Workshop Report

Freshwater Inflow to Texas Bays and Estuaries

June 7-8, 2021

By

Paul A. Montagna and Audrey Douglas
Texas A&M University-Corpus Christi
Harte Research Institute for Gulf of Mexico Studies
6300 Ocean Drive, Unit 5869
Corpus Christi, TX 78412

August 30, 2021

To

Texas General Land Office
Coastal Management Program
Project # 21-155-007-C879

Cite as:

Montagna, P.A. and A.R. Douglas. 2021. Workshop Report: Freshwater Inflow to Texas Bays and Estuaries. Report to the Texas General Land Office for Project # 21-155-007-C879, Texas A&M University-Corpus Christi, Corpus Christi, Texas, USA. 41 pp.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The workshop on “Freshwater Inflows to Texas Bays and Estuaries”, held virtually on June 7-8, 2021, brought together stakeholders from around the state interested in the adaptive management implementation of environmental flow standards for bays and estuaries created under Senate Bill 3 (SB 3). The **purpose** of the workshop was to introduce a new project to synthesize over three decades data and scientific methods on a State-wide basis to create a new version of the classic book “Freshwater Inflows to Texas Bays and Estuaries” (Longley 1994) that may be used as tools for coastal resource management decision-making. The **goals** of this workshop were three-fold: 1) to **ensure stakeholder needs are met** by project products, 2) to **identify existing relevant data** and **potential partners**, and 3) to **identify potential reviewers** for the final product. Stakeholders were invited to the workshop and included representatives from:

1) Federal Agencies: United States Geological Survey (USGS)
2) State agencies: Texas Commission for Environmental Quality (TCEQ), Texas General Land Office (TGLO), Texas Parks and Wildlife Department (TPWD), and Texas Water Development Board (TWDB), Texas State Soil and Water Conservation Board (TSSWCB)
3) Local and Non-governmental Organizations (NGO): Coastal Bend Bays and Estuaries Program (CBBEP), Texas Living Waters Project, Sierra Club Lone Star Chapter, National Wildlife Federation, The Nature Conservancy, Galveston Bay Foundation, Lavaca Bay Foundation, Matagorda Bay Foundation, San Antonio Bay Partnership, Matagorda Bay Mitigation Trust (MBMT), Galveston Bay Estuary Program, Cynthia and George Mitchell Foundation, Ducks Unlimited, Inc., Houston Advanced Research Center, Texas Water Trust, Basin and Bay Area Stakeholder Committees (BBASC), Basin and Bay Expert Science Teams (BBEST)
4) River Authorities: Sabine River Authority, Guadalupe-Blanco River Authority (GBRA), San Antonio River Authority (SARA), Nueces River Authority, Lavaca-Navidad River Authority (LNRA), Brazos River Authority
5) Academia: Texas A&M University-Corpus Christi (TAMUCC), TAMUCC Harte Research Institute for Gulf of Mexico Studies (HRI), TAMUCC Conrad Blucher Institute (CBI), TAMUCC Center for Water Supply Studies (CWSS), Texas A&M University-Galveston (TAMUG), Texas A&M University (TAMU), University of Texas Marine Science Institute (UTMSI), University of Texas Rio Grande Valley (UTRGV), Texas State University Meadows Center for Water and the Environment, Texas Sea Grant

A total of 101 people participated in the workshop over the 2-day period.

Organization of the Workshop

The format of the workshop was designed to group related fields and expertise to facilitate discussion and resource identification/sharing. Due to ongoing COVID-19 concerns and restrictions, the workshop was held in **hybrid model** with participants attending **in-person and joining remotely**. To prevent virtual meeting fatigue, the workshop was held in two half-day meetings. Prior to the event, the organizers distributed the proposed book outline/topics list and short introduction to the project to all participants to promote conceptualization of the issues. By providing lead time for participants to consider the topics, they would be able to better identify and assess stakeholder needs, recognize potential gaps in the proposed work, discover existing data and tools that could be used.

At the meeting, principal investigator Paul Montagna gave a short introduction to the synthesis project and then interviewed William Longley, author of the 1994 "Freshwater Inflows to Texas Bays and Estuaries", to provide more history and context. This interview was followed by short 10-minute presentations on the importance of each proposed topic. Breakout sessions for related topics followed the presentations, which proved to be an effective strategy. The breakout sessions allowed for Co-PIs to meet with relevant stakeholders to ensure the three goals of the workshop were satisfied: 1) to **ensure stakeholder needs are met** by project products, 2) to **identify existing relevant data** and **potential partners**, and 3) to **identify potential reviewers** for the final product. There were three breakout sessions Day 1 and two breakout sessions Day 2.

Main Outcomes from the Workshop

The Freshwater Inflows to Texas Bays and Estuaries Workshop focused on introducing attendees/stakeholders to the project goals and providing an opportunity for attendees to suggest gaps in the approach, identify key topics for inclusion in the project products, identify potential data sources and relevant studies, and identify prospective reviewers for project products. A brief introduction to each proposed topic was provided and helped prepare participants for the breakout sessions. The introductions included why the topic was relevant/important, a proposed approach to the topic, and a little about known data sources. These topic introductions were followed by 60-minute breakout sessions with participants. In the breakout sessions, participants were asked to identify areas of interest/need that should be included in the project products. In particular, stakeholders were asked if Co-PIs covered all issues related to their topic or if a key issue was missed. Breakout session participants were also asked to identify potential data sources, studies of relevance, and prospective reviewers. To summarize:

- In total, **77 stakeholders** representing 39 local, state and federal government agencies and non-governmental organizations and **8 students** representing 3 universities participated in the workshop.
- Five breakout groups were held over two days to discuss stakeholder needs/interests, knowledge and data gaps, potential data sources and sharing, and identification of potential reviewers for project products.
- A common discussion point in the breakout sessions was the appropriate approach and organization of the book and whether the proposed chapter outline may need to be revisited and restructured to better allow for topic cross-over and interdependence. It was determined that Co-PIs need to formulate chapter outlines as soon as possible to further assess these concerns.

- Stakeholders successfully identified key issues that were not included in the initial topic overviews presented by Co-PIs, such as sea level rise, mangrove habitats, extreme events.
- Multiple data sources, ranging from individual studies to government managed long-term datasets, were identified for each topic.
- Several participants volunteered their own datasets for inclusion in the synthesis.
- Fifteen participants volunteered to serve as reviewers for specific topics/chapters and 11 names were suggested as prospective reviewers.

The following sections provide an overview of the workshop, including workshop agenda, topic overviews, breakout session notes, and attendee affiliations and contact information.

Acknowledgments

The project is funded by the Texas General Land Office as a “Project of Special Merit” under the Gulf of Mexico Energy Security Act (GOMESA) program, contract number 21-155-007-C879.

BACKGROUND

The workshop was created as part of a larger project to synthesize freshwater inflow data. The original synthesis (Longley 1994) was published in 1994, so it has been more than 27 years since a State-wide synthesis has been attempted. The project title is "Freshwater Inflows to Texas Bays and Estuaries: A State-Wide Review, Synthesis, and Recommendations," and includes a State-wide multidisciplinary team. The goal is to synthesize data on freshwater inflows to all Texas bays and estuaries. The project will include topics such as, policy and law, climate and hydrology, bay circulation and salinity, habitat and geospatial mapping, water quality, plankton, benthos, habitats, nekton, and data management. Stakeholders, scientists, environmental nonprofits, resource agencies, and others implementing projects in the Texas Coastal Resiliency Master Plan (TCRMP) will use this new information as a tool for coastal resource management decision-making. Project results will guide and inform hydrological, wetland habitat, and oyster reef restoration strategies identified for all regions in the TCRMP.

A first step in the project is to ensure coordination among the many state and local organizations and agencies involved in the freshwater inflow issue, and to ensure that the end products will be useful to stakeholders. The workshop was planned to fulfill this need. Thus, the purpose of the workshop was to introduce the project to synthesize data and scientific methods on a State-wide basis to create tools for coastal resource management decision-making. The goals of the workshop were three-fold: 1) to ensure stakeholder needs are met by project products, 2) to identify existing relevant data and potential partners, and 3) to identify potential reviewers for the final product.

PARTICIPANTS

(see Appendix I for abbreviations and Appendix II for contact information)

Underline indicates BBEST or BBASC member

(##) within parentheses indicates number of participants

Organizers (2)

Paul Montagna (PI), Texas A&M U-Corpus Christi Harte Research Institute (TAMUCC HRI)
Audrey Douglas, TAMUCC HRI

Speakers (10)

Ken Dunton, U Texas at Austin Marine Science Institute/Mission-Aransas San Antonio BBASC/ Nueces, Corpus, Baffin BBEST
James Gibeaut, TAMUCC HRI
Myron Hess, Law Office of Myron Hess PLCC/Colorado, Lavaca, Matagorda BBASC
Xinping Hu, TAMUCC HRI
John Nielsen-Gammon, Texas A&M U
Terry Palmer, TAMUCC HRI
Antonietta Quigg, Texas A&M U-Galveston/Trinity, San Jacinto, Galveston BBEST
Greg Stunz, TAMUCC HRI/Nueces, Corpus, Baffin BBEST
Joe Trungale, Trungale Engineering and Science/Trinity, San Jacinto, Galveston

BBEST/Colorado, Lavaca, Matagorda BBEST
Michael Wetz, TAMUCC HRI

Project Support Staff/Researchers (4)

Noe Barrera, TAMUCC HRI
Rick Kalke, TAMUCC HRI
Mikell Smith, TAMUCC HRI
Jamie Steichen, Texas A&M University-Galveston

Students (8)

Gabrielle David, Del Mar Community College
Elizabeth Del Rosario, TAMUCC HRI
Larissa Dias, TAMUCC HRI
Francesca Filippone, Texas State U
Bimal Gyawali, TAMUCC Center for Water Supply Studies
Elizabeth Harris, TAMUCC HRI
Lauren Renner, TAMUCC HRI
Karin Treviño, TAMUCC HRI

