christi's Allison WWTP is allowed to discharge treated effluent to the Nueces delta. City of Corpus Christi has other substantial wastewater discharges to the Oso Bay drainage. The Nueces BBEST and scientists prior to the BBEST recognized the value of increasing freshwater inflow to the delta. The University of Texas Marine Science Institute illustrated the positive ecological benefits in the delta from the Allison Wastewater Treatment Plant discharge. However there are regulatory obstacles to modifying the plant's permit to maximize its addition of freshwater to the delta. Additionally there are infrastructure and regulatory obstacles associated with shifting wastewater discharges from Oso Creek and Oso Bay to the Rincon Bayou.

The City of Corpus Christi can begin work with its engineers and consultants exploring possible ways to increase discharges to the delta from both infrastructure and regulatory perspectives. It can also initiate interaction with scientists studying the ecological health of the delta to identify seasonality, volumes, water quality, and discharge locations most likely to benefit ecological health of the delta. Studies should document ecological effects of increased wastewater discharges on the delta combined with possible ecological effects of decreased treated wastewater discharged to the Oso Creek drainage.

There may be economic incentive for the City to pursue moving the Allison discharge to the delta. The City must perform nitrogen removal on discharges to the delta in order to avoid ammonium toxicity in discharges to the delta. Elevated nitrogen in the discharge could provide ecological benefits to the delta and eliminate the need for the city to pay to remove it from the discharge. The Nueces River tidal may benefit ecologically since it experiences substantial algal blooms, low oxygen, and fish kills in the vicinity of the Allison discharge to the river. Transferring the entire Allison discharge to the delta would reduce the environmental impacts that occur in the Nueces River tidal. The City might also receive water credit for placing water directly into the delta.

Why: Increasing wastewater discharge of freshwater to the Nueces delta is one method of increasing freshwater inflow to an area needing more freshwater in order to remain healthy. Wastewater discharges may also contribute nutrients and sediment which could support the delta food web.

Where: City of Corpus Christi, its Allison Wastewater Treatment Plant, and wastewater discharges to the Oso Creek drainage basin.

When: Five years from the most recent Allison WWTP wastewater permit renewal to increase flow from the Allison plant to the delta. Fifteen years should be allowed to evaluate regulatory and infrastructure changes necessary to move wastewater discharges from the Oso basin to the Nueces basin.

Who: City of Corpus Christi, technical consultants, TCEQ, EPA, TPWD, TWDB, universities.

Cost: $200,000 for the Allison plant regulatory changes. There is not a cost estimate for the longer term process of evaluating moving treated wastewater from the Oso Basin to the Rincon delta.

Priority #3. Describe relationships between flow and physical, chemical, and biological structure and function of the streams and how these relationships support ecological health

Linkages: This study is linked to the Priority #8 study focused on conducting additional modeling of relationships between in-stream habitat and flow. Habitat mapping, hydraulic measurements, and biological sampling of aquatic species in this Priority #3 study will be used to define species habitat utilization preferences and construct two-dimensional habitat models relating instream habitat and flow in the Priority #8 study.

What: Table 7.2.1 of the Nueces BBEST Environmental Flows Recommendations Report recognized there has been practically no study of the relationship between stream flows and health of Nueces basin streams. The United States Geological Survey (USGS) monitors flow and water chemistry in the basin. TCEQ and the Nueces River Authority (NRA) routinely monitor water quality. The NRA has accumulated considerable qualitative information about how riparian vegetation protects stream health. TPWD has performed very limited biological sampling in some of the streams. The Nueces BBEST contracted for limited assessment of the relationship between flow and habitat availability at three streams in the basin. Regardless of the work done in the past, there has not been enough focused sampling and analysis to understand relationships between flows and water quality, habitat, and biological health in the different types of streams found in the basin.

Texas' regulatory approach to protecting environmental health of streams started with a focus on controlling wastewater discharge quality followed by monitoring water quality to ensure water quality standards were achieved. Agency emphasis since then has expanded to control of nonpoint source pollution and most recently to environmental flows to ensure stream health.

Comprehensive, integrated studies are required to describe how water chemistry, habitat, riparian communities, aquatic communities, and flow regimes interact to provide ecologically healthy streams. Information collected during these studies will identify baseline ecological conditions. NRA and TCEQ field staff should coordinate their routine water quality and flow monitoring to maximize access to sampling resources. Their routine monitoring should form the basis for this monitoring effort in order to avoid duplication in water chemistry sampling and take advantage of the presence of trained staff in the field.

There are three areas of effort unique to the Nueces basin which should be included.

1. Species of state-threatened mussels and a diverse mussel community are found in the basin. Historical monitoring has not included mussels and they should be included in this effort. We should understand when and under what flow conditions mussels spawn and what fish hosts are parasitized by larval mussels.
2. Some streams, particularly in the South Texas Brush Country cease flowing but support perennial pools. These pools should be sampled to describe the ecological services they are providing not only to fish and aquatic invertebrates but also to reptiles, amphibians, riparian vegetation, and wildlife.
3. The ecological role of small pulse events that happen relatively frequently should be investigated.

Seasonal monitoring should be conducted over the range of environmental flow recommendations from subsistence to high pulse flows. Water chemistry sampling should include parameters routinely sampled in the Clean Rivers Program (CRP). Biological and habitat sampling should follow the Texas Instream Flow Program protocols. Water level recorders should be established on Coastal Bend streams to be sampled which do not have USGS flow monitoring.

Since biological, instream habitat, and riparian sampling efforts are anticipated to involve personnel from different organizations, very specific quality assurance and quality control protocols for biological sampling, data collection, mapping, data submittal, data processing, and data storage should 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 and the BBASC to consistently track the ecological condition of the systems over time and assess / validate the environmental flow recommendations and implementation strategies. The sampling regime should support development of habitat suitability criteria.

Why: Long-term data collection and analysis of different components of the ecosystem are necessary to understand the role of different flow regime components in stream ecological health.

Where: Two representative streams in each of the Edwards Plateau, South Texas Brush Country, and Coastal Bend regions of the basin. Sites should be selected which are currently monitored for flow by the USGS. There are relatively few Coastal Bend streams, most of which are not monitored by USGS due to being tidal streams.

When: Seasonal sampling should be conducted for a period of three years at each site. One suggested study design would be to sample each of an Edwards Plateau, South Texas Brush Country, and Coastal Bend streams for three consecutive years and then sample one each of different Edwards Plateau, South

Texas Brush Country, and Coastal Bend streams for a second three-year period. This would provide six years of seasonal data in each of the three regions of the basin.

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

Cost: $810,000 ($135,000 per year) to sample three location four times a year for six years. This cost may be reduced if existing monitoring efforts are coordinated with this proposed sampling. It may also be reduced to the extent that universities can be involved.

Priority #4. Re-examination of the 2001 Agreed Order monthly targets

Linkages: This study is linked to the Priority #1 study focused on SMART Inflow Management. SMART Inflow Management might be enhanced through the re-examination process of the Agreed Order by allowing for water storage options.

What: A re-evaluation of the 2001 Agreed Order freshwater inflow monthly targets.

Why: As described in Section 4.1 of the Nueces BBEST Environmental Flows Recommendations Report, there has been a shift in monthly freshwater inflow patterns to the Nueces Bay, and based on this analysis there is a similar pattern of inflow into the reservoirs. Section 2.3 of the Nueces BBASC Environmental Flows Recommendations Report describes reservoir operations and the Agreed Order, pointing out that there might be an opportunity to better manage the limited freshwater resource by reviewing new data that was not available during the creation of the 1995 Agreed Order, which is the basis for the current pass through operation of the reservoir system.

Pass through targets were originated by looking at historical inflow patterns data into Nueces Bay and then divvying up the 138,000 acre feet among the months that had the highest historical inflow as a way to mimic nature. In reality what we have seen is a shift in the inflow patterns (see Figure 1), which coincidently misses the large pass through target months and could mean less water to the bay, impairing the original intent of the Agreed Order by mimicking nature. A redistribution of pass through targets might insure that the current operations plan mimics a more natural hydrological cycle. Table 2 lists reservoir monthly inflows from lowest to highest from the years of 1995 to 2011. This was constructed to show what percentile of flows are currently being passed through the reservoirs and might be useful for figuring out how the 138,000 acre feet could be redistributed in the future.

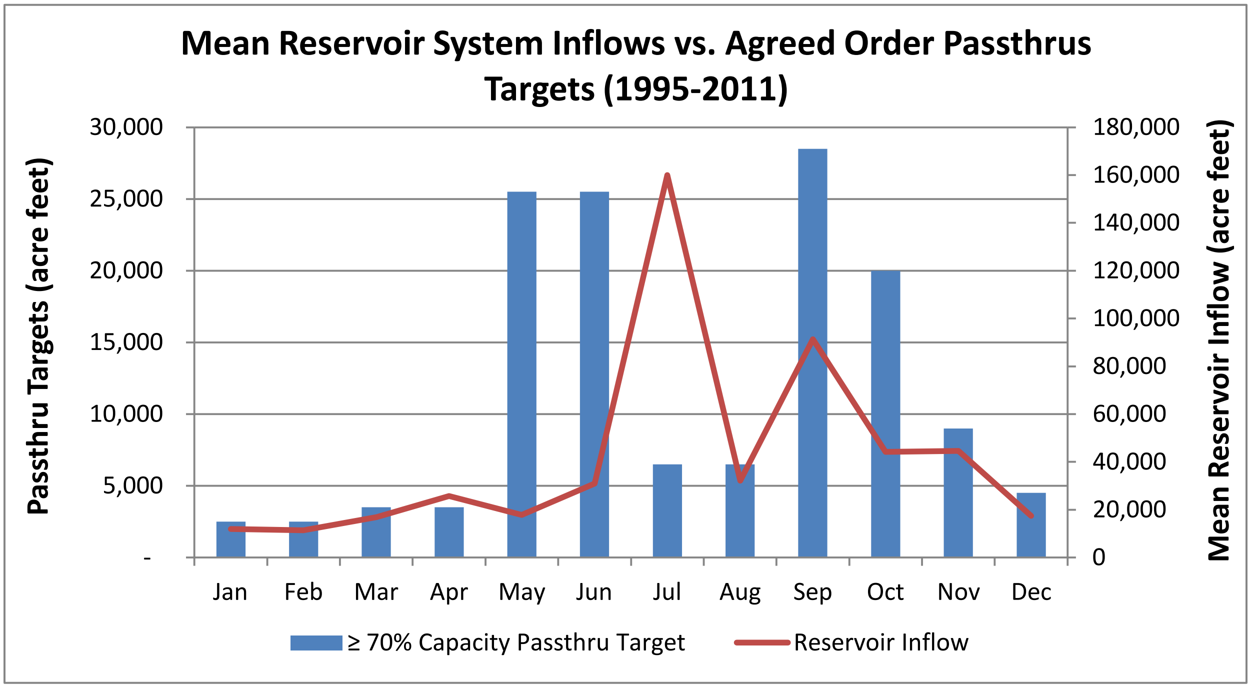


Figure 1. Mean monthly reservoir system inflows vs. the current 2001 Agreed Order pass through targets when reservoir system capacity is above 70%.

Table 2. Monthly reservoir system inflows are listed from lowest to highest by month from years 1995 to 2011. The yellow highlighted numbers represent flows that are within the 2001 Agreed Order pass through targets. The orange highlighted numbers represent flows that are not required to be passed through the reservoir and into the bay because they are flows above the required pass amount. The top blue row shows the 2001 pass through targets. The percentages on the left hand side of the table represent flow percentiles captured under the 2001 Agreed Order.

	Targets	2,500	2,500	3,500	3,500	25,500	25,500	6,500	6,500	28,500	20,000	9,000	4,500
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		1,149	733	433	197	154	6	50	23	273	414	175	251
		1,219	772	471	454	205	64	150	100	397	1,069	262	666
		1,533	873	984	599	258	167	317	141	1,747	1,348	376	939
25%		2,330	1,023	1,772	1,104	462	304	535	232	3,007	2,713	480	1,086
		2,969	2,143	2,083	1,450	1,839	588	814	851	5,892	3,089	2,257	1,717
		4,436	3,434	2,449	2,895	2,236	1,063	1,610	1,805	9,322	5,404	3,040	1,743
		4,490	3,781	4,942	4,062	2,922	1,102	4,991	3,058	12,969	5,813	4,935	2,442
		9,120	4,945	6,020	5,132	4,744	1,995	6,499	4,062	14,722	6,609	6,458	2,532
50%		10,650	7,523	6,877	8,969	5,118	8,720	12,352	4,407	25,016	6,622	14,148	4,657
		11,761	9,135	7,345	10,814	9,741	12,861	16,450	5,835	46,356	7,529	23,315	4,751
		12,062	11,407	8,208	17,556	11,009	13,086	31,883	7,858	49,157	12,610	24,021	10,967
		12,973	11,805	13,787	22,951	12,361	15,500	34,043	9,109	63,766	15,053	39,244	13,685
		13,874	14,252	19,067	24,940	15,558	27,023	131,662	12,967	69,331	17,447	60,179	15,297
75%		16,087	22,090	32,556	26,670	16,101	30,184	141,306	46,656	78,089	24,977	72,664	24,128
		29,170	28,200	35,188	28,802	41,458	77,285	249,346	80,345	79,484	129,887	85,091	58,002
		30,487	32,949	65,052	108,180	71,502	157,810	750,255	107,436	161,588	231,260	169,218	74,930
		37,649	37,374	78,979	171,606	108,092	177,394	1,337,481	260,321	932,297	280,307	253,185	77,334
	Total	201,959	192,439	286,213	436,381	303,760	525,152	2,719,744	545,206	1,553,413	752,151	759,048	295,127

Where: Nueces River Basin.

