Candidate Conservation Agreement with Assurances for the Balcones Spike and Texas Fawnsfoot in the Brazos River Basin

Developed Cooperatively by:

U.S. Fish and Wildlife Service – Southwest Region

and

Brazos River Authority

2021

1.0 Introduction

The Brazos River is the third-longest river in Texas, draining approximately 45,000 square miles as it meanders from northwest to southeast across the state. Due to its size and orientation, the Brazos River basin covers multiple ecoregions. From the arid high plains of west Texas, where some Brazos basin tributaries exhibit salinities greater than that of seawater, to the humid gulf prairies and marshes, the basin is home to a diverse array of aquatic fauna. This fauna includes two freshwater mussel species (Balcones spike [*Fusconaia iheringi*] and Texas fawnsfoot [*Truncilla macrodon*]) which are currently candidates for listing under the Endangered Species Act of 1973 (ESA).

Endangered Species Act (Act) policy allows for non-federal property owners who wish to conduct conservation for non-listed species on non-federal lands the opportunity to voluntarily enter into a Candidate Conservation Agreement with Assurances (CCAA). In return, the U.S. Fish and Wildlife Service (USFWS) may issue a permit under section 10(a)(1)(A) of the Act providing incidental take coverage for the species if listed and regulatory assurances. A property owner is defined as a person with a fee simple, leasehold, or property interest (including owners of water rights or other natural resources), or any other entity that may have a property interest, sufficient to carry out the proposed management activities, subject to applicable state law, on non-Federal land (50 CFR §17.3). A CCAA is an agreement between the USFWS and a property owner that provides a mechanism to implement conservation measures aimed at reducing threats to the candidate species, thereby potentially reducing the need for listing. In the event that the species is listed, the property owner receives assurances, through an Enhancement of Survival Permit, that they will not be required to take additional conservation measures beyond those agreed to in the CCAA (50 CFR §§ 17.22(d) and 17.32(d).

The Brazos River Authority (BRA) is a special district of the State of Texas responsible for the development and management of the water resources of the Brazos River basin. Today, the BRA's staff develop and distribute water supplies (Figure 1), provide water and wastewater treatment, and monitors water quality. The BRA has over 250 employees, of which 15 are environmental professionals who were involved in the development of this CCAA, and an annual operating budget of $58.7 million. As such, the BRA has the authority and capacity to properly implement all of the terms of this CCAA.

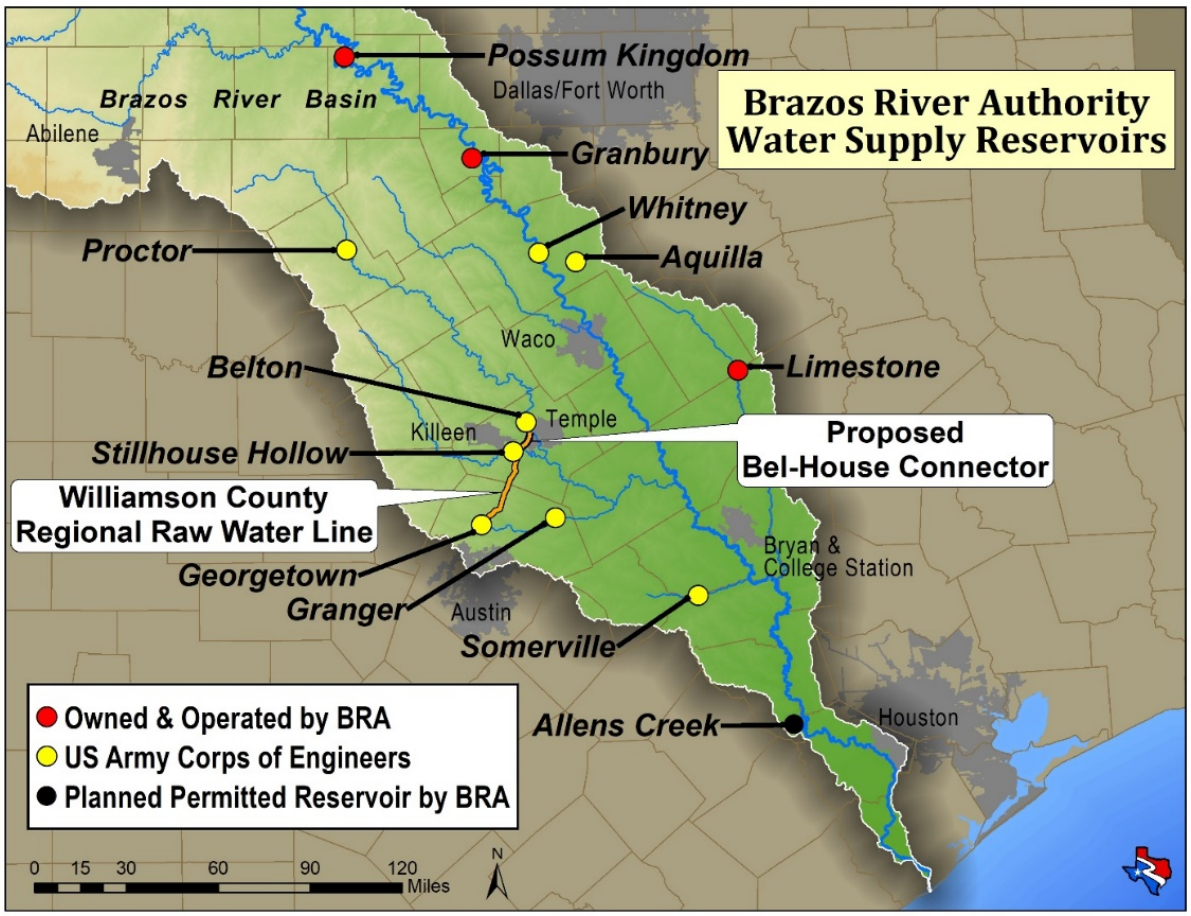


Figure 1. Map depicting Brazos River Authority Water Supply System, "BRA System".

This document represents a voluntary partnership between the Brazos River Authority (BRA) and the USFWS in the form of a Candidate Conservation Agreement with Assurances (CCAA) to address the conservation needs of two species of freshwater mussels currently under review for ESA listing by USFWS (Balcones spike, *Fusconaia iheringi,* and Texas fawnsfoot, *Truncilla macrodon*; collectively referred to as the Covered Species). The Conservation Measures proposed address key current and possible future threats to the Covered Species, to the extent to which those threats are under the control of BRA. The BRA is entering into this CCAA voluntarily to cover BRA's area of influence and does not intend for this agreement to enjoin other property owner's in the basin. The term of this agreement is for twenty years.

1.1 Benefits of this Agreement

This agreement will provide net conservation benefit to the Covered Species through implementation of a comprehensive conservation strategy based on priorities established by national freshwater mollusk experts (FMCS 2016) and tailored to specific threats and hydrologic conditions in the Brazos River basin. BRA is committed to the implementation and funding of the comprehensive conservation strategy described herein. This strategy includes research and monitoring to gain further knowledge of the Covered Species, avoidance to protect existing populations, education and outreach to engage the public, and employs both collaborative

conservation and adaptive management principles to develop a comprehensive adaptive management program that involves collaboration with partners including TPWD and USFWS. It also includes the development of conservation zones and future hydrology modeling to prioritize areas for implementation of specific conservation measures designed to reduce current and future threats to the Covered Species, including avoidance of areas known to support mussel populations. Current threats to the species are summarized in Section 4.0. The conservation strategy, conservation zones, hydrologic modeling, and specific conservation measures are outlined in detail in Section 6.0, 7.0, 8.0, and 9.0, respectively. Conservation measures include: research into how compliance with existing Texas Administrative Code Title 30, Chapter 298 - Environmental Flow Standards for Surface Water (where applicable) provide for the ecological needs of mussels, and work with TCEQ to refine these standards specifically to provide additional benefit to freshwater mussels; avoidance of specific activities in areas known to harbor key populations of the Covered Species; additional applied research to examine the effects of various stressors to Covered Species; long-term monitoring of Covered Species populations, host fish, water quality, and substrate/channel morphology in key areas; surveys to fill existing data gaps in distributional information; updated hydrologic modeling to evaluate future risk to Covered Species; education and outreach to garner public interest in mussel conservation and habitat enhancements; and supporting development of emergency short-term refugia protocols and captive propagation for the Covered Species. Although this agreement specifically provides net conservation to benefit the Covered Species, many of the implemented conservation measures will result in beneficial impacts to other mussel species (**Appendix A**), fish, and native aquatic biota within the Brazos River basin.

Net Conservation Benefit

The agreement, when fully implemented, is expected to provide a net conservation benefit to the Covered Species by the end of its 20–year term. The conservation measures described in the agreement will reduce the extent and severity of threats to populations of the Covered Species that currently occupy stream reaches identified for protection in the agreement. The identification of avoidance and minimization zones will reduce threats associated with physical disturbance associated with the construction of new water supply and delivery infrastructure. Applied research, long-term monitoring, and an adaptive management program tied to changed circumstances will reduce threats associated with periods of critical low flows by providing the BRA with specific trigger points that consider the ecological needs of Covered Species when BRA makes drought management decisions. The BRA system of reservoirs allows BRA the flexibility to adjust to regional drought conditions and provide downstream water users from multiple reservoirs, and in the process provide for environmental flows that consider the needs of the Covered Species. The combination of reduced threats associated with physical disturbance and critical low flows will allow populations to naturally increase in terms of both number of individuals and extent of physical habitat occupied. Measures to guard against critical low flows will also protect against water quality degradation. as cleansing flows dilute potential toxicants. Twenty years represents approximately 2-5 generations for the Covered Species, and increases in population number and extent are expected to be measurable within 20 years and a long-term monitoring program is implemented to document these increases. Opportunities to accelerate

natural increases in population number and extent are anticipated by this agreement as BRA will provide funding for or otherwise assist TPWD and USFWS with population augmentation and species reintroduction efforts, and identify stream reaches appropriate for restoration of mussels. To that end, the BRA will work directly with TPWD and USFWS to translocate individuals of Covered Species in the event of a catastrophic drought (worse than the drought of record) and to reintroduce the Covered Species within currently occupied or historically occupied stream reaches, assuming those actions are deemed to be appropriate by TPWD and USFWS at that time. BRA, through its own actions and by engaging willing partners, will work to demonstrate that a net conservation benefit has been realized within 20 years of the execution of this agreement.

1.2 Purpose of this Agreement

The purpose of this agreement is to provide a mechanism for BRA to implement a variety of conservation measures to benefit the Covered Species within the Covered Area. The conservation measures chosen are specifically designed to maintain and/or increase resiliency, redundancy, and representation, providing a net conservation benefit for the Covered Species, while allowing for ongoing and continued water supply development activities to meet the growing demands of an increasing population within the Brazos River basin over the term of the CCAA. Implementation of the conservation strategy and its conservation measures are expected to result in population increases and habitat improvements for the Covered Species over the twenty-year term of the agreement.

Species Status Assessment (SSA)

In October 2018, the USFWS made a draft of the Species Status Assessment Report for the Central Texas Mussels (SSA report) available for peer and partner reviewers. BRA staff provided partner review and participated in the SSA Science Expert meeting in June 2017. The SSA report assessed the current condition of known populations of the Central Texas Mussels, including Balcones spike and Texas fawnsfoot, and ranked each population as Healthy, Moderately Healthy, Unhealthy, or Functionally Extirpated (Table 5.2; p. 73). For the Brazos River basin, one population of Balcones spike (the Little River basin population) was identified and that population considered to be Unhealthy, primarily because few individuals were found during population surveys and because a low number of sites had evidence of reproduction (Table 5.3; p. 74). One goal of this CCAA is to improve the Balcones spike population in the Little River to an overall Moderately Healthy condition, where Balcones spike can be found in approximately half of all appropriate habitats with more than 25 individuals detected in each survey, and where about half of sites have evidence of reproduction (Table 5.2; p. 73).

The SSA report similarly assessed the current condition of known populations of Texas fawnsfoot (Table 5.6; p. 91) where the Upper Brazos population was ranked as Unhealthy and the Lower Brazos population was ranked as Moderately Healthy (Table 5.7; p. 92). Another goal of this CCAA is to improve the overall condition of the Upper Brazos population of Texas fawnsfoot to Moderately Healthy and to improve the overall condition of the Lower Brazos population of the Texas fawnsfoot to Healthy (Table 5.7; p. 92). BRA will accomplish these goals by reducing threats to the Balcones spike and Texas fawnsfoot in the Brazos River basin,

primarily associated with low flows, reduced substrate suitability, and degraded water quality. BRA will also work with the Service to augment existing populations and reintroduce populations using captive-reared individuals. A third goal of this CCAA is to work with the USFWS to re-establish at least one population each of the Balcones spike and Texas fawnsfoot in the Brazos River basin. These goals are ambitious and while BRA will strive to reach these goals in cooperation with the USFWS, attainment of these goals is not the only way to demonstrate a net conservation benefit by the end of the 20-year term of the CCAA.

2.0 Authority

Sections 2, 7, and 10 of the ESA, along with the Fish and Wildlife Coordination Act, allow USFWS the authority to enter into this agreement. This agreement is prepared in accordance with the USFWS's 1999 CCAA Final Policy (64 FR 32726) and 2016 revisions to the Candidate Conservation Agreements With Assurances Policy (81 FR 95164), which became effective on March 21, 2017 (82 FR 8540). The authority for this action is the Endangered Species Act of 1973, as amended (16 U.S.C 1531 *et seq.*).

3.0 Covered Species

The conservation measures described in this document are designed specifically to provide a net conservation benefit to the Covered Species, and specific details on the distribution and biology of each of these species are provided below. However, the Covered Species often co-occur with other species of native freshwater mussels which will also benefit from this agreement. The other species of native freshwater mussels known to occur in the Brazos River basin are listed in **Appendix A**. In addition to freshwater mussels, this agreement will also benefit other fish and aquatic species in the basin by preserving habitat, maintaining environmental flows, and supporting appropriate water quality conditions for a healthy aquatic community and riverine ecosystem as a whole.

3.1 Balcones Spike

Balcones Spike *Fusconaia iheringi* is a newly recognized species elevated from synonymy with False Spike *Fusconaia mitchelli* (Smith et al. 2020). Prior to the split of Balcones Spike, False Spike (formally described at *Quadrula mitchelli*; Pfeifer et al. 2015) was endemic to the Guadalupe, Colorado, and Brazos river basins of central Texas (Howells et al. 1996; Howells 2014). Balcones Spike is now considered endemic to the Colorado and Brazos river basins, whereas False Spike occurs in the Guadalupe River basin (Smith et al. 2020). Balcones Spike is a medium-sized species most frequently observed at shell lengths ranging from 50 mm to 65 mm (Randklev et al. 2017a) and has a maximum shell length of at least 96 mm (Smith et al. 2020). Shell can be compressed to moderately inflated and its shape is generally sub-quadrate. Balcones Spike is more inflated in Brazos River drainages compared to the Colorado River basin (Smith et al. 2020). Beak is narrow to broad, slightly elevated above the hinge ligament, and typically sculptured with multiple strong w-shaped or double-looped bars (Howells et al. 1996; Howells 2014; Smith et al. 2020). Posterior ridge is moderately sharp dorsally and becomes more broadly rounded towards to the ventral margin (Smith et al. 2020). Periostracum yellow-green to brown

and may have green rays. Nacre is white, with heavier pseudocardinal teeth and light lateral teeth (Howells et al. 1996; Howells 2014; Smith et al. 2020).

For over 30 years, Balcones Spike was believed to be extirpated from the majority of its range or possibly extinct, with no live individuals observed from the late 1970's to early 2010's (Howells 2002; Howells 2003; Randklev et al. 2012). In 2012, live individuals were collected from the San Saba River (Colorado basin), confirming the species was still extant (Randklev et al. 2012). Since then, recent surveys have also observed live individuals in the Little River drainage (Brazos basin), confirming that Balcones Spike still persists within both the Colorado and Brazos basins (Randklev et al. 2013a, b; Randklev et al. 2017a). Currently, the species is known to occur within three distinct areas: Llano River (Colorado basin), San Saba River (Colorado basin), and Little River basin (a Brazos River tributary; Smith et al. 2020).

Historically, within the Brazos basin, Balcones Spike specimens were documented from the Leon River (Bell and Coryell counties; Strecker 1931; Popejoy et al. 2018) and the mainstem Brazos River (Somervell County; Strecker 1931; Randklev et al. 2017a). Recently, Balcones Spike has been observed in the mainstem Little River, with a few live individuals also found in nearby lower Little River tributaries, including the San Gabriel River downstream of Granger Lake, and Brushy Creek near the San Gabriel River confluence (**Figure 2**; Randklev et al. 2013b; Randklev et al. 2017a). However, recent surveys (Bonner et al. 2018) failed to find live individuals at ten sites in the mainstem Little River, suggesting that the species' distribution may be restricted in the Little River basin to near the San Gabriel River confluence. Gravid females were observed within the Little River, San Gabriel River, and Brushy Creek (Randklev et al. 2017a), and a sub-adult (~20 mm) was found in Brushy Creek, indicating that recruitment has recently occurred at some capacity in the Little River basin (Randklev et al. 2017a). Although present in the lower Little River basin, Balcones Spike has not been documented recently from either of the major Little River tributaries (Leon River and Lampasas River). Randklev et al. (2013c) failed to detect Balcones Spike in the Leon River, suggesting that this species may be extirpated from this tributary. A recently dead specimen was reported from the Lampasas River in 1980 (Randklev et al. 2017a); however, there are no recent records of live Balcones Spike from the Lampasas River basin.

Similar to False Spike, Balcones Spike is most frequently associated with fluvial habitats (Howells 2014). Previous surveys observed Balcones Spike most frequently in riffles compared to lentic habitats, although observations are limited (Randklev et al. 2017a).

Life history strategy of Balcones Spike is currently unknown, but Balcones Spike early life history is likely similar to the False Spike. False Spike and other similar mussels parasitize on host fish during the larval stage (i.e., glochidia), receiving nutrition and transport from the host until dropping off as fully-developed juveniles (Barnhart et al. 2008; Fritts et al. 2012; Dudding et al. 2019). False Spike is a short-term brooder that releases glochidia via conglutinate packets during a brief period following glochidia maturation. A study in the lower Guadalupe River observed peak sperm production from late January to early March and gravid females from February to June (Dudding et al. 2020). Confirmed host fish of False Spike include Blacktail

Shiner *Cyprinella venusta* and Red Shiner *Cyprinella lutrensis* (Dudding et al. 2019). Based on this, Balcones Spike most likely also utilize cyprinids as host fish.

Physiological responses and tolerance limits to variations in water quality are also currently unknown for Balcones Spike, but limited data is available for the closely related False Spike. A recent study by Bonner et al. (2018) estimated optimal temperatures for organism growth of 28°C for False Spike from the lower Guadalupe River, and the divide between sublethal and lethal thermal stress was estimated at 31°C. An additional study tested upper thermal tolerances of False Spike adults from the lower Guadalupe River, estimating the 24-hour LT_{05} (i.e., temperature when 5% of the test individuals died) at about 35.4°C and the 10-day LT_{05} at 28.4°C. Lethal LT_{50} (i.e., temperature when 50% of the test individuals died) was estimated to range from 36.2°C for 24-hours to 32.4°C for 10-days (Khan et al. 2020a). Lastly, LT_{50} of False Spike glochidia was estimated at 36.1°C for 12-hours (Khan et al. 2019).

Molecular evidence supports genetic isolation between the Colorado River basin and Brazos River basin Balcones Spike populations (Pfeiffer et al. 2015; Smith et al. 2020). Based on molecular research, each basin likely represents a distinct evolutionarily significant unit (Pfeiffer et al. 2015; Smith et al. 2020).

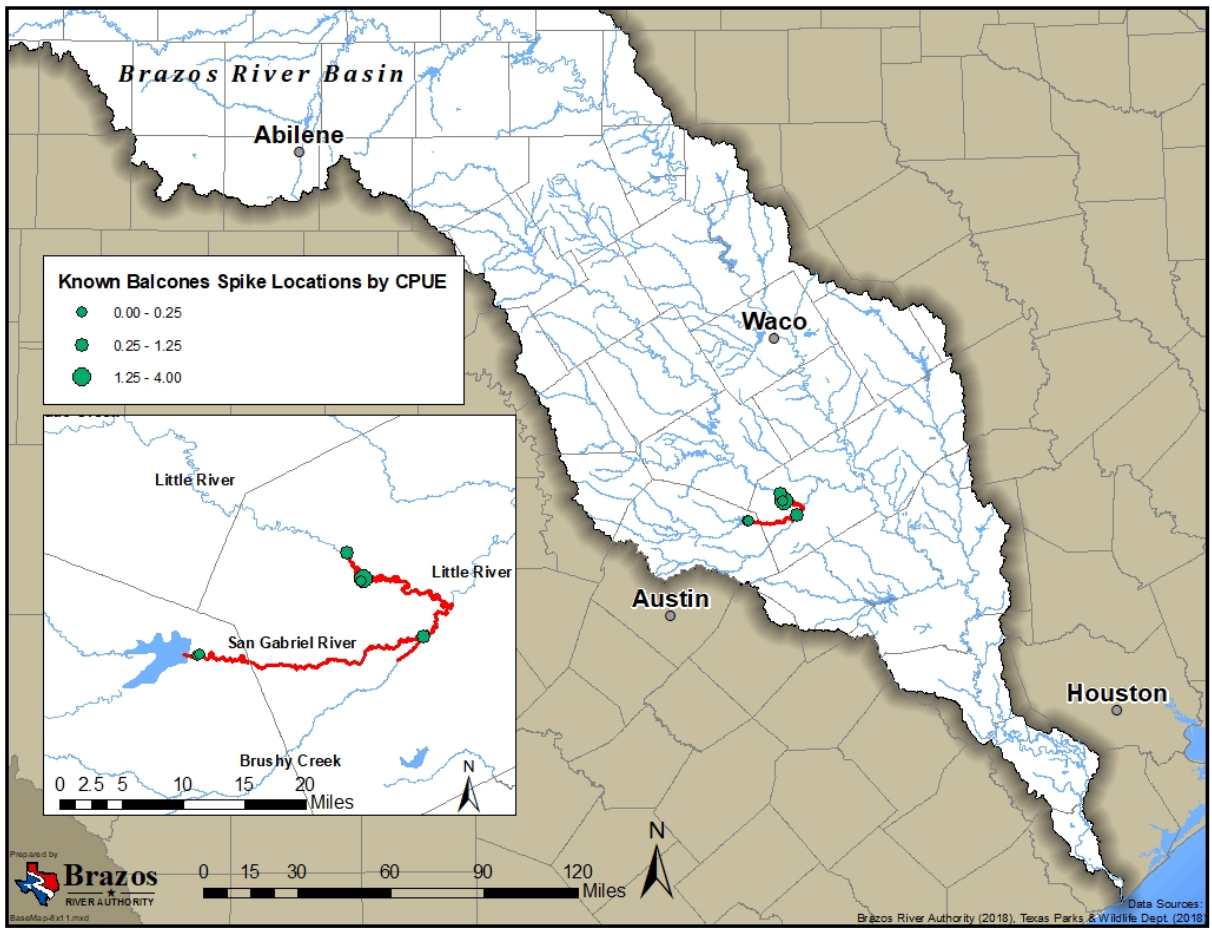


Figure 2. Currently known distribution (occupied stream segments shown in red) and catch-per-unit-effort (CPUE) of Balcones spike within the Brazos River basin.

3.2 Texas Fawnsfoot

The Texas fawnsfoot *Truncilla macrodon* (Lea 1859) is a species of freshwater mussel endemic to the Brazos and Colorado River basins of central Texas (Strecker 1931; Howells et al. 1996; Howells 2014). Recent phylogenetic research suggests that specimens from the Trinity River basin thought to be Fawnsfoot *T. donaciformis* are actually Texas fawnsfoot, extending the species' range further east (Inoue et al. 2017).

Shells are typically small (60 mm or less in length), elongate oval and compressed (Howells et al. 1996; Howells 2014). The beak is above the hinge line with sculpture described as 3-6 single looped concentric ridges, though 1-2 heavier ridges may be present (Howells et al. 1996; Howells 2014). The periostracum is typically light yellow or brown with green rays (Howells et al. 1996; Howells 2014). Similar to other *Truncilla* species, Texas fawnsfoot will often have green rays broken into chevron-like patterns (Howells et al. 1996; Howells 2014). In the shell interior, the nacre is white, pseudocardinal teeth are compressed, and lateral teeth are thin (Howells et al. 1996; Howells 2014).

Within Brazos River basin, historic and zooarchaeological shell records indicate Texas fawnsfoot was widespread (Strecker 1931; Popejoy et al. 2018). The species historically occurred in the mainstem Brazos River (Brazos & Robertson Counties) and in multiple tributaries, including the Leon River (Coryell County), Aquilla Creek (McLennan County), Bosque River (McLennan County), and North Bosque River (McLennan County; Strecker 1931). However, from the time the species was described in 1859 to 2008, only two live specimens were observed, one from the Little Brazos River and one from the mainstem Brazos River. This caused some to question whether viable populations existed (Howells 1996, 1997). However, few extensive surveys were done in this time period and the small size of Texas fawnsfoot allows it to easily go undetected. In 2008, 10 live individuals were observed in the lower Brazos River (Grimes & Washington Counties) and a population was also discovered in the lower Colorado River (Burlakova & Karatayev 2010; Randklev et al. 2010). Since then, the species has been documented at multiple other locations (Johnson and Groce 2012; Randklev et al. 2014a, b; Randklev et al. 2017a, b; TxDOT 2017; Khan et al. 2018; Bonner et al. 2018). Texas fawnsfoot is currently thought to occur in seven distinct areas: the lower Colorado River, the lower San Saba River and nearby stretches of the middle Colorado River, the lower Brazos River and nearby segments of some tributaries (lower Little River, lower Navasota River), the middle Brazos River between Possum Kingdom Reservoir and Lake Granbury, the Clear Fork Brazos River, the middle Trinity River, and the East Fork of the Trinity River (USFWS 2018).

Within the Brazos River basin, recent survey efforts have found Texas fawnsfoot to occur in multiple locations within the three general reaches identified above (**Figure 3**; Karatayev & Burlakova 2008; Randklev et al. 2009; Randklev et al. 2014a, b; Tsakiris & Randklev 2016b; Khan et al. 2018, Bonner et al. 2018). In the Clear Fork Brazos River, 223 recently dead (i.e., nacre still fresh) shells and one live individual were collected during the drought of 2011 near Fort Griffin (HDR 2012). However, surveys at Fort Griffin and two other sites on the Clear Fork in 2017 found only one live mussel and failed to collect any live Texas fawnsfoot, calling into question the status of this population (Bonner et al. 2018). In the middle Brazos River between

Possum Kingdom and Lake Granbury, Khan et al. (2018) observed Texas fawnsfoot as the most abundant mussel species present, although overall abundance and diversity of mussels was rather low. Bonner et al. (2018) found one live juvenile in this reach, suggesting that recruitment is occurring in this stretch. In the lower Brazos River between Waco and Sealy, Texas fawnsfoot was sporadically found, but the species was relatively abundant in some locations (Randklev et al. 2014a, b). It was also observed the Little River upstream of the San Gabriel River confluence and the lower Navasota River in close proximity to the Brazos River confluence (Randklev et al. 2017a, Khan et al. 2018).

Habitat utilization of Texas fawnsfoot appears to be variable with individuals found in a variety of habitat types. In the middle Brazos River and Little River, Texas fawnsfoot has been most frequently observed in riffle habitats (Randklev et al. 2014a, b; Randklev et al. 2017a; Khan et al. 2018). In the lower Brazos River, the species is associated with substrates dominated by pebble or gravel and most frequently observed in deep banks, though observations also occurred in point bar and backwater habitats (Randklev et al. 2014a, b). In the lower Colorado River, Texas fawnsfoot were most commonly found in run edge habitats (Bonner et al. 2018). In the Trinity River, this species was observed in bank and riffle habitats (Randklev et al. 2017b).

Little is known regarding the life history requirements of Texas fawnsfoot (Howells 2014). They are presumed to have a similar reproductive cycle to other *Truncilla* species, which are long-term brooders that parasitize solely on Freshwater Drum *Aplodinotus grunniens* to complete their life cycle (Howells 2014; Barnhart et al. 2008).

Molecular evidence indicates genetic isolation among drainages, and the existence of three separate evolutionarily significant units, which supports that Texas fawnsfoot in the Brazos River basin should be considered a separate conservation unit from the Colorado and Trinity River basins (Inoue et al. 2017). Maintaining representation of Texas fawnsfoot across the three river basins is important for ensuring long-term viability of the species (USFWS 2018).

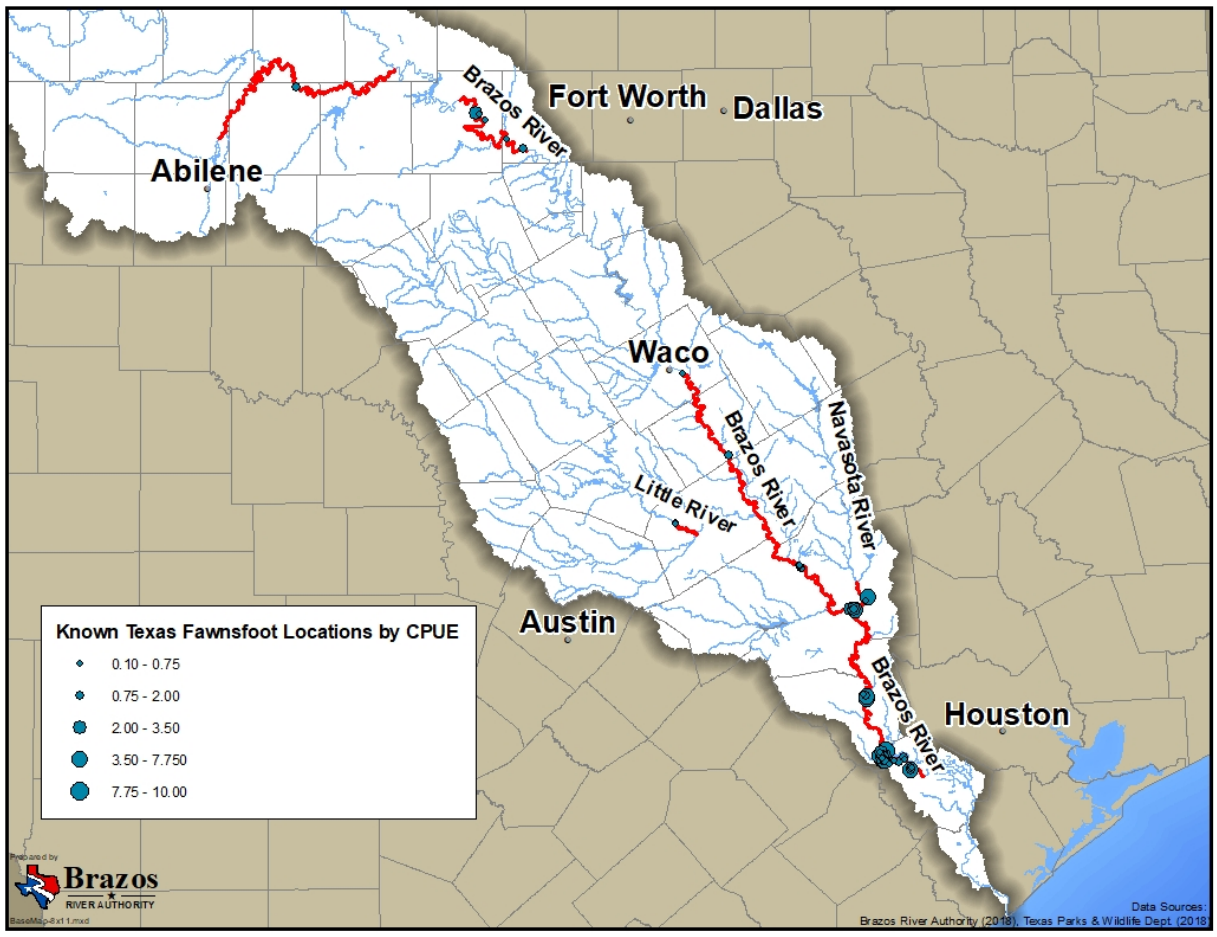


Figure 3. Currently known distribution (occupied stream segments shown in red) and catch-per-unit-effort (CPUE) of Texas fawnsfoot within the Brazos River basin.

4.0 Threats

4.1 Degradation, Loss, and Fragmentation of Habitat

A variety of natural and anthropogenic factors can lead to degradation, loss, or fragmentation of habitat for the Covered Species. Factors influencing water quality and quantity have the potential to degrade mussel habitat, as described in Section 4.2. Sedimentation from runoff and erosion can alter substrate conditions and lead to degradation of mussel habitat. Inundation by reservoirs or desiccation during drought conditions can lead to loss of habitat. Finally, fragmentation can occur as mussel populations become separated by dams or expanses of poor habitat. Such fragmentation can restrict gene flow and result in genetic isolation of previously connected populations.

4.2 Water Quantity

The increase in human demand for water resources has resulted in the modification of riverine systems through groundwater pumping, construction of reservoirs, surface water diversions, and discharges. Resulting alterations to the natural flow regime may change the magnitude, frequency, duration, timing, and flashiness of a river or stream (Poff et al. 1997), thus changing

the temporal and spatial distribution of water quantity and influencing instream organisms such as freshwater mussels.

Large reservoirs typically result in changes to the natural hydrology which include: decreases in peak discharges, increases in minimum flows, increases in base flow levels, and alterations to the timing of low and high flow events (Zhang and Wurbs 2018; Graf 2006; Kondolf and Batalla 2005; Magilligan and Nislow 2005; Wellmeyer et al. 2005). The Brazos basin currently contains 17 major reservoirs for flood control and water supply (Brazos BBEST 2012) and hundreds of surface water diversions, which both influence the distribution and availability of water. As in other areas, post-reservoir hydrology data from the lower Brazos River basin indicate increased base flows, reductions in the duration of extreme low flow events, and reductions in the overall magnitude of high flow pulses (BRA unpublished data). These conditions could potentially have positive influences on mussel communities by preventing desiccation during drought conditions and preventing displacement during extreme high flow events. However, altered hydrology can also negatively impact mussel populations. High water velocities associated with increased base flows can potentially displace settling juveniles before they can establish (Layzer and Madison 1995). Altered hydrology can also lead to changes in bedload movement and sediment scour, displacing juvenile mussels (Layzer et al. 1993). Such hydrologic changes may result in changes to mussel community composition by favoring mussels with certain life history strategies (Khan et al. 2020b). Reductions in water temperature resulting from hypolimnetic reservoir releases may also limit mussel reproduction (Layzer et al. 1993), whereas increases in water temperature due to altered hydrology may negatively impact mussel populations (Khan et al. 2020a). Additionally, deviations to the timing of high and low flows may prevent the presence of the required host fish species during mussel reproductive seasons (Freeman & Marcinek 2006; Gido et al. 2010).

4.3 Water Quality

Anthropogenic activities that alter flow regimes and landscapes may exacerbate natural fluctuations in water quality, and thus influence survival, growth, and reproduction of freshwater mussels (Strayer 2008). Reductions in surface flows have been shown to elevate surface water temperatures and reduce dissolved oxygen concentrations, which may result in high mussel mortality (Gagnon et al. 2004; Golladay et al. 2004; Haag & Warren 2008). Moreover, drought conditions have been shown to cause gravid females to abort immature glochidia, limiting reproductive output, and potentially causing recruitment failure (Aldridge & McIvor 2003).

The input of excess ammonia and nutrients (e.g., nitrate, total phosphorus) also pose a threat to freshwater mussel persistence. In the Brazos basin, the percent of cultivated land at the reach scale and the percent of urban land at the catchment scale have been associated with increased instream nutrient concentrations (Becker et al. 2014). Exposure to elevated levels of ammonia can have lethal and sublethal effects on juvenile mussels and has been implicated as one of the main contributors to the overall decline of mussels throughout North America (Strayer et al. 2004; Newton & Barsch 2007; EPA 2013). This observed sensitivity to ammonia caused the Environmental Protection Agency (2013) to consider the physiological tolerances of mussels when recommending aquatic life criteria for acute (1-hour average: 17 mg TAN/L) and chronic

(30-day rolling average: 1.9 mg TAN/L) exposure to ammonia. In addition to surface runoff, return flows from various entities such as wastewater treatment plants may result in elevated nutrient loading to rivers and lakes. Elevated levels of ammonia and nitrate directly downstream of a wastewater treatment plant in the Grand River, Ontario, Canada has been associated with the extirpation of mussel populations in large sections downstream of the treatment plant (Gillis et al. 2017).

Another water quality issue in the Brazos River basin is the presence of Golden algae. Golden algal blooms produce toxins fatal to various aquatic biota and resulted in multiple fish kills from 2000-2012 in the stretch of river from Possum Kingdom Reservoir downstream to Lake Whitney (Patiño et al. 2014). While Golden algae events do occasionally occur within the reservoirs, there have been no documented Golden algae events in the river since 2012. In addition to fish, these toxic algal blooms may influence freshwater mussels in these areas, although specific data on the effects to freshwater mussel populations is lacking.

4.4 Runoff and Erosion

The landscape within a watershed has a strong influence on channel morphology and hydrodynamics of lotic systems (Brim-Box & Mossa 1999; Newton et al. 2008). Alterations to the landscape (e.g., urbanization, agriculture) have been shown to increase runoff and erosion, which are major contributors to excess fine sediment inputs in river systems (Brim-Box & Mossa 1999). Sedimentation has been shown to negatively impact unionids as well as the ecological integrity of streams, including changes in stream geomorphology, water quality, and reductions in substrate complexity (Poff et al. 1997; Brim-Box & Mossa 1999). Much of the landscape in the Brazos River basin has been modified into rangeland (57%), cropland (24%), and urban development (16%; Dahm et al. 2005). Excess fine sediment inputs have been documented in the Brazos River basin (Dunn and Raines 2001) and pose a potential threat to the Covered Species.

Along with landscape alterations, in-channel modification can alter flow regimes and thus patterns of sediment deposition and scour (Petts 1980; Ligon et al. 1995; Baxter 1997). The Brazos basin currently contains 39 reservoirs with storage capacities of 5,000 acre-feet or greater (Vogl and Lopes 2009). Elevated base flows from dam releases can cause bed scour, which channelizes the river and decreases habitat diversity (Poff et al. 1997). Channelization can also lower the base level of a river and initiate upstream erosion (i.e., head-cutting; Shields et al. 2000).

4.5 Barriers to Dispersal

Dispersal is dependent on movement of host fish and serves several important functions such as connecting subpopulations within the occupied range of a species or allowing a species to move into formerly uninhabited areas (Strayer 2008). Degradation and loss of habitat due to anthropogenic actions may lead to large sections of unsuitable mussel habitat, thus reducing dispersal success (Strayer 2008). Dams can act as permanent barriers to host fish movement, and hydroelectric dams may impinge or entrain hosts and result in mortality (Watters 1996; Newton et al. 2008; Rytwinski et al. 2017). Barriers to dispersal pose a threat to the Covered Species and may prevent intrapopulation connectivity and range expansion.

4.6 Overutilization

Commercial harvest historically influenced freshwater mussels throughout North America and was common in Texas during the 20th century (Howells et al. 1996; Haag 2012). However, currently minimal commercial harvest occurs in Texas. Additionally, harvest is prohibited in some areas identified as mussel sanctuaries by TPWD (Howells 2014). One of these mussel sanctuaries occurs in the Brazos River basin and includes the Brazos River from the dam at Possum Kingdom Reservoir in Palo Pinto County downstream to FM 2580 in Parker County (31 TAC 57.157), a reach of river included in this CCAA. Recreational fishermen sometimes use the soft tissues of mussels as bait. Although the exact level of harvest for bait is unknown (Howells 2014), it is expected to be minimal. The collection of mussels for scientific studies has also been suggested as contributing to the threat of overutilization of freshwater mussels in Texas (USFWS 2018).

4.7 Exotic Species

In the Brazos River basin, the Asian clam *Corbicula fluminea* has been well established for an extended period of time (Fontanier 1982; Karatayev et al. 2005). This species competes with native mussels for space and food (Strayer 1999; Vaughn & Spooner 2006; Ferreira-Rodriquez et al. 2018). Moreover, Asian clams are sensitive to rapid increases in temperature, resulting in mass die offs which have been shown to cause spikes in ammonia concentrations, a known stressor to native mussels (Cherry et al. 2005; Cooper et al. 2005; Newton & Barsch 2007).

The Zebra mussel *Dreissena polymorpha* has been recently introduced to Texas and is currently found in 5 river basins, including the Brazos (TPWD 2019). In the Brazos basin, this invader was first discovered in Lake Belton (Leon River) in 2013 and has since been found in Lake Georgetown, Stillhouse Hollow Lake, and Granger Lake. It is also present in the river systems downstream of these lakes including the Lampasas, Leon, and Little River (TPWD 2019; Bonner et al. 2018). Dreissenid mussels can cause major abiotic alterations in freshwater ecosystems and have had large impacts on aquatic organisms such as freshwater mussels (Baker & Levinton 2003; Burlakova et al. 2014). Like Asian clams, Zebra mussels compete for space and food with native mussels and also has been found aggregated on the posterior end of mussels, preventing the ability of the native mussel to filter, leading to mortality (Nichols & Wolcox 1997; Baker & Levinton 2003). Typically, dreissenid mussels densely colonize slow moving areas of lakes and reservoirs, but do not form dense aggregations in swift flowing river environments. As a result, Zebra mussels are not currently considered a major threat to riverine systems (Karatayev et al. 2017) because they are generally not found in flowing water habitats characteristic of the Covered Species. Since Zebra mussels have invaded certain areas occupied by the Covered Species, continued monitoring is important to evaluate the long-term impacts of this invasive species.

4.8 Climate Change

The ramifications of climate change are expected to intensify several of the threats mentioned above (Wuebbles et al. 2013). Future climate projections predict an increase in annual temperatures throughout the Southwestern United States, with the number of hot days (> 95° F) in Texas expected to double by 2050 (Kinniburgh et al. 2015). Additionally, precipitation

patterns are expected to become more variable, with more intense precipitation events and longer dry periods in between (Kloesel et al. 2018). This will result in more soil moisture stress and influence both surface water and groundwater recharge (Loaiciga et al. 2000; Mace & Wade 2008; Taylor et al. 2012; Kloesel et al. 2018). Climate change combined with expected increased utilization of groundwater resources may result in increased drought frequency and intensity within the Brazos basin (Wuebbles et al. 2013).

5.0 Covered Area

As a Special District of the State of Texas, the BRA is tasked with developing, managing, and protecting the water resources of the Brazos River Basin. For the purposes of this CCAA, the Covered Area is defined as properties owned by the BRA along with areas of the BRA's water supply system (System) within the Brazos River basin (**Figure 4**). The current System includes the three reservoirs BRA owns and operates, Possum Kingdom Lake, Lake Granbury, and Lake Limestone, and conservation storage space in eight U.S. Army Corps of Engineers (USACE) reservoirs, Lakes Proctor, Belton, Stillhouse Hollow, Georgetown, Granger, Somerville, Whitney, and Aquilla. Infrastructure currently associated with BRA's raw water supply operations include the System reservoirs, the East Williamson County drinking water intake structure on Lake Granger, and the Williamson County Regional Raw Water Line (WCRRWL) connecting Lake Stillhouse Hollow to Lake Georgetown. A currently proposed water supply pipeline (Bel-House Connector) will also connect Lake Belton to Lake Stillhouse Hollow. Additionally, BRA has only just recently incorporated groundwater into its formerly all surface water-based System, with the completion of a well into the Trinity Aquifer in east Williamson County.

The Covered Area will include the stream reaches below System reservoirs and associated infrastructure described above (**Figure 1**). Possum Kingdom Reservoir represents the upstream-most BRA-operated infrastructure in the Brazos River basin, and the current Water Management Plan (WMP) focuses on operations of the water supply infrastructure from this point downstream. Brazos River Authority has no infrastructure and limited interests above Possum Kingdom reservoir, and therefore, has no way to directly influence freshwater mussel populations or their habitats in this portion of the basin. However, since the Texas fawnsfoot has been previously documented in the Clear Fork of the Brazos River, the Covered Area was extended to include the Clear Fork of the Brazos River up to Nugent and the mainstem of the Brazos River from the headwaters of Possum Kingdom Lake to the confluence with the Clear Fork of the Brazos River.

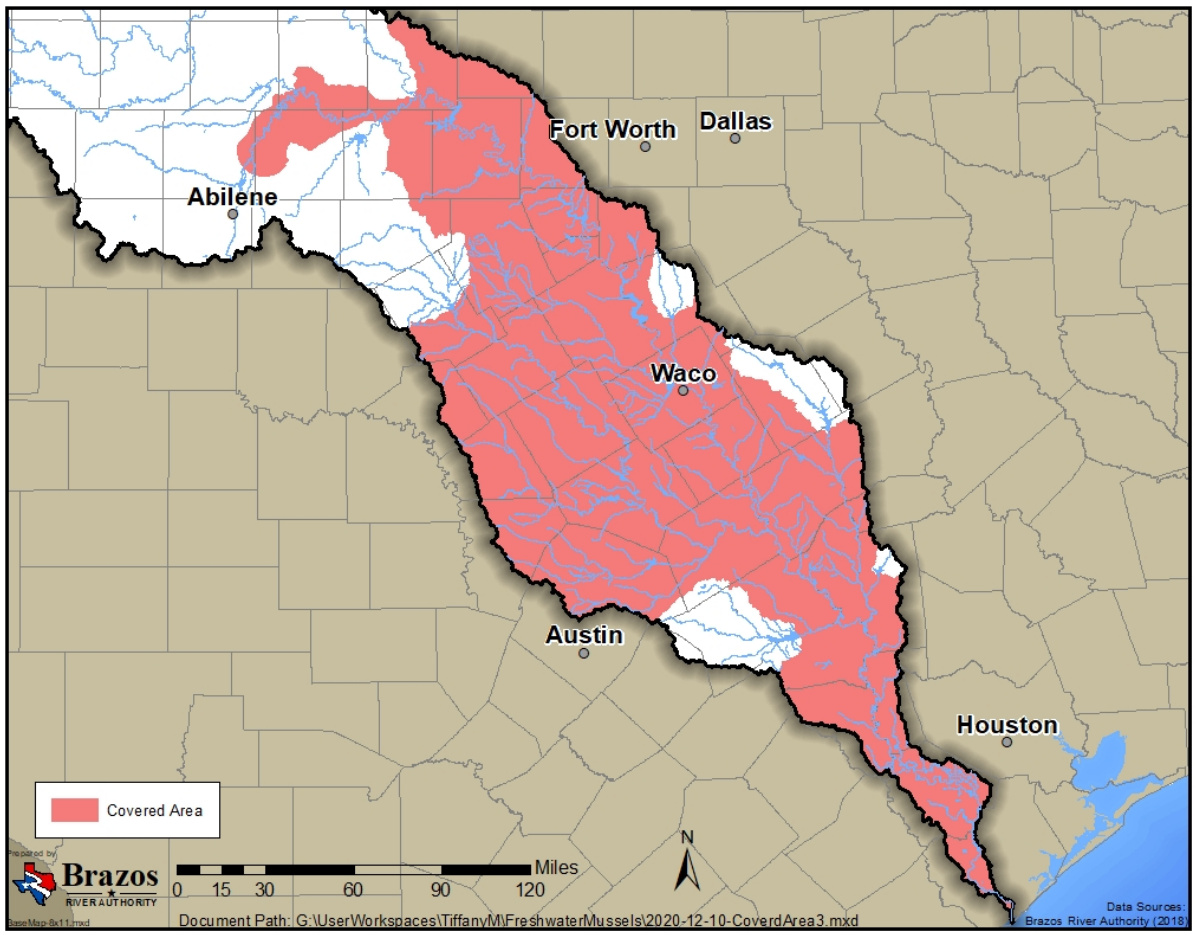


Figure 4. Covered Area.

6.0 Conservation Strategy

The conservation strategy used in this document is based on the Freshwater Mollusk Conservation Society's National Strategy for the Conservation of Native Freshwater Mollusks (FMCS 2016). This publication outlines 10 issues considered as top priorities for freshwater mollusk conservation. **Table 1** provides a list of the 10 issues outlined in the national strategy, a summary of the goals provided in the strategy, and a summary of how the specific conservation measures outlined in this document address each goal, with respect to the Covered Species and their habitats as they occur in the Covered Area.

Although the conservation measures outlined below correspond well with each of the 10 issues identified in the national conservation strategy, they were further refined to address specific threats to the Covered Species in the Brazos River basin. These threats are summarized in Section 4.0. **Table 2** provides a list of the threats identified, the conservation measures that address each threat, and the anticipated results. Additional details on specific conservation measures can be found in Section 9.0.

To assist in guiding implementation of conservation measures, the Covered Area was split into Mussel Conservation Zones based on the current occurrence and abundance of freshwater mussels, as outlined in Section 7.0. Resulting Mussel Conservation Zones allowed for prioritizing specific conservation activities to target key mussel populations. This prioritization, along with future refinements made during the adaptive management process, will help ensure efficient and effective contributions to achieving a substantial net conservation benefit for the Covered Species over the 20-year term of the CCAA and permit.

Lastly, as summarized in Section 8.0, hydrologic modeling was conducted to evaluate future risk of low-flow impacts throughout the Covered Area. The hydrologic modeling approach considers multiple future water-use scenarios defined by regional water planning groups and the BRA, and represents the best estimated projection of water management during the permit period. This allowed for further refinement of conservation measures to prioritize conservation activities in areas of greatest future risk based on projected future water availability. Thus, hydrologic modeling critically informs the BRA in managing its conservation measures and other activities to offset possible future threats to the Covered Species in the Covered Area. Hydrologic modeling will inform conservation actions to be implemented as part of a comprehensive adaptive management program designed to reduce threats associated with critical low flows during times of drought over the 20-year term of the CCAA. The hydrologic modeling will inform how BRA manages its system of reservoirs to supply surface water to downstream customers, while providing for environmental flow needs of the Covered Species.

Table 1. Issues and conservation goals identified in the Freshwater Mollusk Conservation Society's National Strategy for the Conservation of Native Freshwater Mollusks, along with a brief description of how conservation measures in the CCAA address these goals.

Issues	Goals	Conservation Measure	How Measure Addresses Goals
1. Increase knowledge of the distribution and taxonomy of mollusks at multiple scales over time and make that information available.	Understand the status and trends of mollusk populations to better manage and conserve.	Informative Field Investigations and Modeling	Surveys will help fill data gaps in distributional information.
		Long-term Monitoring	Long-term monitoring will assess trends in existing populations over time.
2. Address the impacts of past, ongoing, and newly emerging stressors on mollusks and their habitats.	Minimize threats to mollusks and their habitats.	Informative Field Investigations and Modeling	Future drought scenario modeling will identify spatial and temporal patterns in drought risk to mussel populations and assist in prioritizing conservation actions.
		Environmental Flow Protection	Promotes flow conditions adequate for survival and long-term persistence of Covered Species and strives to assure water quantity.
		Avoidance	Avoids detrimental activities in areas of optimal habitat for Covered Species and prevents further fragmentation.
		Applied Research	Aids in identifying habitat, water quality, and flow-related stressors important in structuring populations of Covered Species and will be used to guide adaptive management.
3. Understand and conserve the quantity and quality of suitable habitat for mollusks over time.	Increase understanding of physical, chemical, and biological characteristics of habitat to support sustainable assemblages of mollusks.	Informative Field Investigations and Modeling	Future drought scenario modeling will identify spatial and temporal patterns in drought risk to mussel populations and assist in prioritizing conservation actions.
		Applied Research	Aids in identifying habitat, water quality, and flow-related stressors important in structuring populations of Covered Species. This information will be used to guide adaptive management.
		Long-term Monitoring	Habitat utilization surveys will assist in understanding habitat requirements of the Covered Species. This data will be essential to the adaptive management process.
		Avoidance	Conserves habitat through avoidance of detrimental activities in areas of optimal habitat.

Table 1 continued

Issues	Goals	Conservation Measure	How Measure Addresses Goals
4. Understand the ecology of mollusks at the individual, population, and community levels.	Increase fundamental knowledge of the biology of mollusks so managers can more effectively conserve them.	Applied Research	Proposed applied research studies will increase the knowledge on the biology of Covered Species at the individual and population level.
		Long-term Monitoring	By evaluating population trends in response to various environmental factors, long-term monitoring will provide data on the ecology of Covered Species.
5. Restore abundant and diverse mollusk populations until they are self-sustaining.	Conserve and restore viable populations and communities of mollusks.	Long-term Monitoring	Population demographic data from long-term monitoring will assist in determining if populations are self-sustaining.
		Applied Research	Reintroduction cage studies will evaluate areas suitable for reintroduction of Covered Species.
		Captive Propagation	Should restoration or supplementation of existing populations be desired, successful captive propagation of Covered Species is necessary to supply organisms.
6. Identify the ecosystem services provided by mollusks and their habitats.	Improve science-based consideration of the social and economic values of mollusk communities and functioning aquatic systems.	Communication / Education / Outreach	Education and outreach activities will highlight the ecosystem services of freshwater mussels and the social and economic value of functioning aquatic systems.
7. Strengthen advocacy and build support for the conservation of mollusks and their habitats.	Increase information sharing and communication among citizens and decision-makers at multiple levels regarding conserving mollusk resources.	Communication / Education / Outreach	Information sharing will occur with state and federal agency personnel through an interagency workgroup, and communication with the public will occur through education and outreach opportunities.
8. Educate and train the conservation community and future generations about the importance of mollusks to ensure conservation efforts continue into the future.	Provide a suite of training opportunities to the greater conservation community and inspire future generations to work on the conservation of mollusks.	Communication / Education / Outreach	Education and outreach activities will include presentations of conservation accomplishments to the greater conservation community and will also focus on educating youth and young professionals about mussel conservation through social media and other avenues.

Table 1 continued

Issues	Goals	Conservation Measure	How Measure Addresses Goals
9. Seek consistent, long-term funding to support mollusk conservation efforts.	Increase funding for mollusk conservation.	Commitment of long-term funding provided by BRA to support this CCAA.	This agreement represents an example of long-term funding by BRA to support mollusk conservation.
10. Coordinate a national strategy for the conservation of mollusk resources.	Increase coordination and information sharing among local, state, national, and international partners in conserving mollusk resources.	Communication / Education / Outreach	Coordination with state and federal agency personnel will occur through and interagency workgroup. Conservation successes of the program will be communicated to national partners in mollusk conservation.

Table 2. Threats to the Covered Species, conservation measures, and a description of how each measure addresses threats.

Threats	Conservation Measures	How Measures Address Threats
Degradation, Loss, and Fragmentation of Habitat	Field Investigations and Modeling	Ongoing survey work will fill data gaps and better define occupied habitat. Hydrologic modeling will identify areas at risk of habitat loss and or fragmentation under future water management scenarios. This information will be used in the adaptive management process to guide on the ground management activities.
	Environmental Flow Protection	Meeting environmental flow standards will preserve available habitat and decrease fragmentation. Flow balancing and flood releases will be evaluated to reduce impacts to mussel habitat, where possible.
	Avoidance	Avoidance of key areas will preserve high quality habitat.
	Applied Research	Habitat quantification tool will aid in identifying key habitat requirements. Studies to evaluate reintroduction opportunities expected to promote expansion of occupied habitat and increases in population numbers.
	Long-term Monitoring	Long-term monitoring of mussels, host fish, water quality, and sediment/channel morphology will assist in identifying trends in habitat availability and population numbers.
Water Quality and Quantity	Field Investigations and Modeling	Drought scenario modeling will identify areas at risk of water quantity issues under future scenarios.
	Environmental Flow Protection	Meeting environmental flow standards will support adequate water quality and quantity, thereby supporting maintenance and expansion of populations and habitats.
	Applied Research	Physiological tolerance research will identify water quality thresholds for Covered Species important in managing water quality. Development of environmental flow methodologies specific to mussels will assist in managing water quantity. Groundwater-surface water interaction studies will assist in understanding the interaction between alluvium and surface flows. This information will help inform management to offset possible risks to populations and habitats and identify opportunities for restoration.
	Long-term Monitoring	Long-term monitoring of water quality conditions, in combination with physiological tolerance studies, will assist in managing water quality to support Covered Species and habitats.
	Communication / Education / Outreach	Educating customers and the public about water conservation through outreach opportunities will assist in maintaining water security into the future.

