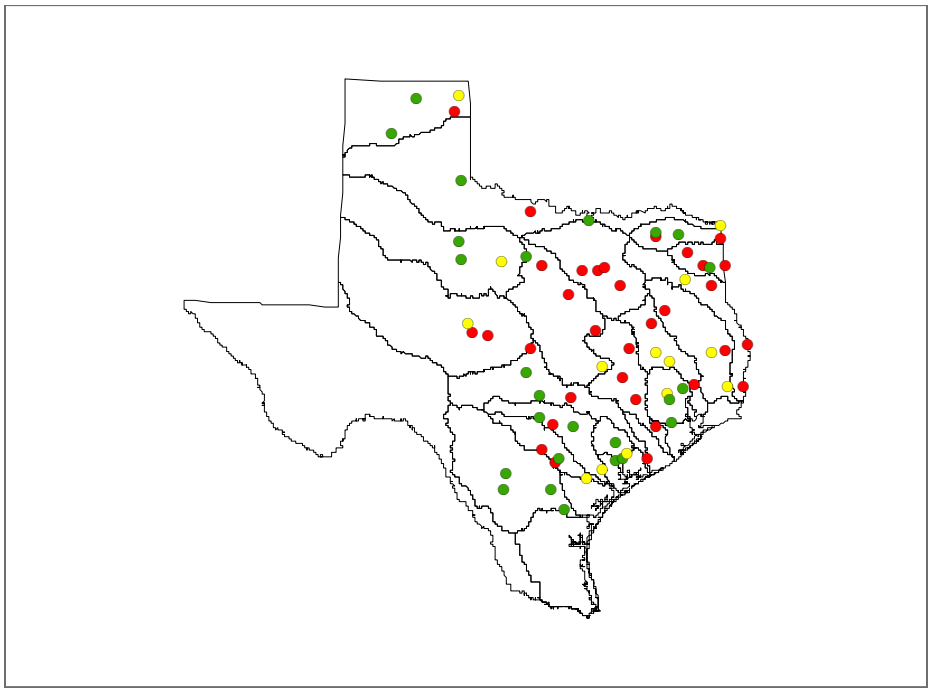

Using Water Availability Models to Assess Alterations in Instream Flows

Draft Report

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October 2003

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The Texas Parks and Wildlife Department (TPWD) is the state agency with primary responsibility for protecting the state's fish and wildlife resources. Related to that responsibility, TPWD provides data and recommendations to conserve those resources to local, state, and federal agencies or private organizations that make decisions affecting them. In addition, the agency makes recommendations to the Texas Commission on Environmental Quality (TCEQ) on scheduling of instream flows and freshwater inflows to Texas estuaries for the management of fish and wildlife resources.

Toward those ends, TPWD has a history of evaluating water development through intensive field studies as well as through desktop or in-office methods. The recent completion of updated water availability models (WAM) by TCEQ offered the opportunity to conduct a broad-scale assessment of instream flow alteration in Texas rivers and streams assuming full exercise of all existing water rights. The evaluation used output from WAMs officially accepted by TCEQ and benchmark instream flow values as a basis for comparing different flow scenarios. These benchmarks are estimates of flow values needed to support adequate instream habitat condition and these are not intended to replace criteria currently in use in planning and permitting processes. Instead the benchmarks were used to help evaluate the overall status, from a fish and wildlife conservation perspective, of hydrologic alteration in river basins throughout the state.

Methods

Water availability model data.—Hydrologic data were assembled from WAM monthly naturalized flows and two regulated flow scenarios: current conditions (i.e., maximum reported water use of the last ten years and minimum return flow ratio for the last 5 years - WAM run 8) and full authorization (i.e. full permitted use and no return flows - WAM run 3). The WAM files were downloaded from the TCEQ website on August 21, 2003 (TCEQ 2003). The WAM for the Rio Grande is currently under development (Steve Densmore, TCEQ personal communication) and is not included in this evaluation.

The current conditions and full authorization scenarios were run for each WAM and the naturalized and regulated flows were extracted from the output file. Since the analysis in this report is limited to primary control points, the WAM input files were modified to output only data for those points in the WAMs that have inflow records. U.S. Geological Survey (USGS) gage name and number were then related to the WAM control point outputs. Detailed descriptions of how the naturalized flow values were derived can be found in Deliverable 5 of the specific WAM study. In general, those preparing the WAMs summed USGS daily flow data to a monthly value and removed the effects of human use of water (diversions, storage and returns). Further, if data for the full period of record was not available statistical regressions to a similar or nearby reference gage were developed and the record extended or missing values filled in. Lastly, naturalized flows were further adjusted to account for negative incremental inflows prior to use in the WAMs and in some cases within the model simulation.

Conversion to daily time-step.—Daily flow records were developed for naturalized, current conditions and full authorization runs at four selected points in each basin or subbasin. Larger basins were subdivided into two to three parts. Long-term daily flow patterns were developed for the selected points. The goal was to find a daily pattern reflective of a natural hydrograph at the site. In some cases a full record was available from the USGS gage while in other cases missing dates needed to be filled with flow records from nearby, similar gages. In addition to filling missing dates, major impacts to natural flows such as reservoirs, return flows and changes in spring flow or recharge rates were identified and, where possible, alternative flow records were substituted. Appendix A details the reference gages used and the potential impacts to natural flows. Monthly values from the WAM runs were converted to daily by applying the following equation 1

$$DQ = MQ * \frac{DGQ}{MGQ} \quad (1)$$

where: DQ – daily flow
MQ – monthly flow from the WAM
DGQ – daily flow from time series developed from USGS gage(s)
MGQ – daily flow from time series developed from USGS gage(s) summed to a monthly value

In our conversion of the monthly WAM naturalized flow series to a daily time step we did not make specific adjustments to account for negative incremental inflows. We cannot determine at this time how the adjustment might influence our results however the conversion method we employed is consistent with past and current water planning efforts (e.g., reservoir firm yield estimates in regional water planning).

Instream flow benchmarks.—Benchmarks were determined by month at specific locations from each WAM river basin by calculating the median daily naturalized flow for that month and multiplying that value by 0.6 (March through September) or 0.4 (October through February). These benchmarks are similar to those derived from the Lyon's method (Bounds and Lyons 1979) in that they are the same percentages of the daily median flow for a given month. However, in order to provide a consistent approach for this statewide evaluation, our analysis is based on naturalized daily flows derived from WAM input files rather than historical gage data as employed by TCEQ (TNRCC 1995). Developing Lyons values from gaged data at each location would have involved substantial judgment decisions regarding appropriate period of records and consideration of heavily modified stream flow records. Since this report attempts to apply a single consistent standard to locations throughout the state, this proved infeasible. Also this provides a static value that can be compared over time, unlike the gaged flows that may change with new permit implementation, new diversions, etc. Median flows (i.e., 50th percentile; normal flow conditions) and 10th percentile flows (low flow conditions) were also calculated.

Comparison of flow scenarios.—For each selected point, exceedance of the instream flow benchmark under full authorization flow conditions was compared to naturalized flow conditions. If the percent of days in which instream flow benchmarks were met or exceeded fell by 25% or more for three consecutive months the location was classified as subject to high alteration. For example, if the flow benchmark was 100 cubic feet per second (cfs) in a given month and flow under natural conditions was equal to or greater than 100 cfs 80% of the days and flow under full authorization was equal to or greater than 100 cfs only 60% of the days then there was a 25% drop in the percent of days meeting or exceeding the benchmark. Should this have occurred for three consecutive months the flow at this point was classified as high alteration. Similarly, medium alteration represents a drop of 10-24% and low alteration represent a drop of less than 10%. Low alteration may also include situations where flow benchmarks were met more often under full authorization than under natural conditions.

Results

Bar charts illustrate the percent of days when an instream flow benchmark was met or exceeded under three flow scenarios: naturalized, current conditions and full authorization. Instream flow benchmarks are displayed horizontally across the top of each graph. Color-coded maps for each basin were produced to indicate the level of instream flow alteration relative to naturalized flow conditions at each location (labeled A through D). The maps include major cities, rivers and reservoirs (both existing and proposed) and SB1 regional planning group boundaries. Normal (median) and low (10th percentile) flow conditions are presented in separate figures as supplementary data intended to provide a context within which to view the primary analysis.

Discussion

It is hoped that the framework presented here will lend itself to further exploration of instream flow alterations and the effects of future water planning and permitting strategies. Color-coded maps illustrate the predicted level of instream flow alteration assuming full use of currently permitted water. A similar map could be developed for the adopted water plans once recommended strategies are modeled in the WAMs. The instream flow alteration classifications are intended to distinguish amongst a wide array of statewide data and may also need to be refined according to the needs and priorities of specific regions. Likewise, while the statistics presented in this report are reasonable, given readily available data, there is no doubt that they could be refined and expanded by regional experts.

Instream flow needs are far more complex than a single set of monthly values; protecting fish and wildlife resources requires more than meeting flow benchmarks a certain percent of the time. Chemical,

biological, and physical factors must also be considered. Thus, the results of this evaluation should not be used as final determinations of instream flow needs since no attempt has been made to address these factors.

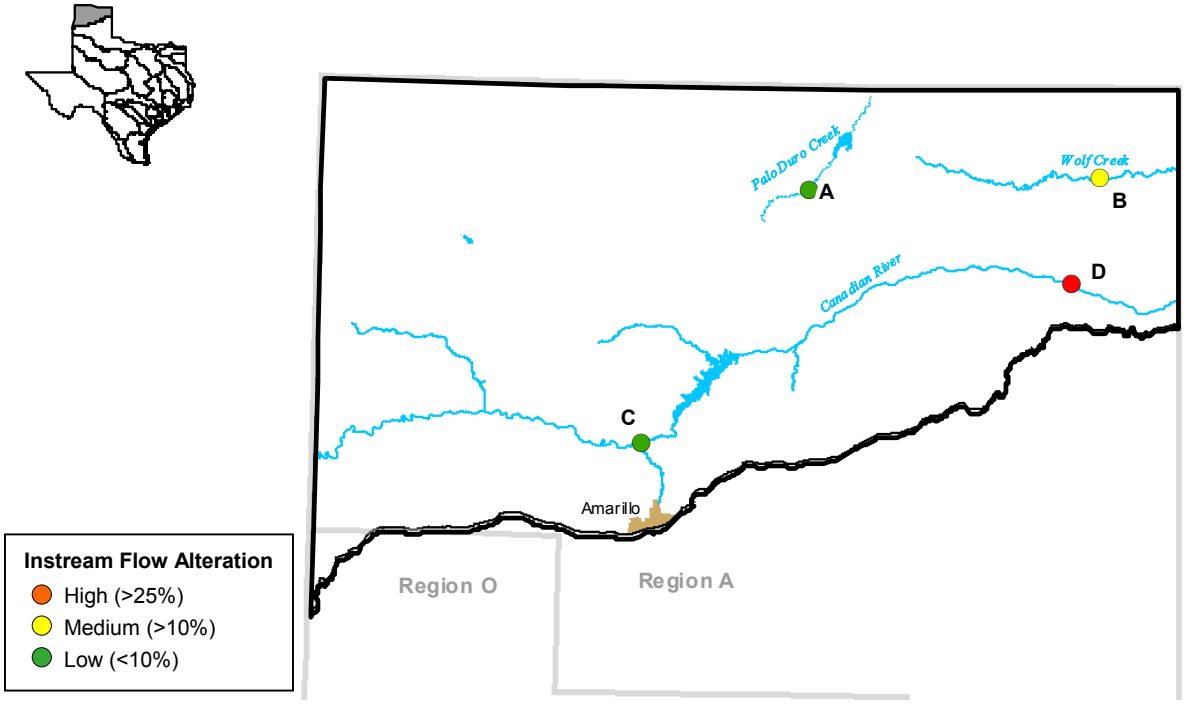
References

Bounds, R.L. and B.W. Lyons. 1979. Existing reservoir and stream management recommendations: statewide minimum streamflow recommendations. Federal Aid Project F-30-R-4. Texas Parks and Wildlife Department, Austin, Texas.

Texas Commission on Environmental Quality. 2003. Water availability models. http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/wam.html Texas Commission on Environmental Quality, Austin, Texas.

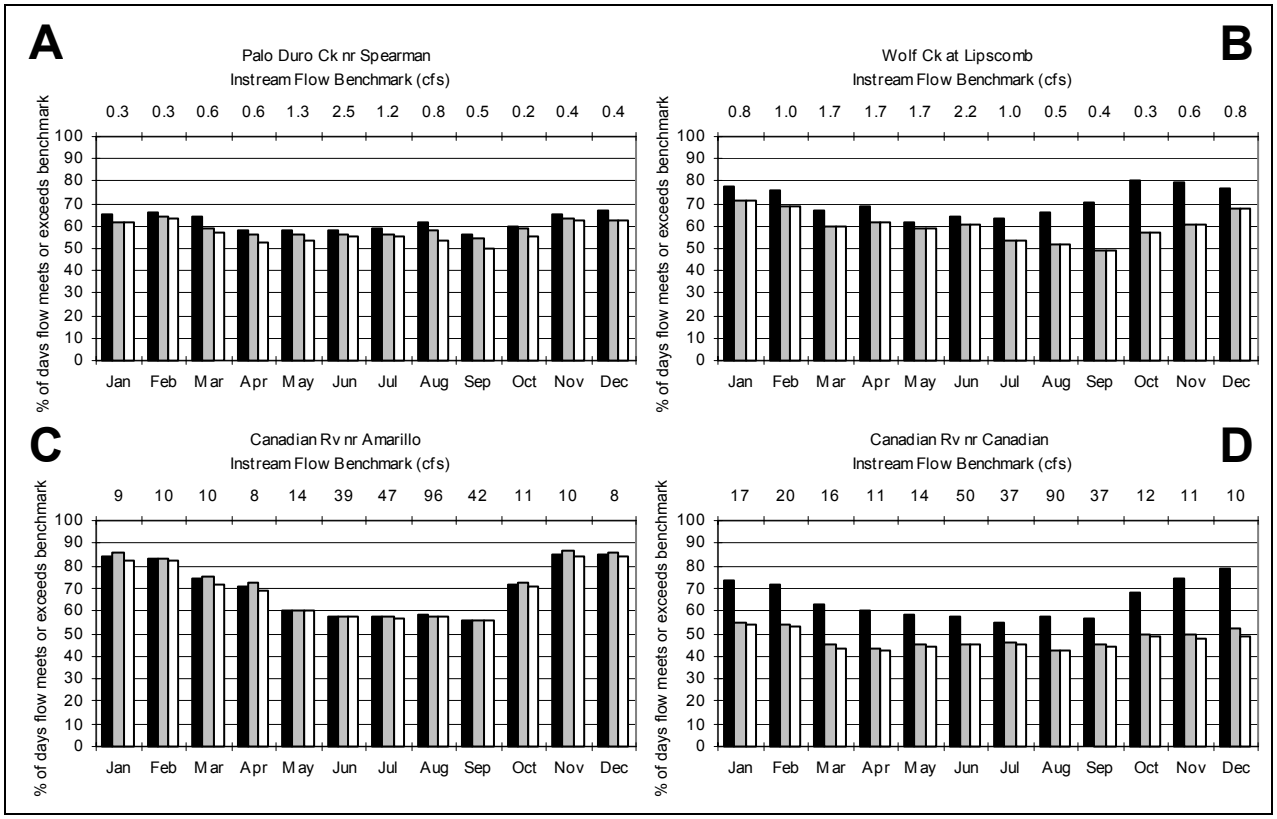
Texas Natural Resource Conservation Commission. 1995. A regulatory guidance document for applications to divert, store or use state water. RG-141. Texas Natural Resource Conservation Commission, Austin, Texas.

Canadian River Basin



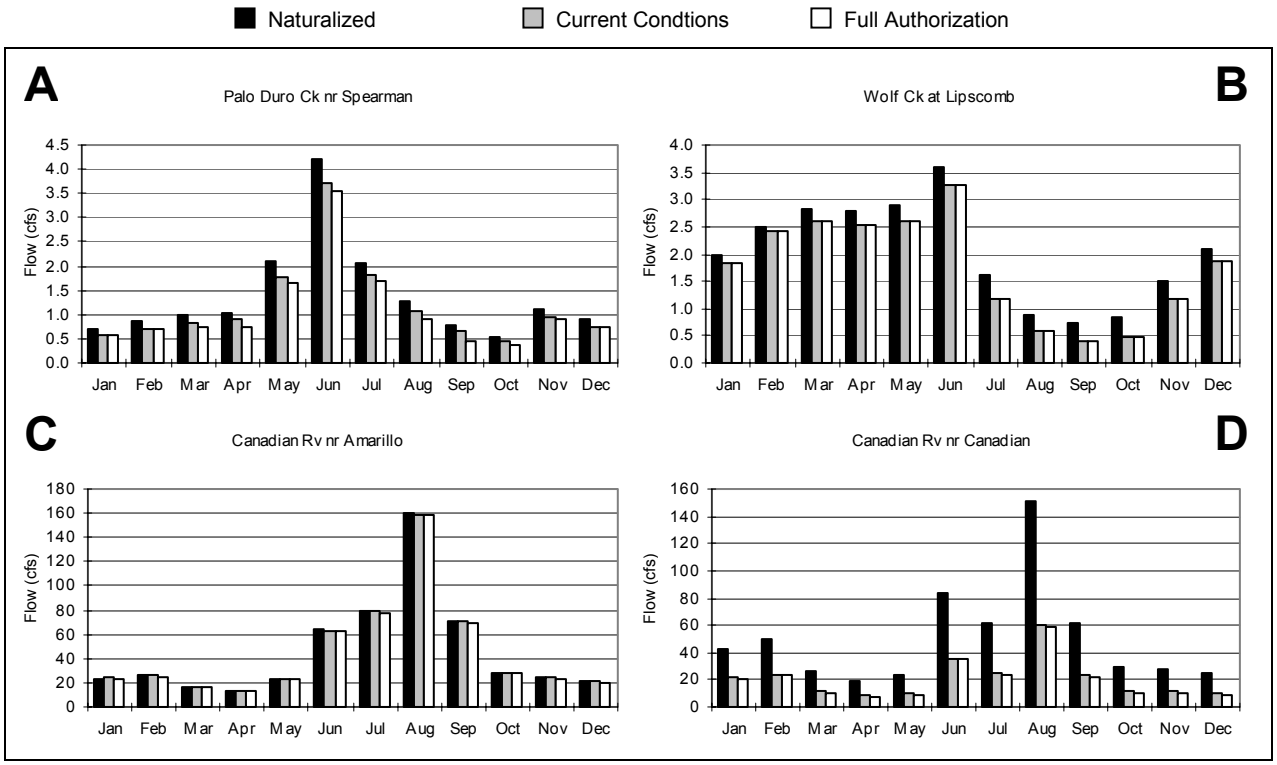
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

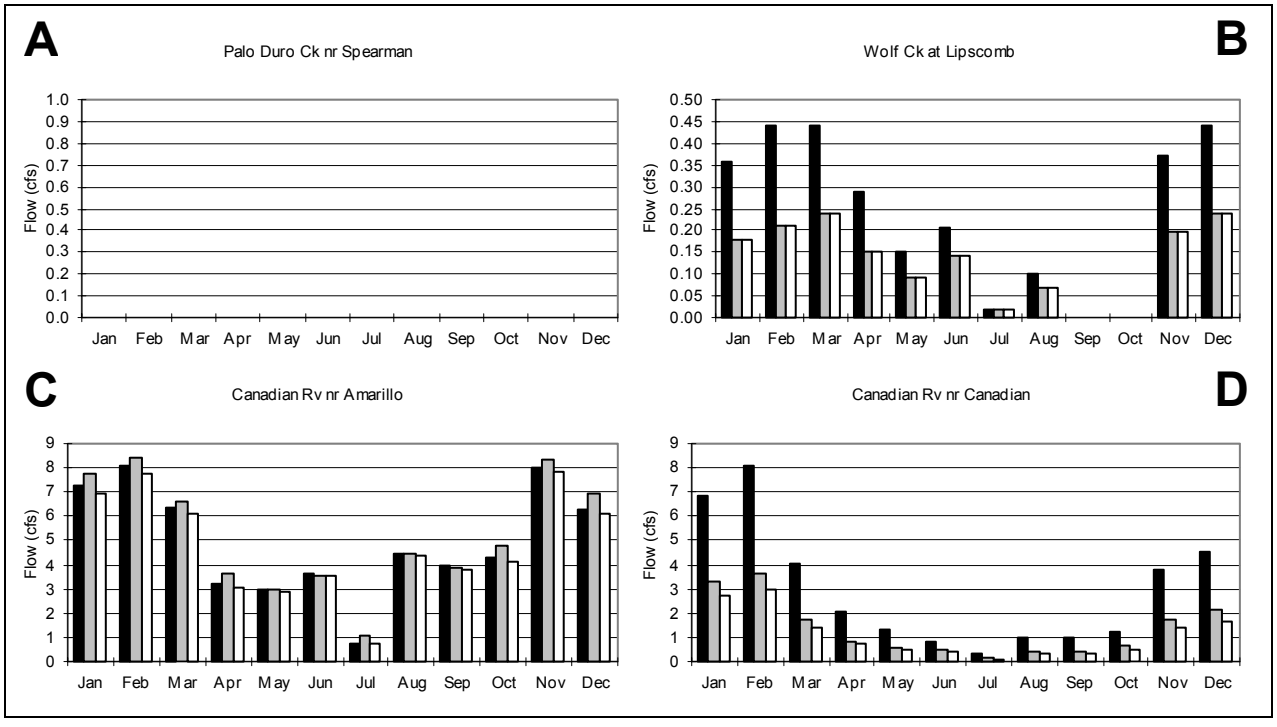


Canadian River Basin (cont.)

