Potential Economic Impacts of Environmental Flows for Central Texas Freshwater Mussels

SUPPORTING INFORMATION

Brad D. Wolaver[1], Cassandra E. Cook[1], David L. Sunding[2], Stephen F. Hamilton[3], Bridget R. Scanlon[1], Michael H. Young[1], Xianli Xu[1], Robert C. Reedy[1]

(1) Bureau of Economic Geology, Jackson School of Geosciences, The University of Texas at Austin, Austin, TX

(2) Department of Agricultural and Resource Economics, University of California at Berkeley, Berkeley, CA

(3) Orfalea College of Business, Cal Poly State University, San Luis Obispo, CA

SI 1. APPROACH FOR CALCULATIONG ECONOMIC LOSSES

SI 1.1 Hydrology of Central Texas Streams

Hydrographs with stream flow, base flow, and precipitation are shown for mussel locations (**Figure 1** to **Figure 3**). A representative hydrograph for the Guadalupe River at Cuero (USGS 8175800) is shown in the paper. Flow duration curves (FDC) are presented for mussel locations (**Figure 4** to **Figure 6**). Additional descriptions of Central Texas stream hydrology is provided in the paper.

SI 1.2 Changes in Surface Water Availability Resulting from Environmental Flows

Changes in regulated flows were assessed by plotting time series stream discharge data for baseline and environmental flow (EF) conditions (**Figure 7** to **Figure 9**). Because the ultimate EF volumes for mussels cannot be predicted with certainty, we considered a range of possible EFs with a 95% probability of streamflow exceedance for a low-EF scenario and a 75% probability of exceedance for a conservatively high-EF scenario. Regulated flows are defined as modeled stream discharge after diversions have occurred to satisfy water rights, fill reservoirs, and maintain EFs (if required) (Wurbs, 2005a).

Regulated flows for the gauges here have relatively small changes between baseline and EF conditions. For example, regulated flows in the Brazos River basin (**Figure 7**) do not show any appreciable changes, apart from minor differences in the low-flow Yegua Creek near Somerville. In the Colorado River basin, the San Saba River at San Saba also does not change much (**Figure 8**), while the Colorado River near San Saba and at Wharton show changes in regulated flow during low-flow, drought conditions that are not present during higher flows. In the Guadalupe-San Antonio River basin, regulated flows at Goliad and Victoria (**Figure 9**) do not change appreciably.

SI 2. APPROACH FOR CALCULATIONG ECONOMIC LOSSES

SI 2.1 Calculating Municipal, Commercial and Industrial, and Agricultural Losses

Losses in the municipal, C&I, and agricultural sectors of each county are measured by computing willingness to pay (WTP) to avoid a water service interruption in each sector following the approach of Jenkins et al. (2003) and Brozovic et al. (2007). WTP is the total amount of money the user would pay to restore water deliveries to the baseline level of use. The framework for calculating losses in each sector relies on demand conditions in each sector, which differ across sectors according to how users in each sector can be anticipated to respond to water shortages.

Demand conditions in each sector can be classified into several broad categories, each with a different priority of use, where WTP for water depends on the intended use of each unit of water. For example, in the residential sector of the municipal water sector, the WTP for water used for drinking and basic sanitation is larger than the WTP for water used for bathing and laundry, which in turn is larger than the WTP for water used for washing cars, for filling swimming pools, and for outdoor irrigation. When faced with a water service disruption of a given magnitude, water users have the choice of which types of water uses to curtail, and the framework for measuring economic losses incorporates the idea that individual water users respond to a water service disruption by eliminating less valuable water units before eliminating more valuable water units, for instance by reducing water used for landscaping irrigation prior to reducing drinking water consumption.

A schedule of consumer WTP for different units of water is represented as a demand curve for water that orders values from highest valued uses to lowest valued uses (**Figure 10**). The WTP for water, which sums the WTP for individual water units, is the area under the demand curve. Prior to a water supply disruption, a user facing a volumetric water rate of P^* consumes all units of water for which the WTP for the unit exceeds the price that must be paid for the water unit, which leads to a level of water consumption of Q^* units. Additional units of water consumption beyond this level have value, but the value of each unit of water to the consumer beyond the quantity Q^* is not high enough to justify paying the volumetric rate to acquire these units.

In the event of a service disruption, consumer WTP to avoid a water service disruption rises with the magnitude of the supply shortage, as consumers are forced to cut more deeply into priority uses of water when faced with larger shortage levels. Consumer WTP to avoid a water shortage sums the WTP for each unit of water from the baseline level (Q^*) to the disrupted level (Q^R), (**Figure 10**). The value of the last unit of water used under rationing, which is consumer WTP for the individual unit Q^R, rises from P^* to P^R in response to reallocation of water to meet only the highest valued uses.

The economic loss calculation places special significance on prevailing water rates in a region prior to a period of supply disruption. Urban water consumers are faced with a given set of water rates that are chosen by their local purveyor, and, given these rates, consumers are generally free to purchase their desired quantities of water. For example, at lower water rates residential consumers make landscaping choices that devote a greater quantity of water to outdoor irrigation uses than they would facing higher water rates, so that the potential for water conservation is greater (and the economic losses are accordingly less) in regions with initially lower water rates.

Water rates combined with consumption levels at the prevailing rates provide information about the value of water to households at a single point on the demand curve. Because this study addresses the economic losses resulting from reduced water consumption below baseline levels, it is necessary to characterize the demand curve at consumption levels that are reduced below baseline levels.

The first component used to measure the economic loss of a water shortage is to define consumer WTP to avoid supply disruptions of given magnitudes. As described above, consumer WTP to avoid a supply disruption that reduces water consumption from an initial level of Q^* units to a rationed level of Q^R units is represented by the shaded region of **Figure 10**. Making use of the water demand function for each region, consumer WTP to avoid a supply disruption integrates the area under the demand curve between the quantities Q^* and Q^R.

The second component used to measure the economic loss of a given supply disruption is to account for the avoided cost of water delivery to individual water purveyors. Following a supply disruption, a smaller quantity of water is delivered to municipal, C&I, and agricultural users, which can reduce the total cost of water distribution. The economic loss following a supply disruption in each sector is the sum of consumers' WTP to avoid a supply disruption net of the avoided cost of water delivery to users in that sector. For municipal and C&I users, the avoided cost of water delivery is the change in system-wide treatment and conveyance cost of delivering Q^R units of water relative to the cost of delivering the baseline level of Q^* units of water.

SI 2.1.1 Consumer Willingness to Pay to Avoid Supply Disruptions

Economic losses are determined by the magnitude of the water supply disruption in each sector of the regional economy. Following Brozovic et al. (2007), we define the severity of the water supply interruption in region i and in sector t as $z_{it} \in [0,1]$, where $z_{it} = 0$ corresponds to a complete outage and $z_{it} = 1$ corresponds to the baseline level of service. The water supply interruption in a given region in a given sector accounts for adjustments at the county level in the water portfolio through changes in groundwater pumping.