Threats	Conservation Measures	How Measures Address Threats
Runoff and Erosion	Environmental Flow Protection	Flood releases will be evaluated to reduce excessive erosion and bank-sloughing downstream.
	Avoidance	Any necessary intake structures will be designed and operated to minimize hydraulic/river bed disturbance.
	Long-term Monitoring	Long-term monitoring of substrate and channel morphology transects will aid in identifying and managing erosion issues.
	Communication / Education / Outreach	Outreach opportunities to educate landowners about best management practices will help reduce runoff and erosion from upland areas.
Barriers to Dispersal	Environmental Flow Protection	Meeting environmental flow standards will minimize fragmentation of habitats and promote population expansion.
	Avoidance	Additional dams will be avoided on the mainstem Brazos, Navasota, and Little Rivers to prevent additional barriers to dispersal.
	Captive Propagation	For populations separated by barriers, developing captive propagation techniques can eventually provide organisms to augment existing populations and/or expand the distribution of the Covered Species. BRA will support and assist TPWD and USFWS with reintroductions of the Covered Species, assuming such actions are deemed to be appropriate by TPWD and USFWS at that time.
Overutilization	Communication / Education / Outreach	Coordinating with Interagency Workgroup will prevent overexploitation of key populations, and encourage collaboration among researchers.
Exotic Species	Communication / Education / Outreach	Outreach will educate the public about the negative impacts of zebra mussels and the proper techniques to prevent their transportation. An established education and outreach program will help prevent future invasions of exotic species.
	Long-term Monitoring	Long-term monitoring of zebra mussel occurrence, in streams, will assist in understanding their current distribution in relation to the Covered Species, and help determine what threats, if any, are posed by zebra mussels to Covered Species. Identified threats will be addressed in coordination with USFWS through the adaptive management program.

7.0 Conservation Zones

To prioritize specific portions of the Covered Area in relation to the current status and distribution of Covered Species and other freshwater mussels, Mussel Conservation Zones were developed. These zones were developed in coordination with USFWS biologists and are based on the best currently available data on occurrence and abundance of freshwater mussels within the Covered Area. Five zones (A-E) were delineated to categorize conservation priority for the Covered Species and other freshwater mussels (**Figure 5**). Boundaries were selected to encompass known occurrences and zones were stratified by abundance in some instances. The metrics used in classification of Mussel Conservation Zones, and exact boundaries of each zone, are outlined in detail below. In application, activities near zone boundaries will include consideration of impacts to downstream zones, where appropriate. Applying adaptive management principles, conservation zones will be updated as additional data collection informs our understanding of Covered Species distributions.

Zone A

Zone A is defined as all stream reaches where Balcones spike is currently known to be present within the Covered Area. False spike has a limited distribution within the Brazos River basin and is relatively rare where it occurs. Therefore, areas where this species occur are of highest conservation priority and will be included in avoidance/minimization zones as outlined in Section 9.4. It should be noted that Texas fawnsfoot is also present in portions of this zone within the mainstem Little River.

Zone A includes portions of the Little River, San Gabriel River, and Brushy Creek in Milam and Williamson counties (**Figure 6**). In the Little River mainstem, Zone A extends for approximately 20.7 stream miles from the FM 1915 crossing on the Little River in Milam County downstream to the confluence of the Little River and San Gabriel River in Milam County. In the San Gabriel River, it extends for 32.8 stream miles from Granger Lake Dam in Williamson County downstream to the confluence of the San Gabriel River and Little River in Milam County. In Brushy Creek, Zone A extends for 3.0 stream miles from the FM 908 crossing downstream to the confluence of Brushy Creek and the San Gabriel River, all within Milam County. In total, Zone A covers approximately 56.4 stream miles within these three streams.

Zone B

Zone B is defined as stream reaches where Texas fawnsfoot is most abundant. Since Texas fawnsfoot is more widely distributed within the Covered Area, abundance was used to stratify conservation priority within the species' range.

Zone B includes portions of the mainstem Brazos River and Navasota River in Brazos, Grimes, Washington, Waller, Austin, and Fort Bend counties (**Figure 7**). In the mainstem Brazos River, Zone B extends 153.9 stream miles from the confluence of Yegua Creek in Washington County downstream to the FM 723 crossing in Fort Bend County. In the Navasota River, Zone B includes 27.7 stream miles from the confluence with Gibbons Creek in Brazos/Grimes County to the confluence with the mainstem Brazos River in Washington/Grimes County.

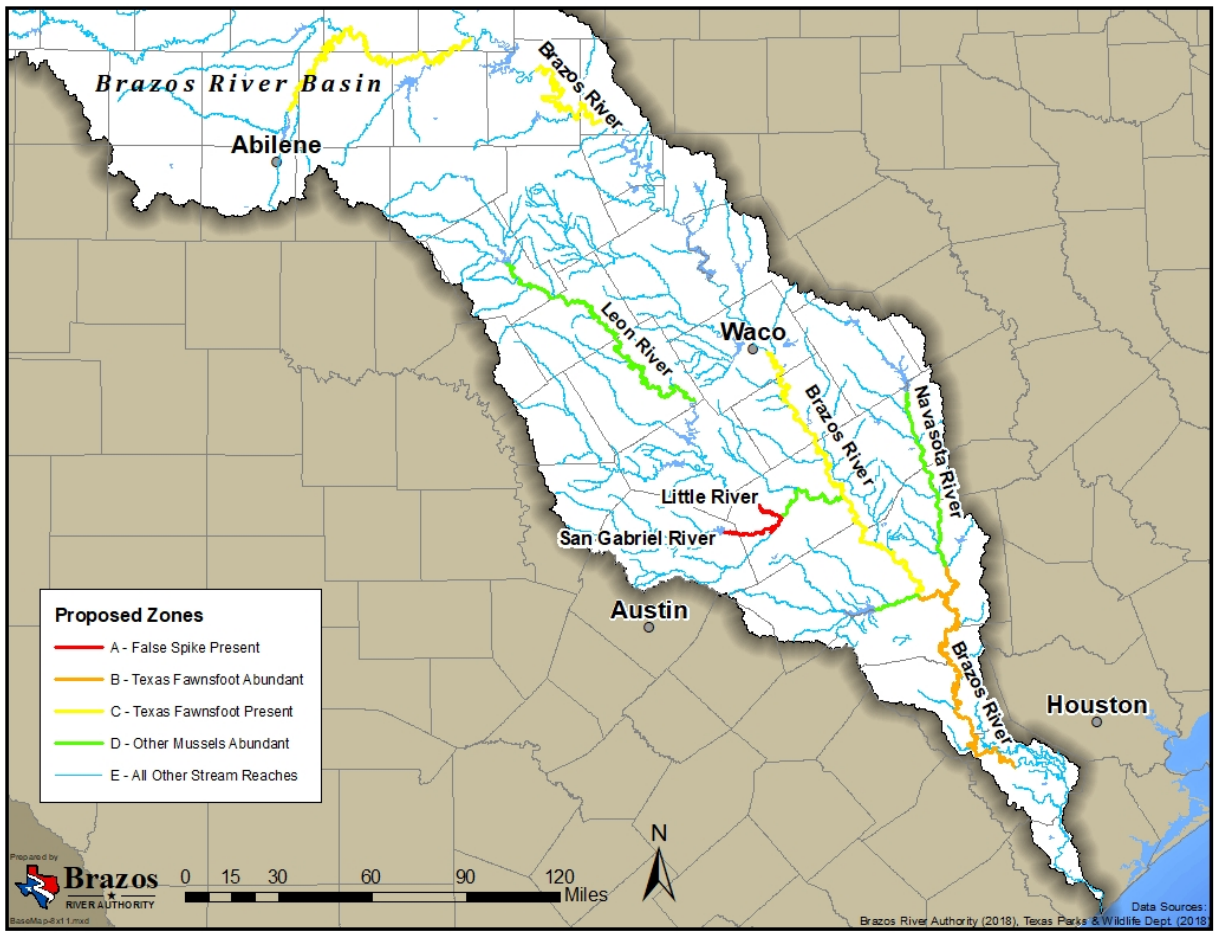


Figure 5. Map of the five proposed Mussel Conservation Zones within the Covered Area.

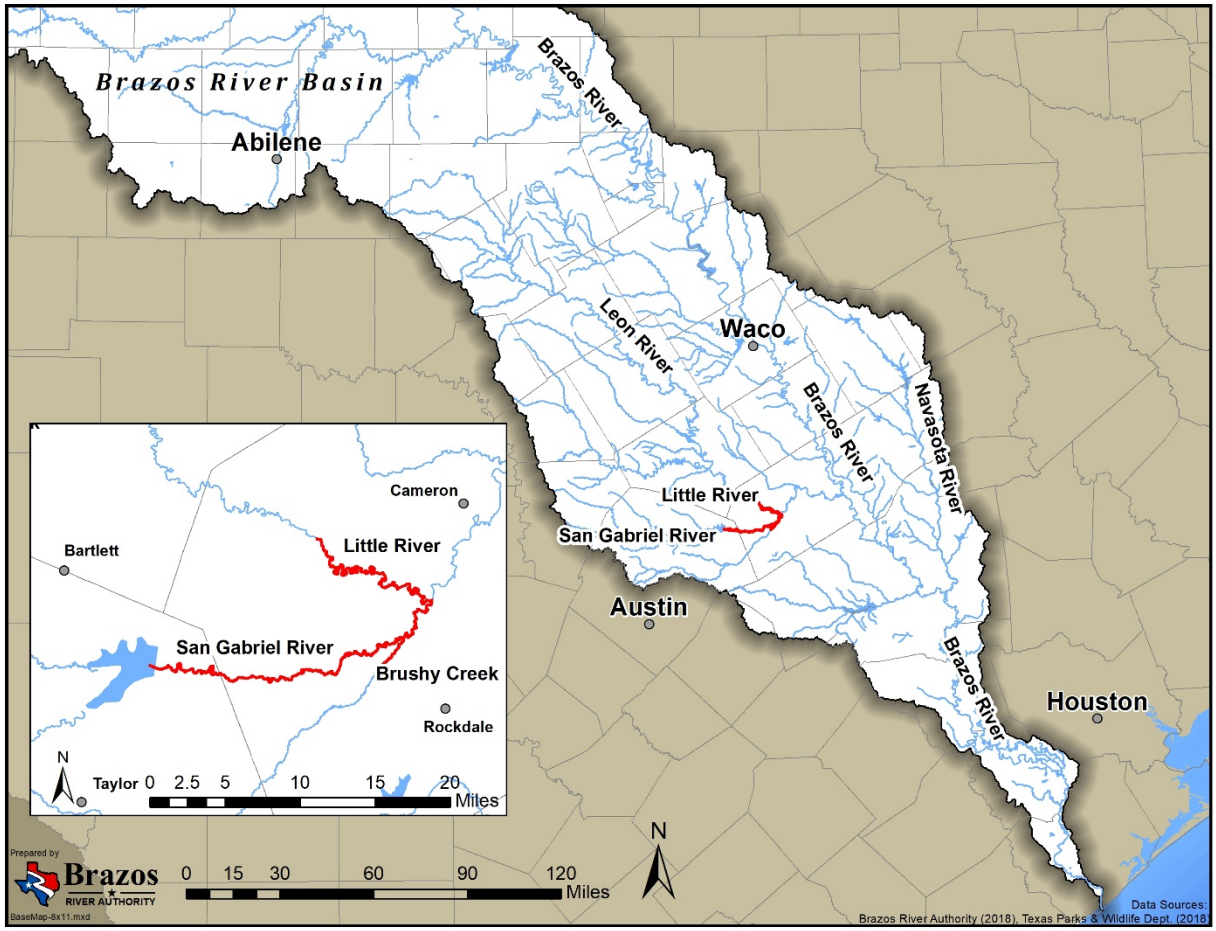


Figure 6. Mussel Conservation Zone A, defined as areas where Balcones spike is present.

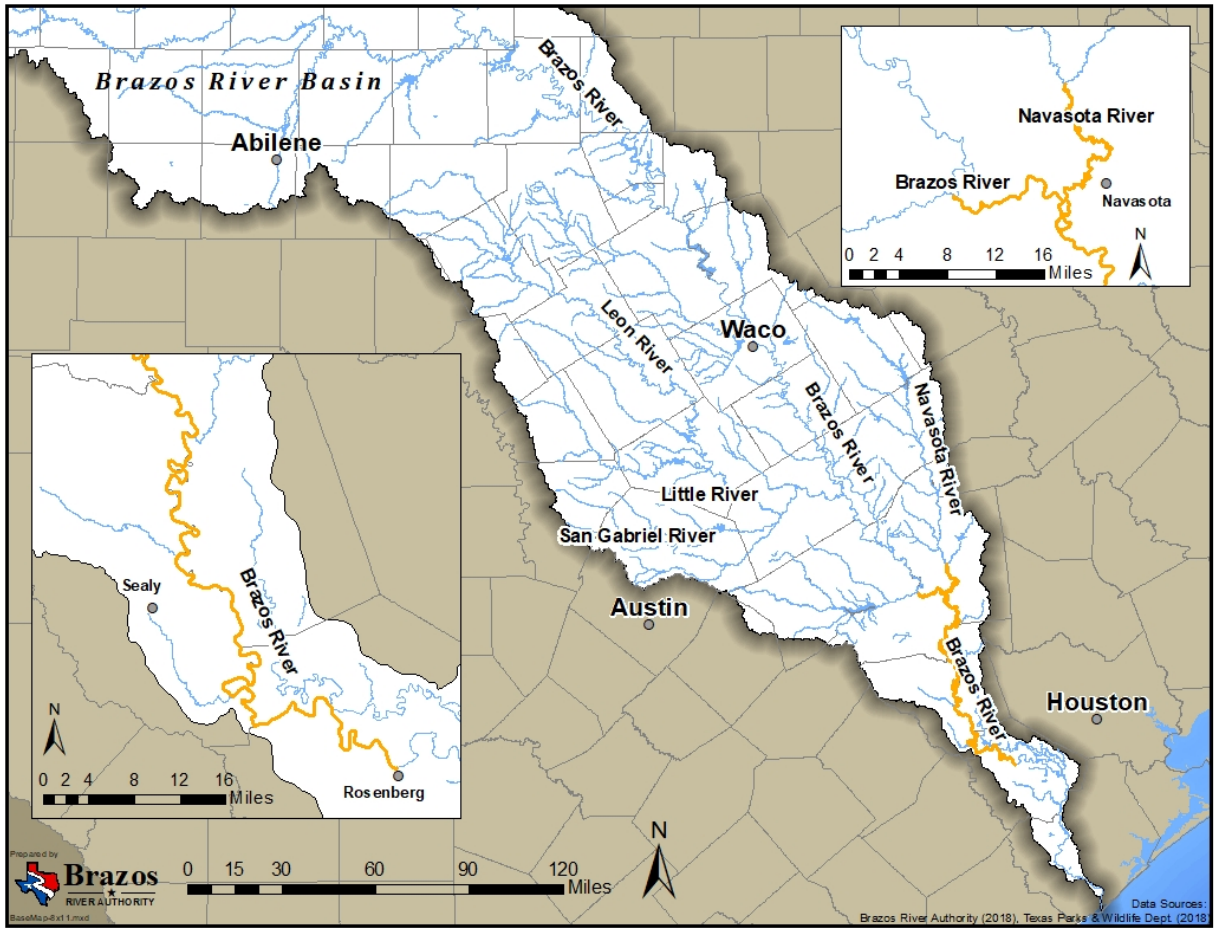


Figure 7. Mussel Conservation Zone B, defined as areas where Texas fawnsfoot is most abundant.

Zone C

Zone C is defined as stream reaches where Texas fawnsfoot is present, but not as abundant as in Zone B, or where abundance data is lacking. Portions of Zone C include Texas fawnsfoot populations which are isolated by reservoirs, and therefore, are of high conservation concern. Given differences in population abundance and isolation, conservation actions may differ between Zone B and Zone C.

Zone C includes portions of the lower Brazos River mainstem in McLennan, Falls, Milam, Robertson, Burleson, and Brazos counties, as well as portions of the middle Brazos River mainstem in Palo Pinto and Parker counties (**Figure 8**). Zone C in the Clear Fork Brazos River extends approximately 171.0 stream miles from FM 600 in Jones County to the confluence with the Brazos River in Young County. In the lower Brazos River, Zone C extends 166.3 stream miles from the SH 6 crossing in McLennan County downstream to the confluence of Yegua Creek and the Brazos River mainstem in Burleson/Brazos counties. In the middle Brazos River mainstem, Zone C extends 79.9 stream miles from FM 4 in Palo Pinto County downstream to FM 1189 in Parker County.

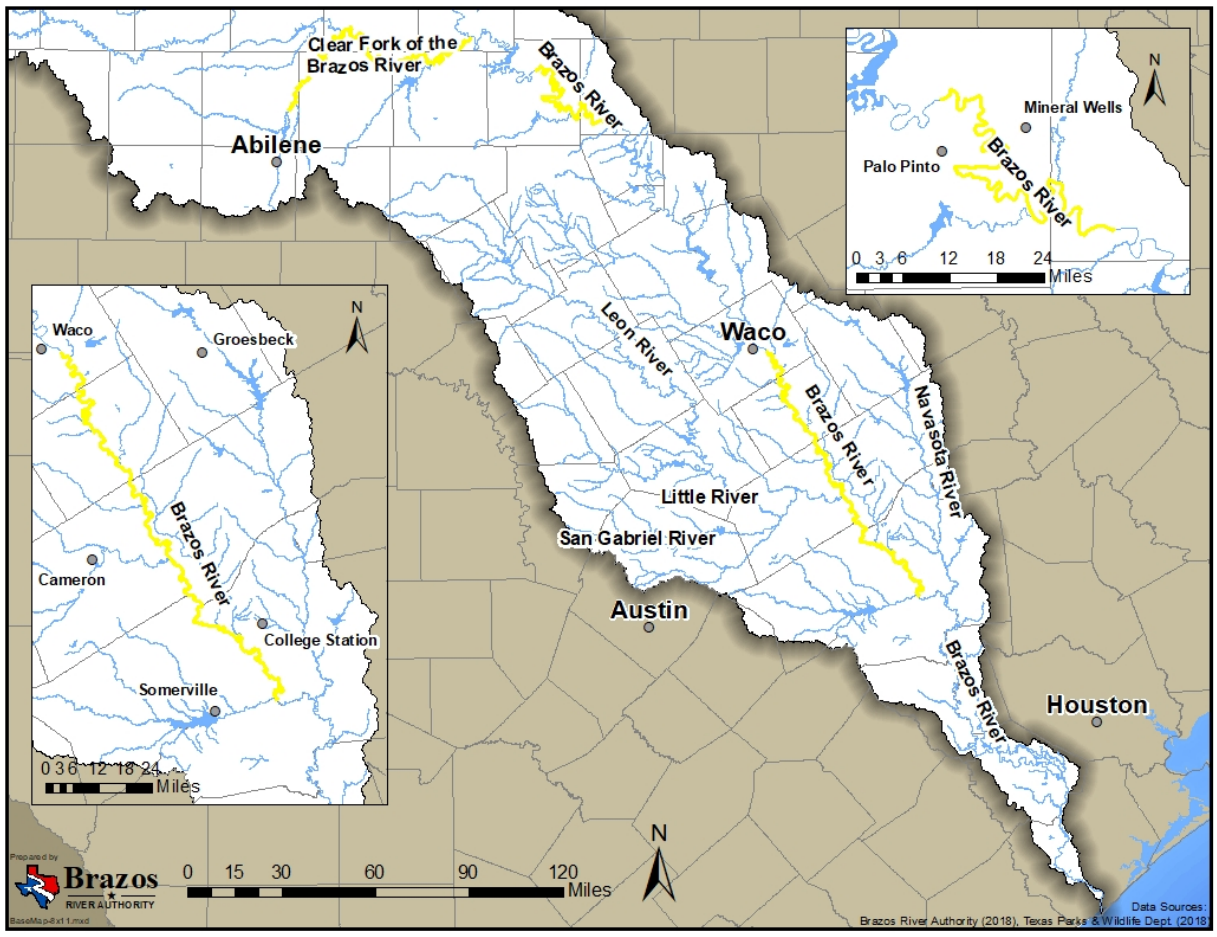


Figure 8. Mussel Conservation Zone C, defined as areas where Texas fawnsfoot is present but not abundant, or where abundance data is lacking.

Zone D

Zone D is defined as stream reaches where Covered Species are absent, but substantial freshwater mussel populations currently exist. Although these mussel populations are of lower conservation priority because the Covered Species are not known to occur in them, they are of conservation significance since abundant mussel populations are known in these areas. Although currently unoccupied, some of the areas in Zone D were historically occupied by the Covered Species and they represent potential areas for habitat restoration and natural population expansion depending on habitat conditions and future hydrologic risk assessment. Additional information will be needed to make those determinations in coordination with USFWS and TPWD. BRA will assist USFWS and TPWD in evaluating potential areas for reintroduction of Covered Species, solely at the discretion of USFWS and TPWD. If USFWS and/or TPWD determine that reintroduction is warranted, then BRA will provide support for logistics and monitoring. Repatriation of Covered Species in Zone D would result in the establishment of new populations, and expansion of existing populations, resulting in significant conservation benefit. BRA has worked with its partners in the basin to improve water quality in several stream reaches identified in Zone D (i.e., Leon and Navasota rivers).

Zone D includes portions of the Leon River in Comanche, Hamilton, and Coryell counties; portions of the Navasota River in Robertson, Leon, Brazos, Madison, and Grimes counties; portions of Yegua Creek in Burleson and Washington counties; and portions of the Little River in Milam County (**Figure 9**). Within the Leon River, Zone D extends 187.5 stream miles from the Lake Proctor Dam in Comanche County to the SH 236 crossing in Coryell County. In the Navasota River, Zone D extends 99.3 stream miles from Lake Limestone Dam in Robertson/Leon counties downstream to the confluence with Gibbons Creek in Brazos/Grimes counties. In Yegua Creek, Zone D extends 20.5 stream miles from Lake Somerville Dam downstream to the confluence with the mainstem Brazos River, all in Burleson/Washington counties. In the Little River, Zone D extends 47.8 stream miles from the confluence with the San Gabriel River to the confluence with the mainstem Brazos River, all in Milam County.

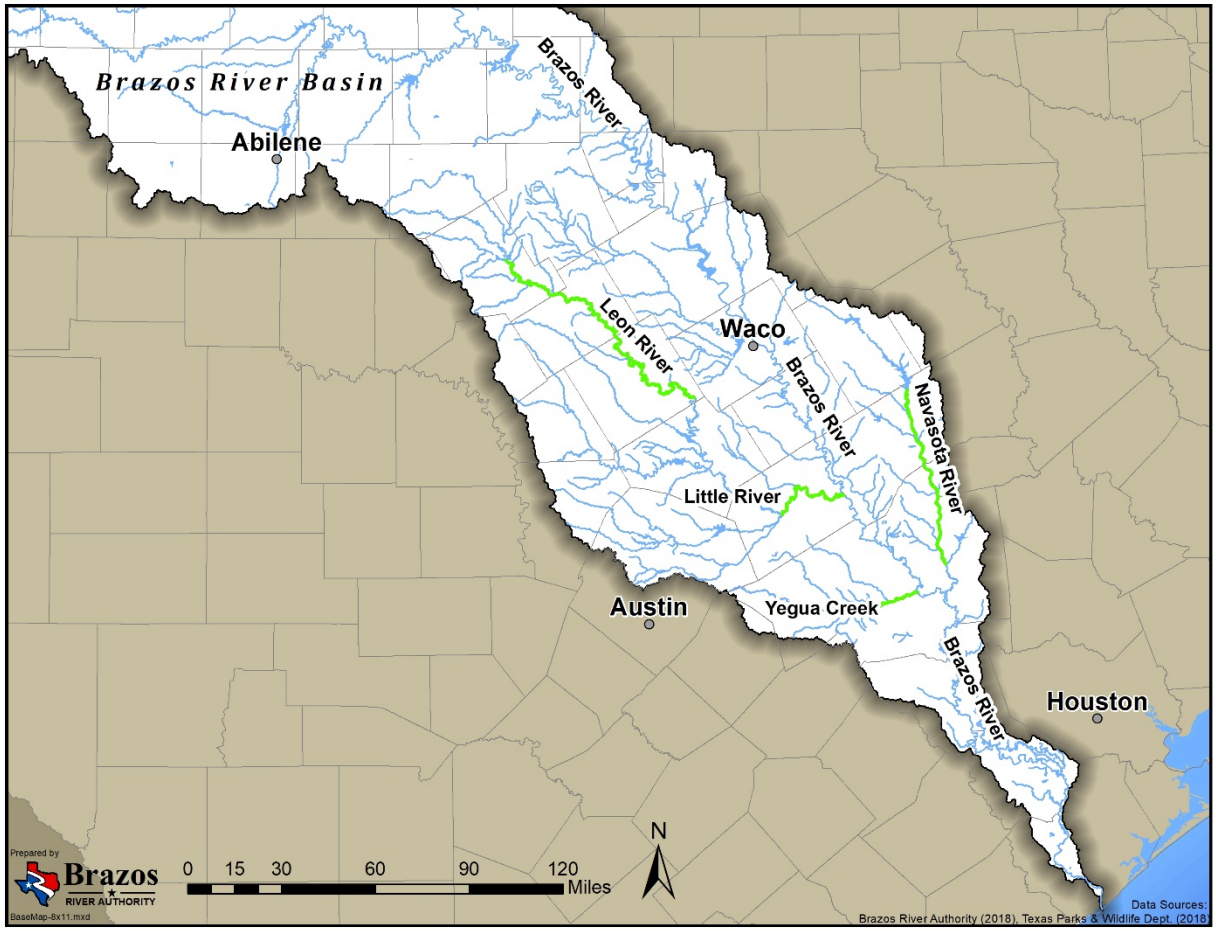


Figure 9. Mussel Conservation Zone D, defined as areas where freshwater mussels are abundant, but Covered Species are not known to occur.

Zone E

Zone E is defined as stream reaches where no substantial mussel populations exist based on currently available data. These areas are currently of lowest conservation priority. It should be noted that not all of Zone E has been surveyed for mussels. Under this CCAA, BRA will perform additional surveys to fill in data gaps. Freshwater mussels may occur in these areas, but at lower abundance.

Zone E includes all of the Covered Area not already assigned to Zone A-D (**Figure 5**).

8.0 Hydrologic Modeling

The Covered Area represents a large portion of the Brazos River basin covering the mainstem Brazos River and multiple tributaries. Hydrologic conditions within this large area are variable and will fluctuate under future scenarios depending on location within the basin, local climatic and geologic conditions, proximity to infrastructure, and local land and water use patterns. Modeling was used to evaluate future hydrologic conditions within portions of the Covered Area, based upon the most current version of TCEQ approved Water Management Plan dated April 2, 2018 (http://www.brazos.org/About-Us/Water-Supply/SysOps). The hydrologic information was overlaid with mussel distributional information to evaluate the frequency of extreme low-flow events in portions of the Covered Area occupied by the Covered Species. This analysis was used as a component of the conservation strategy to evaluate future hydrologic risk within the Covered Area during the permit period, and to guide prioritization of Mussel Conservation Zones, with consideration of streamflow conditions in the future. This hydrologic analysis is summarized below, with specific details presented in **Appendix B**. The intent of this modeling is to provide BRA with the best available information for proactively managing its system of reservoirs to provide surface water to downstream users, while providing for the environmental flow needs of freshwater mussels, including the Covered Species, over the 20-year term of this agreement.

Surface water in Texas is owned by the state and regulated by the Texas Commission on Environmental Quality (TCEQ). Along with hundreds of other water users, the BRA holds permits to divert, store and manage water in the Brazos River basin. To determine specific permit limits on diversion, storage and water management patterns, a computer-based model known as a Water Availability Model (WAM) is used to predict the amount of water that would be in a river or stream under a specified set of conditions. The modeling system used by TCEQ consists of two parts: the modeling program, Water Rights Analysis Package (WRAP), and specific hydrologic input parameters with specified water management. Water use amounts and limits are determined on a month-average basis by analyzing historical climate conditions, including the drought of record, and also including environmental flow conditions. The inputs to the WAM model include “naturalized” flows (that is streamflow that would have been in the river during historical periods in the absence of any water management), and historical precipitation and evaporation. In the Brazos River basin, the BRA was required to extend the hydrology used in the WAM model from 1997 to include the recent drought period, as a condition of the approval of the System Operation Permit. This extended WAM, that incorporates two major drought periods, was approved by TCEQ staff for the period of 1940 through 2015 to evaluate the impact of the recent drought period on the Systems Operation Permit. A version of the WAM does not exist with hydrology extending from 2015 to the present. Although the extended WAM is used for this CCAA hydrologic analysis, it should be noted that TCEQ continues to use the version of the WAM with 1940-1997 hydrology for review of current or pending water right permit applications in the Brazos basin.

Assessing projected water patterns in the Brazos River basin is difficult because of the complexity of the infrastructure and uncertainty of water use patterns. For the 20-year CCAA

time frame, assumptions are necessary on how much water each water rights user will use each month, how much water is returned to the river after it is used (i.e., waste water discharges), and how much storage is available in existing and proposed reservoirs (considering sedimentation which lowers storage capacity over time). For this analysis, conservative assumptions have been used consistent with those approved by TCEQ for recent water rights permitting activities.

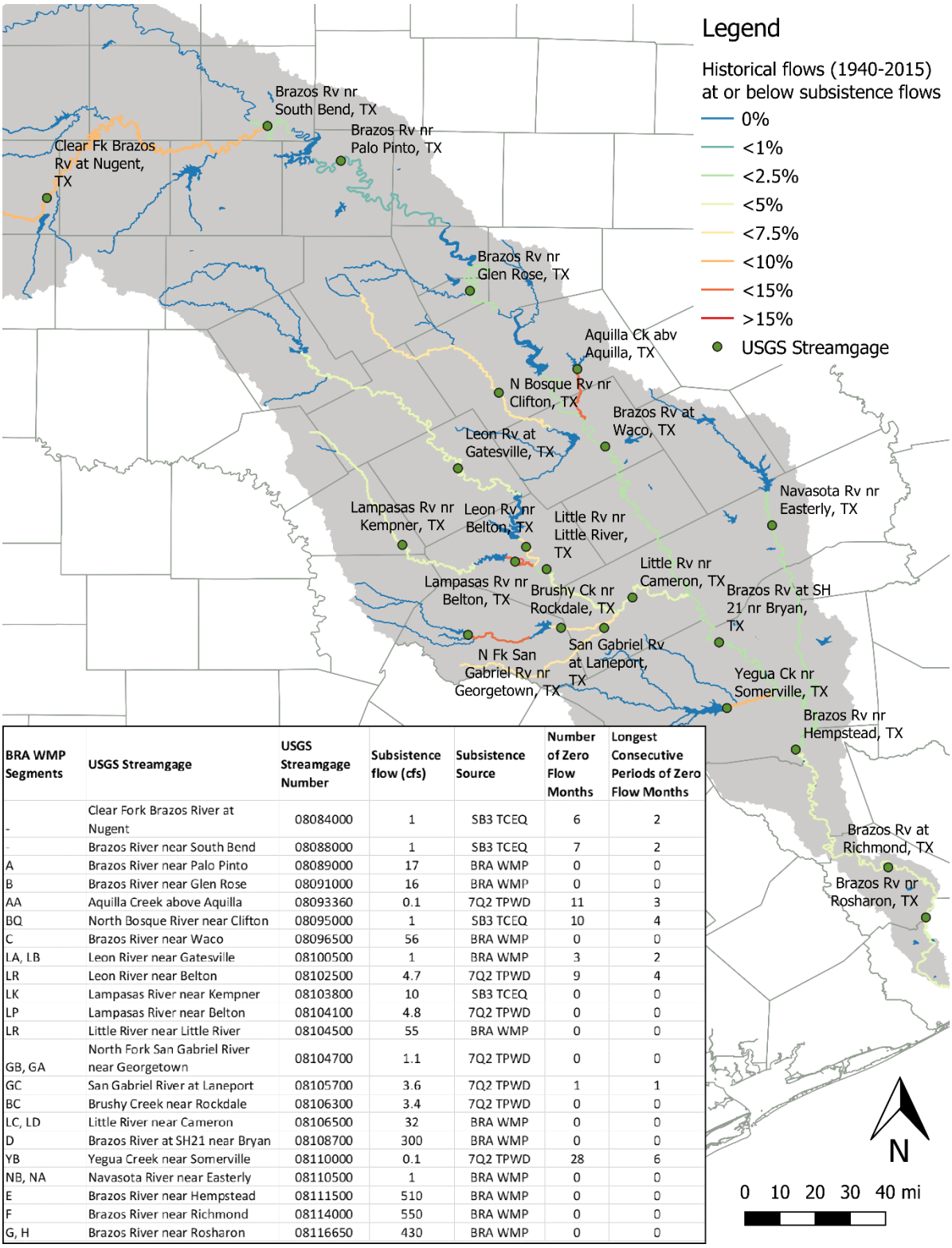
Using the modeling tools and underlying assumptions referenced above, projected flow levels were determined under various scenarios and compared to historical gaged conditions to evaluate changes to water quantity patterns within the basin and future risk to freshwater mussel populations. Monthly-average model results were evaluated in relation to occurrence of subsistence flows (the minimum streamflow needed during critical drought periods to maintain tolerable water quality conditions and to provide minimal aquatic habitat space for the survival of aquatic organisms [NRC 2005]) and zero flows, as these flow conditions were considered to be most relevant to freshwater mussel persistence and most relevant to BRA's management ability. Based on historical gaged conditions, the percentage of months at or below subsistence for each stream segment varied across the basin (**Figure 10**). Under the modeled 2060 scenario, percentage of time at or below subsistence increased in some segments and decreased in others (**Figure 11**). Similar patterns are evident for modeled zero flow months with additional details of hydrologic modeling documented in **Appendix B**.

Although this modeling is complex and based on a variety of inputs, available data and assumptions, some general mechanisms for these projections are apparent. In general, stream segments which show increased frequency of subsistence and zero flows are in areas with predicted increases in local use. Decreased frequency of low flows is typically associated with increased reservoir releases to meet demands of downstream water rights or increased return flows. Understanding such future water use scenarios is critical as a conservation strategy to aid in identification of appropriate conservation activities or restoration projects that could be implemented within each segment. For example, the results of this analysis were used to select stream segments with documented Covered Species populations exhibiting increased frequencies of subsistence or zero flow months under future conditions (e.g., San Gabriel River). These selected stream segments were then given top priority in the CCAA with respect to the proposed conservation measures. These segments are included in Zone A and future infrastructure and development will be avoided in these stream segments as outlined in Section 9.4. In contrast, stream segments with decreased frequency of low flows under future conditions (e.g., Yegua Creek) represent potential areas for population restoration and habitat enhancement projects.

It is important to recognize that results of this analysis represent future combined use by all surface water users within the basin, and that BRA only manages a portion of the combined total. Modeled use of BRA water rights comprised less than 50% of total combined surface water use in the basin, although the degree of BRA's water management varies spatially across the basin and varies in time according to hydrologic conditions. During high flow periods, BRA has limited ability to manage water in the basin because BRA does not control flood storage in any reservoirs. During low flow periods under a full utilization scenario, BRA releases of stored water generally account for between 20-85% of water in covered stream reaches where releases

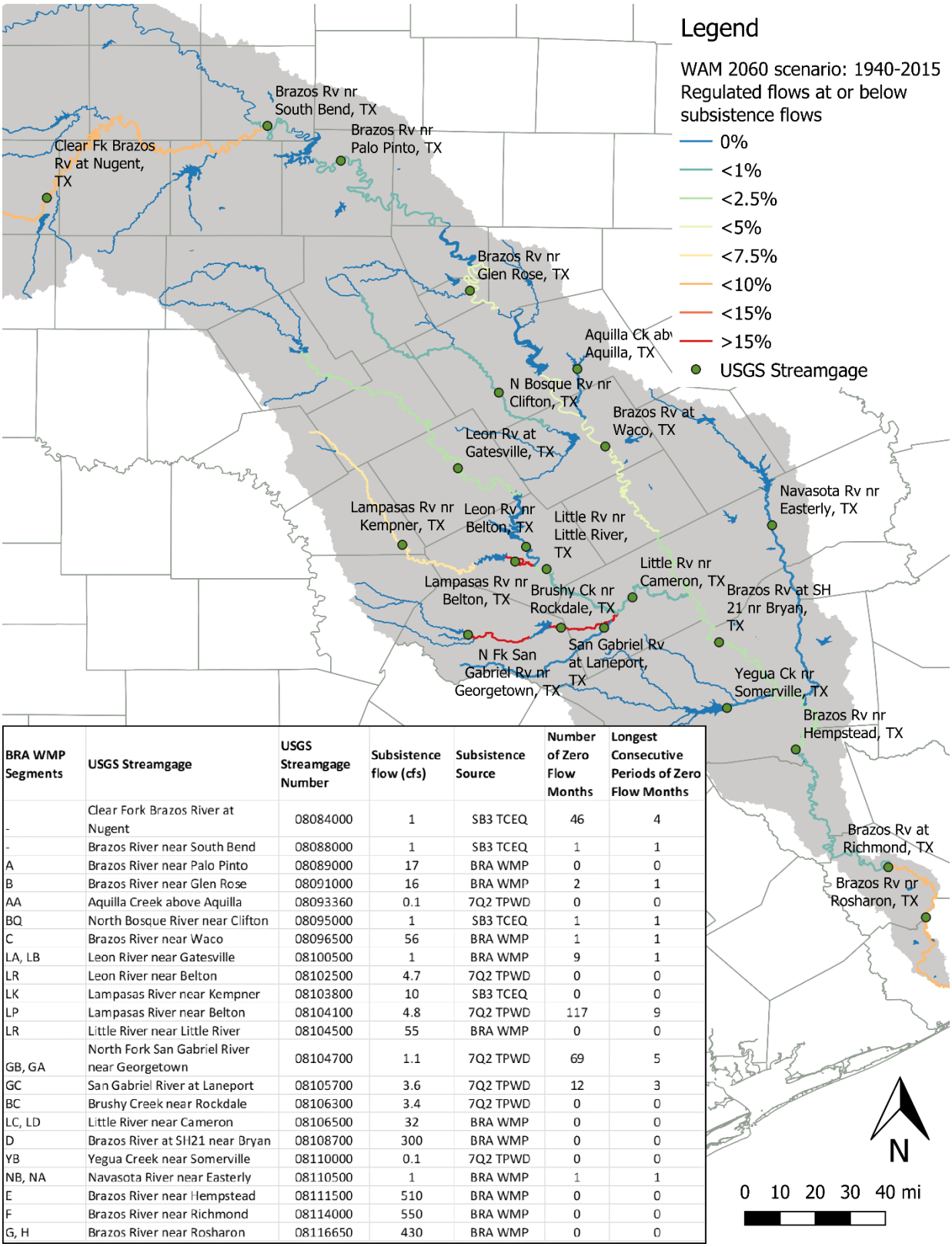
occur, with less management and influence in the lower basin. Thus, BRA releases for water supply purposes during critical low flow periods do provide substantial increases in flow and water quality, directly benefitting downstream mussels. In the Clear Fork Brazos River, BRA operations have no influence on natural stream flows, and the allocation of water to BRA at downstream locations tends to preserve water in the Clear Fork.

These hydrologic modeling efforts inform the BRA about current and future threats associated with altered hydrology (low flows and flooding) to the Covered Species in the Covered Area. This information will be used to inform an adaptive management program, in coordination with the USFWS, to prioritize, define and implement appropriate conservation actions necessary to provide a net conservation benefit to the Covered Species over the 20-year term of the CCAA and permit. These actions include, but are not limited to, strategic water releases as identified above to increase flows, improve water quality, and restoration of instream and adjacent riparian habitats.



BRA WMP Segments	USGS Streamgage	USGS Streamgage Number	Subsistence flow (cfs)	Subsistence Source	Number of Zero Flow Months	Longest Consecutive Periods of Zero Flow Months
-	Clear Fork Brazos River at Nugent	08084000	1	SB3 TCEQ	6	2
-	Brazos River near South Bend	08088000	1	SB3 TCEQ	7	2
A	Brazos River near Palo Pinto	08089000	17	BRA WMP	0	0
B	Brazos River near Glen Rose	08091000	16	BRA WMP	0	0
AA	Aquilla Creek above Aquilla	08093360	0.1	7Q2 TPWD	11	3
BQ	North Bosque River near Clifton	08095000	1	SB3 TCEQ	10	4
C	Brazos River near Waco	08096500	56	BRA WMP	0	0
LA, LB	Leon River near Gatesville	08100500	1	BRA WMP	3	2
LR	Leon River near Belton	08102500	4.7	7Q2 TPWD	9	4
LK	Lampasas River near Kempner	08103800	10	SB3 TCEQ	0	0
LP	Lampasas River near Belton	08104100	4.8	7Q2 TPWD	0	0
LR	Little River near Little River	08104500	55	BRA WMP	0	0
GB, GA	North Fork San Gabriel River near Georgetown	08104700	1.1	7Q2 TPWD	0	0
GC	San Gabriel River at Laneport	08105700	3.6	7Q2 TPWD	1	1
BC	Brushy Creek near Rockdale	08106300	3.4	7Q2 TPWD	0	0
LC, LD	Little River near Cameron	08106500	32	BRA WMP	0	0
D	Brazos River at SH21 near Bryan	08108700	300	BRA WMP	0	0
YB	Yegua Creek near Somerville	08110000	0.1	7Q2 TPWD	28	6
NB, NA	Navasota River near Easterly	08110500	1	BRA WMP	0	0
E	Brazos River near Hempstead	08111500	510	BRA WMP	0	0
F	Brazos River near Richmond	08114000	550	BRA WMP	0	0
G, H	Brazos River near Rosharon	08116650	430	BRA WMP	0	0

Figure 10. Map showing percent of months below subsistence flows based upon historical gage data for stream segments in the Brazos River basin.



BRA WMP Segments	USGS Streamgage	USGS Streamgage Number	Subsistence flow (cfs)	Subsistence Source	Number of Zero Flow Months	Longest Consecutive Periods of Zero Flow Months
-	Clear Fork Brazos River at Nugent	08084000	1	SB3 TCEQ	46	4
-	Brazos River near South Bend	08088000	1	SB3 TCEQ	1	1
A	Brazos River near Palo Pinto	08089000	17	BRA WMP	0	0
B	Brazos River near Glen Rose	08091000	16	BRA WMP	2	1
AA	Aquilla Creek above Aquilla	08093360	0.1	7Q2 TPWD	0	0
BQ	North Bosque River near Clifton	08095000	1	SB3 TCEQ	1	1
C	Brazos River near Waco	08096500	56	BRA WMP	1	1
LA, LB	Leon River near Gatesville	08100500	1	BRA WMP	9	1
LR	Leon River near Belton	08102500	4.7	7Q2 TPWD	0	0
LK	Lampasas River near Kempner	08103800	10	SB3 TCEQ	0	0
LP	Lampasas River near Belton	08104100	4.8	7Q2 TPWD	117	9
LR	Little River near Little River	08104500	55	BRA WMP	0	0
GB, GA	North Fork San Gabriel River near Georgetown	08104700	1.1	7Q2 TPWD	69	5
GC	San Gabriel River at Laneport	08105700	3.6	7Q2 TPWD	12	3
BC	Brushy Creek near Rockdale	08106300	3.4	7Q2 TPWD	0	0
LC, LD	Little River near Cameron	08106500	32	BRA WMP	0	0
D	Brazos River at SH21 near Bryan	08108700	300	BRA WMP	0	0
YB	Yegua Creek near Somerville	08110000	0.1	7Q2 TPWD	0	0
NB, NA	Navasota River near Easterly	08110500	1	BRA WMP	1	1
E	Brazos River near Hempstead	08111500	510	BRA WMP	0	0
F	Brazos River near Richmond	08114000	550	BRA WMP	0	0
G, H	Brazos River near Rosharon	08116650	430	BRA WMP	0	0

Figure 11. Map showing percent of months below subsistence flows based upon hydrologic modeling for the 2060 scenario.

9.0 Conservation Measures

The conservation measures described in this section will be planned and executed in close coordination with USFWS and other key partners. Timing and frequency of conservation measures is discussed in the Implementation Schedule provided in Section 10.0.

9.1 Distributional Freshwater Mussel Surveys and Hydrologic Modeling

9.1.1 Freshwater Mussel Surveys to Fill Data Gaps

To develop a better understanding of the current distribution of the Covered Species, the BRA has commenced mussel surveys in areas throughout the Brazos basin that have either not been surveyed or were previously surveyed without the use of conventional survey methodologies. These surveys will continue upon implementation of this agreement, using survey methods approved by USFWS. Initial survey efforts in the Fall of 2018 were conducted in the Lampasas River sub-basin, which included the mainstem Lampasas River, Sulphur Creek, and Salado Creek. Additional survey locations are planned to include, the Little Brazos River, North Bosque River, Gibbons Creek, and Palo Pinto Creek as these locations have not been previously surveyed.

Additionally, during the first two years of CCAA implementation, BRA will conduct surveys to assess the current status of Balcones spike in the Little River basin and Texas fawnsfoot in the Clear Fork Brazos River.

A minimum of 20 survey sites will be conducted annually for the first two years of the agreement. Should weather or other conditions at the sites, prohibit reaching this target number of survey sites in the first two years of the agreement, the surveys will be completed in the following years as soon as conditions allow.

9.1.2 Additional Hydrologic Modeling

As described in Section 8.0, hydrologic modeling was conducted by BRA to support preparation of this agreement and identify areas of the basin at highest risk under future drought and management scenarios. To keep pace with changing water planning and water use projections within the basin, this analysis will be updated every five years for the life of the permit to guide the adaptive management process (see Section 12.0).

9.2 Communication / Education / Outreach

9.2.1 Coordinate with Agencies through Interagency Workgroup

To promote efficient and effective communication of conservation activities and results of applied research, BRA will engage other agencies including USFWS, TPWD, TCEQ, TXDOT, NRCS and scientists including university researchers and environmental consultants working on freshwater mussel issues in the Brazos River basin through an interagency workgroup. Annual meetings of this group will allow scientists from various agencies and universities to share research and monitoring plans and prevent overutilization of existing populations for scientific research. These meetings will coincide with USFWS' annual Mussel Research and Coordination Meeting. Data sharing will allow all parties to stay up-to-date on ongoing research and assist in making sound conservation and management decisions.

The Mussels of Texas Project collates and displays available mussel distribution information, and is available to help inform entities whose actions could result in harm to mussels. Thus, the Mussels of Texas Project helps inform BRA, and others, in their efforts to minimize and avoid adverse effects to freshwater mussels, including the Covered Species. BRA will contribute data to the Mussels of Texas Project.

9.2.2 Increase Awareness of Freshwater Mussels and Foster Community Engagement

Public outreach and education are critical for successful implementation of any conservation strategy for cryptic species like freshwater mussels. The general public in the Brazos Basin is not largely aware of freshwater mussels, their value, the implications of their decline, activities that may negatively impact them, or the supporting science. To address this knowledge deficit, BRA will establish a comprehensive communication program within two years of final execution of this CCAA that includes freshwater mussels and their habitats.

A multi-media approach will be utilized including in-person presentations and exhibits at community events across the basin, a freshwater mussel-specific informational page on BRA's website, and mussel content on social-media outlets.

Topics to be covered in this multi-media approach will include: general mussel awareness and life cycle needs, ecosystem services, threats to mussel persistence, water quality, water conservation, and riparian restoration.

In addition to the items above, outreach staff will develop a web-based toolbox, within four years of final execution of this CCAA, where landowners can find information on resources to assist them in overcoming barriers to implementing more mussel friendly practices on private property. BRA will work with our partners to help direct interested landowners and others to existing state and federal technical and financial assistance programs, to encourage voluntary habitat and species restoration on private lands in the Covered Area.

9.3 Environmental Flows Protection

9.3.1 Environmental Flow Management

To protect environmental flows in the basin, BRA will manage water supply operations according to the System Operation Permit and associated Water Management Plan (BRA 2018, http://www.brazos.org/About-Us/Water-Supply/SysOps) (WMP) for the life of this CCAA. The System Operation Permit, issued by the TCEQ in 2016, represents a unique, cost-effective, and environmentally-conscious approach by BRA to address current and future water supply needs in the basin. The WMP describes how BRA implements the System Operation Permit and allows BRA to use naturally occurring flows, return flows from wastewater treatment plants, and water supply in 11 existing reservoirs to manage water supply demands in the basin. The WMP incorporates environmental flow standards adopted by the TCEQ in compliance with the Senate Bill 3 process to mimic the natural hydrology of the basin and protect the seasonal distribution of dry, average, and wet conditions. BRA will continue to provide for environmental flows in the Brazos River basin through implementation of the WMP even if TCEQ no longer requires BRA to meet minimum flow standards (see Section 13. Changed Circumstances).

As part of the WMP, diversions of water under the System Operations Permit include prohibitions on diversion when flows are not compliant with TCEQ environmental flow standards. Furthermore, operations under the System Operation Permit and WMP, as with other existing water rights, are conducted in compliance with TCEQ's rules governing watermaster operations (Chapter 304 of Title 30 of the Texas Administrative Code). Prior to the diversion of water under the System Operation Permit and WMP, the BRA and the TCEQ Brazos Watermaster Office ensures operations are compliant with TCEQ environmental flow standards. By maintaining operations in compliance with the WMP for the life of this CCAA BRA is able to manage water use under all of its permits to support water supply needs in the basin, while accounting for existing environmental flow requirements. Additional details of the WMP can be found in the Conformed Technical Report in Support of the Water Management Plan for Water Use Permit No. 5851, accessible online at the BRA website (https://www.brazos.org/About-Us/Water-Supply/SysOps).

Many of the Senate Bill 3 based environmental flow conditions implemented by TCEQ are based on historical hydrology or fish habitat considerations and do not specifically address the environmental flow requirements of freshwater mussels. To address this, as part of applied research activities described below, additional studies are planned to develop assessment methodologies that will help identify the environmental flow needs of freshwater mussels and their host fishes. Thus, BRA's current and future water management activities that meet TCEQ environmental flow standards, combined with proposed applied research and adaptive management, are expected to provide substantial conservation benefit to the Covered Species in the Covered Area.

As new information related to the flow needs of mussels is identified during the execution of applied research, the BRA will collaborate with the TCEQ to integrate this information into future updates of the Texas Environmental Flow Standards for Surface Water (30 TAC §298). Additionally, the BRA will incorporate technical guidance based on the results of applied research studies regarding environmental flow needs of mussels into future updates of the WMP. The incorporation of this technical guidance into the WMP and new environmental flow standards that are protective of mussels by TCEQ could provide a conservation benefit as minimum flows are protected.

A condition of the WMP requires BRA to complete an Annual Environmental Flows Achievement Report which summarized environmental flow achievement from November through the following October. The report clearly identifies all sites that BRA operations may influence that are in compliance with environmental flow standards. The report also identifies any non-compliance with Texas Environmental Flow Standards including subsistence, baseflows and high-flow pulse requirements, identifies if BRA operations under the SYSOPs Permit and WMP caused the non-compliance, and, if so, identifies a corrective action to prevent future non-compliance with Texas Environmental Flow Standards from water storage or diversion under the SYSOPs Permit and WMP. The Annual Environmental Flows Achievement Report includes analysis of Texas Environmental Flow Standards compliance at the following locations where the covered species are known to occur:

- Brazos River at Palo Pinto (USGS 08089000) – Conservation Zone C
- Brazos River at Waco (USGS 08089500) – Conservation Zone C
- Brazos River at SH 21 near Bryan (USGS 08108700) – Conservation Zone C
- Brazos River near Hempstead (USGS 08111500) – Conservation Zone B
- Brazos River near Richmond (USGS 08114000) – Conservation Zone B
- Little River near Little River Academy (USGS 08106500) – above Conservation Zone A
- Little River at Cameron (USGS 08106500) – below Conservation Zone A and in Conservation Zone D

For the purpose of reporting environmental flow achievement to the USFWS, the Clear Fork of the Brazos River near Nugent (USGS 08084000), Conservation Zone C, will be added to the Supplemental Annual Environmental Flows Achievement Report.

The Supplemental Annual Environmental Flows Achievement Report is identical to the Annual Environmental Flows Achievement Report, except it addresses river reaches where no Texas Environmental Flow Standard has been adopted and instead compares flow compliance to the 7Q2 value for those reaches. The Supplemental Annual Environmental Flows Achievement Report will include analysis of 7Q2 compliance in the following Conservation Zones:

- San Gabriel River at Laneport (USGS 08105700) – Conservation Zone A
- Yegua Creek near Somerville (USGS 08110000) – Conservation Zone D
- Leon River at Gatesville (USGS 08100500) – Conservation Zone D
- Clear Fork of the Brazos River at Nugent (USGS 08084000) – Conservation Zone C

9.3.2 Allen's Creek Reservoir Management to Support Environmental Flows

The proposed 9,500-acre Allen's Creek Reservoir is an off-channel reservoir in the lower Brazos River basin (**Figure 12**), meaning that it will not be built on the Brazos River, but rather a tributary (Allen's Creek) that does not provide habitat for the Covered Species (Randklev et al. 2014, p.2) . It is permitted by the Texas Commission on Environmental Quality to capture water during high flow events for release to downstream customers during lower flows, and when full, will provide approximately 100,000 acre-feet of firm water supply per year. The water use permit contains several special conditions dictating how water may be moved into and out of the reservoir that are designed to protect instream uses, water quality and aquatic habitat. These conditions include a maximum diversion rate from the Brazos River, a maximum release rate, and detailed diversion restrictions based on naturalized flows and ambient flow conditions. A copy of the permit can be located at: https://www15.tceq.texas.gov/crpub/index.cfm?fuseaction=iwr.viewdocument&doc_name=Permit%202925B%2Epdf&doc_id=573521202011249&format_cd=pdf.

While the reservoir is permitted by TCEQ and the necessary land has been purchased, before construction the BRA must also complete reservoir design and USACE permitting, which will occur concurrently. Timing of the USACE permitting process is difficult to predict, but BRA anticipates that the permitting process will be complete and construction will begin within the next 15 years and that the reservoir will be operational during the term of this permit. By adding water storage capacity at the bottom of the Basin, near to major downstream water users, BRA

gains additional flexibility to deliver water and maintain environmental flow conditions appropriate for Covered Species through implementation of the System Operations Permit and WMP. That is, adding Allen's Creek Reservoir as part of BRA's system of reservoirs affords BRA additional flexibility to maintain wetted habitats and suitable water quality, benefitting mussels including the Covered Species.

By delivering water to senior water rights holders and customers in the lower Brazos River basin during periods of low flow, via the bed and banks of the Brazos River, this reservoir would contribute to meeting subsistence and base environmental flow requirements in the river, and thus reduce potential drought impacts to freshwater mussels in this area. Note that the initial construction of the Allen's Creek Reservoir is beyond the scope of this CCAA and does not represent a Covered Activity; however, future management and operations of the Allen's Creek Reservoir are Covered Activities expected to reduce the future threat of low flows to Covered Species downstream, thus contributing to a net conservation benefit over the 20-year term of the CCAA and permit. As part of BRA's system of reservoirs, the operation of Allen's Creek Reservoir, will allow BRA greater capacity to deliver surface water to downstream users, and provide for the environmental flow needs of Covered Species and avoid critical low flows during times of severe drought. Thus, the future operation of Allen's Creek Reservoir contributes to, and supplements BRA's existing capability to deliver a net conservation benefit to the Covered Species within the 20-year term of this agreement.