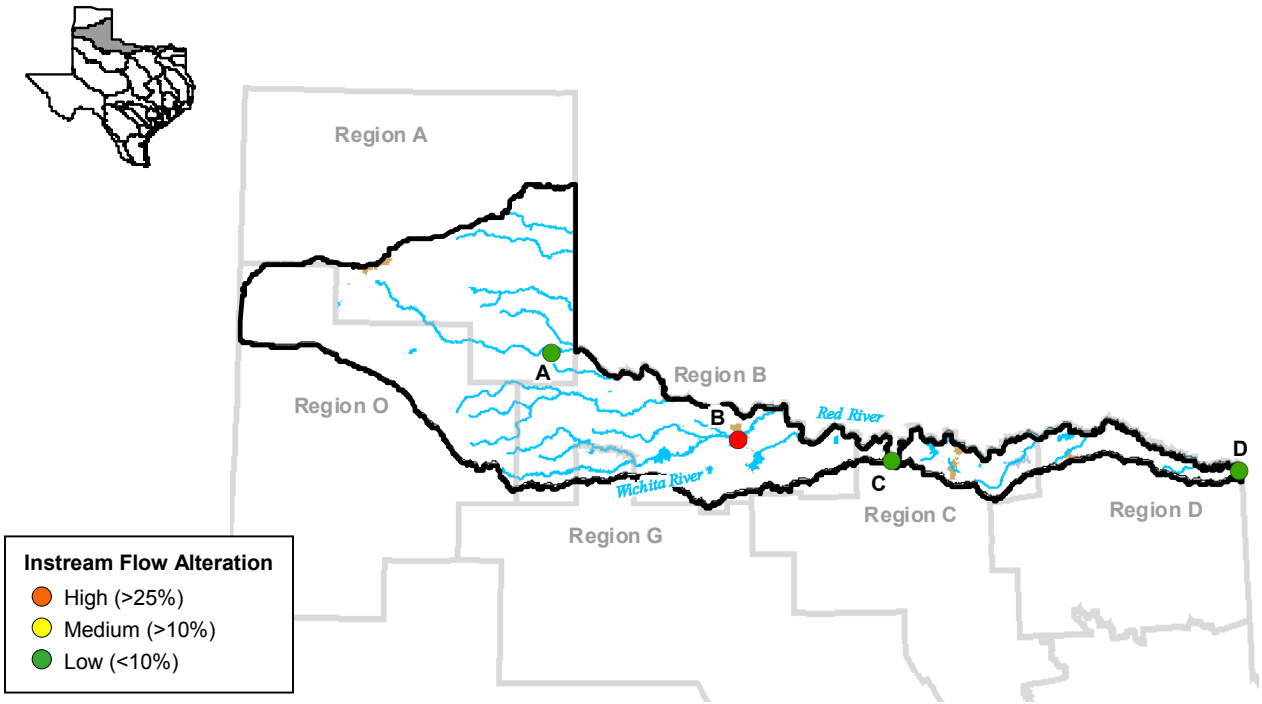
Normal Flow Conditions



Low Flow Conditions

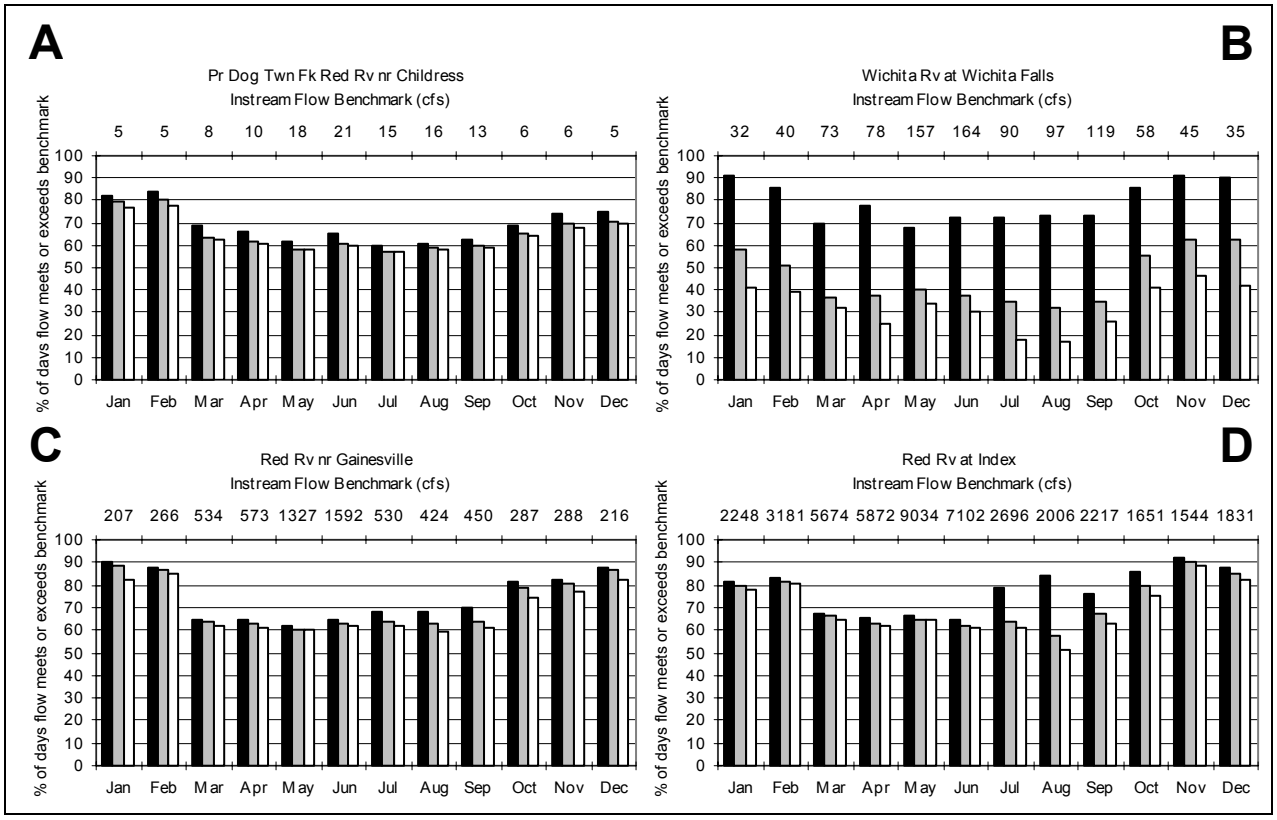


Red River Basin



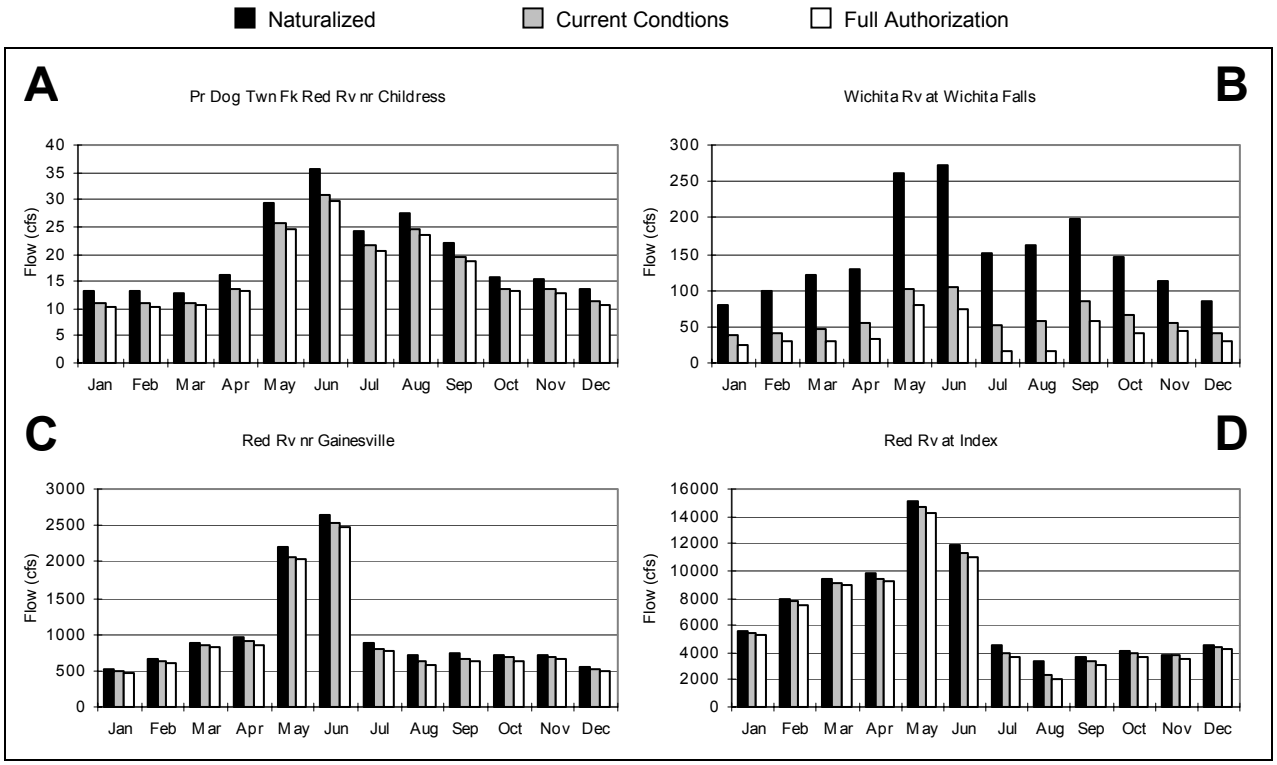
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

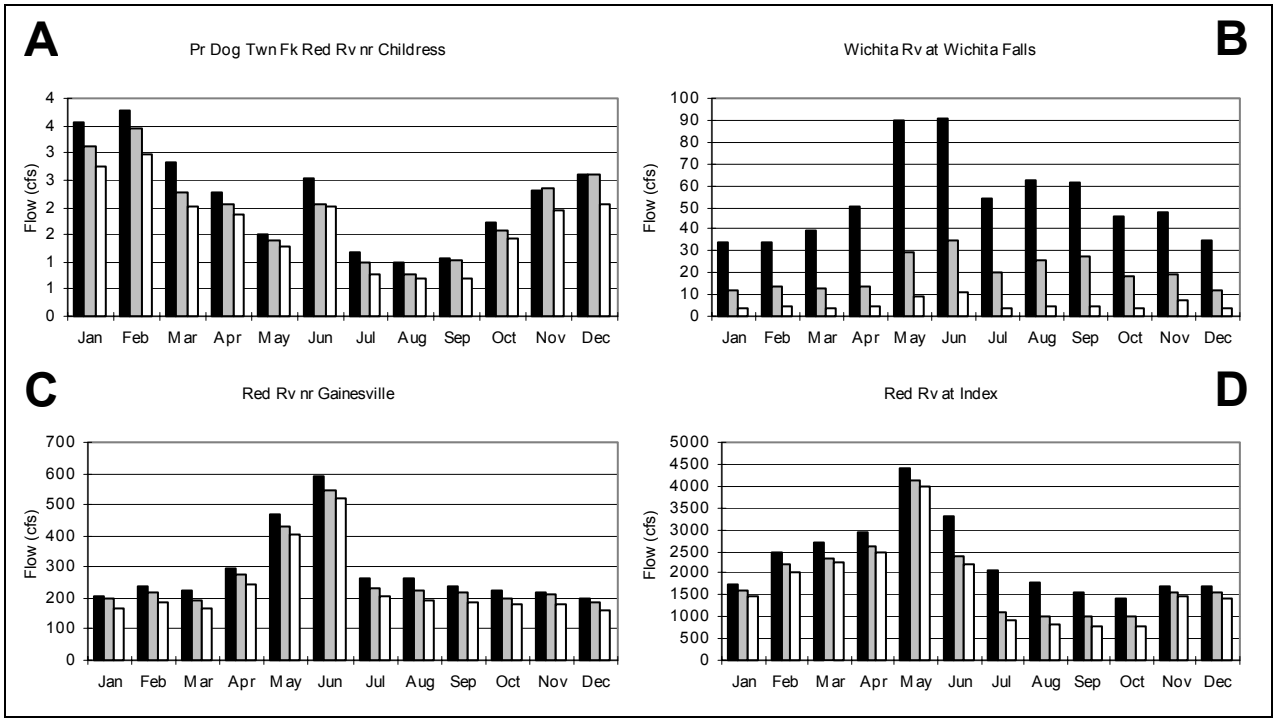


Red River Basin (cont.)

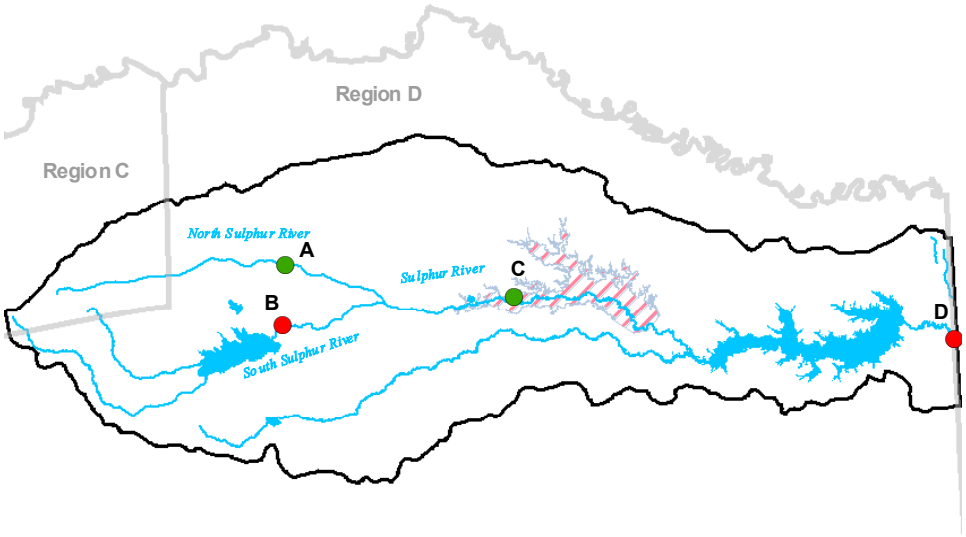
Normal Flow Conditions



Low Flow Conditions



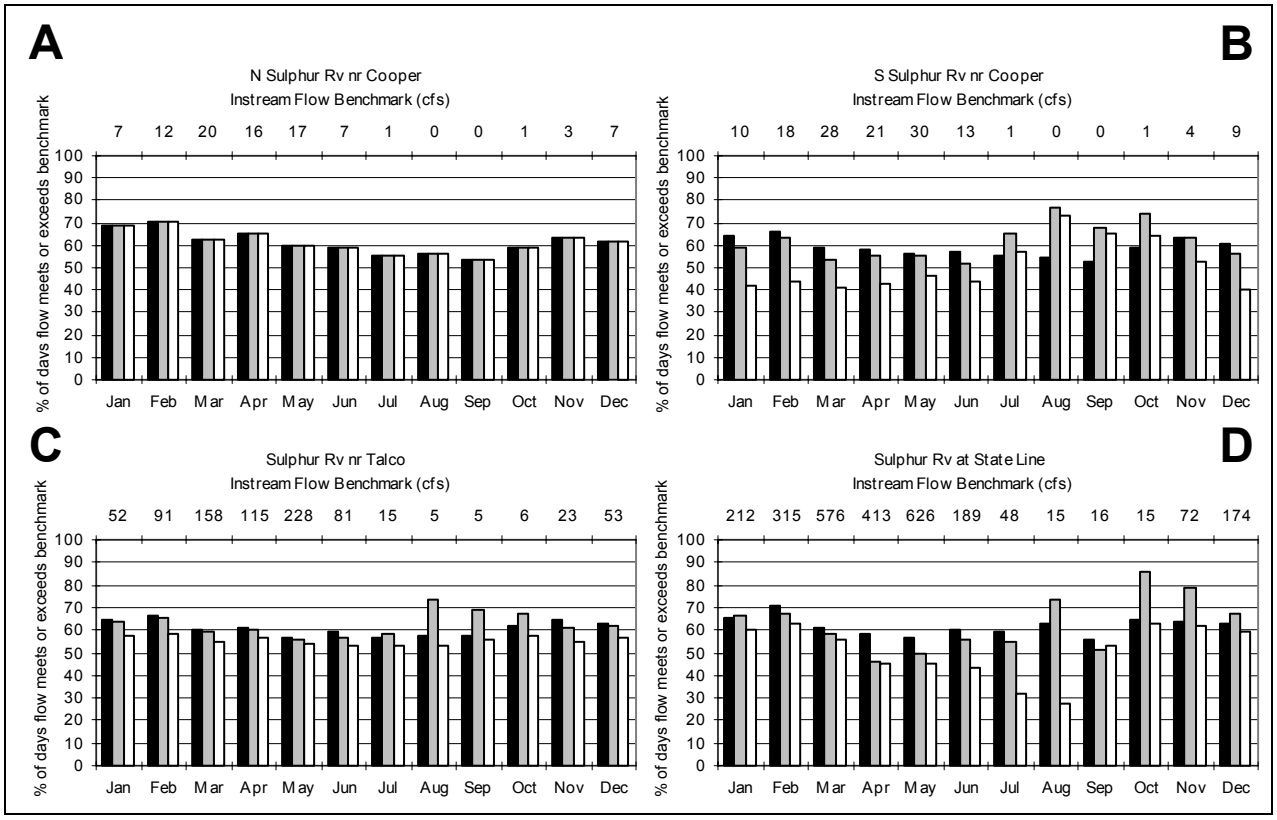
Sulphur River Basin



Instream Flow Alteration
- High (>25%)
- Medium (>10%)
- Low (<10%)

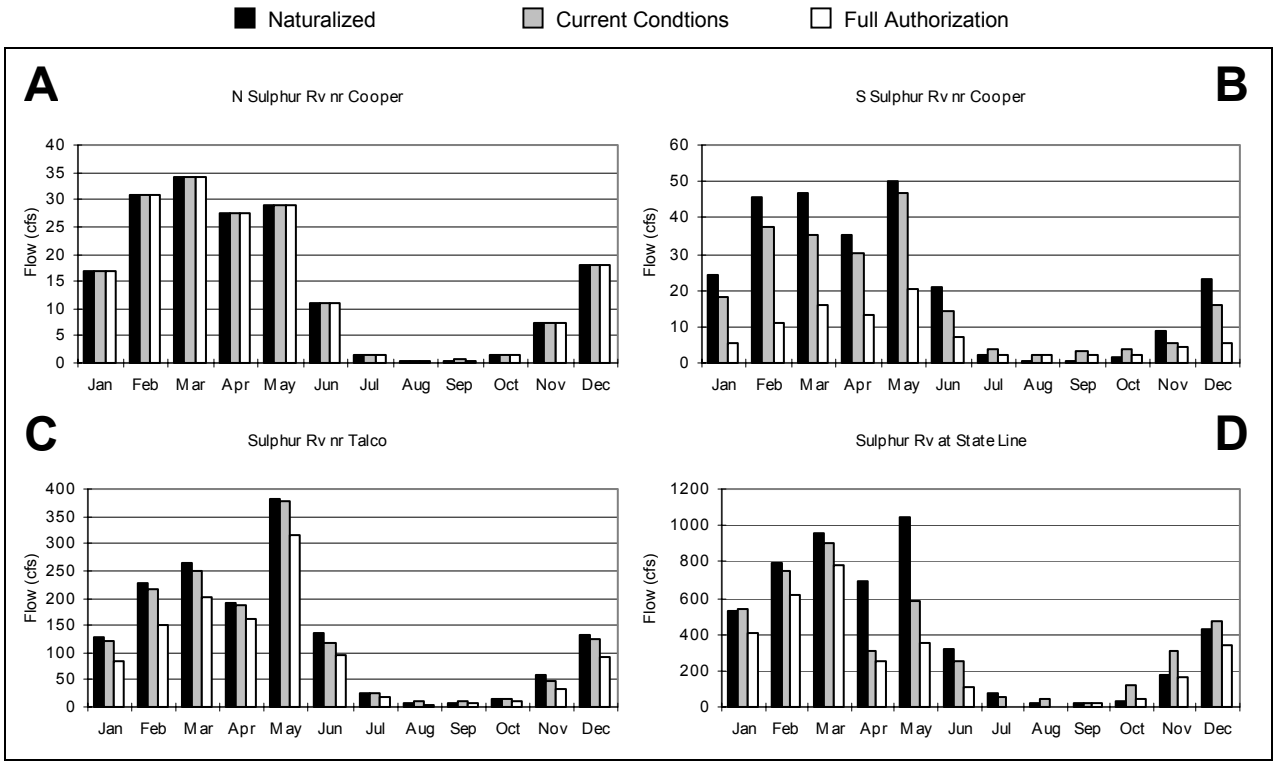
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

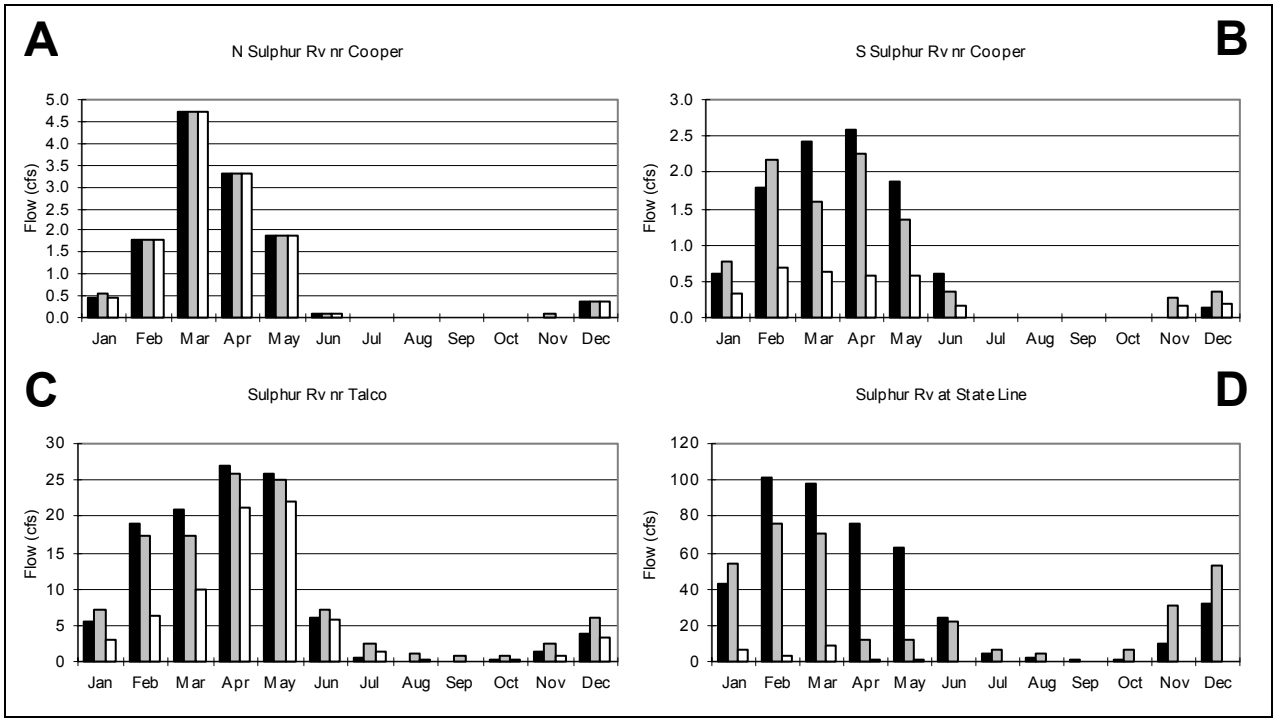


Sulphur River Basin (cont.)