Let $f_{it}(z_{it})$ denote the probability density function of residential water disruption z_{it} in region i in sector t and let $W_i(z_{it})$ denote consumer WTP to avoid a supply disruption z_{it}. The total consumer WTP to avoid a water supply disruption across I regions and T sectors is given by

$$W^R = \sum_{t=1}^{T}\sum_{i=1}^{I}\int_0^1 W_i(x)\, f_{it}(x)dx \quad . \tag{1}$$

For a given region and sector, the computation of $W_i(z_{it})$ involves integrating the area under a demand curve for a shortage level of z_{it}.

This study adopts the approach of Jenkins et al. (2003) and Brozovic et al. (2007) in deriving an equation for the estimation of consumer WTP to avoid water service disruptions. Specifically, water demand elasticities are utilized for each region under a specification of constant elasticity of demand given (i.e., the elasticity of demand is the same everywhere along a constant elasticity demand cure and water price does not change with increasing rate of consumption) by

$$P_{it} = A_{it} Q_{it}^{\frac{1}{\varepsilon_{it}}}, \quad i = 1,2,3,\ldots,I; \; t=1,2,3,\ldots,T. \tag{2}$$

where ε_{it} is the elasticity of water demand in region i and sector t, and A_{it} is a parameter that scales the magnitude of demand to the price in each region.

Let P_{it}^* and Q_{it}^*, respectively, denote the water price and quantity of water consumed by users in region i and sector t under baseline conditions (prior to water rationing). For a given water shortage with an available level of water given by $Q_{it}(z_{it}) < Q_{it}^*$, it is helpful to define the relationship between these quantities in terms of the percentage of water that is rationed in region i and sector t, r_{it}, as

$$Q_{it}(z_{it}) = (1 - r_{it})Q_{it}^* \quad . \tag{3}$$

Making use of equations (2) and (3), consumer WTP to avoid a supply disruption of magnitude z_{it} in region i and sector t can be calculated as follows:

$$W_{it}(z_{it}) = \int_{Q_{it}(z_{it})}^{Q_{it}^*} P_{it}(Q)dQ_{it} = \int_{Q_{it}(z_{it})}^{Q_{it}^*} A_{it} Q_{it}^{1/\varepsilon_i} dQ_{it}$$

$$= \frac{\varepsilon_{it}}{1+\varepsilon_{it}} P_{it}^* Q_{it}^* \left[1 - (1 - r_{it})^{\frac{1+\varepsilon_{it}}{\varepsilon_{it}}} \right] . \tag{4}$$

Consumer WTP to avoid a supply disruption in equation (4) can be calculated for each sector of each county by constructing an aggregate water demand curve to represent demand conditions in each sector (see equation (2)).

Consumer WTP to avoid a supply disruption in equation (4) depends on the prevailing water price paid in each sector of each region under baseline supply conditions, P_{it}^{*}. For irrigation and livestock users, where water prices typically do not exist, the water price is taken to be the implicit value of water at a baseline level of use. For municipal and C&I users in regions in with inclining tiered prices for water, the calculation in equation (4) is based on the price level associated with average municipal and C&I consumption in the region.

Baseline prices per acre-foot (AF) are used to calculate economic losses for municipal and C&I sectors of each county (**Table 1**). Several water purveyors in the region provide data on the average level of use among buyers in each market sector, which allows prices to be aligned with representative users in each county. For water purveyors who do not list average use levels within each market sector, the average use level in Bexar County is used as a proxy for the representative user in the county.

In some cases, water is not allocated by price within the sector, for instance agricultural users may simply divert surface water with a pump. In this case, the relevant water price for calculating economic losses is the implicit value of the water to the user. In these cases, the water price received by other users in the agricultural sector is taken as a proxy for the market price received. For the agricultural sector, the rate paid for Edwards Transfers is $454 per acre-foot for leased firm groundwater permits (HDR, 2010), and this value is used as a proxy for the implicit value of water for agricultural users that do not pay a water price.

Water demand elasticities for each sector of each region are taken from academic studies of water demand conditions. In all water supply cases, price elasticity of demand is negative, meaning that water demand decreases with price increases (e.g., raising water rates to encourage conservation). Municipal demand is characterized using a price elasticity of -0.19, which is consistent with econometric results from comprehensive studies of residential water demand in California and Texas (Berkman et al., 2007; Gaudin et al., 2001; Renwick and Green, 2000). C&I water demand is characterized using a price elasticity of demand of -0.12 based on data from British Columbia and California (McLeod, 1994; Renzetti, 1988). Agricultural demand is characterized using a price elasticity of -0.80 (Norvell and Shaw, 2011).

SI 2.1.2 Avoided Cost of Service

Economic losses that result from water shortages are mitigated to the extent that delivering a smaller quantity of water reduces the system-wide cost of water service. For a given sector of a county, the overall cost of water service to users in the sector often include fixed costs that do not vary with the amount of water delivered through the system (e.g., infrastructure costs, repair and maintenance, and administrative expenses), which implies that the avoided cost that results from water shortage can be relatively small in relation to total cost. For example, expensive water supply projects (e.g., groundwater desalination, aquifer storage and recovery, or pipelines for interbasin water transfers) must be used at all times at full capacity to minimize the unit cost of water delivery. Conversely, surface water sources with treatment at the point of water withdrawal may have avoided costs when demand is low (e.g., savings from reduced chemical inputs and electricity to run pumps and treatment equipment). Throughout this report, the reduction in the cost of water service that occurs in response to a one-unit reduction in water deliveries is referred to as the avoided marginal cost of service.

Let c_{it} denote the avoided marginal cost of service in region *i* and sector *t*. Summing the avoided cost per unit of water across the water rationed in the consumer market in region *i*, the avoided cost of service for a cumulative service disruption across *I* regions and *T* sectors is given by

$$AC^R(z_{it}) = \sum_{t=1}^{T}\sum_{i=1}^{I}\int_0^1 c_{it} r_{it} Q_{it}^* f_{it}(x)dx \quad , \tag{5}$$

where $r_{it}Q_{it}^* = Q_{it}^* - Q_{it}(z_{it})$ is the reduction in water deliveries for the shortage level z_{it}.

For agricultural users, economic losses are calculated under conditions in which there are no avoided marginal costs of service (i.e., water is pumped from a river and delivered to a farm at is relatively inexpensive). The lack of significant savings among irrigation and livestock users from the avoided marginal cost of service reflects baseline conditions in which these users can divert an additional unit of surface water at no cost in their existing conveyance infrastructure.