Additionally, this reservoir will increase the resiliency of the BRA water supply system by increasing total water storage available for release during drought conditions. Increased drought resiliency of the water supply system will also have the benefit of reducing potential drought impacts to freshwater mussels downstream of the project since water will be transported via the bed and banks of the Brazos River. The resiliency and the flexibility of the BRA system of reservoirs affords BRA to ability to provide for the resource of needs of mussel by delivering surface water through the bed and banks of the Brazos River.

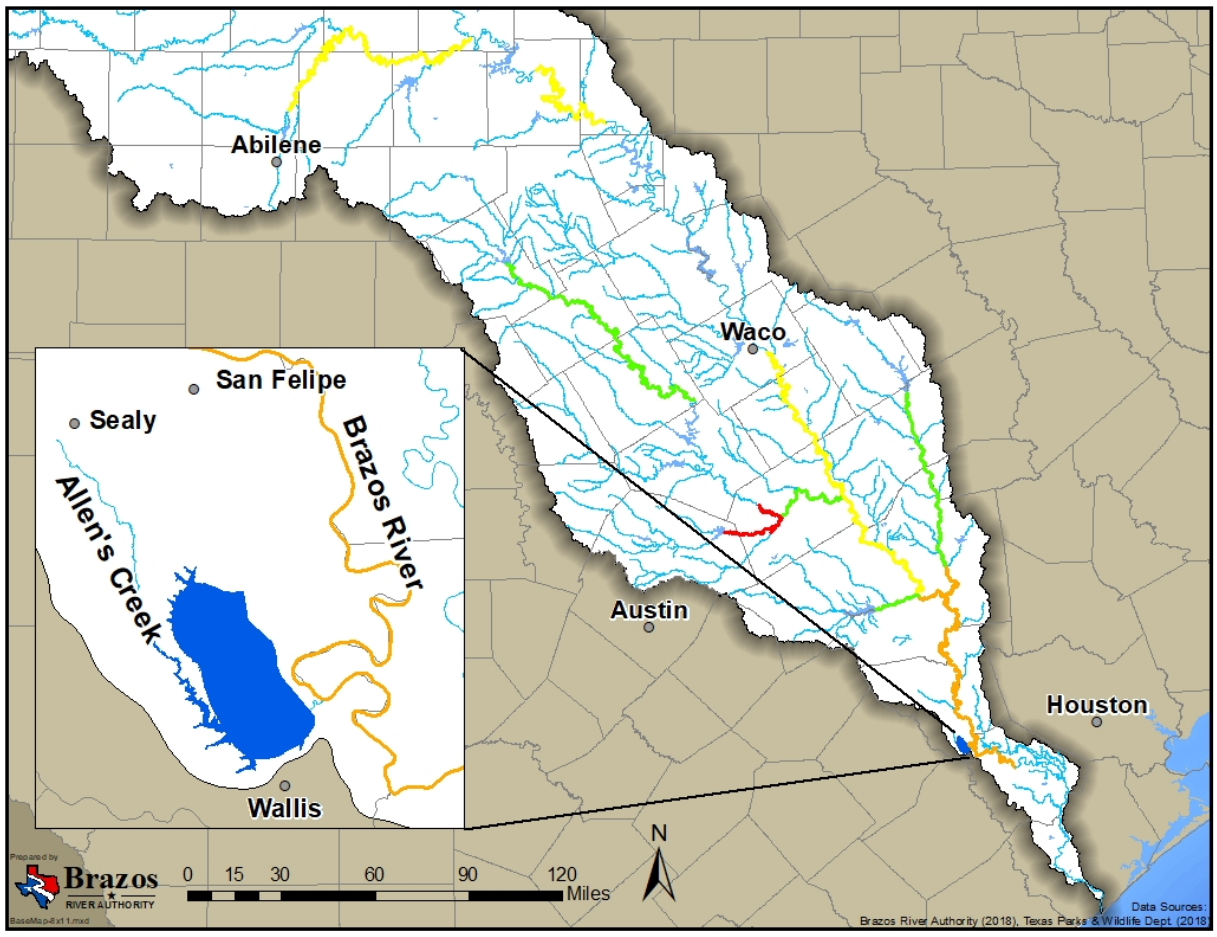


Figure 12. Location of proposed Allen's Creek Reservoir in the lower Brazos River basin in relation to Conservation Zones.

9.3.3 Evaluate Controlled Releases to Minimize Erosion

Extended controlled releases at bank-full discharge can result in erosion of stream banks and scouring of river beds. Such conditions can displace freshwater mussels and damage important habitats. Depending on how controlled releases are concluded, they can result in post-event bank sloughing, which can also degrade instream habitat.

Within the BRA's System, the eight reservoirs owned and operated by the USACE have the ability to capture water during periods of high streamflow and flooding, and release this water gradually to minimize flooding in downstream areas. The release of floodwater stored in these eight USACE reservoirs is determined by USACE. The three reservoirs owned and operated by BRA do not have the ability to store water in order to prevent flood impacts downstream.

The BRA's Operations Procedures for Controlled Releases from its three reservoirs establishes procedures and guidelines for BRA staff to conduct release operations during high inflow events in order to minimize threats to the safety of the dam, impacts to downstream property, and impacts to the downstream river channel. Controlled releases are increased incrementally over time to maintain reservoir levels protective of the dam structure. This may or may not result in

bank-full discharge downstream of the reservoir. Conversely, when the release event is coming to its conclusion, decreases in release rates are also performed incrementally to minimize downstream bank sloughing.

BRA will continue to work to minimize scouring flows from BRA-system reservoirs, when and where possible, by studying ways to manage releases from BRA-owned reservoirs and how managed releases may affect downstream sediment dynamics and mussel beds. If improvements to the Operations Procedures for Controlled Releases are identified that could further minimize downstream erosion, BRA will revise the procedures to incorporate the new recommendation, provided that the proposed improvements do not create other concerns for dam safety or human health and safety.

BRA will also coordinate with the USACE to evaluate potential modifications to flood releases from USACE-owned reservoirs to minimize scouring flows and thus protect mussels, when possible. BRA will work with its conservation partners to help identify state- and federal-funding sources and private landowners interested in implementing habitat restoration projects below these dams, but does not commit any BRA funds at this time.

9.3.4 Voluntary Minimum Flow Releases in the San Gabriel River

The BRA's current WMP (Technical Report Chapter 4) includes maintaining a voluntary minimum flow release of 4 cfs from Lake Granger when water is capable of being released from the reservoir. BRA will work with the USACE to maintain flows of 4 cfs when water is available. There may be several reasons why water is not capable of being released from storage, including, but not limited to: dam maintenance projects restrict the ability to release water, and during periods of drought, water levels fall to an elevation below the elevation at which the dam gates can release water or we are restricted by state regulatory agencies from releasing water.

9.3.5 Amendment of SYSOPs Water Right and Texas Water Trust Donation

The water rights currently granted to the BRA by the TCEQ do not currently authorize the use of appropriated water for maintenance of environmental flows. The BRA is committed to acquiring the necessary amendment of its SYSOPs water right to achieve that legal authority in the upcoming, required, 10-year update to the WMP. The process of revision of the WMP will begin in FY 2022, with the revised WMP submitted to TCEQ for consideration in FY 2026.

In its 2011 and 2014 Memorandums of Understanding with TPWD, regarding work to be done by BRA in the basin in exchange for TPWD's support of the SYSOPs permit, the BRA commits to making a dedication to the Texas Water Trust for environmental flow use. The dedication will be approximately 6,000 ac-ft. BRA and TPWD are currently working to develop a decision matrix on how this water will be used in the basin. Support for freshwater mussels is one of the top priorities being considered in the decision matrix.

Once the amendment to the SYSOPs water right is complete and the decision matrix for the pledged Texas Water Trust water is complete, it will be possible for BRA to make environmental flow releases that benefit freshwater mussels, as dictated by the TPWD-approved decision matrix.

9.3.6 Subordination Agreements above Possum Kingdom Reservoir

Historically, the BRA has entered into two subordination agreements upstream of Possum Kingdom Reservoir (the City of Abilene and West Central Texas Municipal Water District agreement and the City of Lubbock agreement). Subordination agreements are interlocal agreements where a senior water right holder waives their right to make priority calls on water upstream of the location of their water right. The BRA will not enter into any new subordination agreements above Possum Kingdom Reservoir during the term of the CCAA.

9.4 Avoidance and Minimization

To assist in maintaining key populations of the Covered Species, the following avoidance and minimization measures are proposed.

9.4.1 Avoidance and Minimization in the Conservation Zones

Although avoidance and minimization could result in significant costs to BRA during the permit term, these measures were designed to maintain existing populations of the Covered Species, particularly in areas with higher probabilities of drought-related impacts.

- The BRA will not construct additional dams on the mainstem Brazos River, mainstem Navasota River, or mainstem Little River.
- The BRA will not sponsor additional BRA infrastructure or diversion projects that impact the stream bed in Zone A.
- Within Zones B and C, the BRA will conduct mussel surveys to guide placement of any necessary infrastructure/diversions, and they will be sited to minimize disturbance to Covered Species populations.

Active efforts to avoid and minimize disturbances to Covered Species and their habitats, combined with other conservation measures, such as providing appropriate environmental flow conditions and identifying habitat and water quality requirements of the Covered Species, all applied in an adaptive management framework, will allow populations and occupied habitats to expand naturally, contributing to a substantial net conservation benefit for the Covered Species in the Covered Area. Additionally, if new populations of the Covered Species are identified through ongoing or future surveys, Conservation Zones and resulting avoidance and minimization measures will be reevaluated through the adaptive management process in Section 12.0.

9.4.2 Minimization of Non-Flow Related Threats in Conservation Zone A

BRA will convene a stakeholder's group to evaluate if there are other non-flow related measures, that if implemented, would minimize threats and benefit the candidate species in Conservation Zone A. The stakeholder group will also identify potential funding sources, if any, to assist with implementing the identified strategies. The stakeholder's group will include federal, state, and local agencies, university natural resources institutes, local landowners, and concerned citizens.

9.4.3 Encourage Minimization of Disturbance During Design and Construction of Non-BRA Owned Infrastructure

When BRA receives notification or is included as a stakeholder on construction projects occurring in conservation Zones A-C, BRA will formally submit comments notifying the responsible party of the likelihood of the covered species being present in the project area, recommend they perform a survey to determine if the covered species will be affected by the proposed activity, encourage avoidance of disturbance in areas where surveys identify covered species are present, and recommend that they include aquatic and/or riparian habitat restoration as a component of their project, as applicable. If the project requires public notice, through either NEPA or other state public notice process, BRA will formally submit comments in writing to the appropriate regulatory agency espousing avoidance and minimization of impacts to the candidate species.

If we are notified of applications for new water rights in conservation Zone A, we will formally submit comments to the TCEQ protesting the issuance of new water appropriations based on the impact to the covered species.

9.5 Applied Research

As part of the proposed conservation measures, BRA will conduct a variety of applied research to supplement the available knowledge on the Covered Species. Details of each applied research activity are discussed below. This applied research will be conducted in coordination with other agencies/researchers and will include substantial involvement from FWS and TPWD staff biologists. The goal of this research is to better define habitat and water quality requirements of the Covered Species to inform future management decisions and support on-the-ground conservation activities.

9.5.1 Development of a Habitat Quantification Tool

To evaluate the mechanisms influencing occurrence and abundance of the Covered Species in the Covered Area, BRA will develop a freshwater mussel habitat quantification tool within the first three years of implementation of this agreement. The goal of this desktop analysis is to synthesize all available freshwater mussel survey and habitat utilization data within the Covered Areas for evaluating spatial trends and resulting mechanisms that affect mussel occurrence and density. This tool will provide data necessary for identifying landscape-scale mechanisms in explaining mussel occurrence and evaluating reach-scale habitat suitability. Results will aid in prioritizing areas for implementation of various conservation and/or restoration actions. This tool will be extremely helpful in an adaptive management context, and will better position BRA to inform future conservation activities in the Brazos River basin.

9.5.2 Development of Environmental Flow Methodologies Specific to Freshwater Mussels

With the passage of Senate Bill 3, the Texas legislature recognized the importance of maintaining the ecological integrity of Texas river systems. Recent analyses stemming from this legislation have been conducted to determine flow conditions necessary to maintain a sound ecological environment in Texas rivers. This process led to the establishment of environmental flow standards by the TCEQ. However, the majority of the biologically-focused environmental flow research conducted to date has assessed the influence of various flow tiers on instream fish

and riparian vegetation communities. Only recently have environmental flow studies, like the 2018 Instream Flow Study of the Middle and Lower Brazos River, begun to evaluate instream flow requirements of freshwater mussels (TIFP 2018). These evaluations often rely on an aggregation of information from freshwater mussel species across the country. The reliance on data from widespread locations raises question as to whether the environmental flow recommendations are applicable to freshwater mussels in the Covered Area

To provide additional information on instream flow requirements of freshwater mussels in the Covered Area, the BRA will work in conjunction with USFWS staff to develop environmental flow methodologies specific to freshwater mussels in years 3 to 5 and to identify patterns in habitat utilization, availability, and persistence under various flow conditions. This information will be useful in determining flow conditions necessary to support existing and future populations of the Covered Species and to determine if amendments to the State of Texas' Environmental Flow Standards are warranted. Additionally, BRA will use this methodology along with other water management guidance to inform decisions on conjunctive releases. This understanding, applied in an adaptive management framework, will reduce current and future threats associated with low flow events, contributing to a substantial net conservation benefit for the Covered Species. Future, revisions to the State of Texas' Environmental Flow Standards will be addressed under Section 13.0 - Changed Circumstances. BRA will provide information about the instream flow requirements of freshwater mussels to TCEQ and others and inform future revisions to the flow standards.

9.5.3 Evaluate Reintroduction Techniques and Opportunities

To evaluate opportunities for reintroduction of Covered Species into areas of their historic range where they are not currently present, a cage study is planned. This designed experiment will initially use common mussel species as surrogates and compare survival, growth, and reproductive potential in areas currently devoid of mussels to areas that are currently occupied. Common mussel species known to occupy the same areas as Covered Species (e.g., Yellow sandshell *Lampsilis teres*, Threeridge *Amblema plicata*, Pimpleback *Cyclonaias pustulosa*) will be collected from areas of the basin where they are abundant, relocated to unoccupied areas, and placed in experimental cages. A control treatment will consist of an equal number of caged mussels deployed at the original collection site. Experimental cages will be partially filled with native substrate material from the area to allow the mussels to naturally burrow. Transplanted and control mussels will be periodically monitored to evaluate survival, growth, and gravidity.

Habitat data including continuous water temperature and water level data will be recorded at each site. Patterns in growth, survival, and gravidity between the control and treatment will be used to evaluate the potential for reintroduction in the transplant area. Habitat data collected at each location may help elucidate mechanisms behind patterns in mussel occurrence and inform development of the Habitat Quantification Tool (Section 9.5.1) and mussel-specific environmental flow methodologies (Section 9.5.2). Should these techniques prove successful for evaluating reintroduction potential of common species, it is anticipated that results and/or trials could be expanded to Covered Species. The BRA will coordinate closely with TPWD and USFWS on these research activities and any possible reintroductions or augmentations, which

applied in an adaptive management framework, are ultimately expected to contribute to population increases for the Covered Species. BRA will support and assist TPWD and USFWS with reintroductions of the Covered Species, assuming such actions are deemed to be appropriate by TPWD and USFWS at that time. TPWD and USFWS will ultimately need to determine the appropriateness of reintroductions, and judge the efficacy of any future reintroductions of Covered Species.

9.5.4 Analyze Physiological Tolerances of Covered Species

To advance the current science on physiological tolerance of the Covered Species, laboratory studies on water quality tolerance limits will be conducted. If available, this analysis will focus on test organisms produced via captive propagation, rather than specimens collected from the wild. Also, where possible, opportunities will be explored to collaborate with other partners and expand these studies to include populations of the Covered Species outside the Brazos basin. These studies will focus on the influence of water quality parameters believed to pose the highest risk to Covered Species such as water temperature, dissolved oxygen, salinity, turbidity, and ammonia concentrations. Information from these studies will be used in conjunction with water quality monitoring outlined below to evaluate and manage potential water quality stressors in the basin as well as inform development of the Habitat Quantification Tool (Section 9.5.1) and mussel-specific environmental flow methodologies (Section 9.5.2).

9.5.5 Groundwater-Surface Water Interaction Studies

Understanding the hydrologic connection between surface water and groundwater becomes integral to developing strategies to effectively manage these two resources. There is a need for improved science regarding surface water-groundwater interactions as there are thousands of shallow wells in Texas near streams that can affect surface water flow or may be diverting stream water through underflow (Young, et. al, 2018).

The Brazos River Alluvium Aquifer (Alluvium) is an unconfined aquifer that runs from Bosque and Hill Counties in the middle Brazos River Basin through Fort Bend County in the lower Brazos River basin. Previous studies in the northern half of the aquifer (Bosque, McLennan, and Falls Counties) have revealed that there is compartmentalization in some areas of the aquifer, where the aquifer is not influenced by river flows, and in other areas the aquifer is directly recharged by the Brazos River (Jarvis, 2017). To date similar studies have not been conducted in the lower half of the Brazos River Alluvium.

Starting in fiscal year 2020, the BRA will participate with local universities, local groundwater conservation districts, and other interested parties in a planned three-year study. These studies will seek to better understand the interaction between the Brazos River and the Alluvium in Brazos, Grimes and Waller Counties. The team will perform geospatial analysis using Texas Water Development Board's (TWDB) groundwater database and data submitted in Drillers Reports from the area, conduct cross-section monitoring to record changes in bank material and identify possible connectivity between the river and the alluvium. Current and historical water chemistry data of both the Brazos River and Alluvium will be examined for similarities or differences in specific conductance, temperature, cations and anions, and the ratio of hydrogen and oxygen isotopes. Finally, data loggers will be installed to monitor changes in the water table

elevation. The goal of the studies is to provide scientific data and improved understanding on if there is interaction between the river and Alluvium, how any identified interaction impacts water quality and flow in the river, and how the aquifer responds to rainfall events and changing river stages.

A better understanding of these interactions will help TCEQ, TWDB, BRA and groundwater conservation districts make more informed decisions regarding groundwater pumping, implementing environmental flow recommendations, water availability, and water quality. Improved understanding on the above items will also contribute to conservation of freshwater mussels through identification of potential reintroduction areas and future hydrological persistence as managers will be able to make knowledgeable decisions on the interface between the river and aquifer and reduce threats to the long-term viability of freshwater mussels.

9.6 Long-term Monitoring

9.6.1 Key Mussel Populations

Long term monitoring will focus on four key reaches within Zones A, B, and C known to have existing populations of the Covered Species:

1) Little River basin near the San Gabriel River confluence (Zone A);
2) Lower Brazos River near the confluence of Allen's Creek (Zone B);
3) Lower Navasota River near the confluence with the Brazos River (Zone C); and
4) Mainstem Brazos River between Possum Kingdom Reservoir and Lake Granbury (Zone C).

Both site-specific and reach-scale monitoring approaches will be employed to monitor changes in populations of Covered Species through time. For site-specific monitoring, one area with high densities of the Covered Species will be identified within each of the four key reaches above and monitored over the life of the permit. Monitoring will be conducted annually and as streamflow conditions allow for safe and effective sampling. To avoid harming sensitive mussel populations, monitoring will be conducted in close coordination with USFWS and TPWD and may include mark-recapture techniques to evaluate capture probability, survival probability, immigration/emigration rates, local population size, longevity, and mussel growth rates. Additionally, quantitative quadrat-style sampling may be employed to ensure capture of small-bodied mussels such as Texas fawnsfoot, to assess recruitment, and to analyze patterns in mussel density. Monitoring protocol development will be coordinated with and approved by USFWS prior to implementation of any mussel sampling plan.

Reach-level habitat utilization surveys will also be employed within each key reach to examine broader-scale patterns in population abundance and habitat utilization, and to evaluate population expansion/contraction. Sampling locations will be spaced longitudinally throughout the reach and data will be collected by timed searches at multiple mesohabitat types within each sampling location. Detailed habitat data (depth, velocity, substrate, shear stress, etc.) will also be collected at each mesohabitat. This sampling approach will allow for quantification of habitat utilization data and assessment of broader-scale trends in the occurrence and abundance of Covered

Species. This information will be invaluable in supporting several aforementioned conservation measures (Sections 9.5.1 [Habitat Quantification Tool], 9.5.2 [environmental flow methodologies]), and 9.5.3 [reintroduction evaluation]). Results of monitoring will be summarized in annual reports to USFWS. The BRA will coordinate closely with USFWS and other key partners on these monitoring efforts. The long-term monitoring efforts will provide the foundation for an adaptive management program that informs and directs the implementation of conservation measures that are ultimately expected to contribute to increasing population numbers and extent, thus providing a net conservation benefit for the Covered Species.

9.6.2 Host Fish Populations

For the covered species to persist, host fish populations must exist in adequate numbers to ensure survival of early life stages. To monitor host fish populations, BRA will continue fish assemblage monitoring throughout the basin as part of ongoing work with the Clean Rivers Program and ongoing environmental flow standard validation assessments. Data from ongoing monitoring will be evaluated for trends in occurrence and abundance of mussel host species (i.e., Freshwater Drum, Red Shiner, Blacktail Shiner). Annual accounting of host fish monitoring results will be provided to TPWD and USFWS.

9.6.3 Water Quality

Even though there are stream reaches in the Brazos River basin that do not meet state water quality standards, overall trends are positive and the need for additional monitoring remains. Most of Conservation Zones A and B identified in Section 7.0 have experienced significant decreasing trends ($p<0.001$) in ammonia levels since the 1970s. The only Zone B reach not to show a statistically significant trend in ammonia levels is the Navasota River. Seventy-eight percent of the basin's impairments are bacteria-related and 91% are on small prairie streams not currently known to support mussels and 11% of the basin's bacteria impairments are currently proposed by TCEQ to be de-listed, pending approval by the EPA. There are currently, no impairments other than bacteria in any of the Conservation Zones A, B, C or D for any of water quality parameters identified as threats in Section 4.3.

Water quality improvements in the basin can be attributed to the protections afforded in the federal Clean Water Act and the state of Texas' Clean Rivers Act which have resulted in improved regulation of septic systems, sanitary sewer collection systems, and wastewater treatment facilities. While natural habitat preservation around the waterways of the Brazos basin has historically been poor; this tide is changing with the addition of stormwater retention ponds, increased education of the value of riparian vegetation and the promotion of riparian restoration projects, development requirements to limit impervious cover, etc. Additionally, heightened awareness of water quality concerns by basin residents has resulted in the adoption of best management practices (i.e., stormwater improvements, appropriate application of pesticides, disposal of contaminants, etc.) at the local and individual level.

Water quality monitoring conducted by BRA throughout the Brazos River basin as part of the Clean Rivers Program will continue for the 20-year term of the agreement, even if the Clean Rivers Program becomes defunct. Specific to the Covered Species, 15 water quality assessment sites (**Figure 13**) in reaches known to be inhabited by mussels will be evaluated for water

temperature, dissolved oxygen, salinity, and ammonia, in particular. The BRA's annual Basin Highlights report (http://www.brazos.org/About-Us/Water-Quality/Clean-Rivers-Program/Reports-Presentations-and-Meeting-Minutes) summarizes water quality status in the basin, will be included in BRA's annual reporting to USFWS. Additionally, the BRA produces a basin-wide water quality trend analysis report at 5-year intervals. The most current water quality trend analysis can be found in the Brazos River Basin Summary Report 2017, accessible online at: http://brazos.org/About-Us/Water-Quality/Clean-Rivers-Program/Basin-Summary-Report. This water quality trend report for the Brazos River basin will be provided to USFWS every five years, starting in 2023.

BRA's comprehensive water quality monitoring program implemented in support of this CCAA provides information about whether or not water quality is improving or worsening, and how changes in water quality either benefit or harm freshwater mussels. BRA has initiatives and projects, and is able to partner with U.S. Environmental Protection Agency, Texas Commission on Environmental Quality, Texas Parks and Wildlife, Natural Resources Conservation Service (among others) who can fund the development and implementation of water quality improvement programs like Watershed Protection Plans that have been demonstrated to result in positive changes to water quality. Because monitoring information can sometimes be lacking, BRA and partners will be positioned to undertake meaningful projects to improve water quality throughout the Brazos River basin by having a comprehensive water quality monitoring program in place, with a new focus on mussels through this CCAA.

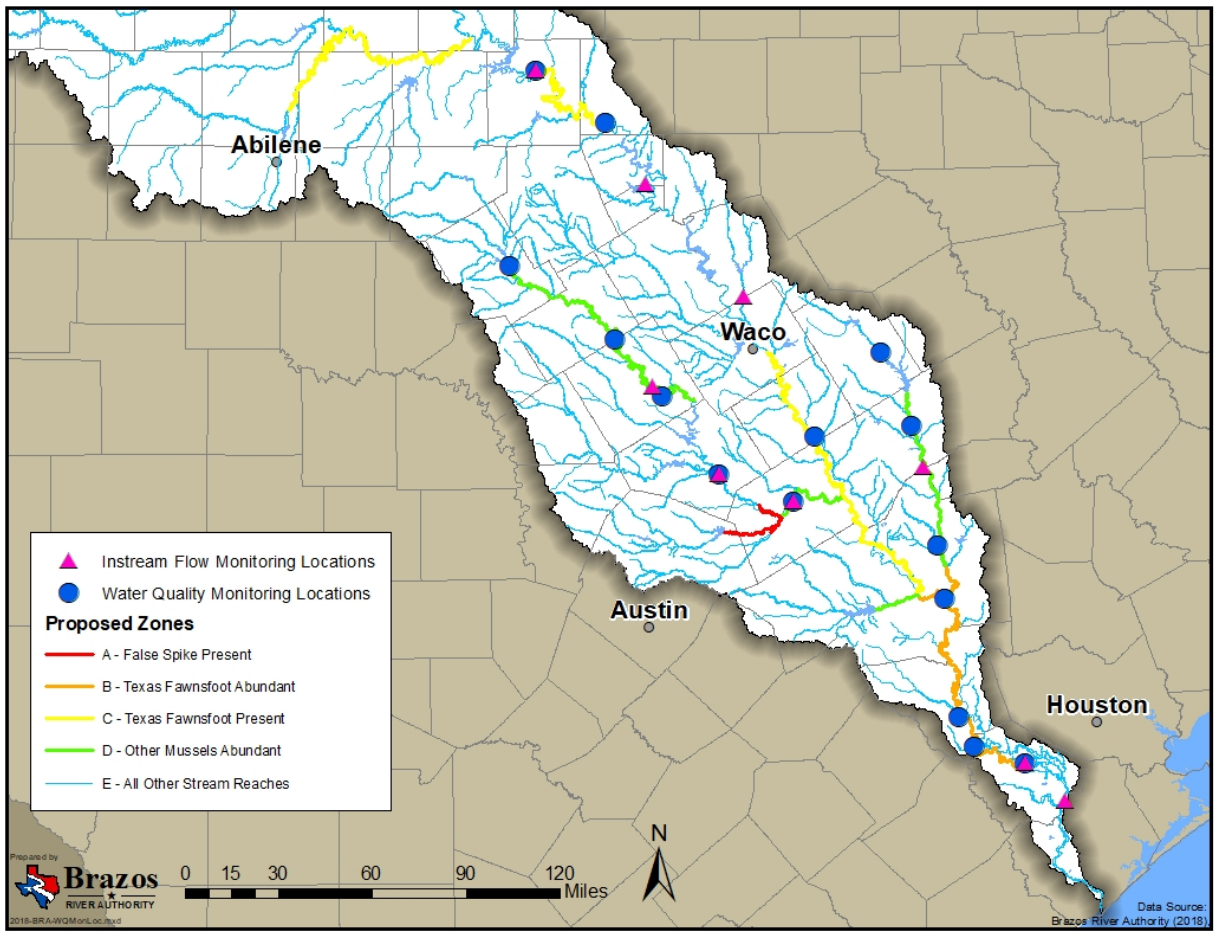


Figure 13. Water quality and instream flow monitoring locations.

9.6.4 Substrate and Channel Morphology

At defined transects within nine instream flow monitoring locations (**Figure 13**), long-term monitoring of substrate composition and channel morphology will be conducted once every five years. Mussel surveys will also be conducted at these transects to determine if mussels are present in the area. If so, long-term monitoring of mussel populations will coincide with channel morphology monitoring.

Four additional transects to monitor substrate and channel morphology will be placed immediately upstream of the four key mussel populations describe in 9.6.1. Transects will be located as close to the instream flow monitoring location as possible, with consideration to where landowner permission can be established.

Data on substrate composition and channel morphology will be collected at these stations, annually the first two years and subsequently every five years. Sampling may be conducted more frequently if high flow events that have the potential to induce channel and sediment movement have occurred. This sampling will be performed when the river is in base flow condition not during periods of elevated flows and will only be conducted when BRA Field Team staff determines conditions are safe to do so.

These surveys will be performed incrementally with the start date to coincide with the key mussel population monitoring detailed in 10.6.1. A section describing these activities will be incorporated into the annual report submitted to USFWS. The section will focus on observed and documented changes in substrate composition and channel morphology over time and the relationship to existing mussel communities. This important component of habitat monitoring, applied in an adaptive management framework and with other conservation measures, will reduce current and future threats associated with habitat degradation, contributing to a substantial net conservation benefit for the Covered Species.

9.6.5 Invasive Species Monitoring

During all monitoring and research activities conducted as part of this agreement TPWD protocols to prevent spread of Aquatic Invasive Species (AIS) will be followed. This includes cleaning, draining, and drying all boats and equipment when moving between sites on different systems. To prevent the possible spread of exotic or otherwise invasive species or disease, BRA will transport freshwater mussels and host fish only under an approved Hazard Analysis Critical Control Points (HACCP[1]) plan.

Additionally, presence/absence monitoring for invasive species will coincide with the water quality monitoring events at the 15 sites identified in Section 9.6.3. If invasive species are identified at any monitoring site, the size of the initial infestation will be estimated and then monitored using repeat photography methods. Infestations of invasive species will also be reported to TPWD and a Sighting Report will be submitted to the USGS Nonindigenous Aquatic Species database.

9.7 Short-term Refugia and Captive Propagation

9.7.1 Contingency Plan for Short-term Refugia

Long-term maintenance of captive mussel populations is not a goal of this agreement. However, to assist in conserving existing key populations of the Covered Species under an extreme drought or other stochastic event, the BRA will work with USFWS to develop a Drought Contingency Plan similar to the USFWS Discussion Paper for Drought Contingency Planning for Freshwater Mussels in the Southeast U.S. This contingency plan will be completed by the end of the first full year of the CCAA and will describe the exact methods and facilities to be used to collect and temporarily maintain a refuge population of Covered Species in the event that an extreme event occurs and both parties agree that it threatens to extirpate an existing population. The BRA will implement the contingency plan in coordination with USFWS when needed to salvage mussels in the event of an extreme drought or other event. Under such a scenario, BRA and USFWS will work together to collect remaining live individuals, transport them to a temporary off-site holding location or relocate them to an *in situ* holding location, and potentially restock the original location upon return of appropriate conditions. Development of this contingency plan will be initiated as soon as this agreement is finalized, so that appropriate methodologies will be in place for short-term refugia should the need arise.

[1] Additional information and training is available at: https://www.fws.gov/fisheries/ANS/ANS-HACCP.html

9.7.2 Captive Propagation

Captive propagation of the Covered Species is useful in providing organisms for research purposes, and after further research and evaluation, may eventually be used to supplement existing populations or to reintroduce the species into historically occupied but currently unoccupied habitats. The BRA plans to provide partial funding to support ongoing efforts by USFWS hatcheries to establish captive propagation for the Covered Species. Beginning at year six following approval/execution of this CCAA, BRA will provide $25,000/year through year ten, and then will provide $15,000/year for years 11 through 20. The first five years of funding for this conservation measure will be to support applied research activities necessary prior to propagation and reintroduction (reintroduction techniques and opportunities [Section 9.5.3] and physiological tolerances investigations [Section 9.5.4]).

This work developing contingency plans, short-term holding strategies, and developing captive propagation techniques will be planned and implemented in close coordination with USFWS and TPWD. Efforts to develop short-term and long-term contingency plans for restoring Covered Species in the event of a natural disaster or other event outside of BRA's control, will bolster resiliency, redundancy, and representation of the Covered Species, contributing to a substantial net conservation benefit. The efforts of BRA will result in additional conservation for the Covered Species, such that in the event of a catastrophic event, BRA will consult with TPWD and USFWS to determine what remedies may be appropriate and partner with TPWD and USFWS to implement those remedies. Investment in a captive propagation program will facilitate future opportunities to reintroduce populations of candidate mussels, ultimately resulting in a net conservation benefit to the species. These efforts coordinated and in collaboration with TWPD and USFWS, to design and implement and a strategy to respond to catastrophic events beyond the control of BRA will enhance the long-time survival of the Covered Species.

10.0 Implementation Timeline

BRA commits to the implementation and funding of the conservation measures described above and listed in Table 3. These measures were strategically planned to maximize usefulness of the resulting data. Many of the conservation measures outlined above have already begun to be implemented. For example, ongoing surveys to fill data gaps in mussel distribution information were initiated in fall 2018, and hydrology modeling has already been initiated to inform development of this CCAA. Additionally, environmental flow management, host fish population monitoring, and water quality monitoring are currently being conducted by BRA and will continue on an annual basis. Substrate and channel morphology monitoring is also ongoing, with surveys conducted on a five-year time step once baseline data is established (**Table 3**). BRA will meet with USFWS annually or more frequently, if necessary, to discuss accomplishments from the previous year, planned activities for the coming year, and identify any needs to adjust the implementation schedule as informed by monitoring and adaptive management program review and other necessary coordination.

Table 3. Implementation timeline demonstrating when each specific conservation measure is to be conducted (X denotes year task will be performed).

Measure	Conservation Measure	Preparation for Implementation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11-20	Year 15
9.1.1	Freshwater Mussel Surveys to Fill Data Gaps	X	X	X										
9.1.2	Additional Hydrologic Modeling	X					X					X		X
9.2.1	Coordinate with Agencies through Interagency Workgroup		X	X	X	X	X	X	X	X	X	X	X	X
9.2.2	Increase Awareness of Freshwater Mussels and Foster Community Engagement	X	X	X	X	X	X	X	X	X	X	X	X	X
9.3.1	Environmental Flow Management	X	X	X	X	X	X	X	X	X	X	X	X	X
9.3.2	Allens Creek Reservoir												X	X
9.3.3	Evaluate Controlled Releases to Minimize Erosion							X						
9.3.4	Voluntary Minimum Flow Releases in the San Gabriel River	X	X	X	X	X	X	X	X	X	X	X	X	X
9.3.5	Amendment of SYSOPs Water Right and Texas Water Trust Donation								X					
9.3.6	Subordination Agreements above Possum Kingdom Reservoir	X	X	X	X	X	X	X	X	X	X	X	X	X
9.4.1	Avoidance and Minimization in the Conservation Zones	X	X	X	X	X	X	X	X	X	X	X	X	X
9.4.2	Minimization of Non-Flow Related Threats in Conservation Zone A	X	X	X	X	X	X	X	X	X	X	X	X	X

Measure	Conservation Measure	Preparation for Implementation	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11-20	Year 15
9.4.3	Encourage Minimization of Disturbance During Design and Construction of Non-BRA Owned Infrastructure	X	X	X	X	X	X	X	X	X	X	X	X	X
9.5.1	Habitat Quantification Tool		X	X										
9.5.2	Environmental Flow Methodologies				X	X	X							
9.5.3	Reintroduction Cage Studies				X	X	X					X		
9.5.4	Physiological Tolerance Studies		X	X										
9.5.5	Groundwater surface studies	X	X	X	X									
9.6.1	Mussel Population Monitoring		X	X	X	X	X	X	X	X	X	X	X	X
9.6.2	Host Fish Population Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X
9.6.3	Water Quality Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X
9.6.4	Substrate and Channel Morphology Monitoring	X	X				X					X		X
9.6.5	Invasive Species Monitoring	X	X	X	X	X	X	X	X	X	X	X	X	X
9.7.1	Contingency Plan Development		X											
9.7.2	Captive Propagation								X	X	X	X	X	X
	Annual reporting		X	X	X	X	X	X	X	X	X	X	X	X
	Adaptive Management Discussion with USFWS		X	X	X	X	X	X	X	X	X	X	X	X

The conservation measures identified in Table 3 and outlined below will also be initiated upon the effective date of this CCAA. A staggered approach to implementation will be necessary, as some conservation measures will provide information necessary for completion of others. A contingency plan for short-term refugia will be developed during Year 1, so that this protocol is in place in the event that an emergency refugia event is triggered. The contingency plan will define emergency events and identify response actions as appropriate. Habitat utilization data collected during the first two years of reach-scale mussel monitoring and development of the habitat quantification tool will be used to inform environmental flow methodology development in Years 3-5. Additional data on environmental flow requirements of freshwater mussels will then be used to evaluate controlled releases in Year 6. Physiological tolerance studies conducted in Years 1-2 will help inform the reintroduction evaluation studies in Years 3-5, by defining important water quality parameters for Covered Species. Similarly, BRA will contribute to USFWS captive propagation in years 6-20, after physiological tolerance information is available and reintroduction evaluations have been conducted. Groundwater-Surface water interaction studies will be complete by Year 5. Because Allen's Creek Reservoir is expected to be completed in approximately 10 – 15 years, associated conservation measures are applied in years 10-20 of the proposed timeline. Other measures will begin upon implementation of the CCAA and be conducted annually for the entirety of the permit. These measures include coordination with the interagency workgroup, education and outreach activities, and ongoing avoidance and minimization measures. For planning and reporting purposes, Year 1 will begin on October 1 following USFWS approval of the CCAA and issuance of 10(a)(1)(A) enhancement of survival permit.

11.0 Monitoring and Reporting

A variety of conservation measures will be conducted on the Covered Species and their habitats as part of this CCAA. This information will be summarized in an annual report which will be submitted by BRA to USFWS each year. The annual report will include, but not be limited to, information on the following items:

- Summary of conservation, research, and monitoring activities conducted for the year (Annually)
- Results of freshwater mussel surveys designed to fill data gaps in the basin (Years 1-2)
- Results of hydrologic modeling (Years 5, 10, 15)
- Summary of community outreach activities (Annually)
- Summary of Environmental Flows Achievement Report (Annually)
- Summary and results of applied research studies (Years 1-5)
- Results of long-term monitoring (Section 9.6) to include key mussel populations, host fish, and water quality annually; and substrate and channel morphology in designated years (1, 5, 10, 15)
- Summary of captive propagation accomplishments (Years 6-20)
- Any mortality/injury to Covered Species observed during the year (Annually)
- Any other necessary interim updates or interesting findings (Annually)
- Compliance and lack of compliance, with lessons learned to avoid issues in the future

- Copies of monitoring plans, HAACP plans, and other required plans (annually)

Annual reports will be due to the appropriate USFWS Ecological Services Field Office on March 15 of each year, and will include at a minimum, a summary of accomplishments and monitoring results from the past year, and plans for the coming year, as described above.

12.0 Adaptive Management Plan and Program

Adaptive management is an important component of any successful conservation agreement, and this agreement will be adaptively managed with collaborative and substantial involvement from both parties. The conservation measures described herein are designed to further refine our knowledge of the current status of Covered Species populations within the Covered Area; avoid and minimize impacts to known populations of the Covered Species; monitor Covered Species and invasive species populations through time; provide additional information on habitat, flow, and water quality requirements of the Covered Species; and simultaneously monitor habitat, flow, host fish, and water quality conditions within the Covered Area. Since some conservation measures center around monitoring and applied research, a robust adaptive management program is particularly essential in this agreement, to allow modification of conservation measures as new data becomes available. To facilitate the adaptive management process, the following adaptive management procedure is proposed.

Approximately one month following submittal of each annual report, or upon the request of either party, both BRA and USFWS will meet to discuss results from CCAA conservation measures that year and discuss any potential modifications to this conservation agreement. Several of the aforementioned conservation measures will play an essential role in adaptive management discussions. Applied research and survey data will aid in identifying habitat, water quality, and water quantity factors important in structuring Covered Species populations. Additionally, long-term monitoring data and updated hydrologic modeling will aid in identifying if and when such stressors occur, or are predicted to occur, in the Covered Area. Together, these conservation measures will provide the basis for adaptive management into the future. It should also be noted that the long-term monitoring program (habitat, mussels, host fish, water quality, and water quantity) will serve as the baseline for evaluation as the CCAA moves forward.

Specific conservation measures which will be systematically reviewed and discussed, along with potential adaptive actions, are provided in **Table 4**. Each of these measured could directly influence potential management adjustments as new information is acquired through time.

Table 4. Conservation measures and examples of potential adaptive actions.

Conservation Measure	Potential Adaptive Action
Distributional Surveys to Fill Data Gaps	New information on Covered Species distributions will be used to facilitate changes to Mussel Conservation Zones and related avoidance/minimization measures.
Updated Hydrologic Modeling	Updated water use projections or climate change forecasts will influence hydrologic modeling and result in changes to expected future risk of key mussel populations that require reevaluation of avoidance and minimization zones.
Communication / Education / Outreach	Newly available or more efficient methods and newly emerging media outlets will be utilized for education and outreach opportunities.
Applied Research (Physiology and Environmental Flows)	Increased knowledge of physiological tolerances and flow-ecology relationships related to mussels will guide the development of freshwater mussel specific environmental flow criteria for potential consideration in TCEQ environmental flow standards reevaluation.
Long-term Monitoring	Long-term trends in habitat, water quality, fish host, or Covered Species populations in a certain reach will inform adjustment to avoidance and minimization measures within that reach.
Short-term Refugia	The contingency plan for short-term refugia will be modified through time as new information, facilities and technologies become available.
Captive Propagation	Should successful captive propagation of the Covered Species become a reality, management decisions will be made regarding the best use of propagated individuals.

During this annual meeting, each party shall present any modifications to the agreement that they propose and the justification for those modifications. If mutually agreed upon, minor amendments are possible as described in Section 17.3. It is understood that adaptive management is a program and not an instantaneous event that relies on a solid baseline understanding and strong science. As such, it is recognized that several of the conservation measures informing these potential modifications will not be substantially completed until year 6 following execution of this agreement.

13.0 Changed and Unforeseen Circumstances

In the case of changed or unforeseen circumstances, assurances listed in this document apply to BRA where the CCAA is being properly implemented. "Changed circumstances" as defined in 50 CFR § 17.are, "changes in circumstances affecting a species or geographic area covered by a conservation plan or agreement that can reasonably be anticipated by plan or agreement developers and the USFWS and that can be planned for (e.g., the listing of new species, or a fire or other natural catastrophic event in areas prone to such events)." "Unforeseen circumstances" are changes in circumstances that could not reasonably have been anticipated by BRA and FWS at the time of the CCAA's negotiation and development, and result in a substantial and adverse change in the status of the species.

13.1 Changed Circumstances

If additional Conservation Measures (including conservation measures and actions as described in this CCAA) are necessary to respond to changed circumstances and the measures were set forth in this CCAA, BRA will implement the measures specified herein. The BRA and the USFWS agree that a changed circumstance will have occurred if, at any time during the course of this agreement, the following conditions apply:

1. Another freshwater mussel or other aquatic species becomes listed within the Covered Area. If so, then conservation zones will be updated to include the distribution of this species, and conservation measures will be evaluated to account for the additional listing. If both parties agree that existing conservation measures are adequate for the newly listed species or agree on additional conservation measures to account for the newly listed species, then this agreement can be amended, preventing the need for a completely new agreement to be developed. Any change in the permit due to the listing of a new species will result in an amendment to the permit. This amendment will be focused only on the amendments proposed, such as, new species and modifications to the conservation measures; but not to any existing conservation measures not affected by the amendment.
2. Critical habitat is designated for covered species or for newly listed aquatic species within the Covered area. If so, then conservation zones will be updated to include the critical habitat, if not already covered, and conservation measures will be evaluated to account for the protection of the critical habitat. If both parties agree that existing conservation measures are adequate for protecting critical habitat or agree on additional conservation measures to protect critical habitat, then this agreement can be amended, preventing the need for a completely new agreement to be developed. Any change in the permit due to the designation of critical habitat for a new species will result in an amendment to the permit. This amendment will be focused only on the amendments proposed, such as modifications to the conservation measures; but not to any existing conservation measures not affected by the amendment.
3. Delisting of a Covered Species. Should USFWS publish a decision to delist a covered species, USFWS will notify BRA once the Final Rule is published in the Federal Register. In response to this changed circumstance, USFWS agrees that BRA may amend the CCAA and related documents to remove the delisted species from the list of Covered

Species and remove some or all the provisions related solely to the delisted species. Any change in the permit due to the delisting of a covered species will result in an amendment to the permit. This amendment will be focused only on the amendments proposed, such as, modifications to the conservation measures; but not to any existing conservation measures not affected by the amendment. BRA acknowledges that if the agreement and permit are amended to remove a covered species, then BRA will no longer receive assurances associated with that species.

4. Special Rules for Threatened Species. In the event that USFWS issues a Special Rule for threatened species, USFWS shall notify BRA of the changed circumstance. In the event of this Changed Circumstance, BRA may amend the CCAA and related documents to incorporate any applicable provisions of the Special Rule into the CCAA. Any change in the permit due to the publication of a special (i.e., 4(d)) rule for a covered species will result in an amendment to the permit. This amendment will be focused only on the amendments proposed, such as, modifications to the conservation measures; but not to any existing conservation measures not affected by the amendment. The net conservation benefit standard for issuance of a CCAA will remain in effect as the USFWS decides whether or not to issue an amended permit.
5. Taxonomic Changes. If taxonomic changes alter the known range, distribution or abundance of a Covered Species in ways that impact the incidental take authorized under this CCAA, BRA will coordinate with USFWS to amend the CCAA and any related documents, as appropriate.
6. New Distributional Information. If new survey expands the known range of distribution of the Covered Species, the BRA will update the Covered Area and conservation zones to include the newly identified range expansion. If both parties agree to the updated Covered Area and conservation zone designation for the range expansion, then this agreement can be amended, preventing the need for a completely new agreement to be developed.
7. TCEQ Environmental Flow Standards are substantially revised. If so, then BRA will coordinate with USFWS to evaluate if revision has the potential to negatively or positively impact Covered Species. If impacts are likely to be positive, no amendment to CCAA will be necessary. If revision has potential to be negative, BRA and USFWS will determine if revision to conservation measures is necessary and feasible and amend CCAA accordingly.
8. TCEQ Environmental Flow Standards are abolished. If so, then BRA agrees to operate following the WMP for the life of this agreement.
9. Environmental Flows Achievement Reports. If new survey expands the known range of distribution of the Covered Species, the BRA will update the Annual Environmental Flows Achievement Report or Supplemental Annual Environmental Flows Achievement Report, as appropriate, to include reporting on environmental flows in the expanded range.
10. Invasive species are determined to be threatening the persistence of the Covered Species in the Covered Area. If so, BRA will work with USFWS and TPWD to conduct research or investigate potential removal and control efforts. Further, BRA will implement

invasive species removal and control efforts that would not exceed 10 percent increase in the total annual operating costs of implementing the CCAA at the time. BRA will seek to cost share or secure matching grants if costs exceed the 10% spending cap for this Changed Circumstance. TPWD and USFWS may contribute funds or in-kind support for invasive species control efforts, at their sole discretion at the time and depending on availability of funds and other resources.

11. Fish host populations are determined to be in decline in the Covered Area. If so, BRA will work with USFWS and TPWD to conduct research or investigate what has led to the decline and what can be done to reverse or prevent further decline. Further, BRA will implement host fish population augmentation efforts that would not exceed 10 percent increase in the total annual operating costs of implementing the CCAA at the time. BRA will seek to cost share or secure matching grants if costs exceed the 10% spending caps for this Changed Circumstance. USFWS may contribute funds or in-kind support for host fish restoration efforts, at their sole discretion at the time and depending on availability of funds and other resources.
12. Additional hydrologic modeling activities identifies new areas of the basin known to be occupied by the Covered Species to be at risk under future drought and management scenarios. BRA will evaluate measures to maintain subsistence flows in these newly identified areas and incorporate this new technical guidance information into the WMP to provide for the ecological needs of the Covered Species.
13. Allen's Creek Reservoir does not become operational during the term of this CCAA. If Allen's Creek Reservoir is not available as part of BRA's system of reservoirs to deliver surface water and flows for Covered Species, then BRA will evaluate other measures to maintain subsistence flows in areas occupied by the Covered Species downstream from Allen's Creek confluence. BRA will implement those measures in close coordination with USFWS.
14. If a catastrophic natural event such as wild fire, tornado, flood, toxicant or contaminant spill, dam failure, water treatment plant failure, or other event or disaster where adverse effects would be expected to temporarily reduce or degrade habitat, USFWS will hold BRA harmless for those impacts that are not a result of BRA's gross negligence. However, consistent with BRA's intent to provide a meaningful net conservation benefit to the Covered Species, BRA will coordinate with TPWD and USFWS and assist those agencies in habitat and population restoration efforts, at the sole discretion of TPWD and USFWS. BRA will make funds and in-kind resources available (not to exceed 10 percent increase in the total annual operating budget of the CCAA at the time) to assist in those efforts. USFWS may contribute funds or in-kind support for restoration efforts, at their sole discretion at the time and depending on availability of funds and other resources.
15. The total costs to implement additional conservation measures associated with a combination of Changed Circumstances will not exceed a total of 20 percent increase in the total annual operating budget of the CCAA at the time, and USFWS will help BRA prioritize which actions would be expected to result in the greatest conservation benefit. USFWS may contribute funds or in-kind support for restoration efforts, at their sole discretion at the time and depending on availability of funds and other resources.

16. If the TCEQ takes an action that adversely impacts a Conservation Measure BRA will coordinate with USFWS to adjust the affected conservation strategy to reduce the impact of the TCEQ's action, if possible. If both parties agree to the adjustment of the impacted Conservation Measure, then this agreement can be amended, preventing the need for a completely new agreement to be developed.

13.2 Unforeseen Circumstances

If additional Conservation Measures (including conservation measures and actions as described in this CCAA) are necessary to respond to unforeseen circumstances, FWS may require additional measures of BRA, but only if such measures are limited to modifications within the CCAA's conservation strategy for the Covered Species, as described in Section 6 of this CCAA, and only if those measures maintain the original terms of the CCAA to the maximum extent possible. These additional Conservation Measures (including conservation measures and actions as described in this CCAA) will not involve the commitment of additional land, water, financial compensation, or additional restrictions on the use of land, water, or other natural resources available for development or use under the original terms of the CCAA without the consent of BRA.

The FWS will demonstrate if unforeseen circumstances exist, using the best scientific and commercial data available. These findings must be clearly documented and based upon reliable technical information regarding the status and habitat requirements of the Covered Species. The FWS will consider, but is not limited to, the following factors:

- Size of the current range of the species;
- Ecological significance of the portion of the range affected by the Covered Area of the CCAA;
- Level of knowledge about the Covered Species and the degree of specificity of the species' conservation program under the CCAA; and,
- Whether failure to adopt additional Conservation Measures would appreciably reduce the likelihood of survival and recovery of the Covered Species.

In the unlikely situation in which an unforeseen circumstance results in likely jeopardy to a species covered by this CCAA and enhancement of survival permit, the Service could revoke this CCAA and permit as a last resort. However, the Service and its cooperators would first exercise all possible means to remedy the situation through other means (50 CFR § 17.22(d)(7).

14.0 Covered Activities

14.1 CCAA related conservation, research, and monitoring activities

Covered Activities for this CCAA include the proposed conservation measures, applied research, long-term monitoring, and adaptive management activities described herein. These activities are designed to increase populations and improve habitat for the Covered Species by protecting critical habitats from future disturbance, ensuring appropriate flow conditions for population persistence, maintaining current data on distribution and population health, identifying

populations of conservation priority, and defining key water quality and habitat stressors. The conservation activities will enable and encourage natural (and perhaps with help from TPWD or FWS sponsored reintroductions) increases in population number and extent of candidate mussels, as threats to the species, namely reduced flows during critical dry periods through management of the BRA system, are reduced through implementation of a comprehensive conservation strategy to benefit mussels in the Brazos basin. Information generated through the applied research and long-term monitoring will be used in an adaptive management framework to facilitate sound management activities, for the purposes of providing a substantial net conservation benefit over the 20-year term of the CCAA and permit. Although harm to the Covered Species is expected to be minimal and incidental to the proposed conservation, research and monitoring activities; all appropriate measures will be taken to minimize harm or incidental take that could occur during the implementation of those activities. Examples of potential incidental take could potentially include death of individual organisms during applied research studies, or disturbance of habitat during monitoring activities. However, since these conservation activities will provide a net conservation benefit over the course of the CCAA, incidental take associated with implementation of these activities, or the water supply management and other legal activities outlined in Section 14.2, will be covered by the ESA section 10(a)(1)(A) enhancement-of-survival Permit, should either of the Covered Species become listed as threatened or endangered.

14.2 Existing BRA Water Supply and Delivery

This CCAA covers the activities conducted by BRA during their day-to-day water supply and delivery operations. Operating the BRA System involves multiple components including physical operation and maintenance of reservoirs and associated diversion, storage, and delivery of surface water, as well as compliance with water right permits and contract requirements.

Routine operation and maintenance activities generally include: water releases from the reservoir; inspections, cleaning, and repairs to intake structures and pump stations; inspecting, cleaning, replacing or repairs to dam gates and other mechanical structures on dams; dewatering concrete stilling basins below reservoirs for dam safety inspection, and when necessary, repairs to this part of the structure; and replacing or adding riprap for erosion control on the river banks immediately downstream of the dams but still within the dam's footprint. Although the known locations of Covered Species are sufficiently downstream of BRA dams to minimize the effects of these activities on the Covered Species, it is possible that these routine operation and maintenance activities could result in take of the Covered Species, should they become listed.

It should be noted that water supply operations in the Brazos River are complex and influenced by multiple users. The water rights associated with the BRA System currently equate to about 38% of the total permitted diversions within the basin. The 11 existing reservoirs authorize a total collective impoundment storage volume of 2,222,949 acre-feet, or approximately 53% of the total permitted storage within the entire basin.

The BRA operates its System in accordance with its water rights and water supply contracts to help meet water needs in the basin and to provide a resilient water supply. During times of drought, when senior water right holders' permitted water supply is not being met through

natural flows, the State of Texas' Water Rights system requires that the BRA allow the passage of inflows through its reservoirs to meet the senior water right holders' needs. This water is transported via the bed and banks of the Brazos River and its tributaries. Additionally, many Brazos basin surface water users that contract with BRA for water supply are located in the lower Brazos basin. The primary method of conveyance of stored waters to these customers is also via the bed and banks of the Brazos River and its tributaries. Thus, during times of drought, downstream water deliveries from the BRA's System result in flow in the Brazos River and its tributaries.