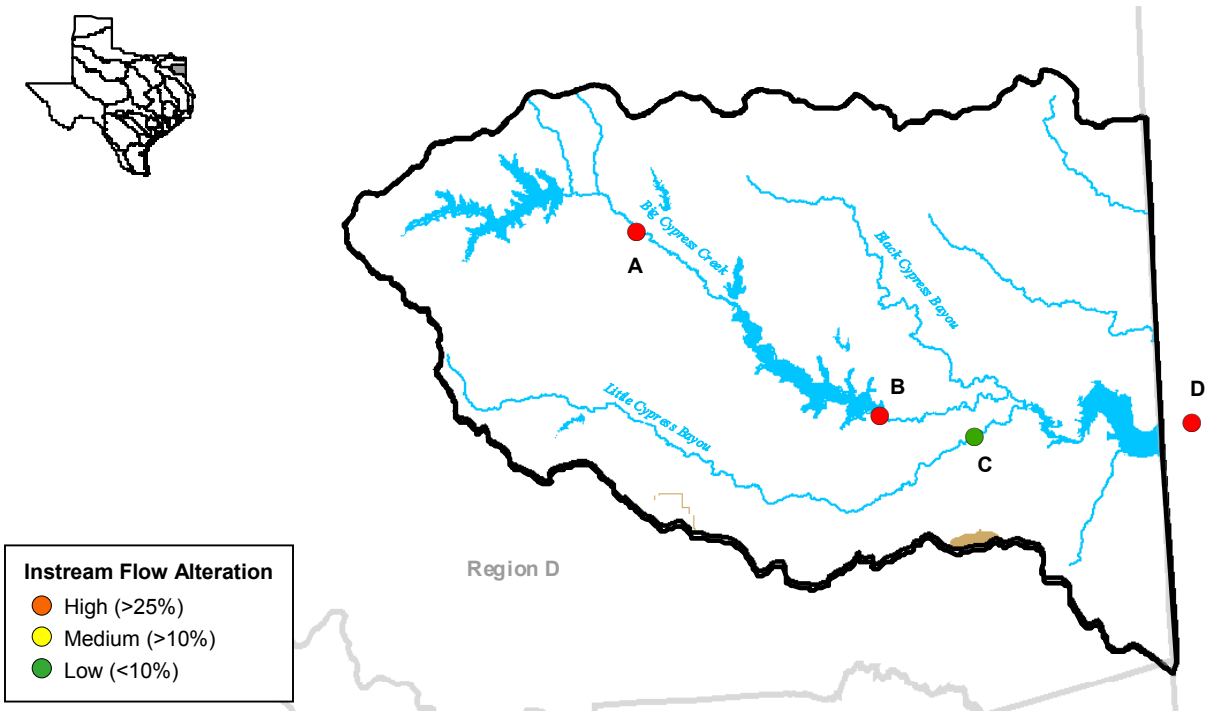
Normal Flow Conditions



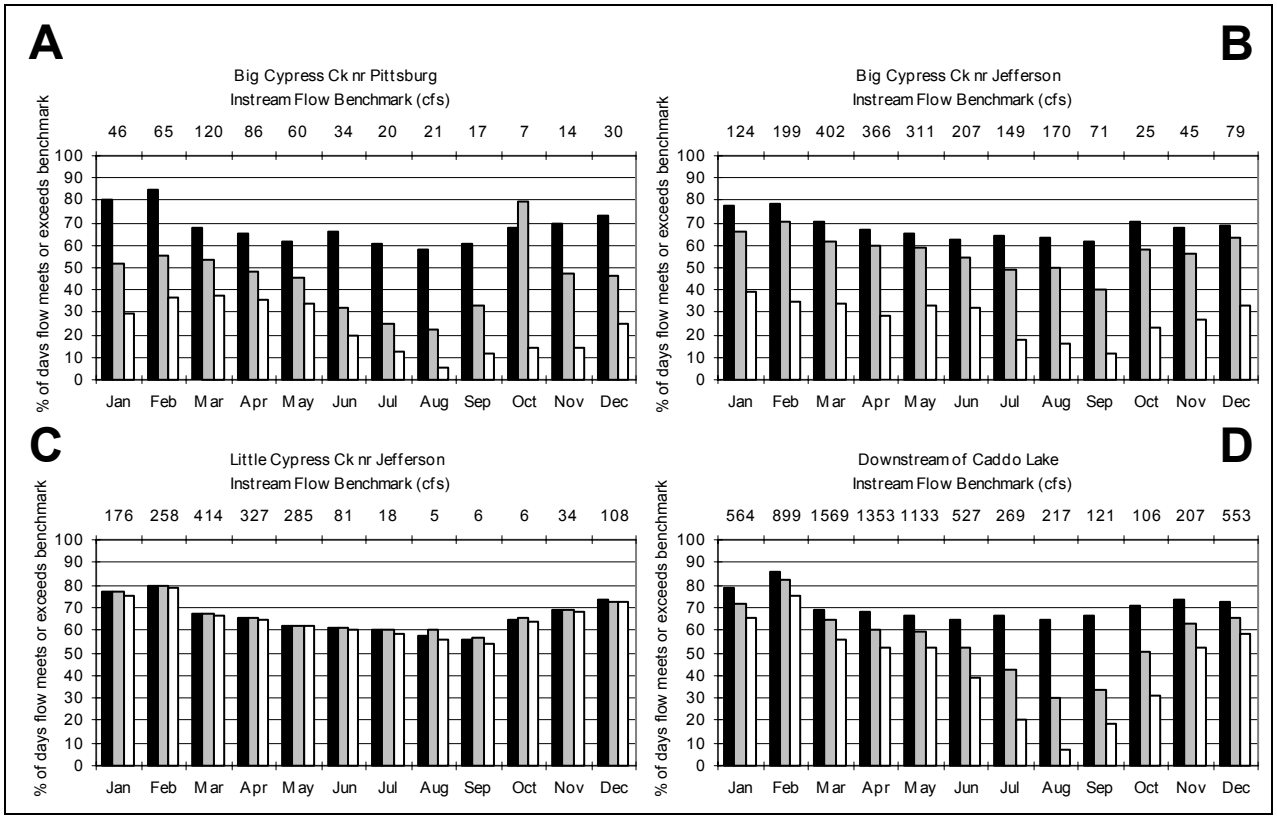
Low Flow Conditions



Cypress River Basin

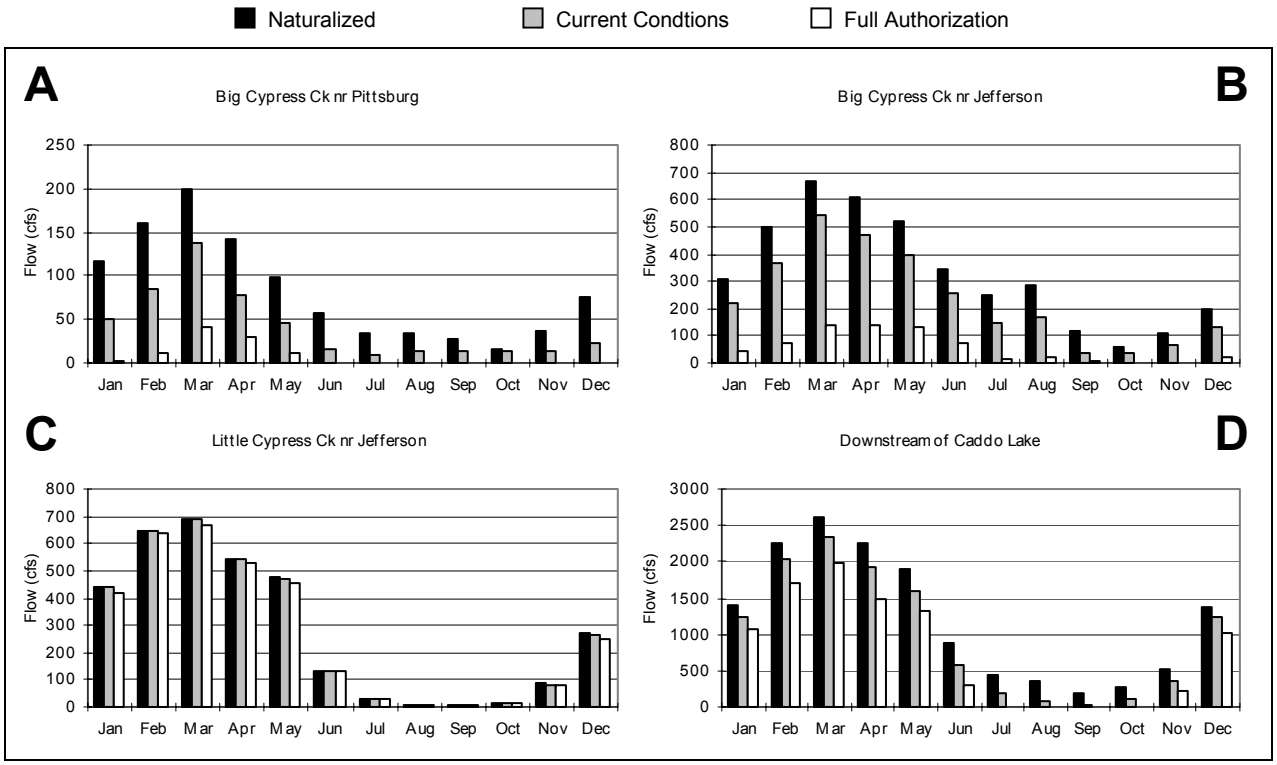


Percent of days when instream flow benchmarks are met or exceeded

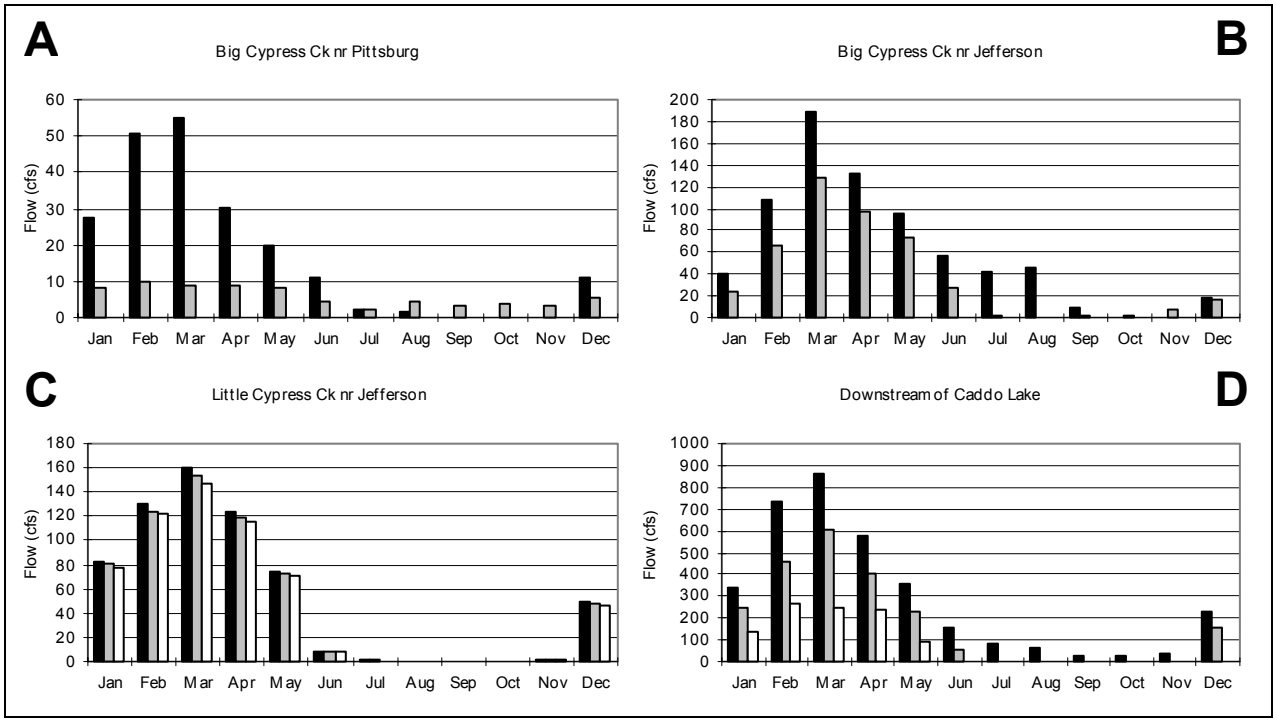


Cypress River Basin (cont.)

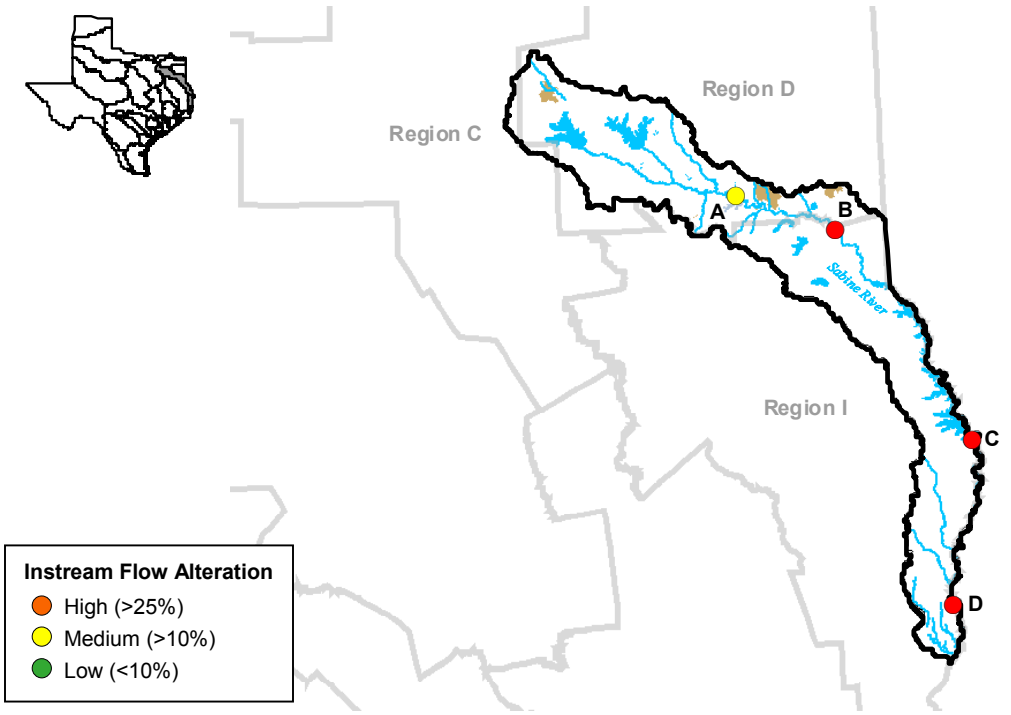
Normal Flow Conditions



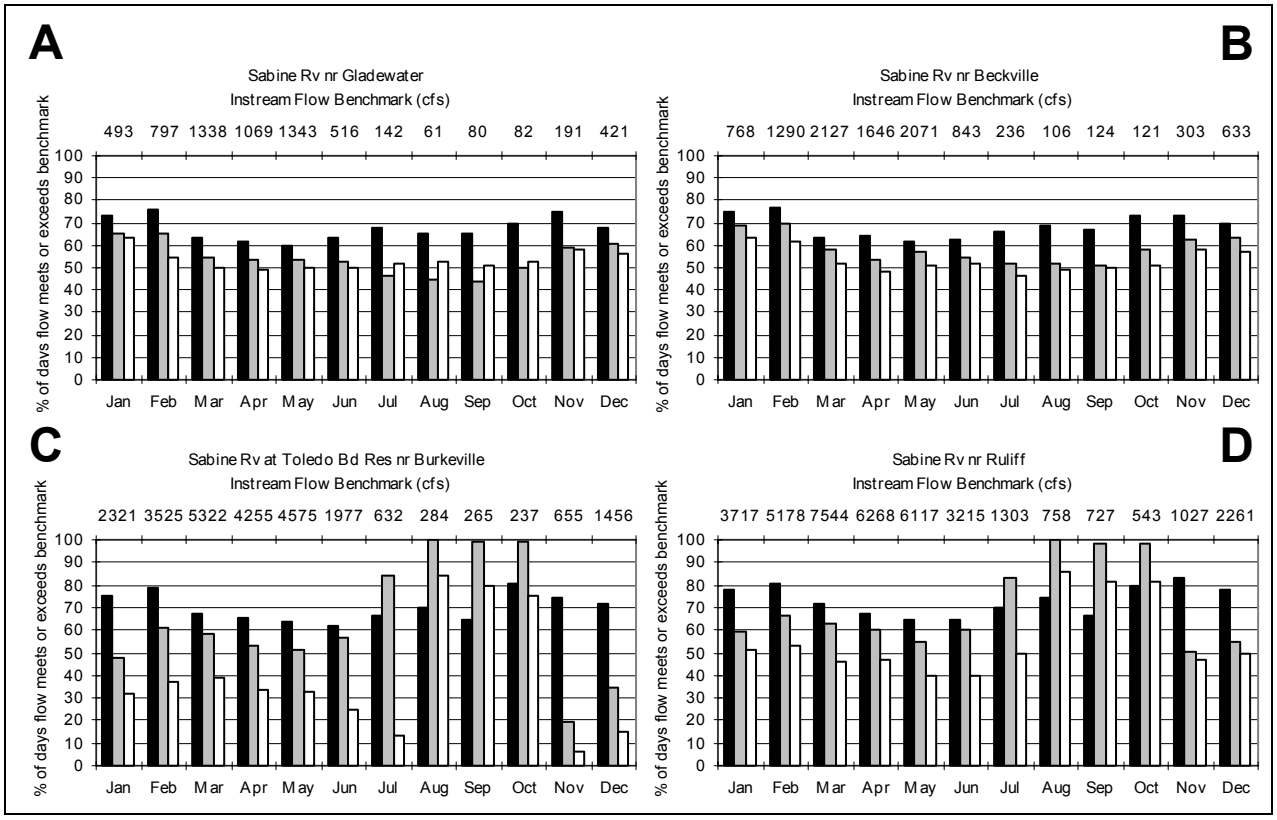
Low Flow Conditions



Sabine River Basin

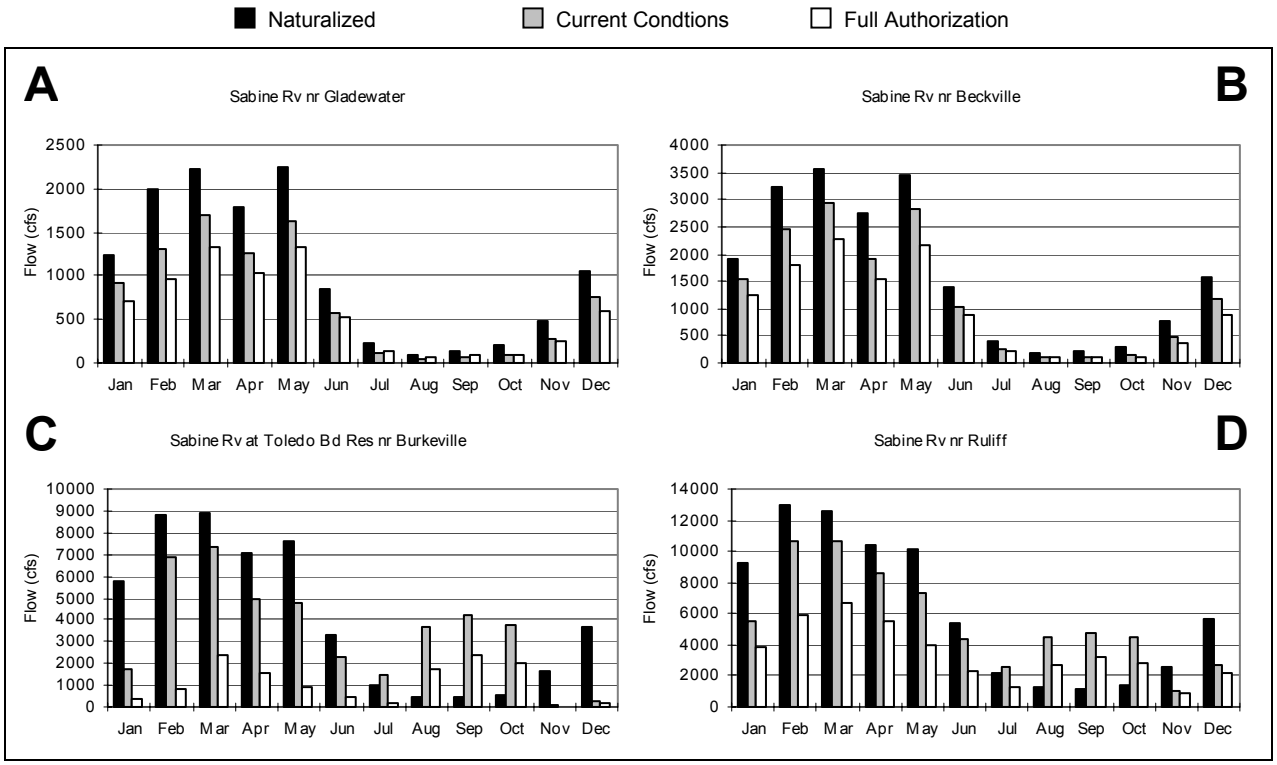


Percent of days when instream flow benchmarks are met or exceeded

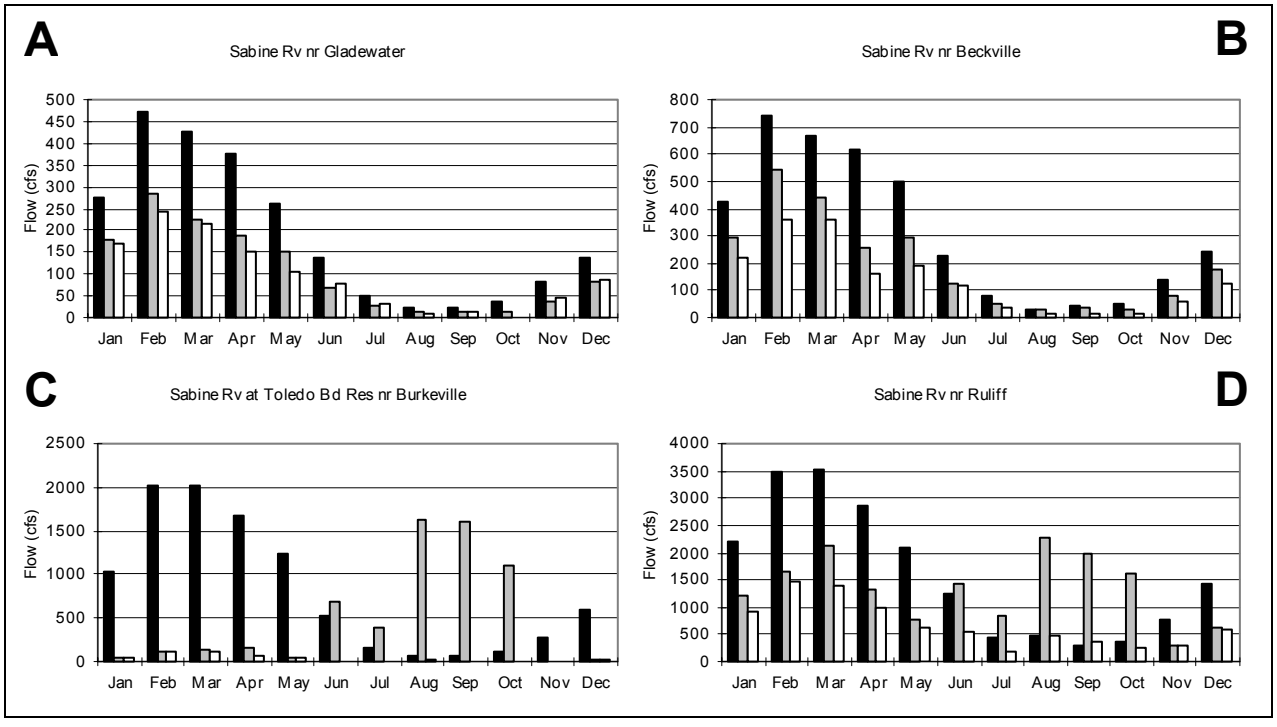


Sabine River Basin (cont.)