Stakeholders (77)

Kathy Alexander, Texas Commission for Environmental Quality (TCEQ)/Colorado, Lavaca, Matagorda BBEST (non-voting member)
Richard Arnett, Texas Parks and Wildlife Department (TPWD)
Morgen Ayers, Texas Sea Grant
Bill Balboa, Matagorda Bay Foundation/Colorado, Lavaca, Matagorda BBASC
John Bartos, Law Offices of John R. Bartos & J. Bernard Schultz/Trinity, San Jacinto, Galveston BBASC
David Bradsby, TPWD/Colorado, Lavaca, Matagorda BBEST (non-voting member)
David Brown, USGS Oklahoma-Texas Water Science Center
Kirby Brown, Ducks Unlimited, Inc.
Patrick Brzozowski, Lavaca-Navidad River Authority, Colorado-Lavaca BBASC
John Byrum, Nueces River Authority
Jessica Chappell, Texas General Land Office
Bryan Cook, Lower Colorado River Authority/Colorado, Lavaca, Matagorda BBEST
Elena Crowley-Ornelas, United States Geological Survey (USGS)
Kevin De Santiago, Texas Water Development Board (TWDB)
Hudson DeYoe, U Texas Rio Grande Valley/Rio Grande BBEST & BBASC
James Dodson, San Antonio Bay Partnership/Nueces, Corpus, Baffin BBASC
Shaun Donovan, San Antonio River Authority
Amanda Fuller, Texas Living Waters Project
Zachary Fuqua, TCEQ
Kyle Garmany, The Nature Conservancy-Texas Chapter
Stephanie Glenn, Houston Advanced Research Center (HARC)
Lisa Gonzalez, HARC
Danielle Goshen, Texas Living Waters Project/Galveston Bay Foundation
Carla Guthrie, TWDB
Lori Hamilton, TCEQ
Thomas B. Hardy, Texas State U Meadows Center for Water and the Environment/ Colorado, Lavaca, Matagorda BBEST/ Mission-Aransas San Antonio BBEST
Leslie Hartman, TPWD
Thomas Hill, Guadalupe-Blanco River Authority/Mission-Aransas San Antonio BBASC
Adrien Hilmy, Coastal Bend Bays and Estuaries Program (CBBEP)
Amin Kiaghadi, TWDB
Chadwick Kinsfather, Lavaca-Navidad River Authority
Bill Kirby, Sabine River Authority
Brian Koch, Texas State Soil and Water Conservation Board
Joseph Kowalski, U Texas Rio Grande Valley

Ken Kramer, Sierra Club Lone Star Chapter/Brazos BBASC/Trinity, San Jacinto, Galveston BBASC
Jungwoo Lee, TWDB
Mike Lee, USGS Oklahoma-Texas Water Science Center
Sky Lewey, Nueces River Authority
Lindsey Lippert, TCEQ
Bill Longley, TWDB, Retired
Melissa Lupher, TWDB
Robert Mace, Texas State U Meadows Center for Water and the Environment
Westin Massey, TCEQ Houston Region
Quinn McColly, Texas Water Trade
Melissa McCutcheon, Texas General Land Office
Julie McEntire, Texas General Land Office
Kristen McGovern, Galveston Bay Estuary Program
Dorina Murgulet, TAMUCC Center for Water Supply Studies
Ram Neupane, TWDB
Jeremy Nickolai, Brazos River Authority
Kimberly Nygren, TCEQ Office of Water
Alex Ortiz, Texas Living Waters Project/Sierra Club Lone Star Chapter
Arsum Pathak, Texas Living Waters Project/National Wildlife Federation
Carrie Thompson, Texas State U Meadows Center for Water and the Environment
James Tolan, TPWD
Evan Turner, TWDB
Jennifer Walker, Texas Living Waters Project/National Wildlife Federation/ Colorado, Lavaca, Matagorda BBASC
Emily Warren, Cynthia and George Mitchell Foundation
Janet Weaver, Lavaca Bay Foundation
David Yoskowitz, TAMUCC HRI
Nathan Pence, Guadalupe-Blanco River Authority
Pamela Plotkin, Texas Sea Grant
Philip Price, Brazos River Authority/Brazos BBEST
Steven Raabe, Matagorda Bay Mitigation Trust
Tony Reisinger, Texas Sea Grant/Rio Grande BBASC
James Rizzo, TAMUCC Conrad Blucher Institute
Kirk Rodgers, USGS RESTORE project
Victor Roland, USGS
Kelly Sanks, USGS
Cory Scanes, Brazos River Authority
Doug Schnoebelen, USGS Oklahoma-Texas Water Science Center
Caimee Schoenbaechler, TWDB
Farnaz Seddighzadeh, Cynthia and George Mitchell Foundation
Jonathon Seedfeldt, Texas Living Waters Project/National Wildlife Federation
Ryan Smith, The Nature Conservancy-Texas Chapter/Nueces, Corpus, Baffin BBEST/ Rio Grand BBEST
Kierstan Stanzel, CBBEP
Gregory Steyer, USGS Oklahoma-Texas Water Science Center

WORKSHOP SCHEDULE

Time	Presenter	Topic
Day 1 PM	**Monday, June 7, 2021**	
1:00	Paul Montagna	Introduction, workshop plan
1:10	William Longley	Recalling the 1994 edition
1:20	Myron Hess	Environmental Flow Policy/Law/Regulations
1:30	John Nielsen-Gammon	Climate
1:40	Joe Trungale	Hydrology and circulation
1:50	Audrey Douglas	Groundwater
2:00	Michael Wetz	Nutrients
2:10	Xinping Hu	Carbon dynamics
2:20	Paul Montagna	Sediments
2:30	Break	
2:45	Breakout sessions	1-Environmental Flow Policy/Law/Regulations 2-Climate/Hydrology/Circulation/Groundwater 3-Nutrients/Carbon/Sediments
3:45	Breakouts end	
4:00	Reconvene and report out	
4:30	Adjourn	
Day 2 AM	**Tuesday, June 8, 2021**	
9:00	Paul Montagna	Introduction, workshop plan
9:10	Jim Gibeaut	Habitats
9:20	Ken Dunton	Wetlands/Seagrasses
9:30	Anonietta Quigg	Plankton
9:40	Paul Montagna	Benthos
9:50	Terry Palmer	Oysters
10:00	Greg Stunz	Nekton
10:10	Break	
10:20	Breakout sessions	1-Habitats: Wetlands/Seagrasses/Oysters 2-Plankton/Benthos/Nekton
11:20	Breakouts end	
11:30	Reconvene and report out	
12:00	Adjourn	

PRESENTATION ABSTRACTS

<u>Introduction (Paul Montagna)</u>

More than 27 years have passed since publication of the seminal book "*Freshwater Inflows to Texas Bays and Estuaries: Ecological Relationships and Methods for Determination of Needs*" (Longley 1994), which had an enormous impact on the management of environmental flows to estuaries in Texas and world-wide. Since then, the 2007 Texas Senate Bill 3 (SB3) changed management goals from a single inflow number to an inflow regime and from protecting seven sport and commercial fisheries to an ecosystem-based management approach. This project will synthesize over two decades of new management goals, data, and scientific methods.

Texas A&M – Corpus Christi (TAMUCC) will use Coastal Management Program Cycle 26 Gulf of Mexico Energy Security Act (GOMESA) funds to conduct a synthesis of freshwater inflows to Texas bays and estuaries and publish the results in a book. The project will include three tasks: data assembly, analyses and mapping, and writing. The project will include eight groups from all over the state and with multidisciplinary backgrounds: policy and law, climate and hydrology, bay circulation and salinity, habitat and geospatial mapping, water column (water quality and plankton), benthos (infauna, oysters, marsh, and seagrass), nekton (fish and mobile benthos), and data management (story maps, GIS, and web portal).

Stakeholders, scientists, environmental nonprofits, resource agencies, and others implementing projects in the Texas Coastal Resiliency Master Plan (TCRMP) can use this new volume as a tool for coastal resource management decision-making. Project results will guide and inform hydrological, wetland habitat, and oyster reef restoration strategies identified for all regions in the TCRMP.

<u>Environmental Flow Policy, Laws, and Regulations (Myron Hess)</u>

The chapter on Environmental Flow Policy, Law & Regulation is designed to provide context for how the science of freshwater inflows fits into the Texas water-rights regulatory process. It will address the role of that science in the state's evaluation and approval of new water-right permits and permit amendments that seek to appropriate state-owned surface water for uses other than flow protection. The discussion also will consider how that science can be used to inform consideration of permit amendments seeking to convert, on a voluntary basis, existing water rights issued for other purposes to use for improved environmental flow protection. The chapter will include an overview of Texas surface-water law, both historical and current, including discussion of when environmental flow protection began to be considered in the approval process and how flow-protection approaches have changed over time.

In particular, the chapter will provide analysis of the environmental-flow-protection components of Senate Bill 3, enacted by the Texas Legislature in 2007. That analysis will address how the various components of that legislation have been implemented to date and the role environmental flow science can play in informing the adaptive management aspects of Senate Bill 3. The chapter also will include a brief discussion of additional policy and regulatory issues that affect environmental flow protection, and for which freshwater inflow science plays a critical role, including Texas groundwater law, the state's water planning process, and federal statutes such as the Endangered Species Act. As appropriate for illustration of the concepts discussed, examples of implementation approaches will be provided.