For municipal and C&I users, a reduction in water supply can result in significant avoided marginal cost. Examples of components of avoided marginal cost include the energy and chemical costs of treating water units that are no longer delivered, the reduction in conveyance costs, and the decrease in energy and chemical costs of wastewater treatment that arise from a smaller level of water use. To derive an estimate of the avoided marginal cost of service, the marginal cost of water is calculated using SAWS contracts, materials and supplies, and expenses data (SAWS, 2010). Specifically, the difference in total operating costs and total production levels in 2008 and 2009 is used to calculate the present value of the cost savings per unit ($/AF) that corresponded to the reduction in SAWS deliveries that occurred between 2008 and 2009. The estimated marginal cost of municipal treated water for SAWS, $275/AF, is used as a proxy for the avoided marginal cost of service to municipal and C&I users in all counties.

SI 2.1.3 Loss Functions

The loss function for each sector in each region is characterized by consumer WTP to avoid a supply disruption in equation (4) net of the avoided cost of service in equation (5). The avoided cost of service for a service disruption across *I* regions and *T* sectors is given by

$$L^R = \sum_{t=1}^{T}\sum_{i=1}^{I}\int_0^1 Q_{it}^* \left(\frac{\varepsilon_{it}}{1+\varepsilon_{it}} \hat{P}_{it}^* \left[1-(1-r_{it})^{\frac{1+\varepsilon_{it}}{\varepsilon_{it}}} \right] - c_{it} r_{it} \right) f_{it}(x)dx \quad . \tag{6}$$

The loss function (6) is calculated for a supply disruption of various magnitudes, as represented by the EF scenarios.

SI 2.2 Calculating Steam Electric Losses

Economic losses to steam electric plants are calculated using average operating frequencies over the period 1934-1989 (using WAM) based upon average expected losses to steam-electric plants over all hydrologic conditions. Water availability modeling explores the boundaries of changes in surface water availability but do not necessarily mean that power generation would stop during modeled water shortages. This approach differs from the approach used to measure municipal, C&I, and agricultural sector losses under normal hydrologic and drought conditions (represented by 50% and 90% probability of water diversion exceedance, respectively).

Publically available operating (**Table 2**) and financial data (e.g., annual revenue, cost, and net revenue estimates; **Table 3**) for the affected steam electric plants in Bexar County are used to calculate economic losses of plant shut-downs. Revenue projections are market calculations using publically available data and do not necessarily reflect actual CPS Energy revenue forecasts. Net summer capacity, which is generally less than net winter capacity, is used to annualize net revenue for the purpose of calculating economic losses. Revenue from electricity sales is calculated as the product of power generation at the net summer capacity of each plant and flat and superpeak prices reported for the Bloomberg Electric Reliability Council of Texas ("ERCOT") South region from 2010 InterContinental Exchange electricity data (EIA, 2012). The variable cost of electricity production is calculated at the net summer capacity of each plant by summing operating and maintenance costs (VOM) (EIA, 2010b) and fuel costs for coal and natural gas (EIA, 2010a). Net revenue for each plant is the difference between revenue from electricity sales and variable production costs.

Due to differences in the way that steam-electric plants utilize water, economic losses to steam electric plants in Bexar County were calculated in the framework of a segmented steam-electric sector. The segmented market framework suppresses the potential to reduce steam-electric losses through water purchases from users in other sectors of the economy. In some cases where the minimum operating level is not met, it would be possible to maintain operation of the plant with a small additional input of water, and water purchases by steam electric plants under these circumstances would be worthwhile at the prevailing Edwards Transfer price. Under drought conditions, water prices would rise with water scarcity in an integrated water market, and explicit modeling of residual demand for water in the steam-electric sector would be necessary to integrate the steam-electric sector with the municipal, C&I, and agricultural sectors of the regional economy.

TABLES

Table 1. Water rates and average consumption.

County		Proxy City	Municipal Average Consumption	Municipal Price	C&I Average Consumption	C&I Price
		[a]	[b]	[c]	[d]	[e]
Bexar	[1]	SAWS	7,801	$1,012.50	volumetric	$1,684.36
Medina	[2]	Devine	7,840	$1,166.55	22,702	$2,492.76
Tom Green	[3]	San Angelo	7,840	$915.64	volumetric	$931.93
Wharton	[4]	Wharton	7,840	$863.51	22,702	$971.04

Notes and Sources:

[a] Rates and consumption data are taken from a representative city from each county.

[b] & [d] Quantities are in gallons per month. Calculated as the total municipal (C&I) consumption divided by the number of municipal (C&I) customers. For Tom Green and Wharton counties, the median average consumption levels in Medina county are taken as a proxy.

[c] & [e] Water rates are in dollars per acre-foot.

[1] Rates available at: http://www.saws.org/service/rates/; consumption data from the 2009 SAWS CAFR available at:http://www.saws.org/who_we_are/Annual_Reports/CAFR/PDF/CAFR_2009.pdf.

[2] Water rates available at: http://www.cityofdevine.com/utility_department.html#4

[3] Water rates available at: http://www.sanangelotexas.org/index

[4] Rates available at: http://www.cityofwharton.com/city-departments/public-works

Table 2. Steam electric plant operating data.

Plant Name	Unit	Nameplate Capacity MW	Net Summer Capacity MW	Net Winter Capacity MW	Fully Loaded Tested Heat Rate Btu/kWh	Prime Mover Category	Primary Fuel Code	Avg Annual Capacity Factor %
Arthur Von Rosenberg	CC	550	450	540	7,184	CC	NG	14.49
J K Spruce	1	566	555	565	11,237	ST	SUB	87.08
J K Spruce	2	820	785	785	11,333	ST	COL	49.93
J T Deely	1	486	440	399	11,435	ST	SUB	63.91
J T Deely	2	446	440	401	11,367	ST	SUB	77.47
O W Sommers	1	446	420	420	10601	ST	NG	12.28
O W Sommers	2	446	420	420	11061	ST	NG	8.56
V H Braunig	1	225	215	220	10,909	ST	NG	7.24
V H Braunig	2	252	220	230	10,661	ST	NG	5.82
V H Braunig	3	417	412	412	10,290	ST	NG	14.52

Source: Generating Unit Capacity as compiled by Ventyx, the Velocity Suite

(Ventyx, 2012)

Table 3. Steam electric plant annual revenue, cost, and net revenue.