How: Through the guidance of the NEAC, which was formed under the 1992 Interim Order and charged with assessing the effectiveness of the water management strategies and operating guidelines for reservoir systems that are contained in the Agreed Order, and with recommending changes to the Agreed Order as needed to the Executive Director of the TCEQ. The NEAC is chaired by the TCEQ and established the current monthly freshwater inflow targets to the Nueces Estuary (in accordance with Special Condition 5.B. of Certificate of Adjudication No. 21-3214). The CCWSM should be run to insure safe yield is not negatively impacted.

When: One year study of existing data.

Who: Members of the NEAC represent state resource management agencies; local governments; water right permit holders; academic institutions; business coalitions; environmental and conservation groups; wholesale water suppliers; commercial and recreational fishing interests; Lake Corpus Christi/Choke Canyon Reservoir interests; and private citizens. Through this group, TCEQ could fund a contractor to re-evaluate the Agreed Order to see if there might be a benefit to both the reservoir system and Nueces Bay and Delta. Consultants familiar with the CCWSM capabilities should also be involved.

Cost: $75,000 to $100,000 to run various modeling scenarios ensuring safe yield of the system is not negatively impacted. Other costs will be variable depending on the extent and complexity of the desired analysis. For example, a redistribution of monthly targets might also impact salinity credits, a re-negotiation of return flows due to changes in operation over the past 20 years (i.e. water reuse), and an evaluation of other Agreed Order components that might be changed if targets are shifted. A full discussion should be initiated at the next NEAC meeting to discuss detail of effort so that an accurate budget can be formalized.

Priority #5. Relationships between salinity and fish/shellfish abundance

Linkages: This study is linked to the Priority #6 study for improving salinity modeling methods for determining environmental flow regimes. Enhancing a salinity model could create a tool for predicting changes in salinity regimes and help understand the relationships between fish and shellfish abundance.

What: The purpose of this study is to describe and design studies to address relationships between abundance of fish and shellfish in the bay and bay salinities. *Note: This study does not include oysters. There is a separate work plan item for this species.*

Why: Defined salinity range and inflow regime typically promote a healthy ecological environment. These environmental patterns maintain the productivity, extent, and persistence of many aquatic habitats and species in estuaries. Thus, freshwater inflow is essential for many adult, post-larval, and juvenile life history stages for numerous estuarine species. In South Texas, relatively predictable freshwater inflows reduce salinity with rainfall, provide nutrients that stimulate primary productivity, and in general enhance the entire food web. Certainly, a better understanding of the relationships between freshwater inflow and abundances of estuarine species is essential and more work is needed to further elucidate the relationships between salinity and fish and shellfish abundance.

Where: The Corpus Christi Bay area was designated as an estuary of national significance by the U.S. EPA in 1992. The Corpus Christi Bay system comprises over 124,700 acres along the central Texas coast. The mouth of the Nueces River empties into Nueces Bay north of Corpus Christi at the San Patricio county line. Most of Nueces Bay is located in the San Antonio-Nueces coastal basin, but a small portion lies in the Nueces-Rio Grande coastal basin. The Corpus Christi Bay system exchanges water with the

Gulf of Mexico through a direct connection at the Aransas Pass. A dominant feature affecting the salinity regime and effects of freshwater inflow to the bay is a deep ship channel that runs the entire length of the bay. This channel facilitates the exchange of bay waters with the Gulf, creating marine conditions in the bay. This large amount of Gulf water exchange allows these marine conditions to persist even during high flow events to the estuary. The limited effect freshwater inflow has on reducing salinity in Corpus Christi Bay is the primary reason this study should be focused on, but not limited to, Nueces Bay. Examination could also rely on salinity studies conducted elsewhere as examples of how specifies react to varying salinities.

How: A rigorous and thorough review of the scientific literature and development of model as to how fish/shellfish responds to freshwater inflow would be the initial approach. The procedures to define the relationships between salinity and fish/shellfish abundance should be based on but not limited to the following methods:

1) Characterize historical patterns of fish/shellfish abundance patterns in response to different inflow regimes;
2) Use empirical data and modern modeling approaches (e.g., predictive models) to model a variety of inflow conditions and how fish/shellfish responds under a variety of conditions;
3) Identify focal species and develop quantitative metrics between freshwater inflow and estuarine health;
4) Carry out key field and/or laboratory studies designed to understand how different salinities affect the populations of key species;
5) Generate predictive maps of how key fish/shellfish respond to varying salinity regimes; and
6) Calculate production for key fish/shellfish species under different salinity regimes.

When: This study would take about one year to complete but should be started as soon as adequate funding is available.

Who: Literature review and laboratory experiments could be performed by university scientists with expertise is the area. Additional proposals and/or funding for the work could be requested through groups such as Texas Sea Grant, the Coastal Bend Bays & Estuary Program (CBBEP), and Mission Aransas National Estuarine Research Reserve (MA-NERR).

Cost: Estimate of $150,000 - $200,000 depending on how much laboratory experimentation is requested/needed.

Priority #6. Improve salinity modeling methods for determining environmental inflow regimes

Linkages: This study is linked to the Priority #1 and #5 studies. Priority #1, SMART Inflow Management, could benefit from an enhanced salinity model that predicts salinity regimes in the Nueces Bay under various environmental conditions. The Priority #5 study, which evaluates salinity relationships to fish and shellfish, could be enhanced with a model that predicts changes in salinity.

What: Identify improvements necessary in methods for determining environmental inflow regimes for estuaries.

What: Carry out improvements to the TxBLEND Hydrodynamic and Salinity Transport Model (TxBLEND Model) or development of better modeling tools to better predict environmental inflow regimes for estuaries.

Why: During the analyses performed by the Nueces BBEST often discovered that the modeling tools available were not adequate to make accurate prediction of inflow and salinities at the desired scale needed. These modeling approaches are certainly effective when used for the intended development purpose; however, they were not necessarily built to answer the questions posed. During the BBEST process there was not time to develop new modeling approaches that would have best addressed the problems at hand. For example, there are certain inflow conditions and certain geographic areas of the Nueces-Corpus Christi Bay estuarine region that proved difficult for the TxBLEND Model to predict salinity accurately, or it was not responsive enough at the intended scale (i.e., fine-scale salinity modeling of Nueces Bay both spatially and temporally). Thus, there is a need for to calibrate and improve TxBLEND or evaluate other model performance.

Where: The mouth of the Nueces River empties into Nueces Bay north of Corpus Christi at the San Patricio county line. Most of Nueces Bay is located in the San Antonio-Nueces coastal basin, but a small portion lies in the Nueces-Rio Grande coastal basin. The Corpus Christi Bay system exchanges water with the Gulf of Mexico through a direct connection at the Aransas Pass. A dominant feature affecting the salinity regime and effects of freshwater inflow to the bay is a deep ship channel that runs the entire length of the bay. This channel facilitates the exchange of bay waters with the Gulf, creating marine conditions in the bay. This large amount of Gulf water exchange allows these marine conditions to persist even during high flow events to the estuary. The limited effect freshwater inflow has on reducing salinity in the Corpus Christi and associated bays and a primary reason this study should be focused on, but not limited to, Nueces Bay.

How:
This study proposes a systematic re-examination of the TxBLEND or other modeling approaches across inflow rates at varying spatial and temporal scales for the Nueces estuary. Model development or improvement should include but not be limited to:

1. Refining and improving model grid;
2. Improving estimates of hydrology and freshwater inflows to the estuary;
3. Improving spatial representation of precipitation falling on the bay; and
4. Improving spatial representation of evaporation from the bay.

When: This study would take about one year to complete but should be started as soon as adequate funding is available.

Who: TWDB with potential support / data from other State agencies. Additional proposals and/or funding for the work could be requested through groups such as Texas Sea Grant, the Coastal Bend Bays and Estuary Program, and Mission Aransas National Estuarine Research Reserve.

Cost: Estimate of $ 150,000**.**

Priority #7. Explore landform modifications to Nueces Bay and Nueces Delta

Linkages: This study is linked to the Priority #6 study for improving salinity modeling methods for determining environmental flow regimes. Enhancing a salinity model could create a tool for predicting changes in salinity regimes and help understand the effects of creating landform modifications in the Nueces Bay and Delta.

What: Maximize benefits of available freshwater inflows from all sources and seasons and climates, from managed events such as but not limited to pumping, low volume natural or induced overbank, use of effluent, use of "banked" storage, to provide protection for or the construction of preferred habitats.

Why: Several threats and opportunities identified by the Nueces BBASC.

a. The volume and availability of water available under existing climate conditions and administration of the current agreed order are frequently limited;
b. The volume of inflow under a greenhouse warmed future are expected to be less than current supply estimates;
c. A low likelihood of achieving the maintenance of desired salinity levels at Salt 3, and/or hoped for habitat restoration in Nueces Bay and within the Delta under current and future climate conditions;
d. Interest to maximize current use of pumping, possible future changes in operational practices (e.g. SMART Inflow Management), possible future reuse of effluent;
e. Construction of preferred habitats (e.g. Spartina alterniflora) without requirement for freshwater to ameliorate hypersaline soil conditions;
f. Use worldwide for effective management for preferred fish and wildlife resources;
g. Recent large and small land modifications and water control projects in Delta have beneficial outcomes;
h. Preliminary TWDB modeling suggest potential for salinity reduction (e.g. in Upper Nueces Bay);
i. Manage Sea Level Rise (SLR) impacts.

How:

1. Synthesis of information on the historic, previous and current landform modification and water control structure proposals, and implemented projects, related to water management, mitigation, habitat construction, habitat enhancement (in Nueces Bay and Delta), and;
2. Synthesis of information concerning apparent effectiveness of implemented modifications, and/or the intended justification and benefit from non-implemented proposals;
3. Conduct a design charette to review results of 1 and 2 and to identify additional concepts or ideas for further evaluation.
4. Prepare preliminary conceptual plan and profile for How #3 identified projects, conduct a preliminary estimate of cost and prepare a study report combining results for 1, 2, 3 and 4.
5. Revisit/re-run TWDB models to verify TWDB 2000 preliminary results and, where the model is directly applicable, to evaluate projects identified in 4.
6. Apply where applicable results and estimates developed under the climate change Work Plan item.

When:

1. 2 to 4 months to complete, including final draft report.
2. See # 1.
3. 1 month after completion of #1 and #2, and 2 months to complete final draft report
4. 4 months to complete after #2, including final draft report.
5. 6 - 8 months after 4, including final draft report.
6. TBD

Who:

1. Literature synthesis by qualified contractor/investigator,
2. Literature synthesis by qualified contractor/investigator;
3. Charette by qualified contractor, convened by NEAC/BBASC, with invited experts, NEAC, BBASC, other invited participants.
4. Conceptual Plans and Estimates by qualified registered engineer or architect contractor.
5. TWDB and/or qualified contractor.
6. TBD

Cost:
1. Literature synthesis: $12,000
2. See #1

[Basis: Proposal, Negotiated Lump Sum Fee, Not to Exceed]
3. Charette: $ 10,000

[Basis: Proposal, Negotiated Lump Sum Fee, Not to Exceed]
4. Conceptual Plans: $65,000

[Basis: Proposal, Negotiated Lump Sum Fee, Not to Exceed]
5. Modeling: $170,000

[Basis: Proposal, Negotiated Lump Sum Fee, Not to Exceed]
6. TBD

Priority #8. Conduct additional modeling of relationships between in-stream habitat and flow

Linkages: This study is linked to the Priority #3 study focused on describing relationships between flow and physical, chemical, and biological structure and function of the streams and how these relationships support ecological health. Habitat mapping, hydraulic measurements, and biological sampling of aquatic species from the Priority #3 study will be used to define species habitat utilization preferences and construct two-dimensional habitat models relating instream habitat and flow.

What: The BBEST and its contractors made considerable progress in understanding relationships between instream habitat suitability, however the work was based on fish habitat relationships from streams outside the basin, was only conducted at three sites, and was only conducted under one flow condition at two of the sites. Factors possibly complicating this analysis include human alterations to physical habitat not associated with flow like channel clearing and shaping for flood control, invasion of noxious plants (giant cane) or animals (armored catfish) that alter physical habitat.

This work plan item should focus on addressing some areas of uncertainty in the flow-habitat analysis and expanding the work to other sites in the Nueces basin. Specific tasks should include:

1. Two-dimensional habitat modeling/habitat mapping. Suitable habitat may be in small, disconnected patches and higher or lower flows might be needed to connect or increase size of suitable habitat patches. In order to address this, a habitat mapping approach such as a 2-dimensional model (e.g., River2D) or MesoHabSim (a habitat simulation model) that produces a spatially explicit, continuous map of habitat at the site at multiple flow levels would be necessary to evaluate how patches of habitat are connected at different flows.
2. Habitat utilization data. Collect information from the Nueces Basin about the instream habitats utilized by different species of fish and their different life stages. Collect more habitat utilization data from different streams in the Nueces Basin and at different flows.
3. Sample the cross-sections measured at the three sites analyzed by the BBEST to obtain at least one additional set of hydraulics measurements near the middle or upper end of the base flow recommendations. This would allow evaluation of another source of uncertainty, the stage-discharge rating curves used at each site.
4. Conduct flow-habitat modeling at more sites in the Nueces Basin. This analysis should first be conducted at all of the perennial streams in the basin for which flow recommendations were made. It should also be conducted for a subset of the intermittent gages.