Climate (John Nielsen-Gammon)

The focus of the chapter will be on climate variations in space and time and how they impact freshwater inflows. In space, the bays and estuaries of Texas lie across a climatic gradient, with relatively large inflows near Louisiana and relatively small inflows near Mexico. This spatial pattern can provide useful guidance for how inflows will be affected by climate change. Model projections indicate a drier regime with more erratic precipitation, so bays and estuaries to the northeast may become more like bays and estuaries to the southwest. The analysis of climate change will rely on both historical data and climate change projections from recent global climate model runs. Fundamental downscaled parameters, such as temperature and precipitation, will be combined with direct simulations of runoff and streamflow when available as model output. Two aspects of this chapter featured prominently in subsequent workshop discussion. First, the chapter is presently not scoped to address climate change-driven sea level rise. Within the book, sea level rise will be discussed in the Habitats chapter. Second, workshop participants suggested a variety of sources for downscaled climate model projections, including the ensemble of downscaled projections generated by the South Central Climate Adaptation Science Center.

Hydrology and circulation (Joe Trungale)

Hydrology strongly affects salinity, nutrient loading and sediment loading to bays and estuaries. There are significant long-term publicly available datasets which can be used to evaluate these relationships. These include TWDB estimates of freshwater inflow summarized by subwatershed which are calculated as the sum of gaged and ungaged runoff minus diversions plus return flows. The TWDB also maintains estimates of direct precipitation and evaporation on the estuaries which are used to calculate estuary water balances. The TWDB also maintains fixed datasondes in each of the bays which collect continuous salinity, temperature, turbidity, dissolved oxygen among other water quality parameters. The TPWD coastal monitoring data includes historic water quality samples as well as biotic data. Both of these datasets can be used to develop statistical relationships between inflow and estuarine conditions and ecological indicators. The TWDB has also developed a 2-dimensional hydrodynamic model (TxBLEND) which can be used to predict salinity conditions throughout each of the seven major estuaries on the Texas coast for a period of record from about 1988 to 2016. They are also in the process of developing a fine resolution 3-dimensitonal model (SCHISM) for the entire Texas coast. These datasets and model (TxBLEND) were originally developed in the same timeframe as the original report on *Freshwater inflow to Texas Bays and Estuaries* (Longley 1994) and employed in the state methodology described therein. They have been employed subsequently most recently within the SB3 studies to determine freshwater inflow needs based on methodologies described in the *Methodologies for Establishing a Freshwater Inflow Regime for Texas Estuaries Within the Context of the Senate Bill 3 Environmental Flows Process* (SAC 2009).

Groundwater (Audrey Douglas)

Groundwater is an important addition to this project as it helps link the climate and hydrological processes to the chemical and biological processes. As part of the water cycle, groundwater is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats for plants and animals. However, groundwater also discharges directly to coastal waters as submarine groundwater discharge and has been found to rival riverine inflows in some places. Submarine groundwater discharge (SGD) comprises any and all flow of water from the seabed to the coastal ocean regardless of fluid composition or driving force. Thus, submarine groundwater discharge may be fresh or saline and one of the big questions to consider is: What is the flux of freshwater due to SGD?

Another important aspect of submarine groundwater discharge is the chemical reactions occurring in the coastal aquifers which may sequester or release carbon, nutrients, metals and other ions, and contaminants. Dissolved solute concentrations are generally greater in discharging groundwater than in the receiving surface water. Thus, even small volumes of submarine groundwater discharge may have a large impact on our coastal ecosystems and drive bio-ecological processes. Thus, the next big question to consider is: What are the materials fluxes from submarine groundwater discharge resulting from these reactions and how are they impacting the ecosystem?

Known datasets:

SGD – Center for Water Supply Studies at TAMUCC (TGLO reports, several peer-reviewed journal articles), peer-reviewed journal articles by Chip Breier

- Studies only cover Baffin Bay, Nueces Estuary, and Aransas-Copano Estuary

Solute fluxes from SGD – CWSS (TGLO reports, several peer-reviewed journal articles)
Gulf Coast Aquifer – TWDB (reports, well database), CWSS (monitoring wells, ongoing projects)

Nutrients (Michael Wetz)

The tentative chapter title: Relationships between freshwater inflow, nutrients and phytoplankton biomass. Phytoplankton form the base of the food web and are often the main primary producer in estuaries. Freshwater inflow variability will modulate phytoplankton biomass and production in estuaries through effects on nutrient delivery and cycling in estuaries, as well as on light availability and flushing rates. The goals of this chapter, and approaches to address these goals, are: 1) Quantify coast-wide relationships between inflow, nutrients and phytoplankton biomass (chlorophyll a) in Texas estuaries. The approach will be to synthesize SPARROW nutrient load models, USGS river discharge data, and TCEQ SWQM water quality data to elucidate coastwide relationships between inflow, nutrients, and phytoplankton biomass. Where deviations from expected patterns are observed, utilize investigator-led sampling programs to explain these deviations (see #2) or develop recommendations for future studies (see #3). 2) Quantify variability in phytoplankton production/biomass in relation to inflow variability and identify key drivers of this variability in individual systems where sufficient data exists (Galveston Bay, Baffin Bay, Mission-Aransas) on spatial and temporal scales. The approach is to synthesize existing higher spatial-temporal resolution nutrient-phytoplankton data from investigator-led programs to elucidate variability in, and bay-specific drivers of, phytoplankton growth/biomass. 3) Highlight data gaps, deficiencies, and future data needs.

Carbon Dynamics (Xinping Hu)

Most Texas estuaries have been experiencing a decline in both alkalinity (mostly bicarbonate) and pH (Hu et al., 2015). This decline was attributed to the decrease in river inflow, which carries the products of continental weathering to the coastal estuaries. In addition, due to the water exchange restriction by the sandbars, a decrease in freshwater input further prolongs estuarine water residence time. As a result, calcifying organisms and biogeochemical reactions could further reduce alkalinity. In addition to alkalinity, rivers can also deliver large amounts of land-derived organic carbon and nutrients to coastal estuaries during strong inflow events. Both organic carbon and nutrients stimulate low oxygen conditions in stratified subsurface waters.

Datasets from United States Geological Survey (USGS), Texas Commission on Environmental Quality (TCEQ), Texas Parks and Wildlife Department (TPWD), and Texas Water Development Board (TWDB), as well as co-PI Hu's data, will be utilized in this synthesis. Specifically, river loading of organic and inorganic carbon will be calculated. Programs such as LOAD ESTimator (LOADEST) will be utilized to calculate river loading time series for Texas major rivers. Box models will be constructed to estimate rates of consumption and production. Temporal changes in dissolved oxygen will be examined in the context of river total organic carbon (TOC), nutrients input, as well as temperature changes using the multidecadal data.

Together, the objective of this chapter is to explore the changing estuarine water biogeochemistry and to unravel the trends of "multistressor" conditions (low oxygen and estuarine acidification) in Texas estuaries over the past few decades.

Sediments (Paul Montagna)

Freshwater inflow transports sediments, nutrients, and organic matter to the coast, and nutrients are often bound to sediment particles. Thus, sediment loading is a critical component of the estuary conditions created by freshwater inflow. Sediment transport is also important for marsh and wetland creation in delta habitats near the confluence of the rivers and bays. Sediments are often finer muds near rivers and coarser sands near the barrier islands. Sediments maps have been created by the University of Texas Bureau of Economic Geology, and sediment load models and data exist at the United States Geological Survey.

Habitats (James Gibeaut)

The vision for this chapter is to relate the distribution of habitats along the coast to freshwater inflows over space and time. We know that habitats vary along the coast and from the upper coast to the lower coast there is a gradient. Variations in salinity, nutrients, and sediments are driven by freshwater inflow causing these trends in habitats. In the north it is more of a marsh dominated habitat with wind-tidal flats becoming more dominant in the south. Seagrasses also become more predominant as you move south. The habitats vary not only in space but also through time. Climate change and human impacts are big drivers of these changes. For example, in the drought of the 1950's we saw more tidal flats in the bays and as we started damming the rivers we saw changes in the bay head delta systems. There is a lot of variation in general habitat assemblage through space and time along the coast. This chapter will tackle the challenge of trying to tease out what freshwater inflow has to do with these spatial and temporal changes. We know that one problem will be that freshwater inflow is not the only pressure that creates habitat variability. Climate change is a major driver controlling freshwater inflow itself. Sea level rise is changing, particularly in time, what our habitat distributions look like. Subsidence increases relative sea level rise and varies greatly along the coast and in historical time due to human causes. Also important is the antecedent topography (i.e., drowned river valleys in the north, bar-built estuary/lagoon in the south) that causes habitat distribution variation. Some interesting questions that we plan to ask in this chapter include: How will habitat distribution change in a particular estuary if freshwater inflow increased by 50% or if it decreased by 50%? Can we create "type" estuaries or conceptual models of what certain conditions of inflow will create concerning habitats? How will sea level rise affect the impacts of freshwater inflow on these marshes (e.g., if you have lower freshwater inflow, there is less sediment coming into the system, particularly in the bay head deltas, so less vertical accretion resulting in environments unable to keep up with sea level rise)? An anticipated challenge for this chapter is having consistent data for habitat coverage along the entire coast through time. We will use data from GLO (underlying data used to determine Resource Management Codes), Texas Coastal Resiliency Master Plan (TCRMP, sea level rise impact modeling on habitat distribution), Coastal Change Analysis Program (CCAP), National Wetlands Inventory (NWI) type maps, and turbidity data from MODIS. We still need more data for sedimentation rates.

Wetlands and Seagrass (Ken Dunton)

Our chapter overview will take advantage of data generated since 2011 from a coastwide monitoring program to assess the status of over 98% (83,000 acres) of the State's seagrasses. This sampling effort extends over 350 km of Texas coastline (see graphic displays of seagrass data at www.texasseagrass.org). The program includes rapid-assessment protocols at over 600 sites along the Texas coast from Galveston Bay south to Lower Laguna Madre as outlined in the Seagrass Conservation Plan (TPWD, 1999) and the Seagrass Monitoring Plan for Texas (Dunton et al., 2011). These data have provided a baseline to assess seagrass condition and areal extent for long-term trend analysis. The large number of stations allow for rigorous statistical analysis in time and space to maximize confidence in trends of seagrass cover and condition in relation to salinity changes. Our review also incorporates indices of ecosystem condition (health) based on measurements of seagrasses and food web structure, both of which are linked to secondary production and sustainable fisheries. Such multiscale and synoptic monitoring has provided an opportunity to integrate water quality parameters with seagrass species composition and percent cover to assess the status of this invaluable resource in relation to both N-loading and freshwater inflows. There are seven major estuarine systems along the Texas coastline that differ considerably with respect to the magnitude of riverine inputs, oceanic influence, mixing and anthropogenic influence. However, the distinct gradient of decreasing rainfall (and thus freshwater inflow) from northeast to southwest is the most distinctive feature of the coastline. With the exception of the Guadalupe Estuary, N loading to these systems is in proportion to freshwater inflow (Fig. 1). Our survey will incorporate both (1) the response of seagrasses to salinity as reflected by freshwater inputs or drought, and (2) food web response to N-loading in estuarine fauna, particularly commercially important shell-and finfish species.