Plant Name	Net Summer Capacity MW[a]	Heat Rate Btu/KWh[b]	Fuel Price (Real $/MMBtu) [c]	Fuel Costs $/MWh[d]	VOM (Real $/MWh)	Annual Hours	Annual Capacity Factor (%)	2010 Generation in MWh	Electricity Price (Real $/MWh)	Variable Cost ($/MWh)	Revenue (million $s)	Costs (million $s)	Net Revenue (million $s)
	[a]	[b]	[c]	[d]= [b]*[c]	[e]	[f]	[g]	[h]=[a]*[f] *[g]/100	[i]	[j]=[d]+[e]	[k]=[h]*[i]	[l]=[h]*[j]	[m]=[k]-[l]
Coal Power Plant									**Flat**				
J K Spruce_1	555	11,237	1.85	20.79	4.28	8,760	87.08	4,233,655	34.41	25.07	$145.67	$106.15	$39.52
J K Spruce_2	785	11,333	1.85	20.97	4.28	8,760	87.08	5,988,143	34.41	25.25	$206.03	$151.20	$54.83
J T Deely_1	440	11,435	1.85	21.15	4.28	8,760	63.91	2,463,347	34.41	25.44	$84.76	$62.66	$22.09
J T Deely_2	440	11,367	1.85	21.03	4.28	8,760	77.47	2,986,004	34.41	25.31	$102.74	$75.58	$27.15
Natural Gas Power Plant									**SuperPeak**				
Arthur Von Rosenberg_CC	450	7,184	4.84	34.77	3.44	8,760	14.49	571,196	60.57	38.21	$34.59	$21.82	$12.77
V H Braunig_1	215	10,909	4.84	52.80	3.44	8,760	7.24	136,358	60.57	56.24	$8.26	$7.67	$0.59
V H Braunig_2	220	10,661	4.84	51.60	3.44	8,760	5.82	112,163	60.57	55.04	$6.79	$6.17	$0.62
V H Braunig_3	412	10,290	4.84	49.80	3.44	8,760	14.52	524,044	60.57	53.24	$31.74	$27.90	$3.84
O W Sommers_1	420	10,601	4.84	51.31	3.44	8,760	12.28	451,806	60.57	54.75	$27.36	$24.73	$2.63
O W Sommers_2	420	11,061	4.84	53.54	3.44	8,760	8.56	314,940	60.57	56.97	$19.07	$17.94	$1.13

Notes:
1. Coal plants analysis uses flat prices.
2. Natural gas plant analysis uses super peak prices.

Sources:
[a],[b],[g]: Generating Unit Capacity as compiled by Ventyx, the Velocity Suite
[c]: Energy Information Administration, 2011 Annual Energy Outlook: Electric Power Projections for EMM Region, Texas Regional Entity, Reference case.
[e]: Energy Information Administration, "Assumptions to the 2011 Annual Energy Outlook", Table 8.2.
[i]: Prices in real 2010 $s from ICE and Bloomberg data.

FIGURES

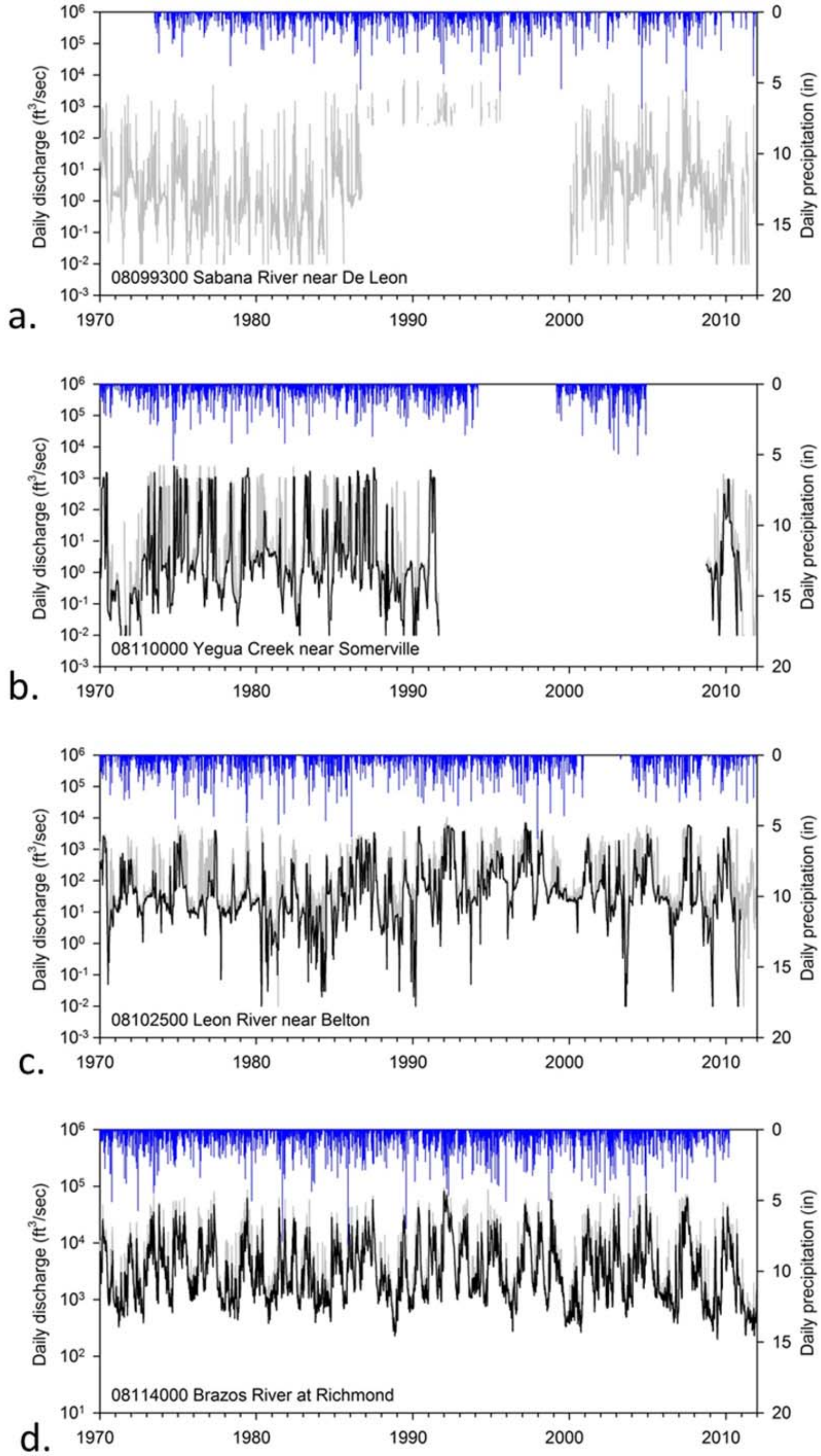

Figure 1. Hydrographs for Brazos River basin

Hydrographs are presented for (a) Sabana River near De Leon, (USGS gauge 08099300; ID# 1), (b) Yegua Creek near Somerville (USGS gauge 08110000; ID# 2), (c) Leon River near Belton (USGS gauge 08102500; ID# 3) and (d) Brazos River at Richmond (USGS gauge 08114000; ID# 4). Refer to **Figure 2** in main report for gauge locations.