Why: This item will strengthen the base flow and subsistence flow components of the flow recommendations by reducing uncertainty on whether the recommended flows would maintain sufficient instream habitat. Conducting this analysis at additional sites would address the assumption that habitat works at all sites just because it did at three of them.

Where: Items 1 and 3 should be conducted at the 3 sites for which the BBEST did the analysis in the report. Item 2 should be done at various sites throughout the basin including, but not limited to, locations with flow recommendations. Item 4 should be performed at all perennial gages and a subset of intermittent gages.

When: Two to three year study. All four items should be accomplished before next examination of the environmental flow standards. For item 4, perennial sites should be the priority.

Who: TPWD River Studies Program, with assistance from the BBEST and basin partners, to supervise and implement contracts to suitable university researchers or private contractors.

Cost: To be determined based on number of sites to include and methods to be utilized. $1,000,000 to $2,000,000 for four to six sites depending availability of data from the Priority #3 study. Cost will also vary based on how much work TPWD and other agencies are able to contribute.

Tier 2a Rivers and Streams Studies

*Disclaimer: Studies listed are not in any prioritized order.

Describe the role of flow in the ecological health of the stream

What: There has been practically no study of the interrelationships between environmental flow regime components and stream health in the Nueces basin. This study will describe the role of flow in the ecological health of the stream. This is an overarching goal that could be accomplished by combining information collected from 2011 through 2020 in the upcoming period between review of the standards with earlier data. The next work plan report could summarize results of monitoring and studies conducted in the basins for this adaptive management process and obtained from other sources during the interim. The analysis in this task is particularly suited to the biennial state-wide water quality assessment based primarily on TCEQ's Surface Water Quality Monitoring (SWQM) and Clean Rivers Program data. TCEQ's SWQM Information System database would be an excellent starting point for this task.

Why: It would be valuable to analyze the results of future studies and monitoring described in the work plan in a holistic manner to improve understanding of flow and environmental health in Nueces basin streams. A synthetic comparison of ecological structural (e.g. fish, macroinvertebrate, riparian, invasives, flow regime) and functional (e.g. river processes - primary and secondary productivity, organic matter dynamics) in relation to flow patterns and measures of ecological health of Nueces basin streams would help validate flow recommendations.

Where: The focus of the report would be on relationships between flows and ecological health in a minimum of two representative streams in each of the Edwards Plateau, South Texas Brush Country, and Coastal Bend reaches. One stream in each reach would be perennial and the other intermittent with perennial pools and flow. There are a number of streams in the Nueces basin which stop flowing at times. Little is known about the ecological structure and function of these pools and particularly the relation of their environmental health to flow. It is important to study how the different flow regime components support environmental health in these perennial pools.

When: 2020 -2021.

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

Cost: $75,000 – 125,000.

Identify stream locations and estuaries not included in the BBEST environmental flow regime report that should be analyzed for relationships between flow and environmental health

What: The Nueces BBASC and BBEST provided environmental flow recommendations for 21 instream locations and one bay throughout the Nueces River Basin, the adjacent Nueces – Rio Grande Coastal Basin, and the associated bays and estuarine systems. Each of these sets of recommendations is associated with a USGS streamflow gaging station having sufficient historical records that meaningful statistical analyses, typically using the Hydrology-based Environmental Flow Regime (HEFR) methodology[1], could be accomplished and considered in the context of available biological, water quality, and geomorphological information. Projected water demands and the potential for future water rights applications, however, were not explicitly considered in the selection of stream locations or estuarine systems for environmental flow regime or standard recommendations. Hence, a desk-top review could be undertaken considering projected water demands and recommended water management strategies from the approved 2016 regional water plans in the context of locations for which environmental flow standards are adopted by TCEQ in 2013. If the locations of standards and water management strategies are not sufficiently proximate to one another and/or geographically relevant biological data are insufficient, key products of this review would be recommendations regarding supplemental stream or estuarine locations for environmental flow standards and/or appropriate biological studies to provide useful metrics for development of relationships between ecosystem health and instream flows or freshwater inflows.

Why: Support the timely and science-based development of relationships between ecosystem health and instream flows or freshwater inflows useful in establishing balanced environmental flow standards applicable to planned water management strategies.

Where: The Nueces River Basin, the adjacent Nueces – Rio Grande Coastal Basin, and associated bays and estuarine systems.

When: To be initiated upon adoption of the 2016 regional water plans in September 2015, approximately 2 years after TCEQ adoption of environmental flow standards for the Nueces River Basin and Nueces – Rio Grande Coastal Basin.

Who: Consultant(s) for regional water plan development and sponsor(s) of recommended water management strategies in the regional water plans with technical support from state resource agencies (TPWD, TWDB, and TCEQ) and scientists in academia.

Cost: $20,000 - $35,000.

Describe ecological services provided by perennial pools

What: Aerial photography and anecdotal reports of landowners indicate there are perennial pools that have not dried up in recent history. Very little is known about the seasonality, persistence, hydrologic extent, and ecological services of these perennial pools. These perennial pools may provide the only aquatic habitat for much of the year and for an extended reach of the river, it is therefore important to understand their relationship to stream flow regimes. It is also fundamentally important to identify what the characteristics are of an ecologically healthy perennial pool.

Stream reaches which stop flowing but maintain perennial pools should be identified in streams of the Edwards Plateau and South Texas Brush Country regions. Since perennial pools may form in reaches away from typical public access monitoring points, landowner permission may be necessary for access to these pools. Water chemistry parameters tested in the Clean Rivers Program should be sampled in the

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[1] SB3 Science Advisory Committee for Environmental Flows. Use of Hydrologic Data in the Development of Instream Flow Recommendations for the Environmental Flows Allocation Process and the Hydrology-Based Environmental Flow Regime (HEFR) Methodology. Third Edition. (http://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/hydrologicmethods06172011.pdf).

pools. The NRA and TCEQ may modify the monitoring schedule for the basin to shift some routine monitoring to these locations.

Continuous recording water quality meters should be used to illustrate diurnal changes in temperature, oxygen (optical dissolved oxygen probes), pH, and conductivity. Water level recorders set to record at least daily should be placed in pools to monitor changes in water level. Sites should be visited once every month or two in order to download data and ensure meters are calibrated and collecting valid data. Satellite imagery should be used to observe how the areal extent of perennial pools expands in response to relatively small high flow pulse events that add water to the pools but which do not reestablish perennial flow. It will be important to monitor the riparian community and compare it to reaches of the river which are completely dry. Flow should be tracked, preferably by USGS gages, both upstream and downstream of the pools in order to understand the relationship between stream flow regime and perennial pool.

In arid areas of Texas, the ecological function of perennial pools extends well beyond the fish and invertebrates inhabiting the pools. Wildlife like reptiles, amphibians, birds, mammals, terrestrial insects rely much more on these sources of water than do wildlife in wetter areas of the state. These ecological interactions are tied to the fish and aquatic invertebrate community. For example, as water level declines in a perennial pool, fish may become more susceptible to juvenile water birds which rely on them as a protein source during critical periods of growth. It is important to monitor utilization of these pools by wildlife and their interaction with the environmental condition of the pools. A continuous recording video camera should be set up to monitor wildlife use of the pools throughout the day and night.

Biological monitoring of fish, benthic macro-invertebrates, and instream habitat should be performed quarterly according to Texas Instream Flow Program protocols. The presence, distribution, and life history of mussels (spawning period, host fish) that are present should be included in monitoring.

Why: Perennial pools in this relatively arid region of Texas may provide the only aquatic habitat available to many organisms in the area.

Where: Three locations. A minimum of one each in the Edwards Plateau, South Texas Brush Country, and Coastal Bend reaches.

When: Three year study in order to capture data over a range of flows.

Who: TPWD, NRA, TCEQ, TWDB, USGS, universities, and technical consultants

Cost: $225,000 ($75,000 per year). Cost may be lower to the extent sampling can be combined with existing monitoring programs.

Identify flow regime components and quantities necessary to sustain mussels and compare to flow regimes identified necessary to sustain fish communities

What: Field reconnaissance by the Nueces BBEST encountered several mussel species in streams in the South Texas Brush Country region of the Nueces Basin. In 2010, TPWD listed 15 species of mussels in Texas as state-threatened while in 2011, the U.S. Fish and Wildlife Service (USFWS) identified five of the state-threatened species as candidates for federal listing. One of the state-listed species which is also considered a candidate species for listing by the USFWS is the golden orb (*Quadrula aurea*) which has been found in Lake Corpus Christi. Mussels are considered the group of aquatic organisms most at risk in Texas with about a third of all known species listed as state-threatened.

Mussels filter water, recycle nutrients, and provide food for a variety of fish and mammals. Mussels have a unique life cycle in which the female mussel releases larvae that parasitize fish for a short period of time after which they settle on the stream bottom. Some species of mussels only parasitize particular species of fish. Consequently, the health of some mussel species is tied directly to the occurrence of specific types of fish hosts. Very little is known about the relationship between mussels and environmental flows.

Fundamental information about the life cycle of mussels in the Nueces Basin is needed in order to understand the relationship between environmental flows and mussel health. Areas of emphasis include:

- Ecological conditions (flow, temperature, season, bottom conditions) when mussels spawn
- Ecological conditions when mussels release parasitic larvae
- Fish species utilized as hosts by parasitic larval mussels
- Ecological conditions needed by fish species that host parasitic larval mussels
- Ecological conditions required by larval mussels to settle and attach to the bottom and survive
- Ecological conditions in which adult mussels grow and survive

Much of this fundamental information will be acquired by scientific research however research will be enhanced by incorporating standardized observations of mussels into existing and future routine water quality and flow monitoring. As the work plan is implemented, opportunities to include mussel sampling and observations in different projects should always be considered.

Researchers would locate mussel communities with safe, legal access for study. Sites should have access to flow data however water level indicators may be placed at the site(s). It may be appropriate to shift routine monitoring to these sites through modification of the CRP monitoring schedule. Routine monitoring would provide water quality information. Two to three sites would be studied. More resources may be needed in the first year in order to identify when mussels are spawning, larval mussels are being released into the water, and larval mussels are settling to the bottom. DNA tissue sampling may be necessary to confirm identification of mussel species.

Why: Research is needed to understand the relationship between flow and the environmental health of mussels and their fish hosts. The ultimate goal of this work is to identify the environmental flow regimes needed to maintain healthy populations of mussels in the Nueces Basin.

Where: Current information indicates most mussels in the basin (including the state-threatened golden orb) occur in the South Texas Brush Country region which is where the scientific research should be focused. Existing and future monitoring programs throughout the basin should identify if there are mussels in the Edwards Plateau and Coastal Bend regions which should be included in scientific research.

When: Scientific research should take a minimum of three years. Standardized observations of mussels should be incorporated into existing and future routine monitoring during all monitoring trips throughout the year.

Who: For scientific research: universities, TPWD, TWDB, USGS, technical consultants, and for routine monitoring: NRA, TCEQ, and USGS.

Cost: $475,000 ($100,000 the first year and $75,000 per year) to conduct for six years. It may be possible to accomplish much of the needed work in three years for an estimated cost of $250,000.

Describe how surface flow patterns and quantities are changing compared to the period of record patterns. Include consideration of possible future flows and diversions

What: The environmental flow analyses and flow regime recommendations of the Nueces BBEST, as well as the environmental flow standards recommendations of the Nueces BBASC, are based on application of the HEFR methodology[2] to the full periods of record for selected USGS streamflow gaging stations. Studies completed in year 2000 analyzing streamflow and areal precipitation[3,4], however, identified statistically significant trends in runoff (streamflow) as a percentage of rainfall within these periods of record. More specifically, these studies show runoff as a percentage of rainfall to be increasing with time in the headwaters of the Nueces River Basin in the Edwards Plateau eco-region (Hill Country) and decreasing with time in the Southern Texas Plains eco-region (Brush Country or Wild Horse Desert). Updated analyses of streamflow and rainfall records, including those from the 2000-2011 period, should be undertaken for confirmation of statistically significant trends and assessment of the potential continuation of any such trends into the future. Moving beyond streamflow per unit rainfall, studies would more explicitly consider potential changes in the magnitudes, frequencies, and durations of seasonal subsistence, base, and pulse flows using the HEFR methodology.

Beyond the recognition of statistically significant trends in streamflow, it is important to identify and understand causative factors influencing such trends. This may be accomplished through correlation analyses of potential causative factors affecting streamflow including, but not limited to, the following: rainfall, air temperature, global climate drivers (e.g., Southern Pacific Oscillation, North Atlantic Oscillation, etc.), weather modification (cloud seeding) activities, diversions, impoundments, reservoir system operations, discharges of treated wastewater, land use, brush proliferation and management activities, and groundwater use and changes in aquifer levels. If statistically significant relationships between streamflow and one or more causative factors can be defined, then historical streamflow records may be adjusted to reflect current and/or future conditions in sub-watersheds throughout the Nueces River Basin.

