



Photo credit: TNC, Brazos Wood Preserve, www.nature.org, ©Jaqueline Ferrato

BRAZOS RIVER ENVIRONMENTAL FLOWS WORKSHOP SUMMARY REPORT

Sustainable Rivers Program, 2024

Allen, D.¹, Whelan, M.¹, Smith, R.², and Winterringer, B.²
¹U.S. Army Corp of Engineers; ²The Nature Conservancy



US Army Corps
of Engineers®



Executive Summary

The Fort Worth District of the United States Army Corps of Engineers (USACE), in partnership with The Nature Conservancy (TNC), hosted an environmental flows (e-flows) workshop in Waco, Texas, as part of the Sustainable Rivers Program (SRP). The workshop was held 16-17 November 2023 and aimed to evaluate opportunities for ecological benefit derived from changes to dam operations in the lower portion of the flood pool at several USACE reservoirs (Proctor Lake, Belton Lake, Stillhouse Hollow Lake, Lake Georgetown, Granger Lake, and Somerville Lake). The goal of the workshop was to identify flood pool release scenarios that could benefit ecological targets of interest to basin stakeholders and project partners. The purpose of the SRP effort is not to develop new environmental flow standards or other flow requirements or water rights conditions, but to make recommendations for how flood pool releases, when available, might be used to benefit downstream river reaches.

Flow recommendations were produced in partnership with experts that work in service of the Brazos River. USACE and TNC convened experts within the basin with local knowledge of fishes, mussels, and floodplains, as well as water quality and water management. Stakeholders and partners present at the workshop included Baylor University, Berg Oliver Associates, Brazos River Authority, Dow Chemical, GDS Associates, Lower Brazos Riverwatch, Natural Resource Conservation Service, Southwestern Power Administration, Texas Parks and Wildlife Department, Texas Water Development Board, University of Texas – Arlington, U.S. Fish and Wildlife Service, and staff from USACE Water Management, Operations, and Regulatory Offices.

Flow recommendations for multiple life history elements of three target groups (fishes, mussels, and riparian/floodplains) were constructed and then unified to derive flood pool flow recommendations that were based on existing information (e.g., SB3 Brazos Bay and Basin Expert Science Team [BBEST] recommended flow regimes, Senate Bill 2 studies, and hydrology analysis from the Environmental Flow Informational Toolkit [EFIT]) (Table 1). The information and results presented in this report consolidate the recommended flows for flow components (i.e., high flows, base flows, subsistence flows), indicate the recommended timeline for the recommendation by flow component by time of year, and note the ecological basis from which they were developed by the three target groups.

The next steps will be simulating flows recommended in this workshop through modeling. Modeling results will be used to test flows and associated environmental responses with the overall goal of implementing recommended flows to benefit fish, mussel, and/or tree populations. Flow recommendations that have the most benefit will be recommended in future Water Control Manual flood control operations updates for respective dams.

Table 1. Summary of e-flows workshop ecological targets per USACE dam, with reference to pertinent USGS gage data and flow frameworks applied in the Brazos River Basin.

USACE DAM:	Proctor	Stillhouse & Belton	Stillhouse, Belton, & Granger	Georgetown	Granger	Somerville
<i>USGS Gage Referenced</i>	<i>Leon R. (Gatesville)</i>	<i>Little R. (Little R.)</i>	<i>Little R. (Cameron)</i>	<i>San Gabriel R. (Georgetown)</i>	<i>San Gabriel R. (Laneport)</i>	<i>Yegua Crk. (Somerville)</i>
<i>Flow Framework ¹</i>	<i>EFIT, Temp.</i>	<i>BBEST</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT, Temp.</i>
Fish	Broadcast Spawners, Freshwater Drum, White Bass, Alligator Gar, American Eel					
Mussels	Geomorphic Processes, Host Access, Subsistence, Mussel Spawn/Brooding, Glochidia Release					
Riparian/ Floodplain	Box Elder, Green Ash, Black Willow, Sapling Support Flows					

¹ Flow recommendations included established flow regulations (e.g., Environmental Flow Informational Toolkit [EFIT], Brazos Bay and Basin Expert Science Team [BBEST], or temperature data [Temp.].

CONTENTS

Executive Summary.....	ii
1.0 Introduction	6
Background	6
Study Area.....	7
Background: Flow-Ecology and Existing Environmental Flows Information.....	9
2.0 Environmental Flow Workshop.....	9
Fish.....	12
Mussels	13
Riparian/Floodplains	14
3.0 Flow Recommendations	15
4.0 Opportunities.....	18
5.0 Next Steps	19
6.0 References	21

FIGURES

Figure 1. Status of rivers engaged in the Sustainable Rivers Program at end of FY 2023.	6
Figure 2. Brazos River watershed and workshop focus reaches.....	8
Figure 3. Brazos River flow schematic and highlighted focus reaches discussed in the workshop.....	8
Figure 4. Observed flow in blue and natural flow in green.....	11
Figure 5. Recommended e-flows for mussels, Little River near Cameron, average year (natural flows in pink, USGS gaged flows at Cameron in black, flow recommendations in green).	14

TABLES

Table 1. Summary of e-flows workshop ecological targets per USACE dam, with reference to pertinent USGS gage data and flow frameworks applied in the Brazos River Basin.	iii
Table 2. Summary of e-flows workshop ecological targets per USACE dam, with reference to pertinent USGS gage data and flow frameworks.....	7
Table 3. Summary of USGS gages and fish species and guilds for which environmental flow recommendations were developed.....	8
Table 4. Summary of USGS gages and mussel life history support needs for which environmental flow recommendations were developed.....	9
Table 5. Summary of USGS gages and riparian/floodplain support needs for which environmental flow recommendations were developed.....	11
Table 6. Timeline of flow pulses recommended for ecological functions for riparian (black), fish (dark grey), and mussels (light grey).....	18
Table 7. Ecological flow targets for the Little River near Cameron and their functions for fishes, mussels and riparian/floodplains. Flow numbers are based on BBEST flow regime recommendations. ...	18
Table 8. Potential reservoir-specific opportunities for deriving ecological benefit from lower flood pool operational changes.....	18

APPENDICES

Appendix A. Workshop Participants

Appendix B. Workshop Agenda

Appendix C: E-Flows Workshop E-flow/Pulse Ideal Recommendation Tables

Table C1. Leon River at Gatesville (BBEST) e-flow/pulse ideal recommendations

Table C2. Little River near Little River (BBEST) e-flow/pulse ideal recommendations

Table C3. San Gabriel River near Georgetown (EFIT) e-flow/pulse ideal recommendations

Table C4. San Gabriel River at Laneport (EFIT) e-flow/pulse ideal recommendations

Table C5. Little River near Cameron (BBEST) e-flow/pulse ideal recommendations

Table C6. Yegua Creek near Somerville (EFIT) e-flow/pulse ideal recommendations

Appendix D: Breakout Group Notes and Tables Summarizing Basis for Flow Recommendations

Table D1. Unification table, environmental flows for the Leon River at Gatesville

Table D2. Unification table, environmental flows for the Little River near Little River

Table D3. Unification table, environmental flows for the San Gabriel River near Georgetown

Table D4. Unification table, environmental flows for the San Gabriel River at Laneport

Table D5. Unification table, environmental flows for the Little River near Cameron

Table D6. Unification table, environmental flows for Yegua Creek nr Somerville

Appendix E: SRP Flow Proposal Forms

1.0 Introduction

The Sustainable Rivers Program (SRP) is a national partnership between the U.S. Army Corps of Engineers (USACE) and The Nature Conservancy (TNC). The mission of SRP is to improve the health and life of rivers by changing dam operations to restore and protect ecosystems, while maintaining or enhancing authorized uses and other project benefits. SRP began in 1998 with an initial collaboration to improve the ecological condition of the Green River in Kentucky. The program was formally established in 2002 and involved 8 river systems. At the end of Fiscal Year (FY) 2023, SRP involved work in 26 USACE Districts and 7 Divisions. Individual projects affect 90+ USACE reservoirs in 45 river systems affecting approximately 12,183 river miles (Figure 1). SRP is the largest scale and most comprehensive program for implementing environmental flows (e-flows) below USACE reservoirs and is growing.



Sustainable Rivers Program (Site Status - Advance - Implement - Incorporate - 2023)

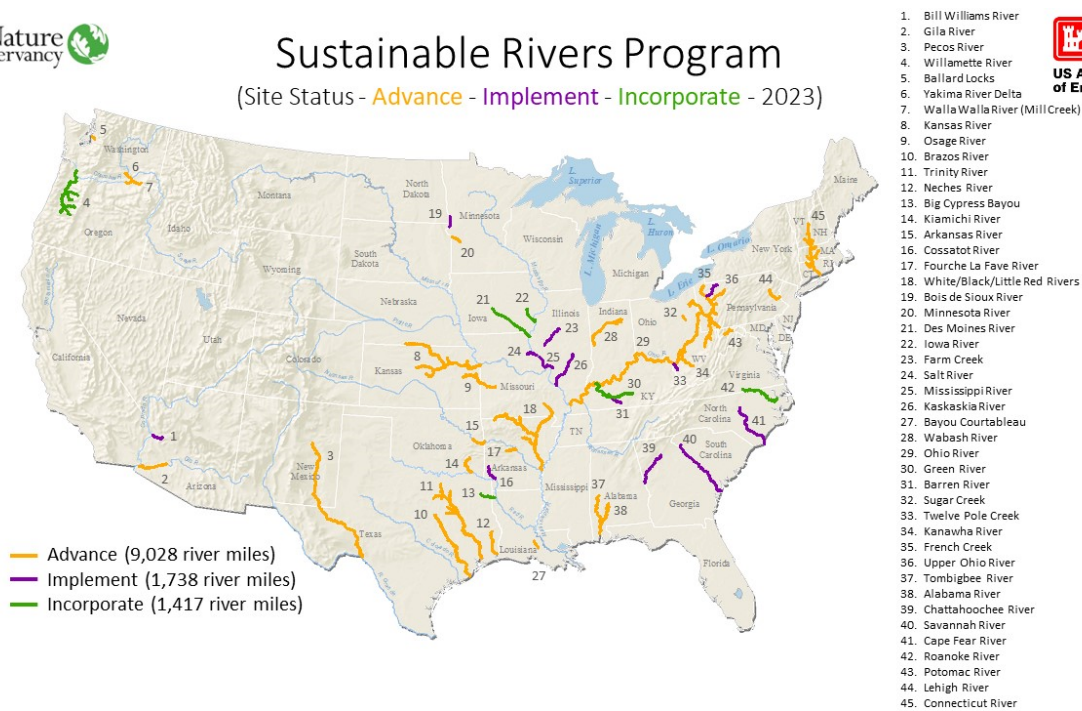


Figure 1. Status of rivers engaged in the Sustainable Rivers Program at end of FY 2023.

Background

The USACE Fort Worth District (SWF) has been a leader in the SRP, with the Big Cypress Bayou/Caddo Lake being one of the original SRP sites (No. 13 in Figure 1). The work has been successful in this location, with the adoption of flow recommendations into the Water Control Manual for Lake O’ the Pines. More recently, a regional workshop convened to evaluate environmental opportunities at other USACE facilities. One of the outcomes of that regional workshop was identifying three potential river systems in Texas: the Brazos, Lower Neches, and Trinity rivers.

In 2021 SWF and TNC coordinated a workshop with the Brazos River Authority (BRA), natural resource agencies, academia, and other scientific experts and environmental practitioners to evaluate interest in pursuing SRP in the Brazos Basin and to identify ecosystem opportunities. The workshop on September 8, 2021, confirmed partner interest in exploring the SRP process in the basin. An e-flows workshop to

explore flood pool flow recommendations in the Brazos River was held 16-17 November 2023. This report presents the results of the November 2023 e-flows workshop.

Study Area

The headwaters of the Brazos River begin near the Texas-New Mexico border, north and west of Lubbock, Texas, and flow 1,280 miles to the Gulf of Mexico near the city of Freeport. The Brazos River basin encompasses approximately 16-percent of the land area of Texas, including all or part of 70 counties, stretching across more than 42,000 square miles. The Brazos River begins at the confluence of the Salt Fork and Double Mountain Fork and major tributaries include the Clear Fork of the Brazos, the Paluxy River, the Bosque River, the Little River, Yegua Creek, the Nolan River, the Leon River, the San Gabriel River, the Lampasas River, and the Navasota River. The study area this workshop focused on was the Little River and Yagua Creek areas containing six USACE-owned dams and their associated reservoirs: Proctor Lake, Belton Lake, Stillhouse Hollows Lake, Lake Georgetown, Granger Lake, and Somerville Lake (Figure 2). Whitney Lake, Aquilla Lake, and Waco Lake are USACE lakes but were excluded from this study. The multipurpose uses of the USACE reservoirs include flood control, water supply, and recreation. Each reservoir is guided by a project specific Water Control Manual to ensure project compliance with congressionally approved operating purposes.

The Brazos River supports many endangered and threatened fishes, salamanders, and mussels and a robust recreational fishery. Near the Gulf of Mexico, the river passes through bottomland hardwood systems in, the MidCoast National Wildlife Refuge (NWR) Complex, Justin Hurst Wildlife Management Area (WMA), the Nannie M. Stringfellow WMA, and Brazos Bend State Park. Potential implementation of flood operations flow recommendations derived during the workshop could benefit these areas as well as aquatic, floodplain, and riparian habitats throughout the basin.

The focus area of the workshop (green area in Figure 2) includes the Leon River from the outflow of Proctor Lake to Belton Lake, the San Gabriel River from the outflow of Lake Georgetown to the Little River, the entire Little River, and Yegua Creek from the outflow of Somerville Lake to its confluence with the Brazos River. We prioritized these areas of the basin for the first phase of the project in response to the 2021 workshop, which highlighted the Little River and tributaries as areas of environmental interest and because opportunities may exist for operational changes leading to environmental benefits. The other USACE reservoirs in the Brazos Basin may be studied at a later date.

Figure 3 shows the focus reaches and respective reservoirs. The hydraulic connectivity of the Brazos River system is an important factor for the ecological targets of each focus reach and for developing recommendations that have potential for implementation.

USACE Operations

The general operations of USACE reservoirs on the Brazos are to release water out of the upper 90% of the flood pool if downstream has capacity for more flow while still maintaining the authorized purpose of flood control. For example, when the flood pool is full or nearly full and rising, releases are typically raised to near the max safe release for the dam (i.e., to protect the structure of the dam). In the lower 10% of the flood pool, releases are tapered to smoothly transition to water supply releases from the conservation pool. Water supply releases occur from the conservation pool and are generally initiated by BRA and then communicated to USACE Water Management to make the release.

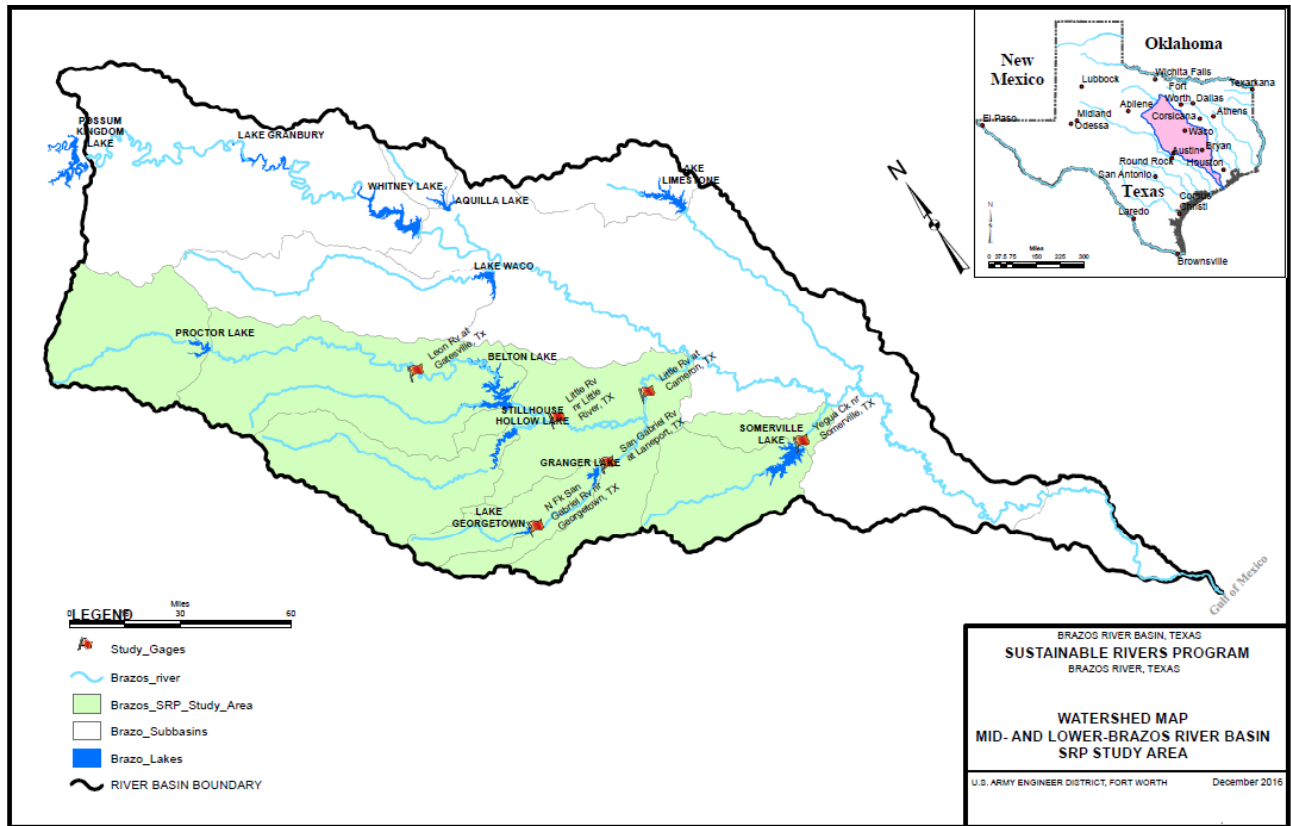


Figure 2. Brazos River watershed and workshop focus reaches.

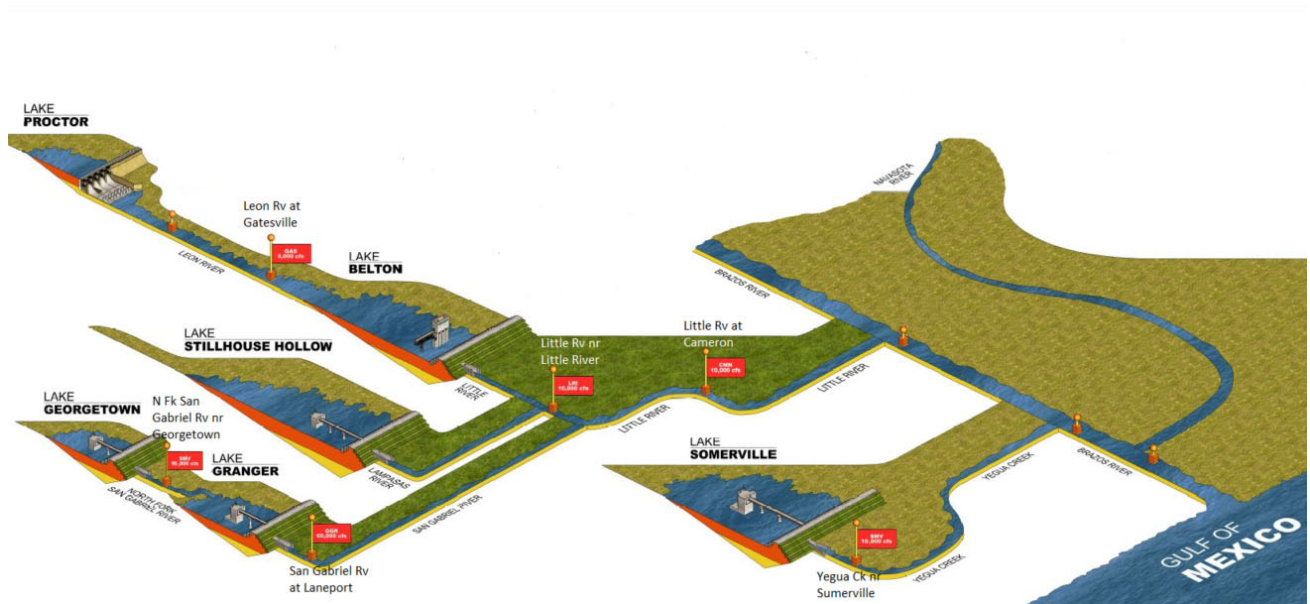


Figure 3. Brazos River flow schematic and highlighted focus reaches discussed in the workshop.