Furthermore, the WMP associated with BRA's System Operation Permit (Water Use Permit No. 5851) requires that the State of Texas' Environmental Flow Standards for the Brazos basin must be met before water can be diverted from the Brazos River and its tributaries under Permit 5851 (BRA WMP Technical Report Section 4.0). The BRA will continue to develop new water supply projects, both surface water and groundwater, with the goal of increasing drought security and water availability for both human and aquatic species, including the Covered Species, in the BRA's System. Coincidentally, environmental flow standards must be accounted for in all new surface water supply projects. Note that construction of new water supply and delivery infrastructure is beyond the scope of this CCAA, and new water supply and delivery infrastructure will be permitted separately should one or more of the Covered Species become listed under the Act. However, maintenance and operation of new infrastructure, like the Allen's Creek project, is expected to further the goals of this CCAA by helping to provide a net conservation benefit to the Covered Species over the 20-year term of this CCAA and permit, as described in Section 9.3.2. Thus, Covered Activities include maintenance and operation of existing as well as future water supply and delivery infrastructure developed in accordance with this CCAA but not their initial construction. New water supply projects that do not result in adverse impacts will provide benefits to freshwater mussels to the extent that BRA can use new water supply to provide for the instream flow and habitat needs of freshwater mussels, especially during droughts, through management of the BRA system of reservoirs.

15.0 Incidental Take

As part of this agreement, a variety of voluntary conservation measures will be implemented to benefit the Covered Species and population monitoring will be conducted to examine trends in population status through time. Should the Covered Species become listed, exact levels of incidental take associated with the activities in this CCAA are undeterminable at this time, but are expected to be minimal. Although minimal incidental take could occur as a result of activities in this agreement, implementation of this CCAA and subsequent conservation measures will provide conservation benefit to the Covered Species that is expected to result in net conservation benefit overall. The USFWS will issue an ESA section 10(a)(1)(A) enhancement-of-survival permit to BRA providing incidental take coverage for the Covered Activities and Conservation Measures described in this CCAA in the event one or more of the Covered Species is subsequently listed as threatened or endangered. Any take will be incidental to otherwise lawful activities described in this CCAA. Further, the BRA does not expect that the Covered Activities and Conservation Measures will result in long-term damages to habitats for the Covered Species.

Incidental Take could occur as a result of BRA's activities that involve operation and maintenance of its existing water supply and delivery infrastructure, and from implementation of its conservation, management, and monitoring program designed to benefit freshwater mussels. For example, Balcones spike or Texas fawnsfoot may be inadvertently harmed by the downstream effects of: individual plant treatment of aquatic-approved herbicides; releases of water from stilling basins that is of high temperature, low dissolved oxygen or otherwise degraded; or through sediments transported downstream following maintenance of reservoir infrastructure including dams, rip-rap, and stilling basins. Further, Balcones spike or Texas fawnsfoot may be inadvertently killed or injured during population surveys and other long-term monitoring activities, or habitat manipulations in the short-term. Considered altogether, incidental take associated with BRA's activities is not expected to be great enough to compromise the viability of populations of Balcones spike or Texas fawnsfoot in the Brazos River basin.

The Covered Species are expected to naturally increase in population numbers and extent following implementation of the conservation measures and associated activities or are otherwise reintroduced. If that were to occur, there is an increased likelihood that injury or death to a Balcones spike or Texas fawnsfoot individual will occur as a result of BRA's ongoing water management and conservation activities. Adverse effects to the Balcones spike or Texas fawnsfoot could occur in the forms of death, injury, and reproductive failure during the implementation of water management or conservation activities. For example, Balcones spike or Texas fawnsfoot may be inadvertently killed or injured during population surveys and other long-term monitoring activities, or habitat manipulations in the short-term. Direct take of Covered Species, if listed and if determined to be necessary, for applied research would be provided for in individual 10(a)(1)(A) scientific permits issued directly to the researchers, and not by the CCAA. Individuals of the Covered Species may experience reproductive failure and reduced growth rates associated with being handled during surveys or relocation events, or from environmental stress associated with short-term periods of reduced flows. Sub-adult life stages including glochidia and juveniles may be especially sensitive. Balcones spike or Texas fawnsfoot may be killed or injured due to infrastructure maintenance or upgrades associated with BRA's surface water supply and delivery operations, or catastrophic failure. Although considered unlikely, Balcones spike or Texas fawnsfoot may also be killed or injured during routine water management activities (i.e., delivering water from BRA reservoirs to downstream customers via the bed and banks of the Brazos River).

The USFWS anticipates that incidental take of Covered Species will be difficult to detect for the following reasons: juveniles of the covered species have a small body size and finding a dead or impaired juveniles is unlikely; losses may be masked by seasonal fluctuations in population size (and detectability) or by losses associated with actions or events outside of BRA's control; losses are most likely to be sub lethal and difficult to measure. Larger individuals are easier to detect, especially because they are usually found in aggregations called mussel beds. Although this agreement does not anticipate that large scale dewatering events of entire mussel beds leading to stranding of adult mussels because of BRA's activities, it is still possible that, in combination with factors outside of BRA's control, the death of mature individuals could be visibly detectable

if entire riffles or bank habitats are persistently dewatered. Sub-adult life stages are not likely to be detected. The level of monitoring identified in this agreement would detect this level of take, especially because BRA will have knowledge of flow conditions in occupied stream reaches. Larger individuals are also more likely to be encountered during monitoring activities and take associated with such encounters is relatively easy to quantify, track, and report.

BRA will notify USFWS as soon as reasonably possible in the event that BRA becomes aware of any take occurring or expected to occur resulting from covered activities or implementation of conservation measures.

The purpose of the agreement is to protect Balcones spike and Texas fawnsfoot habitat areas, and to reduce threats so habitat areas can expand; therefore, USFWS expects that the conservation activities covered by the CCAA and permit will increase the amount and quality of suitable Balcones spike and Texas fawnsfoot habitat. There may be minimal, short-term negative effects to some of the Balcones spike or Texas fawnsfoot habitat features associated with some of the covered activities, but generally the effects are expected to be beneficial and result in a net conservation benefit for the Covered Species in the 20-year term of the agreement.

Level and Type of Take and Impacts

Incidental take should be expressed in terms that are measurable and enforceable in the CCAA and in the incidental take permit. The unit of take must be practicable which means it can be monitored and the results of monitoring can be applied to adaptive management decisions.

We anticipate that incidental take of these species will be difficult to definitively quantify for the following reasons: finding a dead or impaired specimen is unlikely; and losses may be masked by seasonal fluctuations in environmental conditions and/or numbers of each species. Therefore, it is not possible to provide precise numbers of mussels that will be harassed, harmed, or killed during implementation of this CCAA. In such instances where take is otherwise difficult to detect and/or quantify, we may quantify take in terms of some aspect of the species' habitat that may be diminished or removed by the action. We are therefore using a percentage of the stream miles per zone that maybe affected as a habitat surrogate measure to identify when take has been exceeded. Negative effects to mussel habitats associated with BRA's Covered Activities are expected to be temporary in nature, and the magnitude of those effects is expected to vary from year to year. Through implementation of the CCAA, possible temporary habitat disturbance are expected to naturally recover with time.

The causal link between using stream miles of riverine habitat as a surrogate (50 CFR 402.14(i)(1)(i)) for take of individual mussels is the fact that mussels spend the majority of their life cycle relatively immobile with most of their bodies buried in sediment of the stream bed. BRA's covered activities include physical disturbance of stream beds as well as possible changes to water quality, water levels, and flow rates. Activities that disturb stream beds and alter water quality, water levels, and flow rates could injure or kill Balcones spike and Texas fawnsfoot (adult mussels, juveniles, larval glochidia) or displace mussels or their host fish (possibly disrupting reproduction) to unsuitable habitats. Low water levels could expose mussels to desiccation, heat stress, and predation. Water quality degradation could result in excessive valve

closure, which has been reported to have negative effects on mussel health and reproduction (through increased energetic costs and reduced feeding rates; Haney et al. 2019, p. 13).

These take approximations can inform possible levels of injury or death to individuals of the Covered Species due to BRA's Covered Activities, and set targets that can be monitored and reported annually. BRA can monitor and document the percentage of stream miles in each zone affected by its actions (and possibly others), through a variety of measures including remote sensing and habitat monitoring. Additionally, dead shells and recently dead individuals may be detected during routine or contemporaneous monitoring visits, and reported to the Service.

Given Zone A is 56.4 stream miles of potential Balcones spike habitat, and that most of these stream miles are distant from BRA infrastructure that could cause take, one could assume that not more than 10% of those stream miles could be adversely affected by BRA's covered activities over the term of the CCAA, yielding 5.64 stream miles that could somehow be adversely affected in 20 years.

Given Zone B is 181.6 stream miles of potential high density Texas fawnsfoot habitat, and that most of these stream miles are distant from BRA infrastructure that could cause take, one could assume that not more than 10% of those stream miles could be adversely affected by BRA's covered activities over the term of the CCAA, yielding 18.16 stream miles that could somehow be adversely affected in 20 years.

Given Zone C is 246.2 stream miles of potential low density Texas fawnsfoot habitat, and that most of these stream miles are distant from BRA infrastructure that could cause take, one could assume that not more than 10% of those stream miles could be adversely affected by BRA's covered activities over the term of the CCAA, yielding 24.62 stream miles that could somehow be adversely affected in 20 years.

Given Zone D is 355.1 stream miles where Texas fawnsfoot is presumed to be absent but possibly will be restored to low density over the next 20 years, and that most of these stream miles are distant from BRA infrastructure that could cause take, one could assume that not more than 10% of those stream miles could be adversely affected by BRA's covered activities over the term of the CCAA, yielding 35.51 stream miles that could be somehow be adversely affected in 20 years.

Therefore, in total, not more 83.93 stream miles are expected to be harmed by BRA's Covered Activities cumulatively over 20 years. Because incidental take of these species will be difficult to detect and monitor, BRA will notify the Service if it expects its activities will affect more than 10% of the habitat identified in any particular zone, cumulatively in 20 years.

16.0 Regulatory Assurances

If approved, The USFWS provides regulatory assurances to BRA that so long as the CCAA is implemented as agreed, the USFWS will not require additional conservation measures nor impose additional land, water, or resource-use restrictions, beyond those stated and agreed to in this CCAA. These assurances are made consistent with the USFWS Candidate Conservation Agreements with Assurances Policy (2016, 81 FR 95164) and will be authorized in an ESA

Section 10(a)(1)(A) enhancement-of-survival permit that becomes effective when and if either of the Covered Species is listed as threatened or endangered in the future. The enhancement-of-survival Permit will authorize the incidental take of the species by BRA as long as their actions are consistent with the CCAA, subject to the terms and conditions described in 50 CFR 17.22(d)(1) and 50 CFR 17.32(d)(1).

17.0 Agreement Term, Responsibilities, Amendment and Termination

17.1 Agreement Term

This CCAA will have a duration of 20 years from the date of signature. It can be renewed upon application by BRA provided the USFWS determines that it still provides net conservation benefit and still complies with applicable CCAA policy.

Should any of the Covered Species become listed as threatened or endangered, the enhancement of survival permit will become effective and remain in effect through the expiration of the CCAA.

17.2 Responsibilities of Each Party

BRA shall be responsible for:

- Funding, administering, and implementing this CCAA and associated voluntary conservation measures per the designated timeline (Section 10.0)
- Reporting to USFWS as described in Section 11.0
- Notifying the USFWS in the event that any lands, waters, or other rights subject to this CCAA are transferred to another entity.

USFWS shall be responsible for:

- Evaluating the results of monitoring data and conservation measures to assess if the actions of this CCAA are providing the desired net conservation benefit
- Reviewing and approving annual reports submitted by BRA
- Issuing an enhancement-of-survival permit to BRA to allow for incidental take of the Covered Species should either of the Covered Species become listed as threatened or endangered in the future. This permit would only authorize incidental take while conducting Covered Activities within the Covered Area.

Both parties shall be responsible for:

- Alerting the other party should any conflicts with ongoing conservation programs for the Covered Species arise or become known.

17.3 Modifications and Amendments

Any party to this CCAA may propose minor amendments to the agreement by providing written notice to the other party. This written notice will include a description of the proposed amendment, the justification for the amendment, and the expected results or outcomes. Once proposed, the other party has 60 days to respond to the amendment request. Proposed amendments will become effective upon the other parties' written concurrence, and the CCAA

document will be modified or addended, as appropriate, unless there is a change in affects to covered species.

In the event that an amendment results in a different level of take than that associated with the original CCAA, changes in the permit conditions, addition or removal of covered species, an extreme unforeseen circumstance, or a change to the net conservation benefit such that the CCAA standard may not be met, this would be considered a major amendment. A major amendment will be subject to procedural requirements of Federal laws and regulations and a formal CCAA amendment process. This process could include additional analysis by the USFWS, public notification in the Federal Register, and NEPA analysis.

17.4 Dispute Resolution

The BRA and USFWS agree to work together in good faith to resolve any disputes using dispute resolution procedures agreed upon by all parties.

17.5 Termination of CCAA, Suspension or Revocation of Permit

The BRA may terminate the implementation of the CCAA's voluntary management actions at any time for any cause prior to the CCAA's expiration date, even if the expected benefits have not been realized. In such a case, if any of the Covered Species have been listed and an Enhancement of Survival Permit has been issued, BRA would be required to surrender the permit and thus relinquish all associated take authority and assurances.

If issued, the USFWS may suspend or revoke the Enhancement of Survival Permit for cause in accordance with the laws and regulations in force at the time. Criteria for revocation are identified in 50 CFR 17.22 (d)(1) for species that are subsequently listed as endangered and 50 CFR 17.32 (d)(1) for species that are subsequently listed as threatened.

18.0 Authorized Signatures

For the Brazos River Authority:

David Collinsworth

General Manager/CEO

Brazos River Authority

For the U.S. Fish and Wildlife Service:

ADAM ZERRENNER Digitally signed by ADAM ZERRENNER
Date: 2021.06.08 14:05:33 -05'00'

Adam Zerrenner

Field Office Supervisor, Austin Ecological Services Field Office

U.S. Fish and Wildlife Service

19.0 References

Aldridge, D.C., and A.L. McIvor. 2003. Gill evacuation and release of glochidia by *Unio pictorum* and *Unio tumidus* (Bivalvia: Unionidae) under thermal and hypoxic stress. Journal of Molluscan Studies 63:55-59.

Baker, S.M., and J.S. Levinton. 2003. Selective feeding by three native North American freshwater mussels implies food competition with zebra mussels. Hydrobiologia 505:97-105.

Baxter, R.M. 1997. The environmental effects of dams and impoundments. Annual Review of Ecology and Systematics 8:255-283.

Becker, J.C., K.J. Rodibaugh, B.J. Labay, T.H. Bonner, Y. Zhang, and W.H. Nowlin. 2014. Physiographic gradients determine nutrient concentrations more than land use in a Gulf Slope (USA) river system. Freshwater Science 33:731-744.

Barnhart, M.C., W.R. Haag, and R.N. Williams. 2008. Adaptations to host infection and larval parasitism Unionoida. Journal of the North American Benthological Society. 27:370-394.

Bonner, T.H., E.L. Oborny, B.M. Littrell, J.A. Stoeckel, B.S. Helms, K.G. Ostrand, P.L. Duncan, and J. Conway. 2018. Multiple freshwater mussel species of the Brazos River, Colorado River, and Guadalupe River basins. Final Report to Texas Comptroller of Public Accounts.

Brazos River and Associated Bay and Estuary System: Stakeholder Committee and Expert Science Team (Brazos BBEST). 2012. BBEST Environmental Flow Regime Recommendations Report. Texas Commission on Environmental Quality, Austin, Texas.

Brazos River Authority (BRA). 2018. Conformed Water Management Plan for Water Use Permit No. 5851. Available online at: https://www.brazos.org/About-Us/Water-Supply/SysOps

Brim-Box, J., and J. Mossa. 1999. Sediment, land use, and freshwater mussels: Prospectus and problems. Journal of North American Benthological Society 18:99-117.

Burlakova, L.E., and A.Y. Karatayev. 2010. State-Wide Assessment of Unionid Diversity in Texas. Texas Parks and Wildlife, Austin, Texas.

Burlakova, L.E., B.L. Tulumello, A.Y. Karatayev, R.A. Krebs, D.W. Schloesser, D.T. Zanatta, W.L. Paterson, T.A. Griffith, M.W. Scott, and T. Crail. 2014. Competitive replacement of Invasive congeners may relax impact on native species: interactions among zebra, Quagga, and native unionid mussels. PLoS ONE https://doi.org/10.1371/journal.pone.0114926

Cherry, D.S., J.L. Scheller, N.L. Cooper, and J.R. Bidwell. 2005. Potential effects of Asian clam (*Corbicula fluminea*) Die-offs on native freshwater mussels (Unionidae) I: water-column ammonia levels and ammonia toxicity. Journal of the North American Benthological Society 24:369-380.

Cooper, N.L., J.R. Bidwell, and D.S. Cherry. 2005. Potential effects of Asian clam (*Corbicula fluminea*) die-offs on native freshwater mussels (Unionidae) III: porewater ammonia. Journal of the North American Benthological Society 24:381-394.

Dahm, C.N., R.J. Edwards, and F.P. Gelwick. 2005. Gulf Cost Rivers of the Southwestern United States. Rivers of North America. Elsevier Academic Press, NY.

Dall, W.H. 1896. Diagnoses of new mollusks from the survey of the Mexican boundary. Proceedings of the United States National Museum. 18:1-6.

Dudding, J., M. Hart, J. Khan, C.R. Robertson, R. Lopez, and C.R. Randklev. 2019. Host fish associations for two highly imperiled mussel species from the southwestern United States: *Cyclonaias necki* (Guadalupe Orb) and *Fusconaia mitchelli* (False Spike). Freshwater Mollusk Biology and Conservation 22:12-19.

Dudding, J.F., M. Hart, J.M. Khan, C.R. Robertson, R. Lopez, and C.R. Randklev. 2020. Reproductive life history of 2 imperiled and 1 widely-distributed freshwater mussel species from the southwestern United States. Freshwater Science. 39(1):156-168.

Dunn, D.D., and T.H. Raines. 2001. Indications and potential sources of change in sand transport in the Brazos River, Texas. Water-Resources Investigations Report 01-4057. U.S. Geological Survey. Austin, Texas.

Environmental Protection Agency (EPA). 2013. Final Aquatic Life Ambient Water Quality Criteria For Ammonia-Freshwater. 78 FR 52192:52192-52194.

Fontanier, C.E. 1982. The distribution of Corbicula (Bivalvia, Corbiculidae) in the Brazos River system, Texas. Texas Journal of Science 34:5-15.

Ferreira-Rodriquez, N., R. Sousa, and I. Pardo. 2018. Negative effects of *Corbicula fluminea* over native freshwater mussels. Hydrobiologia 810:85-95.

Freeman, M.C., and P.A. Marcinek. 2006. Fish assemblage responses to water withdrawal and water supply reservoirs in piedmont streams. Environmental Management 38:435-450.

Freshwater Mollusk Conservation Society (FMCS). 2016. A National Strategy for the Conservation of Native Freshwater Mollusks. Freshwater Mollusk Biology and Conservation 19:1-21.

Fritts, A.K., M.W. Fritts, S.A. Carleton, and R.B. Bringolf. 2012. Shifts in stable isotope signatures of Freshwater mussel glochidia during attachment to host fish. Journal of Molluscan Studies 79:163-167.

Gagnon, P.M., S.W. Golladay, W.K. Michener, and M.C. Freeman. 2004. Drought response of freshwater mussels (Unionidae) in coastal plain tributaries of the Flint River basin, Georgia. Journal of Freshwater Ecology 19:667-679.

Gido, K.B., W.K. Dodds, and M.E. Eberle. 2010. Retrospective analysis of fish community change during a half-century of land use and streamflow changes. Journal of North American Benthological Society 29:970-987.

Gillis, P.L., R. McInnis, J. Salerno, S.R. de Solla, M.R. Servos, and E.M. Leonard. 2017. Municipal wastewater treatment plant effluent-induced effects on freshwater mussel populations and the role of mussel refugia in recolonizing an extirpated area. Environmental Pollution 225:460-468

Golladay, S.W., P. Gagnon, M. Kearns, J.M. Battle, and D.W. Hicks. 2004. Response of freshwater Mussel assemblages (Bivalvia: Unionidae) to record drought in the Gulf Coastal Plain of Southwest Georgia. Journal of the North American Benthological Society 23:494-506.

Graf, W.L. 2006. Downstream hydrologic and geomorphic effects of large dams on American rivers. Geomorphology 79:336-360.

Haag, W.R., and M.L. Warren. 2008. Effects of severe drought on freshwater mussel assemblages. Transactions of the American Fisheries Society 137:1165-1178.

Haag, W.R. 2012. North American Freshwater Mussels: Natural History, Ecology, and Conservation. Cambridge University Press, New York.

Haney, A., H. Abdelrahman, and J.A. Stoeckel. 2019. Effects of thermal and hypoxic stress on respiratory patterns of three unionid species: implications for management and conservation. Hydrobiologia. https://doi.org/10.1007/s10750-019-04138-4

HDR Engineering, Inc (HDR). 2012. Cedar Ridge Reservoir Project Clear Fork Brazos River Basin Freshwater Mussel Study 2009, 2010, and 2011.

Howells, R.G. 1996. Distributional Surveys of Freshwater Bivalves in Texas: Progress Report for 1995. Texas Parks and Wildlife, Austin, Texas.

Howells, R.G., R.W. Neck, and H.D. Murray. 1996. Freshwater Mussels of Texas. Texas Parks and Wildlife, Austin, Texas.

Howells, R.G. 2002. Distributional Surveys of Freshwater Bivalves in Texas: Progress Report for 2001. Texas Parks and Wildlife, Austin, Texas.

Howells, R.G. 2003. Declining Status of Freshwater Mussels in the Rio Grande, with comments on Other Bivalves. Aquatic Fauna of the Northern Chihuahuan Desert: Contributed Papers from a Special Session within the Thirty-Third Annual Symposium of the Desert Fishes Council.

Howells, R.G. 2014. Field Guide to Texas Freshwater Mussels. BioStudies, Kerrville, TX.

Inoue, K., C.R. Randklev, and A. Pieri. 2017. Molecular studies and their importance to mussel conservation: A Case study of cryptic diversity in central and east Texas. Texas Freshwater Mussel Conservation and Stakeholder Summit. Austin, Texas.

Jarvis, J., B. Byars, S. Wong, W. Hamilton, and J. Yelderman, Jr. 2017. Presentation: "Assessing Recharge in Alluvial Aquifer Systems: an Innovative Approach." The Geological Society of America Annual Meeting, Seattle, Washington. Geological Society of America *Abstracts with Programs.* Vol. 49, No. 6.

Johnson, M.., and J. Groce. 2012. Freshwater mussel survey for Waco District of the Texas Department of Transportation. Austin, Texas.

Karatayev, A.Y., R.G. Howells, L.E. Burlakova, and B.D. Sewell. 2005. History of spread and current distribution of *Corbicula fluminea* (Muller) in Texas. Journal of Shellfish Research 24:553-559.

Karatayev, A.Y. and L.E. Burlakova. 2008. Distributional Survey and Habitat Utilization of Freshwater Mussels. Department of Biology, Stephen F. Austin State University, Nacogdoches, Texas.

Karatayev, A.Y., L.E. Burlakova, and D.K. Padilla. 2017. Can introduced species replace lost biodiversity? A test with freshwater molluscs. https://doiorg.cmich.idm.oclc.org/10.1007/s10750-017-3135-1

Khan, J.M, J. Dudding, M. Hart, R. Lopez, and C. Randklev. 2018. Freshwater mussel (Family: Unionidae) data collection in the Middle Brazos and Navasota Rivers. Natural Resources Institute. Dallas, Texas.

Khan, J.M., M. Hart, J. Dudding, C.R. Robertson, R. Lopez, and C.R. Randklev. 2019. Evaluating the upper thermal limits of glochidia for selected freshwater mussel species (Bivalvia: Unionidae) in central and east Texas, and the implications for their conservation. Aquatic Conserv: Mar Freshw Ecosyst. 2019;1-14. https://doi.org/10.1002/aqc.3136

Khan, J.M., J. Dudding, M. Hart, C.R. Robertson, R. Lopez, and C.R. Randklev. 2020a. Linking flow and upper thermal limits of freshwater mussels to inform environmental flow benchmarks. Freshwater Biology. 2020;00:1-16. https://doi.org/10.1111/fwb.13598

Khan, J.M., J. Dudding, M. Hart, E. Tsakiris, and C.R. Randklev. 2020b. Linking life history strategies and historical baseline information shows effects of altered flow regimes and impoundments on freshwater mussel assemblages. Freshwater Biology. 2020;00:1-12. https://doi.org/10.1111/fwb.13591

Kinniburgh, F., M.G. Simonton, and C. Allouch. 2015. Come heat and high water: risk in the southeastern U.S. and Texas.

Kloesel, K., B. Bartush, J. Banner, D. Brown, J. Lemory, X. Lin, G. McManus, E. Mullens, J. Nielsen-Gammon, M. Shafer, C. Sorenson, S. Sperry, D. Wildcat, and J. Ziolkowska, 2018: Southern Great Plains. *In* Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 987–1035. doi: 10.7930/NCA4.2018.CH23 On the Web: https://nca2018.globalchange.gov/chapter/southern-great-plains

Kondolf, G.M., and R.J. Batalla. 2005. Hydrological effects of dams and water diversions on rivers of Mediterranean-climate regions: examples from California. Pages 197-211 *in* Catchment Dynamics and River Processes: Mediterranean and Other Climate Regions, Volume 7 [Garcia, C. and R.J. Batalla (eds.)]. Elsevier Science.

Layzer, J.B., M.E. Gordon, and R.M. Anderson. 1993. Mussels: the forgotten fauna of regulated rivers. A case study of the Caney Fork River. Regulated Rivers: Research and Management 8:63-71.

Layzer, J.B., and L.M. Madison. 1995. Microhabitat use by freshwater mussels and recommendations for determining their instream flow needs. Regulated Rivers: Research and Management 10:329-345.

Lea, I. 1859. Description of seven new species of Uniones from South Carolina, Florida, Alabama and Texas. Proceedings of the Academy of Natural Sciences of Philadelphia 11:154-155.

Ligon, F.K., W.E., Dietrich, and W.J. Trash. 1995. Downstream ecological effects of dams. BioScience 45:183-192.

Loaiciga, H.A., D.A. Maigment, and J.B. Valdes. 2000. Climate-change impacts in a regional karst aquifer, Texas, U.S.A. Journal of Hydrology 227:173-194.

Mabe, J.S., and J. Kennedy. 2014. Habitat conditions associated with a reproducing population of the critically endangered freshwater mussel *Quadrula mitchelli* in central Texas. The Southwestern Naturalist 59:297-300.

Mace, R.E., and S.C. Wade. 2008. In hot water? How climate change may (or may not) affect groundwater resources of Texas. Gulf Coast Association of Geological Societies Transaction 58:655-668.

Magilligan, F.J., and K.H. Nislow. 2005. Changes in hydrologic regime by dams. Geomorphology 71: 61-78.

Morton, J., C. Robertson, and C.R. Randklev. 2018. Upper thermal limits of freshwater mussels in Texas. 2018 Annual Meeting of the Texas Chapter American Fisheries Society. College Station, Texas.

National Research Council (NRC). 2005. The Science of Instream Flows: A Review of the Texas Instream Flow Program. Washington, DC: The National Academies Press. https://doi.org/10.17226/11197

Newton, T.J., and M.R. Bartsch. 2007. Lethal and sublethal effects of ammonia to juvenile Lampsilis mussels (Unionidae) in sediment and water-only exposures. Environmental Toxicology and Chemistry 26:2057-2065.

Newton, T.J., D.A. Woolnough, and D.L. Strayer. 2008. Using landscape ecology to understand and manage freshwater mussel populations. The North American Benthological Society 27:424-439.

Nichols, S.J., and D.A. Wilcox. 1997. Burrowing saves Lake Erie clams. Nature 289:921-921.

Patiño, R., D. Dawson, and M.M. Van Landeghem. 2014. Retrospective analysis of associations between water quality and toxic blooms of golden alga (*Prymnesium parvum*) in Texas reservoirs: Implications for understanding dispersal mechanism and impacts of climate change. Harmful Algae 33:1-11.

Petts, G.E. 1980. Long-term consequences of upstream impoundment. Environmental Conservation 7:325-332.

Pfeiffer, J.M., N.A. Johnson, C.R. Randklev, R.G. Howells, and J.D. Williams. 2015. Generic reclassification and species boundaries in the rediscovered freshwater mussel *'Quadrula' mitchelli* (Simpson in Dall, 1896). Conservation Genetics 17:279-292.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The Natural Flow Regime: A paradigm for river conservation and restoration. BioScience 47:769-784.

Popejoy, T., S. Wolverton, L. Nagaoka, and C.R. Randklev. 2018. Conservation implications of late Holocene freshwater mussel remains of the Leon River in central Texas. Hydrobiologia 810:477-487.

Randklev, C.R., J.H. Kennedy, and B.L. Lundeen. 2009. Distributional Survey and Habitat Utilization of Freshwater Mussels (Family Unionidae) in the Lower Brazos and Sabine River basins. Department of Biology, University of North Texas, Denton, Texas.

Randklev, C.R., B.J. Lundeen, R.G. Howells, and J.H. Kennedy. 2010. First account of a living population of Texas fawnsfoot, *Truncilla macrodon* (Bivalvia: Unionidae), in the Brazos River, Texas. The Southwestern Naturalist 55:297-298.

Randklev, C.R., M.S. Johnson, E.T. Tsakiris, S. Rogers-Oetker, K.J. Roe, S. McMurray, C. Robertson, J. Groce, and N. Wilkins. 2012. False Spike, *Quadrula mitchelli* (Bivalvia: Unionidae) is not extinct: first account of a live population in over 30 years. American Malacological Bulletin 30:327-328.

Randklev, C.R., E.T. Tsakiris, M.S. Johnson, J.A. Skorupski, L.E. Burlakova, J. Groce, and N. Wilkins. 2013a. Is False spike, Quadrula mitchelli (Bivalvia: Unionidae), Extinct? First Account of a very Recently Deceased Individual in Over Thirty Years. The Southwestern Naturalist 58:247-249.

Randklev, C.R., E.T. Tsakiris, R.G. Howells, J. Groce, M.S. Johnson, J. Bergmann, C. Robertson, A. Blair, B. Littrell, and N. Johnson. 2013b. Distribution of Extant Populations of *Quadrula mitchelli* (False spike). Ellipsaria 15:18-21.

Randklev, C.R., M.S. Johnson, E.T. Tsakiris, J.W. Groce, and N. Wilkins. 2013c. Status of freshwater mussel (Unionidae) communities of the mainstem of the Leon River, Texas. Aquatic Conservation: Marine and Freshwater Ecosystems 23:390-404.

Randklev, C.R., M. Cordova, J. Groce, E.T. Tsakiris, and B. Sowards. 2014a. Freshwater mussel (Family: Unionidae) data collection in the middle and lower Brazos River. Institute of Renewable Natural Resources, Texas A&M University. Texas Parks and Wildlife Contract No. 424520.

Randklev, C. R., N. A. Johnson, T. Miller, J. M. Morton, J. Dudding, K. Skow, B. Boseman, M. Hart, E. T. Tsakiris, K. Inoue, and R. R. Lopez. 2017a. Freshwater Mussels (Unionidae): Central and West Texas Final Report. Texas A&M Institute of Renewable Natural Resources, College Station, Texas.

Randklev, C.R., K. Inoue, M. Hart, and A. Pieri. 2017b. Assessing the Conservation Status of Native Freshwater Mussels (Family: Unionidae) in the Trinity River basin.

Rytwinski, T., D.A. Algera, J.J. Taylor, K.E. Smorkorwoski, J.R. Bennett, P.M. Harrison, and S.J. Cooke. 2017. What are the consequences of fish entrainment and impingement associated with hydroelectric dams on fish productivity? A systematic review protocol. Environmental Evidence https://doi.org/10.1186/s13750-017-0087-x

Shields, F.D., S.R. Knight, and C.M. Cooper. 2000. Cyclic perturbation of lowland river channels and ecological response. Regulated Rivers: Research and Management 16:307-325.

Smith, C.H., N.A. Johnson, K. Havlik, R.D. Doyle, and C.R. Randklev. 2020. Resolving species boundaries in the critically imperiled freshwater mussel species, *Fusconaia mitchelli* (Bivalvia: Unionidae). J Zool Syst Evol Res. 2020;00:1-18. https://doi.org/10.1111.jzs.12412

Sowards, B., E.T. Tsakiris, M. Libson, and C.R. Randklev. 2013. Recent collection of a false spike (*Quadrula mitchelli*) in the San Saba River, Texas, with comments on habitat use. Walkerana 16:63-67.

Strayer, D.L. 1999. Effects of alien species on freshwater mollusks in North America. Journal of the North American Benthological Society 18:74-98.

Strayer, D.L., J.A. Downing, W.R. Haag, T.L. King, J.B. Layzer, T.J. Newton, S.J. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. BioScience 54:429-439.

Strayer, D.L. 2008. Freshwater Mussel Ecology: A Multifactor Approach to Distribution and Abundance. University of California Press, Berkeley, California.

Strecker, J.K. 1931. The Naiades or Pearly Freshwater Mussels of Texas. Baylor University Museum Special Bulletin 2:1-71.

Taylor, R.G., B. Scanlon, P. Döll, M. Rodell, R. van Beek, Y. Wada, L. Longuevergne, M. Leblanc, J.S. Famiglietti, M. Edmunds, L. Konikow, T.R. Green, J. Chen, M. Taniguchi, M.F. P. Bierkens, A. MacDonald, Y. Fan, R.M. Maxwell, Y. Yechieli, J.J. Gurdak, D.M. Allen, M. Shamsudduha, K. Hiscock, P.J-F. Yeh, I. Holman, and H. Treidel. 2012. Ground water and climate change. Nature Climate Change 3:322-329.

Texas Department of Transportation (TXDOT). 2017. Aquatic resource relocation plan: FM 413 at the Brazos River, Falls County, Texas. Texas Parks and Wildlife, Austin, Texas.

Texas Instream Flow Program (TIFP). 2018. Instream Flow Study of the Middle and Lower Brazos River. Final Study Report. https://www.twdb.texas.gov/surfacewater/flows/instream/middle_lower_brazos/index.asp

Texas Parks and Wildlife (TPWD). 2019. The Zebra Mussel Threat. Accessed: on June 7, 2019. https://tpwd.texas.gov/huntwild/wild/species/exotic/zebramusselmap.phtml

Tsakiris, E.T. and C.R. Randklev. 2016a. Distribution and habitat associations of freshwater mussels (Bivalvia: Unionidae) in the lower Guadalupe River, Texas. Texas A&M Institute of Renewable Natural Resources, College Station, Texas.

Tsakiris, E.T., and C.R. Randklev. 2016b. Structural Changes in Freshwater Mussel (Bivalvia: Unionidae) Assemblages Downstream of Lake Somerville, Texas. American Midland Naturalist 175:120-127.

U.S. Fish and Wildlife Service (USFWS). 2018. Species Status Report for the Central Texas Mussels: False Spike (*Fusconaia mitchelli*), Texas Fatmucket (*Lampsilis bracteata*), Texas Fawnsfoot (*Truncilla macrodon*), and Texas Pimpleback (*Cyclonaias petrina*). Austin, Texas.

Vaughn, C.C., and D.E. Spooner. 2006. Scale-dependent associations between native freshwater mussels and invasive *Corbicula*. Hydrobiologia 568:331-339.

Vogl, A.L., and V.L. Lopes. 2009. Impacts of water resources development on flow regimes in the Brazos River. Environmental Monitoring and Assessment 157:331-345.

Watters, T.G. 1996. Small dams as barriers to freshwater mussels (Bivalvia, Unionoida) and their hosts. Biological Conservation 75:79-85.

Wellmeyer, J.L., M.C. Slattery, and J.D. Phillips. 2005. Quantifying downstream impacts of impoundment on flow regime and channel planform, lower Trinity River, Texas. Geomorphology 69:1-13.

Wuebbles, D., G. Meehl, K. Hayhoe, T.R. Karl, K. Kunkel, B. Santer, M. Wehner, B. Colle, E.M. Fischer, R. Fu, A. Goodman, E. Janssen, V. Kharin, H. Lee, W. Li, L.N. Long, S.C. Olsen, Z. Pan, A. Seth, J. Sheffield. And L. Sun. 2013. CMIP5 climate 1 model analyses: climate extremes in the United States. Bulletin of the American Meteorological Society 95:571-583.

Young, S.C., R.E. Mace, and C. Rubinstein. 2018. Surface water-groundwater interaction in Texas. Texas Water Journal, 9(1): 129-149.

Zanatta, D.T., and R.W. Murphy. 2007. Range-wide population genetic analysis of the endangered northern riffleshell mussel, *Epioblasma torulosa rangiana* (Bivalvia: Unionoida). Conservation Genetics 8:1393-1404.

Zhang, Y., and R. Wurbs. 2018. Long-term changes in river system hydrology in Texas. Proclamations of the International Association of Hydrological Sciences 379:255-261.

Appendices

Appendix A. Other Native Freshwater Mussel Species

Although specifically targeted at the two Covered Species (Balcones spike and Texas fawnsfoot), conservation measures identified in this CCAA will result in conservation benefit for all native freshwater mussel species in the Covered Area. Based on historic and current records and recognizing the latest taxonomic changes, there are 22 freshwater mussel species (including Balcones spike and Texas fawnsfoot) that potentially occur in the Brazos River basin and could benefit from conservation measures in this agreement (**Table A-1**; Howells 2014; Williams et al. 2017; Johnson et al. 2018). Although sporadic records occur throughout the basin, the most recent survey data indicate that freshwater mussels are currently most diverse and abundant in the lower mainstem Brazos River, as well as several larger tributaries including the Leon River, Little River, Navasota River, and Yegua Creek (Randklev et al. 2013, 2017; Bonner et al. 2018; Khan et al. 2018). It should also be noted that some portions of the basin have yet to be comprehensively surveyed.

Table A-1. Freshwater mussels of the Brazos River basin.

Scientific Name	Common Name	State Status	Federal Status
Arcidens confragosus	Rock pocketbook		
Amblema plicata	Threeridge		
Cyrtonaias tampicoensis	Tampico pearlymussel		
Cyclonaias pustulosa	Pimpleback		
Fusconaia iheringi	Balcones spike	Threatened	Candidate
Glebula rotundata	Round pearlshell		
Lampsilis hydiana	Louisiana fatmucket		
Lampsilis teres	Yellow sandshell		
Leptodea fragilis	Fragile papershell		
Ligumia subrostrata	Pondmussel		
Megalonaias nervosa	Washboard		
Potamilus streckersoni	Brazos Heelsplitter	Threatened	
Potamilus purpuratus	Bleufer		
Pyganodon grandis	Giant floater		
Quadrula apiculata	Southern mapleleaf		
Toxolasma parvum	Lilliput		
Toxolasma texasiense	Texas lilliput		
Tritogonia verrucosa	Pistolgrip		
Truncilla macrodon	Texas fawnsfoot	Threatened	Candidate
Uniomerus declivis	Tapered pondhorn		
Uniomerus tetralasmus	Pondhorn		
Utterbackia imbecillis	Paper pondshell		

Appendix A References

Bonner, T.H., E.L. Oborny, B.M. Littrell, J.A. Stoeckel, B.S. Helms, K.G. Ostrand, P.L. Duncan, and J. Conway. 2018. Multiple freshwater mussel species of the Brazos River, Colorado River, and Guadalupe River basins. Final Report to Texas Comptroller of Public Accounts.

Howells, R.G. 2014. Field Guide to Texas Freshwater Mussels. BioStudies, Kerrville, TX.

Johnson, N.A., C.H. Smith, J.M. Pfeiffer, C.R. Randklev, J.D. Williams, and J.D. Austin. 2018. Integrative taxonomy resolves taxonomic uncertainty for freshwater mussels being considered for protection under the U.S. Endangered Species Act. Scientific Reports (2018) 8:15892. DOI:10.1038/s41598-018-33806-z

Khan, J.M, J. Dudding, M. Hart, R. Lopez, and C. Randklev. 2018. Freshwater mussel (Family: Unionidae) data collection in the Middle Brazos and Navasota Rivers. Natural Resources Institute. Dallas, Texas.

Randklev, C.R., M.S. Johnson, E.T. Tsakiris, J.W. Groce, and N. Wilkins. 2013. Status of freshwater mussel (Unionidae) communities of the mainstem of the Leon River, Texas. Aquatic Conservation: Marine and Freshwater Ecosystems 23:390-404.

Randklev, C. R., N. A. Johnson, T. Miller, J. M. Morton, J. Dudding, K. Skow, B. Boseman, M. Hart, E. T. Tsakiris, K. Inoue, and R. R. Lopez. 2017. Freshwater Mussels (Unionidae): Central and West Texas Final Report. Texas A&M Institute of Renewable Natural Resources, College Station, Texas.

Williams, J.D., A.E. Bogan, R.S. Butler, K.S. Cummings, J.T. Garner, J.L. Harris, N.A. Johnson, and G.T. Watters. 2017. A revised list of the freshwater mussels (Mollusca: Bivalvia: Unionida) of the United States and Canada. Freshwater Mollusk Biology and Conservation 20:33-58.

Appendix B. Hydrologic Modeling

1.0 Introduction

The hydrologic modeling detailed below was conducted as one component of the conservation strategy outlined in the CCAA above. This hydrologic modeling, summarized in Section 8.0 of the CCAA, was used to evaluate future low-flow risk to freshwater mussels within the Covered Area during the permit period, and to thus assist in spatially and temporally prioritizing conservation measures. The analysis focused on low flow events, as these events were considered most likely to potentially influence freshwater mussel persistence. Although large flood flows may also influence freshwater mussel persistence, the BRA has limited ability to manage flood flows. The U.S. Army Corps of Engineers (USACE) is the primary owner and operator of flood control reservoirs in the basin.

When evaluating future hydrology scenarios, it is important to note that BRA is not the sole water management entity in the basin. Conditions are dependent on inter-related operations of hundreds of other water rights located throughout the basin, and the state of Texas has appointed a Watermaster to oversee use of state water rights permits in the Brazos River basin. This analysis accounted for all water users, not just BRA, to characterize future hydrology in the Covered Area.

Depending on local projected water use patterns, climate variables, and other factors the risk of future low flow conditions are expected to vary throughout the basin. The goal of this study was to evaluate the frequency of low flow conditions within segments of the Covered Area under multiple hydrologic scenarios. This information was then used to identify river segments currently occupied by the Covered Species which may experience increased low flow stress under future scenarios, and to identify areas of lower risk that could potentially serve as areas for restoration and enhancement opportunities. To accomplish this, hydrologic scenarios were modeled based on the Brazos River Water Availability Model (WAM; TCEQ 2018), as detailed below.

2.0 Methods

2.1 Study Area

This analysis focuses on the CCAA Covered Area, which includes the Brazos River basin downstream from its confluence with the Clear Fork as well as the Clear Fork tributary, sub-divided into 22 separate TCEQ stream segments. Each stream segment has an associated USGS gage location used to represent the hydrology in that segment (**Figure B-1**). To evaluate the spatial distribution of BRA management, five select gage locations were analyzed; Brazos River near Palo Pinto, Navasota River near Easterly, Little River near Cameron, Brazos River near Hempstead, and Clear Fork Brazos River at Nugent.

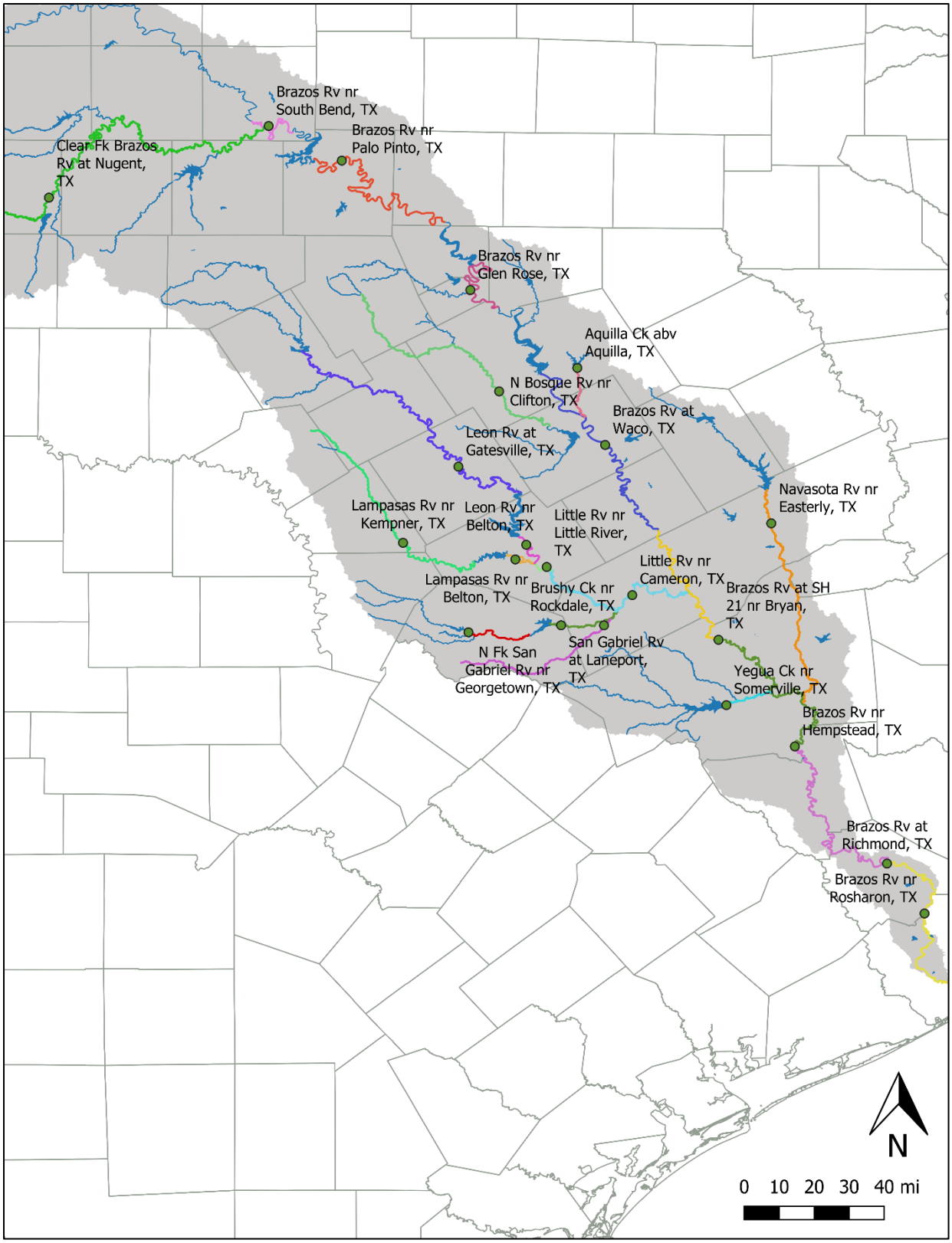


Figure B-1. Map of stream segments and associated gage locations within the Brazos River basin used in this analysis.

2.2 Water Availability Model

Future hydrology estimates were derived from the Water Availability Model (WAM) Water Rights Analysis Program (WRAP) that is relied upon by the state of Texas and maintained by the Texas Commission on Environmental Quality (TCEQ) for water rights permitting in the entire State of Texas, including the Brazos River basin. The WAM is a modeling tool used to predict the amount of water available in a river system under a specified set of conditions. It considers all water users and makes assumptions about water management, including demand schedules; diversion locations; reservoir storage and sedimentation; precipitation and evaporation; stream gains and losses; return flow discharges; and environmental flow conditions. As is typical in WAM modeling, results were simulated on a monthly-average time step. Historical observed stream flow information from USGS gage records were used as a baseline for comparison to model scenarios of projected hydrology to evaluate future changes to hydrologic patterns.

2.3 Model Scenarios

Four different time series representing different scenarios of hydrology and water management were considered for this analysis. Each time series was derived for the period 1940 through 2015 to include drought, base and high flow conditions. The scenarios analyzed included:

1. Naturalized Scenario – represents natural stream flow conditions without any influence of humans, as if no water management, reservoirs, diversions or return flows existed. This naturalized flow time series is used as the basis for the WAM modeling and was calculated based on observed records of stream flows, precipitation, evaporation, diversions, storage and return flows.

2. Historical Conditions – observed stream flow records from USGS, as available during the 1940-2015 period. Historical Conditions can be described as if history would repeat itself.

3. 2060 Scenario – hypothetical scenario where BRA water demands are set at state-projected year 2060 levels at best-anticipated locations, and where return flow discharges are added back into the streams at levels consistent with recent history, and non-BRA water rights are at full-authorization levels. In this scenario, Allen's Creek reservoir is assumed to be constructed and in operation. Although 2060 is beyond the permit term, and thus conservative, this scenario represents the best-known projection of water management that may occur during the 20-year CCAA timeframe.

4. Full Authorization Scenario – hypothetical maximum-use future scenario. All permit holders use their maximum amount of water all of the time, and no water is returned to the river from discharges. Full Authorization can be described as a worst-case scenario for producing low flow events and provides very conservative estimates of future conditions since water demands are not expected to approach full utilization during the CCAA timeframe and a significant portion of diversions are discharged back into the river.

The Naturalized Scenario represents the projected conditions that would have occurred in the absence of any management or infrastructure and is important in understanding the naturally

dynamic nature of the system. Historical Conditions represents what has occurred over the last 75 years. Therefore, Historical Conditions are used as a baseline for comparison. Since the 2060 Scenario is the best representation of future conditions that may occur during the term of the CCAA, the majority of analysis in this document focuses on comparison of Historical Conditions to the 2060 Scenario. The Full Authorization Scenario represents a full-utilization no-return-flow condition that is important for reference, but is unlikely to occur in the timeframe of the CCAA, if ever.

2.4 Flow Conditions and Metrics Evaluated

To assess the future potential for low flow events that may influence freshwater mussel populations in each stream segment the frequency of subsistence and zero flow conditions were calculated from model results. Subsistence flows are defined as "the minimum streamflow needed during critical drought periods to maintain tolerable water quality conditions and to provide minimal aquatic habitat space for the survival of aquatic organisms" (NRC 2005). These values vary among stream segments depending upon stream size, watershed area, etc. When available, previously defined subsistence flow values for each segment were taken from the BRA Water Management Plan or from TCEQ environmental flow standards generated during the Senate Bill 3 environmental flow process (**Table B-1;** BRA 2018, TCEQ 2014). In some instances, where previously-established subsistence flow values were not available, 7Q2 values published by TPWD or TCEQ were used as subsistence values (**Table B-1**). The 7Q2 is a hydrologic statistic that represents the annual lowest mean discharge for 7 consecutive days with a 2-year recurrence interval. It should be noted that due to differences in the way they are calculated, 7Q2 values are often higher than subsistence values from environmental flow analysis. However, in the absence of identified subsistence flow values, 7Q2 values represent a comparable low flow statistic. To analyze the frequency of low flow conditions, the percent of months at or below subsistence and the percent of months at zero flow were calculated for each model scenario within each stream segment.

Table B-1. Gage locations evaluated in this analysis, subsistence flow values used, and source of subsistence values.

USGS Gage	USGS Gage No.	Subsistence Flow (cfs)	Subsistence Source
Clear Fork Brazos River at Nugent	08084000	1	SB3 TCEQ[2]
Brazos River near South Bend	08088000	1	SB3 TCEQ[2]
Brazos River near Palo Pinto	08089000	17	BRA WMP[1]
Brazos River near Glen Rose	08091000	16	BRA WMP[1]
Aquilla Creek above Aquilla	08093360	0.1	7Q2 TPWD[3]
North Bosque River near Clifton	08095000	1	SB3 TCEQ[2]
Brazos River near Waco	08096500	56	BRA WMP[1]
Leon River near Gatesville	08100500	1	BRA WMP[1]
Leon River near Belton	08102500	4.7	7Q2 TPWD[3]
Lampasas River near Kempner	08103800	10	SB3 TCEQ[2]
Lampasas River near Belton	08104100	4.8	7Q2 TPWD[3]
Little River near Little River	08104500	55	BRA WMP[1]
North Fork San Gabriel River near Georgetown	08104700	1.1	7Q2 TPWD[3]
San Gabriel River at Laneport	08105700	3.6	7Q2 TPWD[3]
Brushy Creek near Rockdale	08106300	3.4	7Q2 TCEQ[4]
Little River near Cameron	08106500	32	BRA WMP[1]
Brazos River at SH21 near Bryan	08108700	300	BRA WMP[1]
Yegua Creek near Somerville	08110000	0.1	7Q2 TPWD[3]
Navasota River near Easterly	08110500	1	BRA WMP[1]
Brazos River near Hempstead	08111500	510	BRA WMP[1]
Brazos River near Richmond	08114000	550	BRA WMP[1]
Brazos River near Rosharon	08116650	430	BRA WMP[1]

[1] Subsistence flow values for locations included in the BRA System Operation Permit Water Management Plan (BRA WMP) that are the same as SB3 TCEQ locations.
[2] Subsistence flow values derived from adopted Texas Commission on Environmental Quality (TCEQ) rules for the Brazos River basin, 30TAC 298 G, effective March 6, 2014. These locations are not included in the BRA WMP.
[3] Published 7Q2 subsistence flow values at locations that are part of an environmental flow agreement between BRA and Texas Parks and Wildlife Department (TPWD and BRA 2015).
[4] Published 7Q2 flow values from TCEQ for areas outside of the BRA WMP.

3.0 Results

3.1 Spatial Distribution of BRA Management

Model results were extracted to understand how naturalized flow available for water use at specific locations was allocated to the 1,000+ water right records according to their priority and amount of water demands. These allocated amounts of available flow were divided into two categories: BRA Water Rights and All Other Water Rights. In addition, because BRA stores much of its water when it is first available and then returns that water to the river at a later time by making reservoir releases, BRA releases to downstream customers were also extracted to compare the relative magnitude. This combination of storage and subsequent release is indicative of amounts of water managed by BRA, relative to other water rights users. Excess flood water stored and released by USACE for flood control purposes are generally considered in the

modeling and these flood flows represent a significant volume. However, for this discussion about managed water use to satisfy water demands in the basin, only the portion of flood flows that were claimed or allocated by water users were extracted.

Modeled use of BRA's management of water rights comprised less than 50% of total combined surface water use in the basin, although the degree of BRA's water management varied spatially across the basin and also varied according to hydrologic condition. In the upper basin near Palo Pinto, available flow allotted to and managed by BRA is greater than 50% (**Figure B-2a**). Conversely, the available flow allotted to BRA decreased substantially in the lower Brazos River at Hempstead (**Figure B-2b**), due to multiple other large senior water rights in the lower Brazos River basin. Within the major tributaries, BRA is allotted differing portions of the available water. Due to operating Lake Limestone, BRA also contributed downstream water supply reservoir releases into the Navasota River (**Figure B-2c**). Future BRA management in the Little River, as modeled in the WAM, is primarily based on meeting local customer demands rather than water delivery releases to customers (**Figure B-2d**). However, downstream releases in this reach still occur as a result of USACE flood flow releases. In the Clear Fork Brazos River, approximately 15% of available flow is to be preserved in the stream for BRA use downstream, with none of the flow actively managed by BRA (Figure B-2e).

Although this analysis was based on all flow levels, BRA influence generally increases under low flow conditions and decreases under high flow conditions. During high flow periods, BRA has limited ability to manage water in the basin because BRA does not control flood storage in any reservoirs. During low flow periods under the Full Authorization Scenario, BRA releases of stored water generally account for between 20-85% of water in covered stream reaches, with less management and influence in the lower basin.