Using streamflow records adjusted to current conditions and available relationships between flow and weighted usable habitat area for aquatic species, water quality parameters (e.g., dissolved oxygen), and sediment transport, perform preliminary quantitative assessments of the potential ecological significance of differences between streamflows representative of historical and current conditions. If the differences appear ecologically significant, provide recommendations regarding the scope and budget for more intensive data collection and statistical analyses necessary to further explore or validate apparent relationships between causative factors and streamflow trends in order to provide technical support for potential adjustment of environmental flow standards.

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[2] SB3 Science Advisory Committee for Environmental Flows. Use of Hydrologic Data in the Development of Instream Flow Recommendations for the Environmental Flows Allocation Process and the Hydrology-Based Environmental Flow Regime (HEFR) Methodology. Third Edition. (http://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/hydrologicmethods06172011.pdf).

[3] HDR Engineering, Inc. and Texas A&M University. December 2000. Nueces River Watershed Brush Control Planning, Assessment, and Feasibility Study. Texas State Soil and Water Conservation Board. Nueces River Authority.

[4] HDR Engineering, Inc. and Texas A&M University. December 2000. Frio River Watershed Brush Control Planning, Assessment, and Feasibility Study. Texas State Soil and Water Conservation Board. Nueces River Authority.

Why: Potential adjustment of adopted environmental flow standards to better reflect streamflow magnitude, frequency, and duration representative of conditions during the five to ten year period after TCEQ adoption of environmental flow standards and prior to the next statutory review of these standards.

Where: Nueces River at Laguna, Cotulla, and Three Rivers and Frio River at Concan as these locations have long-term USGS streamflow gaging stations and available flow-habitat, water quality, and/or sediment transport data and analysis tools to support quantitative evaluations.

When: During the five to ten year period immediately after TCEQ adoption of environmental flow standards in 2013.

Who: Federal resource agencies (USGS or National Oceanic and Atmospheric Administration), state resource agencies (TWDB, TPWD, or TCEQ), scientists in academia, and/or consultants.

Cost: $100,000 - $150,000.

Describe groundwater flow into streams and how is it changing

What: Aerial photography and anecdotal reports indicate there are perennial pools, sustained by groundwater, that have not dried up in recent history. There is little known about the relationship between groundwater and stream flow in parts of the basin, particularly in the more arid Edwards Aquifer and South Texas Brush Country regions. Additionally there is increasing pressure on groundwater in the area for industrial, agricultural, and domestic use. How relatively rare floods recharge shallow groundwater aquifers and whether recharge is through river banks or from overbanking flows are poorly understood.

Groundwater monitoring wells should be identified near and distant from the river. Groundwater levels should be monitored at least daily for future comparison to river flows and levels. Satellite imagery and field observations should be obtained showing the areal extent of any overbanking flows and persistence of standing water following overbanking flows.

Stream flow gain-loss studies should be conducted at low and high base flows and during at least one in-channel pulse event.

Why: The purpose of this study is to understand the movement of water between streams and groundwater.

Where: Nueces River in the Edwards Aquifer and South Texas Brush Country regions. Additional areas may be studied in the future.

When: Three year study in order to capture data over a range of flows, particularly high pulse flows.

Who: USGS, TWDB, NRA, GMA's, GCD's, TCEQ, universities, and technical consultants.

Cost: $150,000 ($50,000 per year). Cost may be lower if groundwater and flow monitoring can be combined with existing monitoring programs.

Describe relationships between benthic macroinvertebrates and flow

What: Rapid bioassessment protocols have been developed for benthic macroinvertebrates and additional quarterly monitoring of benthic macroinvertebrates in conjunction with water quality monitoring would help clarify relationships between benthic macroinvertebrates and flow.

Very little is known about benthic macroinvertebrates in Nueces basin streams. Stream macroinvertebrates are periodically decimated by natural disturbances, such as floods and droughts (Resh, et al., 1988). Flow regime plays a major role in structuring habitat conditions for stream macroinvertebrates through direct effects, as well as interaction with substrate, food supply and physio-chemical parameters Nueces BBASC Recommendations Report 104 (Ward, 1992). Benthic macroinvertebrates are reliable indicators of localized alterations in streams (Rosenberg and Resh, 1992) and are being increasingly used in evaluating effects of hydrology and habitat changes. The ability to tie biological data to observable flow levels is critical to a comprehensive environmental flow recommendation. Similar data on macroinvertebrate community and substrate/flow relationships on the Nueces will be equally beneficial for the next round of recommendations and is consistent with Senate Bill 2 studies for the Texas Instream Flow Program (TIFP) involving macroinvertebrate studies. Importantly, the results from this study may improve the ecological understanding of the aquatic communities and their relationship to flow. It may be prudent for the Nueces BBASC to consider and support TIFP related studies on Nueces Basin rivers, in order to fill data gaps on ecological knowledge and flow-ecology relationships within these systems.

Why: The Nueces BBASC recognized the importance of tying site specific biological data to flow levels using fish habitat flow relationships. A similar level of study effort using macroinvertebrate Rapid Bioassessment Protocols, Functional Feeding Group Analysis, and Instream Flow Methodologies with macroinvertebrate targets would be beneficial to the understanding of the Nueces River Basin.

Where: Nueces River at multiple sites, Frio River at multiple sites, Sabinal River, Hondo Creek at Tarpley, Seco Creek at Miller Ranch near Utopia, San Miguel Creek, Atascosa River at Whitsett, and Oso Creek at Corpus Christi.

When: Two years of quarterly monitoring to track seasonal patterns and inter annual variability.

Who: TPWD, TCEQ, TWDB, river authorities, universities, stakeholder organizations, and technical consultants.

Cost: $100,000 – $150,000.

Identify water development activities planned for the future, and how they might influence groundwater, river flows, and physical and hydrologic connections between the two

What: Future water development activities were not explicitly considered in the selection of stream locations for environmental flow regime or standard recommendations. Hydrologic connections between surface water and groundwater, however, were considered with respect to the Edwards Aquifer as environmental flow standard recommendations were provided for several locations immediately upstream and downstream of the outcrop and below Leona Springs. The Nueces BBASC used the proposed Lower Sabinal recharge enhancement project included in the 2012 State Water Plan and potentially located on the Sabinal River on the outcrop of the Edwards Aquifer as an example project to assist in formulation of their recommendations regarding environmental flow standards. Hydrologic connections between surface water and the other major aquifers underlying the Nueces River Basin (i.e. Edwards-Trinity (Plateau), Trinity, Carrizo-Wilcox, and/or Gulf Coast) were not explicitly considered by the Nueces BBASC or BBEST.

Studies under this Work Plan subject area would begin with a desk-top review of recommended water management strategies from the approved 2016 regional water plans in the contexts of locations where surface water / groundwater interactions occur and for which environmental flow standards are adopted by TCEQ in 2013. If the locations of standards and water management strategies are not sufficiently proximate to one another and/or geographically relevant biological data are insufficient, key products of this review would be recommendations regarding supplemental stream locations for environmental flow standards and/or appropriate biological studies to provide useful metrics for development of relationships between ecosystem health and instream flows.

Why: Support the timely and science-based understanding of hydrologic relationships between surface water and groundwater and the springs or stream segments where their interactions are significant in the contexts of planned water supply projects and locations for which environmental flow standards are established.

Where: Locations of planned water supply projects in the Nueces River Basin that may affect surface water / groundwater interactions at springs, the outcrops of major aquifers including the Edwards-Trinity (Plateau), Trinity, Edwards, Carrizo-Wilcox, and/or Gulf Coast.

When: To be initiated upon adoption of the 2016 regional water plans in September 2015, approximately 2 years after TCEQ adoption of environmental flow standards for the Nueces River Basin and Nueces – Rio Grande Coastal Basin.

Who: Consultant(s) for regional water plan development and sponsor(s) of recommended water management strategies in the regional water plans with technical support from state resource agencies (TPWD, TWDB, and TCEQ), federal resource agencies (USGS and USFWS), and scientists in academia.

Cost: $20,000 - $25,000.

Describe changes in geomorphology, i.e. trends in channel elevation, longitudinal profile, width, floodplain width, stream form, bed sediment size, and the role the flow regime contributes to those changes

What: The relatively short amount of time which the BBEST had to develop environmental flow recommendations did not permit in-depth analysis of the relationships between channel shape and flow. Channel morphology is directly related to the amount of sediment that is supplied, the size of the supplied sediment, and the magnitude and duration of flows that are capable of transporting the supplied sediment. In cases where the amount of sediment supplied is similar to the amount of sediment transported, a state of dynamic equilibrium may occur whereby the size and shape of the channel may remain relatively constant even though processes such bank erosion, bar building, and channel migration may occur. A substantial change in the historic flow patterns may disrupt dynamic equilibrium processes, and in these cases, sediment may accumulate or be evacuated from the river channel causing changes to the elevation of the channel bed, channel width, channel plan form, or the size and type of sediment found on the channel bed. If the channel shape changes substantially, it alters the relationships between flow and aquatic habitat and the riparian community.

This would be a desk-top study utilizing available data and aerial photography for at least two representative streams in each of the three reaches. All historical aerial photography would be identified and obtained. Historical aerial photography not in digital format would be scanned and geo-referenced in a geographic information system. For the study reaches, polygons will be created that delineate the active channel. The area of these polygons will be divided by the length of the channel centerline to obtain a reach-averaged channel width for each of the study reaches. Active channel widths will then be compared between the years of aerial photography to determine whether or not the channel has narrowed or widened over the historical record. These changes will then be compared to the hydrologic record in an attempt to correlate changes in channel width to major flooding events or extended droughts. Aerial photography will also be used to track changes in sinuosity to investigate whether the channel plan form is more simple or more complex than in historical times. The channel sinuosity will be calculated by dividing the length of the channel centerline by the length of the centerline of the alluvial valley.

We will also work with the USGS to obtain and analyze all historical discharge measurement notes collected at each stream gage. Each discharge measurement includes water depth and mean velocity at a minimum of 20 points across the channel. Because stage at the time of measurement is recorded in relation to a fixed reference mark, channel cross-section elevations can be referenced in space and compared throughout the period of available data (Smelser and Schmidt, 1998). Thus, by reconstructing the shape of the channel cross section at these gage locations, it is possible to analyze changes in the elevation of the channel bed, the channel width, and whether there has been progressive change in the overall channel geometry.

Review of available literature would guide identification of additional field data that should be collected. Indicators of change in channel morphology and their magnitude will be useful in identifying ecologically harmful changes that have occurred. The cumulative impacts of multiple, relatively small, diversions on channel morphology would be evaluated in this analysis.

Why: This analysis would strengthen the high flow pulse and overbank flow components of the flow regime and standards by better understanding the flows needed to maintain channel processes.

Where: Analysis should be conducted first at the sites that are most likely to have already sustained impacts to geomorphic processes and the sites most likely to sustain impact in the future, especially based on implementation of flow standards.

When: 1-2 year study. Should be completed for priority locations before the next examination of environmental flow standards.

Who: TWDB, other TIFP agencies, and university partners.

Cost: To be determined based on site selections.

Identify the best period of record to use in deciding which hydrologic condition and hydrologic triggers should be used

What: First of all, it is noted that hydrologic conditions and triggers are not included in the environmental flow standards recommendations adopted by consensus of the Nueces BBASC. This decision is supported by technical analyses performed for the Nueces BBASC demonstrating that variability of flows and associated quantitative assessments of weighted usable aquatic habitat, water quality, and sediment transport are adequately protected with multiple tiers of pulses, only a single tier of seasonal base flows, and application of a 50% rule governing flow pass-through requirements between seasonal base and subsistence flows. Hydrologic conditions and triggers have been included in only three of the eight river basins for which TCEQ has adopted environmental flow standards to-date.

If, as a result of including more than a single tier of seasonal base flows or alternative implementation rules, the TCEQ adopts environmental flow standards in 2013 that include hydrologic conditions and associated hydrologic triggers, then desk-top studies to assess the efficacy of such hydrologic conditions and triggers in preserving the natural variability of flows can be undertaken. It is envisioned that such studies would be comparable, in terms of scope, budget, and deliverables to those recently performed for the Nueces BBASC. More specifically, these studies could involve quantitative evaluations of example projects operated subject to alternative environmental flow standards including hydrologic conditions and triggers based on selected period(s) of record, cumulative flows, reservoir storage, Palmer Drought Index, and/or other factors. These quantitative evaluations would likely be reported in terms of firm yield and associated effects on instream flows, usable aquatic habitat, water quality, sediment transport, riparian functions, and freshwater inflows to bays and estuaries.

Why: Potential adjustment of hydrologic conditions and triggers within adopted environmental flow standards, if adopted standards include hydrologic conditions and studies indicate that adjustment is necessary.

Where: Nueces River at Laguna, Cotulla, and Three Rivers and Frio River at Concan as these locations have long-term USGS streamflow gaging stations and available flow-habitat, water quality, and/or sediment transport data and analysis tools to support quantitative evaluations.

When: During the five to ten year period immediately after TCEQ adoption of environmental flow standards in 2013.

Who: Consultant(s) with technical support from state resource agencies (TPWD, TWDB, and TCEQ) and scientists in academia.

Cost: $50,000 - $75,000.