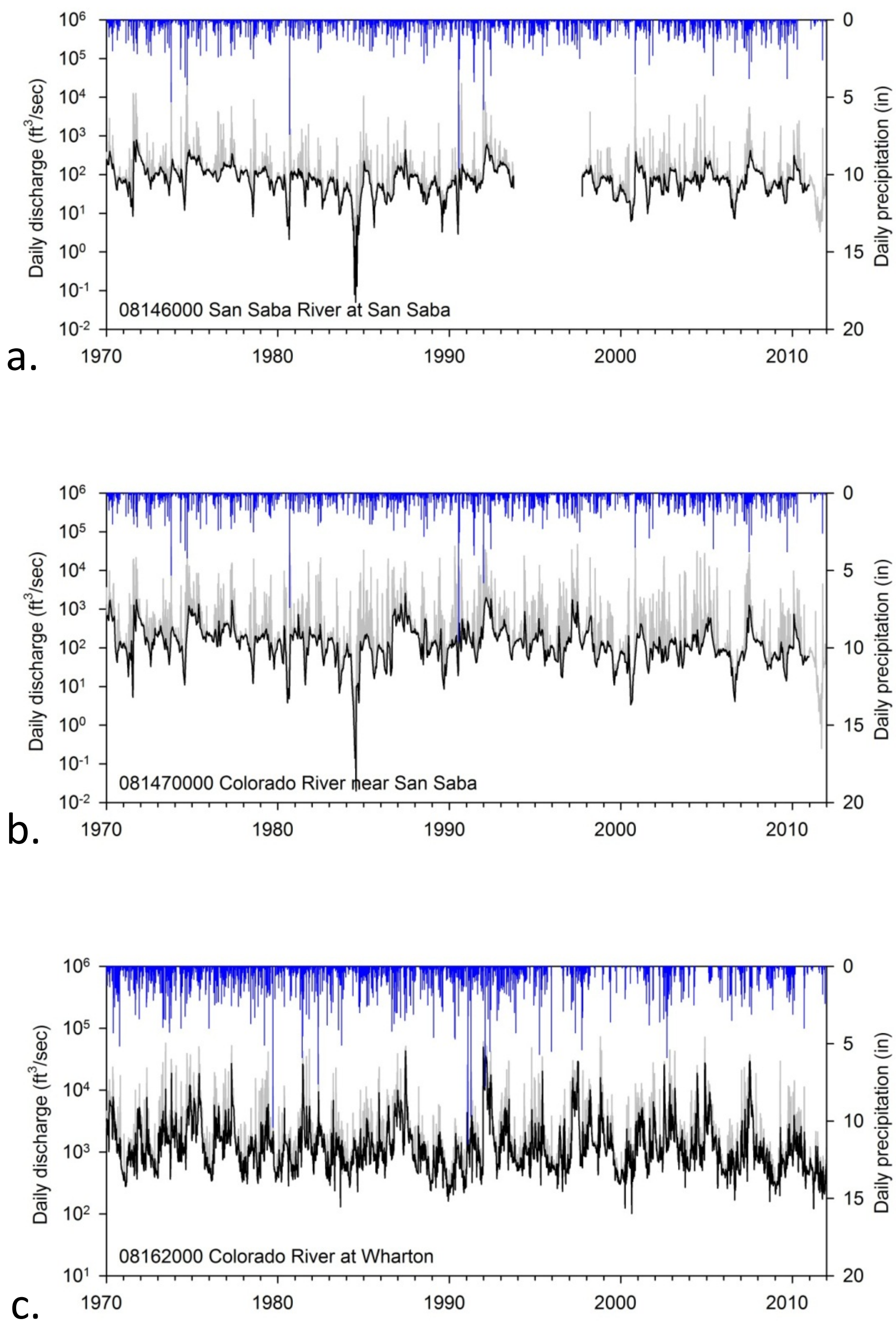

Figure 2. Hydrographs for Colorado River basin

Hydrographs are presented for (a) San Saba River at San Saba (USGS gauge 08146000; ID# 5), (b) Colorado River near San Saba (USGS gauge 081470000; ID# 6), and (c) Colorado River at Wharton (USGS gauge 08162000; ID# 7). Refer to **Figure 2** in main report for gauge locations.