Background: Flow-Ecology and Existing Environmental Flows Information

The goal of the SRP in the Brazos River Basin is to evaluate opportunities for changes to USACE dam operations to benefit downstream ecological conditions. Ecological goals of such flows should be informed by existing information on flow-ecology relationships and existing environmental flow studies and assessments. The Brazos River Basin has been the subject of numerous studies of instream flows, flow-ecology and definition of environmental flow targets and standards. Senate Bill 3 (SB3) in 2007 created a process that established environmental flow standards in most river basins across Texas, including the Brazos River Basin (Brazos BBEST, 2012, Brazos BBASC 2012). As part of this process, the Brazos Bay and Basin Expert Science Team (BBEST) developed “environmental flow analyses and environmental flow recommendations using best available science” within the Brazos River Basin. Subsequently, the Bay and Basin Stakeholder Group developed recommended flow standards, and the Texas Commission on Environmental Quality (TCEQ) adopted final flow standards for several locations in the basin (TCEQ 2014).

The goal of the SRP process is not to revisit existing flow standards, permit conditions, or other flow requirements, or to create new standards, but to simply use existing science to inform our assessment of potential for ecological benefit of voluntary USACE operations in the lower end of the reservoir flood pools (e.g., supplementing flows, when needed in a reach, with temporarily stored flood waters). As such, we chose to use the BBEST recommendations as an initial quantitative basis for defining ecological goals below USACE dams because they reflected the scientific consensus on flow regimes that would maintain a sound ecological environment. BBEST flow regime recommendations define multiple components of an ecological flow regime: subsistence flows; base (for dry, average, and wet years) flows; and seasonal and annual high flow pulses (TIFP 2008). E-flow statistics developed by the BBEST were developed using historical pre-reservoir streamflow. The subsistence flows represent Q95 conditions. The BBEST recommendations were passed along to the Brazos Bay and Basin Area Stakeholder Committee which then tried to balance environmental needs with human needs.

Studies and flow recommendations from the Senate Bill 2 (SB2) study of the Brazos River by the Texas Instream Flows Program were also utilized during the workshop for a subset of locations. In addition, subject matters experts from Texas Parks and Wildlife Department (TPWD) and Texas Water Development Board (TWDB) used published literature and other relevant information to create flow-ecology relationships. At a subset of our study locations where there was no BBEST or SB2 data available, information from TPWD’s Environmental Flow Informational Toolkit (EFIT) data (TPWD 2024) was used as the initial quantification of flow regime components for discussion at the workshop. EFIT was developed by TPWD and partners to inform environmental flow strategies across Texas and provides environmental flows information and data for many river gages across the state. This information included target flow regimes defined using similar methods and the same statistical software as the BBEST (i.e., Hydrology Based Environmental Flow Regime [HEFR], Opdyke et al., 2014).

2.0 Environmental Flow Workshop

The Brazos River SRP E-flows workshop was held at the BRA – Central Office in Waco, Texas, November 16 – 17, 2023. There were three goals of the workshop which are listed below.

Goal 1. Review existing information on flow-ecology and flow recommendations in rivers and streams below USACE dams in the focus area.

Goal 2. Define environmental flow opportunities for the Brazos River and tributaries below USACE reservoir by evaluating information on dam operations and opportunities for ecological benefit derived from changes to operations in the lower portion of the flood pool the USACE reservoirs.

Goal 3. Identify flow release scenarios for further modeling to frame out flow experiments to be evaluated using ecological and other monitoring.

The workshop was a collaboration with environmental experts that work on the Brazos River including BRA, USACE, and other stakeholders to determine idealized outflows from these dams that could help fish, mussels, and floodplain habitats. The workshop had 37 attendees from USACE, TNC, BRA, Dow Chemical, GDS Associates, Lower Brazos Riverwatch, Natural Resource Conservation Service (NRCS), Southwestern Power Administration (SWPA), TPWD, TWDB, University of Texas - Arlington, and U. S. Fish and Wildlife Service (USFWS). The workshop included technical presentations by USACE, TNC, and BRA. A list of participants and their organizations is provided in Appendix A. The agenda is provided in Appendix B.

Breakout groups for fish, mussels, and riparian/floodplains discussed flow needs for fish, mussels, and riparian/floodplains in the six focus reaches: Leon River (one reach), Little River (two reaches), San Gabriel River (two reaches), and Yegua Creek (one reach) (Figure 3). Objectives put to each breakout group were:

1. Examine e-flow relationships – review existing information on environmental flow recommendations and standards (e.g., Senate Bill 3) and their sufficiency in representing ecological/etc. needs for the group’s focal area.
2. Examine e-flow releases – using the ecological flow relationships and any additional information derived from day 1 as well as operational information, define potential flow release modifications (e.g., flow pulses, hold water longer to enhance baseflows) from the flood pool for downstream ecological (and other) benefit.

The Regime Prescription tool (RPT; software made by the Hydrologic Engineering Center <http://www.hec.usace.army.mil/software/hec-rpt/>) was used to quickly plot flow recommendations against existing flow regimes and recorded gage flow. We used RPT in the workshop to visualize potential components of a flow regime recommendation and to capture information on magnitude, timing, duration, and volume of flows along with ecological benefits of the flow components. The recorded gage flow represented the observed streamflow for the reaches and the unregulated streamflow was developed by calculating changes in storage to equivalent flows and adding that to observed downstream flows accordingly, and these flows represent the “natural” predicted streamflow as if the dams were never built. In other words, natural stream flow is a calculation of what the flow would be if the dams were not there per the following equation:

$$\text{Natural Streamflow (cfs)} = \text{Observed Streamflow (cfs)} + \frac{\text{upstream reservoir daily storage change (ac-ft/day)}}{1.983 \text{ (ac-ft per cfs)}}$$

Observed and predicted streamflow data were used in RPT to inform environmental flow recommendations along with the BBEST flows and EFIT flows (where BBEST flows were unavailable) (Table 2).

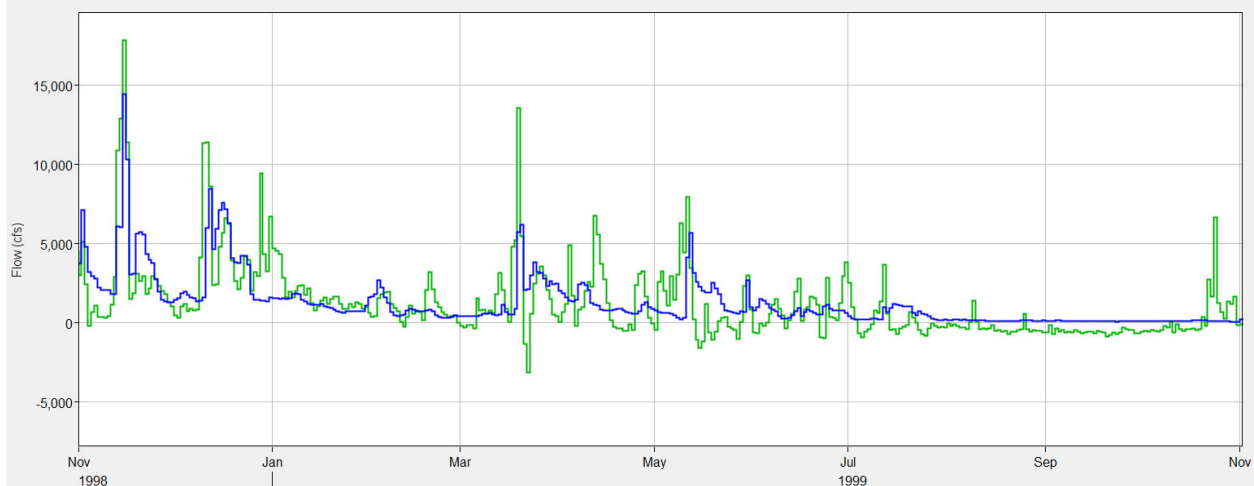


Figure 4. Observed flow in blue and natural flow in green.

Table 2. Summary of e-flows workshop ecological targets per USACE dam, with reference to pertinent USGS gage data and flow frameworks.

USACE DAM:	Proctor	Stillhouse & Belton	Stillhouse, Belton, & Granger	Georgetown	Granger	Somerville
USGS Gage Referenced	Leon R. (Gatesville)	Little R. (Little R.)	Little R. (Cameron)	San Gabriel R. (Georgetown)	San Gabriel R. (Laneport)	Yegua Crk. (Somerville)
Flow Framework ¹	EFIT, Temp.	BBEST	EFIT	EFIT	EFIT	EFIT, Temp.
Fish	Broadcast Spawners, Freshwater Drum, White Bass, Alligator Gar, American Eel					
Mussels	Geomorphic Processes, Host Access, Subsistence, Mussel Spawn/Brooding, Glochidia Release					
Riparian/ Floodplain	Box Elder, Green Ash, Black Willow, Sapling Support Flows					

¹ Flow recommendations included established flow regulations (e.g., Environmental Flow Informational Toolkit [EFIT], Brazos Bay and Basin Expert Science Team [BBEST], or temperature data [Temp.].

The flow components evaluated for each focus reach recommendation included overbank flows, high flow pulses, base flows, and subsistence flows. The breakout groups discussed overbank flows in the context of their ecological and geomorphological importance as a component of the flow regime. However, overbank flows (i.e., floods) will not be intentionally initiated or included as components of recommended SRP flows. Episodic high flow pulses (below flood conditions) provide important functions above base or subsistence flows and opportunities to release pulses may exist when water storage conditions are sufficient. Base and subsistence flows provide the foundation of the flow regime across different hydrologic conditions (i.e., drought, dry, average, or wet years) and provide the ecological benefit of regular flows for an entire season. Subsistence flows are those needed to sustain minimal environmental conditions supporting ecological targets (i.e., mussels in summer during extreme drought).

Each break-out groups' goals and discussion topics for their interest area are described below.

Fish

The goal of the fish group was to identify flow dependencies for fish and to quantify, as best as possible, flow recommendations to restore or maintain these flow dependencies. The group worked with flow-ecology relationship information from TPWD and TWDB and observational data from experts familiar with fisheries in the basin. Water temperature was an important variable discussed in the fish group. Data on flows needed to maintain minimum temperature thresholds were available from TPWD for a subset of gages and were utilized for recommendations at two locations (Leon River at Gatesville and Yegua Creek at Somerville). Flow recommendations from the SB3 BBEST, where available, and the HEFR tables in EFIT for other Brazos River basin gages were referenced and applied, where appropriate. The group weighed the following in defining recommendations:

- building recommendations based on BBEST and/or HEFR versus a new recommendation, and to what level and extent BBEST and EFIT recommendations address flows defined in group session;
- prioritization of when pulses have the most reasonable influence (i.e., recommendations for pulses in dry years versus holding water as long as possible to reserve volume for subsistence or dry base flows); and lastly,
- to what extent reservoir operations should be considered when defining recommendations. Focal species and guilds were broadcast spawning minnows, freshwater drum, white bass, alligator gar, and American eel (Table 3). Despite limited collection records, alligator gar were discussed as they may occur in very small numbers in the lowermost portion of Little River.

For all the focal fish species and guilds, flow recommendations included subsistence flows; base flows for the relevant hydrologic condition (dry, average, or wet year); high flow pulses in reproductive period, which ranges from early spring to late summer, depending on the species/guild; and overbank flows. The group identified flow-dependent fish species or guilds for which recommended flows are needed, and the flow component that these fish depend on (i.e., subsistence flow, base flow, high flow pulses, and/or overbank flows). Available information to quantify target flow magnitude, duration, and timing was used to define the nature of the flow-dependence and to justify the recommendation.

Table 3. Summary of USGS gages and fish species and guilds for which environmental flow recommendations were developed.

USACE DAM:	Proctor	Stillhouse & Belton	Stillhouse, Belton, & Granger	Georgetown	Granger	Somerville
<i>USGS Gage Referenced</i>	<i>Leon R. (Gatesville)</i>	<i>Little R. (Little R.)</i>	<i>Little R. (Cameron)</i>	<i>San Gabriel R. (Georgetown)</i>	<i>San Gabriel R. (Laneport)</i>	<i>Yegua Crk. (Somerville)</i>
<i>Flow Framework¹</i>	<i>EFIT, Temp.</i>	<i>BBEST</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT, Temp.</i>
Fishes						
<i>Broadcast Spawners</i>	x	x	x	x	x	x
<i>Freshwater Drum</i>	x	x	x	x	x	x
<i>White Bass</i>	x	x	x	x		
<i>Alligator Gar</i>			x			
<i>American Eel</i>		x	x		x	

¹ Flow recommendations included established flow regulations (e.g., Environmental Flow Informational Toolkit [EFIT], Brazos Bay and Basin Expert Science Team [BBEST], or temperature data [Temp.].

Mussels

The goal of the mussel break-out group was to identify flow dependencies for mussels and to quantify, as best as possible, flow recommendations to restore or maintain these flow dependencies. Available flow-ecology relationship information and thermal tolerance data from TPWD and TWDB were used to develop recommendations. Additionally, the mussel group worked from existing flow frameworks (i.e., SB3, BBEST, where available, or the HEFR tables in EFIT). The mussel group aimed to:

1. Identify flow-dependent and interrelated dependencies of habitat and water quality (i.e., temperature, dissolved oxygen) to mussels;
2. Identify flow components important to mussel life history needs (i.e., subsistence flow, base flow and/or high flow pulses); and
3. Apply available information to quantify target flow magnitude, duration, and timing.

Flow recommendations were developed for mussels, collectively, rather than per species-specific needs (i.e., flow needs for a fish host) (Table 4). The mussel breakout group discussed distribution, biology, and fish hosts of Texas state listed species (Balcones spike [*Fusconaia iheringi*], the Brazos heelsplitter [*Potamilus streckersoni*], and the Texas Fawnsfoot [*Truncilla macrodon*]); however, flow recommendations did not target individual species. Much of the available information and focus of benefits of flow modifications/components centered on mussel bed maintenance (habitat, recruitment potential) and thermal tolerances of mussels. Per TPWD, “Much of the (TPWD, others) work related to flow ecology of freshwater mussels in Texas involves water temperature. Higher temperatures associated with lower flows can be lethal to freshwater mussels and other aquatic organisms.”

Table 4. Summary of USGS gages and mussel life history support needs for which environmental flow recommendations were developed.

USACE DAM:	Proctor	Stillhouse & Belton	Stillhouse, Belton, & Granger	Georgetown	Granger	Somerville
<i>USGS Gage Referenced</i>	<i>Leon R. (Gatesville)</i>	<i>Little R. (Little R.)</i>	<i>Little R. (Cameron)</i>	<i>San Gabriel R. (Georgetown)</i>	<i>San Gabriel R. (Laneport)</i>	<i>Yegua Crk. (Somerville)</i>
<i>Flow Framework¹</i>	<i>EFIT, Temp.</i>	<i>BBEST</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT, Temp.</i>
Mussels²						
<i>Geomorphic Processes</i>	x	x	x	x	x	x
<i>Host Access</i>	x	x	x	x	x	x
<i>Subsistence</i>	x	x		x	x	x
<i>Mussel Spawn</i>					x	
<i>Glochidia Release</i>					x	
<i>Mussel Brooding</i>					x	
<i>Mussel Habitat</i>					x	

¹ Flow recommendations included established flow regulations (e.g., Environmental Flow Informational Toolkit [EFIT], Brazos Bay and Basin Expert Science Team [BBEST], or temperature data [Temp.].

² Mussel life history needs were discussed for the Granger Dam reach (San Gabriel River) only and the group deemed those ecological indicators were addressed through geomorphic processes, host access, and subsistence flow needs.

During the HEC-RPT exercise (Figure 4), the following topics regarding mussels were discussed to identify possible e-flow opportunities and flow components for mussels in the focus reaches:

1. How can we improve geomorphic processes (e.g., flushing of fine sediments from mussel beds) during wet and average years?
2. How can we improve mussel persistence (bed maintenance, recruitment, and community establishment) through host access (frequency and availability) and habitat forming/maintaining flows in opportunistic times in wet and average years?
3. Flows focused on temperature thresholds during average and dry years.

Experts were asked to consider the life history needs of mussels within each reach throughout the year. Flow components were discussed respective to mussels and included benefits for geomorphic processes, glochidia release timeframes, fish host access, mussel brooding timeframes, mussel habitat, mussel spawning windows, and mussel subsistence. The group ultimately focused on identifying flow recommendations for geomorphic processes and host access due to temporal overlap and shared flow purposes amongst the components during a given year. For example, flows to support fish host access to mussels during glochidia release time periods (i.e., where/when pulses would be key for drum to access mussel beds when mussels are releasing June through November) overlapped with brooding of other species that would benefit from flows to maintain mussel habitat and/or flush fine sediments, which would be beneficial for all mussel life history components.

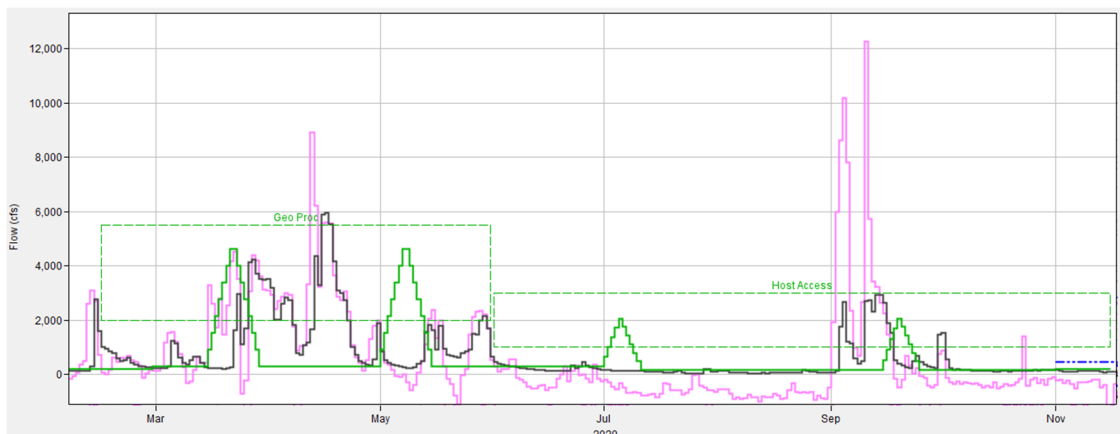


Figure 5. Recommended e-flows for mussels, Little River near Cameron, average year (natural flows in pink, USGS gaged flows at Cameron in black, flow recommendations in green).

Riparian/Floodplains

TWDB provided floodplain data for two gages, Leon River at Gatesville and Little River near Cameron, from the Instream Flows Research and Validation Methodology Framework and Brazos Estuary Characterization Report (Bonner et al., 2015) (Table 5). Discussion on riparian flow needs focused primarily on trees within the riparian areas.