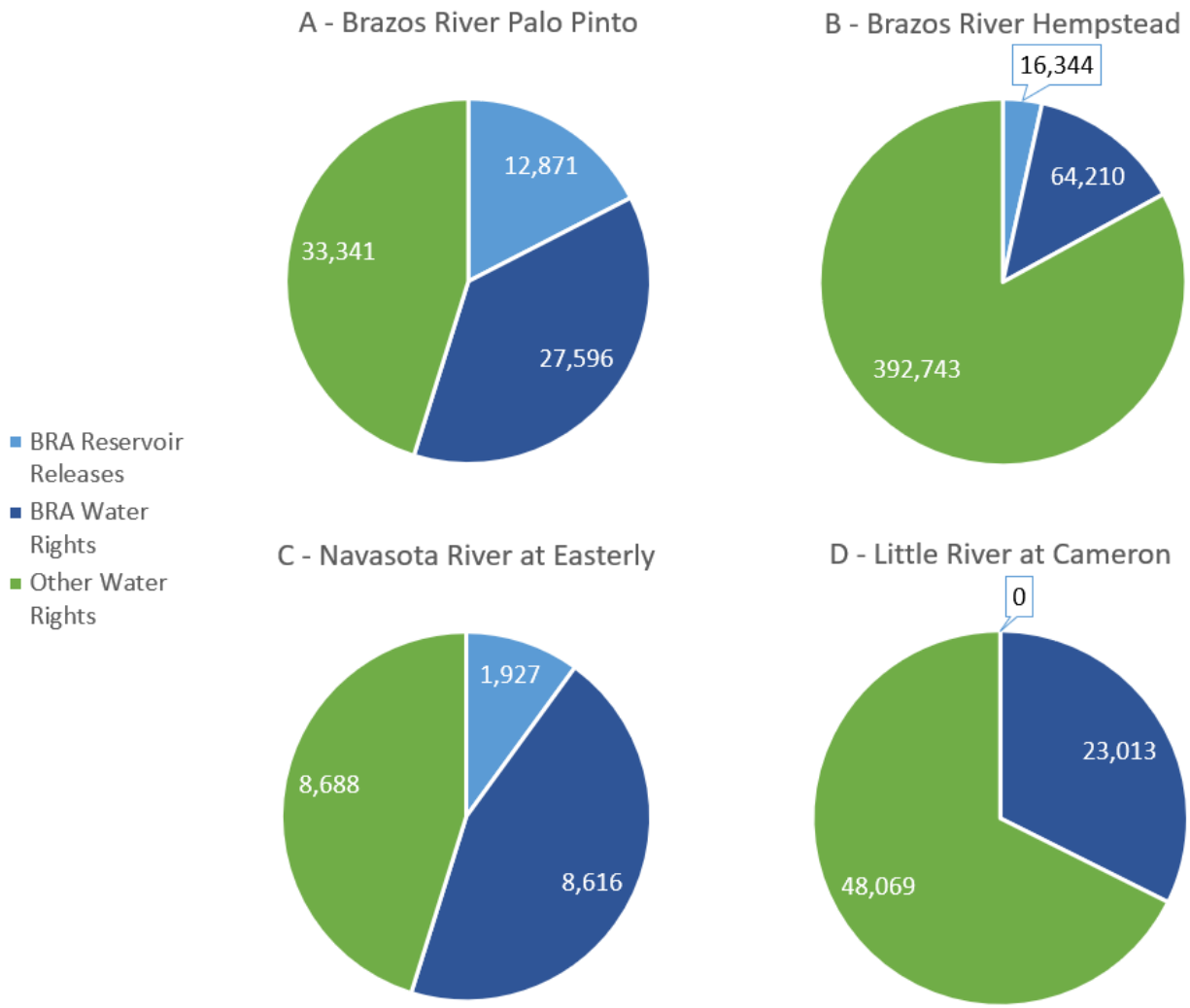


Figure B-2. Spatial distribution of BRA management based on average available flows and reservoir releases (acre-feet/month) at 4 USGS stream gages (Brazos River at Palo Pinto [A] and Hempstead [B], Navasota River at Easterly [C], and Little River at Cameron [D]) under the Full Authorization Scenario, averaged across the simulation period 1940-2015.

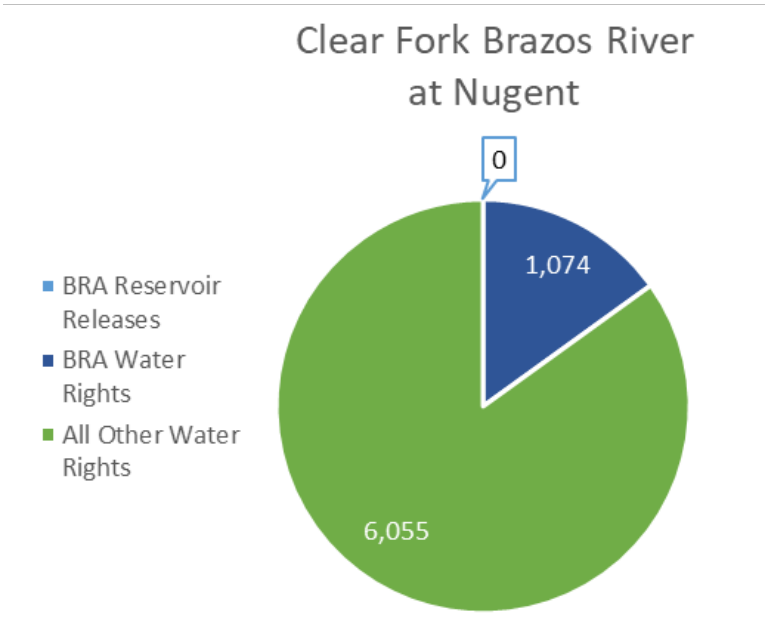


Figure B-2e. BRA Management based on average available flows (acre-ft/month) passing the USGS stream gage Clear Fork Brazos River at Nugent under the Full Authorization Scenario, averaged across the simulation period 1940-2015.

3.2 Subsistence Flows

Subsistence flows are naturally occurring infrequent periods of low flow during drought situations. Therefore, it is not surprising that all stream segments evaluated have experienced subsistence flow conditions under the Naturalized Scenario (**Figure B-3**). The natural frequency of subsistence conditions within each stream segment is projected to have ranged from 1.6% at the Brazos River near South Bend to 23.5% at Aquilla Creek above Aquilla (**Table B-2**). Subsistence flows generally occurred in higher frequency within tributaries than in the mainstem, as smaller watersheds of tributaries are more strongly influenced by localized drought conditions than larger catchments.

Historically, the percent of time at or below subsistence flows ranged from 0.4% at the Brazos River near Palo Pinto to 13.8% in the North Fork San Gabriel River near Georgetown (**Table B-2**, **Figure B-4**). The percent of time at or below subsistence was generally greater in segments where subsistence values were based on 7Q2 values than in segments where subsistence values were determined based on environmental flow analysis. When compared to the Naturalized Scenario, 15 of 22 locations exhibit reduced frequency of subsistence flows under Historical Conditions. The seven locations in which frequency of subsistence flows has increased include Clear Fork Brazos River at Nugent, Brazos River at South Bend, Leon River near Gatesville, Lampasas River near Belton, North Fork San Gabriel River near Georgetown, San Gabriel River at Laneport, and Brazos River near Rosharon.

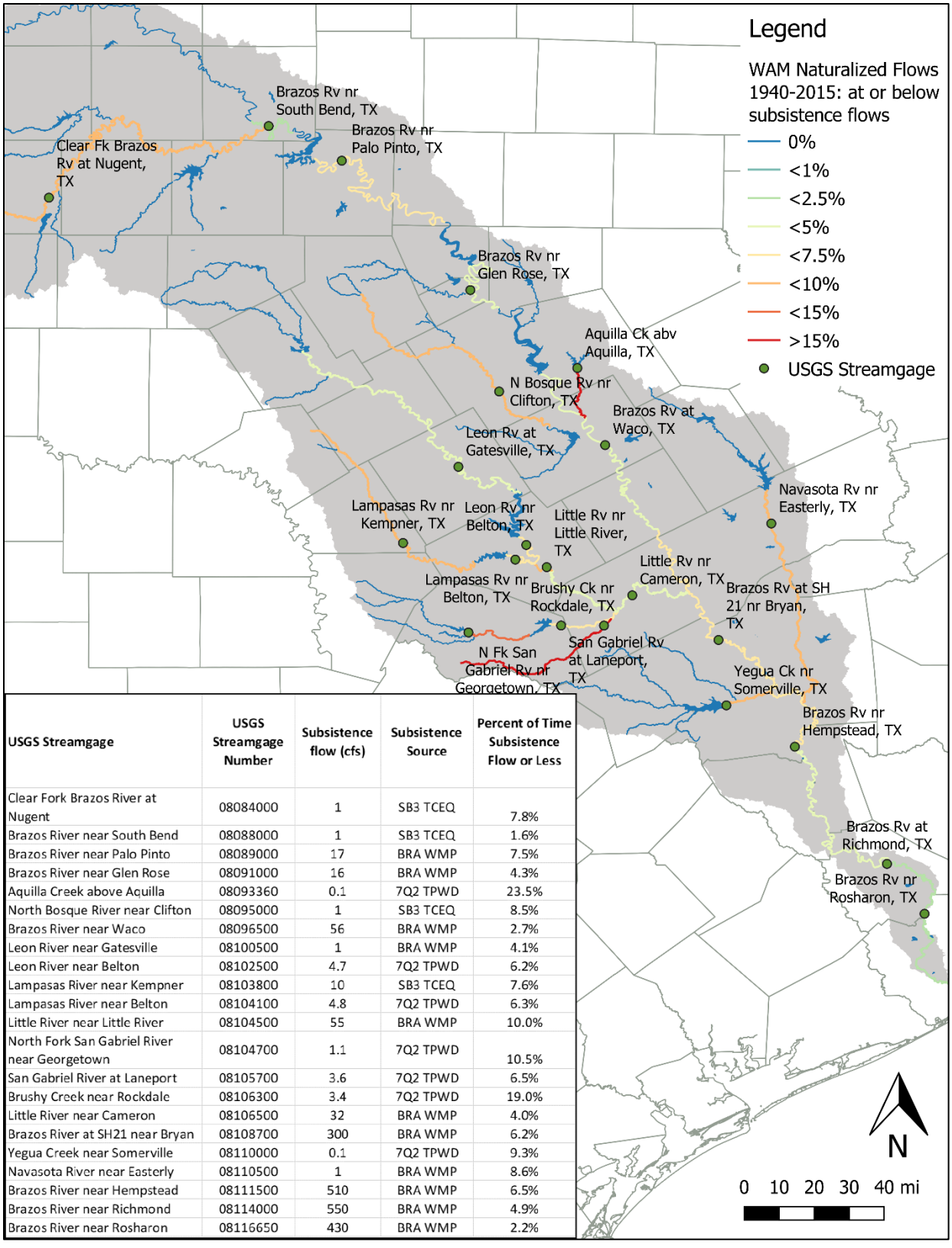
When the 2060 Scenario is compared to Historical, the percentage of time at or below subsistence flows increased in some segments and decreased in others (**Table B-2**, **Figure B-5**).

The percent of time at or below subsistence decreased to 0% in the Navasota River at Easterly, Aquilla Creek above Aquilla, Yegua Creek near Somerville, Brushy Creek near Rockdale, and the Leon River near Belton. Frequency of subsistence flows also decreased considerably in the North Bosque River near Clifton, Leon River near Gatesville, Little River near Cameron, and the Brazos River near Richmond. In contrast, the percentage of time at or below subsistence flows increased considerably in the San Gabriel system (North Fork near Georgetown and mainstem near Laneport), the Lampasas River near Belton, and the lower Brazos River near Rosharon.

When compared to Historical Conditions, the Full Authorization Scenario leads to increased frequency of subsistence in 15 of 22 stream segments, with frequency of subsistence exceeding 15% at multiple sites (**Table B-2**, **Figure B-6**). A general increase in frequency of low flows under this scenario is expected since it includes full utilization of all water rights and no return flows. However, seven locations experienced decreases in frequency of subsistence flows under this scenario, including: Clear Fork Brazos River at Nugent, Aquilla Creek above Aquilla, Leon River near Gatesville, Leon River near Belton, Navasota River near Easterly, Brazos River near Hempstead, and Brazos River near Richmond.

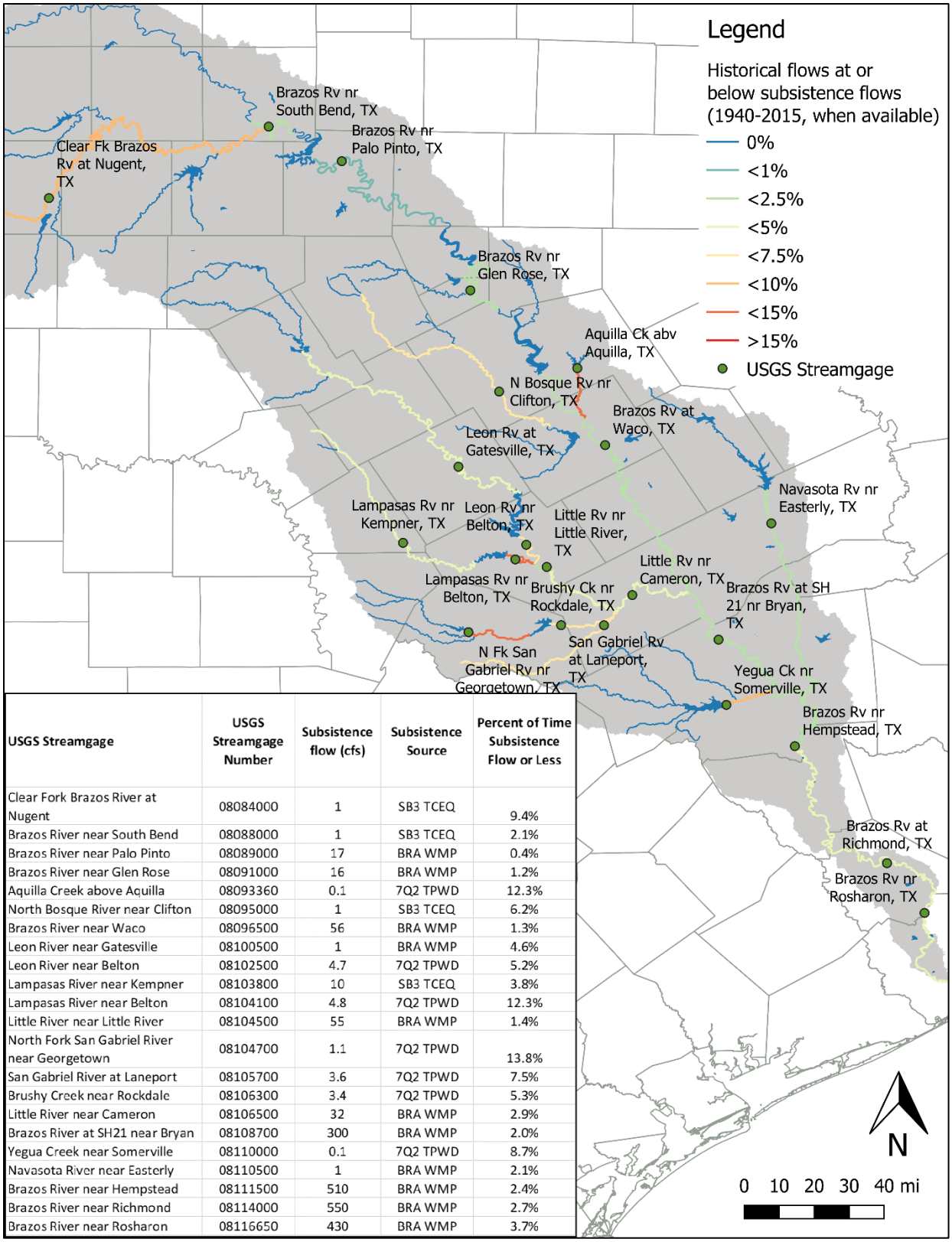
Table B-2. Percent of time at or below subsistence flows for each location under each scenario. The last column represents the best representation of the difference between projected future conditions within the term of the CCAA (2060) and past conditions (Historical). Positive values in the last column represent an increase in the percent of time at or below subsistence flows, whereas negative values represent a decrease.

USGS Gage	USGS Gage No.	Percent of Time at or Below Subsistence				Difference (2060 - Historical)
		Naturalized Scenario	Historical Conditions	2060 Scenario	Full Authorization Scenario	
Clear Fork Brazos River at Nugent	08084000	7.8	9.4	8.7	8.7	-0.7
Brazos River near South Bend	08088000	1.6	2.1	1.0	2.2	-1.1
Brazos River near Palo Pinto	08089000	7.5	0.4	0.3	3.8	-0.1
Brazos River near Glen Rose	08091000	4.3	1.2	3.2	13.3	2.0
Aquilla Creek above Aquilla	08093360	23.5	12.3	0.0	0.0	-12.3
North Bosque River near Clifton	08095000	8.5	6.2	0.1	8.6	-6.1
Brazos River near Waco	08096500	2.7	1.3	3.1	1.7	1.8
Leon River near Gatesville	08100500	4.1	4.6	1.9	4.5	-2.7
Leon River near Belton	08102500	6.2	5.2	0.0	0.0	-5.2
Lampasas River near Kempner	08103800	7.6	3.8	7.3	11.3	3.5
Lampasas River near Belton	08104100	6.3	12.3	48.8	16.2	36.5
Little River near Little River	08104500	10.0	1.4	1.8	30.0	0.4
North Fork San Gabriel River near Georgetown	08104700	10.5	13.8	60.7	50.6	46.9
San Gabriel River at Laneport	08105700	6.5	7.5	24.0	32.2	16.5
Brushy Creek near Rockdale	08106300	19.0	5.3	0.0	19.2	-5.3
Little River near Cameron	08106500	4.0	2.9	0.4	15.7	-2.5
Brazos River at SH21 near Bryan	08108700	6.2	2.0	1.6	2.4	-0.4
Yegua Creek near Somerville	08110000	9.3	8.7	0.0	14.4	-8.7
Navasota River near Easterly	08110500	8.6	2.1	0.0	0.8	-2.1
Brazos River near Hempstead	08111500	6.5	2.4	2.3	0.1	-0.1
Brazos River near Richmond	08114000	4.9	2.7	0.1	0.0	-2.6
Brazos River near Rosharon	08116650	2.2	3.7	9.5	16.3	5.8



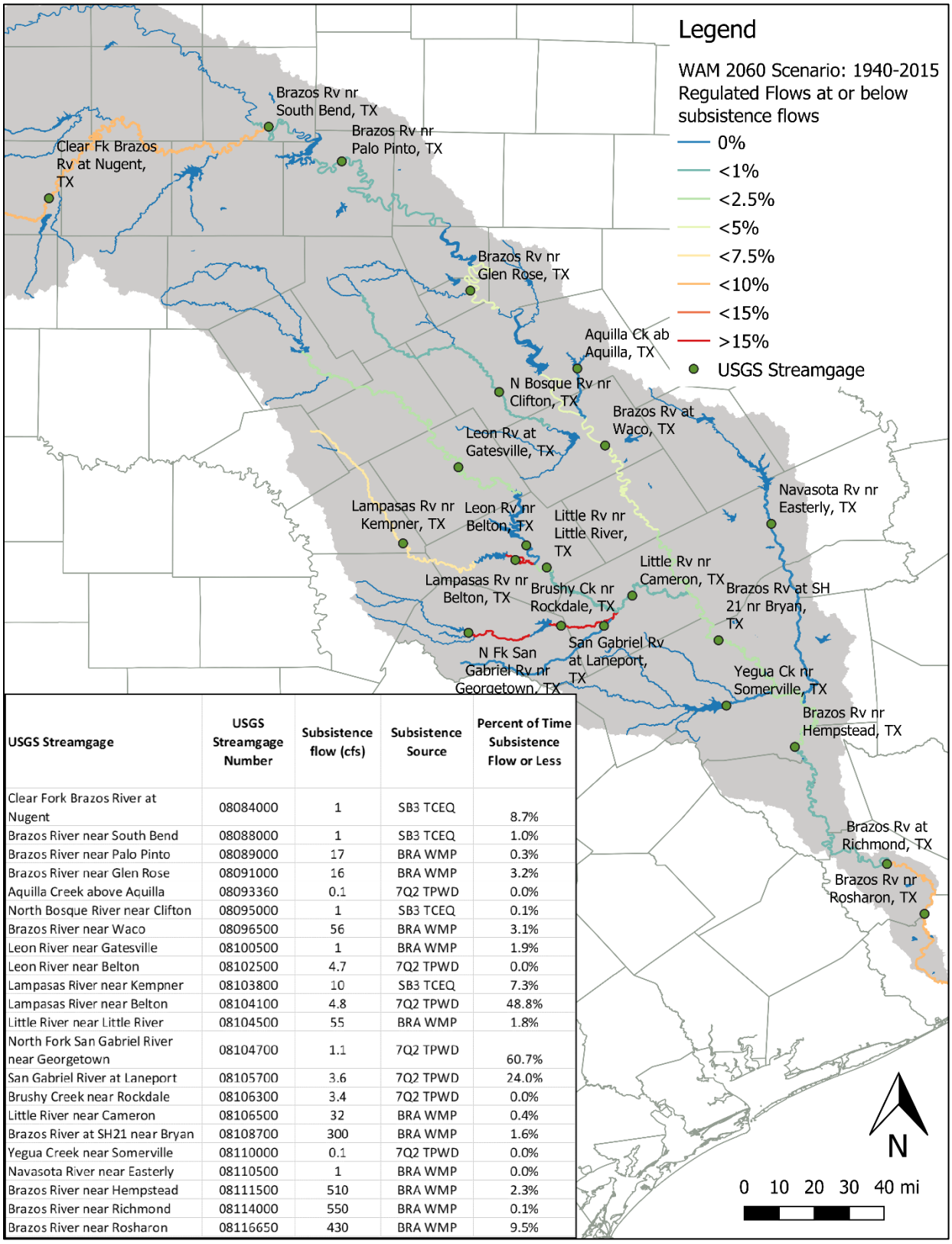
USGS Streamgage	USGS Streamgage Number	Subsistence flow (cfs)	Subsistence Source	Percent of Time Subsistence Flow or Less
Clear Fork Brazos River at Nugent	08084000	1	SB3 TCEQ	7.8%
Brazos River near South Bend	08088000	1	SB3 TCEQ	1.6%
Brazos River near Palo Pinto	08089000	17	BRA WMP	7.5%
Brazos River near Glen Rose	08091000	16	BRA WMP	4.3%
Aquilla Creek above Aquilla	08093360	0.1	7Q2 TPWD	23.5%
North Bosque River near Clifton	08095000	1	SB3 TCEQ	8.5%
Brazos River near Waco	08096500	56	BRA WMP	2.7%
Leon River near Gatesville	08100500	1	BRA WMP	4.1%
Leon River near Belton	08102500	4.7	7Q2 TPWD	6.2%
Lampasas River near Kempner	08103800	10	SB3 TCEQ	7.6%
Lampasas River near Belton	08104100	4.8	7Q2 TPWD	6.3%
Little River near Little River	08104500	55	BRA WMP	10.0%
North Fork San Gabriel River near Georgetown	08104700	1.1	7Q2 TPWD	10.5%
San Gabriel River at Laneport	08105700	3.6	7Q2 TPWD	6.5%
Brushy Creek near Rockdale	08106300	3.4	7Q2 TPWD	19.0%
Little River near Cameron	08106500	32	BRA WMP	4.0%
Brazos River at SH21 near Bryan	08108700	300	BRA WMP	6.2%
Yegua Creek near Somerville	08110000	0.1	7Q2 TPWD	9.3%
Navasota River near Easterly	08110500	1	BRA WMP	8.6%
Brazos River near Hempstead	08111500	510	BRA WMP	6.5%
Brazos River near Richmond	08114000	550	BRA WMP	4.9%
Brazos River near Rosharon	08116650	430	BRA WMP	2.2%

Figure B-3. Percent of time at or below subsistence flow based on the Naturalized Scenario.



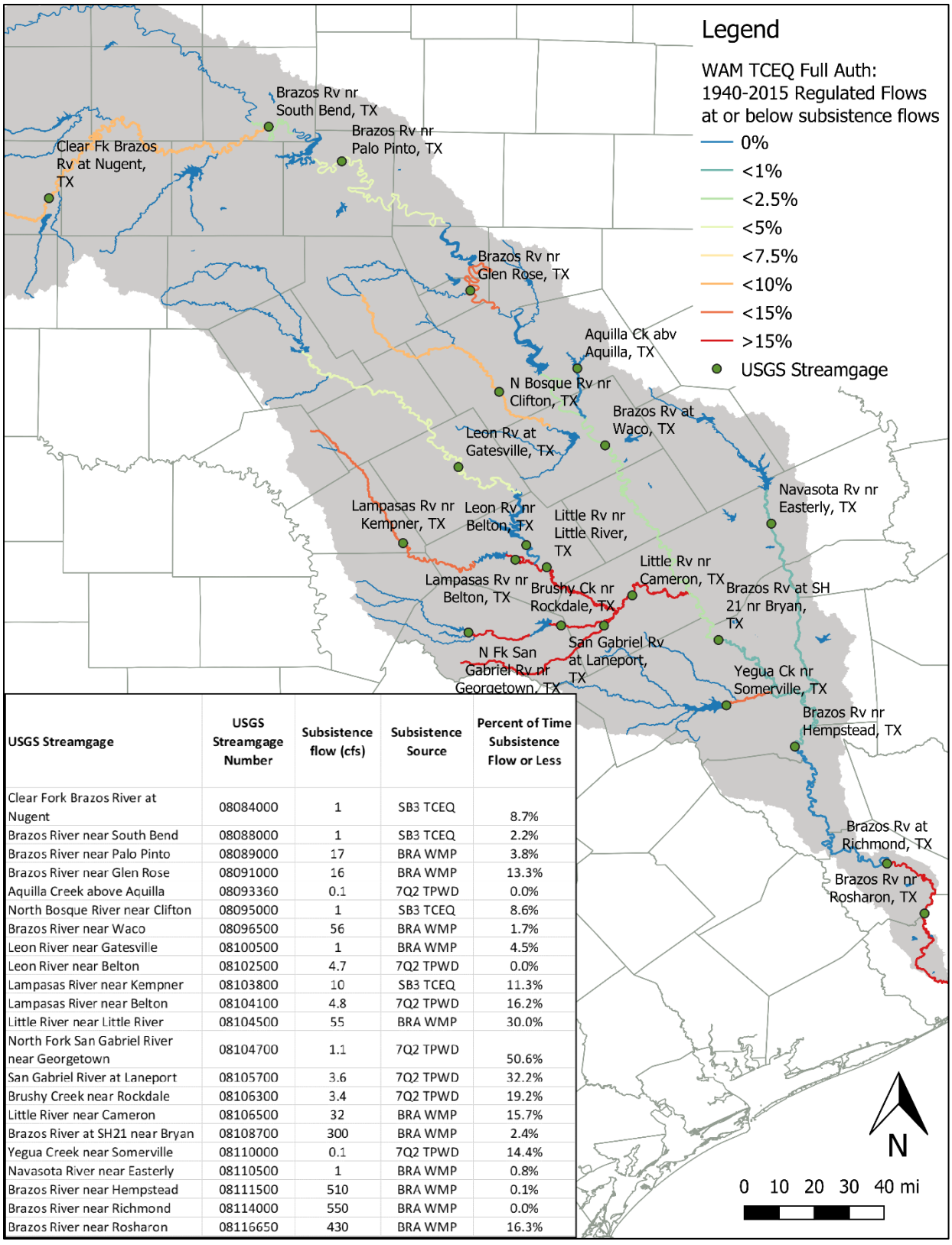
USGS Streamgage	USGS Streamgage Number	Subsistence flow (cfs)	Subsistence Source	Percent of Time Subsistence Flow or Less
Clear Fork Brazos River at Nugent	08084000	1	SB3 TCEQ	9.4%
Brazos River near South Bend	08088000	1	SB3 TCEQ	2.1%
Brazos River near Palo Pinto	08089000	17	BRA WMP	0.4%
Brazos River near Glen Rose	08091000	16	BRA WMP	1.2%
Aquilla Creek above Aquilla	08093360	0.1	7Q2 TPWD	12.3%
North Bosque River near Clifton	08095000	1	SB3 TCEQ	6.2%
Brazos River near Waco	08096500	56	BRA WMP	1.3%
Leon River near Gatesville	08100500	1	BRA WMP	4.6%
Leon River near Belton	08102500	4.7	7Q2 TPWD	5.2%
Lampasas River near Kempner	08103800	10	SB3 TCEQ	3.8%
Lampasas River near Belton	08104100	4.8	7Q2 TPWD	12.3%
Little River near Little River	08104500	55	BRA WMP	1.4%
North Fork San Gabriel River near Georgetown	08104700	1.1	7Q2 TPWD	13.8%
San Gabriel River at Laneport	08105700	3.6	7Q2 TPWD	7.5%
Brushy Creek near Rockdale	08106300	3.4	7Q2 TPWD	5.3%
Little River near Cameron	08106500	32	BRA WMP	2.9%
Brazos River at SH21 near Bryan	08108700	300	BRA WMP	2.0%
Yegua Creek near Somerville	08110000	0.1	7Q2 TPWD	8.7%
Navasota River near Easterly	08110500	1	BRA WMP	2.1%
Brazos River near Hempstead	08111500	510	BRA WMP	2.4%
Brazos River near Richmond	08114000	550	BRA WMP	2.7%
Brazos River near Rosharon	08116650	430	BRA WMP	3.7%

Figure B-4. Percent of time at or below subsistence flow based on Historical Conditions.



USGS Streamgage	USGS Streamgage Number	Subsistence flow (cfs)	Subsistence Source	Percent of Time Subsistence Flow or Less
Clear Fork Brazos River at Nugent	08084000	1	SB3 TCEQ	8.7%
Brazos River near South Bend	08088000	1	SB3 TCEQ	1.0%
Brazos River near Palo Pinto	08089000	17	BRA WMP	0.3%
Brazos River near Glen Rose	08091000	16	BRA WMP	3.2%
Aquilla Creek above Aquilla	08093360	0.1	7Q2 TPWD	0.0%
North Bosque River near Clifton	08095000	1	SB3 TCEQ	0.1%
Brazos River near Waco	08096500	56	BRA WMP	3.1%
Leon River near Gatesville	08100500	1	BRA WMP	1.9%
Leon River near Belton	08102500	4.7	7Q2 TPWD	0.0%
Lampasas River near Kempner	08103800	10	SB3 TCEQ	7.3%
Lampasas River near Belton	08104100	4.8	7Q2 TPWD	48.8%
Little River near Little River	08104500	55	BRA WMP	1.8%
North Fork San Gabriel River near Georgetown	08104700	1.1	7Q2 TPWD	60.7%
San Gabriel River at Laneport	08105700	3.6	7Q2 TPWD	24.0%
Brushy Creek near Rockdale	08106300	3.4	7Q2 TPWD	0.0%
Little River near Cameron	08106500	32	BRA WMP	0.4%
Brazos River at SH21 near Bryan	08108700	300	BRA WMP	1.6%
Yegua Creek near Somerville	08110000	0.1	7Q2 TPWD	0.0%
Navasota River near Easterly	08110500	1	BRA WMP	0.0%
Brazos River near Hempstead	08111500	510	BRA WMP	2.3%
Brazos River near Richmond	08114000	550	BRA WMP	0.1%
Brazos River near Rosharon	08116650	430	BRA WMP	9.5%

Figure B-5. Percent of time at or below subsistence flow under the 2060 Scenario.



USGS Streamgage	USGS Streamgage Number	Subsistence flow (cfs)	Subsistence Source	Percent of Time Subsistence Flow or Less
Clear Fork Brazos River at Nugent	08084000	1	SB3 TCEQ	8.7%
Brazos River near South Bend	08088000	1	SB3 TCEQ	2.2%
Brazos River near Palo Pinto	08089000	17	BRA WMP	3.8%
Brazos River near Glen Rose	08091000	16	BRA WMP	13.3%
Aquilla Creek above Aquilla	08093360	0.1	7Q2 TPWD	0.0%
North Bosque River near Clifton	08095000	1	SB3 TCEQ	8.6%
Brazos River near Waco	08096500	56	BRA WMP	1.7%
Leon River near Gatesville	08100500	1	BRA WMP	4.5%
Leon River near Belton	08102500	4.7	7Q2 TPWD	0.0%
Lampasas River near Kempner	08103800	10	SB3 TCEQ	11.3%
Lampasas River near Belton	08104100	4.8	7Q2 TPWD	16.2%
Little River near Little River	08104500	55	BRA WMP	30.0%
North Fork San Gabriel River near Georgetown	08104700	1.1	7Q2 TPWD	50.6%
San Gabriel River at Laneport	08105700	3.6	7Q2 TPWD	32.2%
Brushy Creek near Rockdale	08106300	3.4	7Q2 TPWD	19.2%
Little River near Cameron	08106500	32	BRA WMP	15.7%
Brazos River at SH21 near Bryan	08108700	300	BRA WMP	2.4%
Yegua Creek near Somerville	08110000	0.1	7Q2 TPWD	14.4%
Navasota River near Easterly	08110500	1	BRA WMP	0.8%
Brazos River near Hempstead	08111500	510	BRA WMP	0.1%
Brazos River near Richmond	08114000	550	BRA WMP	0.0%
Brazos River near Rosharon	08116650	430	BRA WMP	16.3%

Figure B-6. Percent of time at or below subsistence flow under the Full Authorization Scenario.

3.3 Zero Flows

Zero flow conditions are projected to have naturally occurred in most of the stream segments evaluated under drought conditions. Only the Lampasas River near Kempner and the Brazos River near Hempstead show no zero flow months during the Naturalized Scenario (**Figure B-7**). Aquilla Creek above Aquilla and Brushy Creek near Rockdale exhibited the most zero flow months, with 212 and 106, respectively (**Table B-3**).

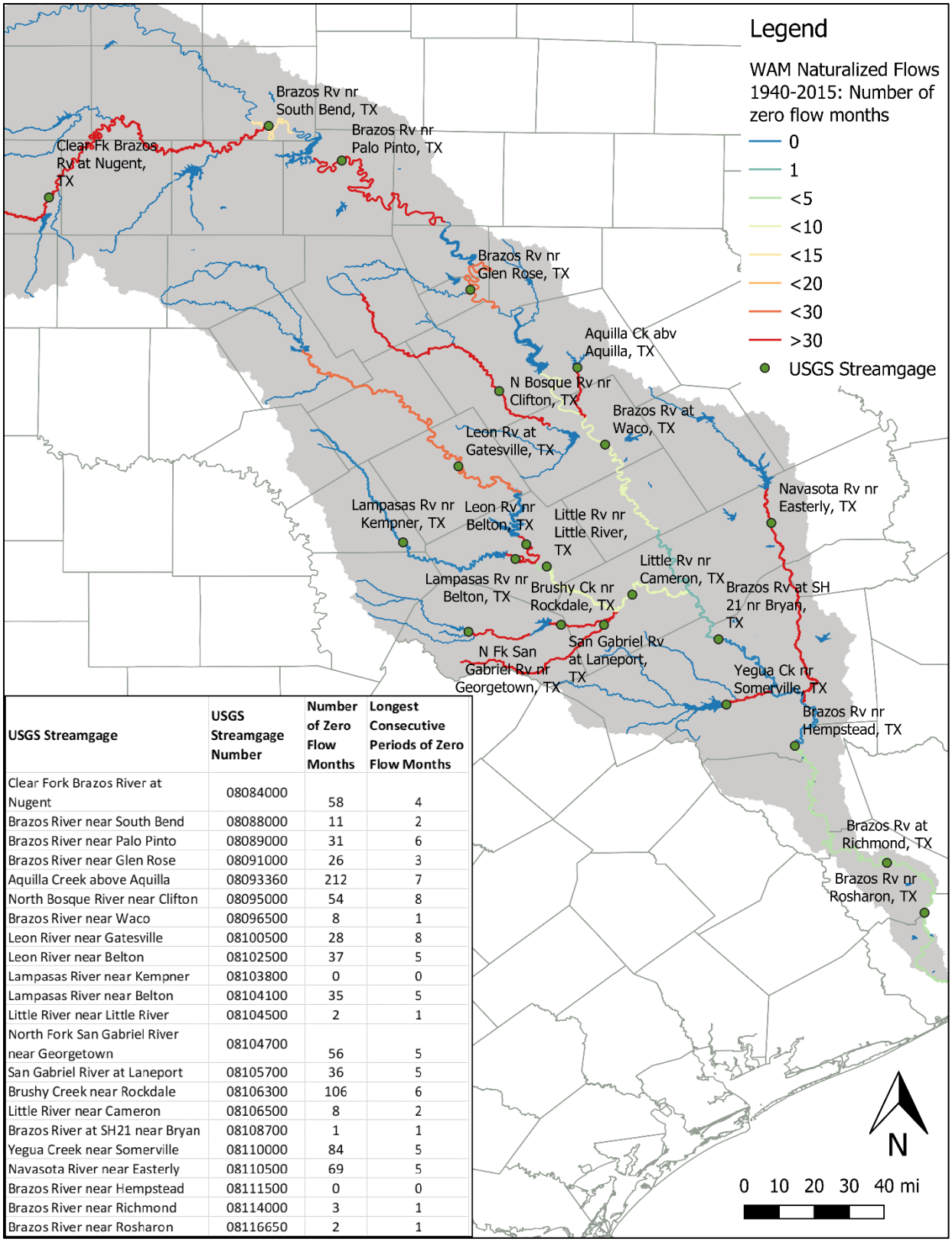
Historically, the number of zero flow months ranges from 0 in most stream reaches to 28 in Yegua Creek near Somerville (**Table B-3**). Other segments with zero flow months in the historical record include Clear Fork Brazos River at Nugent, Brazos River at South Bend, Aquilla Creek above Aquilla, North Bosque River near Clifton, Leon River near Gatesville, Leon River near Belton, and San Gabriel River near Laneport (**Figure B-8**). All locations which experienced zero flow months under the Naturalized Scenario show reductions in the number of zero flow months under Historical Conditions.

When comparing the 2060 Scenario to Historical Conditions, Aquilla Creek above Aquilla, Yegua Creek near Somerville, and Leon River near Belton are projected to experience no zero-flow months despite having them in the historical record (**Table B-3**, **Figure B-9**). The Brazos River near South Bend and North Bosque River near Clifton are also projected to see a reduction in the number of zero flow months. Opposingly, several sites are projected to experience more frequent zero-flow months. The most extreme examples include the Clear Fork Brazos River at Nugent, the Lampasas River near Belton and the North Fork San Gabriel River near Georgetown, which are projected to have 46, 117 and 69 zero flow months, respectively. These are the only three sites which exhibit a higher number of zero flow months in the 2060 Scenario than the Naturalized Scenario.

When comparing the Full Authorization Scenario to Historical Conditions, the occurrence and frequency of zero flow months generally increases due to lack of return flows (**Table B-3**, **Figure B-10**). When comparing Full Authorization to 2060, the same is generally true, although the number of zero flow months actually decreases at Lampasas River near Belton, North Fork San Gabriel River near Georgetown, and the San Gabriel River at Laneport. Given lack of return flows under Full Authorization, more water must be transported downstream through these locations to meet downstream water rights. Under the Full Authorization Scenario, 17 of 22 locations experience fewer zero flow months than under the Naturalized Scenario. Sites with more zero flow months under Full Authorization compared to Naturalized include Brazos River near South Bend, North Bosque River near Clifton, Leon River near Gatesville, Lampasas River near Belton, and North Fork San Gabriel River near Georgetown.

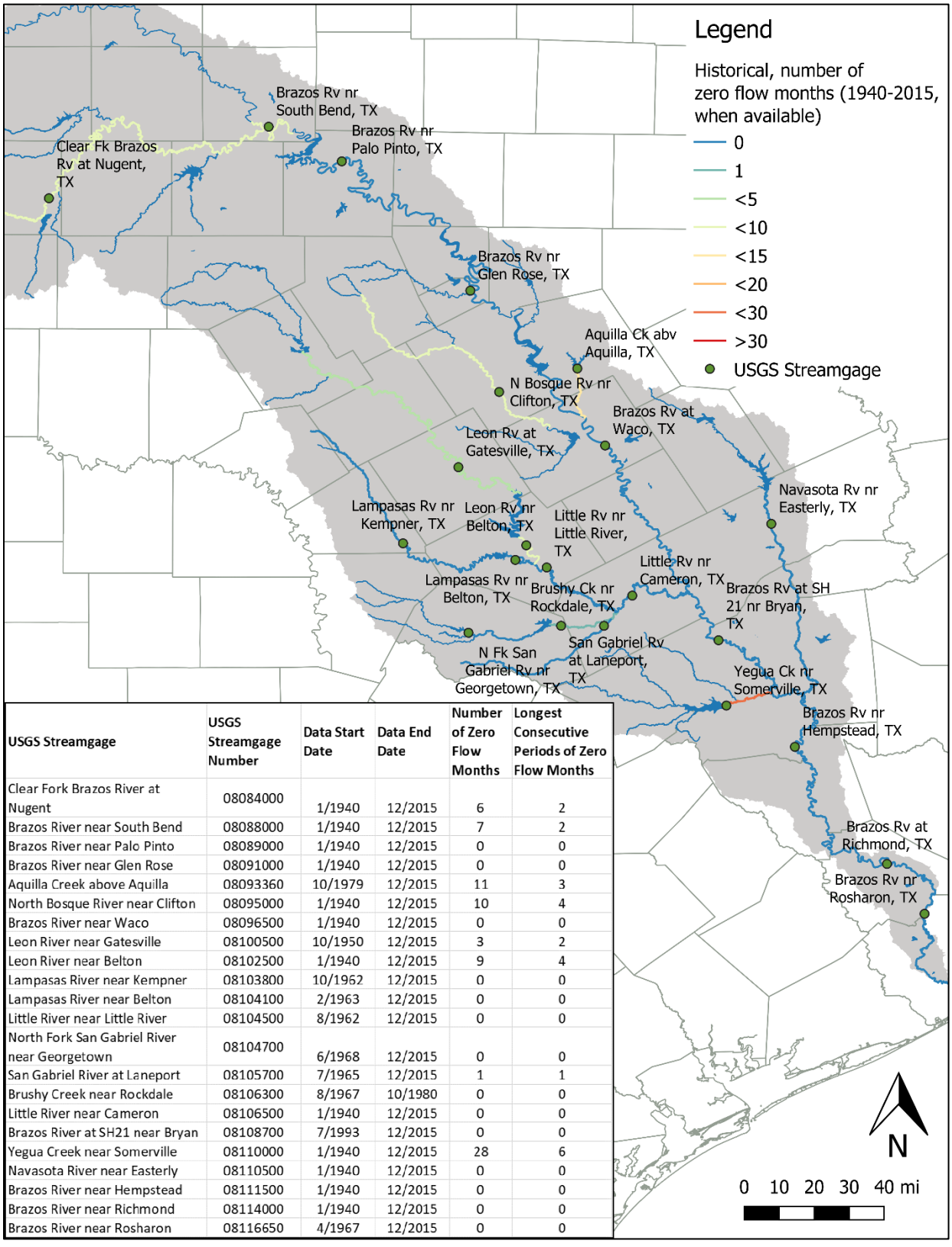
Table B-3. Number of zero flow months for each gage location under each scenario. The last column represents the best representation of the difference between projected future conditions within the term of the CCAA (2060) and past conditions (Historical). Positive values in the last column represent an increase in the number of zero flow months, whereas negative values represent a decrease.

USGS Gage	USGS Gage No.	Number of Zero Flow Months				Difference (2060 - Historical)
		Naturalized Scenario	Historical Conditions	2060 Scenario	Full Authorization Scenario	
Clear Fork Brazos River at Nugent	08084000	58	6	46	47	40
Brazos River near South Bend	08088000	11	7	1	12	-6
Brazos River near Palo Pinto	08089000	31	0	0	4	0
Brazos River near Glen Rose	08091000	26	0	2	12	2
Aquilla Creek above Aquilla	08093360	212	11	0	0	-11
North Bosque River near Clifton	08095000	54	10	1	56	-9
Brazos River near Waco	08096500	8	0	1	1	1
Leon River near Gatesville	08100500	28	3	9	31	6
Leon River near Belton	08102500	37	9	0	0	-9
Lampasas River near Kempner	08103800	0	0	0	0	0
Lampasas River near Belton	08104100	35	0	117	48	117
Little River near Little River	08104500	2	0	0	2	0
North Fork San Gabriel River near Georgetown	08104700	56	0	69	61	69
San Gabriel River at Laneport	08105700	36	1	12	10	11
Brushy Creek near Rockdale	08106300	106	0	0	99	0
Little River near Cameron	08106500	8	0	0	6	0
Brazos River at SH21 near Bryan	08108700	1	0	0	0	0
Yegua Creek near Somerville	08110000	84	28	0	58	-28
Navasota River near Easterly	08110500	69	0	1	8	1
Brazos River near Hempstead	08111500	0	0	0	0	0
Brazos River near Richmond	08114000	3	0	0	0	0
Brazos River near Rosharon	08116650	2	0	0	0	0



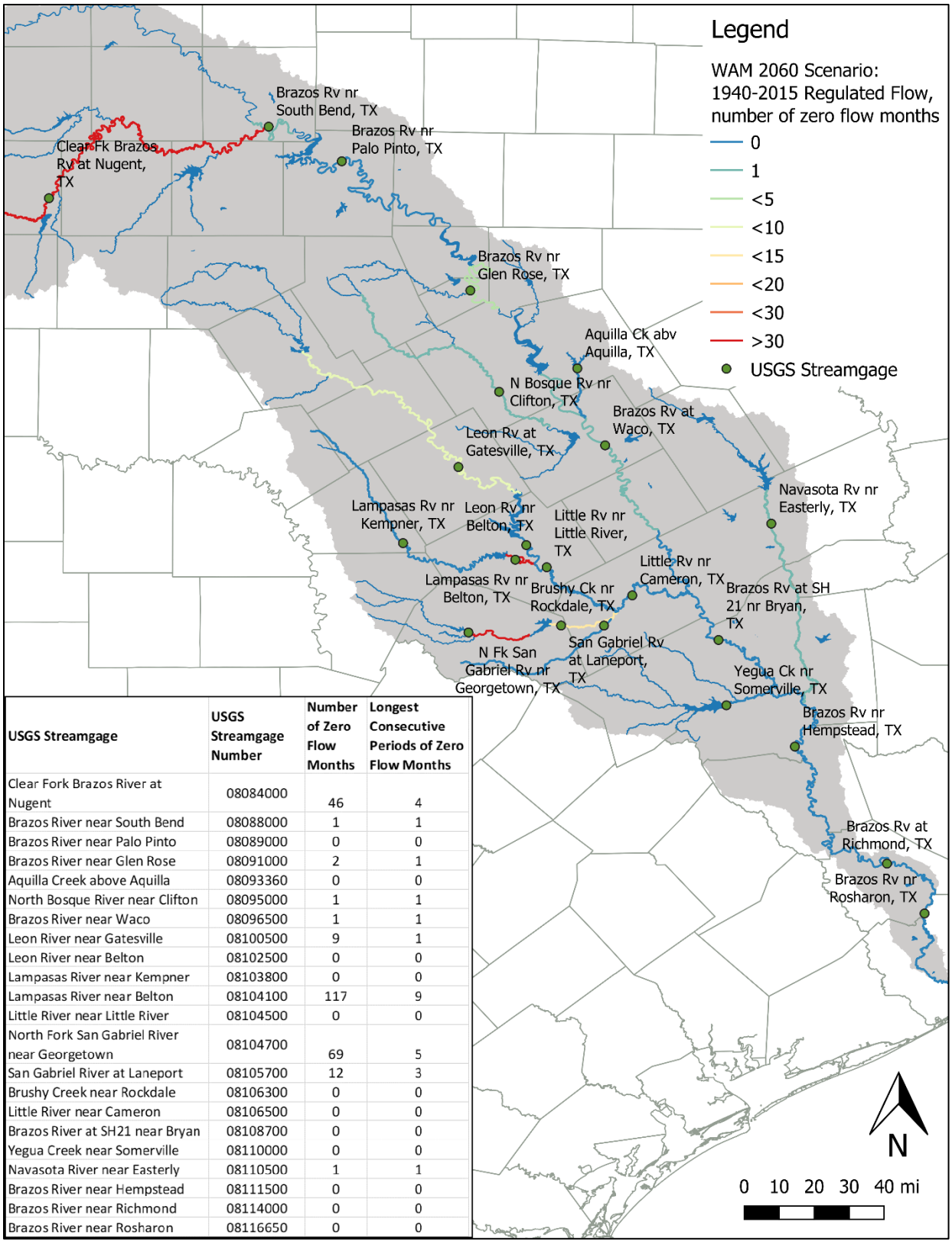
USGS Streamgage	USGS Streamgage Number	Number of Zero Flow Months	Longest Consecutive Periods of Zero Flow Months
Clear Fork Brazos River at Nugent	08084000	58	4
Brazos River near South Bend	08088000	11	2
Brazos River near Palo Pinto	08089000	31	6
Brazos River near Glen Rose	08091000	26	3
Aquilla Creek above Aquilla	08093360	212	7
North Bosque River near Clifton	08095000	54	8
Brazos River near Waco	08096500	8	1
Leon River near Gatesville	08100500	28	8
Leon River near Belton	08102500	37	5
Lampasas River near Kempner	08103800	0	0
Lampasas River near Belton	08104100	35	5
Little River near Little River	08104500	2	1
North Fork San Gabriel River near Georgetown	08104700	56	5
San Gabriel River at Laneport	08105700	36	5
Brushy Creek near Rockdale	08106300	106	6
Little River near Cameron	08106500	8	2
Brazos River at SH21 near Bryan	08108700	1	1
Yegua Creek near Somerville	08110000	84	5
Navasota River near Easterly	08110500	69	5
Brazos River near Hempstead	08111500	0	0
Brazos River near Richmond	08114000	3	1
Brazos River near Rosharon	08116650	2	1

Figure B-7. Number of zero flow months under the Naturalized Scenario.



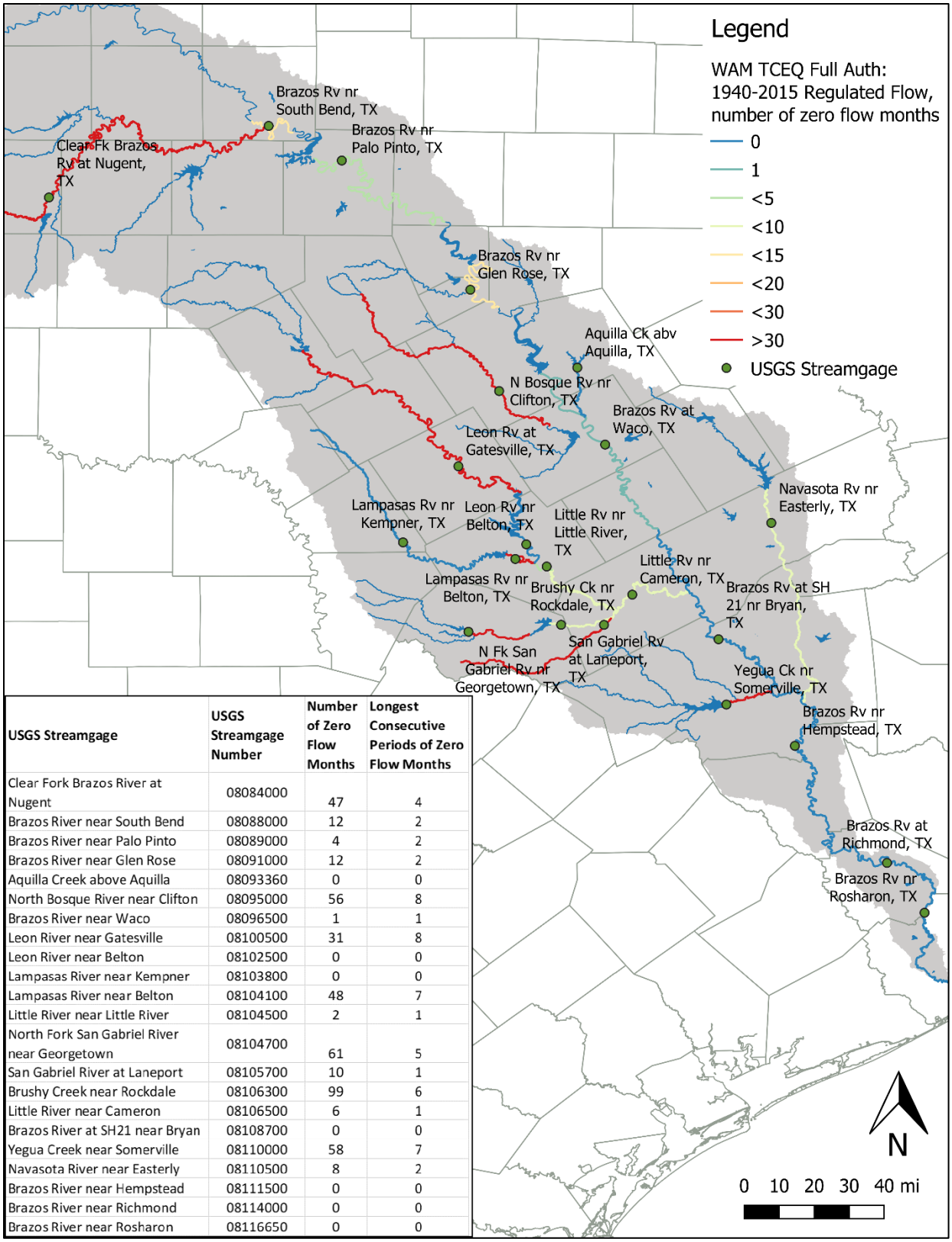
USGS Streamgage	USGS Streamgage Number	Data Start Date	Data End Date	Number of Zero Flow Months	Longest Consecutive Periods of Zero Flow Months
Clear Fork Brazos River at Nugent	08084000	1/1940	12/2015	6	2
Brazos River near South Bend	08088000	1/1940	12/2015	7	2
Brazos River near Palo Pinto	08089000	1/1940	12/2015	0	0
Brazos River near Glen Rose	08091000	1/1940	12/2015	0	0
Aquilla Creek above Aquilla	08093360	10/1979	12/2015	11	3
North Bosque River near Clifton	08095000	1/1940	12/2015	10	4
Brazos River near Waco	08096500	1/1940	12/2015	0	0
Leon River near Gatesville	08100500	10/1950	12/2015	3	2
Leon River near Belton	08102500	1/1940	12/2015	9	4
Lampasas River near Kempner	08103800	10/1962	12/2015	0	0
Lampasas River near Belton	08104100	2/1963	12/2015	0	0
Little River near Little River	08104500	8/1962	12/2015	0	0
North Fork San Gabriel River near Georgetown	08104700	6/1968	12/2015	0	0
San Gabriel River at Laneport	08105700	7/1965	12/2015	1	1
Brushy Creek near Rockdale	08106300	8/1967	10/1980	0	0
Little River near Cameron	08106500	1/1940	12/2015	0	0
Brazos River at SH21 near Bryan	08108700	7/1993	12/2015	0	0
Yegua Creek near Somerville	08110000	1/1940	12/2015	28	6
Navasota River near Easterly	08110500	1/1940	12/2015	0	0
Brazos River near Hempstead	08111500	1/1940	12/2015	0	0
Brazos River near Richmond	08114000	1/1940	12/2015	0	0
Brazos River near Rosharon	08116650	4/1967	12/2015	0	0

Figure B-8. Number of months of zero flow based on Historical Conditions.



USGS Streamgage	USGS Streamgage Number	Number of Zero Flow Months	Longest Consecutive Periods of Zero Flow Months
Clear Fork Brazos River at Nugent	08084000	46	4
Brazos River near South Bend	08088000	1	1
Brazos River near Palo Pinto	08089000	0	0
Brazos River near Glen Rose	08091000	2	1
Aquilla Creek above Aquilla	08093360	0	0
North Bosque River near Clifton	08095000	1	1
Brazos River near Waco	08096500	1	1
Leon River near Gatesville	08100500	9	1
Leon River near Belton	08102500	0	0
Lampasas River near Kempner	08103800	0	0
Lampasas River near Belton	08104100	117	9
Little River near Little River	08104500	0	0
North Fork San Gabriel River near Georgetown	08104700	69	5
San Gabriel River at Laneport	08105700	12	3
Brushy Creek near Rockdale	08106300	0	0
Little River near Cameron	08106500	0	0
Brazos River at SH21 near Bryan	08108700	0	0
Yegua Creek near Somerville	08110000	0	0
Navasota River near Easterly	08110500	1	1
Brazos River near Hempstead	08111500	0	0
Brazos River near Richmond	08114000	0	0
Brazos River near Rosharon	08116650	0	0

Figure B-9. Number of zero flow months under the 2060 Scenario.