Identify key flow-dependent ecosystem functional (create ecological structure) processes associated with a sound ecological environment

What: Riverine ecosystems are complex systems of interacting abiotic and biotic components. This should be a desk top study given the substantial lack of information on the ecological structure of the streams and riparian zones of the Nueces River Basin. The work plan should identify and evaluate key ecosystem processes and services, such as elemental cycling and the productivity of important plant and animal populations. Examples include primary production (periphyton, macrophytes), secondary production, organic matter dynamics (decay rates and biomass of coarse particulate organic matter, fine particulate organic matter), trophic level dynamics and food webs, resistance and resilience of stream communities to drought and floods, invasive species impacts to water quantity and quality (giant cane, salt cedar), invasive species effects on interspecies competition (e.g., giant cane and historical riparian community, zebra mussels and native mussels), community structure and impacts on water quantity (e.g. evapo-transpiration, flow impedance and channel losses). It is critical that the study be multidisciplinary in breadth and developed through an integration of hydrologic analyses and information on the linkages between flow regime and river processes.

Why: To manage these riverine ecosystems effectively, a basic understanding of functional ecological interactions (such as food web dynamics, reproductive cues, species recruitment, and colonization) is required. Attempting to manage a riverine ecosystem without adequate understanding of such processes can be problematic.

Where: Minimum of two representative streams in each of the Edwards Plateau, South Texas Brush Country, and Coastal Bend reaches.

When: Two year study.

Who: TPWD, TCEQ, TWDB, river authorities, universities, stakeholder organizations, and technical consultants

Cost: $50,000 - $100,000.

Develop sustainability boundary analysis

Linkages: This task will benefit from the Priority #3 study. The information on flow biology from this task would inform development of the most meaningful sustainability boundaries. The Nueces BBASC Work Plan Tier 2a project titled "Identify water development activities planned for the future, and how they might influence groundwater, river flows, and physical and hydrologic connections between the two" may involve development of time series of flow resulting from potential water supply projects in additional locations in the basin which could be examined against sustainability boundaries.

What: The primary tasks that need to be addressed in further development of the sustainability boundaries analysis are evaluation of other measures of flow to build boundaries around and to evaluate the best alteration thresholds to define sustainability. The Nueces BBEST experimented with mean monthly flow in its analysis to define normal conditions, but this task should evaluate other potential measures of normal flow conditions. These might include simple measures of flow variability such as median daily or monthly flows across the period of record. They could also be flow components such as base dry flows by month or high flow pulses. Our initial analysis utilized the 10% and 20% thresholds suggested by Richter et al. 2011, but more extensive use of this method should not be made without evaluating and potentially modifying these thresholds or considering other bases (e.g., standard deviation) for defining thresholds. One way thresholds might be evaluated is through flow-ecology relationships built from ecology data from a suite of streams with a range of levels of flow alteration across the Nueces River Basin, central Texas, or all of Texas.

This task should also include consideration of application of the sustainability boundaries approach to other locations in the Nueces River Basin. This would involve using Flow Regime Application Tool (FRAT) or other tools to develop time series of flow for other locations to evaluate flow recommendation implementation scenarios.

Why: There are few methods available to the BBASC and BBEST for evaluating the effects of implementation of flow standards on the sound ecological environment of the basin's rivers and streams. Sustainability boundaries analysis is one method for doing this in that it allows comparison of simple flow statistics from water development scenarios to be compared to bounds that define sustainable alterations from historical conditions.

Where: The analysis should be applied at any locations in the basin for which water supply projects are being considered. Development of sustainability boundary limits should involve information on flow, biology, geomorphology and other factors from throughout the basin.

When: One year study, depending on availability of information from the studies mentioned in the linkages section of this SOW and time series data for locations to be examined. The analysis should be carried out at all locations before the next examination of environmental flow standards.

Who: The TIFP and The Nature Conservancy (TNC), with support of information developed in the studies mentioned in the linkages section of this SOW and from other sources.

Cost: To be refined, but estimated at $5,000-10,000 if data from other Rivers and Streams studies are available to support this task.

Tier 2b Bays Studies

*Disclaimer: Studies listed are not in any prioritized order.

Relationships between freshwater inflow and ecological health

What: The purpose of this study is to further describe relationships between freshwater inflow to bays and physical, chemical, and biological structure and function of the estuaries, and how these relationships support ecological health.

Why: The Nueces Bay and Delta complex has been the subject of much scientific study during the last two decades and has some of the best science available on the relationship between freshwater inflow and bay health. Nonetheless, there is much more information needed to fully understand these relationships in terms of physical, chemical, and biological structure and function. This study should focus on freshwater inflow analyses for on the Nueces Bay and Delta, where the majority of the impacts occur in this estuary.

Where: The Corpus Christi Bay area was designated as an estuary of national significance by the U.S. EPA in 1992. The Corpus Christi Bay system comprises over 124,700 acres along the central Texas coast. The mouth of the Nueces River empties into Nueces Bay north of Corpus Christi at the San Patricio county line. Most of Nueces Bay is located in the San Antonio-Nueces coastal basin, but a small portion lies in the Nueces-Rio Grande coastal basin. The Corpus Christi Bay system exchanges water with the Gulf of Mexico through a direct connection at the Aransas Pass. A dominant feature affecting the salinity regime and effects of freshwater inflow to the bay is a deep ship channel that runs the entire length of the bay. This channel facilitates the exchange of bay waters with the Gulf, creating marine conditions in the bay. This large amount of Gulf water exchange allows these marine conditions to persist even during high freshwater inflow events to the estuary. The limited effect freshwater inflow has on reducing salinity in Corpus Christi Bay is the primary reason this study should be focused on, but not limited to, Nueces Bay.

How: To fully address and describe the relationships between freshwater inflow and ecological health will require a team of experts in hydrology, modeling, geology, geochemistry, and estuarine ecology. The procedures to estimate the amount of freshwater inflow to maintain a sound ecological environment should be based on, but not limited to, the following methods:

1) Characterize historical patterns of hydrology, salinity, and flood events to determine the relationship between inflow and salinity;
2) Use empirical data and modern modeling approaches to examine inflow conditions and how salinity in the entire estuary responds under a variety of conditions;
3) Identify focal species and develop quantitative metrics between freshwater inflow and estuarine health;
4) Make recommendations for inflow needs and a regime to maintain a healthy state; and
5) Identify major data gaps.

When: This study would take several years to complete but should be started as soon as adequate funding is available.

Who: A team of experts will need to be identified with expertise in the key areas described above. Typically these would be university scientists with expertise is the areas. However, there are scientists from TPWD, TWDB, and other groups that would have the capacity to substantially contribute. In addition, the Coastal Bend Bay and Estuary Program would be a key organization to help lead this effort. Additional request for proposals for the work could be requested through groups such as Texas Sea Grant, the CBBEP, and MA-NERR.

Cost: Estimate of $ 300,000 - $ 500,000.

Relationship between freshwater inflow and oysters reefs

What: Describe the relationship between freshwater inflow and location and area of oyster reefs and health and abundance of oysters in Nueces Bay.

Why: Defined salinity range and inflow regime typically promote a healthy ecological environment. These environmental patterns maintain the productivity, extent, and persistence of many aquatic habitats and species in estuaries. Thus, freshwater inflow is essential for many adult, post-larval, and juvenile life history stages for many estuarine species. Clearly, sessile species such as eastern oyster would have been desirable indicators species for Nueces BBEST analyses. They certainly occurred historically at much higher abundances. Unfortunately, there was not enough reliable quantitative data in this region to use this species as an indicator. In South Texas, relatively predictable freshwater inflows reduce salinity with rainfall and provide nutrients that stimulate oyster production. Clearly, a better understanding of the relationships between freshwater inflow and oyster reefs is needed.

Where: The Corpus Christi Bay area was designated as an estuary of national significance by the U.S. EPA in 1992. The Corpus Christi Bay system comprises over 124,700 acres along the central Texas coast. The mouth of the Nueces River empties into Nueces Bay north of Corpus Christi at the San Patricio county line. Most of Nueces Bay is located in the San Antonio-Nueces coastal basin, but a small portion lies in the Nueces-Rio Grande coastal basin. The Corpus Christi Bay system exchanges water with the Gulf of Mexico through a direct connection at the Aransas Pass. A dominant feature affecting the salinity regime and effects of freshwater inflow to the bay is a deep ship channel that runs the entire length of the bay. This channel facilitates the exchange of bay waters with the Gulf, creating marine conditions in the bay. This large amount of Gulf water exchange allows these marine conditions to persist even during high flow events to the estuary. The vast majority of the oyster reefs in the region occur in Nueces Bay because the limited effect freshwater inflow has on reducing salinity occurs in this area. Thus, this is the primary reason this study should focus on, but not necessarily be limited to, Nueces Bay.

How: A rigorous and thorough review of the scientific literature and development of models as to how oysters respond to freshwater inflow would be the initial approach. The procedures to define the relationships between salinity and oyster health should be based on, but not limited to, the following methods:

1) Characterize historical patterns of oyster abundance patterns in response to different inflow regimes;
2) Use empirical data and modern modeling approaches (e.g., predictive models) to model a variety of inflow conditions and how fish/shellfish responds under a variety of conditions;
3) Develop quantitative metrics between freshwater inflow and oyster abundance;
4) Carry out key field and/or laboratory studies designed to understand how different salinities affect the populations of oysters;
5) Generate predictive maps of how oysters respond to varying salinity regimes; and
6) Calculate production for oysters under different salinity regimes.

When: This study would take about one year to complete but should be started as soon as adequate funding is available.

Who: Literature review and laboratory experiments could be performed university scientists with expertise is the area. Additional request for proposals for the work could be requested through groups such as Texas Sea Grant, the CBBEP, and MA-NERR.

Cost: Estimate of $100,000 - $150,000 depending on how much laboratory experimentation is requested/needed.

Identify vegetation/marsh changes occurring in the Rincon Bayou delta and relationship of those changes to freshwater inflow

What: In October 2001, the City of Corpus Christi (City) elected to continue freshwater diversions through the Nueces River Overflow Channel (NOC), which was dug to a depth of 0.3 m to increase freshwater inflows into Rincon Bayou, the natural headwater of the Nueces estuary (see Figure 2). In addition, the Rincon Overflow Channel (ROC), constructed in 1995, provides a connection to the upper Rincon Bayou to an area of hypersaline tidal flats. Discharge exceeding 11.9 $m^3 s^{-1}$ and reaching levels of 1.14 m above Mean Sea Level (MSL) activates the ROC. Inflow through the NOC is measured at the USGS Rincon Gauge, located in Rincon Bayou near Calallen (Station 08211503). This gauge was originally installed in May 1996, removed in August 2000, and re-installed in June 2002.

In late 2009, the City also began pumping water through a pipeline that can deliver up to 3.7×10^6 $m^3 mo^{-1}$ (3,000 acre-ft mo^{-1}) from Calallen Pool directly into the NOC above Rincon Bayou. To better understand the impacts of these freshwater diversions on the Rincon, funds allocated by the City and the US Army Corps of Engineers extended the ecological monitoring program through summer 2011. Monitoring objectives included detecting changes in water column, emergent vegetation, and soil characteristics at several study stations along Rincon Bayou and the Nueces River. Monitoring at many of these stations began during the Bureau of Reclamation (BOR) Demonstration Project that began in 1995. The results of this work have supported numerous publications and led to the development of models that attempt to link freshwater inflow and hydrology with the ecological integrity and productivity of the Rincon marsh system.

Changes in the distribution and abundance of emergent vegetation in estuaries can serve as indicators of long-term environmental conditions. Such changes, in conjunction with relevant physiochemical data, can be used to assess the impacts of water flow modifications and evaluate the effectiveness of management programs. This study will enable us to provide additional data to evaluate the effectiveness of these diversion projects and in achieving a better understanding of the relationship between landscape vegetation patterns (species composition, cover, and distribution) to freshwater inflow throughout the upper and lower reaches of the Rincon Bayou with a focus on porewater salinity, soil moisture, and nutrient content.

Why: Health of the marsh plant community in the Rincon Bayou delta has been used to demonstrate effects of changes in freshwater inflow. Continuation of monitoring that began in 1995, followed by acquisition of aerial color Infra Red (IR) photography, will enable the tracking of changes in vegetation and marsh condition in relation to freshwater inflow patterns.

Where: The Nueces Rincon Bayou marsh system near Corpus Christi.

How: The project would include seasonal sampling along transects first occupied during the BOR Demonstration Project, established in June 1995 and sampled nearly continuously since that time. Stations include those in the upper and lower delta, using transects that run perpendicular to the adjacent tidal creeks.

When: Re-establishment of vegetation transects should be initiated immediately and continued for a minimum of five years to capture vegetative responses to changes in local climatic events.

Who: City of Corpus Christi, CBBEP, and universities.

Cost: Approximately $75-100K/yr. for field studies, exclusive of instrument deployments. This estimate does not include the costs of any aerial photography or related work.