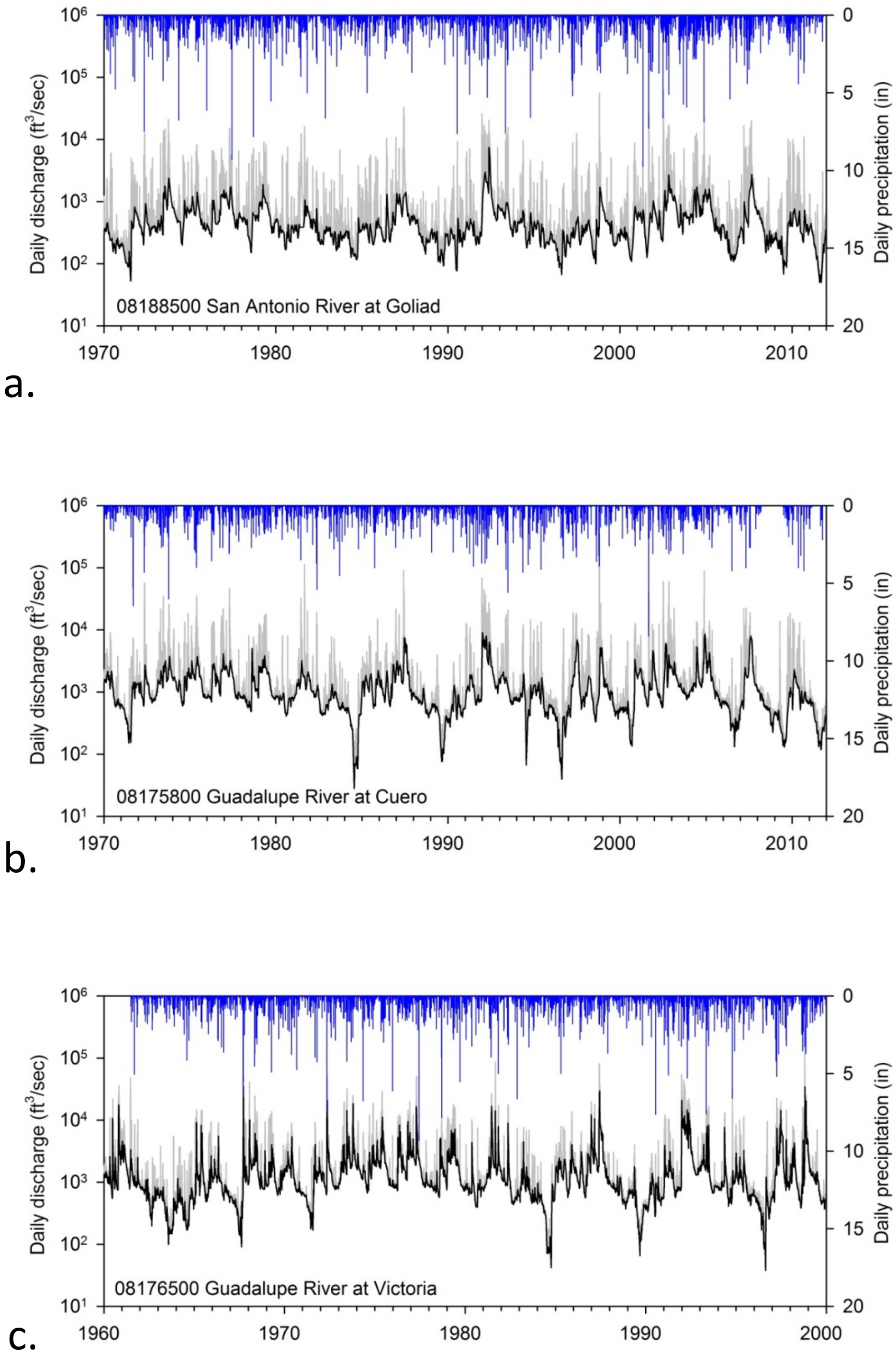

Figure 3. Hydrographs for Guadalupe-San Antonio River basin

Hydrographs are presented for (a) San Antonio River at Goliad (USGS gauge 08188500; ID# 8), (b) Guadalupe River at Cuero (USGS gauge 08175800; ID# 9), and (c) Guadalupe River at Victoria (USGS gauge 08176500; ID# 10). Refer to **Figure 2** in main report for gauge locations.

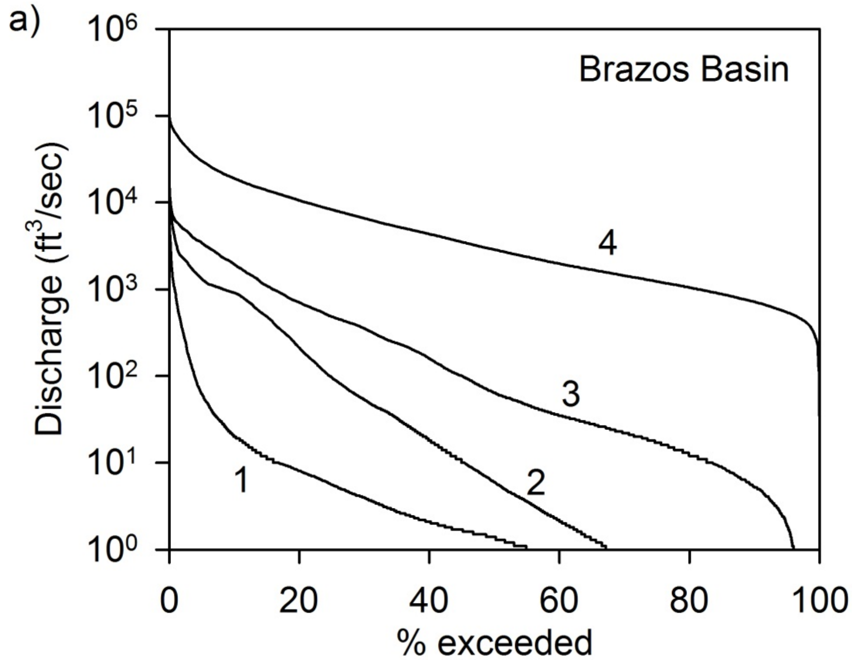

Figure 4. Flow duration curve for the Brazos River basin

The Sabana River (ID #1) and Yegua Creek (ID #2) have highly variable flows. The Leon River near Belton (ID# 3) is occasionally ephemeral, while the Brazos River at Richmond (ID# 4) is the fairly stable.

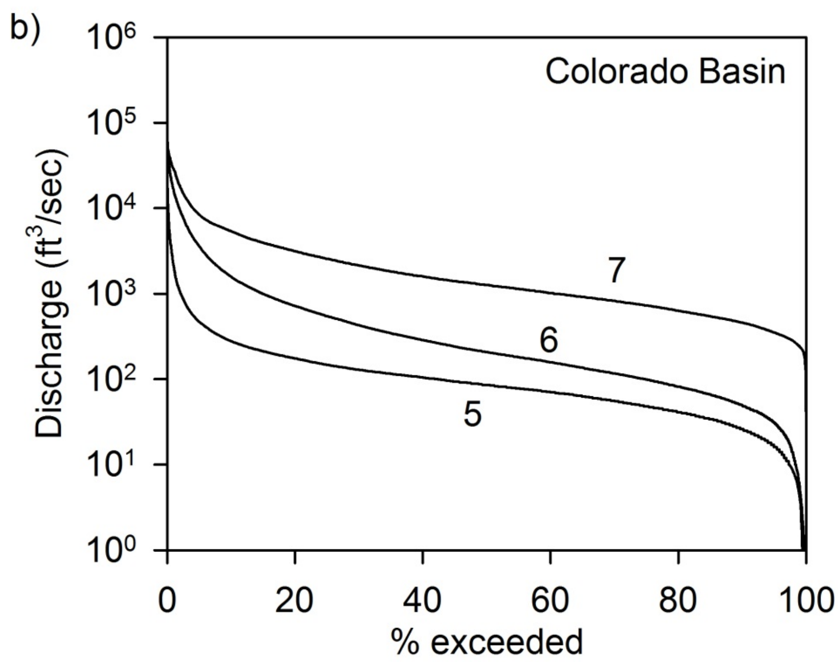

Figure 5. Flow duration curve for the Colorado River basin.

The rivers in the Colorado basin are all fairly stable, however the San Saba River (ID# 5) and Colorado River near San Saba (ID# 6). The San Saba River (ID# 5) has a relatively large groundwater inflow component.

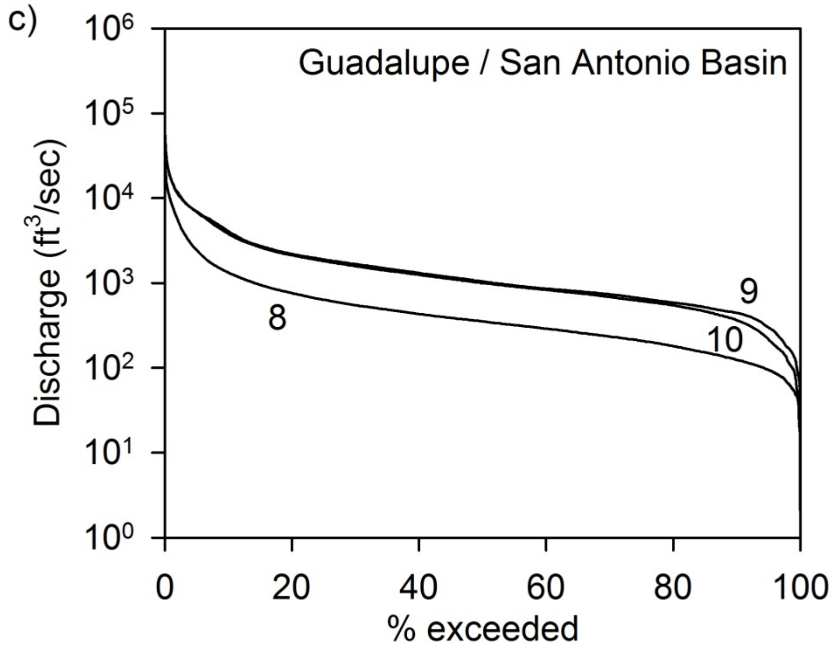

Figure 6. Flow duration curve for the Guadalupe-San Antonio River basin.