The riparian/floodplains group identified that e-flows would be most beneficial when trees that are dropping seeds. For example, a targeted e-flow in the spring followed by another pulse (of timing and magnitude) to maintain or wet the soil to sustain saplings in the drier months of summer would greatly improve riparian/floodplains condition. The group identified specific inundation needs for several tree

species and flow needs to support recruitment success (sapling stages) (Table 5). The riparian/floodplain group relied on information and data from Bonner et al. (2015) and TCEQ flow standards in developing e-flow recommendations for the focus reaches.

Table 5. Summary of USGS gages and riparian/floodplain support needs for which environmental flow recommendations were developed.

USACE DAM:	Proctor	Stillhouse & Belton	Stillhouse, Belton, & Granger	Georgetown	Granger	Somerville
<i>USGS Gage Referenced</i>	<i>Leon R. (Gatesville)</i>	<i>Little R. (Little R.)</i>	<i>Little R. (Cameron)</i>	<i>San Gabriel R. (Georgetown)</i>	<i>San Gabriel R. (Laneport)</i>	<i>Yegua Crk. (Somerville)</i>
<i>Flow Framework ¹</i>	<i>EFIT, Temp.</i>	<i>BBEST</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT</i>	<i>EFIT, Temp.</i>
Riparian/Floodplain						
<i>Box Elder</i>	x		x			
<i>Green Ash</i>	x		x			
<i>Black Willow</i>			x			
<i>Sapling flow</i>	x					
<i>SB3 Spring Pulse</i>		x			x	
<i>EFIT Spring Pulse</i>				x		x

¹ Flow recommendations included established flow regulations (e.g., Environmental Flow Informational Toolkit [EFIT], Brazos Bay and Basin Expert Science Team [BBEST], or temperature data [Temp.].

3.0 Flow Recommendations

Subsequent to the break-out group sessions, the recommended flows from the three groups were compared to begin synthesizing them into a single set of recommendations for each of the six reaches (Photo 1). Flow recommendations from all three groups were combined into unified tables of flow recommendations for each focus reach considered at the workshop. These tables (presented in Appendix C, summarized in Table 6, with an example in Table 7) consolidate the recommended flow components, indicate the recommended timeline for the flow components across months, and note the ecological contexts from which they were developed by the three break-out groups. It is important to note again that the flow recommendations largely follow previous flow regimes recommended by either the Brazos BBEST or developed as part of EFIT (i.e., for gages without BBEST recommendations). Breakout group notes and more details on the justification for the flow recommendations are provided in Appendix D.

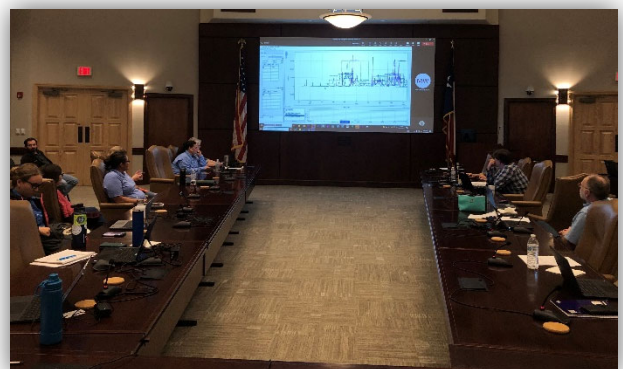


Photo 1. Brazos e-flows workshop unification and discussion, BRA Office, Waco, Texas (photo by B. Winterringer, TNC).

Table 6. Timeline of flow pulses recommended for ecological functions for riparian (black), fish (dark grey), and mussels (light grey).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Geo Process												
White Bass Run												
Box Elder												
Black Willow												
Freshwater Drum												
Riparian SB3 Pulse												
Broadcast Spawners												
Green Ash												
Alligator Gar												
Sapling flow?												
Subsistence- Mussels												
Mussel Brooding												
Mussel Habitat												
Host Access												
Glochidia Release												
American Eel												
Mussel Spawn												

While there are differences between some recommended flow components across the three groups, there were also consistencies (Table 6). These include:

- In March to May there are synergies between all of the floodplain targets, broadcast spawners, freshwater drum targeted pulses, and flows to support geomorphic processes that enable mussel life history support.
- Second, we found that two large pulses in the March to June time frame would address the spring pulse needs of broadcast spawners (these pulses were generally the largest magnitude pulse suggested). In summer, the higher priority would be holding flows for longer release attenuation for subsistence flows for mussels, but one or two pulses could further help mussels and broadcast spawners.
- Three pulses from October to January are recommended for American eel with the earliest suggested to occur in October or November, which could also provide a flow pulse to benefit mussel host access and an early geomorphic process pulse.

Ideally, under the right conditions when flood pool water is accessible, each flow recommendation summarized above could effectively be achieved and address six pulses each designed to achieve a different ecological purpose.

Table 7. Ecological flow targets for the Little River near Cameron and their functions for fishes, mussels and riparian/floodplains. Flow numbers are based on BBEST flow regime recommendations.

Season/Month	Winter				Spring				Summer							
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct				
Overbank Flows*																
Flow Rec.					29,900 cfs											
Fishes					Alligator gar. Overbank flow to access floodplains. Once every 2 years. Check on alligator gar at this gage											
*Note: Overbank Flows and High Flow Pulses shown as peak magnitudes. see RPT boxes for range of flows that meet the recommendation.																
High Flow Pulses																
Flow Rec.					19,700 cfs (32 days)				19,700 cfs (32 days)							
Riparian					Box elder (to 14,800 cfs), green ash (to 13,600). Every 5-10 years. Wet years.											
Fishes					Broadcast spawners. Bankful pulse. Once every 2 years.				Broadcast spawners. To September. Bankful pulse. Once every 2 years.							
Flow Rec.	9,550 cfs (19 days)				12,800 cfs (20 days)				4,800 cfs (14 days)							
Riparian					Black willow (to 10,700 cfs). Every 5-10 years. Wet years.											
Fishes	White bass run, American eel. 7 days. Wet years. (Team box had 12800 cfs)				Freshwater drum, broadcast spawners. 7 days. One per year.											
Mussels	Geomorphic processes. 19 days. Wet years. (Jan to May)				Geomorphic processes. 20 days. Wet years. (Mar to May)				Host access. 14 days. Wet years. (June to Nov)							
Flow Rec.	4,630 cfs (14 days)				7,500 cfs (14 days)				2,070 cfs (10 days)							
Riparian					Black willow, box elder, green ash. (meets low end of range) Every 5-10 years. Wet years.											
Fishes	American eel. 7 days. Average years. (Oct to Jan) incl *White bass run.				Broadcast spawners, freshwater drum. 7 days. One per year.											
Mussels	Geomorphic processes. 14 days. Average years. (Extend to May or Spring pulse achieves)				Geomorphic processes. 14 days. Average years. (4,630 Winter pulse extended to May)				Host access. 10 days. Average years. (June to Nov)							
Flow Rec.	1,080 cfs (7 days)				3,200 cfs (7 days)				560 cfs (14 days)							
Riparian					Black willow, box elder, green ash. (meets low end of range) Every 5-10 years. Wet years.											
Fishes	American eel. 7 days. Dry years. (Oct to Jan)				Broadcast spawners, freshwater drum. 7 days. One per year.											
Mussels					Geomorphic processes. 7 days. Dry years.				Host access. 14 days. Dry years. (June to Nov) (Team box has 4800, 2070 cfs, but these are not feasible)							
Base Flows																
Flow Rec.	460 cfs				760 cfs				330 cfs							
Fishes	Habitat condition, some oxbow access				Habitat condition, some oxbow access				Habitat condition, some oxbow access							
Mussels	Habitats, host access				Habitats, host access				Habitats, host access							
Riparian	Riparian wetting				Riparian wetting				Riparian wetting							
Flow Rec.	190 cfs				310 cfs				160 cfs							
Fishes	Habitat conditions				Habitat conditions				Habitat conditions							
Mussels	Habitats, host access				Habitats, host access				Habitats, host access							
Flow Rec.	110 cfs				140 cfs				97 cfs							
Fishes	Habitat conditions, water quality				Habitat conditions, water quality				Habitat conditions, water quality							
Mussels	Habitats, water quality				Habitats, water quality				Habitats, water quality							
Subsistence																
Flow Rec.	32 cfs				32 cfs				32 cfs							
Fishes	Habitat connectivity, water quality				Habitat connectivity, water quality				Habitat connectivity, water quality							
Mussels	Maintan mussel thermal conditions,				Maintan mussel thermal conditions,				Maintan mussel thermal conditions,							
KEY:																
<table border="1"> <tr> <td style="background-color: #d9ead3;">Wet Years</td> <td style="background-color: #f2dede;">Dry Years</td> </tr> <tr> <td style="background-color: #d9ead3;">Average Years</td> <td style="background-color: #f2dede;">Subsistence</td> </tr> </table>													Wet Years	Dry Years	Average Years	Subsistence
Wet Years	Dry Years															
Average Years	Subsistence															

4.0 Opportunities

The final portion of the workshop was a discussion of dam operations to identify opportunities for flow releases from the lower flood pools to achieve components of the combined flow recommendations. The outcome of the workshop was successful at meeting its intended goals, and specific to Goal 2, which was to define environmental flow opportunities, four opportunities emerged for three of the six focus reaches. Table 8 below lists reservoir-specific opportunities and considerations for further examination for implementation. Opportunities identified are presented as questions as the Brazos River stakeholders and USACE will need to discuss the logistics, feasibility, and willingness for implementation. These opportunities will serve as focal areas for modeling to test feasibility of environmental flows implementation.

Table 8. Potential reservoir-specific opportunities for deriving ecological benefit from lower flood pool operational changes.

Reservoir (River)	Goal	Opportunity	Considerations
Granger Lake (San Gabriel River)	1. Maintain low flows in the San Gabriel River below Granger Lake (and possibly Georgetown) for mussels in summer by keeping flows above the subsistence flow of 4 cfs.	The reservoir can be in flood pool into spring and elevated until June, during which time spring floods are being evacuated. Slow evacuation near bottom of flood pool and release low flows longer for mussels into July and beyond, if possible.	Is there a limitation from low flow gates? Minimal release may be as high as 24 cfs, which would mean facility couldn't hold it at its lowest flow for as long (at 24 cfs water may be evacuated too quickly to sustain a prolonged flow slightly above subsistence flow).
	2. Release a summer pulse of around 2,500 cfs for a variety of purposes.	Slow evacuation near the bottom of the flood pool and release a pulse in June-August. Instead of around 400 cfs for 14 days recommend a 2,500 cfs pulse?	Is it possible to modify evacuation of flood storage to release the pulse? How much volume would this require? How often is required volume available?
Lake Belton & Stillhouse Hollows Lake (Little River at Cameron)	Release a summer pulse of around 4,800 cfs for a variety of purposes.	The reservoir can be in flood pool into spring and up until June, during which time waters from spring floods are being evacuated. Slow evacuation near bottom of flood pool and release a pulse in June-August.	Need to consult stakeholders and experts to ensure that any releases do not worsen stream erosion and back sloughing. Is it possible to hit 4,800 cfs with Belton outflow? Is there a need to also include Stillhouse and Granger?
Lake Somerville (Yegua Creek)	Maintain low flows in the Yegua Creek below Lake Somerville for mussels in summer by keeping flow above the target flow of 5 cfs defined by the mussels breakout group to maintain thermal conditions.	The reservoir can be in flood pool into spring and occasionally until June, during which time spring floods are being evacuated. Slow evacuation near bottom of flood pool and release low flows longer for mussels into July and beyond, if possible.	There is a limitation related to the lake of low flow gates, with a minimal release being 90 cfs out of the flood gates. Is it okay to stay at the minimum for longer? Would more time 90 cfs help or hinder (90 cfs might mobilize the bed more)?

Reservoir (River)	Goal	Opportunity	Considerations
Any Reservoir	Tailor required flood release to meet pulses.	Required flood releases happen most frequently in spring.	<p>Could this affect flood risk or add risk to dam?</p> <p>How frequent do required flood release align with desired pulses?</p> <p>Need to consult stakeholders and experts to ensure that any releases do not worsen stream erosion and back sloughing.</p>

5.0 Next Steps

The third goal of the workshop was to identify flow release scenarios for further modeling to structure flood pool flow experiments and implementation which can be evaluated using ecological and other monitoring. Potential next steps in advancing SRP in the Brazos River Basin are described below.

Model feasibility of the environmental flow release opportunities in the Brazos River Basin. The primary next step is to utilize USACE operational models to evaluate flows for implementation. USACE proposed (SRP FY24 funding) modeling the Brazos River system in RiverWare® and run proposed e-flows and pulses over the longest period of record possible. RiverWare® is a water accounting tool which can calculate multiple lake storages in a river system. The proposed flows and pulses from the flood pool will be modeled and then compared to simulated normal USACE operations. Comparing model results for e-flows and normal operations scenarios will allow for adapting proposed e-flows recommendations, adjustments, and validating proposed e-flow recommendations. Modeling will also allow the district to ensure that proposed e-flow recommendations do not cause more frequent flooding by passing control flows or increasing the frequency of drought conditions by reducing lake storage. Modeling will identify changes in lake storage from proposed e-flow recommendations.

Lake levels and outflows for hydraulic HEC-RAS modeling. HEC-RAS (Hydrologic Engineering Center – River Analysis System) will be used to compare gage data to identify how often flood storage occurs when gages are in dry, average, or wet conditions. HEC-RAS modeling will be used for portions of produced RiverWare® lake levels and outflows to estimate river flow resulting from proposed e-flow recommendations. If needed, the entire period of record will be run through the HEC-RAS model to understand all available scenarios. The HEC-RAS produced inundation mapping will be cross-checked so that the proposed e-flow recommendations are producing the expected flows and inundations while also not exceeding or passing river control point flows.

Previous stream bank erosion studies in the Little River will be reviewed to ensure that pulses minimize stream bank erosion. If previous studies do not address this concern sufficiently, modeling be made to better understand how erosion can be minimized.

Perform HEC-EFM modeling to investigate ecological relationships. USACE will use HEC-RAS inundation results in HEC-EFM (Hydrologic Engineering Center – Ecosystem Functions Model) to evaluated e-flow recommendations developed during the e-flows workshop. HEC-EFM results will be used in HEC-RAS to

create a spatial analysis. The team may also use other ecological models or tools to evaluate benefits to other recommended e-flow components (e.g., flow-temperature models to evaluate benefits to freshwater mussels).

If modeling work by USACE supports implementation, USACE may request a deviation from normal flood operations to test a one-time pulse or multiple test pulses. Coordination with flow target experts to devise a monitoring plan(s) will occur prior to conducting test pulses to evaluate for presumed benefits. Modeling is scheduled for FY24 and FY25. If flows are implementable through normal flood control releases before modeling work is finished, monitoring could be done to evaluate presumed benefits.

In addition to next steps specific to this workshop, USACE is also engaged with other projects like FIRO (Forecast Informed Reservoir Operations) within the district and potential exists for FIRO to contribute input to capacity and limitations of usable flood storage. Additionally, the Brazos SRP Team has discussed the added benefits and coordination needs below and will evaluate these as work progresses because of this workshop.

1. Hold a second environmental flows workshop to discuss opportunities in the other USACE reservoirs in the Brazos River Basin.
2. Review environmental flow targets.
 - Review EFIT results for gages without BBEST.
 - Recommended dry base flows and subsistence flows for Yegua Creek (which were based on EFIT data) and Leon River at Gatesville may need review.
 - There is a question about whether recommendations should include pulses during dry years. Perhaps recommendations should only include small seasonal pulses.
 - Explore other partnerships related to SRP that may support a variety of conservation and management work in the basin, such as monitoring opportunities.

6.0 Selected References

Bonner, T., J. Duke, G. Guillen, K. Winemiller, BIO-WEST (2015). Instream Flows Research and Validation Methodology Framework – Brazos River and Associated Bay and Estuary System. Final Report to Texas Water Development Board. Contract #1400011722. September 24, 2015. 159 pages plus appendices.

Brazos Basin and Bay Area Expert Science Team (BBEST). 2012. Environmental Flow Regime Recommendations Report. Final Submission to the Brazos River Basin and Bay Area Stakeholder Committee, Environmental Flows Advisory Group, and the Texas Commission on Environmental Quality. https://wayback.archive-it.org/414/20210910081328/https://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/brazos_bbest_complete_document.pdf

Brazos Basin and Bay Area Stakeholder Committee (BBASC). 2012. Environmental Flow Standards and Strategies Recommendations Report. Final Submission to the Environmental Flows Advisory Group and the Texas Commission on Environmental Quality. https://wayback.archive-it.org/414/20210910081328/https://www.tceq.texas.gov/assets/public/permitting/watersupply/water_rights/eflows/brazos_bbasc_report_8_22_2012_bbasc.pdf

Opdyke, Daniel R., Edmund L. Oborny, Samuel K. Vaugh & Kevin B. Mayes (2014): Texas environmental flow standards and the hydrology-based environmental flow regime methodology, Hydrological Sciences Journal, DOI: 10.1080/02626667.2014.892600

Texas Commission on Environmental Quality (TCEQ). 2014. Adopted environmental flow standards for the Brazos River and its associated bay and estuary system. <https://wayback.archive-it.org/414/20210527224025/https://www.tceq.texas.gov/assets/public/legal/rules/rules/pdflib/298g.pdf>

Texas Instream Flow Program (TIFP). 2008. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.twdb.texas.gov/surfacewater/flows/instream/doc/R369_InstreamFlows.pdf

Texas Parks and Wildlife Department (TPWD). 2024. The Environmental Flow Information Toolkit. <https://tpwd.maps.arcgis.com/apps/dashboards/6d8e8676ee26436bad542005e7efbeb1>

Appendix A: E-Flows Workshop Attendees

<u>Name</u>	<u>Agency</u>
Cecelia Marascalco	USACE
David Byczek	USACE
Cyndy Ramos	USACE
Danny Allen	USACE
Aaron Abel	BRA
Peyton Lisenby	BRA
Michael Denny	SWPA
Cory Scanes	BRA
Jeremy Nickolai	BRA
Marty Kelly	TPWD
Carly Rotzler	TPWD
Monica Polgar	TPWD
Gloria Piazza	USACE
Jennifer Sleezer	USACE
Heath McLane	USACE
Justin Grimm	BRA
Jenna Olson	BRA
Tiffany Malzahn	BRA
Liza Parker	TNC
Ryan McManamay	Baylor University
Mark Lneders	Baylor University
David Young	TPWD
Stephen Curtis	TPWD
Clint Robertson	TPWD
Niki Ragan-Harbinson	TPWD
Matt Johnson	USFWS
Ryan Smith	TNC
Kyle Garmany	TNC
Matthew Whelan	USACE
Rheannon Hart	USACE
Becca Winterringer	TNC
Mark Wentzel	TWDB
Philip Price	BRA
Melissa Marsh	BRA
ONLINE	
Bruce Bodson	Lower Brazos Riverwatch
Glenn Lord	Dow Chemical
James Striedel	GDS Associates
Kirk Winemiller	Tx A&M
Kyle Wright	NRCS
Mike Homer	TPWD
Nolan Raphelt	TWDB
Richard Heilbrun	TPWD
Ryan King	TPWD
Susan Alford	Berg Oliver
Yu Zhang	University of Texas Arlington
Tim Finley	Dow Chemical
Courtney Sanders	BRA

Appendix B: E-Flows Workshop Agenda

Sustainable Rivers Program
Brazos River Flows Workshop
November 16-17, 2023

Workshop Goals

Identify any opportunities for environmental benefit below U.S. Army Corps of Engineers (USACE) Reservoirs in the Brazos River basin derived from changes to operations in the lower portion of the flood pool. Potential benefits to be evaluated may include helping meet existing e-flow standards/targets where they exist and/or flow targets at locations below USACE dams where e-flow standards are not defined while also not compromising conservation pool storage.