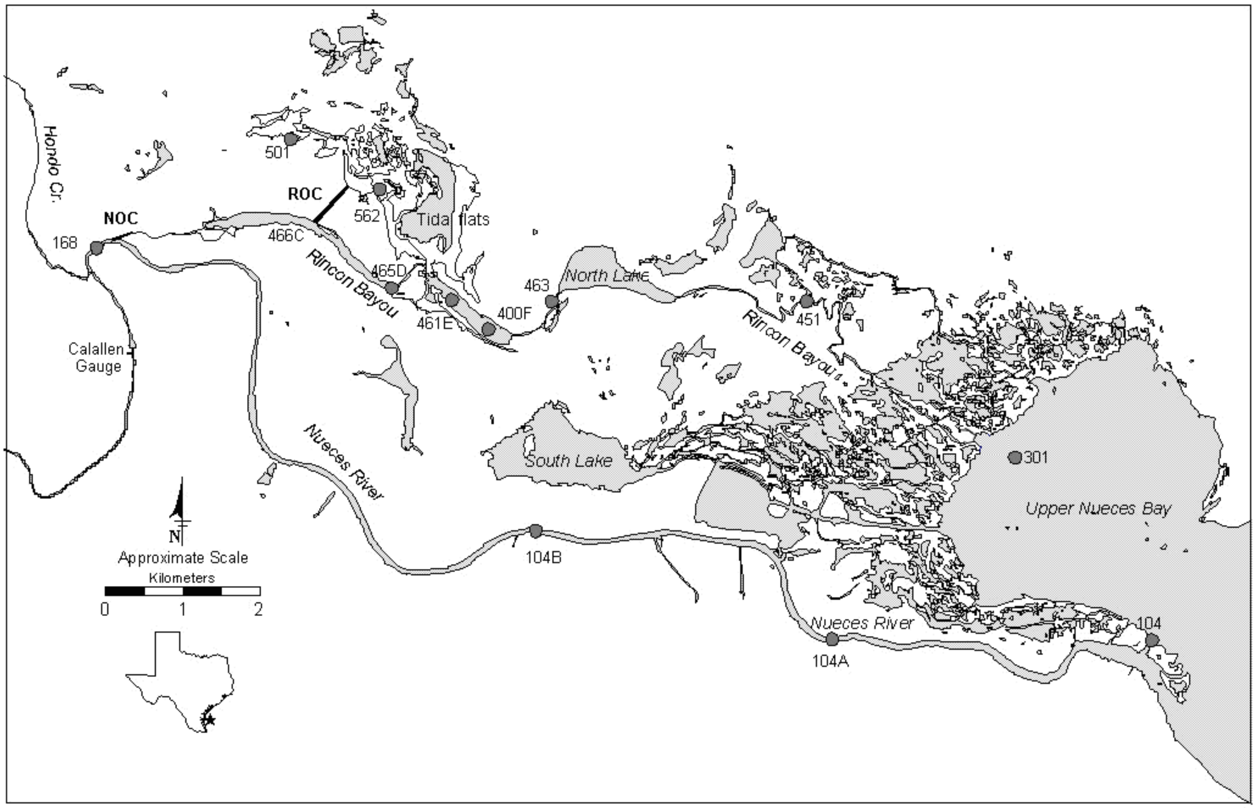

Figure 2. Locations of the Rincon Bayou Diversion Project monitoring stations, the Nueces Overflow Channel (NOC), the Rincon Overflow Channel (ROC), and the Calallen Gauge.

Define ecological effects of zero flow event duration, intervals between periods of zero flow, and long-term frequency of zero flow occurrences

What: From 1989 to October 2011, there has been no flow from the Nueces River into the Nueces River tidal, Nueces Delta, or Nueces Bay during 18 percent of days. Some no-flow periods have lasted for two consecutive months. Only one of the 23 years during this period has had flow every day to the bay. Although considerable analysis of Nueces Bay and delta ecosystems has been conducted and much work is anticipated in the future, relatively little effort has evaluated effects of extended periods of no flow.

The first phase of this effort would analyze all historical data in order to understand how the Nueces River tidal, Nueces Bay, and Nueces delta respond chemically, physically, and biologically to extended periods of no flow. The second phase of this effort evaluates all proposed research projects scheduled for the area and to the extent possible incorporates consideration of the ecological effects of no-flow periods. The third phase of the project would design new monthly sampling and analysis to describe effects on the ecosystems from extended periods of no flow. This phase should include water quality sampling in the Nueces River tidal at a minimum of four locations and in the Nueces delta at a minimum of three locations from just below the Calallen Dam downstream to Nueces Bay. It should also include sampling fish and invertebrates (shrimp and crabs) using standard fish sampling techniques used by TPWD. Sampling of larval fish, crabs, and shrimp (ichthyoplankton) should be conducted in the same places and at the same times. Sampling should be conducted monthly for three years on a schedule adjusted to capture different periods of no-flow. This sampling would be facilitated by placing a continuous recording water quality meter in the Nueces River tidal in the vicinity of Interstate 37. Water chemistry should include parameters included by the CRP.

Why: Delivery of water to the Nueces River tidal, Nueces Delta, and Nueces Bay is currently episodic during low flow conditions. Water may not be delivered for days, weeks, or months. This study will evaluate ecological health of these ecosystems as a result of this inflow pattern.

Where: Nueces River tidal, Nueces Delta, Nueces Bay.

When:

- Phase 1: Historical data review and analysis. One year study.
- Phase 2: Incorporation of no-flow period sampling and analysis in all future monitoring and research projects in the area. Ongoing.
- Phase 3: Three year special study focused on ecological effects of no-flow periods.

Who: Universities, TPWD, TCEQ, TWDB, City of Corpus Christi, CBBEP, technical consultants.

Cost:

- Phase 1: $80,000
- Phase 2: Depending on proposed study design
- Phase 3: $120,000 ($40,000 per year)

Continued monitoring of vegetative indicators

What: Two marsh plant species proved to be useful indicators of the timing and quantity of freshwater inflows. Smooth cordgrass (*Spartina alterniflora*) abundance was strongly correlated with freshwater inflows because it is found adjacent to tidal creeks where it is directly impacted by the salinity of tidal creek water. *Borrichia frutescens*, the primary competitor of *S. alterniflora*, is found at higher elevations where salts concentrate in dry, well-drained sediments. Freshwater inflows are important because they flush accumulated salts from sediment porewaters and maintain adequate soil moisture. Future monitoring should assess whether decreased freshwater inflows are altering the competitive balance among plant species or impacting their distributions. More importantly, the delicate balance between *Spartina* and *Borrichia* reflect long-term changes in the salinity characteristics of the lower marsh system, which are strongly reflective of the waters entering Nueces Bay.

Why: Detailed investigations on the spatial and temporal variability of environmental variables such as porewater salinity are necessary in order to predict the response of vegetation communities to changes in freshwater inflow. Future monitoring of environmental conditions in the Nueces Delta should include porewater measurements taken over a variety of spatial and temporal scales. Previous studies have collected data from selected sites on a quarterly or monthly basis. In contrast to quarterly or monthly monitoring schemes, continuous monitoring can resolve the impact of individual freshwater inflow events. Low cost continuous monitoring of porewater conditions via remotely deployed sensors would enable researchers to investigate the importance of freshwater inflow to vegetation health.

Where: The Nueces Rincon Bayou marsh system near Corpus Christi.

How: The project would include continuous monitoring of sediment porewater salinity and creek salinity using remotely deployed conductivity sensors at three stations in the Nueces marsh (see attached Figure 3). The sensors are buried at a depth of 20 cm below the sediment surface in creek bank and interior marsh areas at two sites. Twenty cm is the rooting depth of the two most common emergent vascular plants in the Nueces River Delta, *Borrichia frustescens* and *Salicornia virginica.* Sensors are also deployed and in the intertidal, shallow creek areas occupied by *Spartina alterniflora* at the same site. Assessments of vegetation changes and condition (e.g. species composition, cover, and distribution) are made on quarterly and linked to variations in salinity.

When: Re-establishment of vegetation transects should be initiated immediately and continued for a minimum of five years to capture vegetative responses to changes in local climatic events.

Who: City of Corpus Christi, CBBEP, and universities.

Cost: Approximately $40-50K/yr. for field studies, exclusive of initial instrument acquisition ($15K).

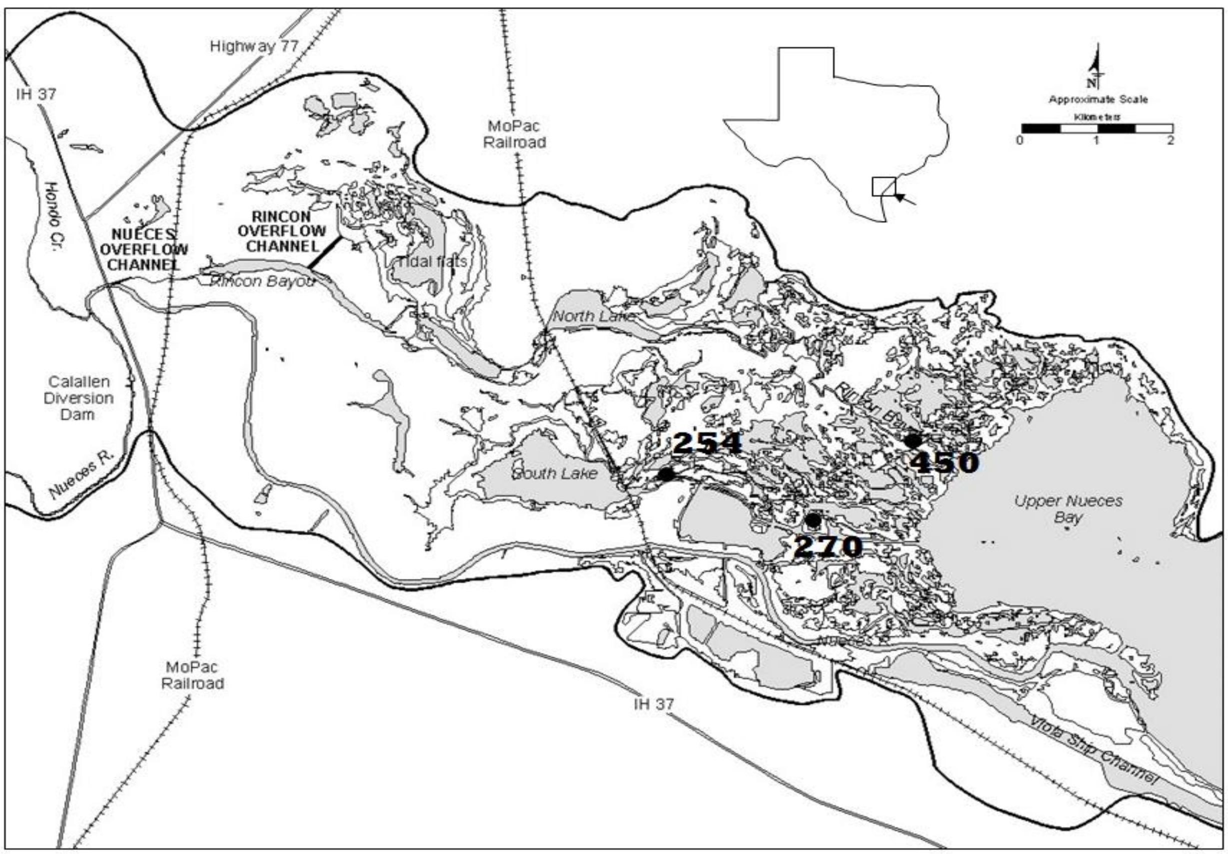

Figure 3. Locations of the stations in the Nueces marsh previously occupied for monitoring of vegetative indicators of two co-occurring plant marsh species characterized by greatly different salinity tolerances (*Spartina alterniflora* and *Borrichia frutescens*).

Safe yield demand vs. current demand evaluation

What: Because demand on the reservoir system (Choke Canyon Reservoir and Lake Corpus Christi combined) will continue to grow from current levels, which will result in less inflows to the bay compared to today's condition, an evaluation should be conducted on the effects this will have on salinities in Nueces Bay and Delta over the long term.

Why: The CCWSM developed and used by HDR Engineering calculates the full use of the current safe yield of the system at 205,000 acft/yr. Actual annual water use under current demands is around 133,000 acft/yr. Safe yield is defined as the volume of water that can be withdrawn from the system every year of the simulation period such that the water remaining in storage during a repeat of the drought of record results in a minimum storage of 75,000 acft remaining in the system. Note that the average usage over the last 20 years is closer to 120,000 acft, but 2 out of the last 3 have been over 133,000 acft. In the future, as higher demands become reality, the reservoir system will be at lower capacities more often, requiring less water to be passed through to the bay due to lower monthly targets established in the 2001 Agreed Order.

Since the Nueces BBASC recommended attainment frequencies modeled by the CCWSM that assume full implementation and use of the safe yield demand of the system, the current conditions in the bay could become less ecologically sound due to reduced freshwater inflow going to the bay over time. Table 3 shows the CCWSM safe yield attainment frequencies vs. the current demand attainment frequencies and the percent reduction in freshwater inflows to the bay as the higher demands are realized. The concern is that the Nueces Bay and Delta may be in an unsound condition with the current level of demand, so additional reductions to bay inflows could result in a less sound ecological environment in the future.

Where: The Reservoir System within the Nueces River basin.

How: Run the CCWSM and take output to plug into the TWDB TxBLEND Model to see changes in bay salinity over time. This evaluation should be brief and show general expected changes to Nueces Bay salinities over time as a result of Nueces BBASC freshwater inflow recommendations. Results could be helpful in determining future reservoir operation and freshwater inflow strategies.

When: Six month study of existing data.