The rivers in the Guadalupe-San Antonio basin have the most stable flows due to nearby springs and San Antonio wastewater input.

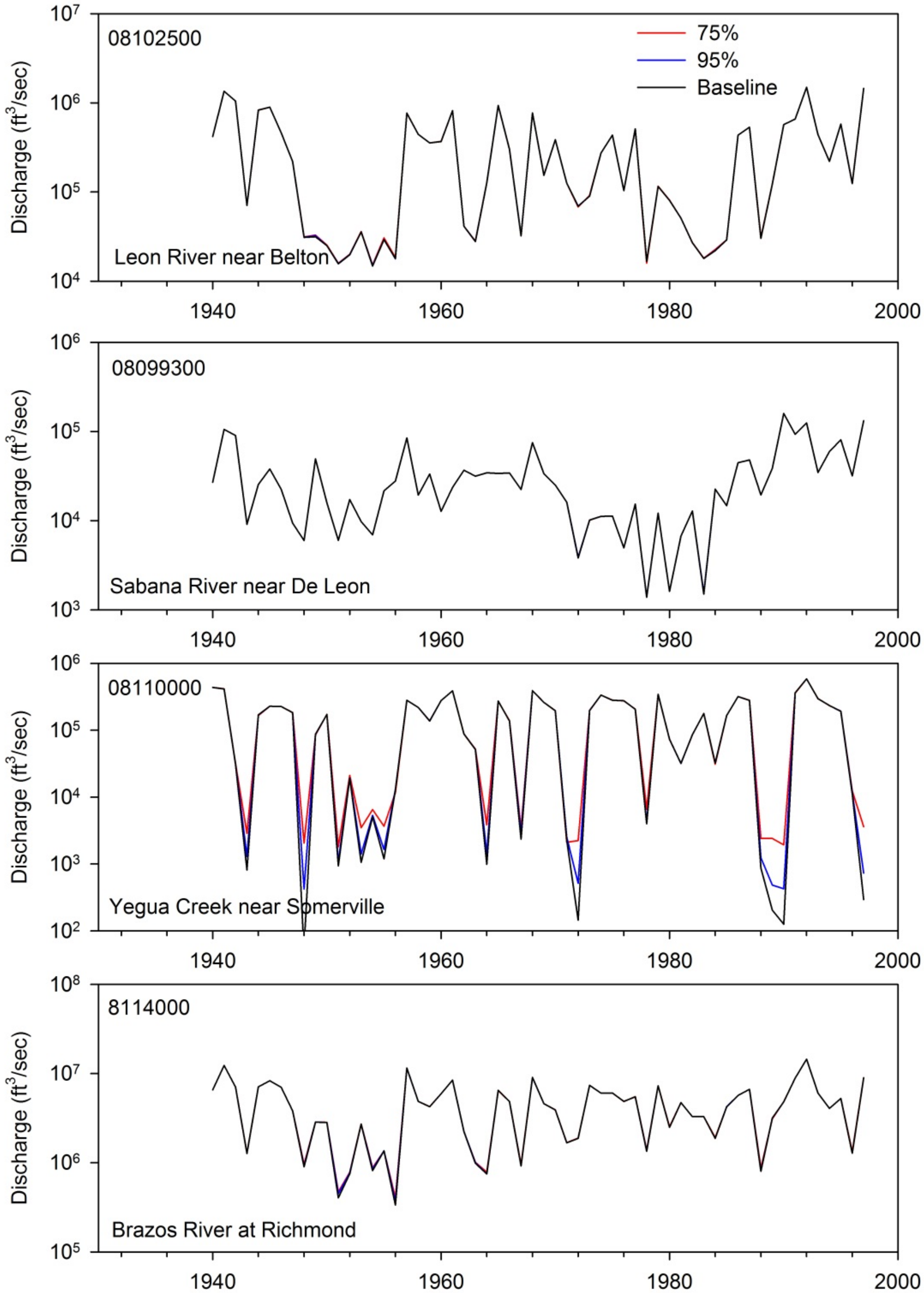

Figure 7. Modeled regulated flows for the Brazos River basin

Gauges include: Sabana River near De Leon (USGS 8099300, ID# 1), Yegua Creek near Somerville (USGS 8110000; ID# 2), Leon River near Belton (USGS 8102500; ID# 3), and Brazos River at Richmond (USGS 8114000; ID# 4)**.**

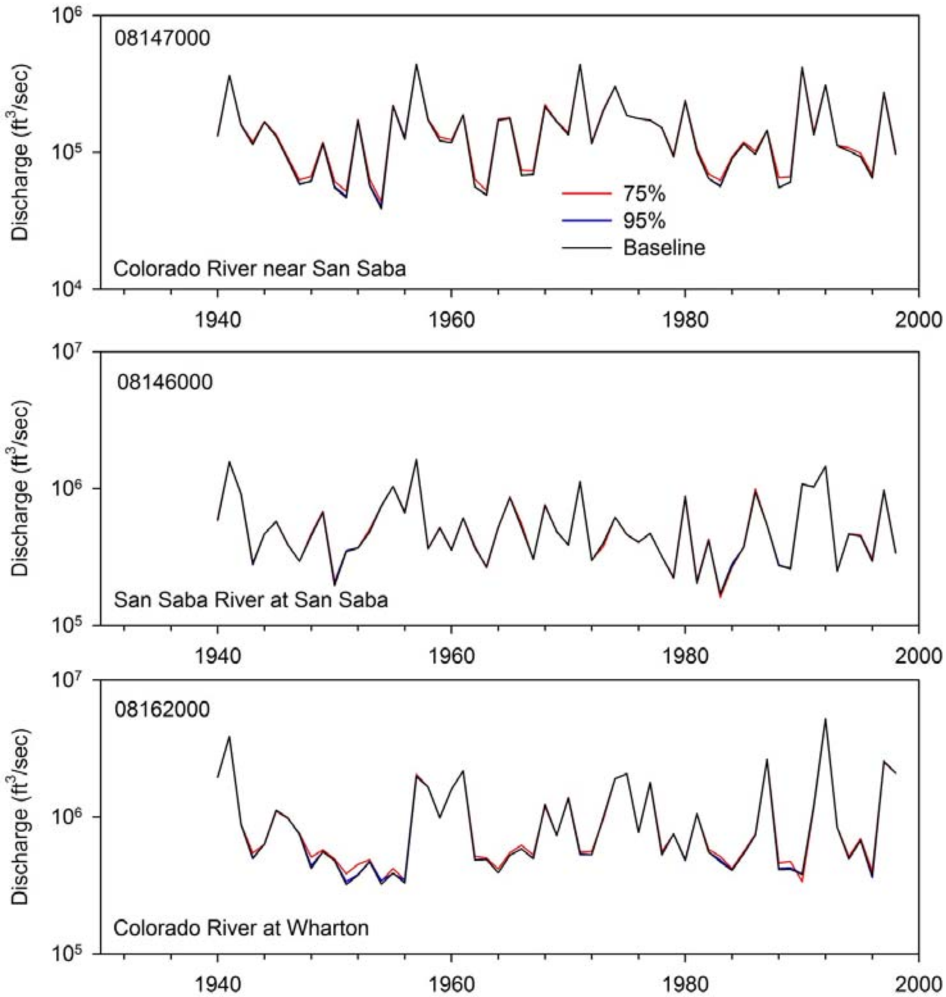

Figure 8. Modeled regulated flows for the Colorado River basin.