Agenda

Day 1

- 9:00 Welcome & Introductions – Jerry Cotter USACE / Tiffany Malzahn BRA / Suzanne Scott TNC
- 9:15 Review of Brazos River SRP Project and Workshop Goals – Danny Allen UASCE
- 9:30 Overview of Brazos River Operations/Hydropower – Matthew Whelan USACE
- 10:00 Introduction to Ecological/Flow Relationships – Ryan Smith TNC/Jeremy Nickolai BRA/Marty Kelly TPWD/Mark Wentzel TWDB
- 11:00 Break
- 11:10 Introduction to Regime Prescription Tool – Matthew Whelan USACE
- 11:45 Questions/Discussion
- 12:00 Lunch (1 hr)
- 1:30 Questions/Discussion
- 1:40 Description of break-out groups – Danny Allen/Ryan Smith
- 1:50 Breakout Group Sessions - Ecological Flow Relationships (see detailed Break-Out Group agenda)
- Fish (Facilitators: Ryan Smith, Marty Kelly, RPT – Rheannon Hart USACE)
- Mussels (Facilitators: Danny Allen, Clint Robertson TPWD, RPT – Becca Winterringer TNC)
- Floodplain (Facilitators: Mark Wentzel, RPT – Matthew Whelan USACE)
- 3:30 Break (15 min)
- 3:45 Break-out Groups report out (10 min per group)

4:15 Synthesis and discussion of groups' findings, similarities/differences in e-flow relationships

4:45 Outline of agenda, plan for day 2

5:00 Close Day 1

Day 2

9:00 Welcome – Ryan/Danny

9:05 Questions/Discussion/Thoughts – Ryan Smith/Danny Allen

9:20 Description of break-out groups (part 2) – Danny Allen/Ryan Smith

9:30 Breakout groups – Environmental Flow Releases (see detailed Break-Out Group agenda)

Fish

Mussels

Floodplain

(include a break at 11:00 or whenever needed)

12:00 Lunch provided by TNC

1:00 Break-out groups present findings (20 min per group)

2:00 Unification of Ecological Flow Recommendations

3:00 Break (15 min)

3:15 Discussion of operational considerations for recommended e-flow releases

4:15 Conclusion and Parting Discussion

4:30 Close Day 2

Break-Out Groups

Group Structure and Facilitation

Fishes – Facilitator: Ryan Smith, Marty Kelly, RPT – Rheannon Hart

Mussels – Facilitator: Danny Allen, Clint Robertson, RPT – Becca Winterringer

Riparian/floodplains – Facilitator: Mark Wentzel, RPT – Matthew Whelan

Break-out Session Groups Goals and Agenda

Break-out session 1 – Environmental Flow Relationships (120 min)

- Goal: review existing information on environmental flow recommendations and standards (e.g., Senate Bill 3) and their sufficiency in representing ecological/etc. needs for the group's focal area
- Introduction to the break-out session, discussion questions, what need to accomplish (5 min)
- Participant introductions (5 min)
- RPT familiarization (5 min)
- Questions/Discussion:
 - Do you have any clarification questions? (e.g., on SRP, on workshop goals)
 - Briefly review focal flow-related elements from 2021 workshop, flow-related challenges to the focal elements, and what components of the flow regime do they relate to (i.e., base flows, higher flow pulses).
 - Do the presented environmental flow standards and/or supplemental ecological flow relationships adequately represent flow needs?
 - What data gaps, additional information do we need?
- Flow components: Missing? Damaging? Priority?

Break-out session 2 – Environmental Flow Releases (from flood pool)

- Goal: using the ecological flow relationships and any additional information derived from day 1 as well as operational information, define potential flow release modifications (e.g., flow pulses, hold water longer to enhance baseflows) from the flood pool for downstream ecological (and other) benefit
- Introduction to the break-out session, discussion questions, what need to accomplish (5+ min)
- Participant introductions (if we have new participants on Day 2) (5 min)
- RPT familiarization (if we have new participants on Day 2) (5 min)
- Questions/Discussion:
 - Do you have any clarification questions?
 - What flow release modifications can we suggest to increase attainment of flow standards or meet ecological flow requirements
 - Consider operational realities
 - What research needs and data gaps are there?
 - Define operational modeling needs and future SRP proposals

Appendix C: E-Flows Workshop E-flow/Pulse Ideal Recommendation Tables

Table C1. Ecological flow targets for the Leon River at Gatesville based on BBEST flow recommendations

Table C2. Ecological flow targets for the Little River near Little River based on BBEST flow recommendations

Table C3. Ecological flow targets for the San Gabriel River near Georgetown based on flows from the Environmental Flow Informational Toolkit

Table C4. Ecological flow targets for the San Gabriel River at Laneport based on flows from the Environmental Flow Informational Toolkit

Table C5. Ecological flow targets for the Little River near Cameron based on BBEST flow recommendations

Table C6. Ecological flow targets for Yegua Creek near Somerville based on flows from the Environmental Flow Informational Toolkit

Table C1. E-flow targets formulated during workshop for the Leon River at Gatesville. Magnitudes and durations based on BBEST flows.

Season/Month	Winter				Spring				Summer			
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Overbank Flows*												
<i>Flow Rec.</i>					7,580 cfs (39 days)				7,580 cfs (39 days)			
Fishes					Broadcast spawners. Bankful pulse. Once every 2 years.				Broadcast spawners. To September. Bankful pulse. Once every 2 years.			
<small>*Note: Overbank Flows and High Flow Pulses shown as peak magnitudes. See RPT boxes for range of flows that meet the recommendation.</small>												
High Flow Pulses												
<i>Flow Rec.</i>					5,300 (33 days)				5,300 (33 days)			
Fishes					Broadcast spawners, freshwater drum. 33 days. Once per year.				Broadcast spawners, freshwater drum. 33 days. Once per year.			
Riparian					Riparian trees-box elder (2600 to 3700, Mar-May), green ash (2600 to 3700, Apr-May), saplings (May-July). 23 days. Every 5-10 years. Wet years.							
<i>Flow Rec.</i>	280 cfs (10 days)				1,390 cfs (18 days)				340 cfs (7 days)			
Fishes	White bass run. 7 days. Wet years. (Note: team box had this as 630 cfs. May need to make this a higher tier or increase to 630 here)				Broadcast spawners, freshwater drum. Bankful pulse. One per year.							
Mussels	Geomorphic processes. 10 days. Wet years. (Extend to May or Spring pulse achieves)				Geomorphic processes. 18 days. Wet years. (Winter pulse extended to May)				Host access. 7 days. Wet years. (June to Nov) (Note: team box has 1'000 cfs, but this magnitude is not feasible, BBEST pulse kept)			
<i>Flow Rec.</i>	100 cfs (7 days)				630 cfs (7 days)				140 cfs (7 days)			
Fishes	White bass run. 7 days. (Note: team box had 630 cfs for Winter also)				Broadcast spawners, freshwater drum. 7 days. One per year.							
Mussels	Geomorphic processes. 6 days. Average years. (Extend to May or Spring pulse achieves)				Geomorphic processes. 6 days. Average years. (100 Winter pulse extended to May)				Host access. 7 days. Average years. (June to Nov)			
<i>Flow Rec.</i>	340 cfs (10 days)				340 cfs (10 days)				58 cfs (7 days)			
Mussels	Geomorphic processes. 10 days. Dry years. (Spring pulse back to Jan, no BBEST Winter pulse)				Geomorphic processes. 10 days. Dry years.				Host access. 7 days. Dry years. (June to Nov)			
Base Flows												
<i>Flow Rec.</i>	52 cfs				54 cfs				27 cfs			
Fishes	Habitat condition, some oxbow access				Habitat condition, some oxbow access				Habitat condition, some oxbow access			
Mussels	Habitats, host access				Habitats, host access				Habitats, host access			
Riparian	Riparian wetting				Riparian wetting				Riparian wetting			
<i>Flow Rec.</i>	20 cfs				24 cfs				12 cfs			
Fishes	Habitat conditions				Habitat conditions				Habitat conditions			
Mussels	Habitats, host access				Habitats, host access				Habitats, host access			
<i>Flow Rec.</i>	9 cfs				10 cfs				5 cfs			
Fishes	Habitat conditions, water quality				Habitat conditions, water quality				Habitat conditions, water quality			
Mussels	Habitats, water quality				Habitats, water quality				Raised from 1 to 5 cfs to maintain thermal conditions below thresholds. Maintain mussel habitats.			
Subsistence												
<i>Flow Rec.</i>	1 cfs				5 cfs				5 cfs			
Fishes	Habitat connectivity, water quality				Habitat connectivity, water quality				Habitat connectivity, water quality			
Mussels	Maintan mussel habitats.				Raised from 1 to 5 cfs to maintain thermal conditions below thresholds. Maintan mussel habitats.				Raised from 1 to 5 cfs to maintain thermal conditions below thresholds. Maintan mussel habitats.			
KEY:												
Wet Years				Dry Years								
Average Years				Subsistence								

Table C2. E-flow targets formulated during workshop for the Little River near Little River. Magnitudes and durations based on BBEST flows.

Season/Month	Winter				Spring				Summer			
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Overbank Flows*												
<i>Flow Rec.</i>					11,700 cfs (14 days)							
Fishes					Alligator gar. Overbank flow to access floodplains. Once every 2 years.							
*Note: Overbank Flows and High Flow Pulses shown as peak magnitudes. see RPT boxes for range of flows that meet the recommendation.												
High Flow Pulses												
<i>Flow Rec.</i>					8,890 cfs (32 days)				8,890 cfs (32 days)			
Fishes					Broadcast spawners, freshwater drum. Bankful pulse. Once every 2 years.				Broadcast spawners. To September. Bankful pulse. Once every 2 years.			
<i>Flow Rec.</i>	2,960 cfs (17 days)				5,310 cfs (23 days)				2,470 cfs (14 days)			
Riparian					Riparian trees. 23 days. Every 5-10 years. Average and wet years.							
Fishes	American eel. Average and wet years. White bass run. 7 days. (Team box had 5310 cfs for Winter also)				Broadcast spawners, freshwater drum. Bankful pulse. 7 days. One per year.							
Mussels	Geomorphic processes. 17 days. Wet years. (Extend to May or Spring pulse achieves)				Geomorphic processes. 23 days. Wet years. (Winter pulse extended to May)				Host access. 14 days. Wet years. (June to Nov)			
<i>Flow Rec.</i>	1,600 cfs (11 days)				3,290 cfs (17 days)				1,060 cfs (10 days)			
Riparian					Riparian trees. 17 days. Every 5-10 years. Average and wet years.							
Fishes	White bass run. 7 days. (Team box had 3290 cfs for Winter also)				Broadcast spawners, freshwater drum. 7 days. One per year.							
Mussels	Geomorphic processes. 11 days. Average years. (Extend to May or Spring pulse achieves)				Geomorphic processes. Average years. (1,600 Winter pulse extended to May)				Host access. 10 days. Average years. (June to Nov)			
<i>Flow Rec.</i>	520 cfs (7 days)				1,420 cfs (10 days)				430 cfs (10 days)			
Riparian					Riparian trees. 10 days. Every 5-10 years. Average years.							
Fishes	American eel. 7 days. Dry years.				Broadcast spawners, freshwater drum. 7 days. One per year. Dry years.							
Mussels					Geomorphic processes. 10 days. Dry years.				Host access. 10 days. Dry years. (June to Nov)			
Base Flows												
<i>Flow Rec.</i>	190 cfs				340 cfs				200 cfs			
Fishes	Habitat condition, some oxbow access				Habitat condition, some oxbow access				Habitat condition, some oxbow access			
Mussels	Habitats, host access				Habitats, host access				Habitats, host access			
Riparian	Riparian wetting				Riparian wetting				Riparian wetting			
<i>Flow Rec.</i>	110 cfs				150 cfs				120 cfs			
Fishes	Habitat conditions				Habitat conditions				Habitat conditions			
Mussels	Habitats, host access				Habitats, host access				Habitats, host access			
<i>Flow Rec.</i>	82 cfs				95 cfs				84 cfs			
Fishes	Habitat conditions, water quality				Habitat conditions, water quality				Habitat conditions, water quality			
Mussels	Habitats, water quality				Habitats, water quality				Habitats, water quality			
Subsistence												
<i>Flow Rec.</i>	55 cfs				55 cfs				55 cfs			
Fishes	Habitat connectivity, water quality				Habitat connectivity, water quality				Habitat connectivity, water quality			
Mussels	Maintan mussel habitats.				Maintain temperature below 32 threshold. Maintan mussel habitats. Balcones Spike host fish (shiners).				Maintain temperature below 32 threshold. Maintan mussel habitats. Balcones Spike host fish (shiners).			
KEY:												
			Wet Years			Dry Years						
			Average Years			Subsistence						

Table C3. E-flow targets formulated during workshop for the San Gabriel River near Georgetown. Magnitudes and durations based on BBEST flows.

Season/Month	Winter				Spring				Summer									
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct						
Overbank Flows*																		
					7,940 cfs													
Converted EFIT to BBEST framework by dropping EFIT Falls flows and extending the other three seasons to cover the appropriate months.																		
*Note: Overbank Flows and High Flow Pulses shown as peak magnitudes. See RPT boxes for range of flows that meet the recommendation.																		
High Flow Pulses																		
<i>Flow Rec.</i>					5,060 cfs				5,060 cfs									
Fishes					Broadcast spawners, freshwater drum. 4150 cfs. 7-19 days. Bankful pulse. Wet years. Once every 2 years.				Broadcast spawners, freshwater drum. 4150 cfs. 7-19 days. Bankful pulse. Wet years. Once every 2 years.									
<i>Flow Rec.</i>					3,370 cfs				3,370 cfs									
Fishes					Broadcast spawners, freshwater drum. 2500 cfs. 7-14 days. Avg years. One per year.				Broadcast spawners, freshwater drum. 2500 cfs. 7-14 days. Avg years. One per year.									
Mussels					Geomorphic processes. 23 days. Wet years. (Winter pulse extended to May)				Geomorphic processes. 23 days. Wet years. (Winter pulse extended to May)									
<i>Flow Rec.</i>	738 cfs				1,740 cfs				513 cfs									
Riparian					Riparian trees. 1260 cfs. 9 days. Every 5-10 years. Wet years.													
Mussels					Geomorphic processes. Average years. (1,600 Winter pulse extended to May)				Host access. 10 days. Average years. (June to Nov)									
<i>Flow Rec.</i>	112 cfs				702 cfs				125 cfs									
Riparian					Riparian trees. 516 cfs. 7 days. Every 5-10 years. Avg, wet years.													
Fishes					Broadcast spawners, freshwater drum. 250 cfs. 7 days. One per year. Dry years.				Broadcast spawners, freshwater drum. 250 cfs. 7 days. One per year. Dry years.									
Mussels					Geomorphic processes. 10 days. Dry years.				Host access. 10 days. Dry years. (June to Nov)									
Base Flows																		
<i>Flow Rec.</i>	42 cfs				46 cfs				40 cfs									
Fishes	Habitat condition, some oxbow access				Habitat condition, some oxbow access				Habitat condition, some oxbow access									
Mussels	Habitats, host access				Habitats, host access				Habitats, host access									
Riparian	Riparian wetting				Riparian wetting				Riparian wetting									
<i>Flow Rec.</i>	24 cfs				24 cfs				22 cfs									
Fishes	Habitat conditions				Habitat conditions				Habitat conditions									
Mussels	Habitats, host access				Habitats, host access				Habitats, host access									
<i>Flow Rec.</i>	9 cfs				13 cfs				9 cfs									
Fishes	Habitat conditions, water quality				Habitat conditions, water quality				Habitat conditions, water quality									
Mussels	Habitats, water quality				Habitats, water quality				Habitats, water quality									
Subsistence																		
<i>Flow Rec.</i>	3 cfs				3 cfs				1 cfs									
Fishes	Habitat connectivity, water quality				Habitat connectivity, water quality				Habitat connectivity, water quality									
Mussels	Maintan mussel habitats.				Maintain temperature below 32 threshold. Maintan mussel habitats. Balcones Spike host fish (shiners).				Maintain temperature below 32 threshold. Maintan mussel habitats. Balcones Spike host fish (shiners).									
<table border="1"> <tr> <td colspan="2">KEY:</td> </tr> <tr> <td>Wet Years</td> <td>Dry Years</td> </tr> <tr> <td>Average Years</td> <td>Subsistence</td> </tr> </table>													KEY:		Wet Years	Dry Years	Average Years	Subsistence
KEY:																		
Wet Years	Dry Years																	
Average Years	Subsistence																	

Table C4. E-flow targets formulated during workshop for the San Gabriel River at Laneport. Magnitudes and durations based on BBEST flows.

Season/Month	Winter				Spring				Summer			
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Overbank Flows*												
					9,560 cfs							
Converted EFIT to BBEST framework by dropping EFIT Falls flows and extending the other three seasons to cover the appropriate months.												
*Note: Overbank Flows and High Flow Pulses shown as peak magnitudes. see RPT boxes for range of flows that meet the recommendation.												
High Flow Pulses												
Flow Rec.		8,740 cfs				8,740 cfs						
Fishes	Broadcast spawners, freshwater drum. 8750 cfs. 7-11 days. Bankful pulse. Wet years. Once every 2 years.				Broadcast spawners, freshwater drum. 8750 cfs. 7-11 days. Bankful pulse. Wet years. Once every 2 years.							
Flow Rec.		6,940 cfs				6,940 cfs						
Fishes	Broadcast spawners, freshwater drum. 6500 cfs. 7-9 days. Avg years. One per year.				Broadcast spawners, freshwater drum. 6500 cfs. 7-9 days. Avg years. One per year.							
Mussels	Geomorphic processes				Geomorphic processes							
Flow Rec.		1770 cfs				3,780 cfs				806 cfs		
Fishes	American eel. 7 days. Avg and wet years. (Oct-Jan) 1,770 cfs				Freshwater drum. 516 cfs. 7 days. One per year. Avg and wet years. (Mar-Jun)				Freshwater drum. 516 cfs. 7 days. One per year. Avg and wet years. (Mar-Jun)			
Riparian					Riparian trees (seeding pulse). 3500 cfs. 8 days. One per year. Avg and wet years.							
Mussels					Geomorphic processes; Host access. 5 days. Average and wet years. (Mar to Dec) (1,000 wet years, 750 avg years)				Geomorphic processes; Glochidia; Host access. 5 days. Average and wet years. (Mar to Dec) (1,000 wet years, 750 avg years)			
Flow Rec.		394 cfs				1,450 cfs				347 cfs		
Mussels					Geomorphic processes; Host access; Brooding. 250 cfs. 5 days. Dry years. (Mar to Dec)				Geomorphic processes; Glochidia; Host access; Brooding. 250 cfs. 5 days. Dry years. (Mar to Dec)			
Base Flows												
Flow Rec.		173 cfs				171 cfs				146 cfs		
Fishes	Habitat, some oxbow access				Habitat, some oxbow access				Habitat, some oxbow access			
Mussels	Habitats				Habitats, host access, brooding				Glochidia, habitats, host access, brooding			
Riparian	Riparian wetting				Riparian wetting				Riparian wetting			
Flow Rec.		86 cfs				56 cfs				77 cfs		
Fishes	Habitat conditions				Habitat conditions				Habitat conditions			
Mussels	Habitats, fertilization				Habitats, host access, brooding				Glochidia, habitats, host access, brooding, fertilization			
Flow Rec.		44 cfs				32 cfs				40 cfs		
Fishes	Habitat, water quality				Habitat conditions, water quality				Habitat conditions, water quality			
Mussels	Habitat, water quality, fertilization				Habitats, water quality, host access, brooding				Habitats, water quality, host access, brooding, fertilization			
Subsistence												
Flow Rec.		25 cfs				20 cfs				4 cfs		
Fishes	Habitat connectivity, water quality				Habitat connectivity, water quality				Habitat connectivity, water quality			
Mussels	Maintain habitats				Maintain temperature below 32 threshold (June). Glochidia release; Host access; Brooding; maintain habitats. Balcones Spike host fish (shiners).				Maintain temperature below 32 threshold. Glochidia release; Host access; Brooding; maintain habitats. Balcones Spike host fish (shiners).			
KEY:												
		Wet Years		Dry Years								
		Average Years		Subsistence								

Table C5. E-flow targets formulated during workshop for the Little River near Cameron. Magnitudes and durations based on BBEST flows.