USGS Streamgage	USGS Streamgage Number	Number of Zero Flow Months	Longest Consecutive Periods of Zero Flow Months
Clear Fork Brazos River at Nugent	08084000	47	4
Brazos River near South Bend	08088000	12	2
Brazos River near Palo Pinto	08089000	4	2
Brazos River near Glen Rose	08091000	12	2
Aquilla Creek above Aquilla	08093360	0	0
North Bosque River near Clifton	08095000	56	8
Brazos River near Waco	08096500	1	1
Leon River near Gatesville	08100500	31	8
Leon River near Belton	08102500	0	0
Lampasas River near Kempner	08103800	0	0
Lampasas River near Belton	08104100	48	7
Little River near Little River	08104500	2	1
North Fork San Gabriel River near Georgetown	08104700	61	5
San Gabriel River at Laneport	08105700	10	1
Brushy Creek near Rockdale	08106300	99	6
Little River near Cameron	08106500	6	1
Brazos River at SH21 near Bryan	08108700	0	0
Yegua Creek near Somerville	08110000	58	7
Navasota River near Easterly	08110500	8	2
Brazos River near Hempstead	08111500	0	0
Brazos River near Richmond	08114000	0	0
Brazos River near Rosharon	08116650	0	0

Figure B-10. Number of zero flow months under the Full Authorization Scenario.

4.0 Discussion

The results of this analysis estimate projected combined use by all surface water users within segments of the Brazos River basin under multiple hydrologic scenarios. It is apparent that the specific influence of BRA's management activities on surface water flows within the Brazos River basin varies spatially, being highest in the upper portions of the Covered Area, lowest in the lower Brazos River, and intermediate in the major tributaries analyzed. Because BRA does not control flood storage, BRA's management influence is limited under high flow conditions, and increases under low flow conditions.

Under a projected natural scenario (Naturalized Scenario), subsistence conditions occurred from 2-24% of the time and zero flow months occurred in all but two stream segments. Over the last 75 years (Historical Conditions), the frequency of such low flow conditions has generally declined due to existing water management and infrastructure. With exceptions in a few stream segments, activities such as releases from reservoirs and return flows from discharges during drought periods have resulted in reductions in the frequency of low flow events. Changes to hydrologic patterns will continue into the future as demands increase and new water management strategies are implemented. To account for potential changes to the frequency of low flow events over the course of the CCAA, the 2060 Scenario was evaluated. Lastly, the Full Authorization Scenario was evaluated to represent a worst-case scenario with full utilization of all water rights and no return flows.

Although 2060 is well beyond the 20-year CCAA permit term, and thus inherently conservative, it is the best-available projection of water management that may occur during the timeframe of this CCAA. Therefore, comparing the 2060 Scenario with Historical Conditions provides the best representation of the difference between future conditions and past conditions. Changes in the number and frequency of low flow events are evident from this analysis, although the direction and magnitude of these changes vary spatially depending on future projections in local water use and other factors.

Although this modeling is complex and based on a variety of inputs, available data, and assumptions outlined above, some general mechanisms for these projections are apparent. In general, stream segments which show increased frequency of subsistence and zero flows are in areas with predicted increases in local use. A good example of this is the North Fork San Gabriel River near Georgetown and the San Gabriel River at Laneport, both of which are projected to see increased frequency of subsistence and zero flow months during the term of the CCAA. Projected population growth within the Williamson County area will result in increased local demand and increased withdrawals from Lake Georgetown and Lake Granger. This is projected to decrease reservoir releases into the North Fork San Gabriel River and San Gabriel River.

Decreased frequency of low flow events is typically associated with increased reservoir releases to meet demands of downstream water rights or increased return flows. A good example of this is Yegua Creek near Somerville. Although this location experienced 28 zero flow days in the historical record, it is projected to see no zero flow days under the 2060 Scenario. Additionally,

the percentage of time that this location experiences subsistence flow levels is projected to decrease. Reductions in low flow events are likely due to increased reservoir releases from Lake Somerville to transport water to senior water rights lower in the basin.

Understanding such future water use scenarios is critical as a conservation strategy to inform implementation and evaluation of conservation measures in each segment. Based on this analysis, stream segments with documented Covered Species populations exhibiting increased frequencies of low flow events under future conditions (i.e., San Gabriel River) were prioritized with respect to the proposed conservation measures. In contrast, stream segments with decreased frequency of low flows under future conditions (e.g., Yegua Creek) represent potential areas for restoration and enhancement opportunities as low flow stresses are expected to be minimal in these areas.

5.0 Appendix B References

Brazos River Authority (BRA). 2018. Conformed Water Management Plan for Water Use Permit No. 5851. Available online at: https://www.brazos.org/About-Us/Water-Supply/SysOps

National Research Council (NRC). 2005. The Science of Instream Flows: A Review of the Texas Instream Flow Program. Washington, DC: The National Academies Press. https://doi.org/10.17226/11197

Texas Parks and Wildlife Department (TPWD) and BRA. 2015. Amendment to Memorandum of Understanding from May 6, 2011, to address environmental flows.

Texas Commission on Environmental Quality (TCEQ). 2014. Environmental Flow Standards for Surface Water: Brazos River and its associated bay and estuary system. Austin, Texas.

TCEQ. 2018. Water Availability Models. Date accessed: 12/19/2018. https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/wam.html

Appendix C. Response to Public Comments

Brazos River Authority QUALITY • CONSERVATION • SERVICE

March 4, 2021

Adam Zerrenner
Field Supervisor
U.S. Fish and Wildlife Service
10711 Burnet Road, Suite200
Austin, TX 78758

Dear Mr. Zerrenner,

Working collaboratively with our partners at U.S. Fish and Wildlife Service (USFWS), the Brazos River Authority (BRA) has developed a Candidate Conservation Agreement with Assurances (CCAA) for the Balcones spike (*Fusconaia iheringi*) (formally described as False spike [*Fusconaia mitchelli*]; Smith et al. 2020) and Texas fawnsfoot (*Truncilla macrodon*) in the Brazos River Basin. This agreement, two years in the making, and an associated application for an enhancement of survival permit were recently submitted to USFWS. On October 6, 2020, USFWS published a notice of availability and request for public comment in the Federal Register. This notice included a preliminary determination that the CCAA is eligible for categorical exclusion under the National Environmental Policy Act (NEPA) and described the expected result of implementation of the CCAA as likely a net conservation benefit to the candidate Balcones spike and Texas fawnsfoot. On November 5, 2020, USFWS received comments on the CCAA from Texas Parks and Wildlife Department (TPWD). On November 6, 2020, USFWS received comments on the CCAA from the Center for Biological Diversity and the National Wildlife Foundation. These comments were provided to BRA for review, and we appreciate the opportunity to respond to these comments. As many of the comments from the different commenters were similar in nature, we offer this combined response.

One commonality throughout all three comments is that it appears the commenters assume that the BRA has autonomy in managing all the water and reservoirs in the basin and is solely responsible for the provision for environmental flows for freshwater mussels. As noted in Section 14.2, water supply operations in the Brazos River are complex and influenced by multiple users. The water rights associated with the BRA System currently equate to about 38% of the total permitted diversions within the basin. The 11 existing System reservoirs authorize a total collective impoundment storage volume of 2,222,949 acre-feet, or approximately 53% of the total permitted storage within the entire basin. Of these 11 System reservoirs, BRA only owns and operates three of the reservoirs. The remaining eight System reservoirs are owned and operated by the U.S. Army Corps of Engineers. In addition, there are twelve other reservoirs within the covered area that are

not part of the BRA System and are owned and operated by a variety of entities. In drafting the CCAA, we were very cautious to include items totally within the realm of BRA's control that we are certain we can deliver on.

BRA has thoroughly reviewed the comments and appreciates the input and suggestions. Based on these comments we have identified areas where we could update and improve the CCAA document. Where appropriate and feasible, we have made edits to the CCAA in response to these comments. The attached modified CCAA document provides a thorough voluntary conservation strategy for ESA-candidate freshwater mussels specific to the Brazos River basin, informed by the National Strategy for the Conservation of Native Freshwater Mussels developed by the Freshwater Mollusk Conservation Society. It proposes avoidance and minimization measures to reduce potential impacts to freshwater mussels and their habitats, a monitoring and adaptive management program to track mussel populations and their habitats within the basin, environmental flow standards and a plan for refinement and adaptive management of these standards into the future, and public outreach and education programs to inform the public about freshwater mussel conservation. As suggested in the USFWS's Federal Register notice, BRA believes this agreement will result in net conservation benefit to the candidate Balcones spike and Texas fawnsfoot, and we look forward to implementing this precedent-setting central Texas freshwater mussel conservation agreement with our partners at USFWS and TPWD.

Sincerely,

Tiffany Malzahn

Tiffany Malzahn
Environmental and Compliance Manager

Comment Topic 1: The CCAA should reference the comprehensive, multidisciplinary Texas Instream Flow Program (TIFP) Study from the middle and lower Brazos River dated June 15, 2018.

Response: A reference to the TIFP report has been added to the CCAA in Section 9.5.2.

Comment Topic 2: Thermal tolerance of 30°C for Brazos Basin mussel species and associated flow recommendations from the TIFP report should be incorporated. Thermal tolerance criteria for False Spike, both adults and glochidia, have been assessed in peer-reviewed publications (Khan et al. 2019 and Khan et al. 2020) that could have been utilized to inform subsistence and low flow conservation criteria.

Response: Use in the CCAA of the TCEQ Environmental Flow Standards flow values from state statute is appropriate as these are the currently recognized and legal standard for environmental flows in the Brazos River basin. Application of different flow values (e.g., values from the TIFP report, or site-specific BRA data, or new research) is outlined in Section 9.3.2.

The TIFP report mentioned above utilized thermal tolerance information for freshwater mussels to aid in establishing subsistence flow recommendations. However, in our professional opinion, that thermal tolerance information was not appropriately applied. The TIFP report cites multiple peer-reviewed publications and a Master's thesis, but provides no details on how 30°C was determined as the water temperature threshold for mussels in the lower Brazos River. Referenced peer-reviewed studies which examined temperature thresholds of early life stages (Pandolfo et al. 2010 and Ganser et al 2013) assess LT50 at multiple timeframes that range from 24-hr to 28-day and the TIFP report does not provide any methodological framework for how their 30°C threshold was selected. It should also be noted that the test animals used for these referenced studies are from nine different species, only one of which is native to Texas. The mussels used were propagated in a lab and the location of source populations is not given. However, it can be assumed that they were taken from latitudes more northern than Texas, and thus, may be adapted to different temperature regimes. Based on this, we do not feel it is an appropriate application to assume that temperature tolerances of these early life stage mussels are the same as those of the Covered Species in the Brazos River basin of Texas.

The commenters point out that there are recent studies which have provided temperature tolerance information for False Spike from the lower Guadalupe River (Khan et al. 2019, Khan et al. 2020). However, a recent phylogenetic study displayed that false spike populations in the Brazos and Colorado River basins were genetically distinct from populations in the Guadalupe River basin. This resulted in a taxonomic revision of the false spike and elevated Brazos and Colorado River basin populations as a distinct species now referred to as the Balcones spike (Smithe et al. 2020).

The thermal tolerance criteria developed by Khan et al. (2019, 2020) for the false spike in the Guadalupe River Basin appears to be generally assumed by the scientific community

to be protective of all species freshwater mussel populations in the Brazos. However, we are not convinced that applying the criteria developed for the false spike in the Guadalupe River basin is appropriate for either the Balcones spike, since it has been determined to be genetically distinct from the false spike, or the Texas fawnsfoot.

We did add reference to the Khan et al. (2019, 2020) papers to the CCAA, we also strongly feel any temperature tolerance data should be put in context with historical temperature regimes within this agreement's covered area to ensure that thresholds selected are ecologically relevant. Table 1 provides a summary of surface water temperatures from historical data from sites within conservation zones A-C available on the Texas Commission on Environmental Quality's Surface Water Monitoring Information System database.

We evaluated water temperatures in the Clear Fork and Upper Brazos, where the Texas fawnsfoot occurs, and the average maximum temperature values are 31.6°C and 33.6 °C respectively. We also compared the historical record of water temperatures in the Clear Fork and Upper Brazos to the 96-hr Acute value of 30.5°C identified for false spike by Khan et al (2019, 2020) and discovered that this criteria is exceeded 2.8% and 5.2% of the time in the respective reaches. Furthermore, in the summer months this criterion is exceeded 10.5% and 22.4% of the time, respectively.

Evaluation of water temperatures in the Central Brazos and Lower Brazos, reveal similar but even more compelling results. The criteria developed by Khan et al (2019, 2020) is exceeded 8.5% and 12.4% of the time in the respective reaches in the historical data set and in the summer months this criterion is exceeded 29.4% and 43.8% of the time.

We feel that the above data indicates that temperature tolerance of the Texas fawnsfoot is greater than that of the false spike as water temperatures above 30.5°C occur in all segments of the Clear Fork and Brazos River. This is especially true in the Lower Brazos where the Texas fawnsfoot is most prevalent. Additionally, statistical analysis reveals significant differences between the lower and central Brazos River and the Little River/San Gabriel river in mean water temperature ($p=0.002$), median water temperature ($p=0.046$), and maximum water temperature ($p=0.003$).

Analysis of newly available temperature threshold information, including how temperature thresholds compare to historical water temperature data and/or result in selection of subsistence flow recommendations in the covered area, is beyond the scope and remaining timeframe of this agreement. However, development and refinement of environmental flow methodologies specific to freshwater mussels is a stated conservation measure in the CCAA, as outlined in Section 9.5.2. As part of this conservation measure, BRA will be working with other conservation partners to evaluate the potential for refinement and revision of existing environmental flow standards to better represent the needs of freshwater mussels.

A reference to the Khan papers has been added to the CCAA in Section 3.1, and a Reference to the TIFP report has been added to Section 9.5.2.

Table 1. Summary of Historic Water Temperature Grab Sample Data at the Water Surface (0.3 m) in Conservation Zones.

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set	Mean (°C)	Median (°C)	Maximum (°C)	Number and % of Values in Spring (>30.5°C)	Number and % of Values in Summer (>30.5°C[1])
Clear Fork of the Brazos River	C	11992	Clear Fork at FM 600 near Nugent	7/30/1973 to 6/10/2019	253	19.1	19.5	32.5	0 (0%)	7 (9.86%)
Clear Fork of the Brazos River	C	11990	Clear Fork at SH 6 in Lueders	8/22/1988 to 6/10/2019	48	18.8	20.8	30.6	0 (0%)	1 (7.14%)
Clear Fork of the Brazos River	C	18766	Clear Fork upstream of confluence with Paint Creek	2/7/2006 to 2/27/2019	46	20.3	19.9	30.7	0 (0%)	1 (7.14%)
Clear Fork of the Brazos River	C	11985	Clear Fork at US 283 Northeast of Fort Griffin	9/3/1968 to 5/21/2019	256	19.0	19.9	32.7	0 (0%)	11 (18.03%)

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set	Mean (°C)	Median (°C)	Maximum (°C)	Number and % of Values in Spring (>30.5°C[1])	Number and % of Values in Summer (>30.5°C[1])
Brazos River Between Lakes PK and Granbury	C	11864	Brazos River at FM 4 near Palo Pinto	9/3/1968 to 8/7/2019	301	19.5	20.0	36.7	0 (0%)	16 (20.78%)
Brazos River Between Lakes PK and Granbury	C	11863	Brazos River at US 281 South of Mineral Wells	9/12/1973 to 7/15/2020	125	20.1	21.2	33.5	0 (0%)	4 (12.90%)
Brazos River Between Lakes PK and Granbury	C	18745	Brazos River 1.74 KM Downstream of US 281	5/18/2005 to 7/15/2020	40	20.9	22.0	31.7	0 (0%)	3 (33.33%)
Brazos River Between Lakes PK and Granbury	C	13543	Brazos River at FM 1189 South of Dennis	1/28/1993 to 8/7/2019	309	20.0	21.1	32.5	1 (1.23%)	18 (22.50%)

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set	Mean (°C)	Median (°C)	Maximum (°C)	Number and % of Values in Spring (>30.5°C[1])	Number and % of Values in Summer (>30.5°C[1])
Brazos River Between Waco and College Station	C	12038	Brazos River Upstream of SH 6 Southeast of Waco	6/5/1991 to 12/15/2020	246	21.9	21.9	34.7	0 (0%)	28 (43.75%)
Brazos River Between Waco and College Station	C	12037	Brazos River at River View Camp Road	3/25/1991 to 5/14/2019	81	21.7	22.0	33.3	0 (0%)	4 (20.00%)
Brazos River Between Waco and College Station	C	12032	Brazos River Downstream of FM 413 Northeast of Rosebud	2/8/1972 to 12/15/2020	504	21.3	22.0	34.6	1 (0.78%)	40 (29.63%)
Brazos River Between Waco and College Station	C	15767	Brazos River at SH 21 Northeast of Caldwell	5/12/1997 to 12/15/2020	130	21.5	22.0	31.7	1 (3.33%)	8 (24.24%)

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set	Mean (°C)	Median (°C)	Maximum (°C)	Number and % of Values in Spring (>30.5°C[1])	Number and % of Values in Summer (>30.5°C[1])
Little River	A	13544	Little River at FM 1600 Southwest of Cameron	9/27/1994 to 7/1/2019	77	20.6	22.1	31.6	0 (0%)	2 (8.70%)
San Gabriel River	A	13648	San Gabriel River North of Laneport	11/4/1981 to 7/1/2019	91	20.4	21.7	30.0	0 (0%)	0 (0%)
San Gabriel River	A	17651	San Gabriel River Northwest of Rockdale	10/27/2015 to 7/1/2019	16	20.0	20.5	29.0	0 (0%)	0 (0%)
Navasota River	B	11873	Navasota River Downstream of SH 6	7/27/1987 to 11/17/2020	63	21.9	23.1	32.5	0 (0%)	10 (55.56%)
Brazos River Between College Station and Richmond	B	12030	Brazos River at SH 105 West of Navasota	2/28/1972 to 12/16/2020	251	22.3	23.0	33.4	1 (1.79%)	33 (47.14%)

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set	Mean (°C)	Median (°C)	Maximum (°C)	Number and % of Values in Spring (>30.5°C[1])	Number and % of Values in Summer (>30.5°C[1])
Brazos River Between College Station and Richmond	B	11850	Brazos River at US 290 Northwest of Hempstead	2/19/1988 to 12/16/2020	286	22.2	23.0	32.3	1 (1.41%)	30 (40.54%)

Comment Topic 3: It is the opinion of commenters that the Texas Environmental Flow Standards are not protective of the candidate species because they are not based on mussel-specific data and were adopted before the TIFP report was complete.

Response: The Texas-adopted environmental flow standards are the currently recognized and legal standard for environmental flows in the Brazos River basin. These were developed through a legislatively mandated process and are enacted by the Texas Commission on Environmental Quality. The BRA has no authority to enact, amend or enforce these standards. When TCEQ adopted the environmental flow standards they stated, "The commission finds that the environmental flow standards adopted herein are adequate to support a sound ecological environment."

The commenters are correct that the initial standards were based mostly off of hydrology, water quality and fisheries data. At the time the environmental flow standards were developed there was a paucity of data regarding the environmental flow needs and tolerances of mussels in the Brazos basin, as there still is. Determining the effectiveness of the Texas Environmental Flow Standards at protecting mussels cannot be evaluated until the paucity of data regarding the environmental flow needs of the candidate species is resolved. These data gaps are something the CCAA tries to resolve.

The commenters are correct that the initial standards were adopted before the completion of the TPWD's 2018 TIFP Report. The timeline for adopting the Texas Environmental Flow Standards was legislatively mandated. TCEQ did not have the option to wait for TPWD to complete and publish the TIFP Report.

Provisions in the CCAA recognizing current knowledge limitations regarding the Texas Environmental Flow Standards and the potential for future refinements are detailed in sections 9, 11, 12, 13. In the interim, what BRA can do to provide a net conservation benefit to the mussels is to complete the applied research (Section 9.5) and long-term monitoring (Section 9.6) conservation measures included in the CCAA and make the resultant data available to the TCEQ when they perform adaptive management reviews of the adopted environmental flow standards for the Brazos River Basin.

Whether the environmental flow standards are amended to incorporate the recommendations in the 2018 TIFP Study, or any of the data to be gathered throughout the term of the CCAA, is a decision of the TCEQ.
The Brazos basin environmental flow standards were adopted by TCEQ in March 2014. Per 30 TAC §298.490, BRA anticipates that TCEQ will reconvene the Brazos Basin Expert Science Team and Stakeholder Committee and begin adaptive management review of the environmental flow standards in 2024. If TCEQ follows the same process mandated by the Texas legislature for the initial development of the Brazos basin environmental flow standards, and if the adaptive management review indicates revisions of some or all of the basin's environmental flow standards in the basin are warranted, adoption of revised standards should occur in 2026.

Comment Topic 4: It is the opinion of commenters that the Texas Environmental Flow Standards are not protective of the candidate species because TCEQ performed a balancing analysis on the standards recommended by the Brazos River Basin and Bay Expert Science Team (BBEST).

Response: The TCEQ-adopted Texas Environmental Flow Standards are the currently recognized and legal standard for environmental flows in the Brazos River basin. These were developed through a legislatively mandated process and are enacted by the Texas Commission on Environmental Quality. The BRA has no authority to enact, amend or enforce these standards. When TCEQ adopted the environmental flow standards they stated, "The commission finds that the environmental flow standards adopted herein are adequate to support a sound ecological environment."

The commenters are correct that the adopted Texas Environmental Flow Standards did undergo a balancing review and edit from the environmental flow standards proposed by the Brazos River Basin and Bay Expert Science Team (BBEST). TCEQ followed a legislatively mandated process, whereby basin stakeholders reviewed the BBEST recommendations, and then made their own recommendations to TCEQ. TCEQ considered both recommendations when drafting and enacting environmental flow standards for the basin.

It should be noted that TCEQ adopted subsistence and baseflow standards recommended by the BBEST, without any balancing (Table 2). Thus, no balancing occurred at the low end of the flow spectrum where mussels are most vulnerable. Balancing occurred only in the recommendations for high flow pulses and overbank flows. While the BBEST often recommended 3-4 tiers of high flow pulses, TCEQ adopted 1-2 of the BBEST recommended tiers of high flow pulses when they codified the environmental flow standards. TCEQ did not include overbank flows in the environmental flow standards for any location, citing that they cannot enact a regulation that will directly threaten human health and welfare.

Whether the environmental flow standards are amended to incorporate the recommendations in the 2018 TIFP Study, or any of the data to be gathered throughout the term of the CCAA, is a decision of the TCEQ. The Brazos basin environmental flow standards were adopted by TCEQ in March 2014. Per 30 TAC §298.490, BRA anticipates that TCEQ will reconvene the Brazos Basin Expert Science Team and Stakeholder Committee and begin adaptive management review of the environmental flow standards in 2024. If TCEQ follows the same process mandated by the Texas legislature for the initial development of the Brazos basin environmental flow standards, and if the adaptive management review indicates revisions of some or all of the basin's environmental flow standards in the basin are warranted, adoption of revised standards should occur in 2026.

Table 2. Comparison of BBEST Recommended Subsistence and Baseflows and TCEQ Adopted Environmental Flow Standards.

Site	USGS Gage	Conservation Zone	Season	BBEST Recommended Subsistence Flow (cfs)	TCEQ Adopted Subsistence Flow (cfs)	Season	Hydrologic Condition	BBEST Recommended Base Flows (cfs)	TCEQ Adopted Base Flows (cfs)
Clear Fork Brazos River at Nugent	08084000	C	Winter	1	1	Winter	Dry	5	5
							Average	8	8
							Wet	13	13
Clear Fork Brazos River at Nugent	08084000	C	Spring	1	1	Spring	Dry	3	3
							Average	6	6
							Wet	12	12
Clear Fork Brazos River at Nugent	08084000	C	Summer	1	1	Summer	Dry	1	1
							Average	4	4
							Wet	9	9
Brazos River near Palo Pinto	08089000	C	Winter	17	17	Winter	Dry	40	40
							Average	61	61
							Wet	100	100
Brazos River near Palo Pinto	08089000	C	Spring	17	17	Spring	Dry	39	39
							Average	75	75
							Wet	120	120
Brazos River near Palo Pinto	08089000	C	Summer	17	17	Summer	Dry	40	40
							Average	72	72
							Wet	120	120

Site	USGS Gage	Conservation Zone	Season	BBEST Recommended Subsistence Flow (cfs)	TCEQ Adopted Subsistence Flow (cfs)	Season	Hydrologic Condition	BBEST Recommended Base Flows (cfs)	TCEQ Adopted Base Flows (cfs)
Brazos River at Waco	08096500	C	Winter	56	56	Winter	Dry	120	120
							Average	210	210
							Wet	480	480
Brazos River at Waco	08096500	C	Spring	56	56	Spring	Dry	150	150
							Average	270	270
							Wet	690	690
Brazos River at Waco	08096500	C	Summer	56	56	Summer	Dry	140	140
							Average	250	250
							Wet	590	590
Leon River at Gatesville	08100500	D	Winter	1	1	Winter	Dry	9	9
							Average	20	20
							Wet	52	52
Leon River at Gatesville	08100500	D	Spring	1	1	Spring	Dry	10	10
							Average	24	24
							Wet	54	54
Leon River at Gatesville	08100500	D	Summer	1	1	Summer	Dry	4	4
							Average	12	12
							Wet	27	27

Site	USGS Gage	Conservation Zone	Season	BBEST Recommended Subsistence Flow (cfs)	TCEQ Adopted Subsistence Flow (cfs)	Season	Hydrologic Condition	BBEST Recommended Base Flows (cfs)	TCEQ Adopted Base Flows (cfs)
Little River near Little River	08104500	Above A	Winter	55	55	Winter	Dry	82	82
							Average	110	110
							Wet	190	190
Little River near Little River	08104500	Above A	Spring	55	55	Spring	Dry	95	95
							Average	150	150
							Wet	340	340
Little River near Little River	08104500	Above A	Summer	55	55	Summer	Dry	84	84
							Average	120	120
							Wet	200	200
Little River near Cameron	08106500	D	Winter	32	32	Winter	Dry	110	110
							Average	190	190
							Wet	460	460
Little River near Cameron	08106500	D	Spring	32	32	Spring	Dry	140	140
							Average	310	310
							Wet	760	760
Little River near Cameron	08106500	D	Summer	32	32	Summer	Dry	97	97
							Average	160	160
							Wet	330	330

Site	USGS Gage	Conservation Zone	Season	BBEST Recommended Subsistence Flow (cfs)	TCEQ Adopted Subsistence Flow (cfs)	Season	Hydrologic Condition	BBEST Recommended Base Flows (cfs)	TCEQ Adopted Base Flows (cfs)
Brazos River at SH 21 near Bryan	08108700	C	Winter	300	300	Winter	Dry	540	540
							Average	860	860
							Wet	1760	1760
Brazos River at SH 21 near Bryan	08108700	C	Spring	300	300	Spring	Dry	710	710
							Average	1260	1260
							Wet	2460	2460
Brazos River at SH 21 near Bryan	08108700	C	Summer	300	300	Summer	Dry	630	630
							Average	920	920
							Wet	1470	1470
Navasota near Easterly	08110500	D	Winter	1	1	Winter	Dry	9	9
							Average	14	14
							Wet	23	23
Navasota near Easterly	08110500	D	Spring	1	1	Spring	Dry	10	10
							Average	19	19
							Wet	29	29
Navasota near Easterly	08110500	D	Summer	1	1	Summer	Dry	3	3
							Average	8	8
							Wet	16	16

Site	USGS Gage	Conservation Zone	Season	BBEST Recommended Subsistence Flow (cfs)	TCEQ Adopted Subsistence Flow (cfs)	Season	Hydrologic Condition	BBEST Recommended Base Flows (cfs)	TCEQ Adopted Base Flows (cfs)
Brazos River near Hempstead	08111500	B	Winter	510	510	Winter	Dry	920	920
							Average	1440	1440
							Wet	2890	2890
Brazos River near Hempstead	08111500	B	Spring	510	510	Spring	Dry	1130	1130
							Average	1900	1900
							Wet	3440	3440
Brazos River near Hempstead	08111500	B	Summer	510	510	Summer	Dry	950	950
							Average	1330	1330
							Wet	2050	2050
Brazos River at Richmond	08114000	B	Winter	550	550	Winter	Dry	990	990
							Average	1650	1650
							Wet	3310	3310
Brazos River at Richmond	08114000	B	Spring	550	550	Spring	Dry	1190	1190
							Average	2140	2140
							Wet	3980	3980
Brazos River at Richmond	08114000	B	Summer	550	550	Summer	Dry	930	930
							Average	1330	1330
							Wet	2190	2190

Comment 5: Texas Environmental Flow Standards are only applied to the BRA's SYSOPs permit and SYSOPS Water Management Plan (WMP) and not to BRA water rights that pre-date the adoption of the standards.

Response: The commenters are correct that the Texas Environmental Flow Standards are not retroactive to BRA water rights issued before their adoption. However, we still believe the SYSOPs permit provides benefits to the flows in the Brazos Basin by increasing the BRA's operational flexibility to ensure water is available for senior water rights and BRA customers during dry times.

On average, nearly six million acre-feet (acft) of water per year pass the southernmost downstream monitoring gage on the Brazos River flowing unused into the Gulf of Mexico. The SYSOPs permit allows BRA access for water supply purposes to a portion of these flows when they are available in the stream and environmental flow standards are being met. It also allows BRA to use their water supply in the eleven System reservoirs conjunctively. This provides BRA the operational flexibility to select which water supply sources are used to satisfy the diversion requirements of senior water rights and BRA customers. During wet times when water in the Brazos River is plentiful, water may be diverted by senior water rights and/or BRA customers from that available in the Brazos River, versus releasing water from storage. This allows BRA to hold water in storage, thus ensuring water is available during dry times to flow downstream to satisfy senior water rights and BRA customers and to also benefit freshwater mussels and other aquatic organisms.

The BRA's SYSOPs and WMP permit specifically requires BRA to maintain environmental flow conditions in the WMP that comply with the TCEQ-adopted Environmental Flow Standards. If TCEQ amends any of the existing environmental flow standards as a result of the adaptive management review process, BRA will then be required to amend the WMP to comply with the newly adopted environmental flow standards.

Additionally, the SYSOPs permit contains several special conditions that contribute to flow maintenance in the Brazos River basin in areas where the covered species are known to occur. One condition requires that BRA maintain a minimum release schedule from Possum Kingdom based on season and lake level. The only exception to this release schedule requirement is when inflows to the reservoir are less than the defined release level. When this happens, the release may be adjusted to match reservoir inflows.

Another condition prevents BRA from diverting or impounding water, if such diversions or impoundments would cause the flow at USGS Gage 081166550 (Brazos River near Rosharon) to fall below the lesser of 630 cfs, or the Dow Chemical Company's (a senior water right in Brazoria County) daily pumping rate. The USGS gage at Rosharon sits on the Fort Bend/Brazoria County line and is the lowest USGS gage in the non-tidally influenced portion of the Brazos River. The Dow Chemical Company's diversion points are in Brazoria County, the last county in the Brazos River basin before the confluence with the Gulf of Mexico. This requirement often results in flows greater than the 430 cfs

subsistence requirements that the Texas Environmental Standards requires at USGS Gage 081166550.

BRA's largest water supply customers are in the lower Brazos River basin. SYSOPs provides the BRA the potential opportunity to offset reduced flows in a particular river reach with water deliveries especially during drought and summer seasons when the downstream demand for water is at peak. When water is available in those reaches, deliveries can meet dual purposes of meeting water supply demands and the flow needs of freshwater mussels, thus providing a net conservation benefit to the covered species.

It should be noted that during times of drought, water may not be available to be released or lake levels may reach a level where releases are not possible. BRA's lakes Possum Kingdom, Granbury and Limestone are equipped with low flow outlets. Low flow operations will be conducted as described in the CCAA and according to BRA's water rights, and BRA's Water Management Plan. Releases from USACE reservoirs will be conducted as described in the CCAA and according to BRA's water rights and BRA's Water Management Plan and the USACE's Reservoir Control Office as specified in the USACE water control plan and manual of operation as prescribed by the Secretary of the Army and as required by law.

Additionally, the TCEQ has created the Brazos Basin Watermaster whose area of authority includes the Brazos River basin downstream and including Possum Kingdom Lake. The Watermaster ensures compliance with water rights, ensures compliance with environmental standards, coordinates diversions to prevent water from being wasted or used in excess of a specific water right, and responds to complaints regarding inappropriate use of water. When the basin is experiencing drought conditions, and stream flow is diminished, the Watermaster is responsible for allocating available water among the water right holders according to priority date. Some of the largest and oldest water rights in the state are in the Lower Brazos basin in Fort Bend and Brazoria counties. This will ensure flow during dry times as these water rights holders needs will have to be met before others can divert water higher in the system.

Comment 6: BRA should commit to making water releases from storage under its various water rights to benefit the covered species.

Response: The water rights currently granted to the BRA by the TCEQ do not currently authorize the use of appropriated water for maintenance of environmental flow requirements. The BRA is committed to acquiring amendments necessary to achieve that legal authority in the upcoming update to its WMP. The process of revision of the WMP will begin in FY 2022, with the revised WMP submitted to TCEQ for consideration in FY 2026.

The BRA's current WMP includes maintaining a voluntary minimum flow release of 4 cfs from Lake Granger when water is capable of being released from the reservoir. There may be several reasons why water is not capable of being released from storage, including, but not limited to: dam maintenance projects restrict the ability to release water, and during

periods of drought, water levels fall to an elevation below the elevation at which the dam gates can release water or we are restricted by state regulatory agencies from releasing water. No regulatory requirements exist for this release, the purpose of this voluntary release is for downstream domestic and livestock water needs. While the purpose of this release is for water supply purposes, it also benefits covered species in the San Gabriel River.

In its 2011 and 2014 Memorandums of Understanding with TPWD, regarding work to be done by BRA in the basin in exchange for TPWD's support of the SYSOPs permit, the BRA commits to making a dedication to the Texas Water Trust for environmental flow use. The dedication will be approximately 6,000 ac-ft. BRA and TPWD are currently working to develop a decision matrix on how this water will be used in the basin. Support for freshwater mussels is one of the top priorities being considered in the decision matrix.

BRA added a subsection in 9.3 – Environmental Flows Protection discussing the voluntary minimum flow release in the San Gabriel and a reference to BRA WMP Technical Report Chapter 4 – Water Supply Operations.

BRA added a subsection in 9.3 – Environmental Flows Protection describing that we will be actively seeking amendment to the SYSOPs water right for the authority to make releases for environmental flows. In this new section, we will discuss that we are actively working with TPWD on a decision matrix for the use of this water and that supporting the covered species is one of the top priorities.

Comment 7: Texas Environmental Flow Standards adopted by the State of Texas do not cover all areas currently occupied by the covered species or where the covered species may occur into the future. Specific references to the San Gabriel River and Brushy Creek are cited by one commenter.

Response: The commenter is correct that the two cited streams, the San Gabriel River and Brushy Creek, do not have adopted Texas Environmental Flow Standards. However, both stream reaches contribute flow to the downstream control point, Little River at Cameron. Given that there is another upstream Environmental Flow Standard on the Little River at Little River Academy which is above the confluence of Brushy Creek and the San Gabriel, it is possible to utilize the flows at these two control points to diagnose a flow concern in the cited stream reaches.

It should also be noted the BRA has no water storage on Brushy Creek.

Additionally, the BRA has no authority to enact, amend or enforce environmental flow standards in these reaches. Whether the Texas Environmental Flow Standards are amended to incorporate control points on this stream is a decision of the TCEQ. BRA anticipates that TCEQ will begin adaptive management review of the environmental flow standards in 2024.

More than once in the comments, there appears to be an expectation that the BRA and Texas regulatory agencies can accurately predict where the covered mussels might be discovered in the future or reintroduced and that current regulatory processes should be

able to account for these future populations. The BRA and Texas regulatory agencies cannot at this time account for future discoveries or future decisions by USFWS or TPWD to reintroduce the species. The BRA does include revision of the Mussel Conservation Zones based on new information on the covered species distribution in the CCAA in Section 12 – Adaptive Management.

Even though conservation zone revision based on new distributional information is already included in Section 12 of the CCAA, BRA added language regarding revision of mussel conservation zones based on changes in the distribution of the covered species to Section 13.1 – Changed Circumstances.

Comment 8: Flows in the San Gabriel and gate releases from Lake Granger during the summer of 2018 were referenced in multiple places inferring poor water supply management practices by the BRA.

Response: In 2018, the USACE performed a significant dam maintenance project on the downstream side of the reservoir. The project included placement of a coffer dam, de-watering and inspections of the outlet works and stilling basin, and repair of any damage found during the inspection. The project did include relocation of fish and freshwater mussels in the project area and in accordance with TPWD *Guidelines for Aquatic Resource Relocation Plan for Fish and Shellfish, Including Freshwater Mussels*.

The low flows observed in the summer of 2018 were a direct result of the USACE's maintenance project which was critical to continued safety of the dam.

Comment 9: Hydrology modeling should be conducted using daily-time step models not the monthly WAM model.

Response: We feel the commenters misunderstood the use of the hydrology modeling. The hydrology modeling was used in the CCAA to identify relative change between hydrologic scenarios and to identify location-based conservation strategies. The hydrology tool used in the CCAA analysis is the same one used by TCEQ for evaluating permitted water use, the WAM/WRAP model, and has been developed by TCEQ with monthly flow values. Zero-flow and low-flow conditions identified by this analysis indicate steady long-term conditions (e.g., a zero-flow month is comprised of at least 30 continuous zero flow days). The analysis monthly timestep is suitable for the stated purpose of evaluating future hydrological risk and as a guide to prioritizing zones (Section 8).

The five-year updates will similarly be utilized to inform adaptive management decisions regarding future hydrological risk and as guide to prioritizing zones. Using a monthly timestep model is suitable for this purpose. Adaptive management review (Section 12) will be used to integrate CCAA applied research with the hydrology thresholds in future analyses.

In Section 11 – Monitoring and Reporting, BRA does commit to submit to USFWS the Environmental Flows Achievement Report we are required to produce under the SYSOPs permit and WMP and the Supplemental Environmental Flows Achievement Report we are

required to produce under our MOU's with TPWD. These reports do rely on daily flow data and accomplish what the commenters desire regarding assessment of attainment of flows on a daily basis.

The Annual Environmental Flows Achievement Report summarizes environmental flow achievement from November through the following October. The report clearly identifies all sites that BRA operations may influence that are in compliance with environmental flow standards. The report also identifies any non-compliance with Texas Environmental Flow Standards including subsistence, baseflows and high-flow pulse requirements. If any non-compliances are identified the report also includes an evaluation to determine if BRA operations under the SYSOPs Permit and WMP caused the non-compliance, and, if so, identifies a corrective action to prevent future non-compliance with Texas Environmental Flow Standards from water storage or diversion under the SYSOPs Permit and WMP. The Annual Environmental Flows Achievement Report includes analysis of Texas Environmental Flow Standards compliance at the following locations where the covered species are known to occur:

- Brazos River at Palo Pinto (USGS 08089000) – Conservation Zone C
- Brazos River at Waco (USGS 08089500) – Conservation Zone C
- Brazos River at SH 21 near Bryan (USGS 08108700) – Conservation Zone C
- Brazos River near Hempstead (USGS 08111500) – Conservation Zone B
- Brazos River near Richmond (USGS 08114000) – Conservation Zone B
- Little River near Little River Academy (USGS 08106500) – above Conservation Zone A
- Little River at Cameron (USGS 08106500) – below Conservation Zone A and in Conservation Zone D

The Supplemental Annual Environmental Flows Achievement Report is identical to the Annual Environmental Flows Achievement Report, except it addresses river reaches where no Texas Environmental Flow Standard has been adopted and instead compares flow compliance to the 7Q2 value for those reaches. The Supplemental Annual Environmental Flows Achievement Report includes analysis of 7Q2 compliance in the following Conservation Zones:

- San Gabriel River at Laneport (USGS 08105700) – Conservation Zone A
- Yegua Creek near Somerville (USGS 08110000) – Conservation Zone D
- Leon River at Gatesville (USGS 08100500) – Conservation Zone D

BRA added assessment of Texas Environmental Flow Standards attainment at the Clear Fork near Nugent to the Supplemental Annual Environmental Flows Achievement Report for submittal to USFWS.

Comment 10: Hydrology modeling should not have been extended out to 2060 as this is beyond the term of the CCAA. A 2040 run would be more useful.

> **Response:** We did perform a 2040 modeling run when conducting the initial hydrology analysis, results between the 2040 and 2060 runs were very similar. For display purposes we chose 2060. The 5-year modeling updates include updating all scenarios included in Appendix B. While we understand the opinion that the 2060 scenario is beyond the proposed term of the CCAA and permit and thus of little value, we strongly believe updating of the historical conditions and full authorization scenarios will provide insight into flow conditions expected during the term of the CCAA and permit. We feel the 2060 scenario is valuable because it provides insight into long-term, anticipated conditions contemplated in the basin's Regional Water Plans and does provide a longer look into the future giving some insight into the potential impact of near-term climate change.

Comment 11: CCAA should evaluate habitat quality when no dam releases are occurring.

> **Response:** We believe habitat quality evaluations should occur across the range of conditions experienced by the candidate species, otherwise bias can be entered into the data set. Additionally, different flow conditions can have different implications for the survival of the candidate species. However, it should be noted that safety considerations restrict collecting data during high flow events.

Comment 12: CCAA should plan in advance for changed circumstances if TCEQ takes an action that adversely impacts a conservation measure identified in the CCAA.

> **Response:** Changes to TCEQ flow standards are specifically addressed as a Changed Circumstance in Section 13.1, Item 6. The BRA has no authority over future changes that the TCEQ may make to the SB 3 environmental flow standards. All we can do is participate as a stakeholder during the public comment period, and if asked, participate on the basin Science Team. Through this process we can advocate that the data collected under this CCAA be included in the analyses that leads up to recommended changes.
>
> Again, the commenters appear to expect the BRA to be able to predict all possible future actions of a regulatory agency over which they have no authority. Without some indication of the nature and level of magnitude of the impact a future change by the TCEQ might have on a conservation measure, planning a changed circumstances response that is meaningful is beyond BRA's ability.
>
> **BRA added a general statement to Section 13.1 – Changed Circumstances regarding evaluating future actions of the TCEQ that adversely impact the successful completion of a conservation measure and, if possible, during annual adaptive management reviews BRA will make adjustments to the affected conservation strategy to reduce the impact of the TCEQ's action.**

Comment 13: The commitment regarding participation in the "Mussels of Texas Project" seems unduly conditional.

> **BRA strengthened the language to say we will contribute data to the Mussels of Texas database.**

Comment 14: False spike has recently been taxonomically split into two species; Brazos and Colorado River false spike are now considered Balcones spike *Fusconaia iheringi*, and Guadalupe River false spike remain *F. mitchelli* (Smith et al. 2020).

> **Response: Changed name of the false spike (*Fusconaia mitchelli*) to the Balcones spike (*Fusconaia iheringi*) throughout the CCAA.**

Comment 15: The Texas Threatened and Endangered Species List was updated in 2020 and includes the addition of the Brazos heelsplitter (*Potamilus streckersoni*) as State Threatened. Appendix A in the draft CCAA should be revised to reflect the current list of State Threatened species, including the Brazos heelsplitter. The CCAA may also need to be revised to place this State Threatened species in context.

> **Response: Appendix A has been modified to include Brazos heelsplitter and to reflect the state-threatened mussel species in the Covered Area**. Until the Brazos heelsplitter is evaluated by USFWS, no further revision to the CCAA is necessary.

Comment 16: The CCAA assumes that current habitat conditions for covered species are stable, which may not be the case for some populations; this is a concern given some populations may decline or become extirpated before any actionable conservation measures are enacted through the agreement.

> **Response:** It is unclear exactly what in the CCAA is interpreted as implying or assuming that habitat conditions for the covered species are stable. The CCAA describes existing habitat conditions but makes no comment on habitat trajectory. The commentor is correct, populations may decline or become extirpated before the CCAA is executed or can be fully implemented. The purpose of the CCAA is to provide a net conservation benefit to the candidate species within the sphere of BRA's management area. In Section 1 it is clearly stated that the CCAA covers activities in the BRA's area of influence and is not intended to enjoin other properties or parties.

Comment 17: Section 4.2 generalizes the effects of reservoirs on streamflow as "increased base flows, reductions in the duration of extreme low flow events, and reductions in the overall magnitude of high flow pulses." Although this may apply to the "lower Brazos River basin," hydrologic alteration downstream of tributary reservoirs (Table B-2; Lampasas downstream of Stillhouse Hollow Reservoir, North Fork San Gabriel River downstream of Georgetown Reservoir; San Gabriel River downstream of Granger Reservoir) likely results in longer duration and more frequent dewatering events, reduced flows during drought and summer seasons, and increased maximum water temperature, predation, and mortality.

Response: Such homogenization of flow conditions is the most common impact of reservoirs and applies to not only the lower Brazos River, but also tributaries such as the Navasota and Yegua Creek, as documented in recent peer-reviewed literature (Khan et al 2019). However, it does not apply in all cases, as also referenced. Regardless, of the stream reaches referenced in the comment the candidate species are only known to currently occur in the San Gabriel River downstream of Lake Granger.

Tables 3 and 4 provide a summary of daily historic flow data zero flow days and days below subsistence flow in Conservation Zones A – C before and after dam construction. It should be noted that a zero-flow day does not necessarily equate to a dewatering event. Unfortunately, USGS gage data does not provide the data necessary to determine whether the site was completely dewatered on that day, or still had water but no flow.

From these tables it can be observed that the commenters statement about longer and more frequent dewatering events is not supported by the data in all but one segment, the San Gabriel River. Table 5 provides a more detailed summary of daily historic zero flow days and below subsistence events in the San Gabriel River. Figure 1 displays the frequency and duration of zero flow events, while Figure 2 displays the frequency and duration of events below subsistence. The event in Figure 1 with 47 consecutive days of zero flows began on August 21, 1984 and concluded on October 6, 1984, the PHDI values for this time period reveal that the area had been in severe drought for 51 days prior to the fist zero flow day, and in mild to moderate drought for three months before that. Eight of the events in Figure 2 occurred in 2018, when the U.S. Army Corps of Engineers performed an extensive maintenance project on the downstream side of Lake Granger dam.

Regression analysis comparing the historical record of daily mean discharge, zero flow days, and days below subsistence to the numeric Palmer Hydrological Drought Index (PHDI) value reveals significant positive relationships between the flows in the San Gabriel River and the severity of hydrological drought ($p<0.001$ for all three). Figures 3-5 Displays the relationship between mean daily discharge, zero flow days, and days below subsistence and the associated PHDI numeric value.

Regression analysis comparing the historical record daily mean discharge, zero flow days, and days below subsistence to the Palmer Hydrological Drought Index (PHDI) category also reveals significant positive relationships between the flows in the San Gabriel River and the severity of hydrological drought ($p<0.001$ for all three). Figures 6-8 show that the flows in the river are highly influenced by the drought-flood cycle.

We used the PHDI for these analyses, versus the more commonly used Palmer Drought Severity Index, because the PHDI is a developed to quantify hydrological impacts of drought (e.g., reservoir levels, groundwater levels, stream flow, etc.). The PHDI is a long-term drought index responds more slowly to changing conditions, and is thus more conservative, than the Palmer Drought Severity Index. The scale of the PHDI is displayed in the table below.

The water rights that BRA owns do not currently authorize use of appropriated water for maintenance of environmental requirements, however BRA is committed to acquiring amendments necessary to achieve that legal authority in the upcoming update to its Water Management Plan.

PHDI numeric scale and associated category label.

PHDI Range	Category
>4.00	Extreme wetness
3.00 - 3.99	Severe wetness
1.50 - 2.99	Mild to moderate wetness
-1.49 - 1.49	Near normal
-1.50 - -2.99	Mild to moderate drought
-3.00 - -3.99	Severe drought
<-4.00	Extreme drought

The water rights that BRA owns do not currently authorize use of appropriated water for maintenance of environmental requirements, however BRA is committed to acquiring amendments necessary to achieve that legal authority in the upcoming update to its Water Management Plan.

By agreeing to not sponsor additional BRA infrastructure or diversion projects within the area occupied by Balcones Spike (Conservation Zone A), BRA has maximized the conservation impact within this reach within the realm of our control.

While BRA's largest water supply customers are in the lower Brazos River basin, there exists potential opportunities to offset reduced flows in the tributaries with water deliveries especially during drought and summer seasons when the downstream demand for water is at peak. Deliveries can meet dual purposes of meeting water supply demands and environmental needs.

BRA added a conservation measure to convene a stakeholder's group specific to Conservation Zone A to identify other non-flow related measures that if implemented, would be beneficial to the candidate species in this zone.

Table 3. Summary of Zero Flows in Conservation Zones.

Stream Reaches Currently Inhabited by Covered Species	Zone	USGS Gage #	Historical Record Range	Monthly Modeled Naturalized Flow Zero Flow Months[2] (±10%)[1]	Monthly Modeled Naturalized Flow Longest Consecutive Period of Zero Flow Months[2] (±10%)[1]	Percent of Zero Flow Days in Historical Data Set (±5%)[1]	Percent of Pre-dam Zero Flow Days in Historical Data Set (±5%)[1]	Percent of Post-dam Zero Flow Days in Historical Data Set (±5%)[1]
Brazos River Between Lakes PK and Granbury	C	08089000	1/2/1924 to current	31	6	1.01%	5.64%	0.00%
Brazos River Between Waco and College Station	C	08096500	1/10/1898 to current	8	1	0.06%	0.13%	0.00%
Little River	A	08104500	10/1/1983 to current	2	1	0.00%	0.00%	0.00%
San Gabriel River	A	08105700	7/16/1965 to current	36	36	0.26%	0.00%	0.36%
Navasota River	B	08110500	3/27/1924 to current	69	69	0.52%	0.91%	0.00%
Brazos River near Bryan	C	08108700	7/14/1993 to current	1	1	0.00%	NA	NA
Brazos River Between Navasota and Hempstead	B	08111500	10/01/1938 to current	0	0	0.00%	0.00%	0.00%
Brazos River at Richmond	B	08114000	1/1/1903 to 6/30/1906 and 10/1/1922 to current	3	1	0.00%	0.00%	0.00%

[1] The December 4, 1992 USGS Policy Statement on Stage Accuracy states that, "Accuracies of discharge records for individual days commonly are about 5 to 10 percent." For this analysis we assumed 5% margin of error. The 10% margin of error on modeled naturalized flow is a combination of the assumed 5% margin of error on the USGS gage data and the 5% margin of error assumed in the TCEQ daily water use values.

[2] Monthly Modeled Naturalize Flow values from Appendix B of the CCAA.

Table 4. Summary of Historic Flows Below the Q95 by Conservation Zone Pre- and Post-Dam Construction

Stream Reaches Currently Inhabited by Covered Species	Conservation Zone	USGS Gage #	Historical Record Range	Q95 for Reach (cfs) (±5%) [1]	Monthly Modeled Naturalized Flow Percent of Data Below Q95 (±10%)[2]	Daily Percent of Historical Data below Q95 (±5%)	Percent of Pre-dam Data below Q95 (±5%)	Percent of Post-dam Data below Q95 (±5%)
Brazos River Between Lakes PK and Granbury	C	08089000	1/2/1924 to current	17[3]	7.50%	4.69%	19.80%	1.40%
Brazos River Between Waco and College Station	C	08096500	1/10/1898 to current	56[3]	2.70%	6.14%	6.96%	5.47%
Little River	A	08104500	10/1/1983 to current	55[3]	10.00%	6.84%	12.73%	5.48%
San Gabriel River	A	08105700	7/16/1965 to current	1.59[4]	6.50%	4.99%	2.17%	6.00%
Navasota River	B	08110500	3/27/1924 to current	1[3]	8.60%	4.78%	7.99%	0.62%
Brazos River near Bryan	C	08108700	7/14/1993 to current	300[3]	6.20%	4.60%	NA	4.60%
Brazos River Between Navasota and Hempstead	B	08111500	10/01/1938 to current	510[3]	6.50%	5.68%	10.14%	4.50%
Brazos River at Richmond	B	08114000	1/1/1903 to 6/30/1906 and 10/1/1922 to current	550[3]	4.90%	5.50%	5.42%	5.54%

[1] The December 4, 1992 USGS Policy Statement on Stage Accuracy states that, "Accuracies of discharge records for individual days commonly are about 5 to 10 percent." For this analysis we assumed 5% margin of error.

[2] The 10% margin of error on modeled naturalized flow is a combination of the assumed 5% margin of error on the USGS gage data and the 5% margin of error assumed in the TCEQ daily water use values.

[3] Texas Environmental Flow Standards in 30 TAC §298 Subchapter G

[4] Calculated the Q95 for the San Gabriel River using historical USGS discharge data set from USGS Gage 08105700-San Gabriel Rv at Laneport, TX

Table 5. Summary of Flows in the San Gabriel River at Laneport.

USGS Gage 08105700	Number of Values in Data Set	Minimum Flow (cfs)[1]	Maximum Flow (cfs)[1]	Mean Flow (cfs)[1]	Number of Zero Flow Events in Historical Data Set (±5%)[1]	Percent of Zero Flow Days in Data Set (±5%)[1]	Number of Below Subsistence Events[2] (±5%)[1]	Percent of Below Subsistence Flow Days in Data Set (±5%)[1]
Pre-dam	5303	0.28	14200	280	0	0.00%	8	2.17%
Post-dam	14923	0.00	6870	253	3	0.36%	87	6.00%

[1] The December 4, 1992 USGS Policy Statement on Stage Accuracy states that, "Accuracies of discharge records for individual days commonly are about 5 to 10 percent." For this analysis we assumed 5% margin of error. The 10% margin of error on modeled naturalized flow is a combination of the assumed 5% margin of error on the USGS gage data and the 5% margin of error assumed in the TCEQ daily water use values.