Gauges include: San Saba River at San Saba (USGS 8146000; ID# 5), Colorado River near San Saba (USGS 8147000; ID# 6), and Colorado River at Wharton (USGS 8162000; ID# 7)

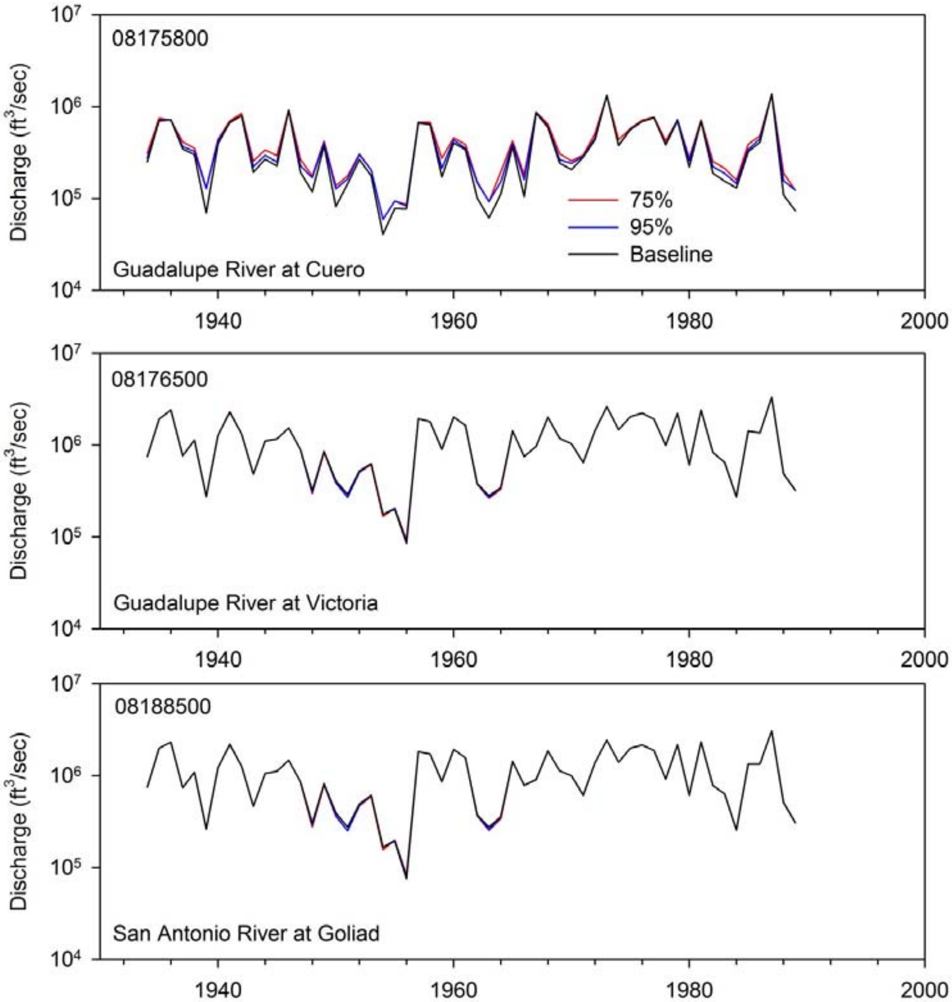

Figure 9. Modeled regulated flows for the Guadalupe-San Antonio River basin.

Gauges include: San Antonio River at Goliad (USGS 8188500; ID# 8), Guadalupe River at Victoria (USGS 8176500; ID# 9), and the Guadalupe River at Cuero (08175800; ID# 10).

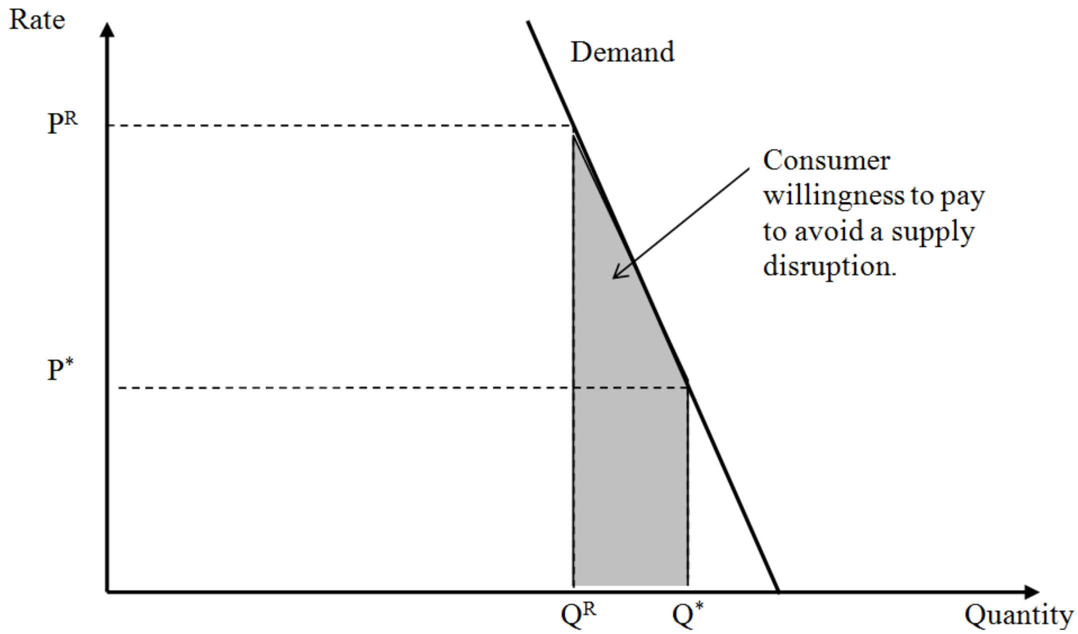

Figure 10. Consumer willingness to pay to avoid a supply disruption.

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