Season/Month	Winter				Spring				Summer			
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Overbank Flows*												
Flow Rec.					29,900 cfs							
Fishes					Alligator gar. Overbank flow to access floodplains. Once every 2 years. Check on alligator gar at this gage							
*Note: Overbank Flows and High Flow Pulses shown as peak magnitudes. see RPT boxes for range of flows that meet the recommendation.												
High Flow Pulses												
Flow Rec.					19,700 cfs (32 days)				19,700 cfs (32 days)			
Riparian					Box elder (to 14,800 cfs), green ash (to 13,600). Every 5-10 years. Wet years.							
Fishes					Broadcast spawners. Bankful pulse. Once every 2 years.				Broadcast spawners. To September. Bankful pulse. Once every 2 years.			
Flow Rec.	9,550 cfs (19 days)				12,800 cfs (20 days)				4,800 cfs (14 days)			
Riparian					Black willow (to 10,700 cfs). Every 5-10 years. Wet years.							
Fishes	White bass run, American eel. 7 days. Wet years. (Team box had 12800 cfs)				Freshwater drum, broadcast spawners. 7 days. One per year.							
Mussels	Geomorphic processes. 19 days. Wet years. (Jan to May)				Geomorphic processes. 20 days. Wet years. (Mar to May)				Host access. 14 days. Wet years. (June to Nov)			
Flow Rec.	4,630 cfs (14 days)				7,500 cfs (14 days)				2,070 cfs (10 days)			
Riparian					Black willow, box elder, green ash. (meets low end of range) Every 5-10 years. Wet years.							
Fishes	American eel. 7 days. Average years. (Oct to Jan) incl *White bass run.				Broadcast spawners, freshwater drum. 7 days. One per year.							
Mussels	Geomorphic processes. 14 days. Average years. (Extend to May or Spring pulse achieves)				Geomorphic processes. 14 days. Average years. (4,630 Winter pulse extended to May)				Host access. 10 days. Average years. (June to Nov)			
Flow Rec.	1,080 cfs (7 days)				3,200 cfs (7 days)				560 cfs (14 days)			
Riparian					Black willow, box elder, green ash. (meets low end of range) Every 5-10 years. Wet years.							
Fishes	American eel. 7 days. Dry years. (Oct to Jan)				Broadcast spawners, freshwater drum. 7 days. One per year.							
Mussels					Geomorphic processes. 7 days. Dry years.				Host access. 14 days. Dry years. (June to Nov) (Team box has 4800, 2070 cfs, but these are not feasible)			
Base Flows												
Flow Rec.	460 cfs				760 cfs				330 cfs			
Fishes	Habitat condition, some oxbow access				Habitat condition, some oxbow access				Habitat condition, some oxbow access			
Mussels	Habitats, host access				Habitats, host access				Habitats, host access			
Riparian	Riparian wetting				Riparian wetting				Riparian wetting			
Flow Rec.	190 cfs				310 cfs				160 cfs			
Fishes	Habitat conditions				Habitat conditions				Habitat conditions			
Mussels	Habitats, host access				Habitats, host access				Habitats, host access			
Flow Rec.	110 cfs				140 cfs				97 cfs			
Fishes	Habitat conditions, water quality				Habitat conditions, water quality				Habitat conditions, water quality			
Mussels	Habitats, water quality				Habitats, water quality				Habitats, water quality			
Subsistence												
Flow Rec.	32 cfs				32 cfs				32 cfs			
Fishes	Habitat connectivity, water quality				Habitat connectivity, water quality				Habitat connectivity, water quality			
Mussels	Maintan mussel thermal conditions,				Maintan mussel thermal conditions,				Maintan mussel thermal conditions,			
KEY:												
Wet Years				Dry Years								
Average Years				Subsistence								

Table C6. E-flow targets formulated during workshop for Yegua Creek near Somerville. Magnitudes and durations based on BBEST flows.

Season/Month	Winter				Spring				Summer					
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct		
Overbank Flows														
					14,700 cfs									
Converted EFIT to BBEST framework by dropping EFIT Falls flows and extending the other three seasons to cover the appropriate months.														
*Overbank Flows and High Flow Pulses shown as peak magnitudes. see RPT boxes for range of flows that meet the recommendation.														
High Flow Pulses														
Flow Rec.		9,110 cfs					9,110 cfs							
Fishes	Broadcast spawners, freshwater drum. Bankful pulse. Wet years. Once every 2 years.					Broadcast spawners, freshwater drum. Bankful pulse. Wet years. Once every 2 years.								
Flow Rec.		5,780 cfs					5,780 cfs							
Fishes	Broadcast spawners, freshwater drum. Bankful pulse. Wet years. Once every 2 years.					Broadcast spawners, freshwater drum. Bankful pulse. Wet years. Once every 2 years.								
Fishes	Riparian trees (seeding pulse). 2000 cfs. 8 days. Every year. Wet years.													
Mussels	Geomorphic processes. (add Wet years here? Didn't add because it's much lower)					Geomorphic processes. (add Wet years here? Didn't add because it's much lower)								
Flow Rec.		2,130 cfs					1,800 cfs				267 cfs			
Riparian														
Mussels	Geomorphic processes; Host access. 5 days. Average and wet years. (Mar to Dec) (1,000 wet years, 750 avg years)					Geomorphic processes; Host access. 5 days. Average and wet years. (Mar to Dec) (1,000 wet years, 750 avg years)				Geomorphic processes; Host access. 5 days. Average and wet years. (Mar to Dec) (1,000 wet years, 750 avg years)				
Flow Rec.		722 cfs					660 cfs				86 cfs			
Riparian						(add anything here?)								
Fishes						**Broadcast spawners, freshwater drum. One per year. Dry years.				**Broadcast spawners, freshwater drum. One per year. Dry years.				
Mussels	Geomorphic processes; Host access. 200 cfs. 5-14 days. Dry years. (Mar-Dec)					Geomorphic processes; Host access. 200 cfs. 5-14 days. Dry years. (Mar-Dec)				Geomorphic processes; Host access. 200 cfs. 5-14 days. Dry years. (Mar-Dec)				
Base Flows														
Flow Rec.		41 cfs					39 cfs				15 cfs			
Fishes	Habitat condition, some oxbow access					Habitat condition, some oxbow access				Habitat condition, some oxbow access				
Mussels	Habitats, host access					Habitats, host access				Habitats, host access				
Riparian	Riparian wetting					Riparian wetting				Riparian wetting				
Flow Rec.		16 cfs					19 cfs				4 cfs			
Fishes	Habitat conditions					Habitat conditions				Habitat conditions				
Mussels	Habitats, host access					Habitats, host access				Habitats, host access				
Flow Rec.		6 cfs					6 cfs				1 cfs			
Fishes	Habitat conditions, water quality					Habitat conditions, water quality				Habitat conditions, water quality				
Mussels	Habitats, water quality					Habitats, water quality				Habitats, water quality				
Subsistence														
Flow Rec.		1 cfs					1 cfs				1 cfs			
Fishes	Habitat connectivity, water quality					Habitat connectivity, water quality				Habitat connectivity, water quality				
Mussels	Maintan mussel habitats.					Maintan temperature below 32 threshold. Maintan mussel habitats. Balcones Spike host fish (shiners).				Maintan temperature below 32 threshold. Maintan mussel habitats. Balcones Spike host fish (shiners).				
KEY:														
Wet Years					Dry Years									
Average Years					Subsistence									

Appendix D: Breakout Group Notes and Tables Summarizing Basis for Flow Recommendations

The appendix details all of the e-flow components that were defined by the Fishes, Mussels, and Riparian/Floodplain breakout groups. Justifications for the e-flows are based on breakout group discussions, notes from the workshop that were recorded by notetakers, and notes from the workshop recorded in RPT and notes of individual breakout group participants. Individual e-flow components for each breakout group are specified below.

Fishes Breakout Group

The goal of the fishes group was to identify flow dependencies for fish and to quantify, as best as possible, flow recommendations to restore or maintain these flow dependencies. The group worked with flow-ecology relationship information from TPWD and TWDB and observational data from experts familiar with fisheries in the basin. Water temperature was an important variable discussed in the fish group. The fish group identified the following 5 flow components:

White Bass Runs

Inflows into Granger Lake need to be kept suitably high such that white bass can run upstream as part of their spawning migration. Georgetown Reservoir is located upstream of Granger and may be able to augment flows as necessary to keep inflows to Granger suitably high. Connectivity is important for successful white bass spawns as is maintaining water temperatures of 12-20° C during the runs and ensuring that waters do not become stagnant. These flows and temperatures would be required during February and March.

Freshwater Drum

In Texas, freshwater drum spawn in open water between March and June with most spawning activity occurring in April and May. Eggs float until hatching. A pulse flow during this period is recommended to trigger spawning activity of the freshwater drum (TPWD, <https://tpwd.texas.gov/huntwild/wild/species/fwd/>).

Broadcast Spawners

Broadcast spawners would require a bank full pulse once every two years occurring from March to September to maximize occasional dispersal of fertilized eggs throughout the system. At least one high pulse per year is recommended.

Alligator Gar

Although alligator gar may not be present in this section of the Brazos River system, gar require overbank flows once every two years. The overbank flow would connect with backwater areas or oxbows for young gar to feed and grow before reconnecting with the main channel during the next flood event.

American Eel

Mature eels will migrate from freshwater rivers in October to January to spawn in the ocean in late winter through spring. Multiple pulse flows during this period are recommended to trigger the

migration into the rivers, support spawning, and post-spawn returns to the ocean (<https://txstate.fishesoftexas.org/anguilla%20rostrata.htm>).

Mussels Breakout Group

The goal of the mussel break-out group was to identify flow dependencies for mussels and to quantify, as best as possible, flow recommendations to restore or maintain these flow dependencies. Available flow-ecology relationship information and thermal tolerance data from TPWD and TWDB were used to develop recommendations. Considerations related to mussels included flow and water temperature dynamics related to host fish, spawning, brooding, and survival during low flows. The mussels group identified the following 6 flow components:

Host Access

Fish host access to mussels during glochidia release is extremely important and occurs from June through September. Pulses are important so that fish can access mussel beds when they are releasing glochidia. Timing of pulses should be based on pulses generated by rain fall events that would occur in the natural flow regimes. Dry years pulses of up to 750 cfs may be required and should be stepped up in 100- to 200-cfs increments.

Base/Subsistence Flow

Another important flow requirement for mussels is the maintenance of subsistence flows during the summer to ensure that water temperatures do not exceed 32° C resulting in mussel mortality. These flows should be sufficient to minimize mortality related to thermal stress.

Geomorphic Processes

The mussel beds need to be flushed to remove sediments that have accumulated in the substrate. Pulses over 1,500 cfs would be required to flush sediments from the mussel beds in the summer and fall.

Spawning

Mussels fertilize from late October through February. Flow should be between 25 and 50 cfs to facilitate the distribution of gametes in the water column.

Glochidia Release

Glochidia release occurs from 1 June through 15 November and requires flows of 50 to 100 cfs.

Brooding

Mussels brood throughout the spring through winter and require flows of 100-300 cfs between May and September.

Riparian/Floodplains Breakout Group

The goal of the riparian/floodplains break-out group was to identify flow dependencies for riparian ecosystems and related geomorphic processes and to quantify, as best as possible, flow

recommendations to restore or maintain these flow dependencies. Available flow-ecology relationship information from TPWD and TWDB were used to develop recommendations. TWDB provided floodplain data for two gages, Leon River at Gatesville and Little River near Cameron, from the Instream Flows Research and Validation Methodology Framework and Brazos Estuary Characterization Report (Bonner et al., 2015). Discussion on riparian flow needs focused primarily on tree communities within the riparian areas. The riparian/floodplain group identified the following 5 flow components:

Multiple Riparian Pulses

There were multiple pulse components (4) designed to occur at least once every 5-10 years in spring to disperse seeds. Riparian vegetation communities are adapted to and dependent on high pulse and overbank flows that regularly inundate riparian areas, disperse seeds, establish conditions conducive to seedling establishment, maintain mature plants, and deter the establishment of terrestrial (non-riparian) species. Life stage and species-specific criteria related to the riparian pulses are listed below.

Box Elder

Seeds March to May

Black Willow

Seeds in late March to May and especially in late April to May.

Green Ash

Seeds April to May

Riparian SB3 Pulse

This pulse was originally defined as part of the BBEST flow recommendations. The breakout group discussed and concurred with its value for Riparian ecosystems and incorporated this pulse recommendation as part of the workshop outcomes. Pulse needed to disperse seed to high channel and low floodplain areas and to inhibit encroachment of upland plant species.

Sapling flow

A second pulse in the summer between May and July, after a spring riparian pulse was made, would help saplings survive.

Although e-flow targets are presented in Appendix C, tables for Appendix D are presented here to provide the detail discussed in the breakout groups.

Please note that the “pulse” columns (date and peak) in tables D1 to D6 are populated based on data entered into HEC-RPT. Those data were used during the workshop to draw a specific trace of the flow components and are not meant to be prescriptive in terms of exact dates or flows. In practice, actual e-flow pulses should be made within the seasonal and flow ranges tabulated in the “when” and “flow range” columns.

Table D1. Unification table showing all ecological functions of flows discussed by the three breakout groups for the Leon River at Gatesville. Cell shading indicates breakout group as follows: red=fishes, blue=mussels, green=riparian/floodplains.

Leon River At Gatesville Unification					Pulse			
Name	Description	State	Flow Range	When	Date	Peak cfs	Days of Peak	Duration
Broadcast Spawners	Increasing on positive rates of change, based on Dr. Josh Perkin et al. -- 1 bankful pulse for wet -- once every 2 year pulse from EFIT	Wet	250 to 8000 cfs	Mar-Sep	01-Jul, 31-Mar	630, 7580	1, 1	7, 39
		Avg	250 to 4000 cfs	Mar-Sep	01-Jul, 31-Mar, 01-Mar	630, 5300, 630	1, 1, 1	7, 33, 7
Box Elder	Box elder 2,600 cfs to 3,700 cfs in spring every 5-10 years. likely already hitting these flows with flood events. Looking for about 3-5 days of flows.	Wet	2600 to 3700 cfs	Mar-May		3200	3	5
Green Ash	Green ash 2,600 cfs to 4,220 cfs late spring April-May every 5-10 years. Likely already hitting these flows with flood events.	Wet	2600 to 4220 cfs	Apr-May		3700	3	5
Freshwater Drum		Wet	250 to 1750	Mar-Jun	15-Apr	630	1	7
		Avg	250 to 1750	Mar-Jun	15-Apr	630	1	7
Geo Process	Expand time and add pulses for channel maintenance second is to repair and clean riffles and shoals ** look at San Gabriel wet lines for geo proc. for duration for pulse in April*** Mimic BBEST timing of pulses and mangnitude in Spring	Wet	500 to 3000 cfs	15-Jan to 30-May	15-Feb, 15-Apr	280, 1390	2, 2	10, 18
		Avg	50 to 400 cfs	15-Jan to 30-May	15-Feb, 15-Apr	100, 100	2, 2	6, 6
		Dry	500 to 5000 cfs	15-Jan to 30-May	15-Feb, 15-Apr	340, 340	2, 2	10, 10
White Bass Run	Inflows into Granger need to be kept so that the bass can run upstream -- conductivity important for this even is important -- fishery importance -- water temperature drives the runs and cannot be stagnant temps b/w 12-20 C	Wet	250 to 4500 cfs	Feb-Mar	15-Apr, 15-Feb	630, 630	1, 1	7, 7
		Avg	250 to 4500 cfs	Feb-Mar	15-Apr, 15-Feb	630, 630	1, 1	7, 7
Host Access	Wet- Two pulses based on hydrology, quick ramp up and lag on ramp down *** Avg - mimicking nat flow in wet years BBest but twice during summer, keep magnitude same, short ramp up, extended ramp to 140 cfs, one day at max, then 4 day ramp down twice in the season *** increase host availability to increase mussel presence	Wet	300 to 2000 cfs	01-Jun to 15-Nov	15-Jun, 30-Aug	1000, 1000	1, 1	7, 7
		Avg	50 to 500 cfs	Jun-Nov	15-Jun, 30-Aug	140, 140	1, 1	7, 7
		Dry	25 to 100 cfs	Jun-Nov	15-Jun, 30-Aug	58, 58	1, 1	7, 7
Sapling Flow	Maybe too detailed to make a sapling flow.	Wet	Variable	May-Jul	Post seeding above months			
Subsistence- Mussels	Increase BBEST subsistence recommendation to 5 cfs to give mussels some support May through September protective of temperature thresholds	Avg	5 cfs	May-Sep				
		Dry	1 cfs	01-May to 30-Sep				

Table D2. Unification table showing all ecological functions of flows discussed by the three breakout groups for the Little River near Little River. Cell shading indicates breakout group as follows: red=fishes, blue=mussels, green=riparian/floodplains.