[2] Calculated the Q95 for the San Gabriel River using historical USGS discharge data set from USGS Gage 08105700-San Gabriel Rv at Laneport, TX

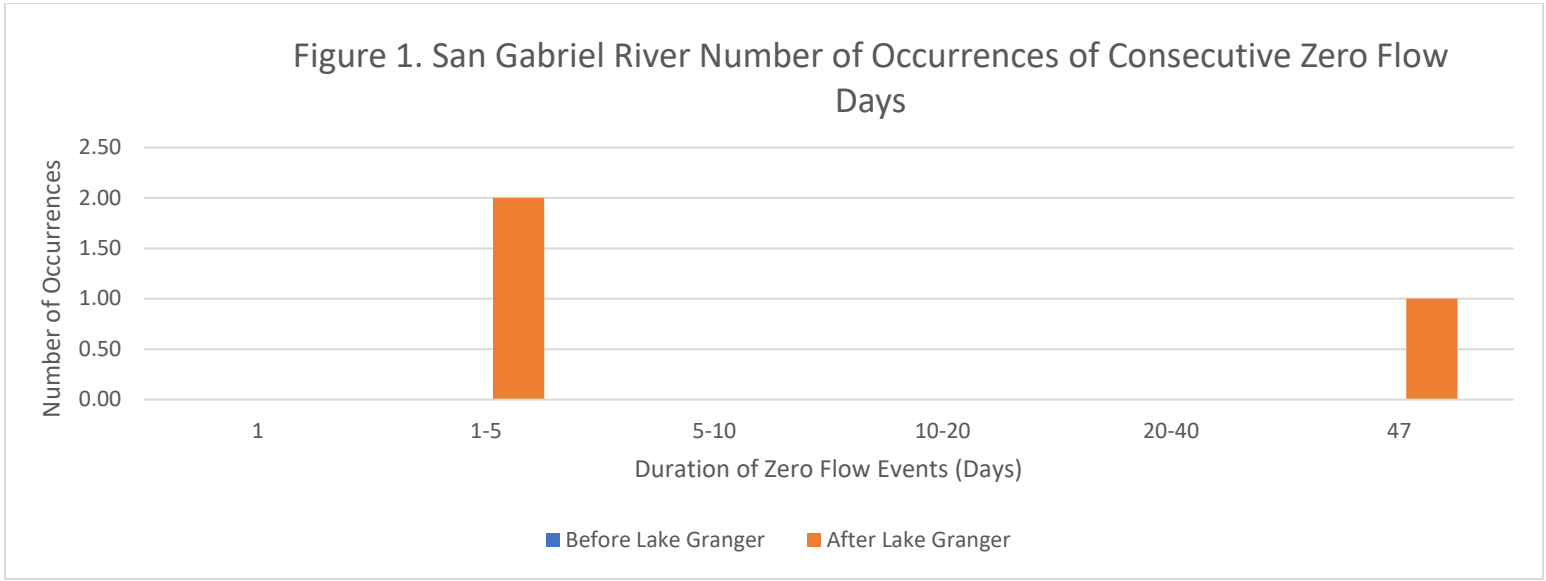


Figure 1. San Gabriel River Number of Occurrences of Consecutive Zero Flow Days
Number of Occurrences
2.50
2.00
1.50
1.00
0.50
0.00
1
1-5
5-10
10-20
20-40
47
Duration of Zero Flow Events (Days)
Before Lake Granger
After Lake Granger

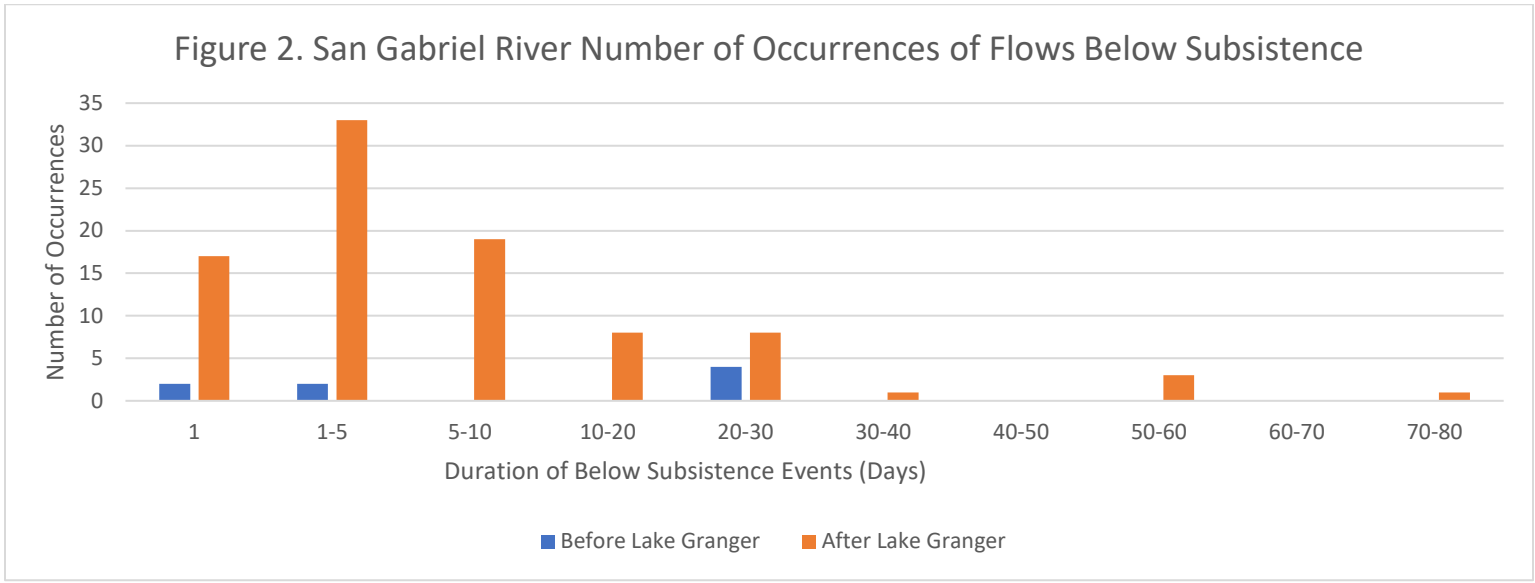


Figure 2. San Gabriel River Number of Occurrences of Flows Below Subsistence
Number of Occurrences
35
30
25
20
15
10
5
0
1
1-5
5-10
10-20
20-30
30-40
40-50
50-60
60-70
70-80
Duration of Below Subsistence Events (Days)
Before Lake Granger
After Lake Granger

Figure 3. Comparison of Palmer Hydrological Drought Index to Mean Daily Discharge in the San Gabriel River

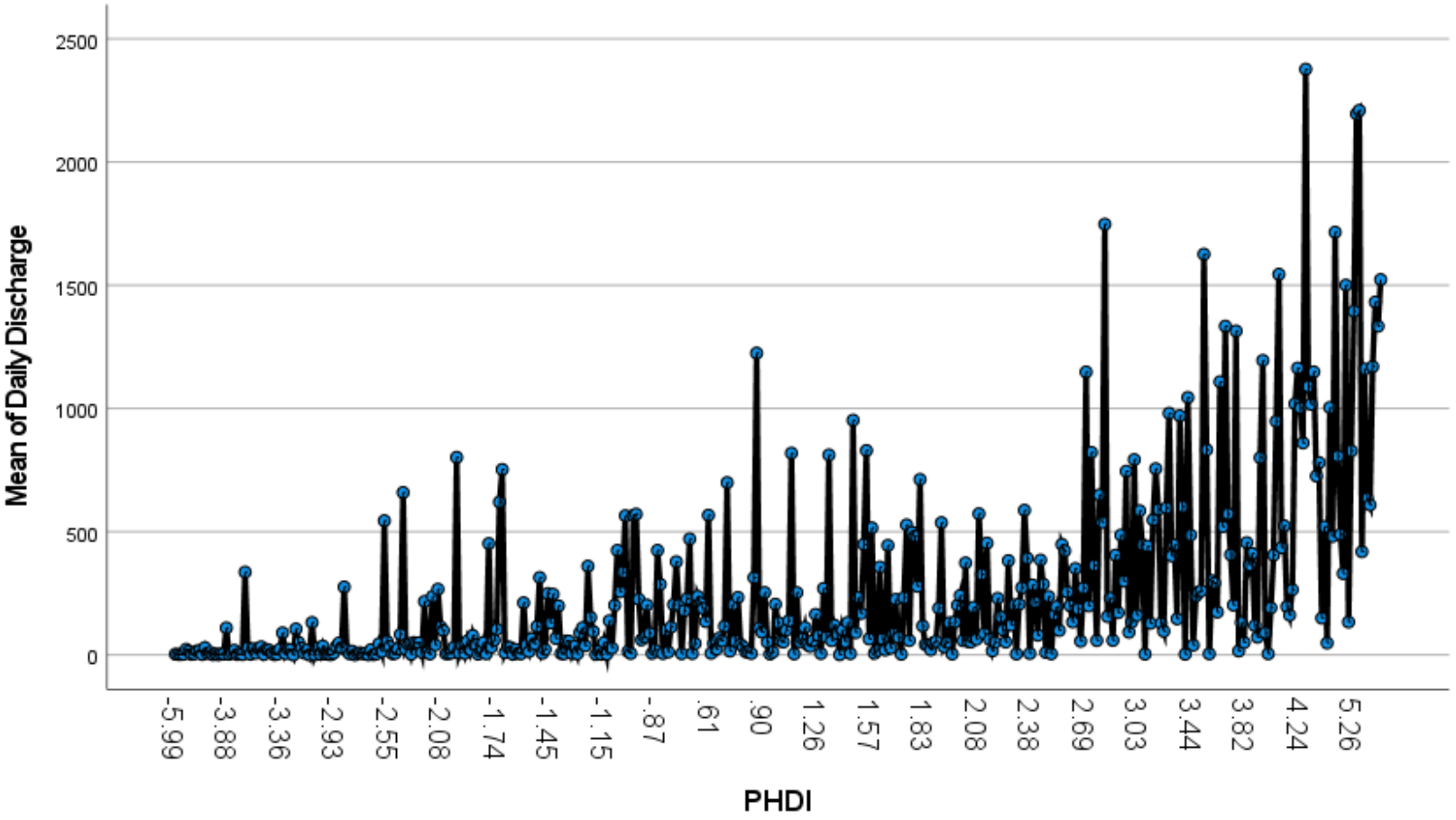


Figure 4. Comparison of Palmer Hydrological Drought Index to Zero Flow Days in the San Gabriel River

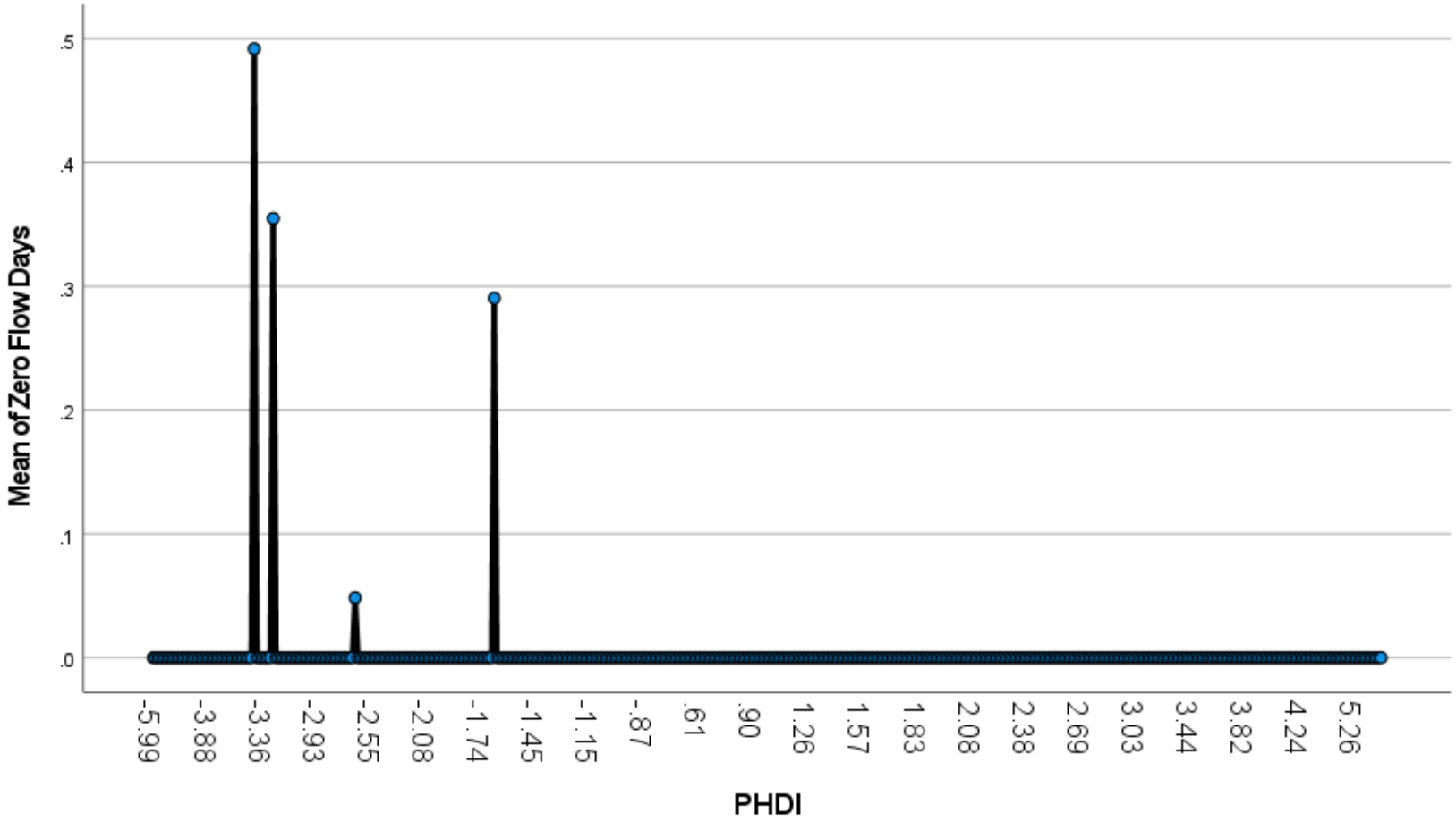


Figure 5. Comparison of Palmer Hydrological Drought Index to Subsistence Flows in the San Gabriel River

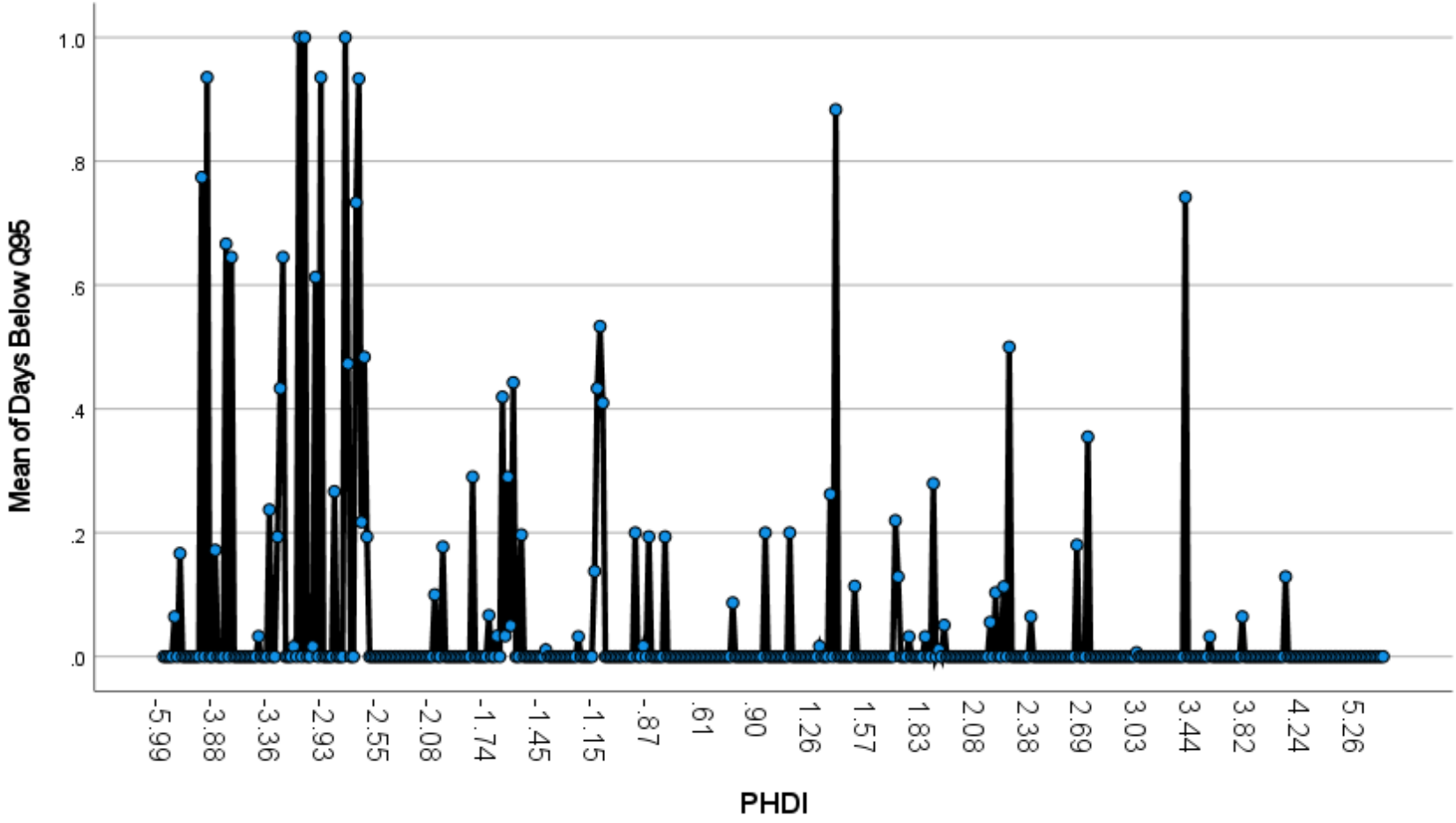


Figure 6. Comparison of Palmer Hydrological Drought Index Category to Mean Daily Discharge in the San Gabriel River

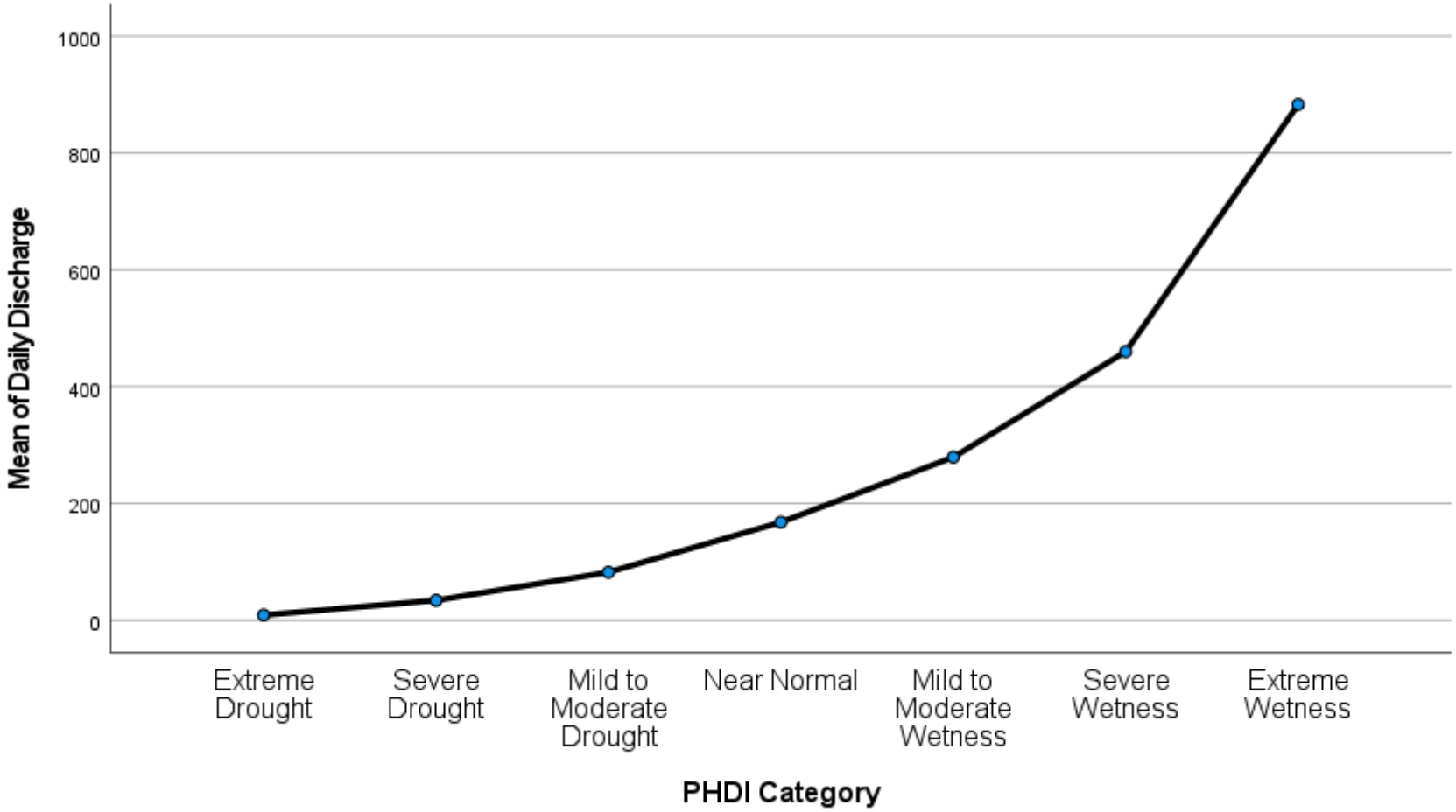


Figure 7. Comparison of Palmer Hydrological Drought Index Category to Zero Flow Days in the San Gabriel River

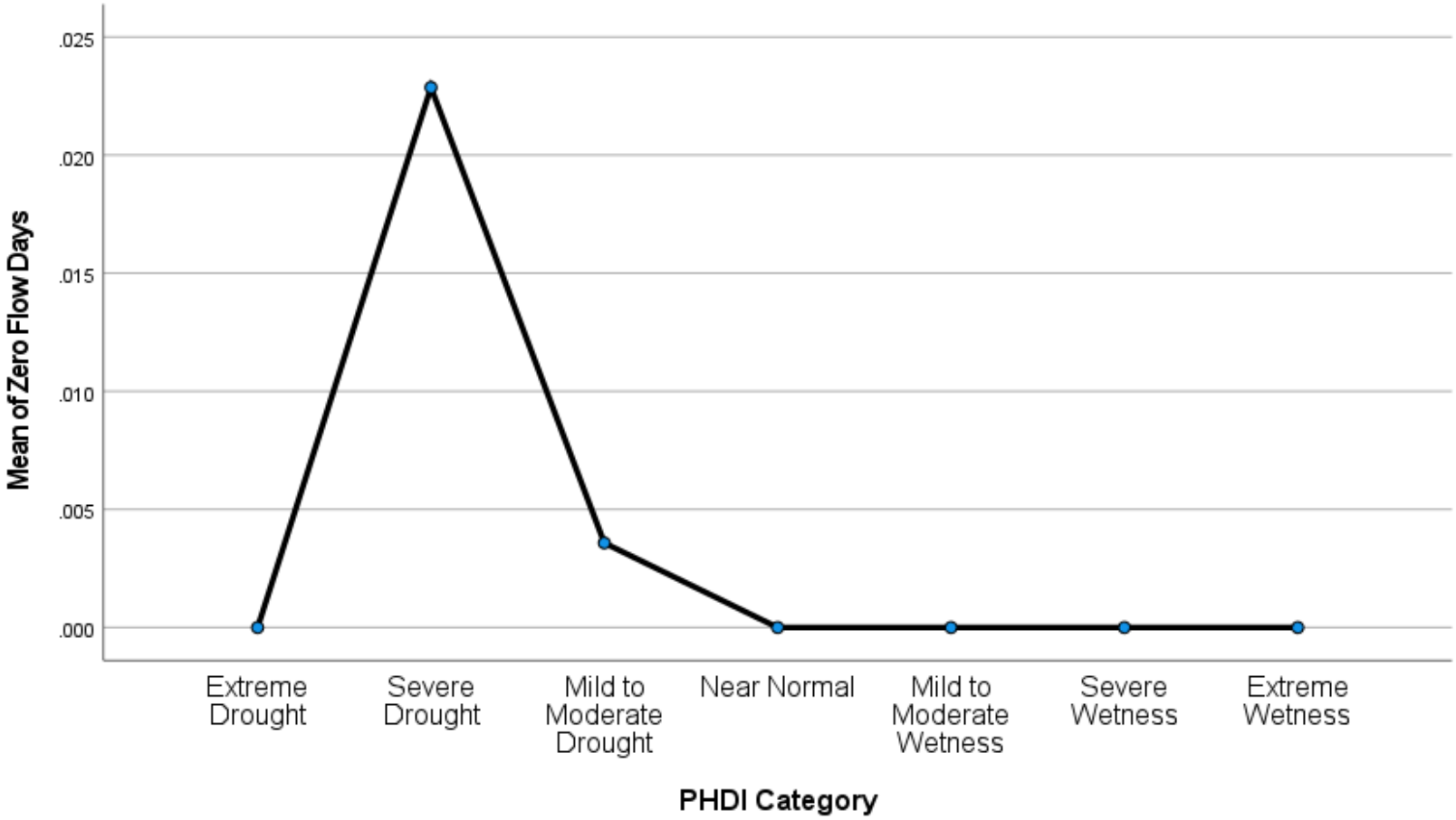
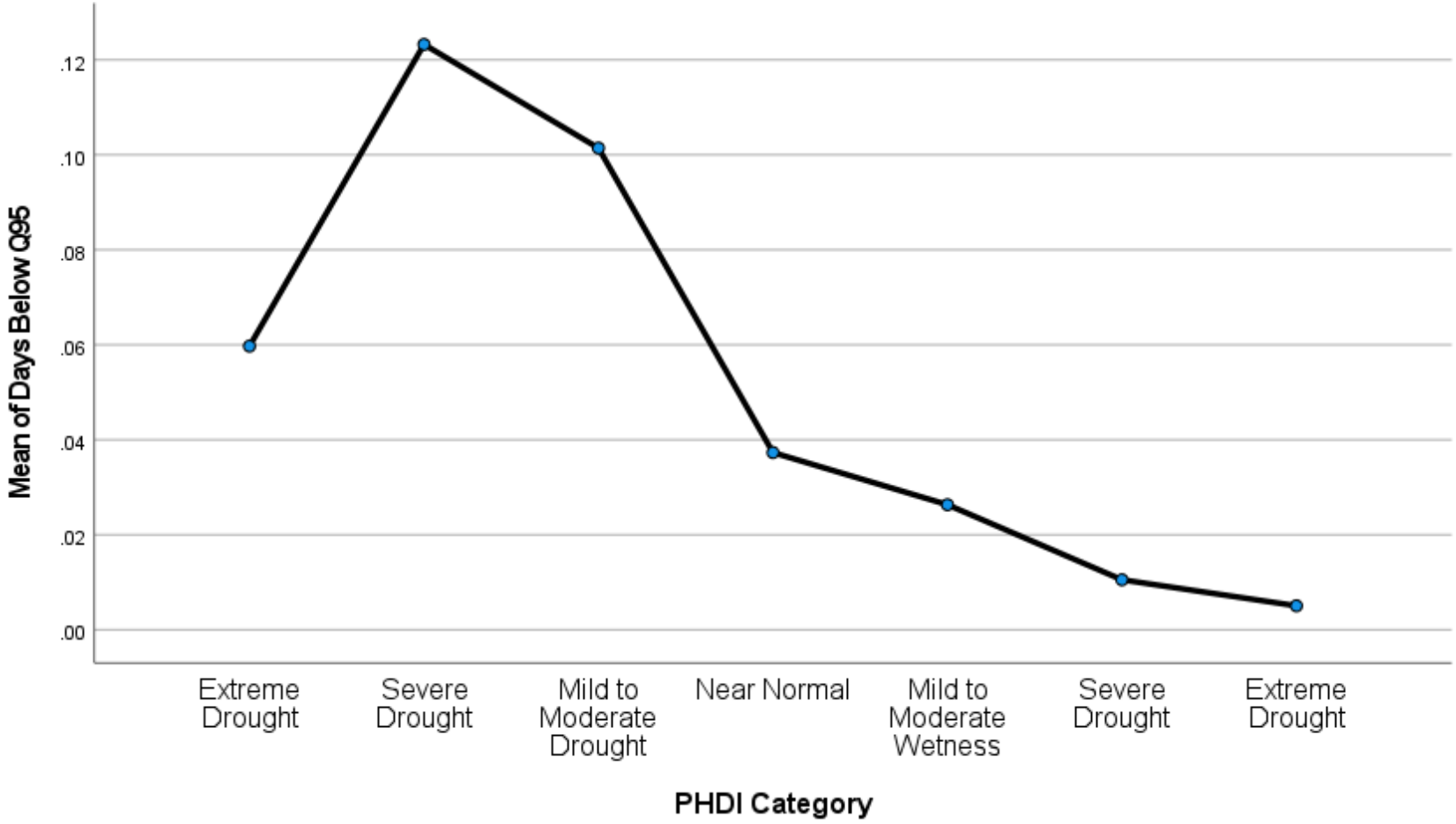


Figure 8. Comparison of Palmer Hydrological Drought Index to Subsistence Flows in the San Gabriel River



Comment 18: The covered area should include riverine reaches, as appropriate, upstream of Possum Kingdom Reservoir as BRA continues to consider subordination of water rights to upstream users. Flows could be reduced or altered in upstream reaches as a result of BRA actions.

> **Response: BRA revised the CCAA to include the Brazos River above Possum Kingdom Reservoir to the confluence of the Clear Fork of the Brazos River and the Clear Fork of the Brazos River up to Nugent in the covered area. The Clear Fork of the Brazos River from its confluence with the Brazos River up to Nugent is identified as a Conservation Zone C river reach.**
>
> Historically, the BRA has entered into two subordination agreements upstream of Possum Kingdom Reservoir: the City of Abilene and West Central Texas Municipal Water District agreement; and the City of Lubbock agreement). BRA has no intention of entering into additional subordination agreements in the future. **BRA added a conservation measure in Section 9.3 committing that we will not enter into any new subordination agreements above Possum Kingdom Reservoir.**

Comment 19: The CCAA should include an additional high priority conservation zone for the false spike (similar to conservation Zone C for Texas fawnsfoot) to identify river reaches where false spike has historically occurred.

> **Response:** Conservation Zones were based on current distribution of candidate species, not historical distributions. River reaches that were historically occupied are not necessarily conducive to restoration or reintroduction, as habitat conditions may not currently support the species. To identify river reaches that were historically occupied and may be appropriate for restoration or reintroduction, we are developing a habitat quantification tool (Section 9.5.1 of Conservation Measures) that examines reach-scale factors important in structuring habitat for these species. Output from this tool will aid in identifying river reaches that currently support appropriate habitat conditions for restoration or reintroduction.

Comment 20: The CCAA is asserting that extended periods of bankfull flow events from reservoir operations may lead to excess bank erosion that could be detrimental to mussel habitat. However, stream erosion is a result of excess shear stress and is dependent upon multiple factors, but primarily the substrate particle size distributions and the amount of time when stream power exceeds the threshold at which incipient motion of particles occur.

> **Response:** We concur with the commenters that stream erosion is a result of multiple factors. However, extended periods of bankfull flow events sometimes occur below USACE flood-control reservoirs as large flood events are captured and released over a long temporal window to minimize downstream flooding. While BRA reservoirs do not provide flood control, there have been periods where prolonged periods of wet weather have also caused extended periods of bankfull flows in some river reaches. Such extended periods of bankfull flows can be problematic in that they result in excessive sediment movement and streambank erosion, especially when concluded abruptly as this can lead to streambank sloughing.

Section 9.3.3 proposes to evaluate the BRA's existing Operations Procedures for Controlled Releases for the three BRA-owned reservoirs to determine if there are adjustments that can be made to release protocols that minimize bank sloughing potentially caused after high flow releases. We also agree to coordinate with the USACE to evaluated potential modifications to high flow releases from USACE-owned reservoirs. This item was high-flow release strategy investigation was specifically requested by USFWS during CCAA development. **BRA added language to Section 9.3.3 that should the evaluation of BRA's existing Operations Procedures for Controlled Releases identify improvements that could further minimize downstream erosion, BRA will revise the operating procedures to incorporate the new recommendations provided that the proposed improvements do not create other concerns for dam safety or human health and safety.**

Additionally, the CCAA specifically addresses issues associated with stream geomorphology and sediment transport by proposing long-term monitoring of substrate and channel morphology at nine existing instream flow monitoring transects as well as four additional transects placed upstream of key mussel habitats. Data from this monitoring will be used in an Adaptive Management context over the course of the 20-year CCAA term. This is outlined in Section 9.6.4 of the CCAA.

Comment 21: Hydrologic variation is a key component to maintaining the ecological function of river systems. A natural flow regime includes high flow pulses and overbank flows which are necessary to maintain the function of riparian areas and energy inputs for mussels. Commenters encourage the application of a natural flow regime to generate a comprehensive recommendation for instream flows that are supportive of mussel biology and protective of mussel habitat. As presented in the CCAA, the effects of hydrologic alteration on stream geomorphology and sediment transport and the associated effects on mussel habitat are not addressed.

Response: We are well aware of, and acknowledge, the benefits of high flow events to structuring riverine habitat, and the potential negative impacts to specific mussel populations due to streambed scour. BRA has no control over when and where high flow events occur.

The three reservoirs that BRA owns and operates (Possum Kingdom, Lake Granbury, and Lake Limestone) are water supply reservoirs with no flood control space. Once these reservoirs reach full capacities, inflows are passed downstream in a manner not to exceed the rate of that entering the reservoir. Therefore, releases during high inflow events at BRA owned and operated reservoirs frequently mimic the natural flow regime for high flow pulse and overbank events.

The Water Management Plan (WMP) specifically addresses the capture of storm pulses entering the reservoirs and passing to achieve high flow pulse events in downstream reaches.

Releases from the remaining reservoirs that are part of the BRA system are managed, owned, and operated by USACE. BRA has consulted with the USACE on the eight federal

flood storage projects within the BRA water supply system on safely managing high-flow pulses and overbank flows. Basically, the rule curves for flood regulation are designed to limit streamflow at downstream controls with maximum discharge strictly defined and followed to avoid downstream flooding and risk to human life. The USACE recognizes the ecological importance of overbank flows and is willing to use the flexibility in release decisions up to the maximum allowed limits to achieve connection between the river channel and aquatic habitats in the floodplain, and is committed to assist the BRA in meeting WMP requirements to the extent possible.

Flooding is the costliest natural hazard in the United States and causes more fatalities than any other natural hazard. Neither the BRA nor the USACE have the authority to prevent citizens from living in flood vulnerable places and neither agency is going to espouse not controlling high flows to the extent possible and purposely allowing overbank events to occur that have the very real potential to cause harm to human life. Despite the presence of reservoirs in the Brazos basin, overbank flows still occur when nature provides more precipitation than the normal carrying capacity of the stream channel or accumulates faster than surface absorbency allows.

Comment 22: Additional surveys can provide important information. However, there is no specific commitment to any level of survey effort. Additional, comments indicate concern that some populations of the covered species might be extirpated before the CCAA is executed or fully implemented.

Response: To address concerns that extirpation has already occurred, BRA added language to Section 9.1.1 committing to conduct surveys of the Balcones spike in the Little River basin and Texas fawnsfoot in the Clear Fork of the Brazos River during the first year of the CCAA, weather permitting.

To address the concern over the lack of commitment to any level of survey effort BRA added language to Section 9.1.1 committing to 20 survey sites, annually for the first two years. Should weather or other conditions at the survey sites preclude reaching the annual target, the survey sites will be completed in the following years as soon as conditions allow.

Comment 23: When water does become available from Allens Creek Reservoir, it will mean less water will be released from reservoirs farther up the Brazos River basin to meet downstream needs. That reduction in releases from upstream would reduce flows in areas of the Brazos River where Covered Species currently are known to occur that are upstream of the location where releases from ACR would reach the river. BRA should make a specific commitment to manage its releases from ACR to meet flows needed for the covered species.

Response: There is no need to make a specific commitment for the mussels because by planned operation as a water supply source for Fort Bend and Brazoria Counties, the movement of water for water supply purposes will also benefit mussel populations from the confluence of Allens Creek through Fort Bend County. By relying on AC for routine water demands by users in Fort Bend and Brazoria Counties, allow smore water to be held

in storage higher in the basin. This means water will be available during dry times to flow downstream, through occupied habits to reach the water users in in the lower basin.

Any reduction in releases from upstream reservoirs occurring as a result of increased use of Allen's Creek Reservoir are included in the modeling assessment. The modeling results, that include Allen's Creek as a fully operational reservoir throughout the simulation period, show higher (increased) or comparable Brazos River flow conditions upstream of Allen's Creek Reservoir for 2060 conditions compared to naturalized or historical (Table B-2 and B-3, Brazos River Near Waco, at SH21 near Bryan, and near Hempstead). Downstream of ACR, the increased water demand result in lower Brazos River flow conditions compared to historical with increased amount of time below subsistence flow, but the general increase in river flow conditions during low-flow conditions alleviates all month-long zero-flow conditions that occur as part of the naturalized flow scenario (e.g., Table B-3: Naturalized Flow scenario has 2 months zero-flow in Rosharon reach with no months zero-flow in 2060 scenario).

Comment 24: Hydrology modeling results seem to double-count the benefit of Allens Creek Reservoir.

Response: No net benefits were assessed based upon the results of hydrological modeling. Rather, the modeling was used to help prioritize reaches based on potential future hydrology conditions. The net benefit to mussels discussed in the CCAA is the increase in flow during low flow periods resulting from the operational ability to store water higher in the system to deliver downstream during dry times. The construction of Allens Creek Reservoir to provide water supply for routine demands in the Lower Basin is what allows BRA to store water higher in the system for downstream releases in dry times. Modeling could be presented to illustrate the difference to Brazos River flows with and without the Allen's Creek Reservoir permit; however, because the reservoir has already been permitted and some flow benefits are afforded inside the existing System Operation Permit, a specific modeling assessment was not deemed necessary.

Comment 25: How will BRA go about encouraging others to minimize disturbance to the riverbed and hydraulics?

Response: BRA added language to section more thoroughly articulate how we will go about encouraging others to minimize disturbance. When we are notified or included as stakeholders on construction projects occurring in conservation Zones A-C, BRA will notify the responsible party of the likelihood of freshwater candidate species, recommend they perform a survey to identify if any candidate species will be affected by the proposed activity, encourage avoidance of disturbance in areas where surveys identify candidate species presence, and recommend that they include aquatic and/or riparian habitat restoration as a component of their project, as applicable. If the project requires public notice, through the NEPA process, BRA will formally submit comments in writing to the appropriate regulatory agency espousing avoidance and minimization of impacts to the candidate species.

If we are notified of applications for new water rights in conservation Zone A, we will formally submit comments to the TCEQ protesting the issuance of new water appropriations based on the impact to the covered species.

Comment 26: The research to develop environmental flow study methodologies specific to freshwater mussels is likely beneficial but should be targeted at more than a revision of the regulatory components of the Environmental Flow Standards. The knowledge gained should be used to guide water management decisions under existing and new water rights in order to maintain protective flow levels.

Response: BRA added language to Section 9.5.2 that we will use the knowledge gained from these studies to guide water management decisions and conjunctive releases.

Comment 27: Approving the CCAA will allow more pollution and degraded water quality.

Response: BRA does not believe the CCAA allows for introduction of contaminants into the environment that would cause adverse change in water quality. Any activity that results in the introduction of contaminants into surface water in the state of Texas would have to undergo Texas Pollution Discharge Elimination System permitting. None of the proposed conservation measures require this permitting as none of the proposed activities will result in introduction of contaminants.

Comment 28: Approving the CCAA will green-light unchecked sprawl development

Response: The BRA does not have any powers to authorize or prohibit development of private lands and therefore, has no authority to prevent sprawl development into the basin.

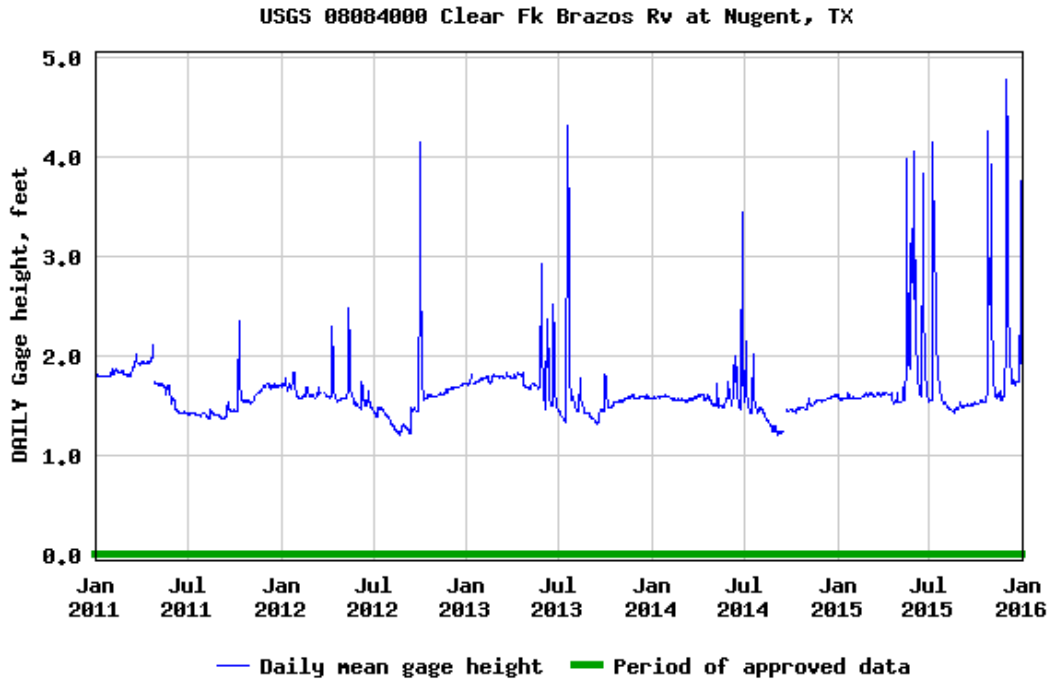
Comment 29: The drought of 2011 dewatered significant stretches of creeks and rivers in the Brazos River watershed, resulting in severe population declines suffered by several mussel species including the Texas fawnsfoot and false apike.

Response: The 2011 drought was the most severe one-year drought on record according to Texas State Climatologist, John Nielsen-Gammon (https://climatexas.tamu.edu/news/2011/articles/texas-drought-officially-the-worst-ever.php). The four year stretch of the drought, were the driest on record for the Wichita Falls area, which includes a portion of the Upper Brazos (https://climatexas.tamu.edu/news/2015/articles/texas-drought-still-alive-and-well.php). A persistent La Niña weather pattern was the main cause of the extreme dryness observed during this time. The 2011-2015 drought, was declared a new drought of record for the upper portion of the Brazos River basin, including: Possum Kingdom Lake, Lake Granbury, Lake Whitney, and Lake Proctor (https://www.brazos.org/Portals/0/Documents/WMP-2018/DroughtStudyFinal.pdf). The result of the declaration of a new drought of record for the basin was a decreased amount of water available for appropriation under the BRA's SYSOPs permit.

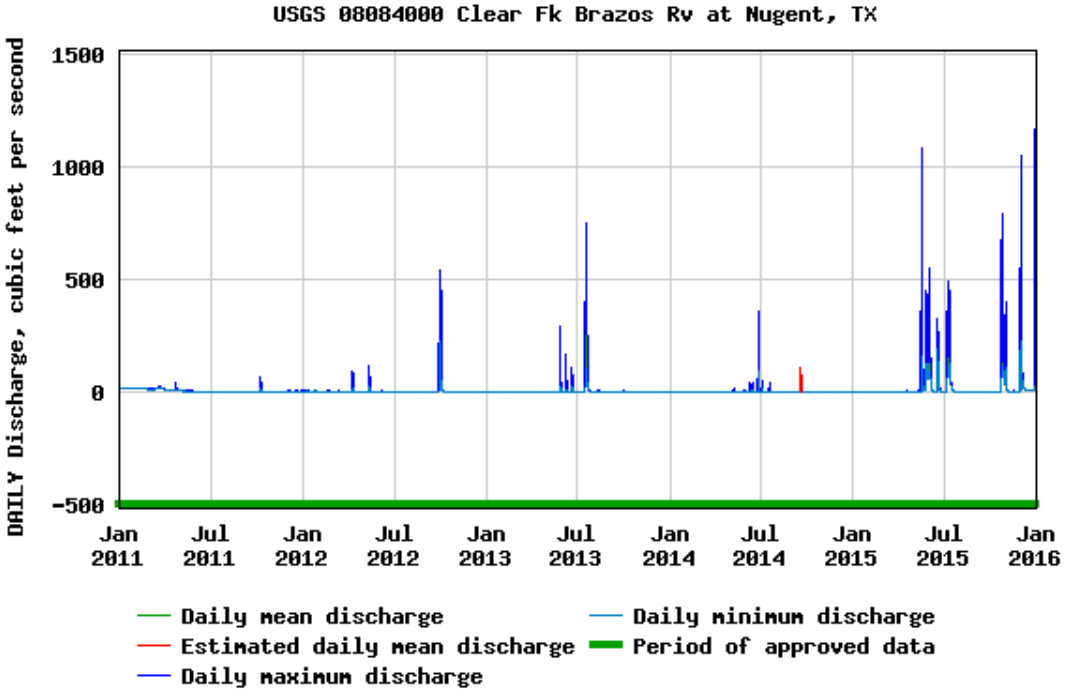
The commenter is correct that some stream and creek stretches in the Brazos River watershed, especially those above Possum Kingdom Reservoir, experienced dewatering.

However, no segments known to support either candidate species in this portion of the basin were completely dewatered. Below are charts from the USGS (https://waterdata.usgs.gov/tx/nwis/current/?type=flow&group_key=basin_cd) showing that water levels in the areas in the Upper Brazos basin known to support the Texas fawnsfoot experienced low water levels but were never completely dewatered. Only the Clear Fork of the Brazos River experienced extended periods of no flow, but this location is above the BRA's system reservoirs, and thus above our ability to influence flows. Dewatering did not occur in the stretches of the Little River and San Gabriel River, which support the false spike, and the Brazos River below Waco, which support populations of the Texas fawnsfoot.