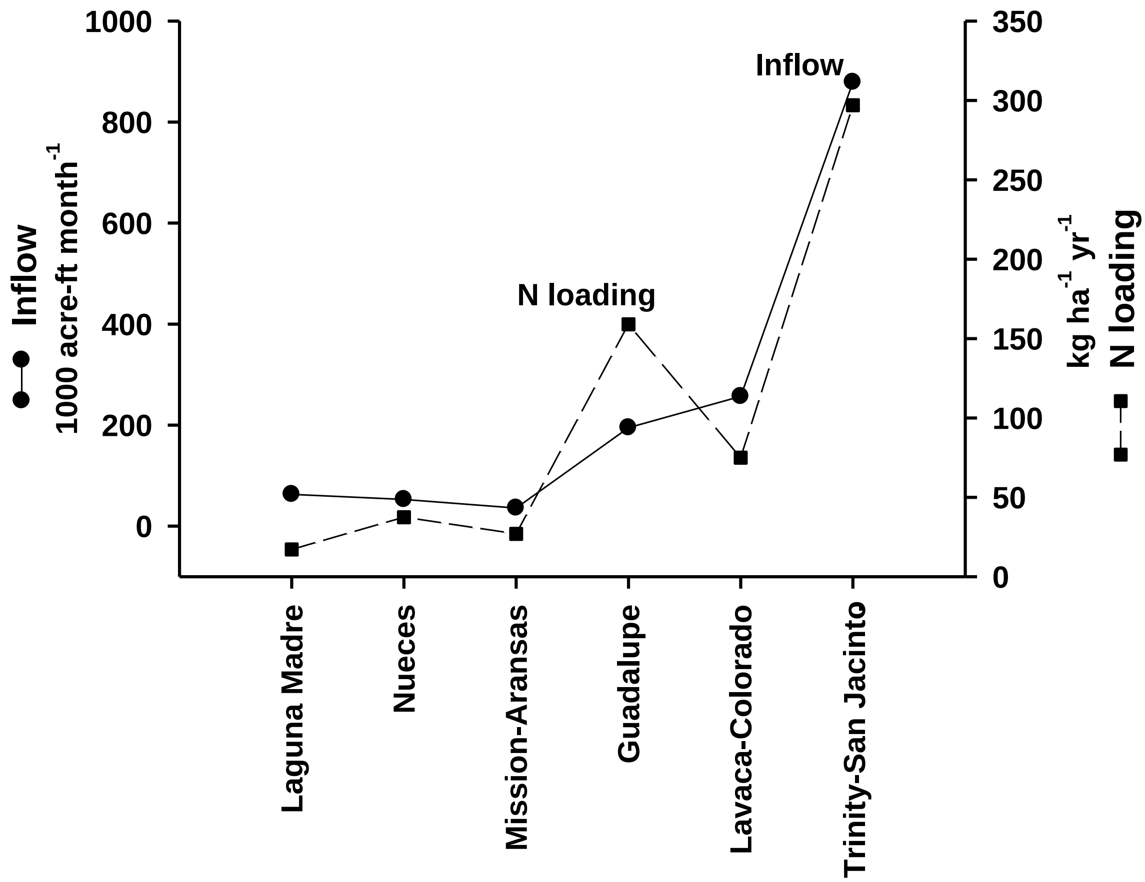

Figure 1. Average monthly inflows and annual mass loading of nitrogen in six Texas estuaries. Adapted from Longley, 1994 and Brock (TWDB, unpublished data).

Plankton (Antonietta Quigg)

The tentative chapter title is: "Effects of freshwater inflow variability on plankton composition." Plankton form the base of the food web. Inflow variability will modulate plankton composition in estuaries, which in turn will determine whether the plankton are edible and capable of supporting higher trophic levels, or not. In some cases, environmental conditions can lead to toxic or noxious harmful algal blooms (HABs). The three goals of this chapter are to: 1) Describe the phytoplankton community and the relationship with freshwater inflow within the Texas estuaries. The approach is to synthesize data on plankton community composition and its relationship with inflow from individual bay systems where sufficient data exists, such as Galveston Bay, Baffin Bay, and Mission-Aransas Estuary. 2) Report information about the harmful algal species present in Texas estuaries in terms of their relationship with freshwater inflows. The approach is to synthesize knowledge on key harmful algal bloom-forming taxa in Texas and any known relationships with inflow. 3) Highlight data gaps, deficiencies, and future data needs.

Given the general lack of data on plankton composition, we expect this chapter to be more descriptive in nature and heavily focused on highlighting future needs (*see #3).*

Benthos (Paul Montagna)

Benthic infauna (i.e., invertebrates > 0.5 mm in length) are excellent bioindicators of sediment quality and estuarine health, because they are relatively long-lived, fixed in place, integrate variations in the overlying water column over time, and are forage for commercial and recreational fish species. Benthos must respond to ephemeral changes in the overlying water column because they don't move as much as nekton, therefore benthic organisms have been used as bioindicators of freshwater inflow effects on bays and estuaries since the 1990's. Diversity is an especially important metric of estuarine health because during disturbances, sensitive species decline or disappear, and tolerant species stay the same or increase. Benthic community metrics have been correlated with inflow or lags in inflow. Mollusks, especially filter-feeding bivalves, have been identified as the best bioindicators of inflow effects. Bivalves depend on microalgal production, which depends on nutrient transport by river flow. Studies demonstrated that infauna in Texas estuaries respond to salinity and not sediment type, likely because the habitats are similar throughout the coast. Extensive benthic data sets area available for most Texas estuaries except for Sabine Lake.

Oysters (Terry Palmer)

Long-term changes in freshwater inflows over a climatic gradient along the Texas coast have provided an opportunity to examine relationships between inflows and oyster (*Crassostrea virginica*) dynamics; specifically, the oysters' relationship with the oyster disease, *Perkinsus marinus*. The prevalence and intensity of *P. marinus* infections within *C. virginica* will be used as bioindicators to identify the environmental conditions (salinities and temperatures) needed to regulate *P. marinus* on both local and regional scales. On a local scale, *P. marinus* infection in market and submarket oysters will be compared among seven stations along a freshwater inflow gradient within the Mission-Aransas Estuary (MAE). These MAE stations have been sampled quarterly for oyster disease and water quality from 2004 until present. On a regional scale, at least 18 years (1998 to >2015) of oyster disease, freshwater inflow, and salinity data from six Texas estuaries will be compiled to determine freshwater needs across a climatic gradient, and to link salinity regimes and oyster disease dynamics. Most, if not all, of the regional-scale *P. marinus* oyster infection and simultaneously sampled salinity and temperature data will be compiled from Oyster Sentinel (https://oystersentinel.cs.uno.edu), a database established in 2007 by Thomas M. Soniat (University of New Orleans) and the late Sammy M. Ray (Texas A&M University at Galveston).

Nekton (Greg Stunz)

There are common themes and overlap among a number of abiotic and biotic components for freshwater inflow as it relates to nekton abundance and distribution. A challenge we have understanding these impacts for these mobile marine species is they are a few ecological steps removed from the actual inflow itself and are, by definition, mobile. For example, salinity, nutrients, sediment, habitat, migrations from spawning to nursery areas, and many other factors clearly affect their population dynamics, but often indirectly. Moreover, the diversity of flow regimes along the Texas coast represents an interesting challenge as it progresses from very water rich areas in the north such as Sabine Lake to very water poor areas of the Laguna Madre system in the south. Thus, while this sets up a unique 'natural experiment,' there is not a one-size-fits-all approach. We will have to apply our analyses in a regional structure, since those freshwater regimes differ. Together, these will allow us to develop a perspective of "how much freshwater does an estuary need" for sentinel nektonic species that would be applicable across a wide range of conditions. Additionally, there are other processes influencing nekton occurring that we will have to control and account for. These may contribute as much or than the actual flow regime and include dynamics such as fishery extraction, changes in habitat through time, and regulatory changes that can potentially cofound conclusions based solely on freshwater inflows. Meshing all these factors together and accounting for them in an overall model will be essential. Similar to the benthic infauna components, there are also spatial influences on nekton dynamics, such as head waters, primary and secondary bays, distance from tidal inlets that link the estuaries to the Gulf of Mexico, and others. Fortunately, we have a wealth of robust data sets that will help inform our analyses. Our next steps will be to collect and begin initial analyses of these data sets to better inform and test our hypotheses for the role of freshwater inflow on nekton dynamics.