Little River near Little River Unification					Pulse			
Name	Description	State	Flow Range	When	Date	Peak cfs	Days of Peak	Duration
SB3 Large Spring Pulse	Lack of exact data for this gage but hitting one of two of these SB3 spring pulses for a wet or average year every 5-10 years is recommended for trees	Wet	3800 to 6000 cfs	Mar-Jun		5310		23
SB3 Medium Spring Pulse		Wet	2000 to 3800 cfs	Mar-Jun		3290		17
SB3 Medium Spring Pulse		Avg	2001 to 3800 cfs	Mar-Jun		3290		17
SB3 Small Spring Pulse		Avg	1000 to 2000	Mar-Jun		1420		10
Broadcast Spawners	Increasing on positive rates of change, based on Dr. Josh Perkin et al. -- 1 bankful pulse for wet -- once every 2 year pulse from EFIT	Wet	250 to 10,000 cfs	Mar-Sep	01-Jul, 31-Mar	5310, 8890	1, 1	7, 32
		Avg	250 to 10,000 cfs	Mar-Sep	01-Jul, 31-Mar, 01-Mar	3290, 8890, 3290	1, 1, 1	7, 32, 7
		Dry	250 to 4000 cfs	Mar-Sep	01-Jul, 01-Mar	1420, 1420	1, 1	7, 7
Freshwater Drum		Wet	250 to 3500 cfs	Mar-Jun	15-Apr	5310	1	7
		Avg	250 to 1750 cfs	Mar-Jun	15-Apr	3290	1	7
		Dry	250 to 1750 cfs	Mar-Jun	15-Apr	1420	1	7
Geo Process	Mimic BBEST pulses	Wet	1000 to 6500 cfs	15-Jan to 30-May	15-Jan to 01-May	2960, 5310	2, 2	17, 23
	Bounding box similar to Leon for channel maintenance ***BBEST - 2 pulses, magnitude 4630 cfs, 14 days ***	Avg	1000 to 2000 cfs	15-Jan to 30-May	15-Mar, 01-May	1600, 1600	2, 2	11, 11
	Mimic BBEST pulses	Dry	1000 to 2000 cfs	15-Jan to 30-May	15-Mar, 01-May	1420, 1420	2, 2	10, 10
American Eel		Wet	250 to 3500 cfs	Oct-Jan	31-Oct, 15-Nov, 15-Jan	2960, 2960, 2960	1, 1, 1	7, 7, 7
		Avg	250 to 3500 cfs	Oct-Jan	31-Oct, 15-Nov, 15-Jan	2960, 2960, 2960	1, 1, 1	7, 7, 7
		Dry	250 to 3500 cfs	Oct-Jan	31-Oct, 15-Nov, 15-Jan	520, 520, 520	1, 1, 1	7, 7, 7
White Bass Run	Inflows into Granger needs to be kept so that the bass can run upstream -- conductivity important -- fishery importance -- water temperature drives the runs, flows cannot be stagnant, water temps between 12-20 C	Wet	250 to 4500 cfs	Feb-Mar	15-Apr, 15-Feb	5310, 5310	1, 1	7, 7
		Avg	250 to 4500 cfs	Feb-Mar	01-Apr, 15-Feb	3290, 3290	1, 1	7, 7
Alligator Gar	Not sure the gar exist here, but maybe with the right hydrologic conditions they might be able to migrate up to this location -- the overbank flows need to occur every 2 years	Wet	0 to 12000 cfs	May-Jul	20-May	11700	1	14
Host Access	BBEST recommendations and observed were used to derive at two pulse events - time and magnitude	Wet	500 to 3000 cfs	01-Jun to 15-Nov	1-Jul, 15-Sep	2470, 1060	1, 1	14, 10
		Avg	500 to 1750 cfs	01-Jun to 15-Nov	1-Jul, 15-Sep	1060, 1060	1, 1	10, 10
		Dry	500 to 1000 cfs	01-Jun to 15-Nov	1-Jul, 15-Sep	430, 430	1, 1	10, 10
Subsistence-Mussels	Subsistence flow for average years for mussels, maintain temperature below thermal mortality threshold, maintaining mussel habitats, and supporting host fish (shiners). *Mussels group noted lower subsistence flows of 32 cfs at Little River near Cameron and 55 cfs at Little River near Little River and questioned if 32 cfs would be sufficient there also	Dry	55 cfs (*32 cfs, see note in description)	01-May to 30-Sep				

Table D3. Unification table showing all ecological functions of flows discussed by the three breakout groups for the San Gabriel River near Georgetown. Cell shading indicates breakout group as follows: red=fishes, blue=mussels, green=riparian/floodplains.

San Gabriel near Georgetown Unification					Pulse			
Name	Description	State	Flow Range	When	Date	Peak cfs	Days of Peak	Duration
BB Large Spring Pulse	Lack of exact data for this gage but hitting one of two of these SB3 spring pulses for a wet or average year every 5-10 years is recommended for the trees	Wet	500 to 1750 cfs	Mar-May		1260		9
BB Small Spring Pulse		Wet	250 to 1000 cfs	Mar-May		516		7
BB Small Spring Pulse		Avg	250 to 1000 cfs	Mar-May		516		7
Broadcast Spawners	Increasing on positive rates of change, based on Dr. Josh Perkin et al. -- Wet -- 1 bankful pulse for wet, once every 2 year pulse from EFIT, -- Ave -- 1 per year high pulse recommendation	Wet	250 to 4500 cfs	Mar-Sep	01-Jul, 31-Mar	516, 4150	1, 1	7, 19
		Avg	250 to 4000 cfs	Mar-Sep	01-Jul, 31-Mar	516, 2500	1, 1	7, 14
		Dry	250 to 4000 cfs	Mar-Sep	1-Jul	250	1	7
Freshwater Drum		Wet	250 to 1750 cfs	Mar-Jun				
		Avg	250 to 1750 cfs	Mar-Jun				
		Dry	250 to 1750 cfs	Mar-Jun				
Geomorphic Processes	Flush out beds *** sediment ** pulses for host access achieve the geomorphic process needs in summer/fall **no pulses developed for component ** e-fit meets pulses for geo. morph. processes** if pulses e-fit or natural pulses don't in any given year the a small pulse in Spring ** pulse based on nat. flows in magnitude and duration ***reflect natural high flow pulses that occur throughout the year	Wet	50 to 3000 cfs	01-Mar to 01-Dec	15-Mar	3000	5	5
		Avg	50 to 3000 cfs	01-Mar to 01-Dec	15-Mar	2500	5	5
		Dry	50 to 300 cfs	01-Mar to 01-Dec	15-Mar	1500	5	5
White Bass Run	Inflows into Granger needs to be kept so that the bass can run upstream -- conductivity important -- fishery importance -- water temperature drives the runs, flows cannot be stagnant, water temps between 12-20 C	Wet	250 to 4500 cfs	Feb-Mar	15-Apr, 15-Feb	516, 516	1, 1	7, 7
Host Access	Fish host access to mussels during glochidia release time periods *** flow component is for drum only *** pulses will be key for drum to access mussel beds when they are releasing *** May through November is the overlap window *** pulse in May mimics naturalized flow in magnitude and duration***pulse to mimic natural flow earlier in fall in average year and higher in magnitude ** mimic natural hydrograph in wet years during window with two pulses - duration and magnitude	Wet	5 to 3000 cfs	01-May to 15-Nov	15-May, 15-Aug	3000, 2000	1, 1	19, 19
		Avg	5 to 3000 cfs	01-May to 15-Nov	15-May, 15-Aug	600, 1000	1, 1	14, 14
		Dry	5 to 750 cfs	01-May to 15-Nov	15-May, 10-Sep	600, 600	1, 1	14, 14
Subsistence-Mussels	Subsistence flow for average years for mussels, maintain temperature below thermal mortality threshold, maintaining mussel habitats, and supporting host fish (shiners).	Dry or Sub	4 cfs	01-May to 30-Sep				

D4. Unification table showing all ecological functions of flows discussed by the three breakout groups for the San Gabriel River at Laneport. Cell shading indicates breakout group as follows: red=fishes, blue=mussels, green=riparian/floodplains.

San Gabriel near Laneport Unification					Pulse			
Name	Description	State	Flow Range	When	Date	Peak cfs	Days of Peak	Duration
BB Large Spring Pulse	Seeding pulse, Efit Large Spring pulse would be a good target. About 3 days of peak would be ideal for trees but is bad for storage looking for ideal situation to get rid of a large amount of flood storage.	Wet	3500 to 6000 cfs	Mar-May		3500	3	8
Broadcast Spawners	Increasing on positive rates of change, based on Dr. Josh Perkin et al. -- 1 bankful pulse for wet -- once every 2 year pulse from EFIT	Wet	250 to 9000 cfs	Mar-Sep	01-Jul, 31-Mar	2000, 8750	1, 1	7, 11
		Avg	250 to 6800 cfs	Mar-Sep	01-Jul, 31-Mar	1000, 6500	1, 1	7, 9
Freshwater Drum		Wet	250 to 1750 cfs	Mar-Jun	15-Apr	516	1	7
		Avg	250 to 1750 cfs	Mar-Jun	15-Apr	516	1	7
Geomorphic Processes	Flush out beds *** sediment *** timing TBD ** pulses for host access achieve the geomorphic process needs in summer/fall **no pulses developed for component ** e-fit meets pulses for geo. morph. processes** if pulses e-fit or natural pulses don't in any given year the a small pulse in Spring ** pulse based on nat. flows in magnitude and duration ***reflect natural high flow pulses that occur throughout the year	Wet	50 to 1500 cfs	01-Mar to 01-Dec	15-Mar	1000	5	5
		Avg	50 to 1500 cfs	01-Mar to 01-Dec	15-Mar	750	5	5
		Dry	50 to 300 cfs	01-Mar to 01-Dec	15-Mar	250	5	5
American Eel		Wet	250 to 3500 cfs	Oct-Jan	31-Oct, 15-Nov, 15-Jan	1770, 1770, 1770	1, 1, 1	7, 7, 7
		Avg	250 to 1500 cfs	Oct-Jan	31-Oct, 15-Nov, 15-Jan	1000, 1000, 1000	1, 1, 1	7, 7, 7
Mussel Spawn	Mussel fertilization - ** Fall through winter***Late Oct through Feb	Avg	25 to 50 cfs	15-Oct to 15-Feb				
		Dry	25 to 50 cfs	15-Oct to 15-Feb				
		Sub	25 to 50 cfs	15-Oct to 15-Feb				
Glochidia Release	BBEST recommendations and observed were used to derive at two pulse events - time and magnitude	Wet	50 to 100 cfs	01-Jun to 15-Nov				
		Avg	50 to 100 cfs	01-Jun to 15-Nov				
	LTB - release glochidia (tie to fish host access) *** likely release during same brooding window	Dry	50 to 100 cfs	01-Jun to 15-Nov				
		Sub	50 to 100 cfs	01-Jun to 15-Nov				

D4 (continued). Unification table showing all ecological functions of flows discussed by the three breakout groups for the San Gabriel River at Laneport. Cell shading indicates breakout group as follows: red=fishes, blue=mussels, green=riparian/floodplains.

San Gabriel near Laneport Unification					Pulse			
Name	Description	State	Flow Range	When	Date	Peak cfs	Days of Peak	Duration
Host Access	Fish host access to mussels during glochidia release time periods *** flow component is for drum only *** pulses will be key for drum to access mussel beds when they are releasing *** May through November is the overlap window *** pulse in May mimics naturalized flow in magnitude and duration***pulse to mimic natural flow earlier in fall in average year and higher in magnitude ** WET mimic natural hydrograph in wet years during window with two pulses - duration and magnitude WET AVG pulse to mimic natural flow earlier in fall in average year and higher in magnitude ** same btwn ave and dry states AVG DRY step up in increments 100-200 cfs and step down for total pulse duration 14 days to max. magnitude of 600 and ramp down the same DRY	Wet	5 to 1500 cfs	01-May to 15-Nov	15-May, 15-Aug	1000, 500	1, 1	19, 19
		Avg	5 to 3000 cfs	01-May to 15-Nov	15-May, 15-Aug	150, 500	1, 1	14, 14
		Dry	5 to 750 cfs	01-May to 15-Nov	15-May, 10-Sep	150, 150	1, 1	14, 14
		Sub	500 to 1000 cfs	01-May to 15-Nov				
Mussel Brooding	Longterm brooders - spring - summer through winter	Wet	100 to 300 cfs	01-May to 15-Nov				
		Avg	100 to 300 cfs	01-May to 30-Sep				
		Dry	100 to 300 cfs	01-May to 30-Sep				
		Sub	100 to 300 cfs	01-May to 30-Sep				
Mussel Habitat	Flow target for mussel habitat habitat maintenance *** wetted perimeter *** host fish habitat for balcones spike *** base flow to maintain***during summer average is 77 cfs *** dry summer is 40 cfs *** wet is 149 cfs based on historical stats	Wet	40 to 149 cfs	01-Jun to 30-Sep				
		Avg	40 to 149 cfs	01-Jun to 30-Sep				
		Dry	40 to 149 cfs	01-Jun to 30-Sep				
		Sub	40 to 149 cfs	01-Jun to 30-Sep				
Subsistence-Mussels	Subsistence flow for average years for mussels, maintain temperature below thermal mortality threshold, maintaining mussel habitats, and supporting host fish (shiners)	Avg	4 cfs	01-May to 30-Sep				
		Dry	2 cfs	01-May to 30-Sep				
		Sub	2 cfs	01-May to 30-Sep				

Table D5. Unification table showing all ecological functions of flows discussed by the three breakout groups for the Little River near Cameron. Cell shading indicates breakout group as follows: red=fishes, blue=mussels, green=riparian/floodplains.

Little River near Cameron Unification					Pulse			
Name	Description	State	Flow Range	When	Date	Peak cfs	Days of Peak	Duration
Black Willow	Every 5-10 years, likely already hitting these flows with flood events. Looking for about 3-5 days of flows.	Wet	7800 to 10700 cfs	Mar-May				
Box Elder		Wet	1900 to 14,800 cfs	Mar-May				
Green Ash	Every 5-10 years, likely already hitting these flows with flood events.	Wet	7800 to 13600 cfs	Apr-May				
Freshwater Drum		Wet	250 to 13000 cfs	Mar-Jun	15-Apr	12800	1	7
		Avg	250 to 10000 cfs	Mar-Jun	15-Apr	7550	1	7
		Dry	250 to 10000 cfs	Mar-Jun	15-Apr	3200	1	7
Broadcast Spawners	Increasing on positive rates of change, based on Dr. Josh Perkin et al. -- 1 bankful pulse for wet -- once every 2 year pulse from EFIT	Avg	250 to 20000 cfs	Mar-Sep	01-Jul, 31-Mar	7550, 19700	1, 1	7, 32
		Dry	250 to 20000 cfs	Mar-Sep	1-Jul	3200	1	7
Geo Process	Mimic BBEST pulses	Wet	3000 to 15000 cfs	15-Jan to 30-May	15-Mar, 01-May	9550, 12800	2, 2	19, 20
	Bounding box similar to Leon for channel maintenance***BBEST - 2 pulses, magnitude 4630 cfs, 14 days ***	Avg	2000 to 5500 cfs	15-Jan to 30-May	15-Mar, 01-May	4630, 4630	2, 2	14, 14
	Mimic BBEST pulses	Dry	1000 to 5000 cfs	15-Jan to 30-May	15-Mar, 01-May	3200, 3200	2, 2	7, 7
Host Access	BBEST recommendations and observed were used to derive at two pulse events - time and magnitude	Wet	1000 to 5000 cfs	01-June to 15-Nov	1-Jul, 15-Sep	4800, 2070	1, 1	14, 10
		Avg	1000 to 3000 cfs	01-June to 15-Nov	1-Jul, 15-Sep	2070, 2070	1, 1	10, 10
		Dry	1000 to 5000 cfs	01-June to 15-Nov	1-Jul, 15-Sep	4800, 2070	1, 1	14, 10
White Bass Run	Inflows into Granger needs to be kept so that the bass can run upstream -- conductivity important -- fishery importance -- water temperature drives the runs, flows cannot be stagnant, water temps between 12-20 C	Wet	250 to 14000 cfs	Feb-Mar	15-Apr, 15-Feb	12800, 12800	1, 1	7, 7
American Eel		Avg	250 to 3500 cfs	Oct-Jan	31-Oct, 15-Nov, 15-Jan	4630, 4630, 4630	1, 1, 1	7, 7, 7
		Dry	250 to 3500 cfs	Oct-Jan	31-Oct, 15-Nov, 15-Jan	1080, 1080, 1080	1, 1, 1	7, 7, 7

Table D6. Unification table showing all ecological functions of flows discussed by the three breakout groups for Yegua Creek near Somerville. Cell shading indicates breakout group as follows: red=fishes, blue=mussels, green=riparian/floodplains.

Yegua Creek near Somerville Unification					Pulse			
Name	Description	State	Flow Range	When	Date	Peak cfs	Days of Peak	Duration
BB Large Spring Pulse	Seeding pulse, Efit Large Spring pulse would be a good target. About 3 days of peak would be ideal for trees but it is bad for storage - looking for ideal situation to get rid of a large amount of flood storage.	Wet	1800 to 2500 cfs	Mar to May		2000	3	8
Geomorphic Processes	Flush out beds *** sediment *** timing TBD ** pulses for host access achieve the geomorphic process needs in summer/fall **no pulses developed for component ** e-fit meets pulses for geo. morph. processes** if pulses e-fit or natural pulses don't in any given year the a small pulse in Spring ** WET/AVG pulse based on nat. flows in magnitude and duration ***reflect nat. high flow pulses that occur throughout the year WET/AVG, DRY pull in EFIT spring small pulse event that occurs in March 5d @1500 DRY	Wet	50 to 2500 cfs	01 Mar to 01 Dec	15-Mar,	1000	5	5
		Avg	50 to 3000 cfs	01 Mar to 01 Dec	15-Mar,	750	5	5
		Dry	50 to 300 cfs	01 Mar to 01 Dec	15-Mar,	200	5	5
Host Access	Fish host access to mussels during glochidia release time periods *** flow component is for drum only *** pulses will be key for drum to access mussel beds when they are releasing *** May through November is the overlap window *** pulse in May mimics naturalized flow in magnitude and duration***pulse to mimic natural flow earlier in fall in average year and higher in magnitude ** WET/AVG mimic natural hydrograph in wet years during window with two pulses - duration and magnitude WET/AVG, DRY step up in increments 100-200 cfs and step down for total pulse duration 14 days to max. magnitude of 600 and ramp down the same DRY	Wet	5 to 3000 cfs	01 May to 15 Nov	15-May, 15-Aug	1000, 500	1, 1	19, 19
		Avg	5 to 3000 cfs	01 May to 15 Nov	15-May, 15-Aug	200, 600	1, 1	14, 14
		Dry	5 to 750 cfs	01 May to 15 Nov	15-May, 10-Sep	200, 200	1, 1	14, 14
Subsistence-Mussels	Subsistence flow for average years for mussels, maintain temperature below thermal mortality threshold, maintaining mussel habitats, and supporting host fish (shiners)	Dry	4 cfs	01 May to 30 Sep				
		Sub	4 cfs	01 May to 30 Sep				

Appendix E: SRP Flow Proposal Forms

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Support healthy riparian areas along mainstem Brazos River.

Vegetation communities within the riparian zone are important components of the river-floodplain ecosystem. Vegetation in riparian zones serves as an important natural biofilter, protecting aquatic environments from excessive sedimentation, polluted surface runoff, and erosion. They also supply shelter and food for many aquatic and terrestrial animals, and shade that is an important part of stream temperature regulation. Riparian vegetation communities are adapted to and dependent on high pulse and overbank flows that regularly inundate riparian areas, disperse seeds, establish conditions conducive to seedling establishment, maintain mature plants, and deter the establishment of terrestrial (non-riparian) species.

Studies of riparian areas along the middle and lower Brazos River identified box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), black willow (*Salix nigra*), and eastern cottonwood (*Populus deltoides*) as dominant tree types within riparian/floodplain areas indicative of healthy riparian areas. These four tree species were selected as key species by the TIFP (2018) study of the middle and lower Brazos River. Based on transect studies, seeding and germination periods, and requirements for seed dispersal and seedling and sapling growth, reach specific flow recommendations to benefit these species were developed.