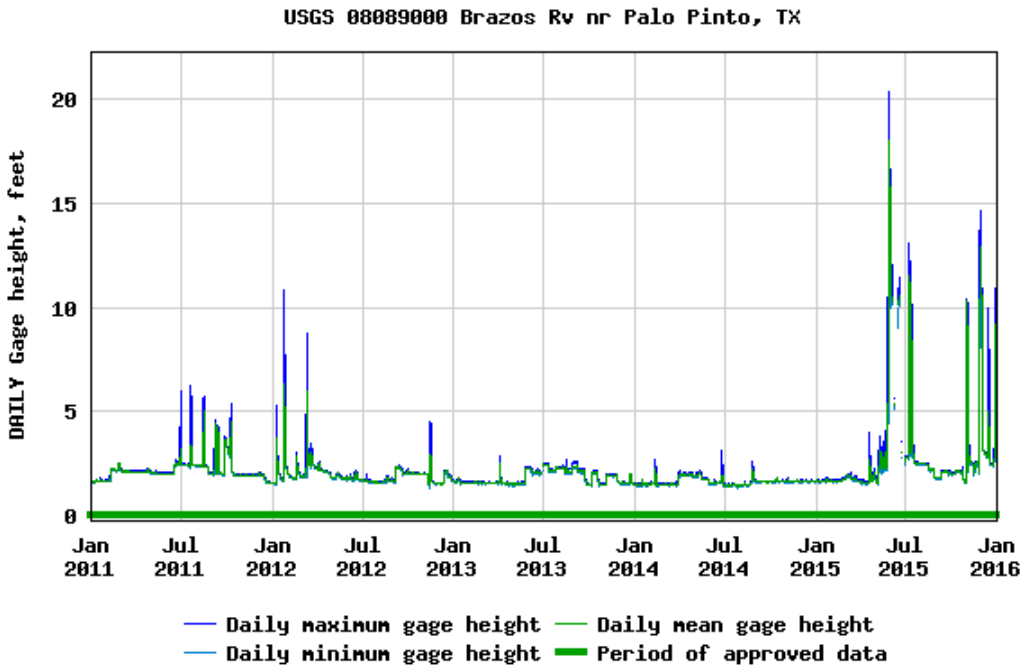
Gage height, feet



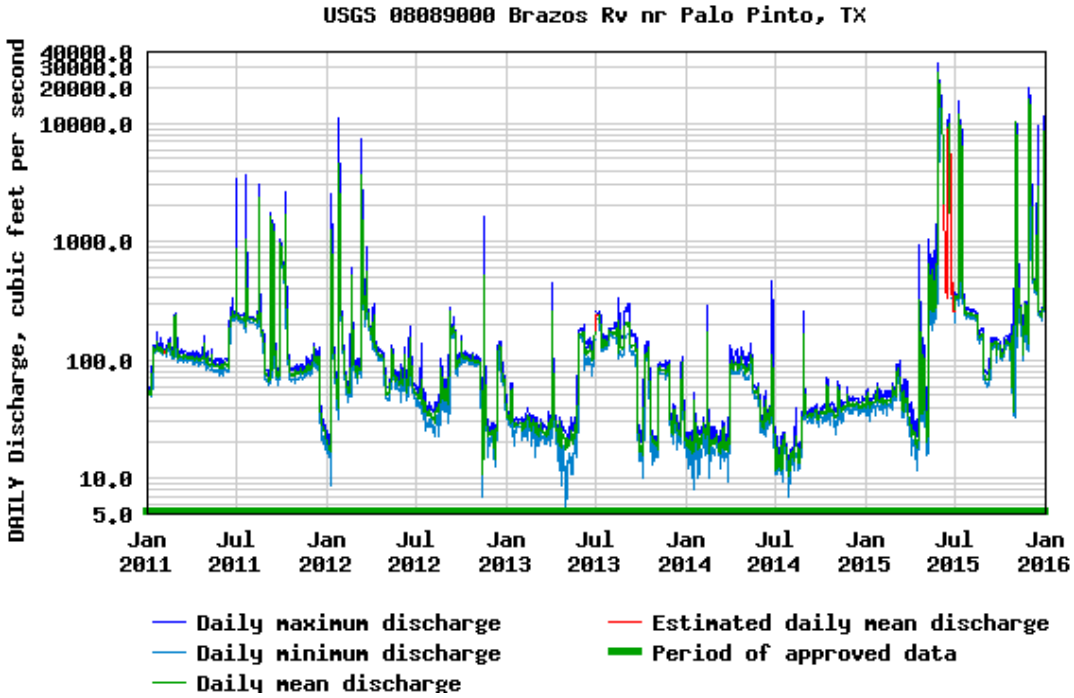
Discharge, cubic feet per second



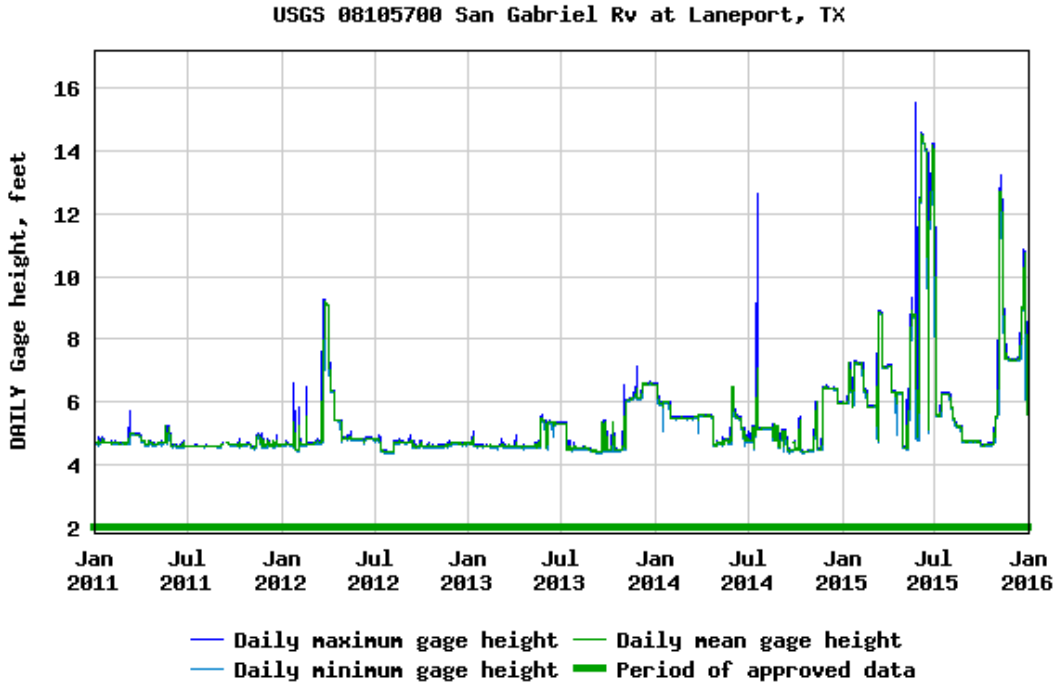
Gage height, feet



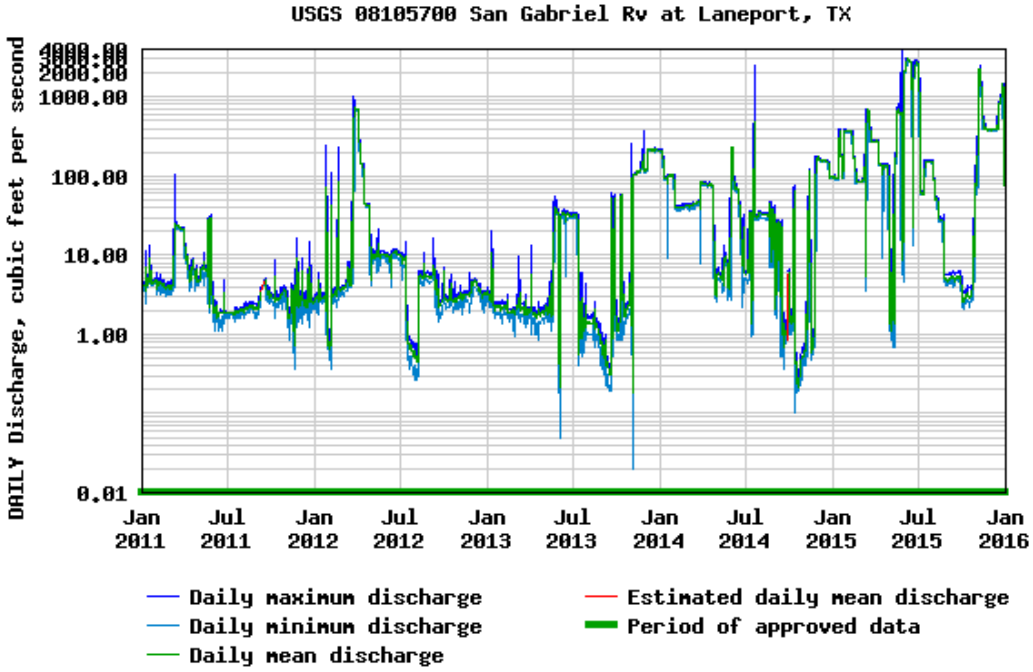
Discharge, cubic feet per second



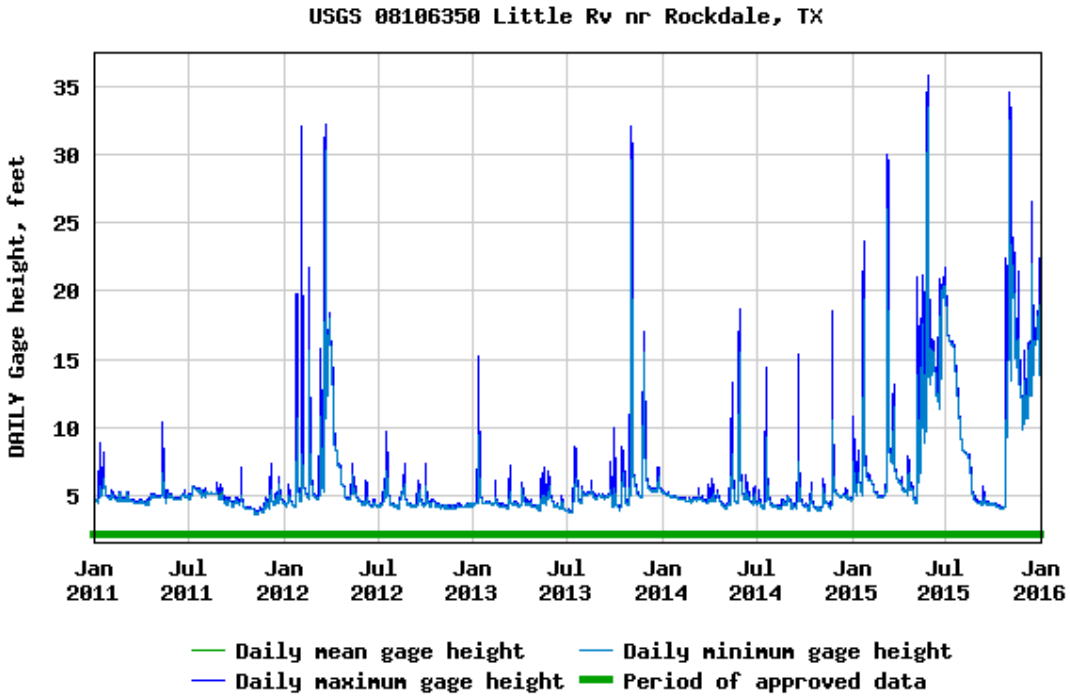
Gage height, feet



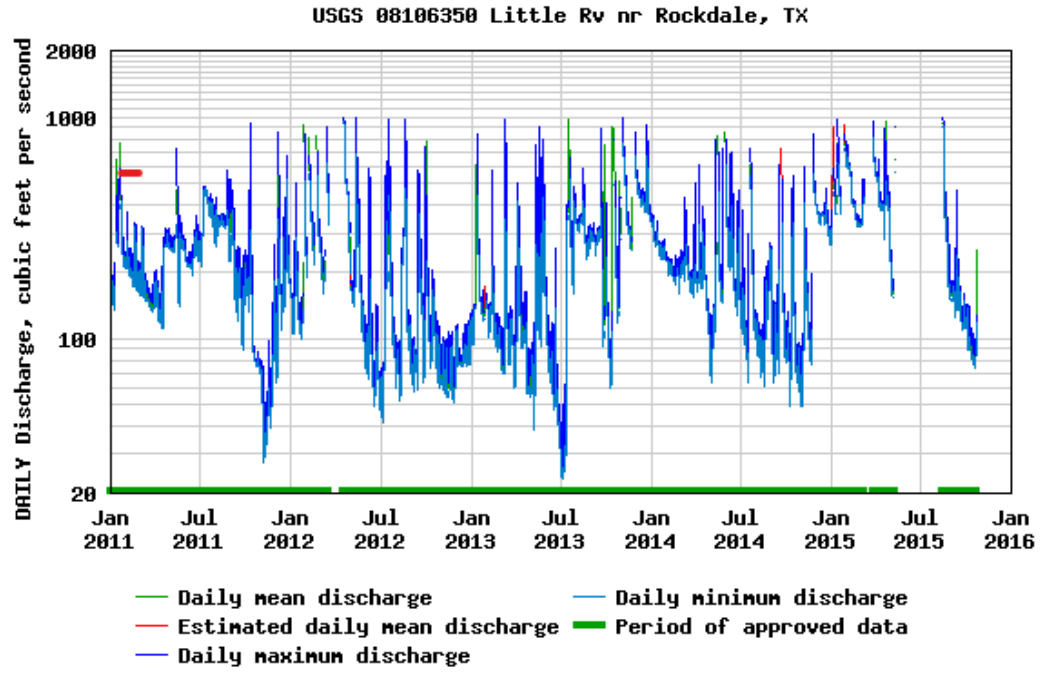
Discharge, cubic feet per second



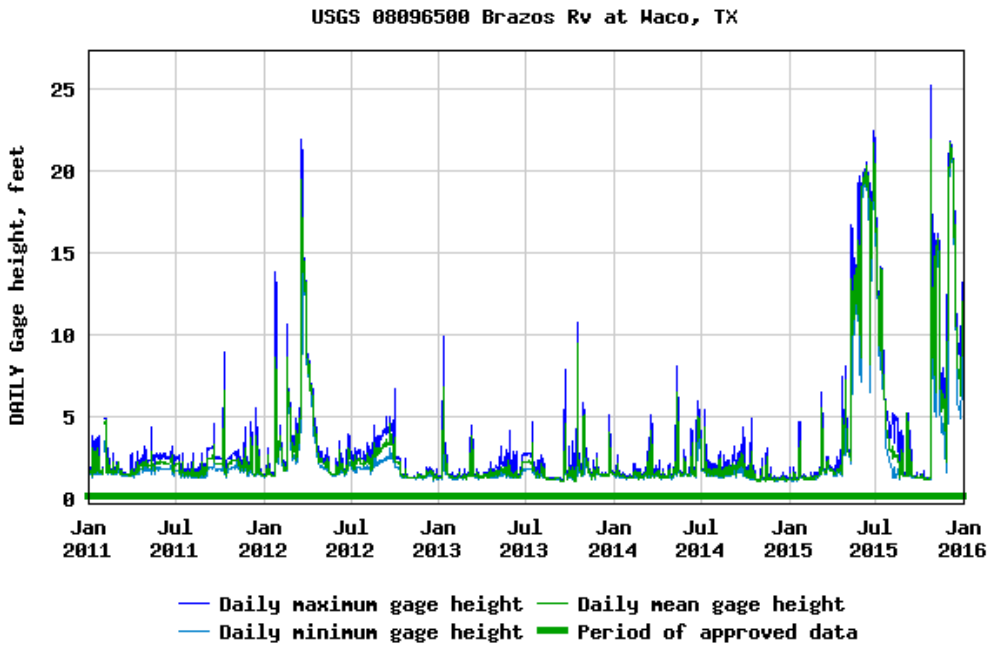
Gage height, feet



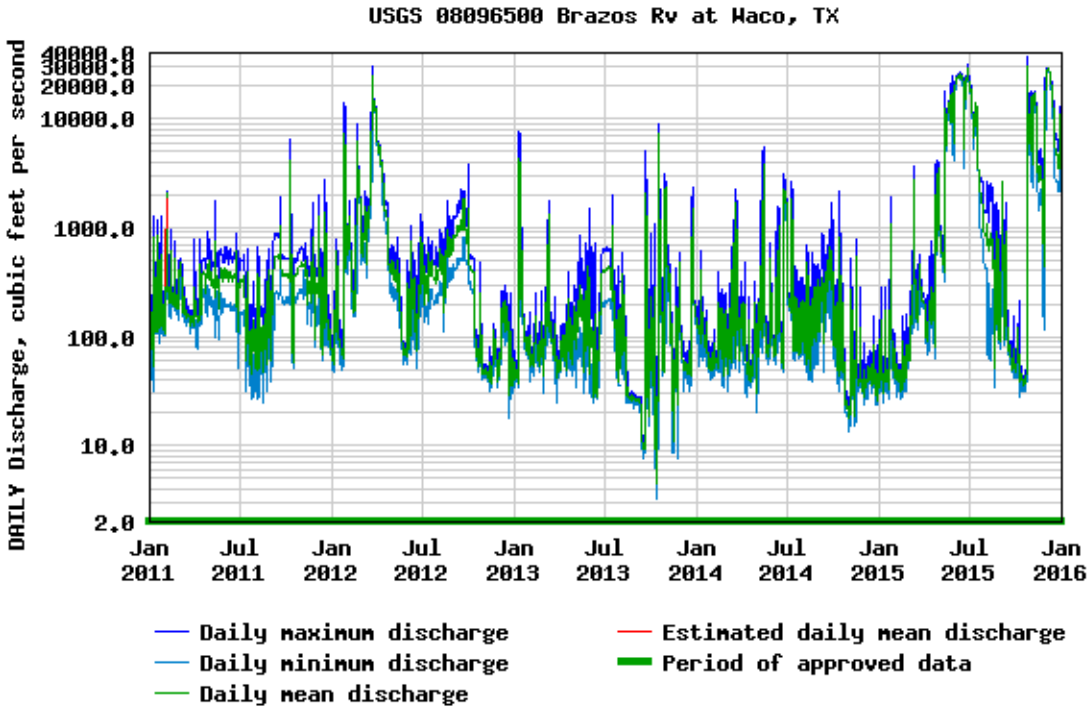
Discharge, cubic feet per second



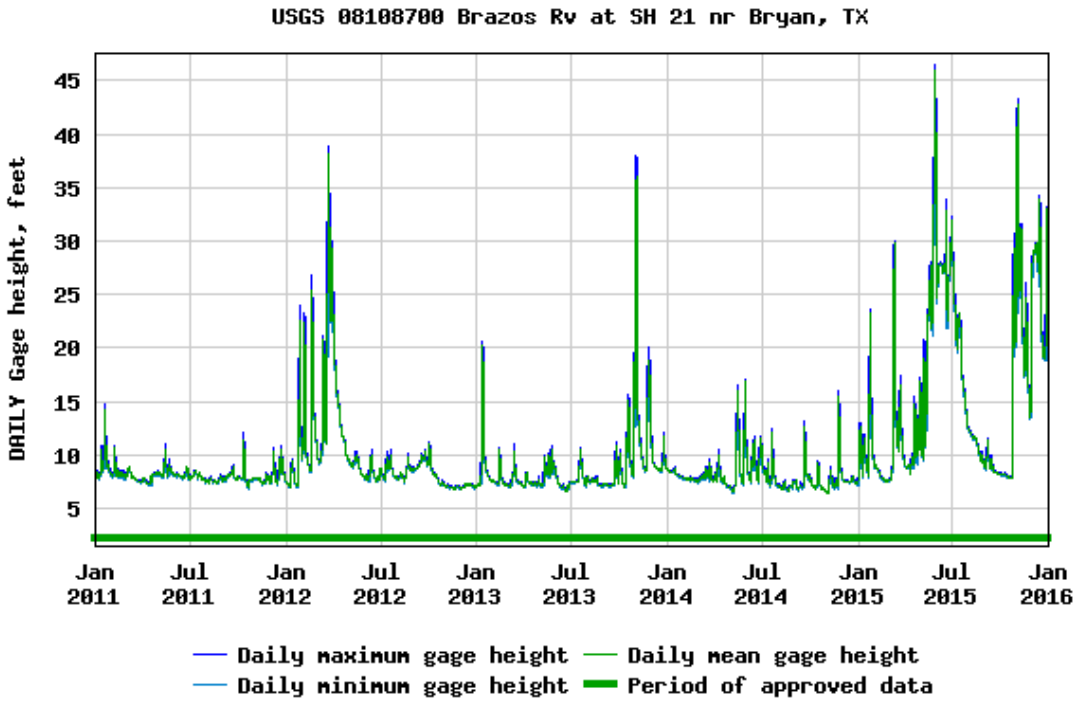
Gage height, feet



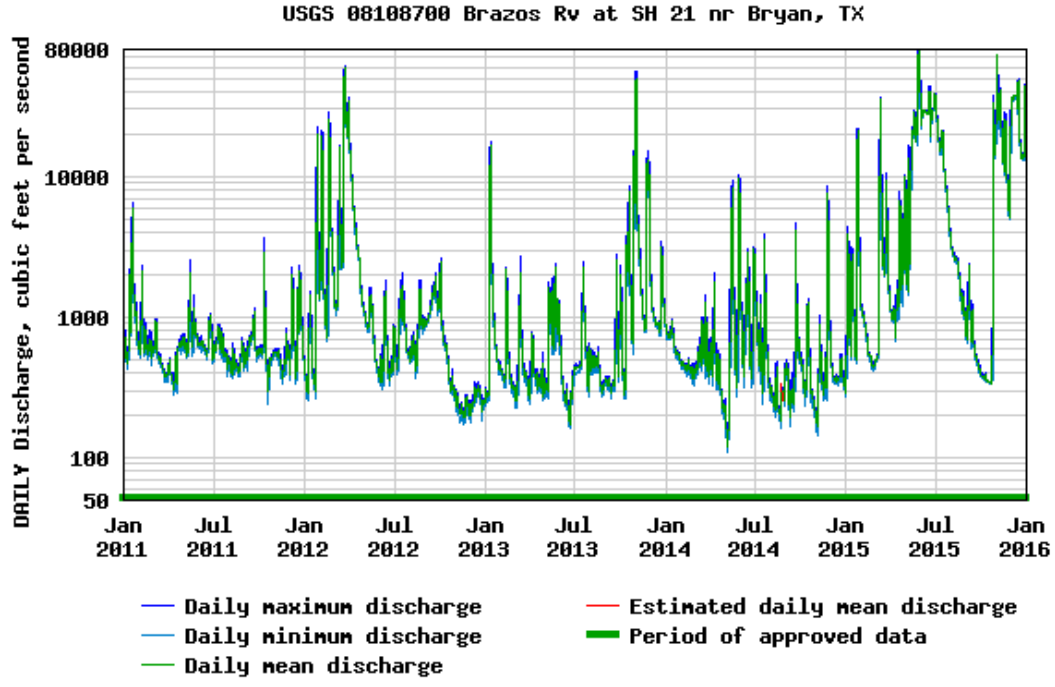
Discharge, cubic feet per second



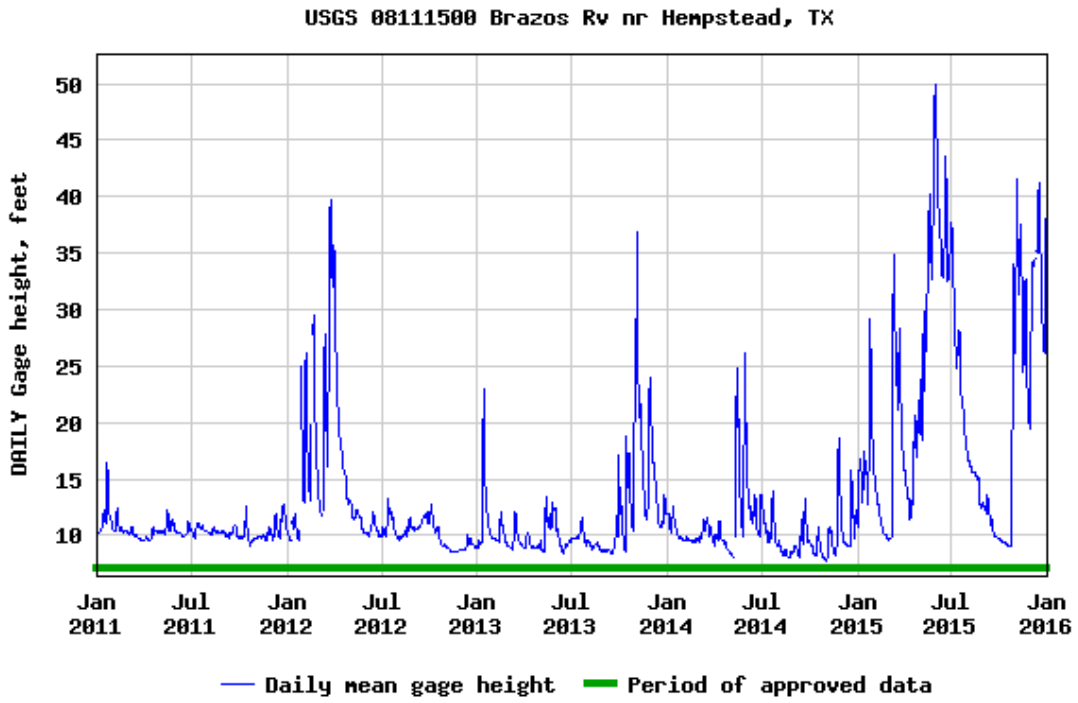
Gage height, feet



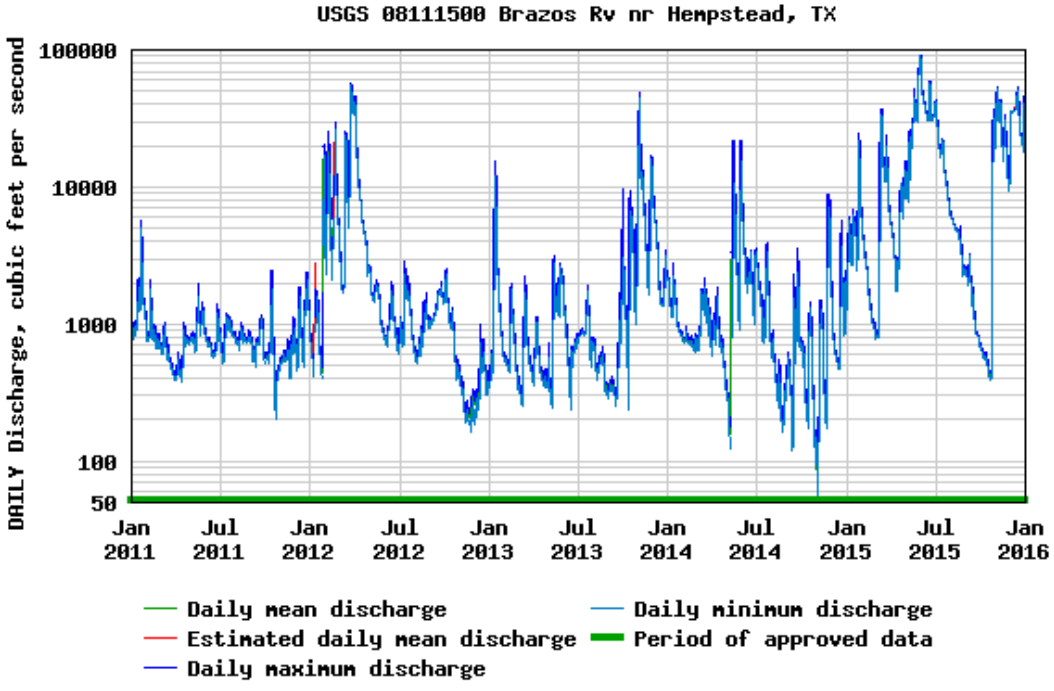
Discharge, cubic feet per second



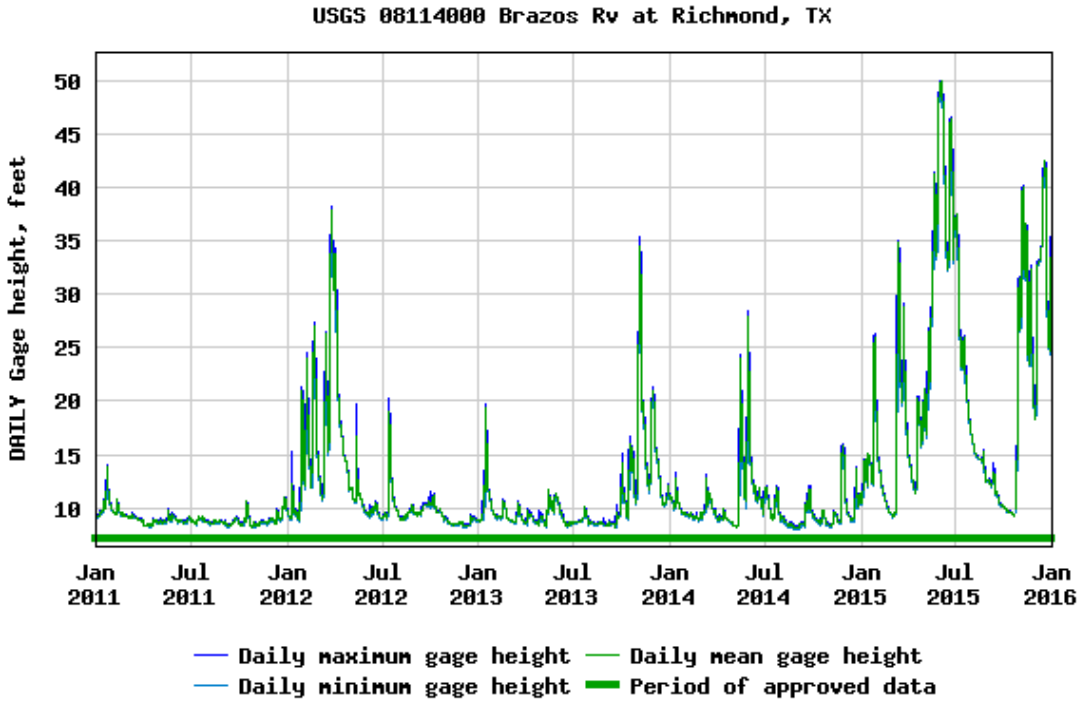
Gage height, feet



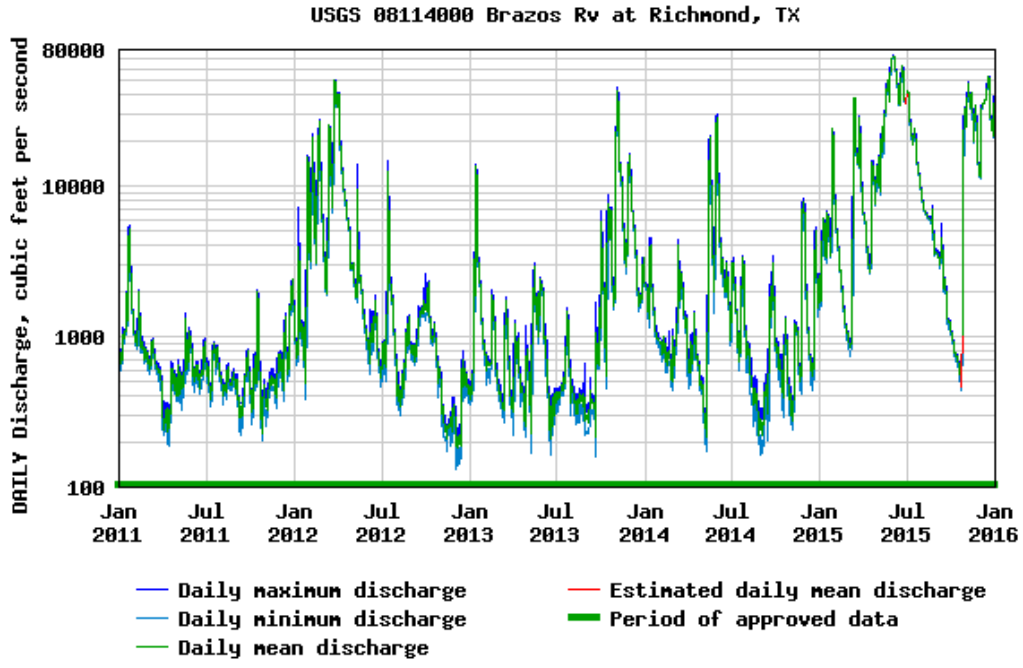
Discharge, cubic feet per second



Gage height, feet, Radar Sensor



Discharge, cubic feet per second, Radar Sensor



Comment 30: There are no restrictions on the activities of industry, agriculture and developers on behalf of the mussels.

Response: The BRA has no authority to regulate the activities of industry, agriculture, or developers. However, in Section 9.4 we do pledge that the BRA will not construct any additional dams on the mainstem of the Brazos River, the Navasota River or the mainstem of the Little River. Additionally, in that section we commit that we will not sponsor additional BRA infrastructure or diversions in Zone A. These two items through this agreement extends the maximum protection to the mussels that the BRA can provide with its current legislatively granted authority. As there is no additional water available for appropriation by TCEQ in the Little River watershed, by committing to not sponsor any new diversions in conservation Zone A, BRA is essentially controlling the activity of industry and developers in this area.

Comment 31: There is no guarantee of water quality or water quantity for the mussels.

Response: No single entity can guarantee either water quality or water quantity as both parameters have many contributing factors, including climatological influences beyond any agencies control. BRA does not have regulatory authority over either item in the basin. We have guaranteed what we are confident that we can deliver on in within the BRA's legislatively granted authority.

Comment 32: The CCAA relies on standards developed for fish, not mussels, and on existing regulations promulgated by Texas authorities, standards which have not been updated to those recommended by the EPA.

Response: It is not exactly clear what is being referred to in this comment. For this response we are assuming that the commenter is referencing the EPA's 2013 *Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater*, as this is the only recommendations made by EPA in regard to freshwater mussels that BRA is aware of. BRA has no surface water quality standard making authority, this authority resides with the TCEQ. The Texas Surface Water Quality Standards are effective for Clean Water Act purposes only when they are approved by EPA.

TCEQ is actively conducting studies and evaluations to develop potential numerical nutrient criteria for selected streams, rivers, and estuaries in Texas. However, due to the quick conversion of ammonia to nitrate in surface water, ammonia is not one of the parameters being specifically explored. TCEQ is focusing the development of numeric nutrient standards on a line of evidence framework which includes the evaluation of total nitrogen (ammonia is a component of total nitrogen), total phosphorus, and transparency, along with the response variable of chlorophyll a.

It is BRA's understanding that TCEQ is relying on the 2013 EPA document as a technical resource in developing surface water quality standards and procedures to translate those standards into effluent limits in TPDES permits. Table 4 presents general statistics of the historical data on ammonia concentrations at sites in Conservation Zones A-C.

We performed and analysis comparing ammonia concentration data to the acute and chronic criteria recommended in the EPA's 2013 *Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater* (Table 5). The general acute and chronic criteria recommendations assume a water temperature of 20° and a pH of 7.0. However, it is acknowledged in the guidance document that there is a direct relationship between ammonia toxicity and water temperature and pH.

EPA's 2013 *Aquatic Life Ambient Water Quality Criteria for Ammonia – Freshwater* guidance document provides a matrix of what acute ammonia toxicity levels are based on water temperature and pH for waters with unionid mussels present. We identified the highest water temperature ever recorded for each site and the highest pH ever recorded for each site and identified the appropriate acute ammonia toxicity level associated with the highest recorded water temperature and pH value. This represents the worst-case scenario for toxicity levels by site. We then performed a preliminary screening of the historical ammonia data available for each site using the identified, worst-case toxicity level. The ammonia concentration data at nine sites never exceeded this worst-case toxicity level (Table 5). Six sites exceeded the worst-case toxicity level between one and three times in the historical data set and two sites exceeded the worst-case toxicity level 10 or more times.

For the sites where there were exceedances of the worst-case toxicity level, we then identified the appropriate daily toxicity value for all ammonia values where associated water temperature and pH data were available. This daily analysis revealed that at no time did any of these sites exceed the daily acute criteria (Table 6).

Table 4. Historic Ammonia Grab Sample Data at the Water Surface (0.3 m) in Conservation Zones A through C.

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set	Mean (mg/L)	Median (mg/L)	Maximum (mg/L)
Clear Fork of the Brazos River	C	11992	Clear Fork at FM 600 near Nugent	8/28/1973 to 6/10/2019	196	0.09	0.06	0.42
Clear Fork of the Brazos River	C	11990	Clear Fork at SH 6 in Lueders	8/23/1988 to 6/10/2019	30	0.08	0.06	0.26
Clear Fork of the Brazos River	C	18766	Clear Fork upstream of confluence with Paint Creek	2/7/2006 to 2/27/2019	42	0.08	0.05	0.76
Clear Fork of the Brazos River	C	11985	Clear Fork at US 283 Northeast of Fort Griffin	2/4/1972 to 5/21/2019	168	0.10	0.05	0.10
Brazos River Between Lakes PK and Granbury	C	11864	Brazos River at FM 4 near Palo Pinto	2/4/1972 to 1/6/2021	139	0.07	0.05	0.74
Brazos River Between Lakes PK and Granbury	C	11863	Brazos River at US 281 South of Mineral Wells	9/12/1973 to 8/30/1995	55	0.09	0.07	0.50
Brazos River Between Lakes PK and Granbury	C	13543	Brazos River at FM 1189 South of Dennis	1/28/1993 to 1/7/2021	132	0.05	0.05	0.21
Brazos River Between Waco and College Station	C	12038	Brazos River Upstream of SH 6 Southeast of Waco	6/5/1991 to 12/15/2020	104	0.07	0.05	0.19

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set	Mean (mg/L)	Median (mg/L)	Maximum (mg/L)
Brazos River Between Waco and College Station	C	12037	Brazos River at River View Camp Road Upstream of the Confluence with Flat Creek	3/25/1991 to 5/14/2019	78	0.09	0.05	0.94
Brazos River Between Waco and College Station	C	12032	Brazos River Downstream of FM 413 Northeast of Rosebud	4/26/1972 to 12/15/2020	266	0.09	0.05	0.71
Brazos River Between Waco and College Station	C	15767	Brazos River at SH 21 Northeast of Caldwell	9/5/2012 to 12/15/2020	108	0.06	0.05	0.37
Little River	A	13544	Little River at FM 1600 Southwest of Cameron	9/27/1994 to 7/1/2019	32	0.05	0.05	0.12
San Gabriel River	A	13648	San Gabriel River North of Laneport	11/4/1981 to 7/1/2019	81	0.08	0.05	1.85
San Gabriel River	A	17651	San Gabriel River Northwest of Rockdale	10/27/2015 to 7/1/2019	14	0.05	0.05	0.05
Navasota River	B	11873	Navasota River Downstream of SH 6 North of Navasota	7/28/1987 to 11/17/2020	45	0.06	0.05	0.28
Brazos River Between College Station and Richmond	B	12030	Brazos River at SH 105 West of Navasota	3/6/1972 to 12/16/2020	130	0.07	0.05	0.32
	B	11850	Brazos River at US 290 Northwest of Hempstead	2/19/1988 to 12/16/2020	144	0.06	0.05	0.58

Table 5. Comparison of historic surface water ammonia concentrations in Conservation Zones A through C compared to EPA recommended acute and chronic ammonia criteria for waters at 20°C and pH=7.0.

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Number of Values in Data Set	2013 EPA Acute Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Acute Level	2013 EPA Chronic Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Chronic Level	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and pH[5]
Clear Fork of the Brazos River	C	11992	Clear Fork at FM 600 near Nugent	196	17.00	0	1.90	0	0
Clear Fork of the Brazos River	C	11990	Clear Fork at SH 6 in Lueders	30	17.00	0	1.90	0	0
Clear Fork of the Brazos River	C	18766	Clear Fork upstream of confluence with Paint Creek	42	17.00	0	1.90	0	2
Clear Fork of the Brazos River	C	11985	Clear Fork Northeast of Fort Griffin	168	17.00	0	1.90	0	10

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Number of Values in Data Set	2013 EPA Acute Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Acute Level	2013 EPA Chronic Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Chronic Level	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and pH[5]
Brazos River Between Lakes PK and Granbury	C	11864	Brazos River at FM 4 near Palo Pinto	139	17.00	0	1.90	0	3
Brazos River Between Lakes PK and Granbury	C	11863	Brazos River at US 281 South of Mineral Wells	55	17.00	0	1.90	0	3
Brazos River Between Lakes PK and Granbury	C	13543	Brazos River at FM 1189 South of Dennis	132	17.00	0	1.90	0	0

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Number of Values in Data Set	2013 EPA Acute Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Acute Level	2013 EPA Chronic Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Chronic Level	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and pH[5]
Brazos River Between Waco and College Station	C	12038	Brazos River Upstream of SH 6 Southeast of Waco	104	17.00	0	1.90	0	0
Brazos River Between Waco and College Station	C	12037	Brazos River at River View Camp Road Upstream of the Confluence with Flat Creek	78	17.00	0	1.90	0	3

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Number of Values in Data Set	2013 EPA Acute Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Acute Level	2013 EPA Chronic Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Chronic Level	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and pH[5]
Brazos River Between Waco and College Station	C	12032	Brazos River Downstream Northeast of Rosebud	266	17.00	0	1.90	0	13
Brazos River Between Waco and College Station	C	15767	Brazos River at SH 21 Northeast of Caldwell	108	17.00	0	1.90	0	0
Little River	A	13544	Little River Southwest of Cameron	32	17.00	0	1.90	0	0

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Number of Values in Data Set	2013 EPA Acute Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Acute Level	2013 EPA Chronic Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Chronic Level	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and pH[5]
San Gabriel River	A	13648	San Gabriel River North of Laneport	81	17.00	0	1.90	0	1
San Gabriel River	A	17651	San Gabriel River Northwest of Rockdale	14	17.00	0	1.90	0	0
Navasota River	B	11873	Navasota River Downstream of SH 6 North of Navasota	45	17.00	0	1.90	0	0

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Number of Values in Data Set	2013 EPA Acute Ammonia Level Recommendation (mg/L)[2]	Number of Values Greater than 2013 EPA Acute Level	2013 EPA Chronic Ammonia Level Recommendation (mg/L)[4]	Number of Values Greater than 2013 EPA Chronic Level	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and pH[3]
Brazos River Between College Station and Richmond	B	12030	Brazos River at SH 105 West of Navasota	130	17.00	0	1.90	0	0
Brazos River Between College Station and Richmond	B	11850	Brazos River at US 290 Northwest of Hempstead	144	17.00	0	1.90	0	1

[2] EPA recommended acute and chronic ambient water quality criteria for ammonia at ph = 7.0 and water temperature = 20°C published in EPA, 2013, *Aquatic Life Ambient Water Quality Criteria for Ammonia-Freshwater*, Pg. xii.

[3] Acute criteria for ammonia adjusted based on water temperature and pH as published in EPA, 2013, Aquatic Life Ambient Water Quality Criteria for Ammonia-Freshwater, Table N.1, Pg. 233.

Table 6. Daily ammonia toxicity analysis for sites where ammonia levels exceeded the EPA's recommended acute criteria based on the site's highest recorded daily water temperature and highest recorded daily pH.

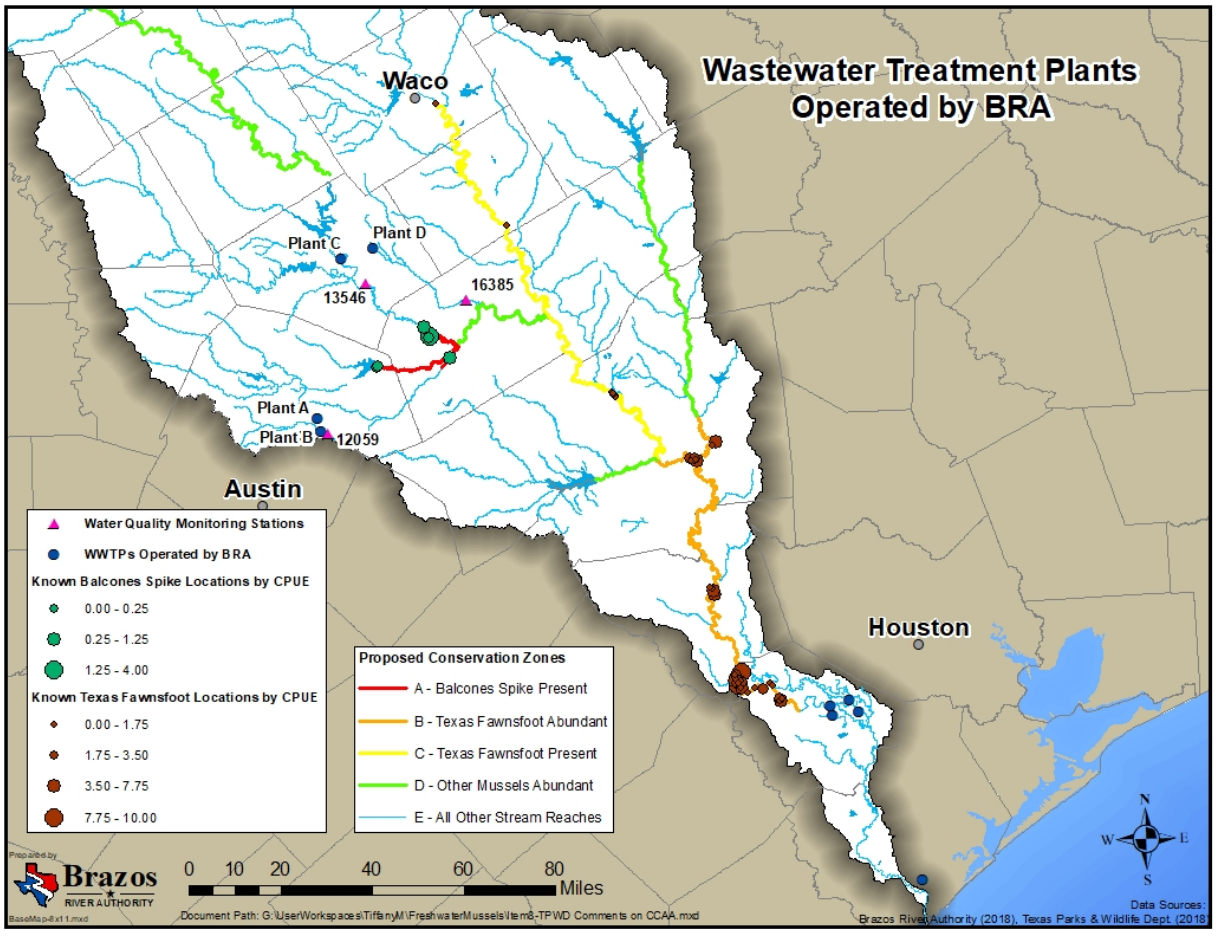
Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values in Data Set with Associated Water Temperature and pH Data	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and Highest Recorded pH	Number of Values Greater than Acute Criteria based on Daily Water Temperature and pH[4]	Percent Exceedance of Daily Acute Criteria based on Daily Water Temperature and pH
Clear Fork of the Brazos River	C	18766	Clear Fork upstream of confluence with Paint Creek	2/7/2006 to 2/27/2019	34	2	0	0.00%
Clear Fork of the Brazos River	C	11985	Clear Fork at US 283 Northeast of Fort Griffin	2/4/1972 to 5/21/2019	164	10	0	0.00%
Brazos River Between Lakes PK and Granbury	C	11864	Brazos River at FM 4 near Palo Pinto	2/4/1972 to 1/6/2021	121	3	0	0.00%
Brazos River Between Lakes PK and Granbury	C	11863	Brazos River at US 281 South of Mineral Wells	9/12/1973 to 8/30/1995	46	3	0	0.00%

Stream Reaches Currently Inhabited by Covered Species	Zone	Site Number	Site Location	Historical Record Range	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and Highest Recorded pH	Number of Values Greater than Acute Criteria based on Site's Highest Recorded Temperature and Highest Recorded pH	Number of Values Greater than Acute Criteria based on Daily Water Temperature and pH[4]	Percent Exceedance of Daily Acute Criteria based on Daily Water Temperature and pH
Brazos River Between Waco and College Station	C	12037	Brazos River at River View Camp Road Upstream of the Confluence with Flat Creek	3/25/1991 to 5/14/2019	76	3	0	0.00%
Brazos River Between Waco and College Station	C	12032	Brazos River Downstream of FM 413 Northeast of Rosebud	4/26/1972 to 12/15/2020	253	13	0	0.00%
San Gabriel River	A	13648	San Gabriel River North of Laneport	11/4/1981 to 7/1/2019	81	1	0	0.00%
Brazos River Between College Station and Richmond	B	11850	Brazos River at US 290 Northwest of Hempstead	2/19/1988 to 12/16/2020	134	1	0	0.00%

[4] Acute criterion for ammonia adjusted based on water temperature and pH as published in EPA, 2013, Aquatic Life Ambient Water Quality Criteria for Ammonia-Freshwater, Table N.1, Pg. 233.

Comment 33: BRA manages several wastewater treatment plants upstream of known areas of occurrence for covered species (see CCAA Figure 5). Ammonia concentrations from these plants are a concern if they exceed Environmental Protection Agency (EPA) thresholds for total ammonia nitrogen, which are based primarily on freshwater mussel tolerances (EPA 2013). Conservation measures should include conducting daily water quality monitoring for contaminants including, but not limited to, ammonia, and planned actions for when thresholds are exceeded.

Response: The commenter is correct the BRA does operate nine wastewater treatment plants (see attached map). Four of these facilities discharge above known locations of one or both of the covered species. Two of these facilities are in Williamson County, Plant A discharges into Cottonwood Creek and Plant B into Brushy Creek. Two are in Bell County, Plant C discharges into Nolan Creek and Plant D into an unnamed tributary of Little Elm Creek. Four are in Fort Bend County and discharge into: Rabbs Bayou diversion channel, Fort Bend County Levee Improvement District No. 7 Ditch, Fort Bend County Drainage Ditch D, or Steep Bank Creek. The final facility is in Brazoria County discharges into the intercoastal waterway.



While the BRA does operate these facilities, the BRA does not own them. The agreements under which we operate do not provide BRA the authority to dictate treatment technologies

or treatment efficiencies. All operating agreements require BRA to operate the WWTPs within the terms and conditions of each facility's, individual, TCEQ issued Texas Pollutant Discharge Elimination System (TPDES) permit. The terms and conditions included in TPDES permits are developed by the Texas Commission on Environmental Quality (TCEQ) and approved by the U.S. Environmental Protection Agency. The best way to effectuate lower ammonia concentrations in TPDES permits is through negotiation and discussion with the TCEQ, not through this CCAA.

We do want to highlight however, that at BRA operated wastewater facilities it is routine operational protocol at all facilities that dissolved oxygen, chlorine residual, dechlorination effectiveness, and ammonia are monitored daily at the facilities. This data is reviewed daily by the Chief Operators and if it appears that discharge levels are trending toward non-compliance, the Chief Operators direct their staff to take measures to adjust the treatment process to bring the facility back into compliance. We do not believe a specific plan of action in the CCAA is necessary for wastewater operations because this is already being done as a part of routine operations.

While we are aware of the EPA's 2013 recommendations, it will be up to TCEQ to decide if they will amend ammonia discharge levels in TPDES permits or surface water quality standards in response to this document. Additionally, the EPA's recommendations are based on toxicology studies covering a range of species, over the entirety of the United States. Thus, the recommendations provide little direct useful data when trying to manage a specific species with a limited distribution in a specific part of the country. In Section 9.5.4, BRA does pledge to advance the current science on the physiological tolerance of the covered species in the Brazos basin of several water quality parameters, including ammonia.

Only the facilities operated by BRA in Williamson and Bell counties discharge above known locations of the covered species. We evaluated the ammonia levels in these four discharges over the last three years and compared them to the EPA's 2013 recommendations for the acute (17 mg/L) criteria. None of these plants violated the EPA's 2013 recommended acute level (Chart 1). When compared to the recommended chronic criteria (1.9 mg/L) Plant A never exceeded this level, Plants B and D exceeded it less than 1% of the time and Plant C exceeded it less than 2.5% of the time (Chart Two).

Additionally, for Plants A and B whose effluents both eventually reach Brushy Creek, the nearest downstream monitoring location, Site 12059, has no water quality data monitored in the last three years that exceeds the EPA's 2013 recommended chronic criteria (Chart 3). Similarly, site 13546, which is the closest water quality monitoring site on the Little River to Plant C's discharge, and site 16385, on Big Elm Creek, which is closest to Plant D's discharge both also displays no exceedance of the EPA's 2013 recommended chronic criteria for ammonia. This data clearly indicates, that while WWTP discharge of ammonia may have an effect in the mixing zone of the discharge, that once it leaves the mixing zone it has little impact on downstream water quality and downstream waters do not violate either the EPA's 2013 recommended acute or chronic criteria for ammonia.

Chart 1. BRA Operated WWTP Ammonia Discharge Concentrations for Facilities in Williamson and Bell Counties Compared to EPA Recommended Acute Criteria

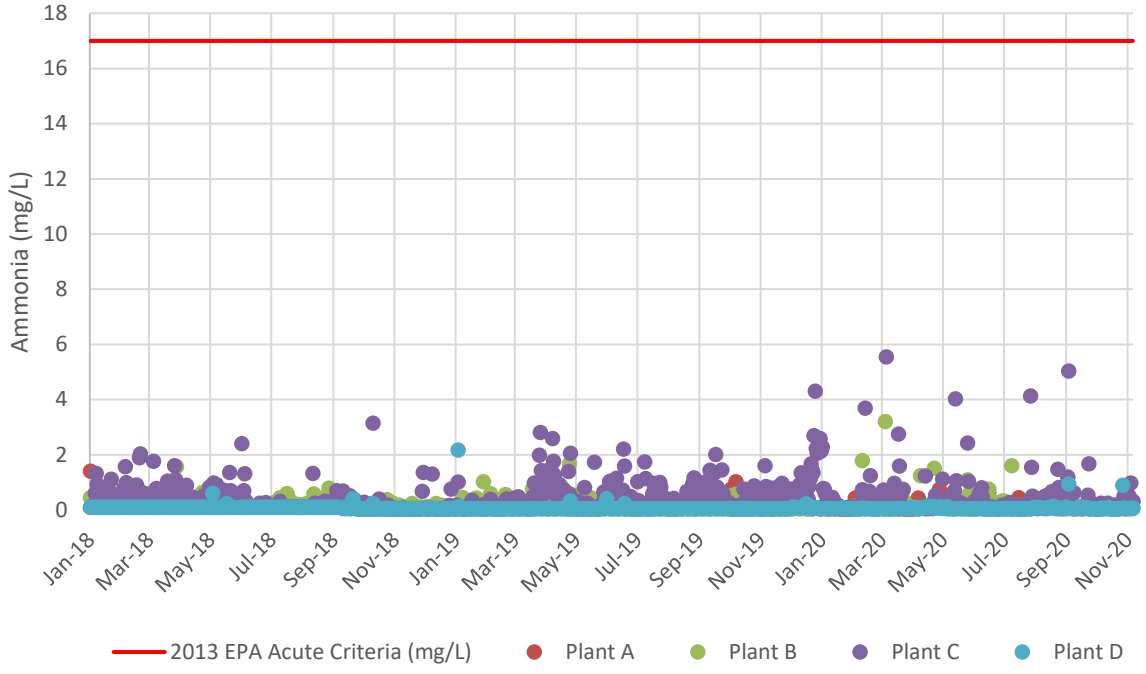
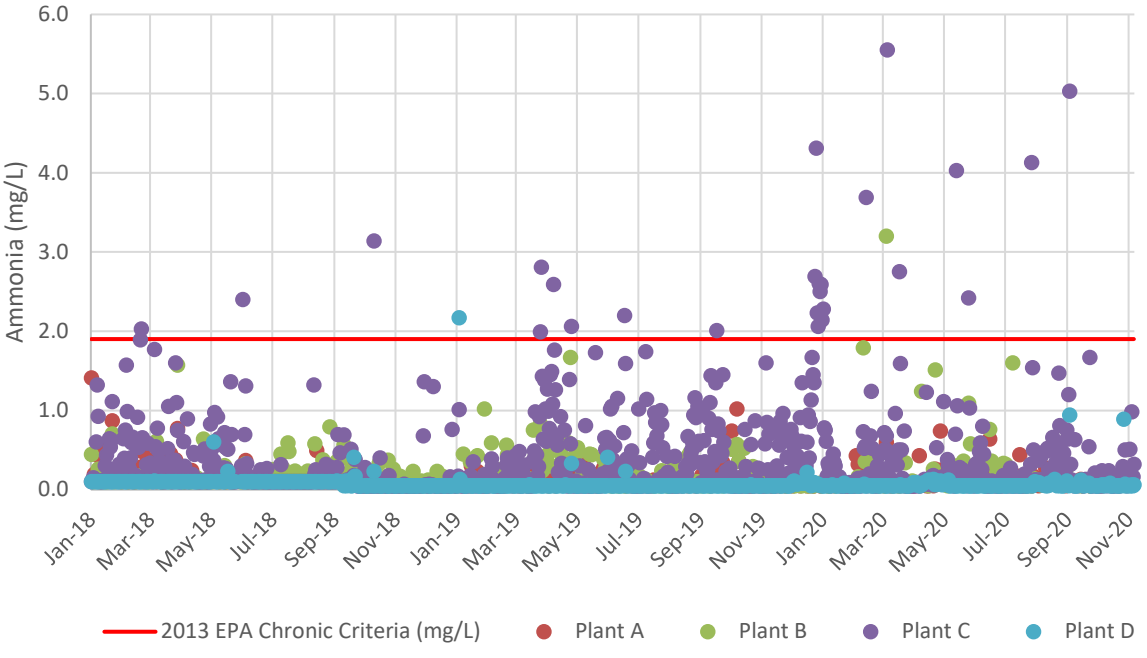
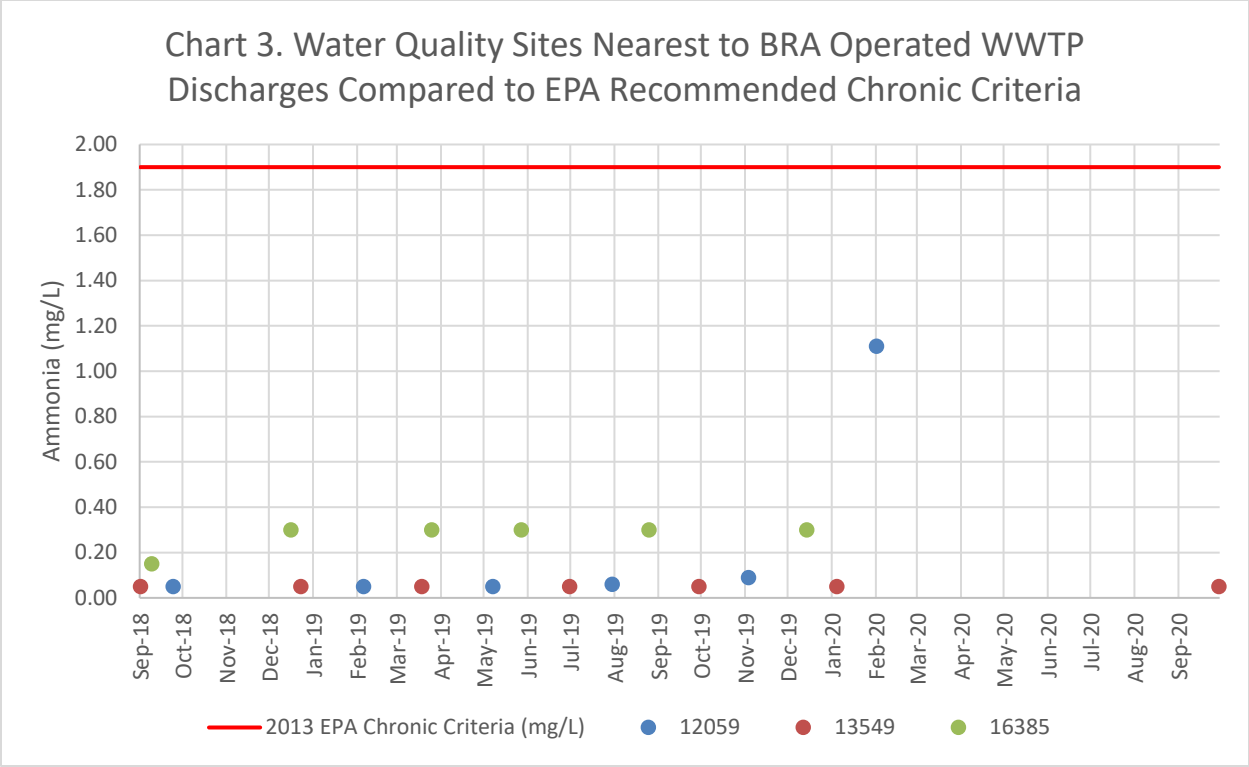


Chart 2. BRA Operated WWTP Ammonia Discharge Concentrations for Facilities in Williamson and Bell Counties Compared to EPA Recommended Chronic Criteria





Furthermore, Plants A, B, and C, as a requirement of their TPDES permit, undergo quarterly toxicity testing to identify any chronic effect of their effluents and semiannual to toxicity testing to identify any acute effect of their effluents. Plant D, as a requirement of its TPDES permit, undergoes quarterly 48-hr acute toxicity testing and semiannual 24-hr acute toxicity testing to gage the effect of its effluent on the receiving stream. Table 1 presents the organisms used for both chronic and acute testing at each facility. The testing frequency and organisms are identified in each facilities TPDES permit. It should be noted that *Ceriodaphnia dubia* and *Pimephales promelas* were among the species evaluated by EPA in the development of its 2013 ammonia criteria recommendations, and while *Daphnia pulex* was not included, its close relative *Daphnia magna* was. This testing is performed by third-party laboratory. Over the last three years, none of the four facilities have failed the quarterly toxicity testing (Table 2). We will be happy to provide the toxicity testing reports for review if desired.

Table 2. Species requirements for biomonitoring by facility TPDES permit.

Plant	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Plant D	Plant D
Species	Acute	Chronic	Acute	Chronic	Acute	Chronic	24-hr Acute	48-hr Acute
Ceriodaphnia dubia	x	x		x		x		
Pimephales promelas	x	x	x	x	x	x	x	x
Daphnia pulex			x		x		x	x

Table 2. Results for the last three years of TPDES required biomonitoring for the four wastewater treatment plants which discharge above segments known to support covered the species.

Plant	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Plant D	Plant D
Quarter	Acute	Chronic	Acute	Chronic	Acute	Chronic	24-hr Acute	48-hr Acute
Q1 2018	*C. dubia* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)
Q2 2018		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)		*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)

Plant	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Plant D	Plant D
Quarter	Acute	Chronic	Acute	Chronic	Acute	Chronic	24-hr Acute	48-hr Acute
Q3 2018	*C. dubia* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)
Q4 2018		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)		*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)

Plant	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Plant D	Plant D
Quarter	Acute	Chronic	Acute	Chronic	Acute	Chronic	24-hr Acute	48-hr Acute
Q1 2019	*C. dubia* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)
Q2 2019		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)		*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)

Plant	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Plant D	Plant D
Quarter	Acute	Chronic	Acute	Chronic	Acute	Chronic	24-hr Acute	48-hr Acute
Q3 2019	*C. dubia* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)
Q4 2019		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)		*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)

Plant	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Plant D	Plant D
Quarter	Acute	Chronic	Acute	Chronic	Acute	Chronic	24-hr Acute	48-hr Acute
Q1 2020	*C. dubia* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)
Q2 2020		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)		*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)

Plant	Plant A	Plant A	Plant B	Plant B	Plant C	Plant C	Plant D	Plant D
Quarter	Acute	Chronic	Acute	Chronic	Acute	Chronic	24-hr Acute	48-hr Acute
Q3 2020	*C. dubia* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (23% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)	*D. pulex* and *P.Promelas* survival both pass at the 100% effluent concentration	*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)
Q4 2020		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (100% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (46% effluent)		*C. dubia* survival and reproduction and *P.Promelas* survival and growth both pass at the critical low flow concentration (49% effluent)		*D. pulex* and *P.Promelas* survival both pass at the critical low flow concentration (100% effluent)

The wastewater treatment plants operated by BRA that discharge into river segments above known populations of the covered species are in compliance with both the ammonia effluent standards identified by TCEQ in each plant's respective TPDES permit and are also compliant with the EPA's 2013 recommended chronic and acute criteria for ammonia. BRA's standard operating practice at these facilities is to conduct daily water quality monitoring and to adjust the treatment process if that daily monitoring reveals a problem, therefore adding this to the CCAA would not represent any new actions on the part of the BRA or contribute to the net conservation benefit of the covered species.

We are also hesitant to add our routine operations of wastewater treatment facilities into the CCAA, as we only operate and do not own the facilities. Additionally, we compete for the operating contracts with other providers at an interval determined by each facility's owners. There is no guarantee the BRA will continue to operate these facilities over the 20-year term of the CCAA. If an owner selects to contract with another provider, there is nothing the BRA can do to influence the daily operation protocols, level of maintenance, or treatment technologies utilized by the owner, and thus could be in violation of the CCAA.

We respect the commenter's concerns for ammonia in wastewater treatment discharges, but we do not believe the CCAA is the appropriate mechanism to effectuate reduced ammonia concentrations in wastewater treatment plant effluents. This is a concern that should be addressed with the TCEQ.

Comment 34: Significant portions of river habitat would be destroyed through authorization of this CCAA.

Response: BRA proposes no activities in the CCAA that would destroy river habitat in the areas known to be occupied by the candidate species.

Comment 35: This CCAA does not effectively address the effects of global warming.

Response: We believe this CCAA meets the USFWS' requirements for the permit term sought. We did prioritize reaches on full range of wet to drought in the hydrology modeling and believe that represents the full range of conditions anticipated for the 20-year term.