Who: With overall guidance and technical support from the NEAC, HDR Engineering could run the CCWSM under various scenarios to develop outputs necessary for the TWDB to run TxBLEND.

Cost: To be determined, anticipated at $10,000 for running the CCWSM and developing the necessary outputs to deliver to TWDB.

Table 3. Nueces BBASC recommendations showing current demand percent attainment vs. safe yield demand and the percent reduction of freshwater to the bay as current demand reaches 205,000 acft/yr.

	Target Volume (acft)	BBEST Recommended % Attain	Current Demand D=133K % Attain	Safe Yield Demand D=205K % Attain	Current Demand vs. Safe Yield % Reduction
Winter High Flow	125,000	20	13	11.5	-1.5
Spring High Flow	250,000	25	14	11.5	-2.5
Summer / Fall High Flow	375,000	20	13	12.5	-0.5
Annual High Flow	750,000	25	20	16	-4
Winter Base Flow	22,000	60	30	23	-7
Spring Base Flow	88,000	60	37	29	-8
Summer / Fall Base Flow	56,000	75	45	40	-5
Annual Base Flow	166,000	80	58	47	-11
Winter Subsistence Flow	5,000	95	88	68	-20
Spring Subsistence Flow	10,000	95	95	88	-7
Summer / Fall Subsistence Flow	15,000	95	90	74	-16
Annual Subsistence Flow	30,000	95	99	94	-5

Ecologically sound environment strategy effectiveness program

What: A program designed to evaluate effectiveness of voluntary strategies to meet environmental flow standards used in areas where there may be inadequate amounts of water for an environmentally sound stream or estuary; in this case, the Nueces Bay and Delta. The program should focus on freshwater inflow strategies being implemented in these areas to quantitatively confirm that flows are helping to meet biological and water quality needs of the estuary.

Why: After an extensive review and analysis of comprehensive data sets that exists for the Nueces Estuary system, the BBEST reached consensus that all rivers, streams, and bays were sound ecological environments, except for the Nueces Bay and Delta region, which were determined to be unsound ecological environments. This conclusion was based in part on the substantial alterations in freshwater reaching the Nueces Bay and Delta, which have likely contributed to a failure to sustain a healthy complement of native species and its associated beneficial physical processes. In particular, the reduction of inflow caused:

- Loss/alteration of key habitat features and natural flow regimes required by indicator species (*Spartina alterniflora*, benthic infauna, oysters, *Rangia*); and
- Nutrient elemental cycling and sediment loading to be compromised.

A study program structured to evaluate the effectiveness of freshwater inflow strategies being implemented would substantiate that successful measures are being taken to restore and sustain Nueces Bay and Delta.

Where: Nueces River below Calallen Dam and Nueces Bay and Delta.

How: Design a program that uses desk-top and field studies to determine strategy effectiveness in restoring ecological structure and function provided by a sound flow regime. A number of field studies could be implemented, including the use of plankton tows, benthic cores, vegetation transects, data sondes, and benthic sleds in the Nueces Delta. In Nueces Bay, TPWD bag seine and trawl data are a good start with possibly adding plankton tows, benthic cores, and oyster abundance transects.

A less expensive alternative to biological sampling would be to monitor salinity levels throughout the estuary and periodically sample biological components. TPWD's data would also be available for identifying long term trends for certain species.

When: Begin on the Nueces River below Lake Corpus Christi to Nueces Bay and Delta as soon as possible. This program will be a long term commitment to ensuring strategies being implemented are meeting the goal of restoring and sustaining a sound Nueces Bay and Delta.

Who: TCEQ, TPWD, TWDB, NRA, NEAC, CBBEP, and stakeholders.

Cost: Probably in the range of $50,000 to $500,000 per year. These prices are based on data collection efforts funded by the City of Corpus Christi in the Nueces Delta and Bay for over a decade during the 1990s and 2000s. The NEAC should meet to develop and agree upon a program framework, and determine how the program would be funded long term.

Evaluate probable effects of climate change (a greenhouse warmed future) on water resources including supply, demand, and the ecological condition of rivers and streams and associated bays in the Nueces Basin

What: Effect of climate change (a greenhouse warmed future) on:

1A) Water resources (supply, demand, and achievement of Nueces BBASC recommended environmental flow standards above Choke Canyon and Lake Corpus Christi Reservoir [Reservoir System];

1B) Water resources below the Reservoir System including availability and volume of inflow for Nueces Delta and Bay salinity management.

2.0) Sea Level Rise and on Nueces Bay and Delta estuarine resources.

Why: Several overall threats identified by the Nueces BBASC. Potential for reduced precipitation, increased temperature, increased evapo-transpiration, altered rainfall, altered runoff characteristics, pattern and volume, threats to supply, increase in demand, threats to the ecological condition of rivers & streams and the Nueces Bay and Delta.

1A. Threats to water resources above the Choke Canyon Reservoir are predominantly in the form of:

a. Implications for decreased probability of achieving Nueces BBASC recommended environmental flows;
b. Implications for reduced aquifer levels and effect on spring flow (upper basin headwaters);
c. Implications for increased aridity and increased frequency of occurrence or duration of drought (basin wide);
d. Implications on agriculture and other regional economies, water quality in rivers and streams, and downstream supply.

1B. Threats to water resources the area below the Reservoir System are predominantly in the form of:

a. Reduced inflow frequency and volume potentially available under the current Agreed Order for Nueces Delta and Bay management;

b. Reduced supply from Reservoir System to meet future projected demand and future climate change induced demand.

2.0 Sea level rise threats to the estuaries are predominantly in form of:

1. Prediction of significant increase of the elevation of marine salinity water levels and resultant increased inundation of coastal resources (Nueces Delta and Bay);
2. Implications of inundation induced change of estuarine and palustrine habitats (Nueces Delta and Bay) including vegetation;
3. Implications of increased volume of marine salinity water in Nueces Bay on the effectiveness of inflow potentially available for salinity reduction at Salt 3 and within the Delta, under the existing meteorological climate and current Agreed Order.
4. Implications of increased volume of marine salinity water in Nueces Bay on the effectiveness of inflow potentially available for salinity reduction, under a climate change induced reduction in supply.

How: 1.0 (1A/1B, Basin and/or Sub-basin)

1.1 Synthesis of existing information on the effects of predicted warmed future on regional climatology , e.g. precipitation, temperature, evapotranspiration, runoff and associated, and characterize the probable impacts on water resources in the Nueces basin;

1.2 Identify and summarize updated information future regional temperature predictions;

1.3 If necessary, conduct basin wide and sub-basin specific (i.e. coastal vs. interior) climate modeling to refine the likelihood and/or probability of impact of the warmed future on water resources;

1.4 Apply changes characterized under 1, 2 and/or 3 to develop time-step predictions and apply the predictions with the Corpus Christi Water Supply Model to determine the effect on the Nueces BBASC environmental flows recommendations;

1.5 Conduct workshop to discuss the results and the effect on water planning and management for the sub-basin above Choke Canyon Reservoir and below Choke Canyon Reservoir.

How: 2.0 (Nueces Bay and Delta)

2.1 Synthesis of existing information on range of SLR scenarios, including consensus and accelerated rise predictions, and identify a rate of relative sea level rise (RSLR).

2.2 Identify and summarize updated information on sea level rise and regional global warming temperature predictions. Prepare report.

2.3 If no practical estimate of the local subsidence rate (LSR) is identified during 2.1 or 2.2, adopt a reasonable estimate for general planning applications and utilize it for the 2.1 and 2.2 estimates. Going forward, if the lack of an actual RLS for the Delta is deemed to be of such a critical and significant data gap compared to the SLR estimates and all other conservative factors typically incorporated by engineering design, a Nueces Bay and Delta specific LSR study may be contemplated;

2.4 Compile and summarize topographic and bathymetry information (e.g. LiDAR) for Nueces Delta and Bay;

2.5 Literature synthesis of salinity/inundation requirements and/or tolerances of select vegetation and habitat/ecotones for Nueces Delta and Bay (e.g. *Spartina* species; *Borrichia*, *Salicornia* species, *Batis*, *Halodule/Ruppia*, oyster);

2.6 Compile and synthesize information on scenario selection dependant vulnerability assessments/predictions of change to Delta shoreline location and/or vegetation composition, habitat/ecotone distribution, water quality;

2.7 If 2.6 does not provide time-step predictions for practicable planning applications, conduct study based on 2.1, 2.2, 2.3, 2.4, and 2.6 and develop time step predictions;

2.8 Couple changes predicted under 1A and 1B and 2.7 and compare to BBASC recommended environmental flows potentially available under the existing Agreed Order.

2.9 Apply TWDB hydrodynamic circulation-salinity models to Nueces Bay to evaluate inflow changes predicted under HOW 1A/1B and/or 2.8.

When: 1.0 Basin and/or Sub-basin

1.1 2 to 3 months, including final report
1.2 See 1.1
1.3 8 to 15 months including final report
1.4 6 months after 1.1, 1.2, 1.3, including final report
1.5 3 month after 1.4 including final report

When: 2.0 SLR Nueces Bay and Delta

2.1 3-6 months including final report
2.2 See 2.1
2.3 See 2.1
2.3.a. If unique LSR Study: 60 months
2.4 Concurrent with 2.1
2.5 Concurrent with 2.1
2.6 5 to 8 month including final report
2.7 TBD 8 months after 2.6 including final report
2.8 5 to 8 months after 1A, 1B and 2.6 or 2.7 including final report
2.9 8 to 15 months after 1A, 1B and or 2.8 including final report

Who: 1.0 Basin and/or Sub-basin

1.1 Literature synthesis by qualified contractor/investigator
1.2 See 1.1
1.3 Modeling by qualified contractor/investigator
1.4 Modeling by qualified contractor/investigator
1.5 Workshop by NEAC/BBASC with qualified contractor support

Who: 2.0 SLR Nueces Bay and Delta

2.1 Literature synthesis by qualified contractor/investigator
2.2 See 2.1
2.3 See 2.1
2.3.a. If unique LSR Study, by qualified contractor/investigator
2.4 Literature synthesis by qualified contractor/investigator
2.5 Literature synthesis by qualified contractor/investigator
2.6 Literature synthesis by qualified contractor/investigator
2.7 See 2.6 or by qualified contractor/investigator
2.8 Analysis by qualified contractor/investigator
2.9 Modeling by qualified contractor/investigator

Cost: Note - All Costs Basis: Proposal, Negotiated Lump Sum Fee, Not to Exceed

2.1 $ 8,000
2.2 See 2.1
2.3 See 2.1
2.3.a TBD $450,000
2.4 $ 8,000
2.5 $8,000
2.6 $8,000
2.7 TBD $75,000
2.8 $65,000
2.9 $95,000

Nueces watershed pre- and post-development nutrient budgets

What: Develop a nutrient budget for both pre- and post-development for the Nueces watershed.

Why: Nutrient inputs to coastal waters are an important element in the ecology and health of estuarine ecosystems. EPA has been encouraging states to address nutrients in a quantitative manner, and particularly favors establishment of numerical criteria for nutrients. The Nueces BBASC agrees that there is certainly a potential for nutrient levels to affect aquatic plants and biological resources and believes there is a need for a watershed approach to effective management of these resources. A fundamental aspect of this approach is recognition that not only can nutrient loading be high enough to degrade some aspects of water quality but that nutrient loading may also have been artificially reduced to levels that adversely affect ecological productivity. Management means first identifying problems resulting from nutrient loading that is too high or too low for a particular resource. Once problems are identified, there is a need to formulate cost-effective strategies to solving the problems.

Figure 4 shows trends in chlorophyll *a* data in the Texas Coastal Bend area. The data indicate a probable decrease in chlorophyll *a* concentration in Nueces Bay and a possible decrease in much of Corpus Christi Bay since the early 1970s. During this period there was considerable population growth and increase in wastewater nutrient loads. But there was also navigation channel deepening, upstream reservoir development (Choke Canyon was completed in 1982), and diversion of a small part of the municipal wastewater flow from the Nueces River to the delta. The net effect has been a probable reduction in primary productivity in Nueces Bay.

The overall situation is that while we have some broad understanding and a little specific information, there is much we do not know about both historical and current nutrient supplies in Nueces Bay and their relationship to ecological health of the bay. EPA is correct--there is a need to address nutrients. What is needed is a quantitative understanding of historical or natural supplies of all nutrient forms, along with anthropogenic changes in these supplies, in order to facilitate building consensus on a desired future condition in terms of chlorophyll *a* and other measures of estuarine productivity. When we have consensus on a goal, we can formulate appropriate management measures for nutrients. This will probably require some level of quantitative analysis or modeling to quantify the effects of various measures.

Where: Lower Nueces River to Nueces Bay and Delta.

How: It would be possible to produce nutrient budgets for the Nueces watershed for both the present and pre-development condition. We have an extensive network of stream gauges and monitoring data, and workable estimates can be made of the nutrients contained in macro-detritus that has not been measured in a systematic fashion. Having annual loads for both the pre-development and present condition would provide a strong indication of trends and potential problems. While the data exist to perform that type of analysis, it would require some effort and expense.

When: Nutrient data compilation could begin as soon as funds become available, allowing 1 year to analyze data and develop a pre-development and post-development nutrient budget for the Nueces system.

Who: USGS, TCEQ, Harte Research Institute for Gulf of Mexico Studies (HRI), CBBEP, and technical consultants.