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River at SH 21 near Bryan, USGS Gage # 08108700 (Table E1)

Table E1. Flow Target, Timing, Frequency, and Duration.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
58,200	Feb-Nov	~2:5 yrs	14	Inundate floodplain and riparian forest community
53,000	Feb-May	~1:2 yrs	3	Inundate box elder habitat
53,000	Jun-Oct	~1:2 yrs	3	Inundate box elder habitat
49,500	Feb-Nov	~1:2 yrs	14	Inundate floodplain and riparian forest community
49,000	Feb-Nov	2/yr every ~1:2yrs	4	Inundate box elder and black willow habitat

49,000	Feb-May	~1:2 yrs	3	Inundate cottonwood habitat
49,000	Jun-Oct	~1:2 yrs	3	Inundate cottonwood habitat
46,000	Feb-May	~1:2 yrs	3	Inundate cottonwood habitat
46,000	Jun-Oct	~1:2 yrs	3	Inundate cottonwood habitat
44,000	Mar-May	3/yr every ~1:2 yrs	4	Inundate black willow habitat
44,000	Jun-Aug	2/yr every ~1:2 yrs	4	Inundate black willow habitat
44,000	Sep-Nov	2/yr every ~1:2 yrs	4	Inundate black willow habitat
40,000	Jun-Aug	2/yr every ~1:2 yrs	4	Black willow recruitment
36,000	Jun-Aug	2/yr every ~2:3 yrs	4	Black willow recruitment
31,000	Mar-Sep	3/yr every ~2:3 yrs	3	Inundate green ash, black willow, box elder, and cottonwood habitat
31,000	Feb-May	~2:3 yrs	3	Box elder recruitment
31,000	Jun-Oct	~2:3 yrs	3	Box elder recruitment
10,000	Mar-May	3/yr	4	Black willow recruitment
10,000	Jun-Aug	2/yr	4	Black willow recruitment
10,000	Sep-Nov	2/yr	4	Black willow recruitment
9,000	Mar-May	3/yr	4	Black willow recruitment
9,000	Jun-Aug	2/yr	4	Black willow recruitment
9,000	Sep-Nov	2/yr	4	Black willow recruitment
6,000	Mar-Sep	3/yr	4	Inundates channel up to estimated mean highwater mark
6,000	Mar-May	3/yr	4	Black willow recruitment
6,000	Jun-Aug	2/yr	4	Black willow recruitment
6,000	Sep-Nov	2/yr	4	Black willow recruitment
4,000	Jun-Aug	2/yr	4	Black willow recruitment
4,000	Sep-Nov	2/yr	4	Black willow recruitment

Shortcomings: Exact frequency that large flows are required is not known. Large, long-lived tree species such as eastern cottonwood do not need significant recruitment every year for survival. However, good recruitment years are required periodically to ensure survival. Frequency of higher flows could be patterned on historical and/or current occurrence of these flows in the system.

The mainstem channel of the Brazos River near Bryan shows signs of incision (approximately 0.3 feet per decade). As the main channel of the river degrades, higher flows are required to inundate riparian areas.

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Support healthy riparian areas along mainstem Brazos River.

Vegetation communities within the riparian zone are important components of the river-floodplain ecosystem. Vegetation in riparian zones serves as an important natural biofilter, protecting aquatic environments from excessive sedimentation, polluted surface runoff, and erosion. They also supply shelter and food for many aquatic and terrestrial animals, and shade that is an important part of stream temperature regulation. Riparian vegetation communities are adapted to and dependent on high pulse and overbank flows that regularly inundate riparian areas, disperse seeds, establish conditions conducive to seedling establishment, maintain mature plants, and deter the establishment of terrestrial (non-riparian) species.

Studies of riparian areas along the middle and lower Brazos River identified box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), black willow (*Salix nigra*), and eastern cottonwood (*Populus deltoides*) as dominant tree types within riparian/floodplain areas indicative of healthy riparian areas. These four tree species were selected as key species by the TIFP (2018) study of the middle and lower Brazos River. Based on transect studies, seeding and germination periods, and requirements for seed dispersal and seedling and sapling growth, reach specific flow recommendations to benefit these species were developed.

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River at SH 21 near Bryan, USGS Gage # 08108700 (Table E2)

Table E2. Flow Target, Timing, Frequency, and Duration.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
58,200	Feb-Nov	~2:5 yrs	14	Inundate floodplain and riparian forest community
53,000	Feb-May	~1:2 yrs	3	Inundate box elder habitat
53,000	Jun-Oct	~1:2 yrs	3	Inundate box elder habitat
49,500	Feb-Nov	~1:2 yrs	14	Inundate floodplain and riparian forest community
49,000	Feb-Nov	2/yr every ~1:2yrs	4	Inundate box elder and black willow habitat
49,000	Feb-May	~1:2 yrs	3	Inundate cottonwood habitat
49,000	Jun-Oct	~1:2 yrs	3	Inundate cottonwood habitat
46,000	Feb-May	~1:2 yrs	3	Inundate cottonwood habitat
46,000	Jun-Oct	~1:2 yrs	3	Inundate cottonwood habitat
44,000	Mar-May	3/yr every ~1:2 yrs	4	Inundate black willow habitat
44,000	Jun-Aug	2/yr every ~1:2 yrs	4	Inundate black willow habitat
44,000	Sep-Nov	2/yr every ~1:2 yrs	4	Inundate black willow habitat
40,000	Jun-Aug	2/yr every ~1:2 yrs	4	Black willow recruitment
36,000	Jun-Aug	2/yr every ~2:3 yrs	4	Black willow recruitment
31,000	Mar-Sep	3/yr every ~2:3 yrs	3	Inundate green ash, black willow, box elder, and cottonwood habitat
31,000	Feb-May	~2:3 yrs	3	Box elder recruitment
31,000	Jun-Oct	~2:3 yrs	3	Box elder recruitment
10,000	Mar-May	3/yr	4	Black willow recruitment
10,000	Jun-Aug	2/yr	4	Black willow recruitment
10,000	Sep-Nov	2/yr	4	Black willow recruitment
9,000	Mar-May	3/yr	4	Black willow recruitment
9,000	Jun- Aug	2/yr	4	Black willow recruitment
9,000	Sep-Nov	2/yr	4	Black willow recruitment
6,000	Mar-Sep	3/yr	4	Inundates channel up to estimated mean highwater mark
6,000	Mar-May	3/yr	4	Black willow recruitment
6,000	Jun-Aug	2/yr	4	Black willow recruitment
6,000	Sep-Nov	2/yr	4	Black willow recruitment
4,000	Jun-Aug	2/yr	4	Black willow recruitment
4,000	Sep-Nov	2/yr	4	Black willow recruitment

Shortcomings: Exact frequency that large flows are required is not known. Large, long-lived tree species such as eastern cottonwood do not need significant recruitment every year for survival. However, good recruitment years are required periodically to ensure survival. Frequency of higher flows could be patterned on historical and/or current occurrence of these flows in the system. The mainstem channel of the Brazos River near Bryan shows signs of incision (approximately 0.3 feet per decade). As the main channel of the river degrades, higher flows are required to inundate riparian areas.

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Lateral connectivity between mainstem Brazos River and oxbow lakes and floodplain habitats.

In meandering lowland floodplain rivers like the middle and lower Brazos River, oxbow lakes and other floodplain habitats are important components of the river-floodplain ecosystem. These habitats serve as spawning and nursery habitat for many fish species and contribute to overall species richness. Lateral connectivity established during high flow pulse events is essential for movement of species between the main-stem river and floodplain habitats.

Flow requirements of Shoal Chub (*Macrhybopsis hyostoma*) are indicative of the flow requirements of broadcast spawning cyprinids in the Brazos River basin. A study of Shoal Chub identified a relationship between high flow pulses and recruitment in the middle and lower Brazos River. Greater levels of recruitment were associated with the occurrence of two flow pulses of 5,000 cfs during the reproductive season (April-September) (recruitment was reduced for smaller or larger pulses). A seven-day pulse duration meets requirements for spawning and suspension of eggs and larvae in the water column for broadcast spawning cyprinids (including Shoal Chub). Eggs hatch within one to two days, depending on temperature, and larvae require an additional two to three days to reach swim-up and move into low velocity feeding habitats. To meet the needs of broadcast spawning cyprinids, TIFP (2018) recommended two pulses of 5,000 cfs, with a duration of seven days for each pulse, during April-September for all sites on the Brazos River below Waco.

Flow requirements of Alligator Gar (*Atractosteus spatula*) are indicative of the flow requirements of fish species that utilize oxbow lakes and other floodplain habitats along Texas rivers. Periodic high flow events during the April through July spawning season provide connection to floodplain habitats where Alligator Gar lay adhesive eggs onto plant matter. Successful recruitment requires pulse flow durations sufficient for eggs to hatch and for larvae to develop and avoid stranding as flood waters recede. A pulse duration of 14 days allows for Alligator Gar eggs to hatch and free-swimming larvae to develop sufficiently to ensure a successful recruitment class. A study on the middle Trinity River in Texas found that strong Alligator Gar year classes were associated with floodplain inundation events with durations greater than 30 days. A study of oxbow lakes developed location specific flood pulse magnitudes necessary for connection to the mainstem Brazos River. To meet the needs of Alligator Gar and other species that utilize floodplain habitats and oxbow lakes, TFIP (2018) recommended reach specific flow requirements along the middle and lower Brazos River (Table E2).

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River near Hempsted, USGS Gage # 08111500

Table E2. Recommended flow requirements per flow target, timing, frequency, and duration.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
73,000	Any	~1:3 yrs	3	Oxbow connectivity, foodweb dynamics, fish biodiversity
73,000	May-Jul	~1:3 yrs	14	Alligator Gar recruitment, oxbow connectivity
42,000	Any	~3:5 yrs	3	Oxbow connectivity, foodweb dynamics, fish biodiversity
42,000	May-Jul	~3:5 yrs	14	Alligator Gar recruitment, oxbow connectivity
32,000	Any	~2:3 yrs	3	Oxbow connectivity, foodweb dynamics, fish biodiversity
32,000	May-Jul	~2:3 yrs	14	Alligator Gar recruitment, oxbow connectivity
5,000	Apr-Sep	2/yr	7	Pelagic broadcast spawning cyprinids

Shortcomings: Exact frequency that large flows are required is not known. Large, long-lived species such as Alligator Gar do not need significant recruitment every year for survival. However, good recruitment years are required periodically to ensure survival. Frequency of higher flows could be patterned on historical and/or current occurrence of these flows in the system.

Exact oxbow lake connection flows vary over time as lakes evolve (trend is progressively higher flows to connect as lakes get older and higher sediment deposits separate them from mainstem river). Long-term maintenance of oxbow lake habitat requires periodic creation of new oxbow lakes (with associated initially frequent connection to mainstem river). New oxbow lake creation appears to have slowed in the Brazos River basin in recent decades.

The mainstem channel of the Brazos River near Hempstead shows signs of incision (approximately 0.7 feet per decade). As the main channel of the river degrades, higher flows are required to connect with oxbow lakes. Requirements for higher connectivity flows due to channel incision occur independently of (and in addition to) requirements for higher connectivity flows as oxbow lakes age.

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Support healthy riparian areas along mainstem Brazos River.

Vegetation communities within the riparian zone are important components of the river-floodplain ecosystem. Vegetation in riparian zones serves as an important natural biofilter, protecting aquatic environments from excessive sedimentation, polluted surface runoff, and erosion. They also supply shelter and food for many aquatic and terrestrial animals, and shade that is an important part of stream temperature regulation. Riparian vegetation communities are adapted to and dependent on high pulse and overbank flows that regularly inundate riparian areas, disperse seeds, establish conditions conducive to seedling establishment, maintain mature plants, and deter the establishment of terrestrial (non-riparian) species.

Studies of riparian areas along the middle and lower Brazos River identified box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), black willow (*Salix nigra*), and eastern cottonwood (*Populus deltoides*) as dominant tree types within riparian/floodplain areas indicative of healthy riparian areas. These four tree species were selected as key species by the TIFP (2018) study of the middle and lower Brazos River. Based on transect studies, seeding and germination periods, and requirements for seed dispersal and seedling and sapling growth, reach specific flow recommendations to benefit these species were developed (Table E3).

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River near Hempstead, USGS Gage # 08111500

Table E3. Recommended flow requirements per flow target, timing, frequency, and duration.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
58,200	Feb-Nov	~1:2 yrs	14	Inundate floodplain and riparian forest community
45,000	Feb-May	~2:3 yrs	3	Inundate box elder and cottonwood habitat
45,000	Jun-Oct	~2:3 yrs	3	Inundate box elder and cottonwood habitat
39,000	Mar-May	3/yr every ~1:2 yrs	4	Inundate black willow habitat
39,000	Jun-Aug	2/yr every ~1:2 yrs	4	Inundate black willow habitat
39,000	Sep-Nov	2/yr every ~1:2 yrs	4	Inundate black willow habitat
24,000	Mar-May	3/yr every ~2:3 yrs	4	Black willow recruitment
24,000	Jun-Aug	2/yr every ~2:3 yrs	4	Black willow recruitment
24,000	Sep-Nov	2/yr every ~2:3 yrs	4	Black willow recruitment
18,000	Mar-May	3/yr every ~4:5 yrs	4	Black willow recruitment
18,000	Jun-Aug	2/yr every ~4:5 yrs	4	Black willow recruitment
18,000	Sep-Nov	2/yr every ~4:5 yrs	4	Black willow recruitment
5,000	Mar-May	3/yr	4	Inundates channel up to estimated mean highwater mark; black willow recruitment
5,000	Jun-Aug	2/yr	4	Inundates channel up to estimated mean highwater mark; black willow recruitment
5,000	Sep-Nov	2/yr	4	Inundates channel up to estimated mean highwater mark; black willow recruitment

Shortcomings: Exact frequency that large flows are required is not known. Large, long-lived tree species such as eastern cottonwood do not need significant recruitment every year for survival. However, good recruitment years are required periodically to ensure survival. Frequency of higher flows could be patterned on historical and/or current occurrence of these flows in the system. The mainstem channel of the Brazos River near Hempstead shows signs of incision (approximately 0.7 feet per decade). As the main channel of the river degrades, higher flows are required to inundate riparian areas.

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Base flows along mainstem Brazos River.

Objectives for base flows are to provide 1) suitable aquatic habitat for all life stages of native species, 2) suitable in-channel water quality, 3) connectivity along channel corridor, and maintain 4) soil moisture and groundwater table in riparian areas, 5) diversity of habitats, and 6) intra- and inter-annual variability.

Studies of fish guild and hydraulic habitats at two study sites (Marlin and Hearne) identified flows between 190 and 6,000 cfs as providing a diverse mixture of habitat conditions sufficient to support all fish guilds and a variety of hydraulic habitats. Interannual variability was recommended with flows between 850 and 6,000 cfs during wet years, 435 and 3,000 cfs during average years, and 160 and 1,100 cfs during dry years. Intra-annual variability that mimicked historical hydrology was recommended with higher flows in May and June and lower flows August through December. Because of thermal tolerances of juvenile mussels, flows above 190 cfs during summer months were recommended (Table E4).

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River near Highbank, USGS Gage # 08098290

Table E4. Recommended flow requirements per flow target, timing, frequency, and duration (combining recommendations from Marlin and Hearne study sites).

Month	Dry Base Flow (cfs)	Average Base Flow (cfs)	Wet Base Flow (cfs)	Notes
Jan	245	670	1,320	Averaging results from study sites
Feb	190	520	1,040	Averaging results from study sites
Mar	300	820	1,610	Averaging results from study sites
Apr	490	1,345	2,640	Averaging results from study sites
May	1,090	2,990	5,870	Averaging results from study sites
Jun	1,050	2,880	5,660	Averaging results from study sites
Jul	220	670	1,310	Averaging results from study sites
Aug	190	570	1,185	Avg. results adj. for mussel thermal tolerance limits
Sep	250	825	1,615	Averaging results from study sites
Oct	255	700	1,375	Averaging results from study sites
Nov	160	435	850	Averaging results from study sites
Dec	175	480	945	Averaging results from study sites

Shortcomings: Flow conditions naturally vary considerably with the Brazos basin, both between years and within years. These variable conditions allow for some fish guilds to excel in some years and other fish guilds to excel in other years. The exact balance of variability required to maintain historical fish populations in the basin is not known but assumed to be similar to that displayed in historical flow records.

Base habitat availability may not be the driving factor influencing populations of all fish guilds. For example, some populations may be limited by the occurrence of larger flows that serve as spawning cues and/or provide access to floodplain habitats such as oxbow lakes.

The physical condition of the stream bed allows individual flow rates to support a wide variety of habitat conditions. This provides operational flexibility in that a wide range of flow rates support at least some habitat for most fish guilds. However, the mainstem channel of the Brazos River near Highbank shows signs of incision (approximately 0.2 feet per decade). As the mainstem channel degrades, flow-habitat relationships may change with individual flows no longer able to support a high diversity of habitat conditions (Figures B1, B5, and 11).

Figures from Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Background:

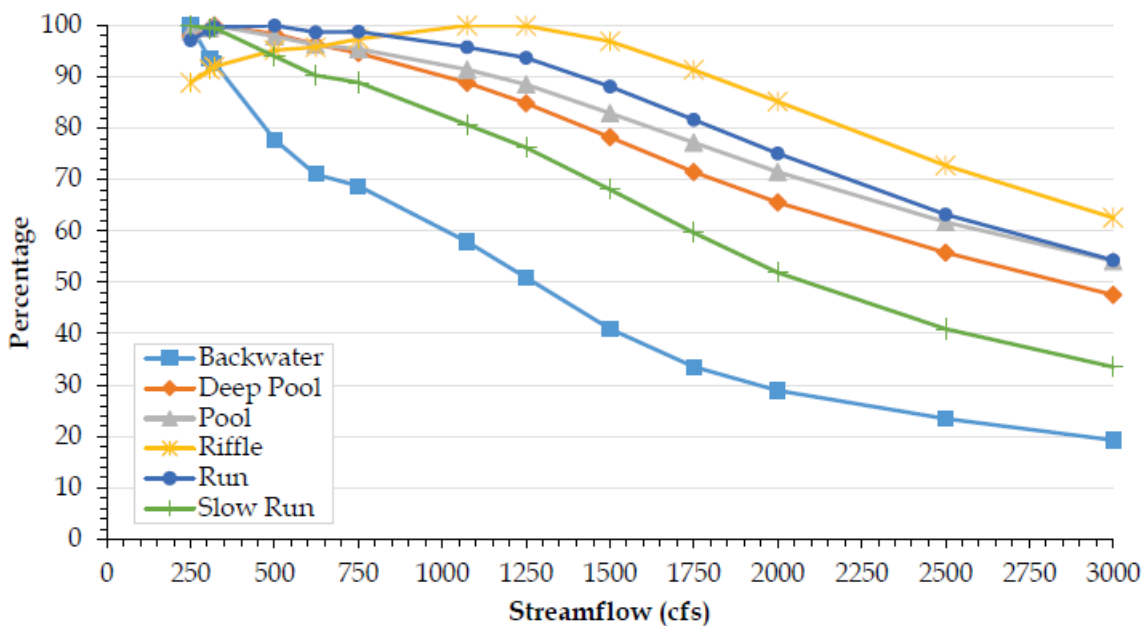


Figure B - 1. Percent maximum of weighted usable area versus simulated discharge for fish habitat guilds at the Marlin study site.

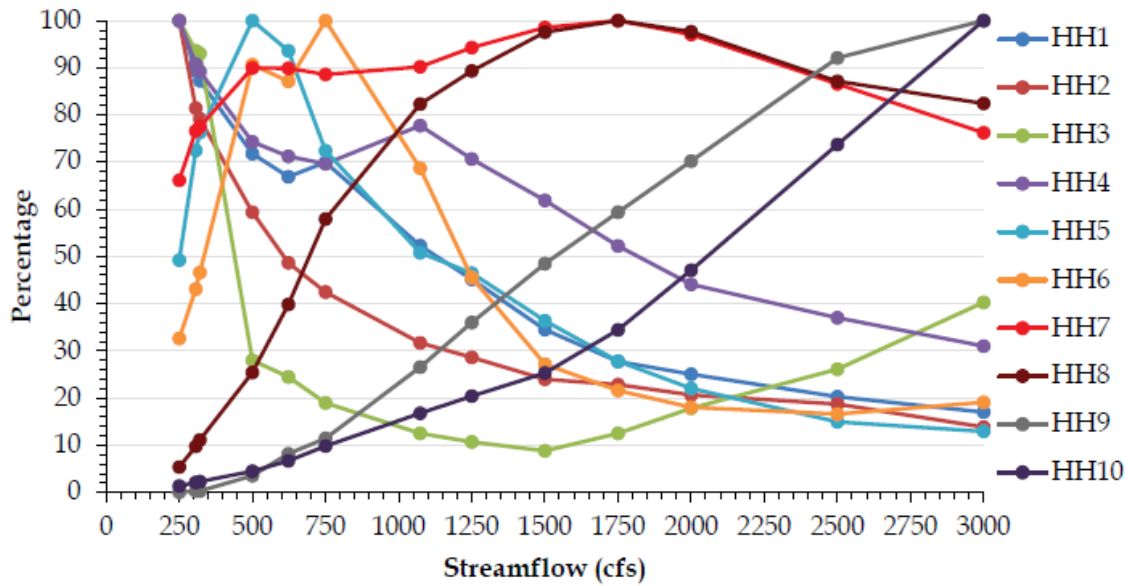


Figure B - 5. Percent maximum of hydraulic habitat criteria at the Marlin study site.