BREAKOUT GROUP DISCUSSIONS

(##) indicates number of participants

<u>Day 1</u>

Environmental Flow Policy, Law, and Regulations Breakout Group (36)

Myron Hess (Chair), Elizabeth Harris (notetaker), Gabrielle David (notetaker), Kathy Alexander, Richard Arnett, John Bartos, David Bradsby, Patrick Brzozowski, James Dodson, Francesca Filippone, Amanda Fuller, Zachary Fuqua, Danielle Goshen, Carla Guthrie, Lori Hamilton, Leslie Hartman, Bill Kirby, Ken Kramer, Sky Lewey, Lindsey Lippert, Robert Mace, Westin Massey, Quinn McColly, Julie McEntire, Kimberly Nygren, Alex Ortiz, Nathan Pence, Pamela Plotkin, Steven Raabe, Cory Scanes, Caimee Schoenbaechler, Jonathon Seefeldt, Carrie Thompson, Jennifer Walker

Q1: How environmental flow policies, laws, and regulations impact freshwater inflow? Suggestions for topics to be considered for inclusions:

- Does local government jurisdiction have impact?
  - E.g., consider how impervious cover could impact freshwater inflows
- Seasonal info → How does that go into water rights and regulations? How does TCEQ use standards to write permits?
- Examples/Case studies of application of flow protection and flow standards in permitting would be helpful
  - Agreed Order for inflows to Nueces Bay could be one example
  - Lower Colorado River Authority Water Management Plan could be good example to illustrate how new science on flows can be incorporated over time
  - Examples of how flow standards are applied in permitting process
- How state allows voluntary transactions that can impact freshwater → what mechanisms? What are the constraints?
- Overview of SB 3 flow protection process including for revisiting freshwater inflow standards in SB 3 adaptive management process.
- Term beneficial use → Are there constraints on what constitutes beneficial use?
- How percolation relates to flows?
- History of how the flow protection system has worked
- Incorporate discussion of new flood planning process? Worth acknowledging future possible impacts?
  - Major storage projects → May not be able to project enough info for substantive discussion but could be good just to acknowledge, without extensive discussion.
- Re-use discussion & its challenges → Basic right to complete consumptions. Challenges of reuse/dedication of return flows. Protect return flows. Good to have historical context of flow protection and its evolution. Consider City of Houston reuse applications, with commitment to Galveston Bay inflows, as examples of potential approaches.
- Groundwater interaction with surface water and bay inflows.
- Mention implications of diversions that are done without permits: exempt pumping, recharge enhancements, new rules regarding aquifer recharge and aquifer storage and recharge permits, etc.
- Logistical difficulty of timelines

- Regional water planning– environmental consideration generally is very qualitative; could be done differently for better outcomes.
  - Look at what can be done to advance environmental flows?
  - We have processes from agencies for framework to help make decisions- its worth it to mention there is a disconnect btw water rights, SB-3, etc. Regional water planning processes – we know there can still be short falls – does not match up as well as it could.
  - Region L did cumulative flow impacts analyses in early rounds and new projects must be assessed against SB 3 flow standards
- Should desalination be considered?
  - Yes – larger context is salinity, are the bays and estuaries balanced? – laws governing desalination and how that may factor into freshwater inflow policy and law
  - It will impact bays – how will use of saline aquifers affect inflow?
  - Consider acknowledging 2018 study to designate appropriate desalination discharge and diversion zones by Texas Parks and Wildlife Department and General Land Office
  - ASR – deserve treatment – maximizing use of permits – will have major impacts on flows
- Inter-basin transfer?
  - River authority has rights to move freshwater around - will have huge impacts
  - Anthropogenic impacts – water levels
  - Discussion of historical ranges of species and how environmental flow has changed?
- Regulation of Reuse
  - Consider implications of push for Texas Land Application Permits in lieu of discharge permits for effluent – wastewater discharge can be beneficial for flows if it is cleaned properly
  - GBRA – The Aransas Project agreement – could lead to e-flows into the bay

Q2: What key topics that pertain to freshwater inflow and environmental flow policies, laws, and regulations should be addressed? (Continuation of discussion under Q1)

- Climate change
- Federal regulatory programs affecting flows – Endangered Species Act (ESA) as a key example?
- Concept of focus flows – potential for targeting, both location and time, limited quantities of inflows to benefit key species?
- Discussion of regulatory authority, TCEQ has authority over interbasin transfer, etc
  - powers – legal designation

Q3: Who would like to be a reviewer for the final products concerning environmental flow policies, laws, and regulations

- David Brasdby (TPWD)
- Leslie Hartman (TPWD)
- Nathan Pence (Guadalupe-Blanco River Authority)
- Jennifer Walker (Texas Living Waters Project/NWF Texas Coast and Water Program)

- Alex Ortiz (Texas Living Waters Project/Sierra Club Lone Star Chapter)
- James Dodson (San Antonio Bay Partnershop, GroundswellTX)

Climate, Hydrology, Circulation, and Groundwater Breakout Group (22)
John Nielsen-Gammon (co-chair), Joe Trungale (co-chair), Audrey Douglas (notetaker), Karin Treviño (notetaker), Bill Balboa, David Brown, Elena Crowley-Ornelas, Kevin De Santiago, James Gibeaut, Stephanie Glenn, Bimal Gyawali, Amin Kiaghadi, Jungwoo Lee, Melissa Lupher, Ram Neupane, Jeremy Nickolai, Arsum Pathak, Philip Price, Tony, Reisinger, Victor Roland, James Tolan

Q1: How does freshwater inflow to bays and estuaries relate to climate, hydrology, circulation, and groundwater?

- Why is sea level rise (SLR) not being included?
    - SLR is compounded by increasing freshwater inflows
    - fundamental impacts for SLR and freshwater inflow will be similar, but should not underestimate SLR
- Does SLR cause changes in estuarine temperature? → no one was sure
- Planning to incorporate SLR in the "Habitat" chapter(s) (Gibeaut – Day 2)
    - Spatial variability along the coast/relate to changes in freshwater inflow
    - How habitat distribution may change
- "The big three": sediment, salinity, nutrients
    - Sediment and nutrient inputs can be connected to this chapter.
    - Salinity variability will be included
    - Relate hydrology to salinity, nutrients, and sediments
- Will extreme events be included?
    - Yes, will be included in climate chapter with some related projections in relation to freshwater inflow
    - Some discussion of Hurricanes to be included (e.g., Harvey)
- Loss of freshwater inputs (ex. Big Boggy study)

Q2: What data sources are available that pertain to freshwater inflow's relationship to climate, hydrology, circulation, and groundwater?

- Big Boggy bayou (on-going) – diverting flow into rice wetlands
    - Data on return flows from rice irrigation is not well captured in models → Need better return flow estimates
- Water data for Texas
    - FWI = Gaged -diversions + return flows + modelled
    - Fresh water inflow data from TWDB: https://www.waterdatafortexas.org/coastal/hydrology
    - Freshwater estimates were more realistic than the gage data for how much water actually makes it to the bay
        - Can we incorporate the dams from further downstream?

        - USGS looking into adding new gages downstream in tidally influenced areas → new methods for dealing with tidal influence
    - Where do we need more gages? Do the gages currently used accurately represent freshwater inflows?
    - Known gaps
        - Lower Laguna Madre to upper Laguna Madre
        - Brazos to Galveston
- USGS Lower Mississippi-Gulf Water Science Center
    - Georgia to Oklahoma modeled stream flow from 1950 to 2009
        - Network analysis study
        - Best places to put stream gages?
        - Do they conform with TWDB ungaged estimates or is the methodology too different? → They did not match
    - RESTORE (Kirk Rodgers)
        - 6 years so far
        - Trend analysis of 139 stream gages
        - Data visualization tool (https://www.usgs.gov/apps/ecosheds/lmg-restore/)
    - Streamflow alteration study in progress
        - Streamflow alteration assessments to support bay and estuary restoration in the Gulf States (https://www.sciencebase.gov/catalog/item/59b7ed9be4b08b1644df5d50)
- Use existing downscaled data
    - NOAA SCIPP (Southern Climate Impacts Planning Program) has data from 1970's to present.
- Future climate scenarios

Q3: Who would like to be a reviewer for the final products concerning climate, hydrology, and circulation, and groundwater?

- Volunteered
    - Kirk Rodgers (USGS) – Hydrology and Climate
    - Mike Lee (USGS) – Hydrology
    - Arsum Pathak (Texas Living Waters Project/National Wildlife Federation Texas Coast and Water Program) – Climate
    - Ram Neupane and Melissa Rohal (TWDB) – Hydrology
- Suggested
    - Victor Roland (USGS) – Hydrology and Climate
    - Dorina Murgulet (TAMUCC CWSS)– Hydrology and Climate
- Additional Comments/Questions
    - Time frame for project is year and half.
    - Looking for reviewers in a year (fall of next year) → or sooner if the chapter is ready
    - Review the document or some writing as well? Just document review

Nutrients, Carbon, and Sediments Breakout Group (18)
Paul Montagna (chair), Xinping Hu (co-chair), Michael Wetz (co-chair), Lauren Renner (notetaker), Mikell Smith (notetaker), Elizabeth Del Rosario, Ken Dunton, Rick Kalke, Mike Lee, Melissa McCutcheon, Terry Palmer, Antonietta Quigg, Kelly Sanks, Doug Schnoebelen, Kiersten Stanzel, Jamie Steichen, Gregory Steyer, Evan Turner, Janet Weaver

Approaches

- Estuary comparison and wet vs. dry years
- Example data sets that provide process information so you could extrapolate to systems without data
- Concentrations versus loads for sediments and nutrients (organics, dissolved, and particulates)
    - Linkages between flows, plankton, and sediments
    - Loads would gain value if dedicated chapter.
    - Software: Loadest, SPARROW
- How many WQ chapters? Separate Nutrients independently?

Q1: Nutrients, carbon dynamics, and sediments?

- Nutrients
    - Dissolved vs. total → particulates???
    - Inorganic vs. organic
- Carbon
    - Organic: chlorophyll as an indicator of productivity
    - Inorganic: alkalinity, pH, carbonate
        - Dissolved oxygen (DO) as a multiple stressor
        - DO relationships to salinity, temperature, climate, productivity
- Climate change
    - Temperature and precipitations changes
    - Wind variability, wind gradient, with climate change?
- Sediments
    - Evan Turner – data set that does not fit would be nice to include

Q2: What data sources are available that pertain to freshwater inflow's relationship to nutrients, carbon dynamics, and sediments?