Cost: To be refined, likely to range between $50,000 to $100,000.

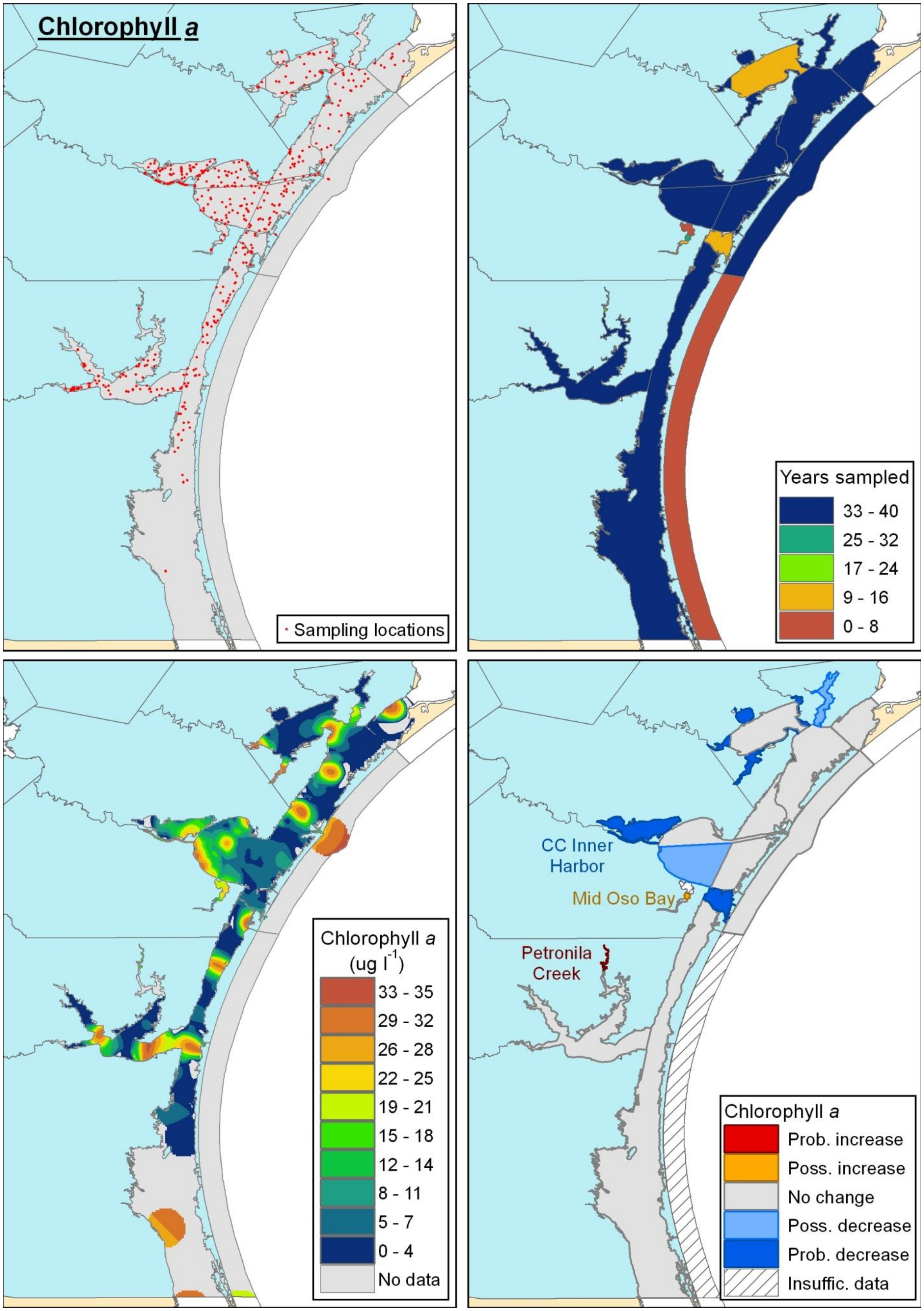

Figure 4. Spatio-temporal patterns of Chlorophyll-*a* concentrations in CBBEP waters. (Montagna and Palmer, 2012.

Assessment of sediment transport and loadings into the Nueces Delta and Estuary

What: As described in Section 5.3 of the Nueces BBEST Environmental Flows Recommendations Report there is a decrease in the quantity of sediment reaching the estuary. This study aims to evaluate sediment transport and loading entering the Nueces Estuary, primarily into Nueces Bay and Delta, 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 Nueces Bay. 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 Nueces Estuary by the USGS that evaluated sediment sources in the lower Nueces River (below Lake Corpus Christi) into Nueces Bay. The objectives of this work are:

1. Collect flow and sediment transport data in the Nueces River above the Calallen Dam, and calculate loadings to Nueces Bay and 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 Nueces Delta, and calculate whether current sediment diversion into Nueces Bay offsets this subsidence.

Why: The sediment delivered to the estuary during times of floods is the source of new material for creating new habitat. In the Nueces Estuary there are two major reservoirs that have had an impact on sediment loading to the bay, Lake Corpus Christi (constructed in 1958) and Choke Canyon Reservoir (constructed in 1982). Since the construction of these reservoirs and the subsequent drought from 1983-1996, freshwater inflows to Nueces Bay were decreased by 55 percent (Asquith et al., 1997) and by 99.6 percent into the Nueces Delta (BOR, 2000). Rasser (2009) estimated a 2.5 meter per year loss of the Nueces Delta at the interface with the bay between the years of 1997 to 2005. Other studies have shown that more than 95 percent of the Nueces River Basin is upstream of Lake Corpus Christi (Longley, 1994), and Leibbrand (1987) demonstrated that Lake Corpus Christi is an effective sediment sink, retaining 97 percent of the sediment entering the lake between 1977 and 1985. These studies suggest that along with wind and wave action and relative sea level rise, that there is a lack of sediment loading in order to keep up with these other erosion processes. In the latest study by Ockerman in 2010, sediment sources and quantities being delivered to the estuary pre vs. post Lake Corpus Christi were modeled. The study found that when comparing pre and post loads that there was over a 62% decrease in sediment loading to the Nueces Estuary since the construction of Lake Corpus Christi.

Regional water supply needs, water management strategies, modified landscapes, and natural variability have created a condition that inhibits quantities of sediment needed for creating sustainable habitat within the Nueces Estuary. While sediment load downstream of Lake Corpus Christi has appeared to decrease, detailed impacts, benefits, deficiencies or needs associated with these reduced sediment loads have not been clearly defined by existing studies. In Section 5.3 of the Nueces BBEST Environmental Flows Recommendations Report, the BBEST states that future considerations might include investigations that address spatial extent or location of impact (e.g., in the vicinity of the dam, along the Nueces River between the dam and the estuary, near the City of Corpus Christi water supply intake, and/or within the Nueces Delta) and should also address magnitude and character of sediment needs (i.e. daily or annual volumes of particular sediment grain size classes). The Nueces BBEST continues by discussing that other studies may relate sediment loads to ecological needs, which may be species-specific and may include marsh maintenance, in-stream turbidity/clarity, and in-stream habitat including channel bed characteristics.

Where: The lower Nueces River (below Lake Corpus Christi) is the conduit for water supply to the City of Corpus Christi and surrounding communities. For this reason, it may be difficult to create a solution for getting sediment to from the Nueces River to the Nueces Delta, but these are the target locations for sediment transport.

How: Sediment Collection and Discharge Measurements: USGS stream gage No. 08211500 on the Nueces River near Calallen, 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, *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 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 Calallen. This would include a recording current meter, so the gage is set up for digital measurement and data logging. The Conrad Blucher Institute has already installed 3 stations along the lower Nueces River using OBS technology for measuring Total Suspended Solids (TSS), of which data could be used for analyzing water-sample determinations, especially sample collection during floods. Subsidence measurements in the Nueces Delta could be conducted according to standard methods performed by the University of Texas-Bureau of Economic Geology (UT-BEG).

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 could be conducted through a cooperative effort between the USGS and the TWDB, as currently being performed in Galveston and Matagorda Bays, if funding is available. 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. Conrad Blucher Institute should be part of the automated recording measurements.

A Subsidence analysis project in the Nueces Delta could be conducted by an experienced contractor such as UT-BEG or HRI 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 possible funding partners being USGS, TWDB (through dollars dedicated through the legislature), and TCEQ. This funding is divided up into 2 phases. Subsidence study costs are estimated at $125,000 to support the study and a variety of contractors are capable of performing the work (e.g. HRI, UT-BEG).

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.

5.0 Work Plan Subjects for Adaptive Management

The table below identifies each Work Plan subject, the original project number (ID#) prior to prioritization, author of Scope of Work (Primary), what hydrological or biological component the subject relates to, the original source of the project idea (BBEST or BBEST or both), the final BBASC ranking of the Tier 1 projects, and a column to eventually identify an entity that will take the lead on implementing the activity (currently listed as to be determined "tbd").

ID #	Subject	Primary BBEST/ BBASC Member	Flow Regime Component			Hydro-logy	Source	BBASC Rank	Funding ID Lead
			Subsist-ence	Base	Pulse				
	RIVERS AND STREAMS								
1	Describe relationships between flow and physical, chemical, and biological structure and function of the streams and how these relationships support ecological health	Buzan	X	X	X		BBEST	3	tbd
2	Describe the role of flow in the ecological health of the stream	Arsuffi	X	X	X		BBEST		tbd
3	Identify stream locations and estuaries not included in the BBEST environmental flow regime report that should be analyzed for relationships between flow and environmental health	Vaugh				X	BBEST		tbd
4	Conduct additional modeling of relationships between in-stream habitat and flow	Smith	X	X			BBEST	8	tbd
5	Describe ecological services provided by perennial pools	Buzan	X		X		BBEST		tbd
6	Identify flow regime components and quantities necessary to sustain mussels and compare to flow regimes identified necessary to sustain fish communities	Buzan		X			BBEST		tbd
7	Describe how surface flow patterns and quantities are changing compared to the period of record patterns. Include consideration of possible future flows and diversions	Vaugh				X	BBEST		tbd
8	Describe groundwater flow into streams and how is it changing	Buzan	X	X			BBEST		tbd
9	Describe relationships between benthic macroinvertebrates and flow	Arsuffi	X	X			BBEST		tbd

10	Identify water development activities planned for the future, and how they might influence groundwater, river flows, and physical and hydrologic connections between the two	Vaugh				X	BBEST		tbd
11	Describe changes in geomorphology, i.e. trends in channel elevation, longitudinal profile, width, floodplain width, stream form, bed sediment size, and the role the flow regime contributes to those changes	Smith			X		BBEST		tbd
12	Identify the best period of record to use in deciding which hydrologic condition and hydrologic triggers should be used	Vaugh				X	BBEST		tbd
13	Identify key flow-dependent ecosystem functional (create ecological structure) processes associated with a sound ecological environment	Arsuffi	X	X	X		BBEST		tbd
14	Develop sustainability boundary analysis	Smith				X	BBEST		tbd
	BAYS								
ID #	**Subject**	**Primary BBEST/ BBASC Member**	**Flora/ Fauna**	**Sedi-ment**	**Nutr-ients**	**Inflow**	**Source**	**BBASC Rank**	
15	Relationships Between Freshwater Inflow and Ecological Health	Stunz	X			X	BBEST		tbd
16	Relationships between salinity and fish/shellfish abundance	Stunz	X				BBEST	5	tbd
17	Improve methods for determining environmental inflow regimes	Stunz				X	BBEST	6	tbd
18	Relationship Between Freshwater Inflow and Oysters Reefs	Stunz	X			X	BBEST		tbd
19	Evaluate potential for Allison wastewater effluent with its nutrients and other return flows (e.g., Oso Bay returns) to improve environmental health of the Rincon Bayou delta	Buzan				X	BBEST/ BBASC	2	tbd
20	Identify vegetation/marsh changes occurring in the Rincon Bayou delta and relationship of those changes to freshwater inflow	Dunton	X			X	BBEST		tbd
21	Define ecological effects of zero flow event duration, intervals between periods of zero flow, and long-term frequency of zero flow occurrences	Buzan				X	BBEST		tbd
22	Continued monitoring of vegetative	Dunton	X				BBEST		tbd

	indicators								
23	Salinity Monitoring and Real Time (SMART) Inflow Management Study	Jace Tunnell				X	BBASC	1	tbd
24	Re-examination of the 2001 Agreed Order Monthly Targets	Jace Tunnell				X	BBASC	4	tbd
25	Safe yield demand vs. current demand evaluation	Jace Tunnell				X	BBASC		tbd
26	Explore Landform Modifications to Nueces Bay and Nueces Delta	Carangelo				X	BBASC	7	tbd
27	Ecologically Sound Environment Strategy Effectiveness Program	Jace Tunnell	X			X	BBEST		tbd
28	Evaluate probable effects of climate change (a greenhouse warmed future) on water resources including supply, demand, and the ecological condition of rivers and streams and associated bays in the Nueces Basin	Carangelo	X			X	BBEST/ BBASC		tbd
29	Nueces Watershed Pre- and Post-Development Nutrient Budgets	Jace Tunnell			X		BBASC		tbd
30	Assessment of Sediment Transport and Loadings into the Nueces Delta and Estuary	Jace Tunnell		X		X	BBASC		tbd