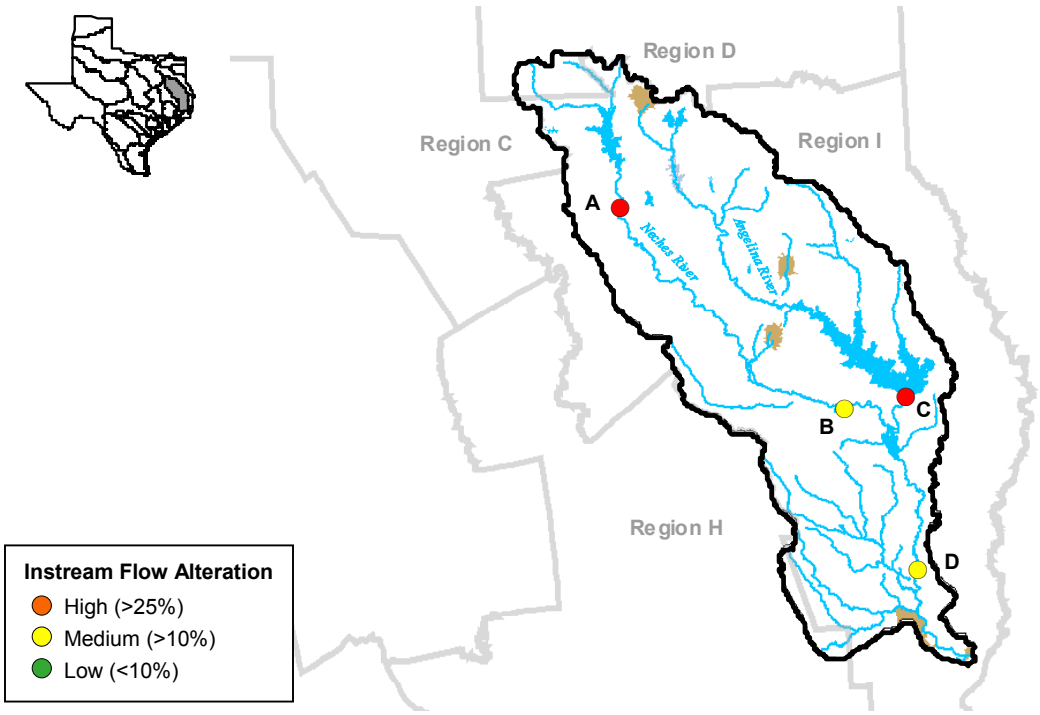
Normal Flow Conditions



Low Flow Conditions

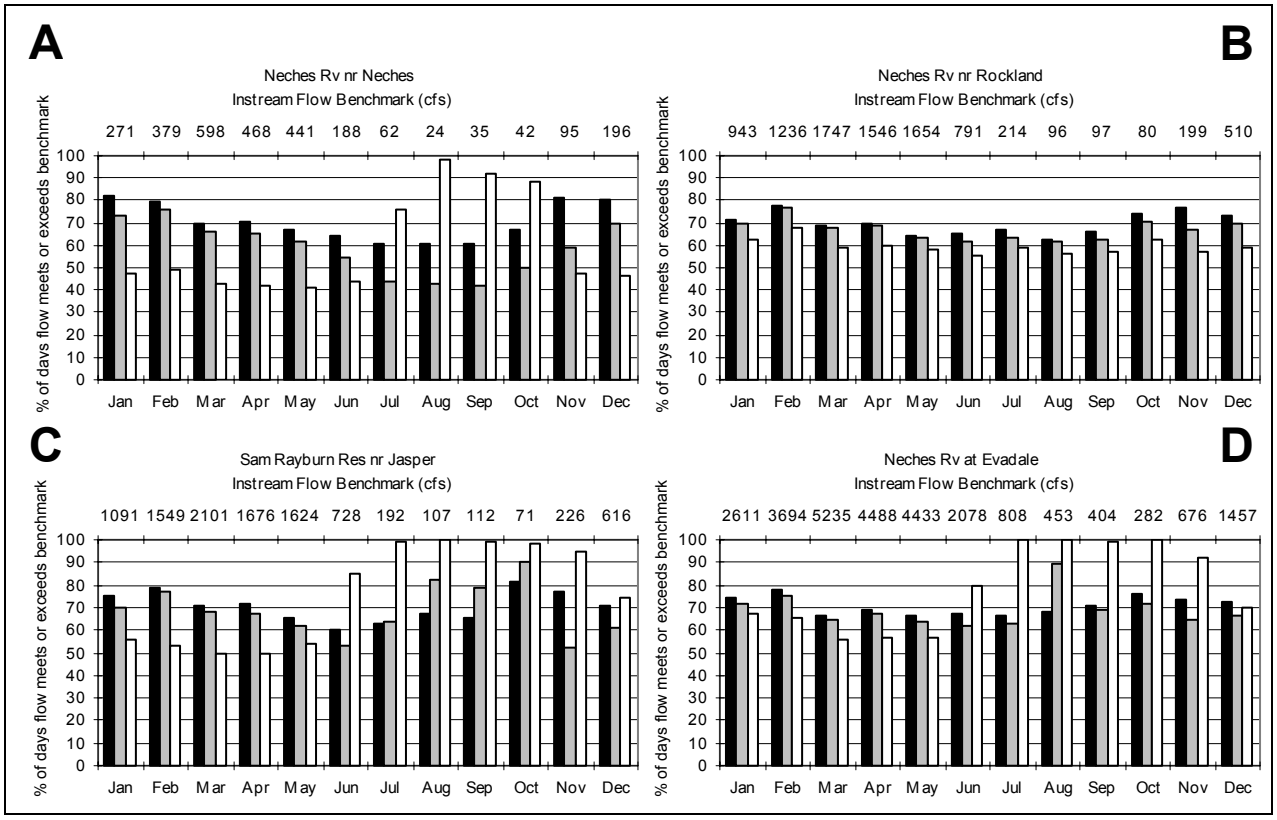


Neches River Basin



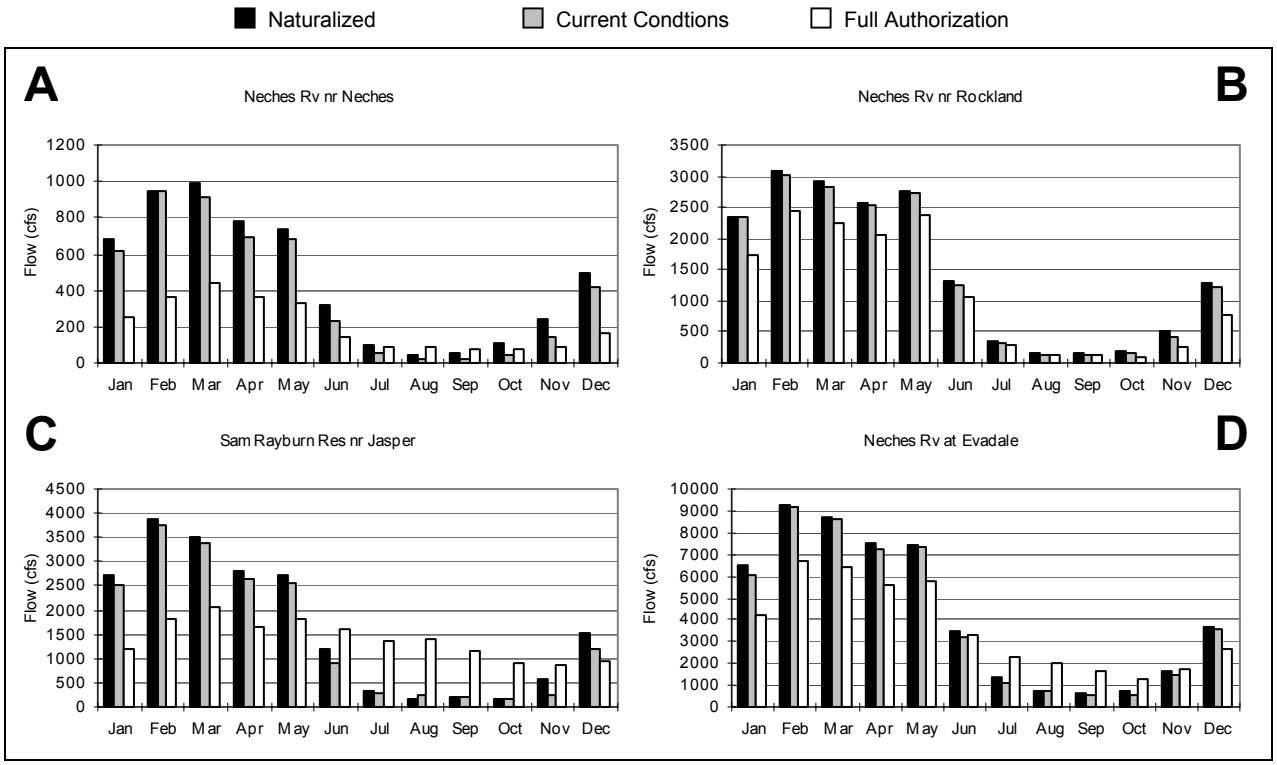
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

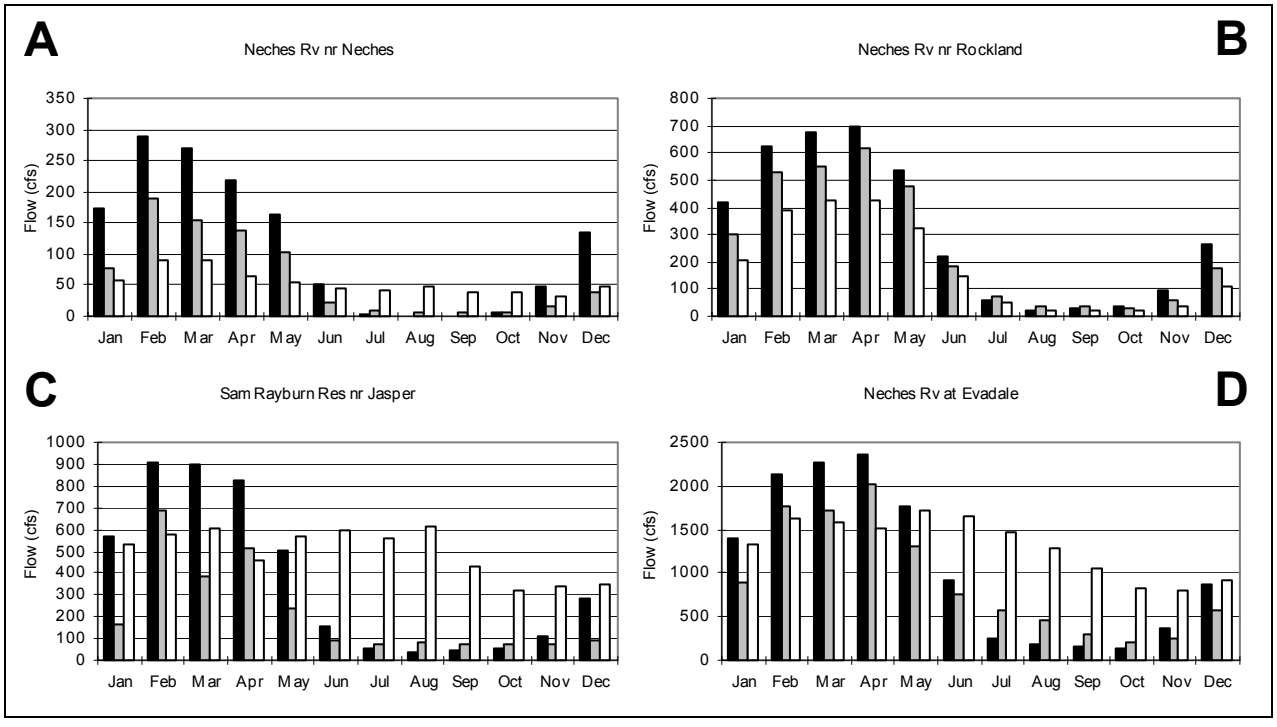


Neches River Basin (cont.)

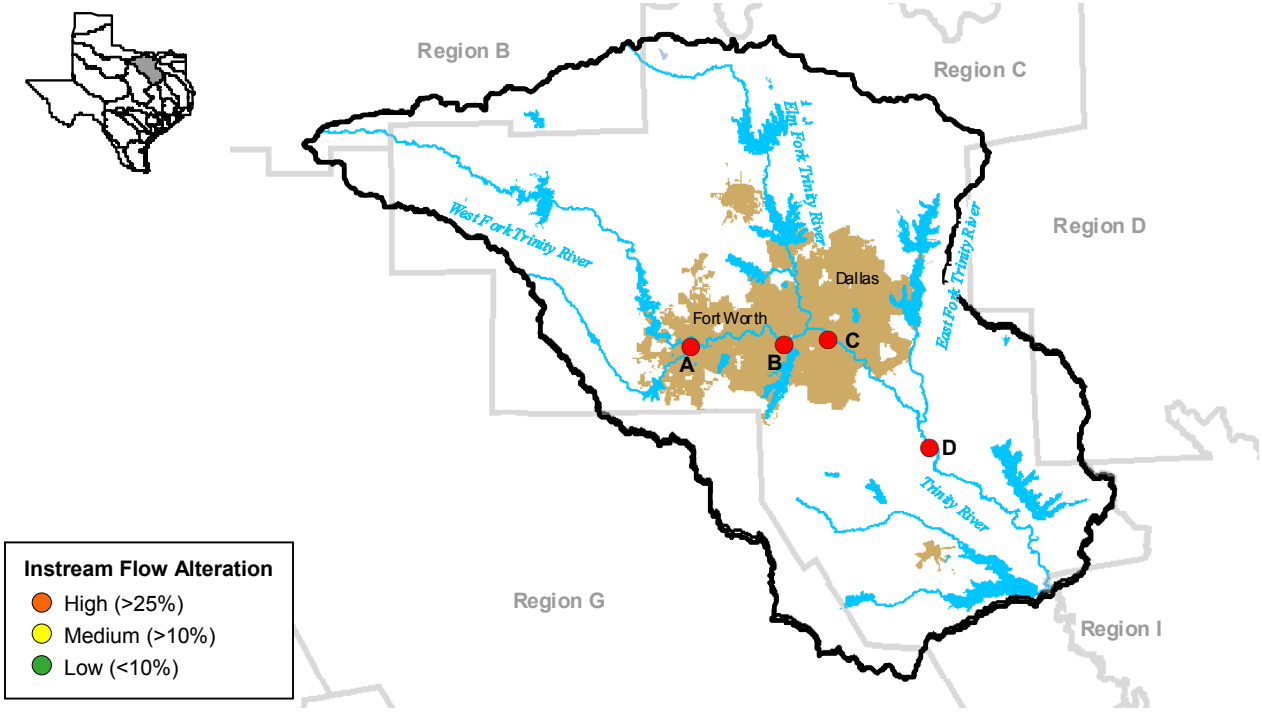
Normal Flow Conditions



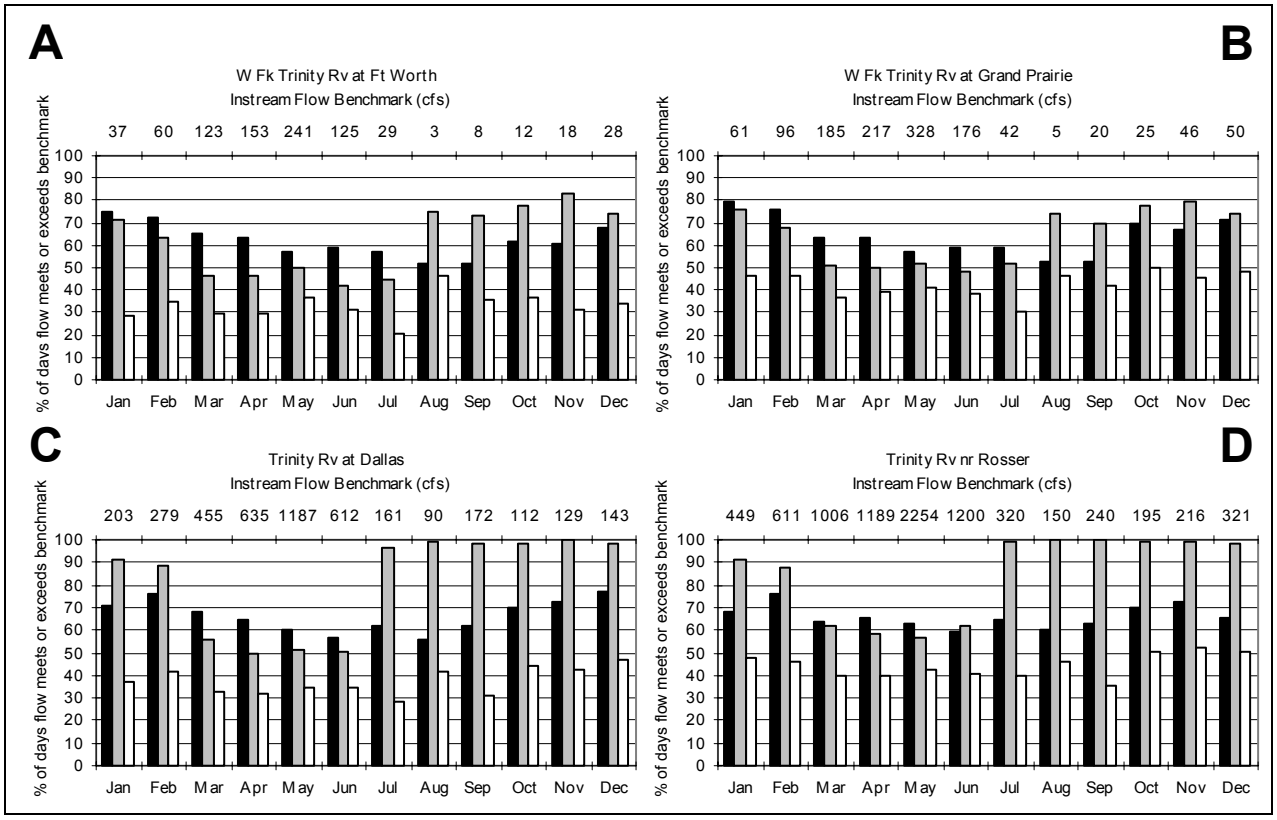
Low Flow Conditions



Upper Trinity River Basin

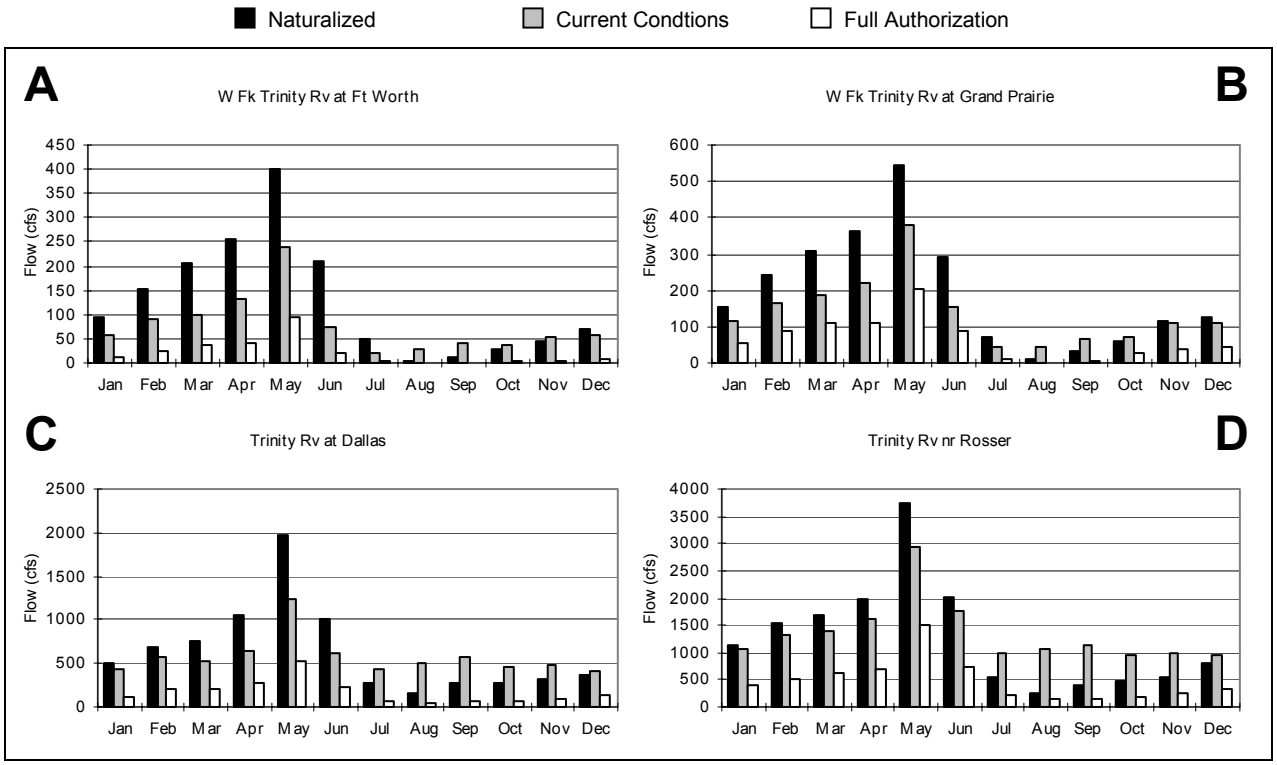


Percent of days when instream flow benchmarks are met or exceeded



Upper Trinity River Basin (cont.)

Normal Flow Conditions



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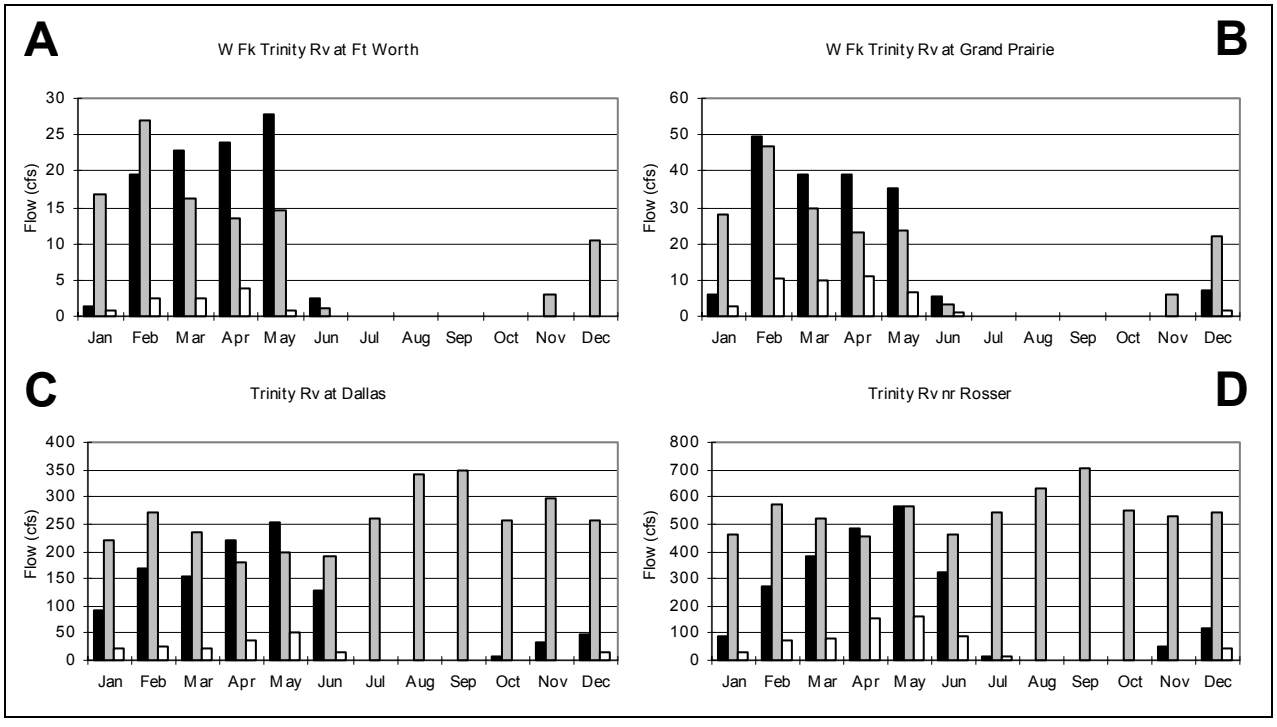
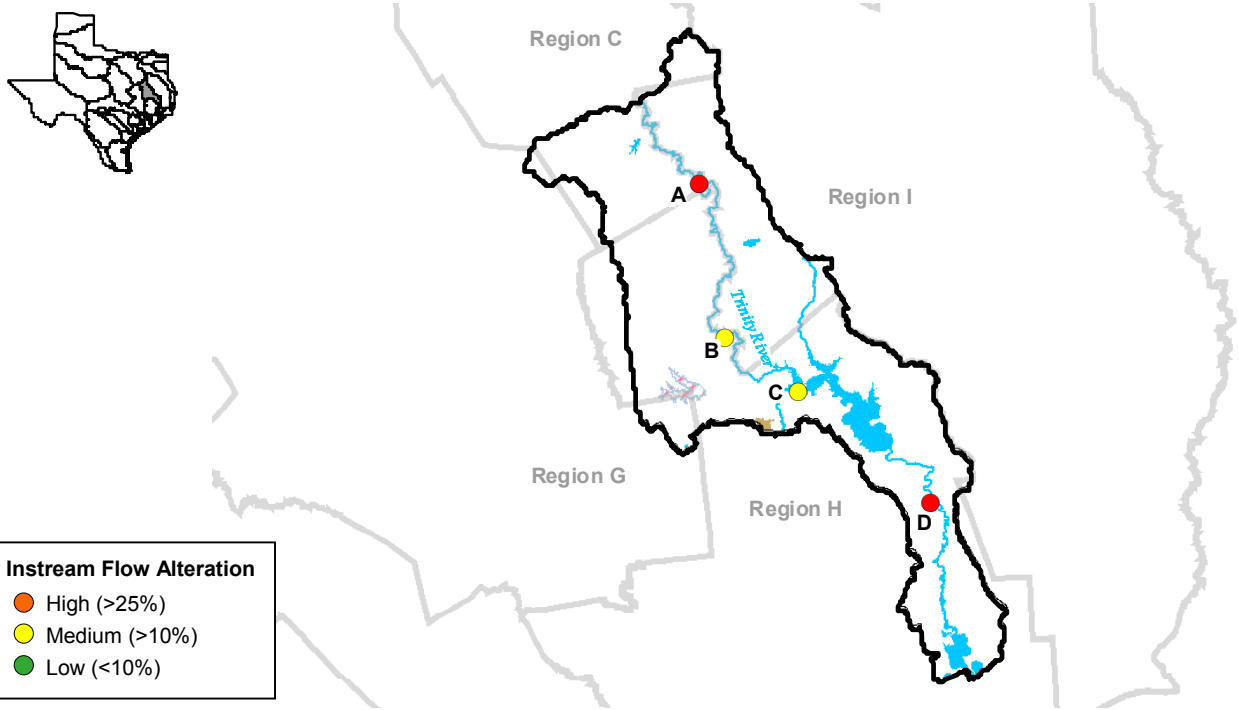
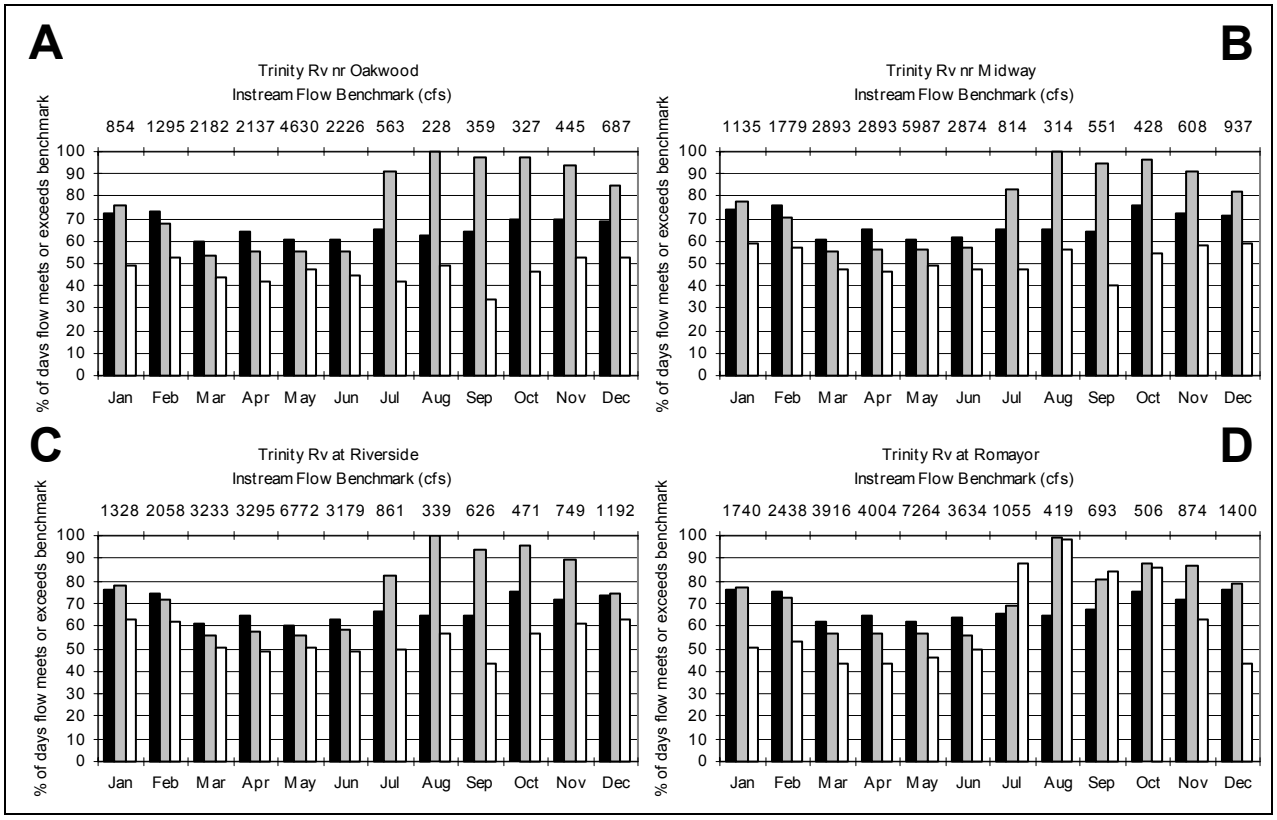