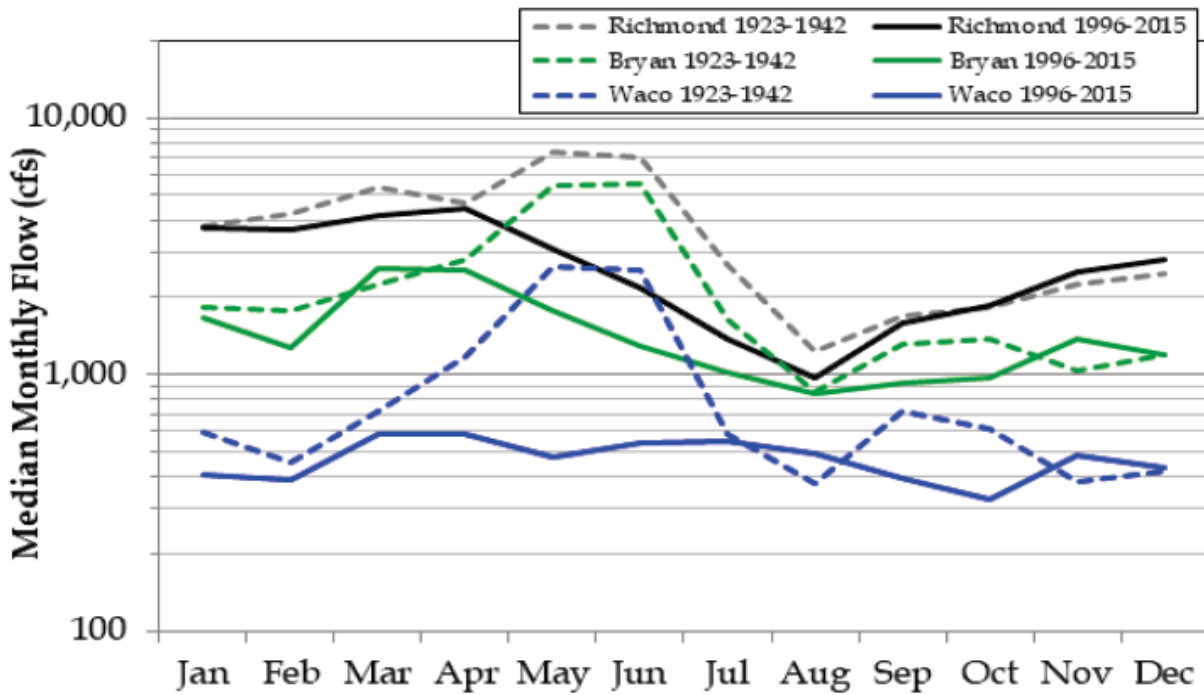


Figure 11. Median monthly flows for Waco, Bryan, and Richmond for two-time periods (1923-1942 and 1996-2015).

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Lateral connectivity between mainstem Brazos River and floodplain habitats.

In meandering lowland floodplain rivers like the middle and lower Brazos River, floodplain habitats are important components of the river-floodplain ecosystem. These habitats serve as spawning and nursery habitat for many fish species and contribute to overall species richness. Lateral connectivity established during high flow pulse events is essential for movement of species between the main-stem river and floodplain habitats.

Flow requirements of Shoal Chub (*Macrhybopsis hyostoma*) are indicative of the flow requirements of broadcast spawning cyprinids in the Brazos River basin. A study of Shoal Chub identified a relationship between high flow pulses and recruitment in the middle and lower Brazos River. Greater levels of recruitment were associated with the occurrence of two flow pulses of 5,000 cfs during the reproductive season (April-September) (recruitment was reduced for smaller or larger pulses). A seven-day pulse duration meets requirements for spawning and suspension of eggs and larvae in the water column for broadcast spawning cyprinids (including Shoal Chub). Eggs hatch within one to two days, depending on temperature, and larvae require an additional two to three days to reach swim-up and move into low velocity feeding habitats. To meet the needs of broadcast spawning cyprinids, TIFP (2018) recommended two pulses of 5,000 cfs, with a duration of seven days for each pulse, during April-September for all sites on the Brazos River below Waco (Table E5).

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River near Highbank, USGS Gage # 0809290

Table E5. Recommended flow requirements per flow target, timing, frequency, duration, and purpose.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
5,000	Apr-Sep	2/yr	7	Pelagic broadcast spawning cyprinids

Shortcomings: The mainstem channel of the Brazos River near Highbank shows signs of incision (approximately 0.2 feet per decade). As the main channel of the river degrades, higher flows may be required to connect with floodplain habitats.

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Support healthy riparian areas along mainstem Brazos River.

Vegetation communities within the riparian zone are important components of the river-floodplain ecosystem. Vegetation in riparian zones serves as an important natural biofilter, protecting aquatic environments from excessive sedimentation, polluted surface runoff, and erosion. They also supply shelter and food for many aquatic and terrestrial animals, and shade that is an important part of stream temperature regulation. Riparian vegetation communities are adapted to and dependent on high pulse and overbank flows that regularly inundate riparian areas, disperse seeds, establish conditions conducive to seedling establishment, maintain mature plants, and deter the establishment of terrestrial (non-riparian) species.

Studies of riparian areas along the middle and lower Brazos River identified box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanica*), black willow (*Salix nigra*), and eastern cottonwood (*Populus deltoides*) as dominant tree types within riparian/floodplain areas indicative of healthy riparian areas. These four tree species were selected as key species by the TIFP (2018) study of the middle and lower Brazos River. Based on transect studies, seeding and germination periods, and requirements for seed dispersal and seedling and sapling growth, reach specific flow recommendations to benefit these species were developed (Table E6).

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River near Highbank, USGS Gage # 08098290

Table E6. Recommended flow requirements per flow target, timing, frequency, duration, and purpose.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
52,000	Feb-Apr	2/yr every ~1:10 yrs	3	Inundate box elder, cottonwood, and green ash habitat
52,000	May-Nov	2/yr every ~1:10 yrs	3	Inundate box elder, cottonwood, and green ash habitat
47,000	May-Jun	2/yr every ~1:5 yrs	3	Green ash recruitment
38,200	Feb-Nov	~1:4 yrs	14	Inundate floodplain and riparian forest community
37,000	Mar-May	3/yr every ~1:4 yrs	4	Inundate black willow habitat
37,000	Jun-Aug	2/yr every ~1:4 yrs	4	Inundate black willow habitat
37,000	Sep-Nov	2/yr every ~1:4 yrs	4	Inundate black willow habitat
36,300	Feb-Nov	~1:3 yrs	14	Inundate floodplain and riparian forest community
30,000	May-Jun	2/yr every ~1:2 yrs	3	Green ash recruitment

23,000	Mar-Nov	3/yr every ~1:2 yrs	14	Inundate floodplain and riparian forest community
21,000	Mar-May	3/yr every ~2:3 yrs	4	Inundate black willow habitat
21,000	Jun-Aug	2/yr every ~2:3 yrs	4	Inundate black willow habitat
21,000	Sep-Nov	2/yr every ~2:3 yrs	4	Inundate black willow habitat
15,000	Mar-May	3/yr every ~2:3 yrs	4	Black willow recruitment
15,000	Jun-Aug	2/yr every ~2:3 yrs	4	Black willow recruitment
15,000	Sep-Nov	2/yr every ~2:3 yrs	4	Black willow recruitment
13,000	May-Jun	2/yr every ~2:3 yrs	3	Green ash recruitment
7,000	Mar-May	3/yr	4	Black willow and green ash recruitment
7,000	Jun-Aug	2/yr	4	Black willow and green ash recruitment
4,500	Mar-Nov	3/yr	4	Inundates channel up to estimated mean highwater mark

Shortcomings: Exact frequency that large flows are required is not known. Large, long-lived tree species such as eastern cottonwood do not need significant recruitment every year for survival. However, good recruitment years are required periodically to ensure survival. Frequency of higher flows could be patterned on historical and/or current occurrence of these flows in the system.

Flows above 45,000 cfs have not occurred on the Brazos River near Highbank since 1994. Riparian tree communities in areas inundated by flows greater than 45,000 cfs may not be viable long-term.

The mainstem channel of the Brazos River near Highbank shows signs of incision (approximately 0.2 feet per decade). As the main channel of the river degrades, higher flows are required to inundate riparian areas.

NAME: MARK WENTZEL

Email: Mark.wentzel@twdb.texas.gov Company: Texas Water Development board

Purpose: Lateral connectivity between mainstem Brazos River and oxbow lakes and floodplain habitats.

In meandering lowland floodplain rivers like the middle and lower Brazos River, oxbow lakes and other floodplain habitats are important components of the river-floodplain ecosystem. These habitats serve as spawning and nursery habitat for many fish species and contribute to overall species richness. Lateral connectivity established during high flow pulse events is essential for movement of species between the main-stem river and floodplain habitats.

Flow requirements of Shoal Chub (*Macrhybopsis hyostoma*) are indicative of the flow requirements of broadcast spawning cyprinids in the Brazos River basin. A study of Shoal Chub identified a relationship between high flow pulses and recruitment in the middle and lower Brazos River. Greater levels of recruitment were associated with the occurrence of two flow pulses of 5,000 cfs during the reproductive

season (April-September) (recruitment was reduced for smaller or larger pulses). A seven-day pulse duration meets requirements for spawning and suspension of eggs and larvae in the water column for broadcast spawning cyprinids (including Shoal Chub). Eggs hatch within one to two days, depending on temperature, and larvae require an additional two to three days to reach swim-up and move into low velocity feeding habitats. To meet the needs of broadcast spawning cyprinids, TIFP (2018) recommended two pulses of 5,000 cfs, with a duration of seven days for each pulse, during April-September for all sites on the Brazos River below Waco.

Flow requirements of Alligator Gar (*Atractosteus spatula*) are indicative of the flow requirements of fish species that utilize oxbow lakes and other floodplain habitats along Texas rivers. Periodic high flow events during the April through July spawning season provide connection to floodplain habitats where Alligator Gar lay adhesive eggs onto plant matter. Successful recruitment requires pulse flow durations sufficient for eggs to hatch and for larvae to develop and avoid stranding as flood waters recede. A pulse duration of 14 days allows for Alligator Gar eggs to hatch and free-swimming larvae to develop sufficiently to ensure a successful recruitment class. A study on the middle Trinity River in Texas found that strong Alligator Gar year classes were associated with floodplain inundation events with durations greater than 30 days. A study of oxbow lakes developed location specific flood pulse magnitudes necessary for connection to the mainstem Brazos River. To meet the needs of Alligator Gar and other species that utilize floodplain habitats and oxbow lakes, TIFP (2018) recommended reach specific flow requirements along the middle and lower Brazos River (Table E7).

Texas Instream Flow Program (TIFP), 2018, Instream flow study of the middle and lower Brazos River, http://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

Flow Location: Brazos River at Richmond, USGS Gage # 08114000

Table E7. Recommended flow requirements per flow target, timing, frequency, duration, and purpose.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
50,000	Any	~1:2 yrs	3	Oxbow connectivity, foodweb dynamics, fish biodiversity
50,000	May-Jul	~1:2 yrs	14	Alligator Gar recruitment, oxbow connectivity
40,000	Any	~2:3 yrs	3	Oxbow connectivity, foodweb dynamics, fish biodiversity
40,000	May-Jul	~2:3 yrs	14	Alligator Gar recruitment, oxbow connectivity
5,000	Apr-Sep	2/yr	7	Pelagic broadcast spawning cyprinids

Shortcomings: Exact frequency that large flows are required is not known. Large, long-lived species such as Alligator Gar do not need significant recruitment every year for survival. However, good recruitment years are required periodically to ensure survival. Frequency of higher flows could be patterned on historical and/or current occurrence of these flows in the system.

Exact oxbow lake connection flows vary over time as lakes evolve (trend is progressively higher flows to connect as lakes get older and higher sediment deposits separate them from mainstem river). Long-

term maintenance of oxbow lake habitat requires periodic creation of new oxbow lakes (with associated initially frequent connection to mainstem river). New oxbow lake creation appears to have slowed in the Brazos River basin in recent decades.

The mainstem channel of the Brazos River at Richmond shows signs of incision (approximately 1.5 feet per decade). As the main channel of the river degrades, higher flows are required to connect with oxbow lakes. Requirements for higher connectivity flows due to channel incision occur independently of (and in addition to) requirements for higher connectivity flows as oxbow lakes age.

NAME: MARTY KELLY

EMAIL: MARTY.KELLY@TPWD.TEXAS.GOV COMPANY: TPWD

Purpose: Alligator gar are a large-bodied, long-lived periodic strategist. Alligator gar adults and juveniles (particularly juveniles) commonly move into flooded plains to feed opportunistically on insects, amphibians, and other fishes that also exploit temporarily abundant food resources, and for spawning. Allen et al. (2014), Buckmeier et al. (2013), and Kluender et al. (2016) reported the least amount of movement during the cooler winter season and increased movement relative to warmer temperatures and higher water levels associated with their spawning season. Because of the infrequent occurrence of successful reproductive conditions, alligator gar population growth is temporally sporadic, characterizing them as periodic life history strategists (Winemiller et al 1992).

Spawning habitat: Alligator gar are non-guarding open substrate spawners with adhesive eggs that stick to plant materials and require the inundation of floodplain habitat (inundated riparian areas, flood plains, vegetated backwater areas, oxbow lakes, and bottomland swamps). Allen et al. (2020) and Buckmeier et al. (2017) provide comprehensive reviews of previous studies that indicate that Alligator Gar spawning and successful population recruitment in floodplain settings occurs during favorable conditions that correspond to four synchronous environmental criteria:

1. Floods and high flow pulse (HFP) events during the warmer months of April–July with water temperatures of 20–31°C
2. Hydrologically connected inundation depths sufficient to enable fish movement between the river and suitable spawning vegetation cover types on the floodplain.
3. Presence of suitable vegetation cover types including grasses, herbaceous, and/or shrubby, low woody vegetation in low velocity inundated areas
4. Flood durations within suitable vegetation cover types exceeding five days to allow for egg hatching, larval development, and swimming access to rearing environments including permanently wetted floodplain water bodies (e.g., oxbows), tributaries (floodplain or otherwise), or the mainstem river.

Recruitment: Fertilized alligator gar eggs are deposited over vegetation and hatch in approximately 48 hours. Larval fish have special cement glands that allow them to attach to plants or other substrate while developing (Simon 1999) and will remain there for 2 to 4 days drifting back into main channels as

flood waters recede. The preferred habitat of alligator gar is deep slow-moving pools within the main channel of large rivers, as well as backwater areas and oxbow lakes. High flow pulses in spring months are critical to provide a connection between off-channel oxbows and the main river. Such floodplain habitats provide optimum conditions for recruitment and growth of juveniles.

Flow Target: From Buckmeier et al (2017) “At each of these gages, we used the National Weather Service (NWS) classification of “minor flood” to represent conditions that approximated our criteria (i.e., inundate floodplain habitats to a depth of at least 1 m) based on field observations. A suitability value of 1 was assigned when a flood pulse exceeded the minor flood classification for a minimum of 5 days.” Hayden et al (2023) suggests that tributaries are important to ALG during periods of lower flows and higher temps. Table E8 lists flow recommendations.

Table E8. Recommended flow requirements per flow target, timing, frequency, duration, and purpose.

Flow (cfs)	Timing	Frequency	Duration (days)	Purpose
73,000	Any	~1:3 yrs		3 Oxbow connectivity, foodweb dynamics, fish biodiversity
73,000	May-Jul	~1:3 yrs		14 Alligator gar recruitment , oxbow connectivity
42,000	Any	~3:5 yrs		3 Oxbow connectivity, foodweb dynamics, fish biodiversity
42,000	May-Jul	~3:5 yrs		14 Alligator gar recruitment , oxbow connectivity
32,000	Any	~2:3 yrs		3 Oxbow connectivity, foodweb dynamics, fish biodiversity
32,000	May-Jul	~2:3 yrs		14 Alligator gar recruitment , oxbow connectivity
5,000	Apr-Sep	2/yr		7 Pelagic broadcast spawning cyprinids

Flow Location: USGS Gage Name	Location and Associated Reservoir	Environmental Flows
08084000 Clear Fork Brazos River at Nugent, TX	Downstream Fort Phantom Hill Lake	Brazos Standard [6]
08089000 Brazos River near Palo Pinto, TX	Downstream Lake Possum Kingdom	Brazos Standard [9]
08091000 Brazos River near Glen Rose, TX	Downstream Lake Granbury	Brazos Standard [10]
08096500 Brazos River at Waco, TX	Downstream Waco Lake	Brazos Standard [12]
08100500 Leon River at Gatesville, TX	Downstream Proctor Lake	Brazos Standard [13]
08104500 Little River near Little River, TX	Downstream Belton and Stillhouse Hollow Lake	Brazos Standard [15]
08106500 Little River near Cameron, TX	Downstream Granger Lake	Brazos Standard [16]
08111500 Brazos River near Hempstead, TX	Downstream Lake Somerville	Brazos Standard [19]
08116650 Brazos River near Rosharon, TX	Downstream Smithers Lake	Brazos Standard [21]

Complete description, location, and environmental flow standards graphics under 30 TAC §298.480(4) are located [here](#).

Duration: Flooded vegetation exceeding 5 days (Buckmeier et al 2017). Meitzen et al (2023) – This study was specific to the Guadalupe River. HFP occurrences an average of every **1.5 years for a 20-day duration**; small floods that related to the greatest increase in suitable habitat occurred on an average of every 5 years with an average duration of 7.25 days. **TIFP (2018) recommends 14 days.**

Shortcomings: TIFP (2018) recommendations are specifically for the main stem of the Brazos and not appropriate for the tributaries.

References:

ALLEN, Yvonne; Kimmel, Kayla; Constant, Glenn. 2020. Using Remote Sensing to Assess Alligator Gar Spawning Habitat Suitability in the Lower Mississippi River. *North America Journal of Fisheries Management*. Vol 40 Issue 3.

HENDRICKSON, Dean A., and Adam E. Cohen. 2022. Fishes of Texas Project Database (Version 3.0). <http://doi.org/10.17603/C3WC70>. Accessed (November 2023).

MEITZENM, K.M.; Robertson, C.R.; Jensen, J.L.; Daugherty, D.J.; Hardy, T.B.; Mayes, K.B. 2023. Applying Floodplain Inundation Modeling to Estimate Suitable Spawning Habitat and Recruitment Success for Alligator Gar in the Guadalupe River, Texas. *Hydrology*. Vol 10, Issue 123. <https://doi.org/10.3390/hydrology10060123>

TIFP (Texas Instream Flow Program). 2018. Instream flow study of the middle and lower Brazos River. Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, and Texas Water Development Board. https://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/doc/BrazosRiverBasin_FinalRecommendationsReport_180615.pdf

WINEMILLER, K.O.; Rose, K.A. 1992. Patterns of life-history diversification in North American fishes: Implications for population regulation. *Can. J. Fish. Aquat. Sci.* 49, 2196–221.