- Sonde: dissolved oxygen, salinity, temperature
    - TCEQ Surface Water Quality Montoring (SWQM)
    - TPWD
    - HRI
    - Mission-Aransas National Estuarine Research Reserve (MANERR) System-Wide Monitoring Program (SWMP)
        - Monitoring of water quality and weather conditions
        - Biological monitoring
        - Mapping of Reserve habitats and watersheds
        - 5 water quality monitoring stations → temperature, salinity, DO, depth, pH, turbidity, chlorophyll/algal biomass

- TWDB (https://www.waterdatafortexas.org/coastal) → largely unexplored
- UTRGV (Hudson DeYoe)
- Temperature in continuous measurements is reliable for climate changes studies

- Nutrient data
  - SWQM
  - HRI
  - MANERR SWMP
  - UTRGV (Hudson DeYoe)
  - TAMUG
- Carbonate
  - SWQM
  - HRI
  - CWSS
- Sediments
  - MANERR Surface Elevation Tables (SET)
  - marker horizons
  - Katie Swanson or Jace Tunnell
  - Jennifer Wren TAMUK
  - Dave Davis and Dan Roelke near Port A.
  - USGS Mike Lee → monitoring, discrete samples
  - Doug Schnoebelen (USGS)
  - Kathy
- The USGS Texas Water Science Center is evaluating the variability of nutrient and sediment concentrations and loads entering Texas bays and estuaries across a range of hydrologic conditions in Galveston Bay (inflow from the Trinity and San Jacinto Rivers), Matagorda Bay (inflow from the Colorado River), San Antonio Bay (inflow from the Guadalupe River), and Nueces Bay (inflow from Nueces River). https://www.usgs.gov/centers/ot-water/science/nutrient-and-sediment-monitoring-inflows-texas-bays-and-estuaries?qt-science_center_objects=0#qt-science_center_objects
- Gulf coast data inventory: https://restorethegulf.gov/cmap
- Updated SPARROW model: https://www.usgs.gov/mission-areas/water-resources/science/sparrow-modeling-estimating-nutrient-sediment-and-dissolved?qt-science_center_objects=0#qt-science_center_objects
- SPARROW Mapper for Southwest: https://sparrow.wim.usgs.gov/sparrow-southwest-2012/
- https://www.usgs.gov/mission-areas/water-resources/science/sparrow-mappers?qt-science_center_objects=0#qt-science_center_objects

Q3: Who would like to be a reviewer for the final products concerning nutrients, carbon, and sediments?

- Nutrients
  - Evan Turner (TWDB)
  - Jay Pinckney (U South Carolina)
  - Dan Roelke
- Sediments
  - Wayne Gardner (retired)

- Timothy Dellapena (TAMU)
  - Mandy Joye – did some stuff in 90's while at TAMU
- Carbon (organic and inorganic)
  - Jay Pinckney
  - Kimberly Yates

Day 2

Habitats: Wetlands, Seagrasses, and Oysters Breakout Group (27)

James Gibeaut (co-chair), Ken Dunton (co-chair), Terry Palmer (co-chair), Gabrielle Davis (notetaker), Audrey Douglas (notetaker), Kathy Alexander, Bill Balboa, Kevin De Santiago, James Dodson, Francesca Filippone, Danielle Goshen, Myron Hess, Xinping Hu, Brian Koch, Joseph Kowalski, Ken Kramer, Mike Lee, Lindsey Lippert, Bill Longley, Dorina Murgulet, Ram Neupane, John Nielsen-Gammon, Alex Ortiz, Arsum Pathak, Nathan Pence, Victor Roland, Kelly Sanks, Caimee Schoenbaechler

Q1: Are we covering all the issues related to wetlands, seagrasses and oyster habitats? What's missing?

- Is the goal broader scope? Or more about quantifying these impacts on specific habitats?
  - quantify as data will allow
  - with what is used create a conceptual model within this synthesis
- Sea level rise
  - erosion
    - coast-wide study – how erosion is impacting salt marshes
  - habitat expansion/contraction
- Mangrove expansion
  - localized
  - effected wetlands
  - impact on salt marshes specifically
  - did the recent freeze event have any impact on the mangrove range?
  - The Contribution of Mangrove Expansion to Salt Marsh Loss on the Texas Gulf Coast (Armitage et al. 2015) (https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0125404)
- Sedimentation and accretion
  - decreasing rates
  - expanding real-time coastal monitoring network
  - tying it to real-time estimate of sediment contributions
  - collecting nutrient samples of the well
  - looking at real-time sediment and nutrient distribution
  - moving gauges to as low in watershed as possible
    - in tidally influenced areas → new
  - distribution of sediment is quite variable
  - Looked at deposition rates at some deltas
    - wanted to use model done by Calloway
    - was able to look at effect of inflow on building Louisiana wetlands
    - were unable to use the info
    - Calloway's was much more specific

        - would've liked it because we wanted to make sure deltas do not disappear under sea level rise
- Oysters
- Benthic habitat maps
    - An area that needs more data, but first need to find all existing data to build upon
- Connection to hydrology/groundwater
    - Submarine groundwater discharge has been linked to various habitats (e.g., coral reefs, oyster reefs, wetlands)

Q2: What data sources are available that pertain to freshwater inflow's relationship to wetlands and seagrasses?

- Data used will be made publicly available → ensure accessibility
    - GRIIDC resources
    - Not sure how data that is shared for the book, but is not authorized to share publicly will be handled
- Sedimentation/Deposition
    - Peter Santchi – sedimentation rates around the Bay
    - John Anderson – deltas
    - Calloway did paper comparing deposition rates in deltas – has cite in TX
- Oysters
    - USDA remote sensing
    - Groundwater Influence
        - Spalt et al. 2018 – Copano Bay paleovalley, submarine groundwater discharge, and oyster reef location
        - Spalt et al. 2020 – Copano Bay paleovalley, submarine groundwater discharge, and oyster reef location
- Benthic habitat maps
    - TPWD side-scan data
    - Emma Clarkson
    - Tim Dellapena – also side-scanned Lavaca Bay
    - Biowest – Lower Matagorda Bay
    - Army Corps of Engineers – Sometimes do surveys
    - Laguna Madre – BEG may have data
- USGS Digital Shoreline and Analysis Tool (DSAS) erosion analysis tool
- Bureau of Economic Geology – shoreline change rates
- Coastal change hazards portal
    - sea level rise
    - vegetated marsh ratios
    - https://marine.usgs.gov/coastalchangehazardsportal/
- Dr. Anita Thorhaug – extensive research on seagrass beds in the Gulf
- Hudson DeYoe mentioned the seagrass survey back in 2013 → also included a sediment survey

Q3: Who would like to be a reviewer for the final products concerning wetlands and seagrasses?

- Volunteered
    - Hudson DeYoe (UTRGV) – seagrass & mangrove

    - Joe Kowalski (UTRGV) – seagrasses
    - Arsum Pathak (Texas Living Waters Project/NWF – SLR, wetlands
    - Mike Lee (USGS) – anything sediment related
    - Kevin De Santiago (TWDB) – oysters
- Suggested reviewers
    - Emma Clarkson (TAMUCC) – anything mapping
    - Dr. Anita Thorhauf (Yale University) – seagrasses

Plankton, Benthos, and Nekton Breakout Group (21)
Paul Montagna (chair), Antonietta Quigg (co-chair), Greg Stunz (co-chair), Elizabeth Harris (notetaker), Lauren Renner (notetaker), Noe Barrera, David Bradsby, Elizabeth Del Rosario, Zachary Fuqua, Rick Kalke, Bill Kirby, Melissa Lupher, Kimberly Nygren, Philip Price, Cory Scanes, Doug Schnoebelen, Jamie Steichen, James Tolan, Joe Trungale, Evan Turner

Q1: Are we covering all the issues related to plankton, benthos, and nekton?
- How do we fulfill the needs of the stakeholders?
- Food web connectivity
    - Stable isotope studies
- Compare space and time-spatial data set
    - Ex. Nueces Bay study helps with time comparisons wet v dry.
- Have not talked about benthic microalgae, only data from Baffin Bay
- Does freshwater inflow (FWI) act differently in different bays?
    - Different biological responses to FWI?
    - Each bay and estuary is unique
    - Different management strategies?
- Euryhaline vs stenohaline species
    - Salinity tolerances
    - FWI indicators?
- Can we validate that the standards are protective using bioindicators?
    - Achieves one set of objectives
- Should this be a chapter?
    - <u>For PI's: chapter outlines sooner than later</u>
    - 2 or 3 smaller chapters rather than 1
    - Have a synthesis chapter at the end to deal with food webs and connections
    - End chapters with recommendations
        - Identify data gaps and indicators
        - Will have subjective comments and analysis (no objective analysis)
        - Will look at trends
- The future?? Future issues
    - Climate change?
    - Population growth?
    - How will it affect FWI?
    - A paragraph or chapter?

    - If it gets hotter/saltier → less DO in the water
    - Look at DO, temp, salinity in Chemical chapters
    - Are there tipping points that drive regime change?
- Who is available to help with QA/QC who can help with plankton??
    - Providing meta data
- Benthos → infauna, live in mud, worms, clams, crustaceans
- Some meiofauna

Q2: What data sources are available that pertain to freshwater inflow's relationship to plankton, benthos, and nekton?

- Paul to get UTMSI/TWDB early NIPS and San Antonio Bay and Lavaca Bay stuff to plankton group
- Benthos = Infauna
- Have nutrients and chlorophyll data set
- Are we going to go back to gather all the data sets?
- Have TPWD data set
- Need ichthyoplankton data
- Sabine Lake Data
    - HRI Report card could not find much
    - Bill Kirby, data is focused on river not tidal
    - Rangia study by Norman Johns, data for Sabine, Galveston, and across Texas
    - Matthew Houch at Lamar did work in Sabine Lake (Rangia??)
    - TCEQ Orange County
    - Tidal sections -Jim Tolan
    - Check spills and kills team for after Rita

Q3: Who would like to be a reviewer for the final products concerning plankton, benthos, and nekton?