Lower Trinity River Basin



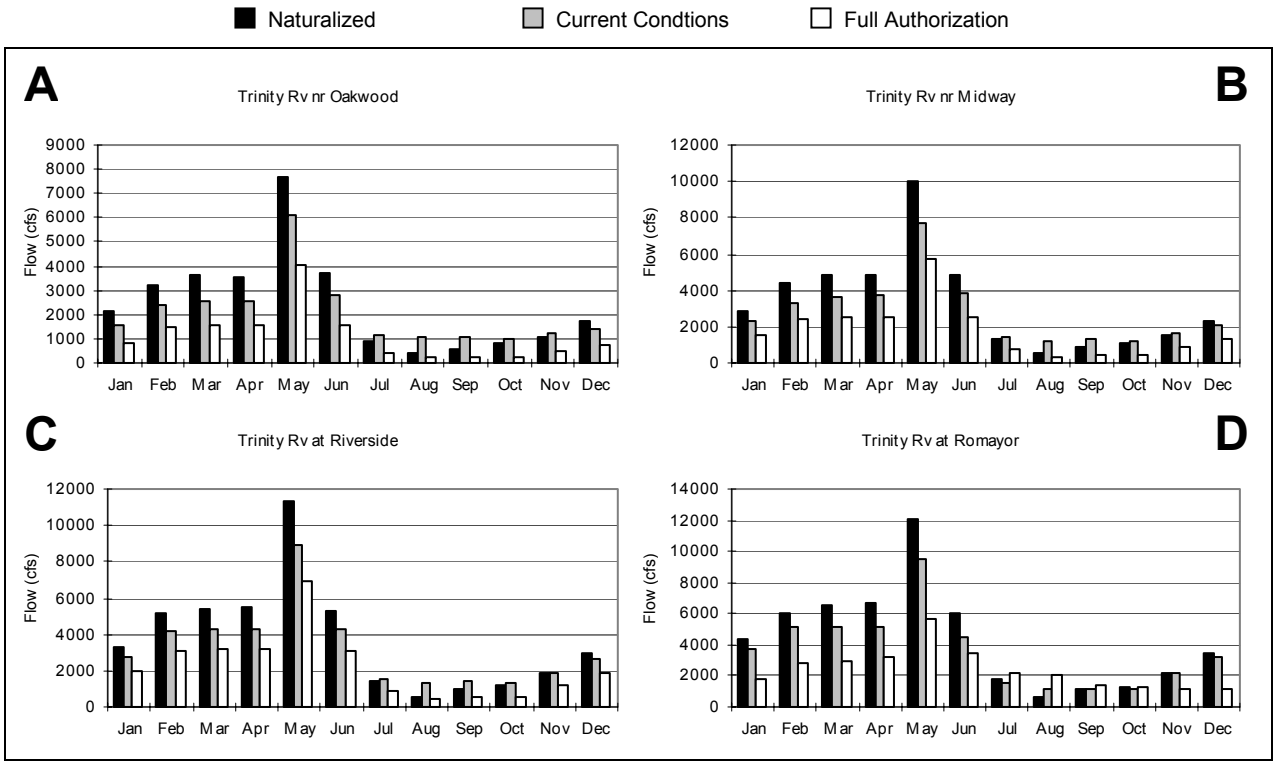
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

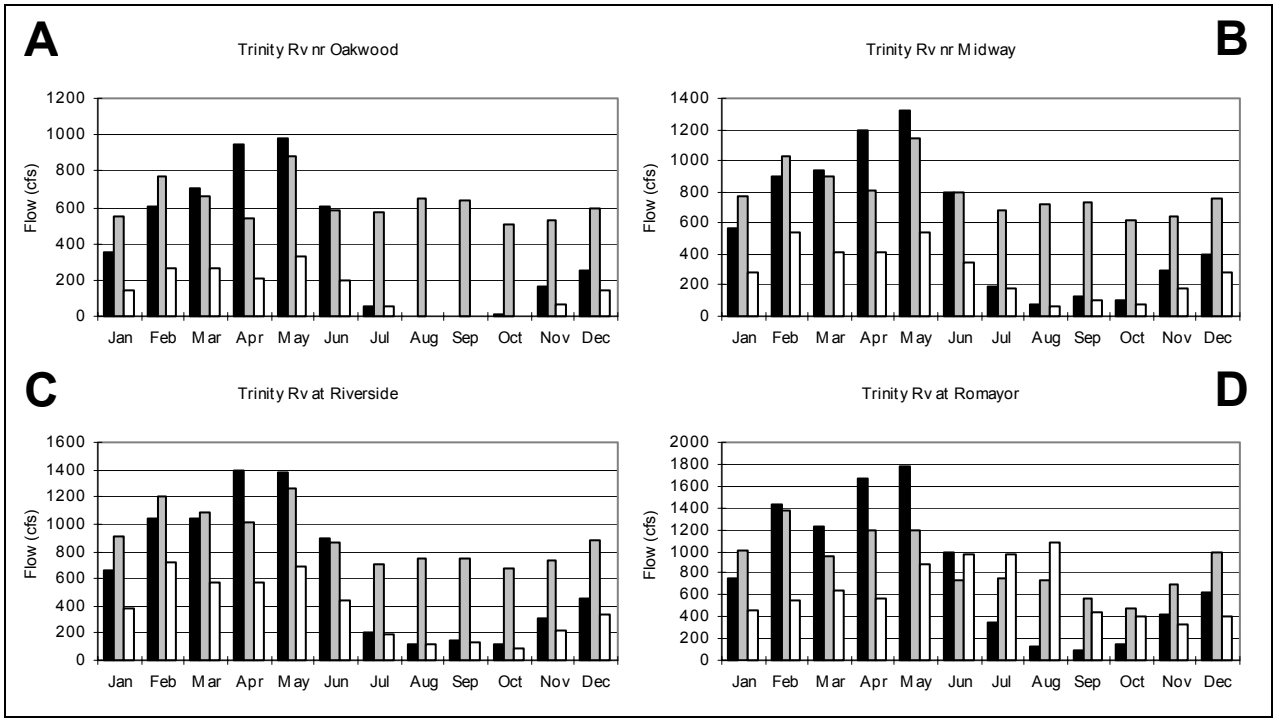


Lower Trinity River Basin (cont.)

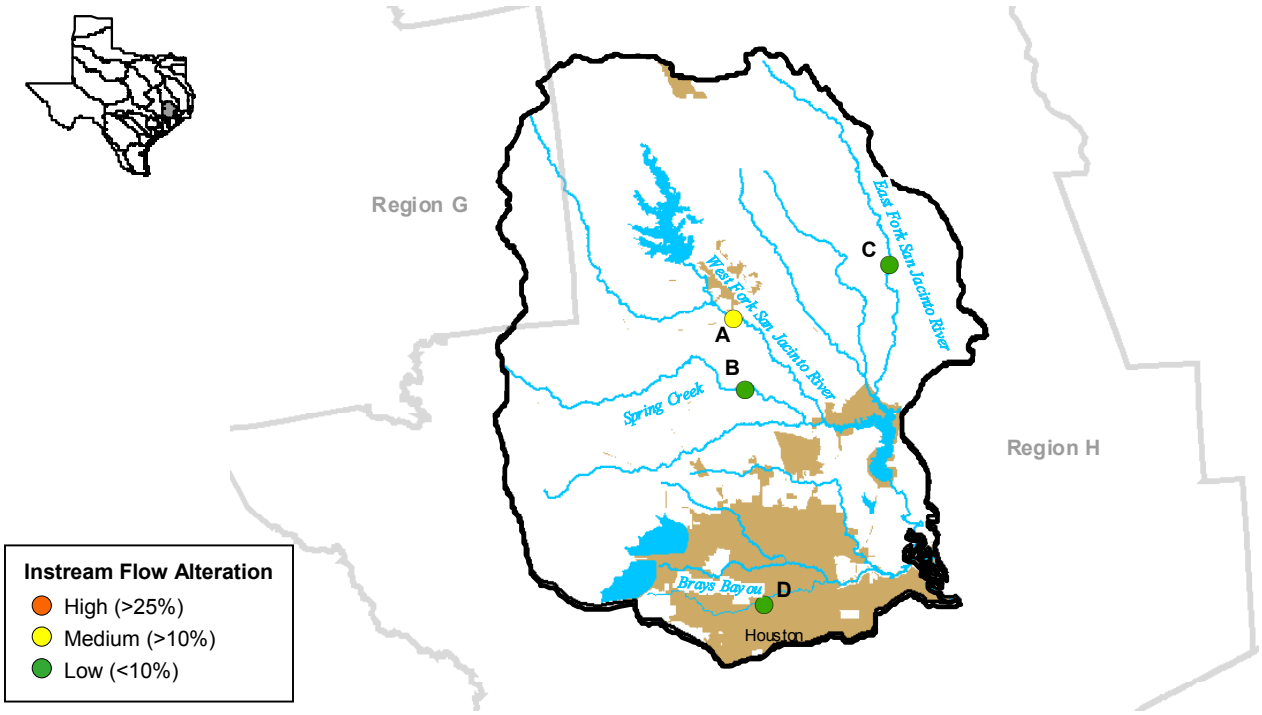
Normal Flow Conditions



Low Flow Conditions

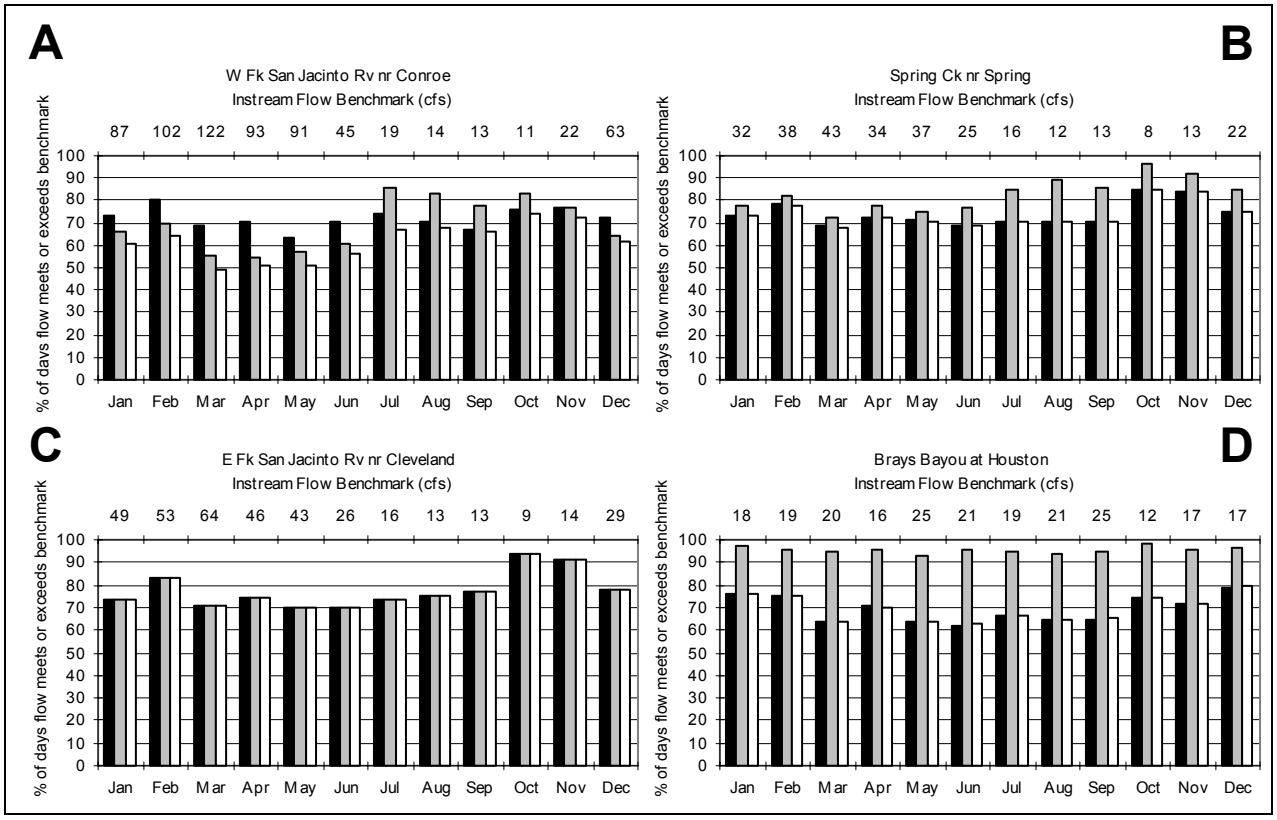


San Jacinto River Basin



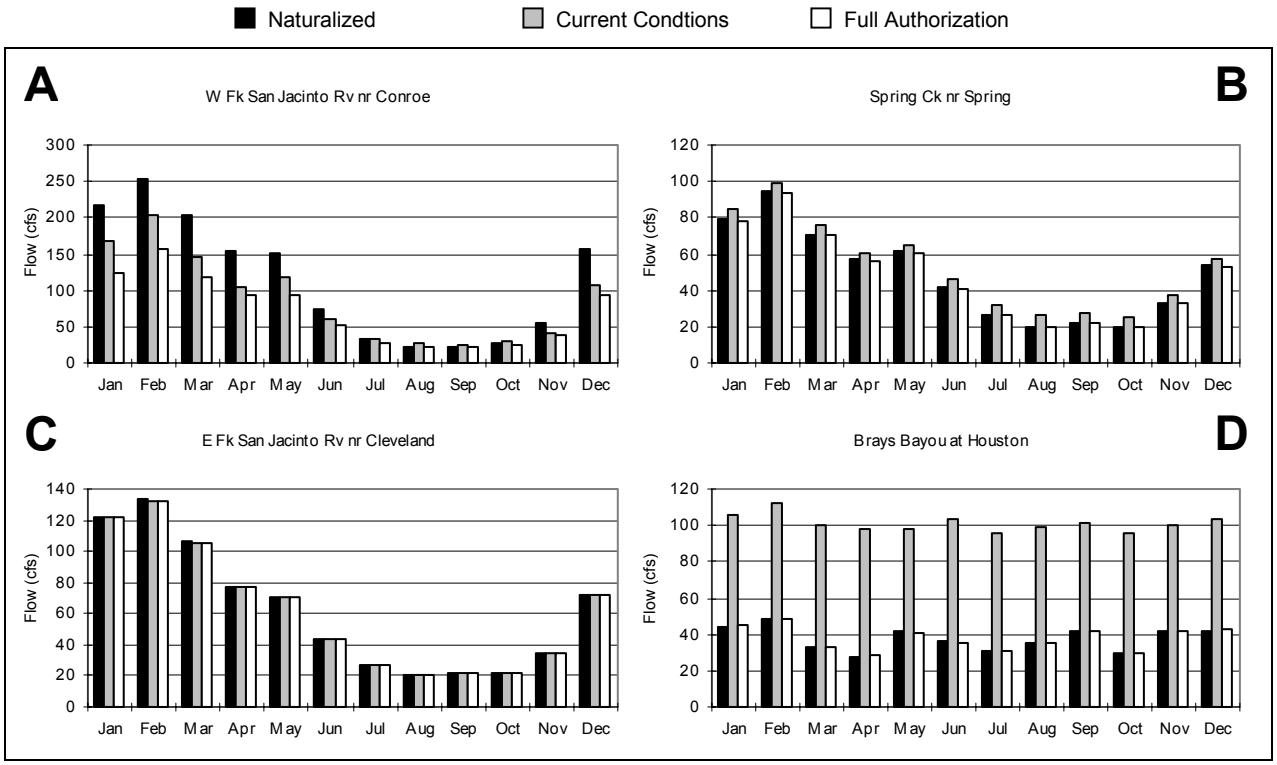
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

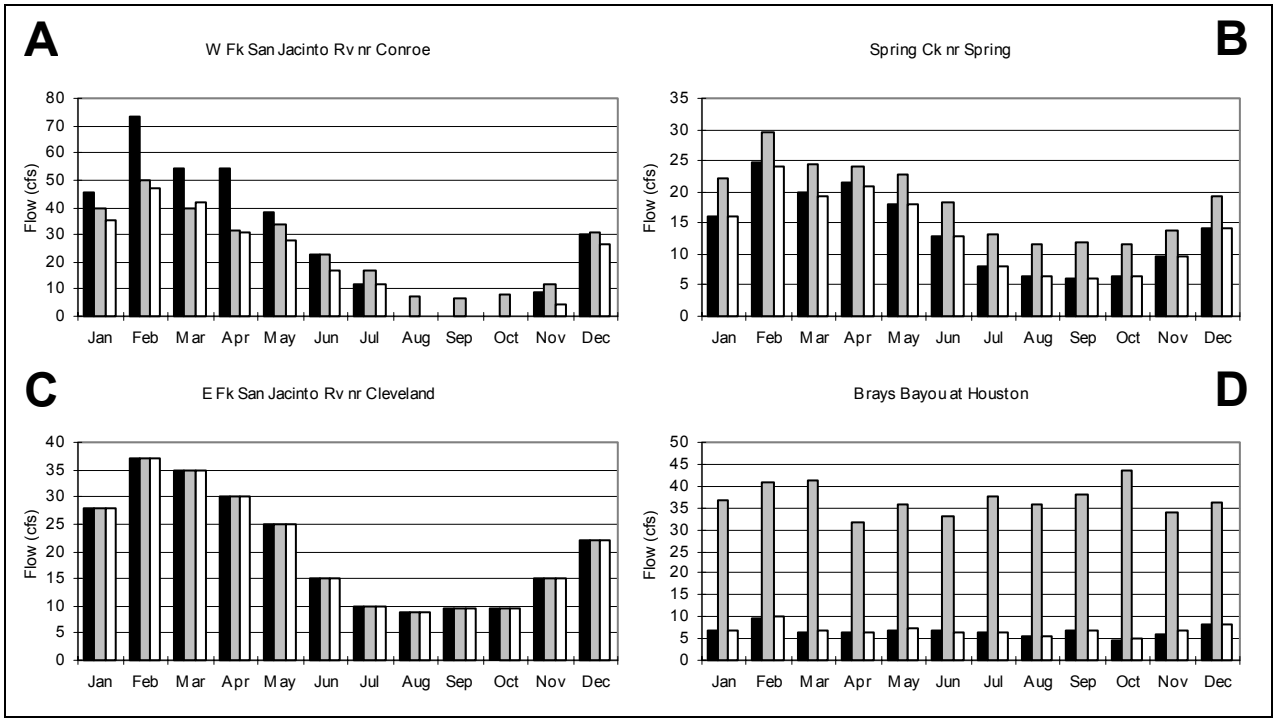


San Jacinto River Basin (cont.)