- Nekton
    - James Tolan (TPWD)
- Plankton
    - Ed Buskey
- Benthos
    - Evan Turner (TWDB)
    - Melissa Lupher (TWDB)

REFERENCES

Dunton, K., Pulich, W., Mutchler, T. 2011. A seagrass monitoring program for Texas coastal waters: Multiscale integration of landscape features with plant and water quality indicators. Final report to the Coastal Bend Bays & Estuaries Program, Project 0627. The University of Texas Marine Science Institute, Port Aransas, Texas, USA. http://www.texasseagrass.org/doc/A%20Seagrass%20Monitoring%20Program%20for%20Texas%201-10-11.pdf

Hu, X., Beseres Pollack, J., McCutcheon, M.R., Montagna, P.A., Ouyang, Z., Long-term alkalinity decrease and acidification of estuaries in Northwestern Gulf of Mexico. *Environmental Science & Technology* 49, 3401-3409.

Longley, W.L., ed. 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas·Parks and Wildlife Department, Austin, TX. 386 pp. https://repositories.lib.utexas.edu/bitstream/handle/2152/6728/FreshwaterInflows-+Ecological+Relationships+and+Methods+for+Determination+of+Needs+-+1994.pdf?sequence=2

Science Advisory Committee. 2009. Methodologies for Establishing a Freshwater Inflow Regime for Texas Estuaries Within the Context of the Senate Bill 3 Environmental Flows Process. Report # SAC-2009-03-Rev1., June 5, 2009. Available at http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/eflows/fwi20090605.pdf

TPWD (Texas Parks and Wildlife Department). 1999. Seagrass conservation plan for Texas. Texas Parks and Wildlife Department, Austin, Texas. 84 pp. http://www.tpwd.texas.gov/seagrass

APPENDIX I: Abbreviations

BBASC	Basin and Bay Area Stakeholder Committees
BBEST	Basin and Bay Expert Science Teams
BRA	Brazos River Authority
CCAP	Coastal Change Analysis Program
CBBEP	Coastal Bend Bays and Estuaries Program
CGMF	Cynthia and George Mitchell Foundation
CWSS	Center for Water Supply Studies
DU	Ducks Unlimited, Inc.
FINS	Freshwater inflow needs study
FWI	Freshwater I\inflow
GBEP	Galveston Bay Estuary Program
GBF	Galveston Bay Foundation
GBRA	Guadalupe-Blanco River Authority
GIS	Geographic Information System
GOMESA	Gulf of Mexico Energy Security Act
HAB	Harmful Algal Bloom
HARC	Houston Advanced Research Center
HRI	Harte Research Institute for Gulf of Mexico Studies
LBF	Lavaca Bay Foundation
LNRA	Lavaca-Navidad River Authority
LOADEST	Load Estimator
MBF	Matagorda Bay Foundation
MBMT	Matagorda Bay Mitigation Trust
MCWE	Meadows Center for Water and the Environment
MODIS	Moderate Resolution Imaging Spectroradiometer
NGO	Non-governmental Organizations
NRA	Nueces River Authority
NWF	National Wildlife Federation
PLLC	Professional Limited Liability Company
SABP	San Antonio Bay Partnership
SAC	Science Advisory Committee
SARA	San Antonio River Authority
SC	Sierra Club Lone Star Chapter
SCHISM	Semi-implicit Cross-scale Hydroscience Integrated System model

SGD	Submarine Groundwater Discharge
SRA	Sabine River Authority
TAMU	Texas A&M University
TAMUCC	Texas A&M University-Corpus Christi
TAMUG	Texas A&M University-Galveston
TCEQ	Texas Commission for Environmental Quality
TCRMP	Texas Coastal Resiliency Master Plan
TGLO	Texas General Land Office
TLW	Texas Living Waters Project
TNC	The Nature Conservancy
TOC	Total Organic Carbon
TPWD	Texas Parks and Wildlife Department
TSG	Texas Sea Grant
TSSWCB	Texas State Soil and Water Conservation Board
TSU	Texas State University
TWDB	Texas Water Development Board
TWT	Texas Water Trust
TXBLEND	Texas Hydrodynamic and Salinity Model
USGS	United States Geological Survey
UTMSI	University of Texas Marine Science Institute
UTRGV	University of Texas Rio Grande Valley

APPENDIX II: Participant Contact Information

Organizers

Paul Montagna
  Texas A&M University-Corpus Christi – Harte Research Institute, HydroEcology Chair
  Paul.montagna@tamucc.edu

Audrey Douglas
  Texas A&M University-Corpus Christi – Harte Research Institute, Postdoctoral Research Associate in HydroEcology
  Audrey.douglas@tamucc.edu

Speakers

Ken Dunton
  University of Texas at Austin – Marine Science Institute, Professor
  Mission-Aransas San Antonio BBASC, Nueces, Corpus, Baffin BBEST
  Ken.dunton@utexas.edu

James Gibeaut
  Texas A&M University-Corpus Christi – Harte Research Institute, Coastal and Marine Geospatial Sciences Endowed Chair
  James.gibeaut@tamucc.edu

Myron Hess
  Law Office of Myron Hess PLCC, Environmental Law Attorney
  Colorado, Lavaca, Matagorda BBASC (vice-chair)
  myron@myronhess.com

Xinping Hu
  Texas A&M University-Corpus Christi – Harte Research Institute, Ecosystem Science and Modelling Chair
  Xinping.hu@tamucc.edu

John Nielsen-Gammon
  Texas A&M University – Department of Atmosphere Sciences, Regents Professor
  n-g@tamu.edu

Terry Palmer
  Texas A&M University-Corpus Christi – Harte Research Institute, Research Specialist & Doctoral Candidate in Coastal and Marine System Science
  Terry.palmer@tamucc.edu

Antonietta Quigg
  Texas A&M University-Galveston – Department of Marine Biology, Regents Professor
  Trinity, San Jacinto, Galveston BBEST
  quigg@tamug.edu

Greg Stunz
  Texas A&M University-Corpus Christi – Harte Research Institute, Fisheries and Ocean Health Endowed Chair & Center for Sportfish Science and Conservation Director
  Nueces, Corpus, Baffin BBEST
  Greg.stunz@tamucc.edu

Joe Trungale

Trungale Engineering and Science
Trinity, San Jacinto, Galveston BBEST, Colorado, Lavaca, Matagorda BBEST
joe@trungaleengineering.com

Michael Wetz
Texas A&M University-Corpus Christi – Harte Research Institute, Coastal Ecosystem Processes Chair
Michael.wetz@tamucc.edu

Project Support Staff/Researchers

Noe Barrera
Texas A&M University-Corpus Christi – Harte Research Institute, Research Specialist
noe.barrera@tamucc.edu

Rick Kalke
Texas A&M University-Corpus Christi – Harte Research Institute, Research Specialist
rick.kalke@tamucc.edu

Mikell Smith
Texas A&M University-Corpus Christi – Harte Research Institute, Project Manager
Mikell.smith@tamucc.edu

Jamie Steichen
Texas A&M University-Galveston, Instructional Professor
Jamie.steichen@tamu.edu

Students

Gabrielle David
Del Mar Community College, Undergraduate Research Assistant with Texas A&M University-Corpus Christi – Harte Research Institute HydroEcology Group
gabriellehdavis@gmail.com

Elizabeth Del Rosario
Texas A&M University-Corpus Christi – Harte Research Institute HydroEcology Group, Doctoral Candidate in Coastal and Marine System Science
edelrosario@islander.tamucc.edu

Larissa Dias
Texas A&M University-Corpus Christi – Harte Research Institute Ecosystem Science and Modeling Group, Doctoral Candidate in Coastal and Marine System Science
ldias@islander.tamucc.edu

Francesca Filippone
Texas State University, Doctoral student in Geography
Ffilippone1@gmail.com

Bimal Gyawali
Texas A&M University-Corpus Christi – Center for Water Supply Studies, Doctoral Candidate in Coastal and Marine System Science
bgyawali@islander.tamucc.edu

Elizabeth Harris
Texas A&M University-Corpus Christi – Harte Research Institute HydroEcology Group, Master's student in Environmental Science
Eharris3@islander.tamucc.edu

Lauren Rener
Texas A&M University-Corpus Christi – Harte Research Institute HydroEcology Group, Master's student in Environmental Science
lrener@islander.tamucc.edu

Karin Treviño
Texas A&M University-Corpus Christi – Harte Research Institute HydroEcology Group, Master's student in Environmental Science
Ktrevino24@islander.tamucc.edu

Stakeholders

Kathy Alexander
Texas Commission for Environmental Quality (TCEQ), Water Availability Division Technical Specialist
Colorado, Lavaca, Matagorda BBEST (non-voting member)
Kathy.alexander@tceq.texas.gov

Richard Arnett
Texas Parks and Wildlife Department (TPWD)
Richard.arnett@tpwd.texas.gov

Morgen Ayers
Texas Sea Grant, Natural Resources Specialist
Moren.ayers@tamu.edu

Bill Balboa
Matagorda Bay Foundation, Executive Director
Colorado, Lavaca, Matagorda BBASC (chair)
bbalboa@matbay.org

John Bartos
Law Offices of John R. Bartos & J. Bernard Schultz, Attorney
Trinity, San Jacinto, Galveston BBASC
jbartos@htownlaw.com

David Bradsby
Texas Parks and Wildlife Department (TPWD) – Water Quality Branch, Program Leader
Colorado, Lavaca, Matagorda BBEST (non-voting member)
David.bradsby@tpwd.texas.gov

David Brown
United States Geological Survey (USGS) – Oklahoma-Texas Water Science Center, Associate Director Gulf Coast Texas Program
dsbrown@usgs.gov

Kirby Brown
Ducks Unlimited, Inc., Conservation Outreach Biologist
Kbrown2@ducks.org

Patrick Brzozowski
Lavaca-Navidad River Authority, General Manager
Colorado-Lavaca BBASC
pbrzozowski@lnra.org