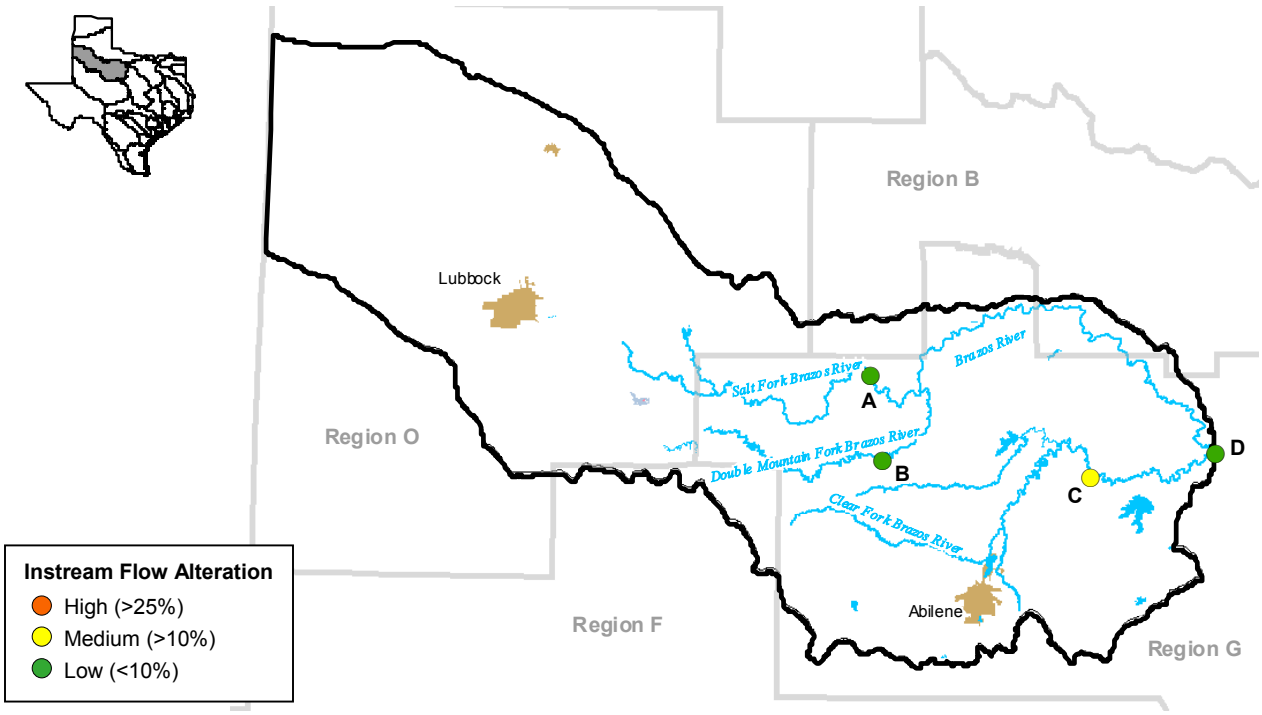
Normal Flow Conditions



Low Flow Conditions

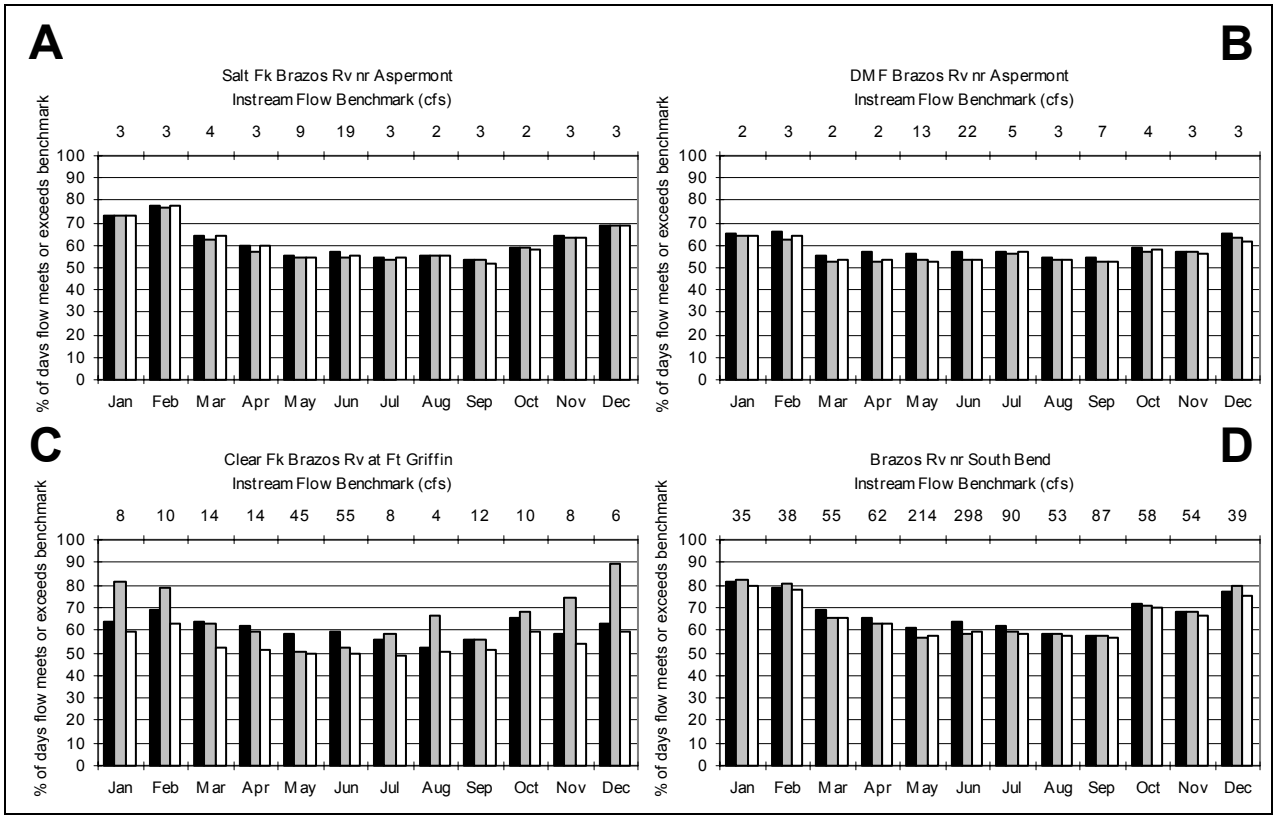


Upper Brazos River Basin



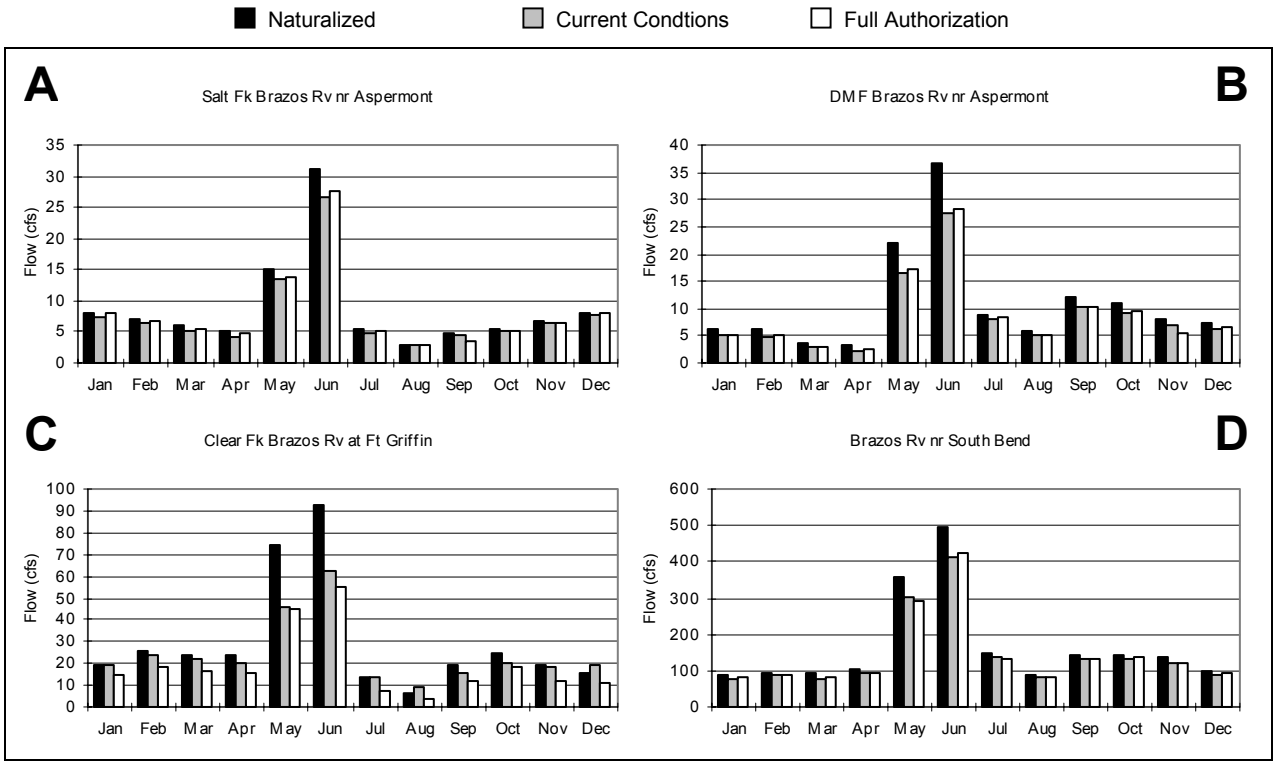
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

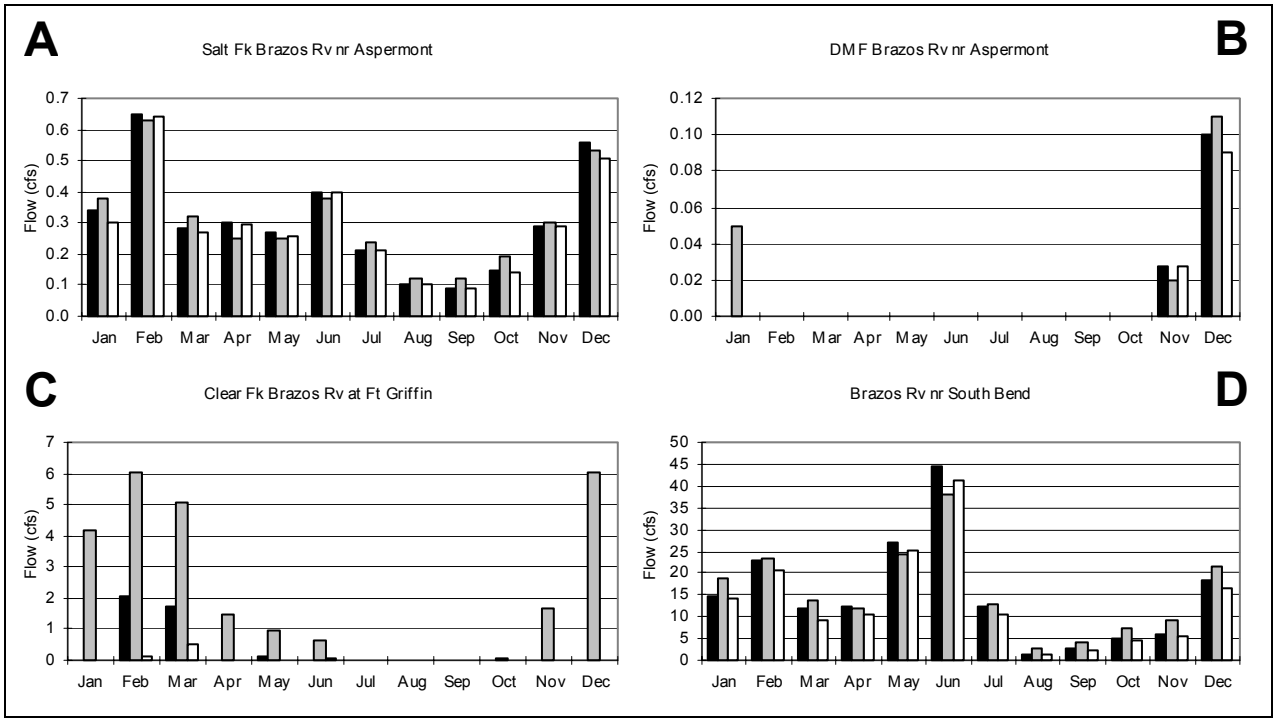


Upper Brazos River Basin (cont.)

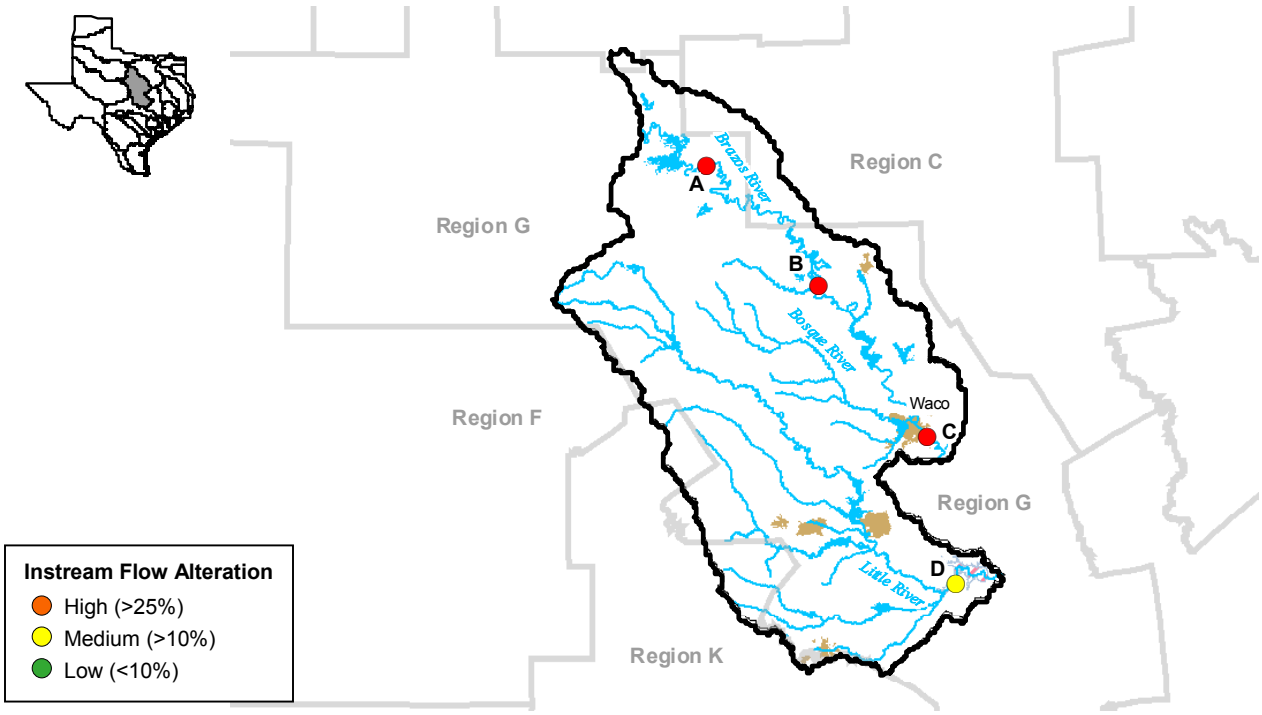
Normal Flow Conditions



Low Flow Conditions

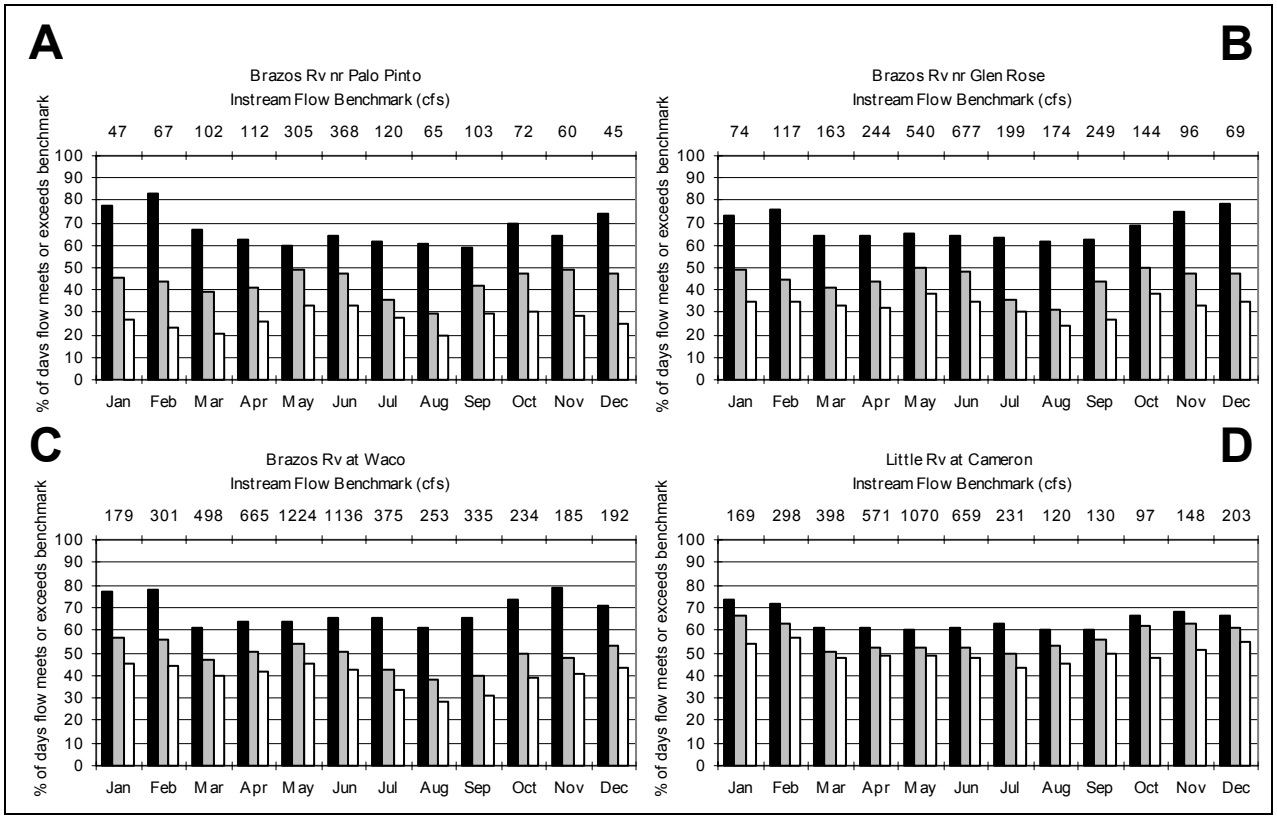


Middle Brazos River Basin



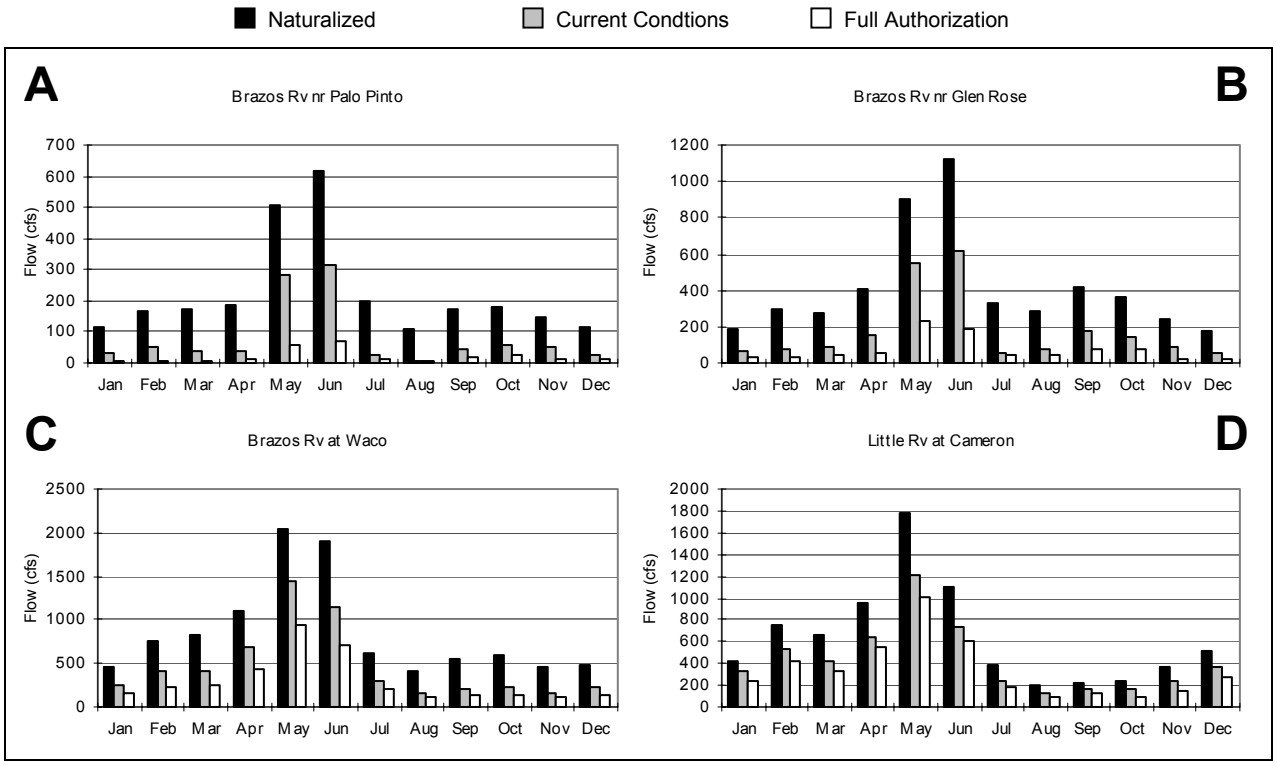
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

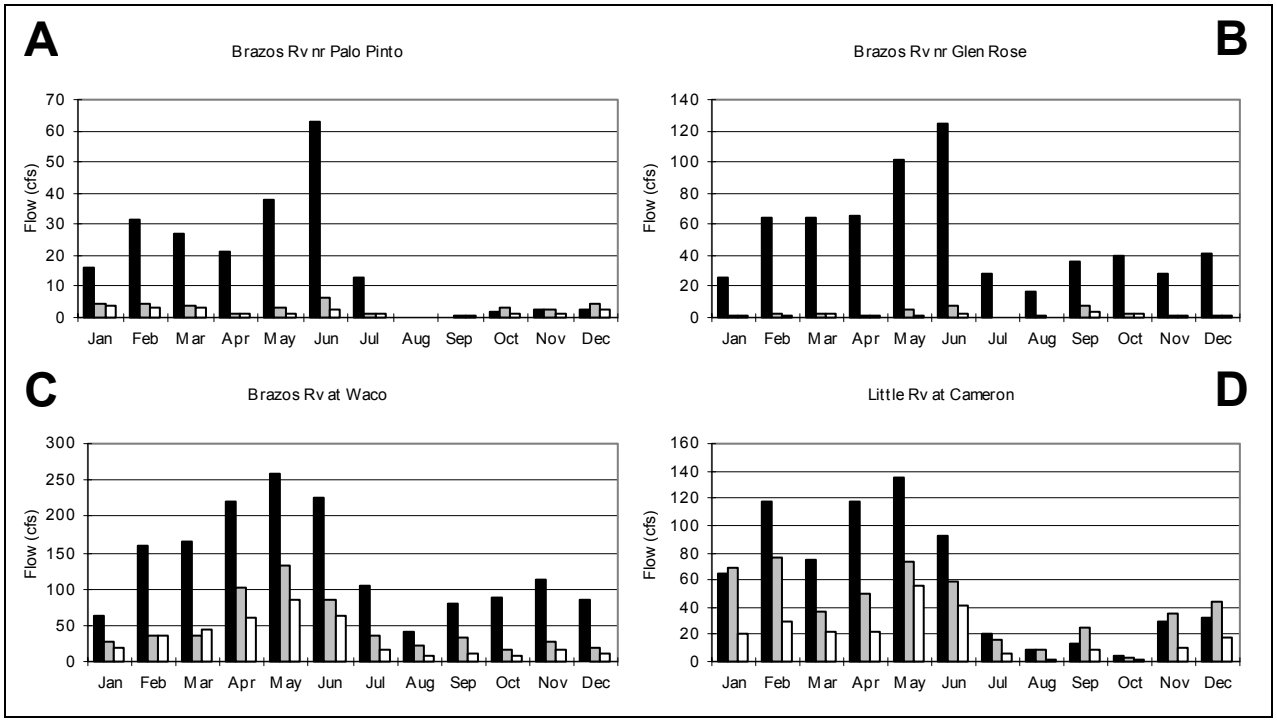


Middle Brazos River Basin (cont.)

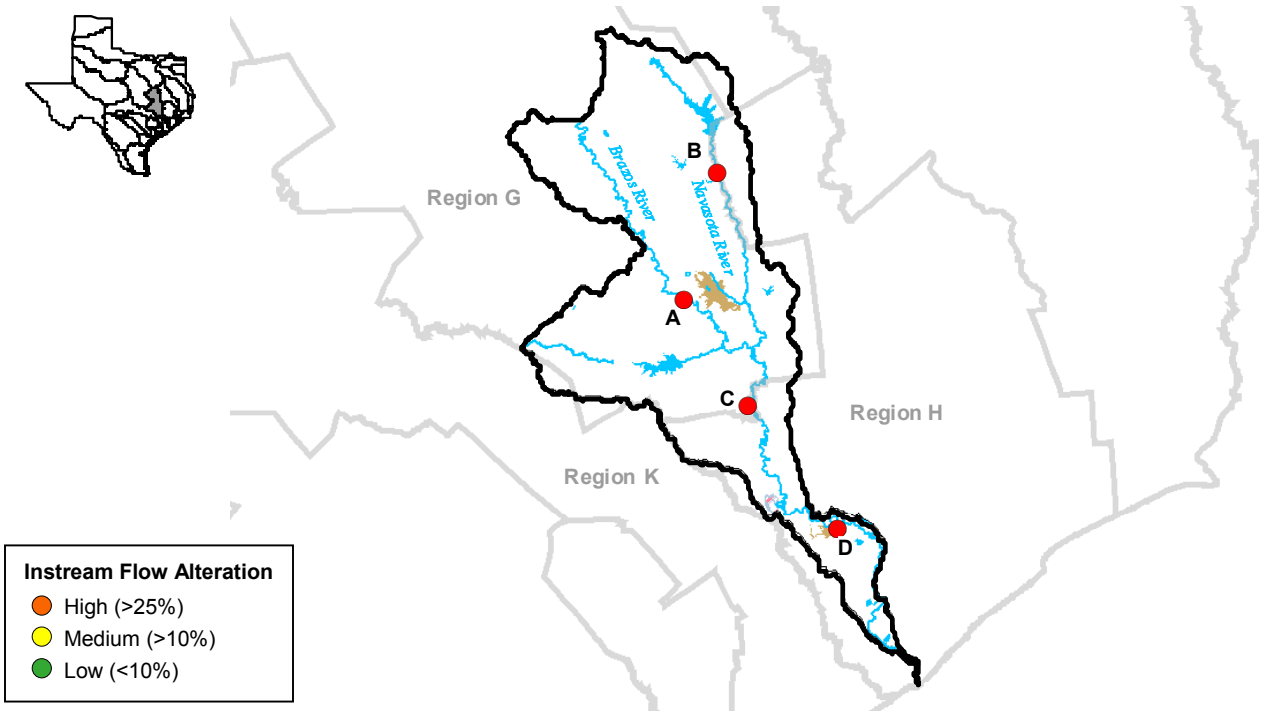
Normal Flow Conditions



Low Flow Conditions

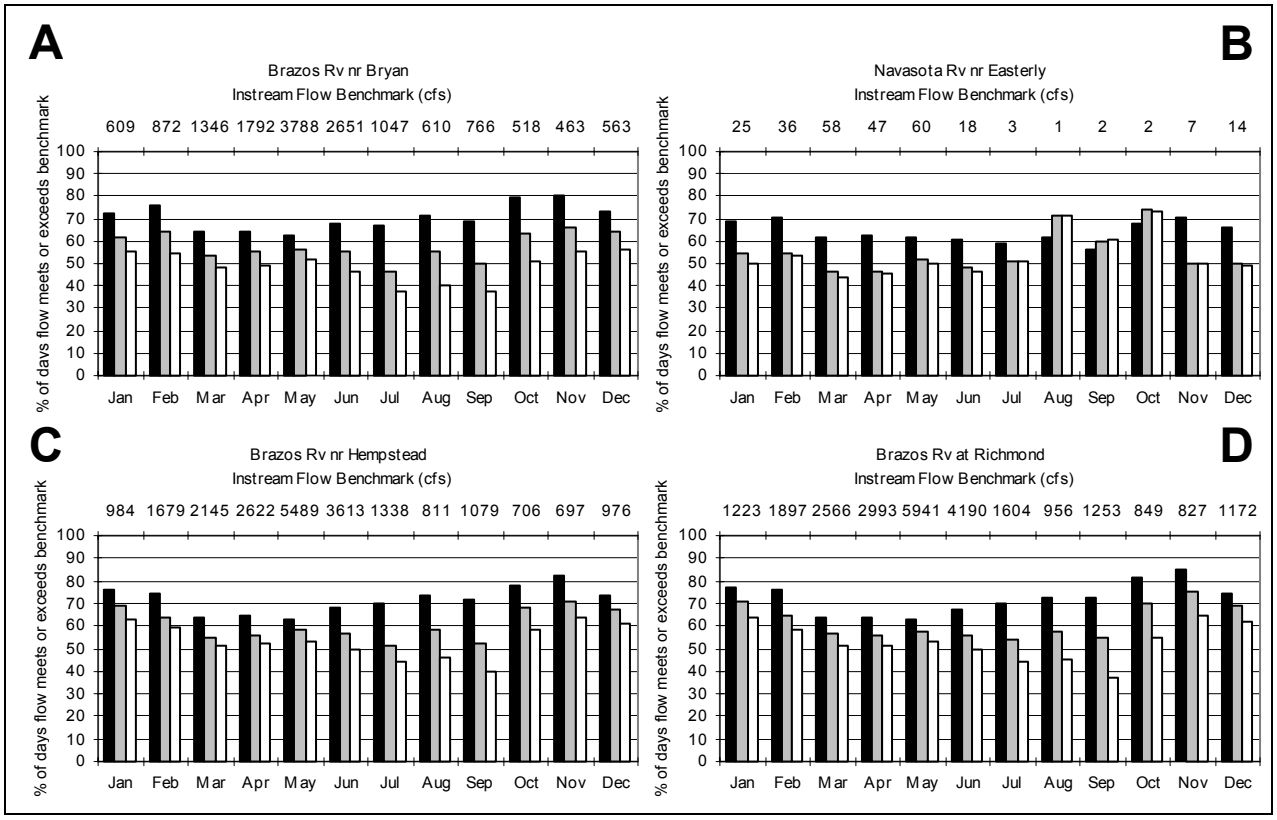


Lower Brazos River Basin



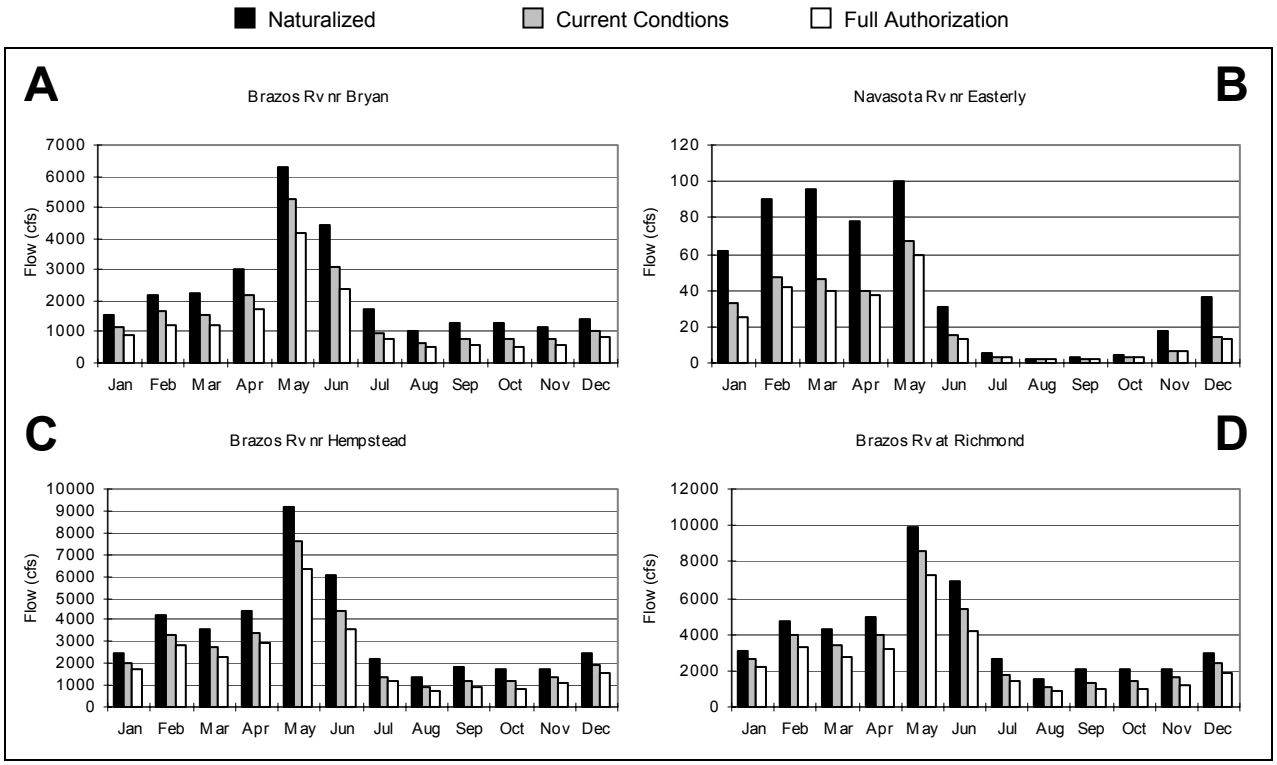
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

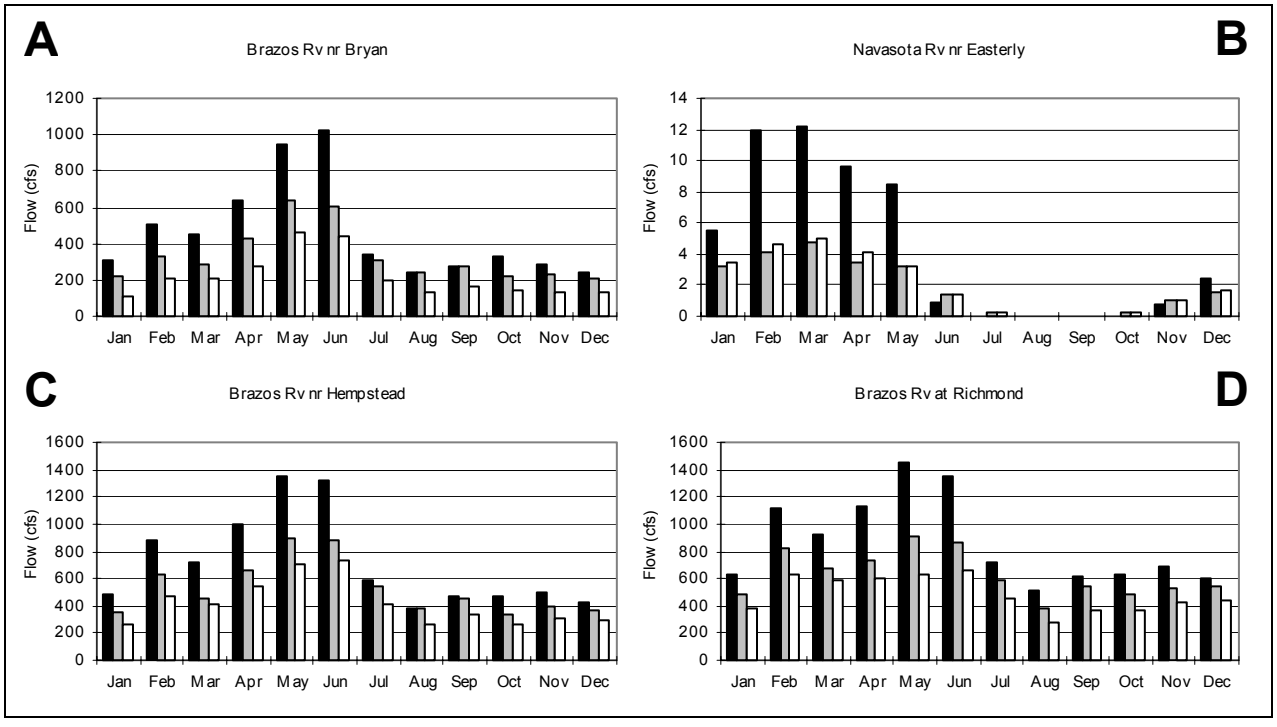


Lower Brazos River Basin (cont.)

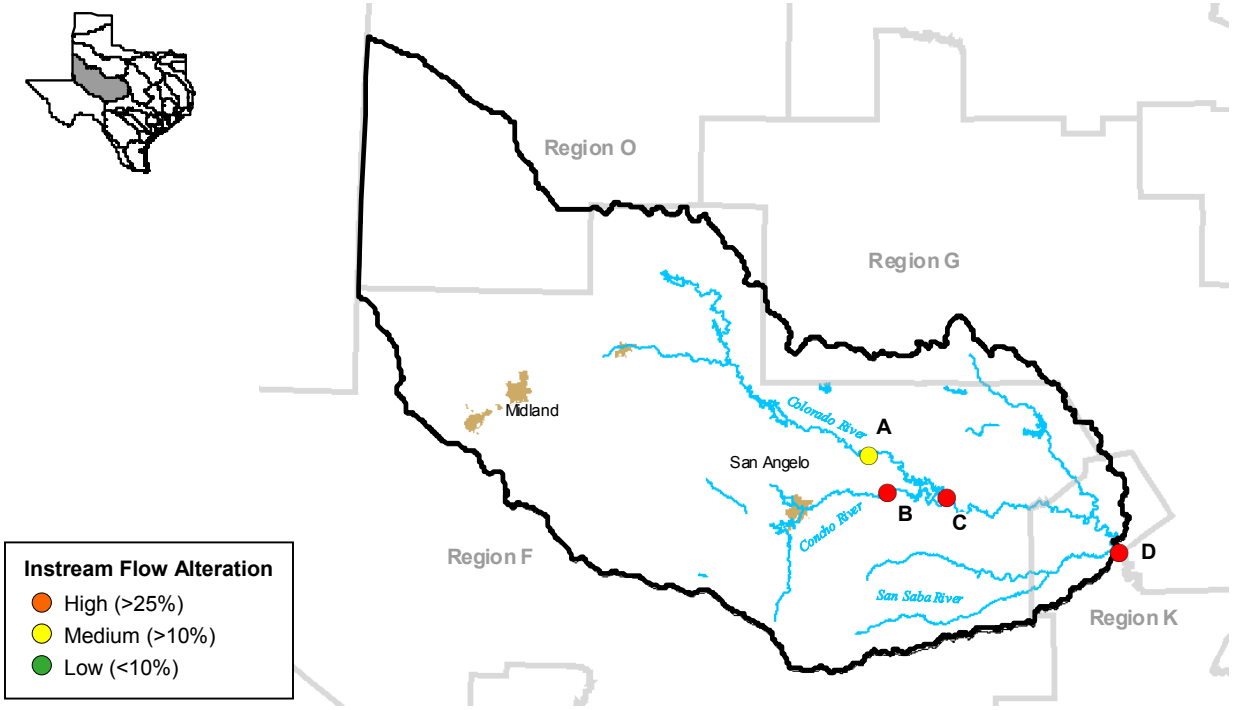
Normal Flow Conditions



Low Flow Conditions

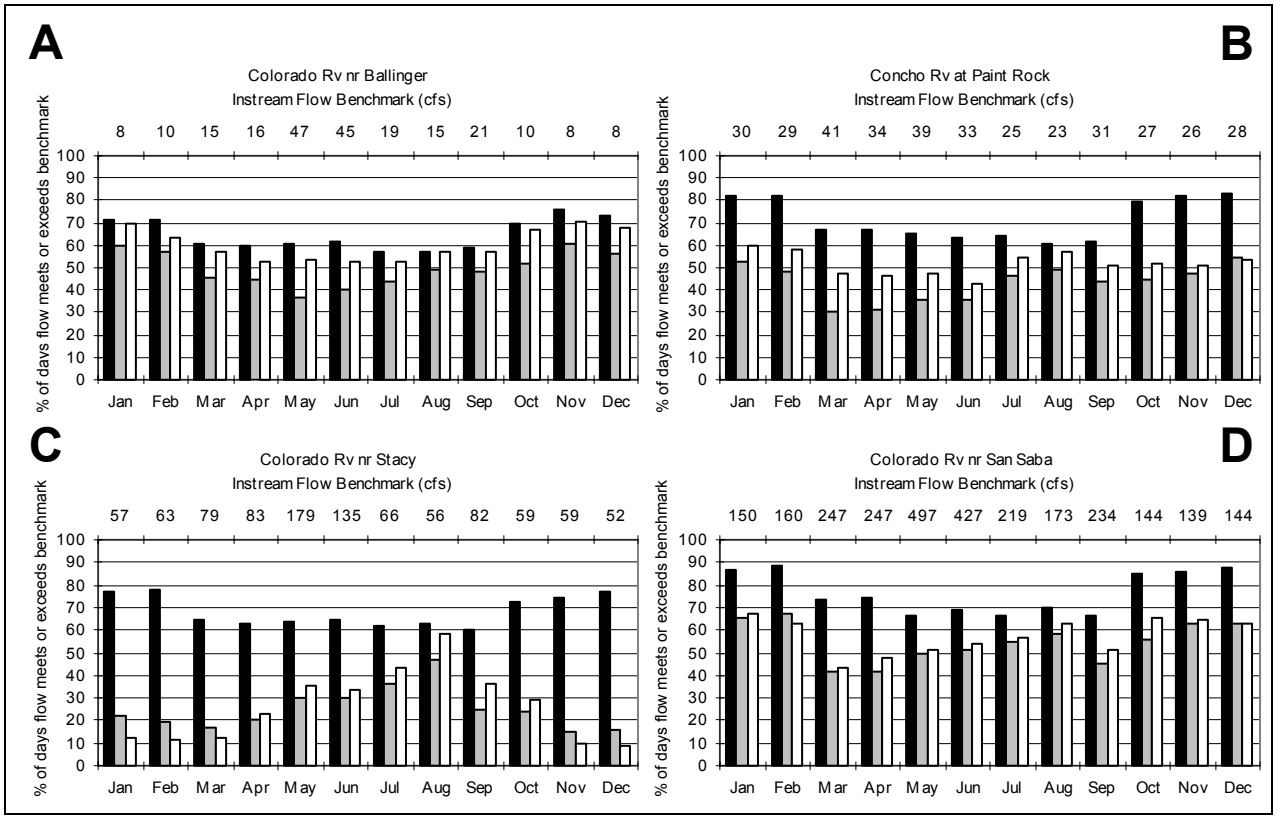


Upper Colorado River Basin



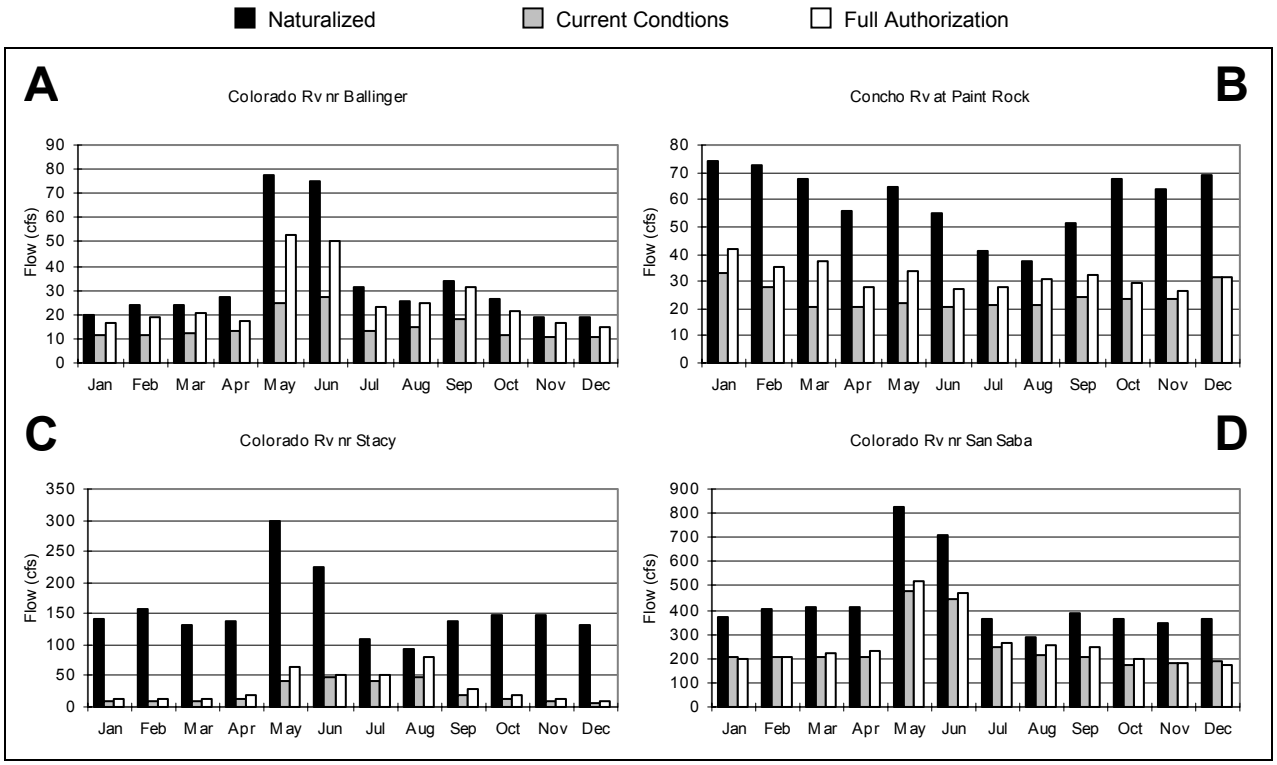
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

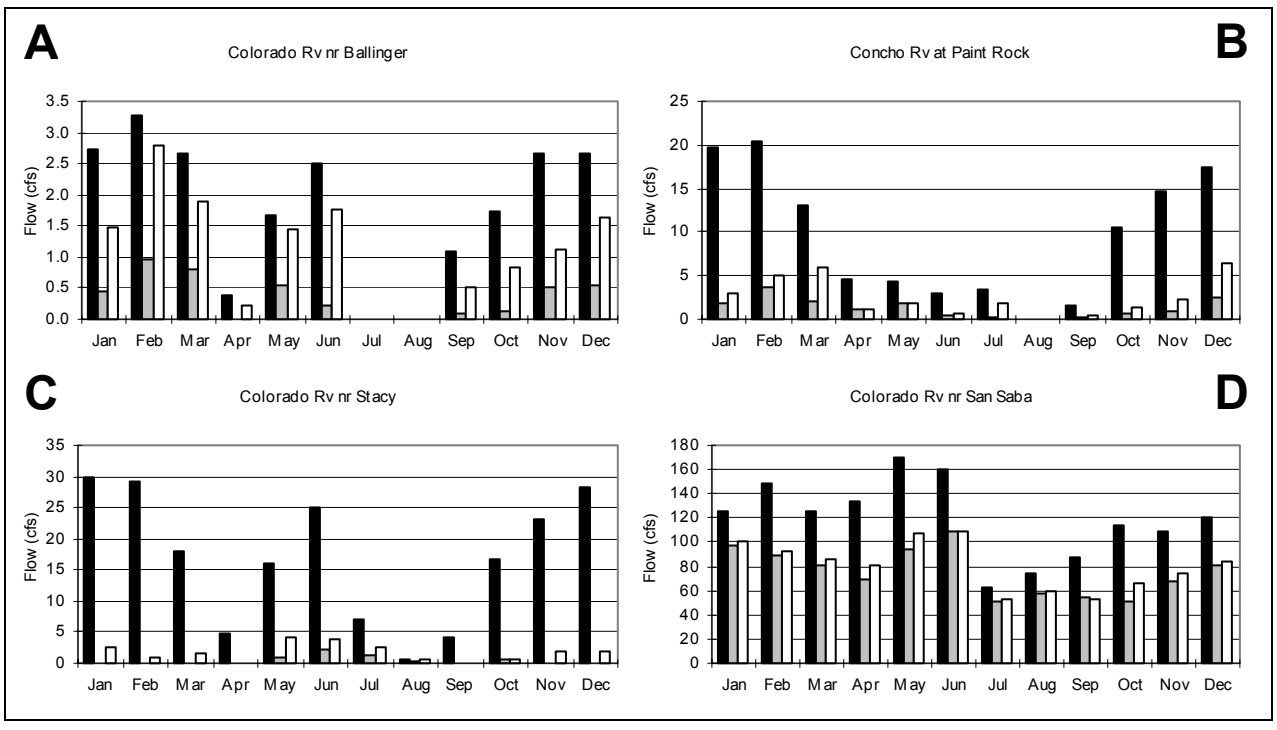


Upper Colorado River Basin (cont.)