John Byrum
Nueces River Authority, Executive Director

jbyrum@nueces-ra.org
Jessica Chappell
Texas General Land Office, Project Director
Jessica.chappell@glo.texas.gov
Bryan Cook
Lower Colorado River Authority, Water Quality Manager
Colorado, Lavaca, Matagorda BBEST
Bryan.cook@lcra.org
Elena Crowley-Ornelas
United States Geological Survey (USGS) – Texas Water Science Center, Student Trainee
Ecrowley-ornelas@usgs.gov
Kevin De Santiago
Texas Water Development Board (TWDB) – Surface Water-Coastal Science, Field Hydrologist
Kevin.desantiago@twdb.texas.gov
Hudson DeYoe
University of Texas Rio Grande Valley – Department of Biology, Professor
Rio Grande BBEST & BBASC
Hudson.deyoe@utrgv.edu
James Dodson
San Antonio Bay Partnership, Project Manager
Nueces, Corpus, Baffin BBASC
Jdodson27@gmail.com
Shaun Donovan
San Antonio River Authority, Environmental Sciences Manager
sdonovan@sariverauthority.org
Amanda Fuller
Texas Living Waters Project
National Wildlife Federation, Director Texas Coast and Water Program
fullera@nwf.org
Zachary Fuqua
Texas Commission for Environmental Quality (TCEQ), Water Quality Investigator for the Corpus Christi Regional Office
Zachary.fuqua@tceq.texas.gov
Kyle Garmany
The Nature Conservancy-Texas Chapter, Water and Agriculture Program Director
Kyle.garmany@tnc.org
Stephanie Glenn
Houston Advanced Research Center (HARC), Program Director Hydrology and Wetlands
sglenn@harcresearch.org
Lisa Gonzalez
Houston Advanced Research Center (HARC), President
lgonzalez@harcresearch.org
Danielle Goshen
Texas Living Waters Project
Galveston Bay Foundation, Water Policy Specialist

dgoshen@galvbay.org
Carla Guthrie
Texas Water Development Board (TWDB) – Surface Water, Director
Carla.guthrie@twdb.texas.gov
Lori Hamilton
Texas Commission for Environmental Quality (TCEQ), Water Quality Planning Division Deputy Director
Lori.hamilton@tceq.texas.gov
Thomas B. Hardy
Texas State University – Meadows Center for Water and the Environment, Meadows Professor for Environmental Flow
Colorado, Lavaca, Matagorda BBEST, Mission-Aransas San Antonio BBEST
TH31@TxState.edu
Leslie Hartman
Texas Parks and Wildlife Department (TPWD), Matagorda Bay Ecosystem Leader
Leslie.hartman@tpwd.texas.gov
Thomas Hill
Guadalupe-Blanco River Authority, Senior Advisor to the General Manager
Mission-Aransas San Antonio BBASC
thill@gbra.org
Adrien Hilmy
Coastal Bend Bays and Estuaries Program (CBBEP), Project Manager
ahilmy@cbbep.org
Rick Kalke
Texas A&M University-Corpus Christi – Harte Research Institute, Research Assistant
Amin Kiaghadi
Texas Water Development Board (TWDB), Coastal Flood Modeller
Amin.kiaghadi@twdb.texas.gov
Chadwick Kinsfather
Lavaca-Navidad River Authority, Director of Environmental Services
ckinsfather@lnra.org
Bill Kirby
Sabine River Authority, Natural Resource Management Director
bkirby@sratx.org
Brian Koch
Texas State Soil and Water Conservation Board – Nonpoint Source Management Program, Regional Watershed Coordinator
bkoch@tsswcb.texas.gov
Joseph Kowalski
University of Texas Rio Grande Valley – Department of Biology, Research Associate
Joseph.kowalski01@utrgv.edu
Ken Kramer
Sierra Club Lone Star Chapter, Chapter Director (retired) and Water Conservation Committee Chair
Brazos BBASC, Trinity, San Jacinto, Galveston BBASC
kramerkenw@gmail.com

Jungwoo Lee
Texas Water Development Board (TWDB) – Surface Water-Coastal Science, Coastal Modeler
Jungwoo.lee@twdb.texas.gov
Mike Lee
United States Geological Survey (USGS) – Oklahoma-Texas Water Science Center, Southeast Texas Branch Chief
mtlee@usgs.gov
Sky Lewey
Nueces River Authority, Resource Protection and Education Director
slewey@nueces-ra.org
Lindsey Lippert
Texas Commission for Environmental Quality (TCEQ), Galveston Bay Estuary Program Natural Resource Uses Coordinator
Lindsey.lippert@tceq.texas.gov
Bill Longley
Texas Water Development Board (TWDB) – Retired
Elmo943z@gmail.com
Melissa Lupher
Texas Water Development Board (TWDB) – Surface Water-Coastal Science, Hydrologist
Melissa.lupher@twdb.texas.gov
Robert Mace
Texas State University – Meadows Center for Water and the Environment, Executive Director
Robertmace@txstate.edu
Westin Massey
Texas Commission for Environmental Quality (TCEQ) – Houston Region, Water Section Manager
Westin.massey@tceq.texas.gov
Quinn McColly
Texas Water Trade, Conservation Finance Director
mccolly@texaswatertrade.org
Melissa McCutcheon
Texas General Land Office, Coastal Project Manager/Natural Resource Specialist
Melissa.mccutcheon@glo.texas.gov
Julie McEntire
Texas General Land Office, Project Manager
Julie.mcentire@glo.texas.gov
Kristen McGovern
Galveston Bay Estuary Program, Monitoring and Research Coordinator
Kristen.mcgovern@tceq.texas.gov
Dorina Murgulet
Texas A&M University-Corpus Christi – Center for Water Supply Studies, Director & Associate Professor of Hydrogeology
Dorina.murgulet@tamucc.edu
Ram Neupane

Texas Water Development Board (TWDB) – Surface Water-Coastal Science, Coastal Hydrologist
Ram.neupane@twdb.texas.gov

Jeremy Nickolai
Brazos River Authority, Field Operations Manager
Jeremy.nickolai@brazos.org

Kimberly Nygren
Texas Commission for Environmental Quality (TCEQ) – Office of Water, Water Availability Division Deputy Director
Kim.nygren@tceq.texas.gov

Alex Ortiz
Texas Living Waters Project
Sierra Club Lone Star Chapter, Water Resources Specialist
Alex.ortiz@sierraclub.org

Arsum Pathak
Texas Living Waters Project
National Wildlife Federation, Adaptation and Coastal Resilience Specialist
pathaka@nwf.org

Nathan Pence
Guadalupe-Blanco River Authority, Executive Manager of Environmental Science and Community Affairs
npence@gbra.org

Pamela Plotkin
Texas Sea Grant, Director
plotkin@tamu.edu

Philip Price
Brazos River Authority, Senior Water Resources Engineer
Brazos BBEST
Phil.price@brazos.org

Steven Raabe
Matagorda Bay Mitigation Trust, Trustee
trustee@mbmtrust.com

Tony Reisinger
Texas Sea Grant, Extension Agent Cameron County
Rio Grande BBASC
e-reisinger@tamu.edu

James Rizzo
Texas A&M University-Corpus Christi – Conrad Blucher Institute, Assistant Director Operations
James.rizzo@tamucc.edu

Kirk Rodgers
United States Geological Survey (USGS) – RESTORE project, Principal Investigator and Hydrologist
krodgers@usgs.gov

Victor Roland

United States Geological Survey (USGS) – Lower Mississippi-Gulf Water Science Center, Hydrologist
vroland@usgs.gov

Kelly Sanks
United States Geological Survey (USGS)
ksanks@usgs.gov

Cory Scanes
Brazos River Authority, Aquatic Scientist
Cory.scanes@brazos.org

Doug Schnoebelen
United States Geological Survey (USGS) –Texas Water Science Center, Branch Chief – South Texas Program
dschnoebelen@usgs.gov

Caimee Schoenbaechler
Texas Water Development Board (TWDB) – Surface Water-Coastal Science, Manager
Caimee.schoenbaechler@twdb.texas.gov

Farnaz Seddighzadeh
Cynthia and George Mitchell Foundation, Land Conservation and Water Program Associate
fseddighzadeh@cgmf.org

Jonathon Seedfeldt
Texas Living Waters Project
National Wildlife Federation, Communications Manager
seefeldtj@nwf.org

Ryan Smith
The Nature Conservancy-Texas Chapter, Aquatic Ecologist
Nueces, Corpus, Baffin BBEST, Rio Grande BBEST
Ryan_smith@tnc.org

Kierstan Stanzel
Coastal Bend Bays and Estuaries Program (CBBEP), Director of Partnerships
kstanzel@cbbep.org

Gregory Steyer
United States Geological Survey (USGS) – Southeast Region, Science Advisor – Gulf of Mexico
steyerg@usgs.gov

Carrie Thompson
Texas State University – Meadows Center for Water and the Environment, Director of Operations
carriethompson@txstate.edu

James Tolan
Texas Parks and Wildlife Department (TPWD), Coastal Fisheries Biologist
James.tolan@tpwd.texas.gov

Evan Turner
Texas Water Development Board (TWDB) – Surface Water-Coastal Science, Coastal Scientist
Evan.turner@twdb.texas.gov

Jennifer Walker
    Texas Living Waters Project
    National Wildlife Federation, Deputy Director
    Colorado, Lavaca, Matagorda BBASC
    walkerj@nwf.org

Emily Warren
    Cynthia and George Mitchell Foundation, Land Conservation and Water Program Officer
    ewarren@cgmf.org

Janet Weaver
    Lavaca Bay Foundation, Vice President/Treasurer
    info@lavacabay.org

David Yoskowitz
    Texas A&M University-Corpus Christi – Harte Research Institute, Senior Executive Director & Socioeconomics Endowed Chair
    David.yoskowitz@tamucc.edu