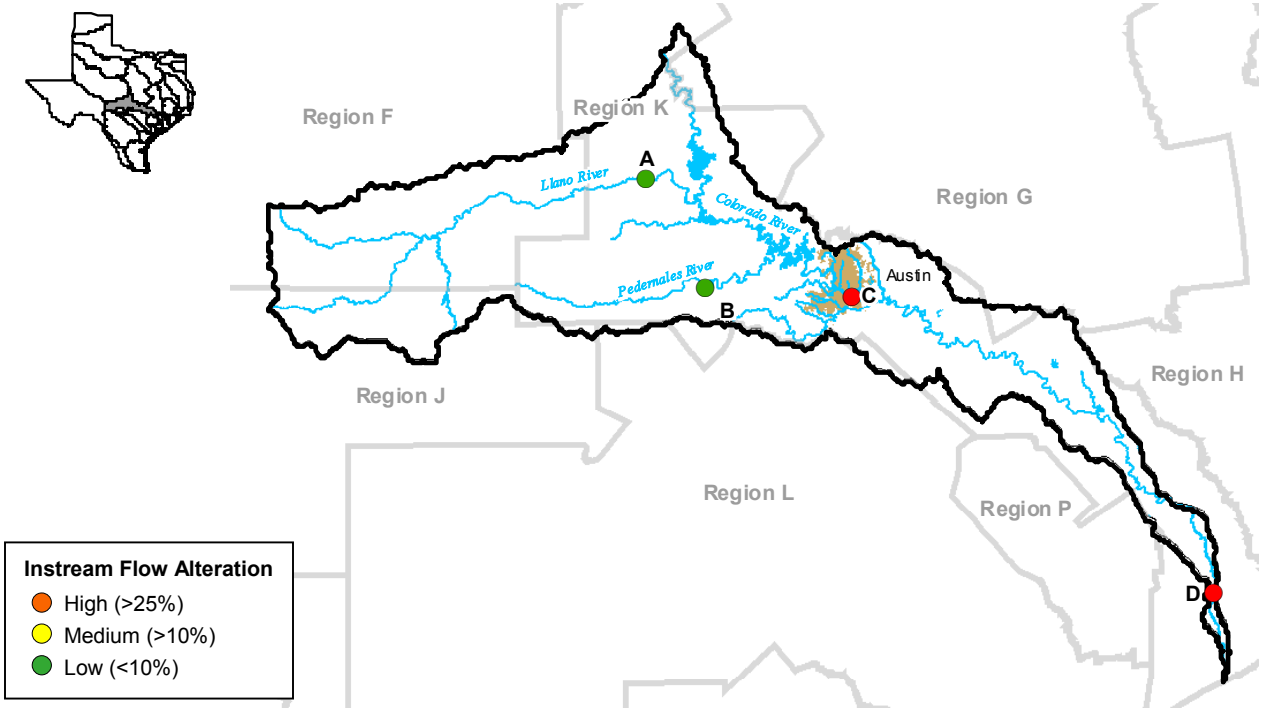
Normal Flow Conditions



Low Flow Conditions

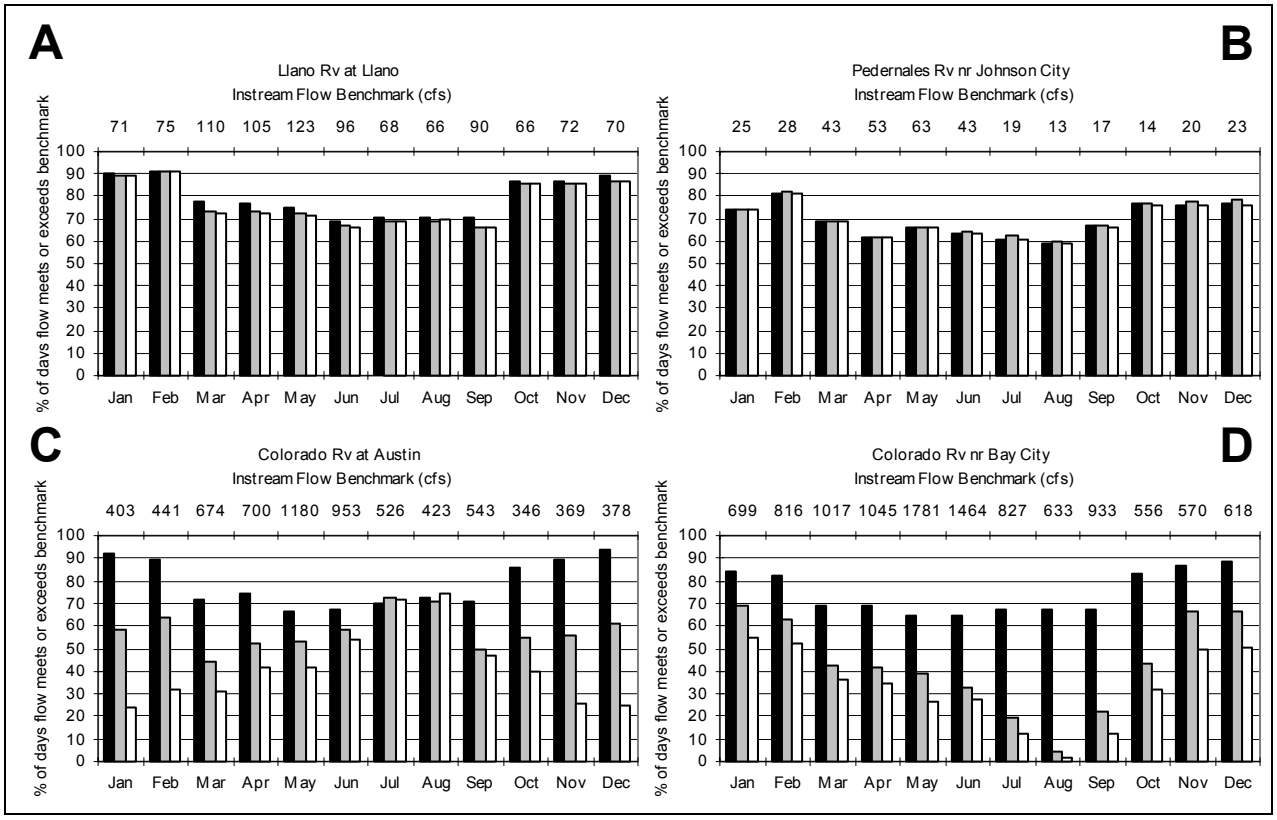


Lower Colorado River Basin



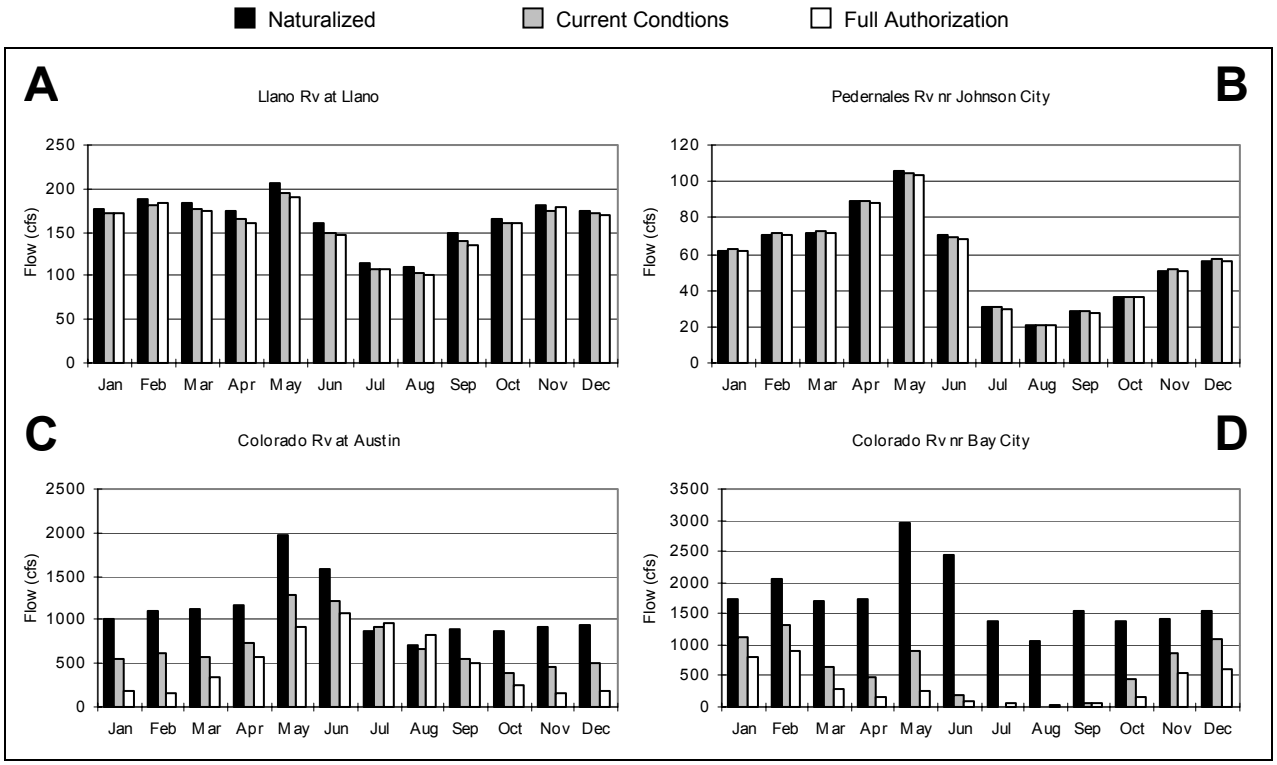
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

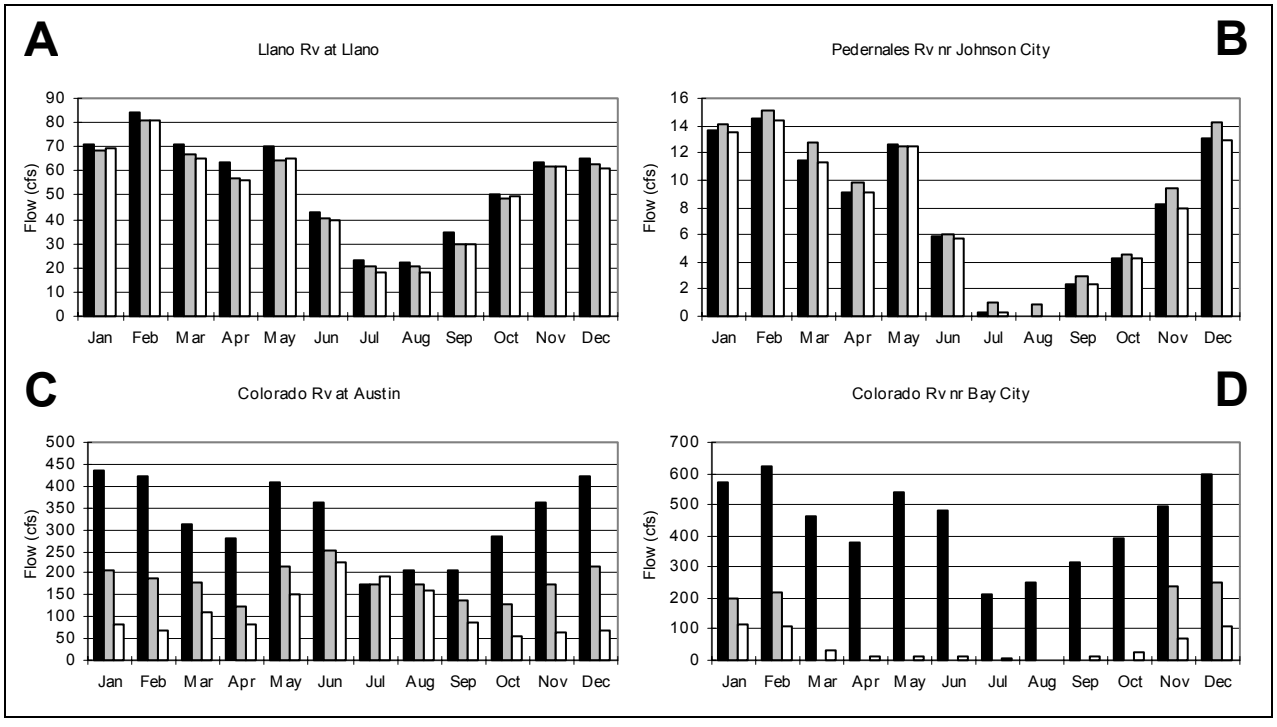


Lower Colorado River Basin (cont.)

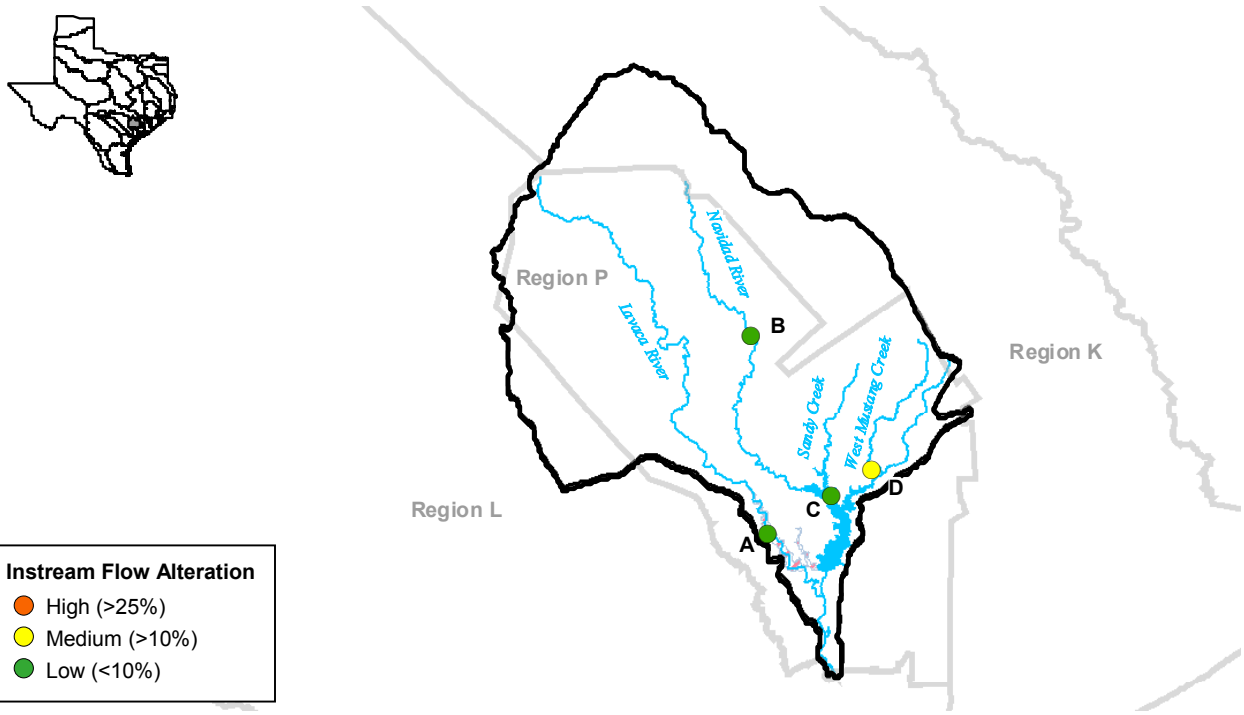
Normal Flow Conditions



Low Flow Conditions

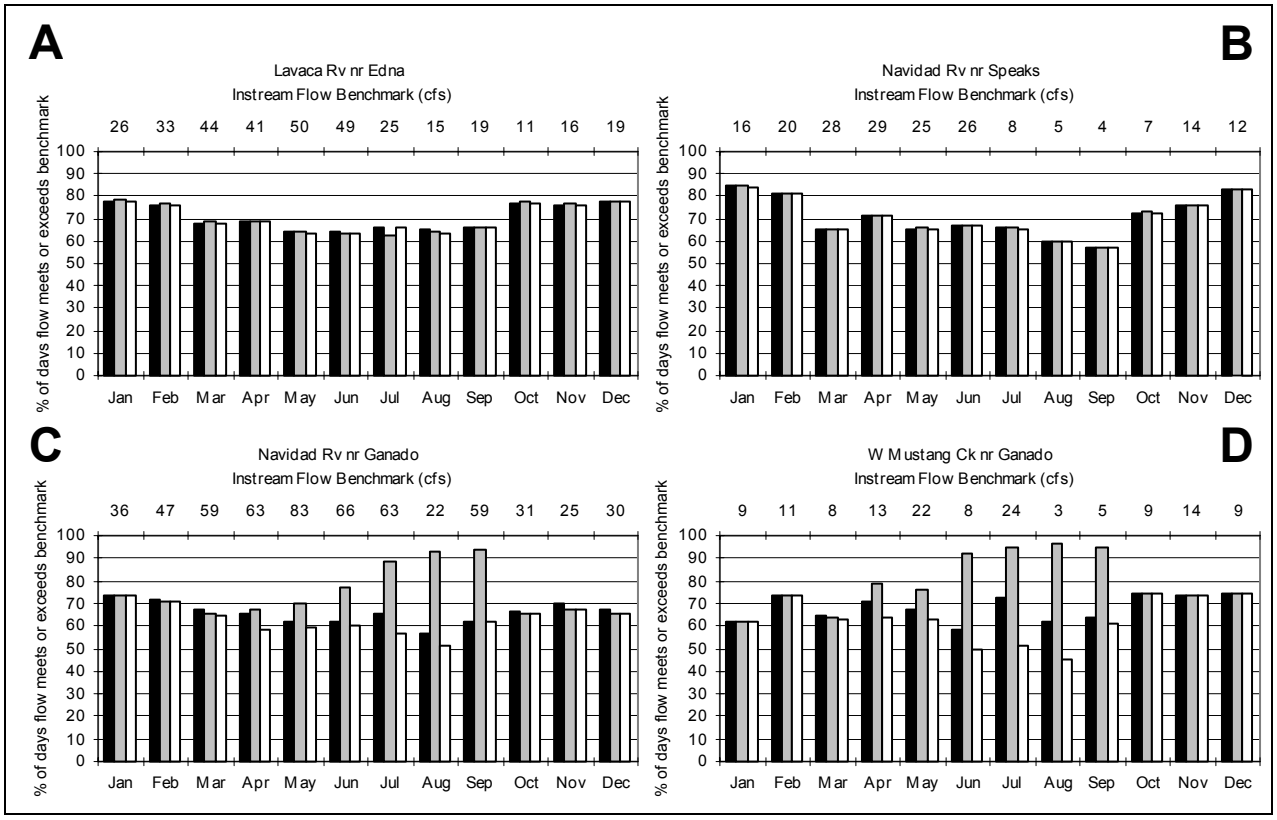


Lavaca River Basin



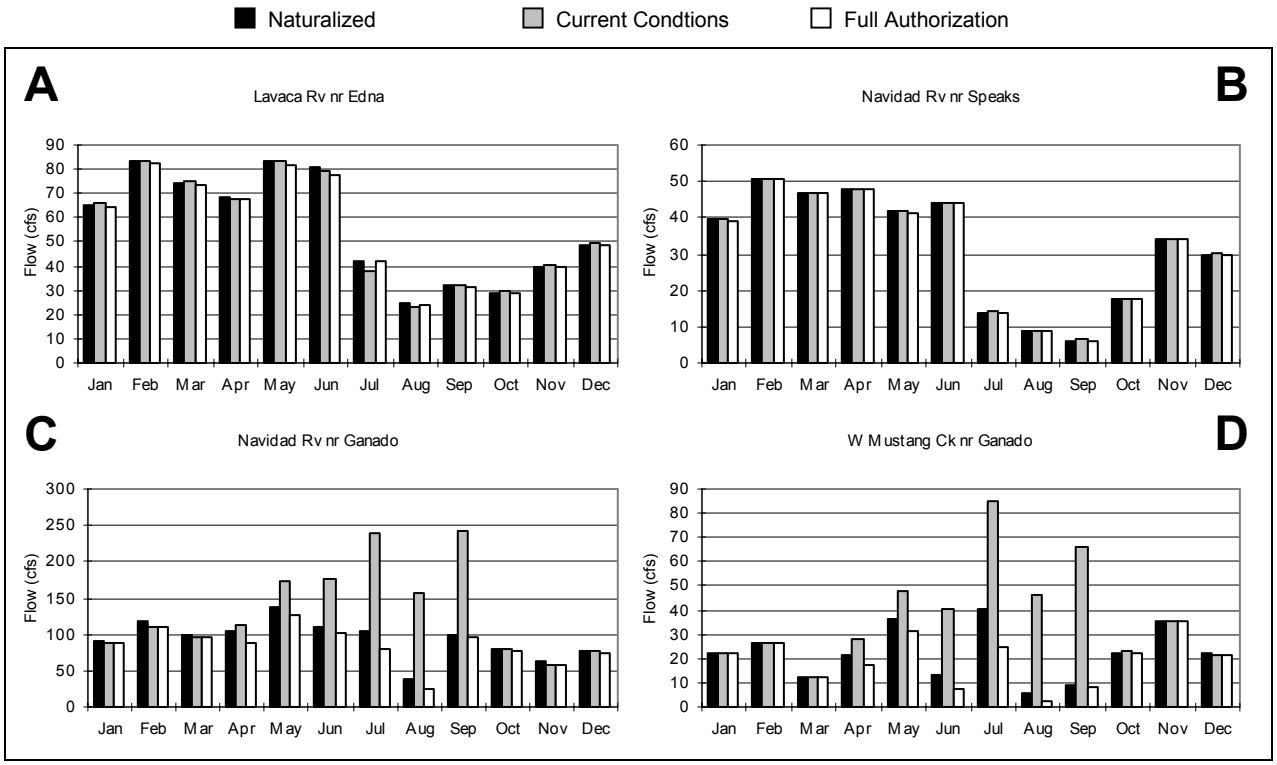
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

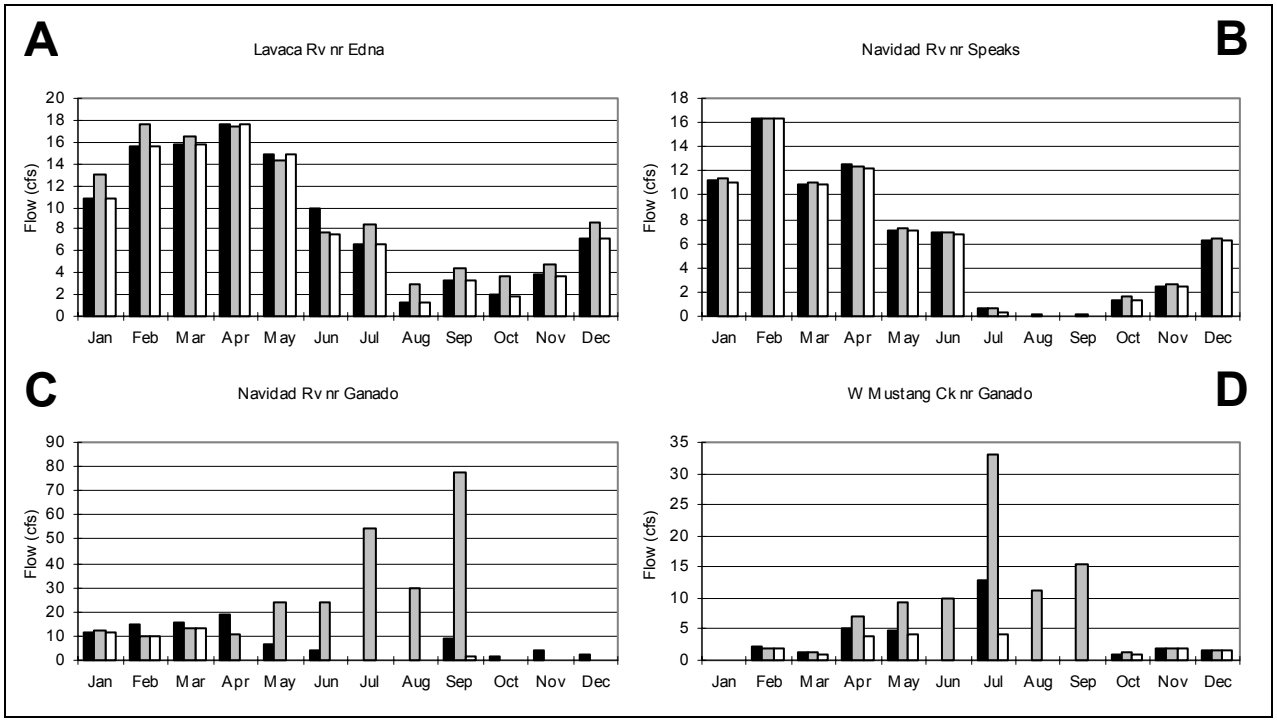


Lavaca River Basin (cont.)

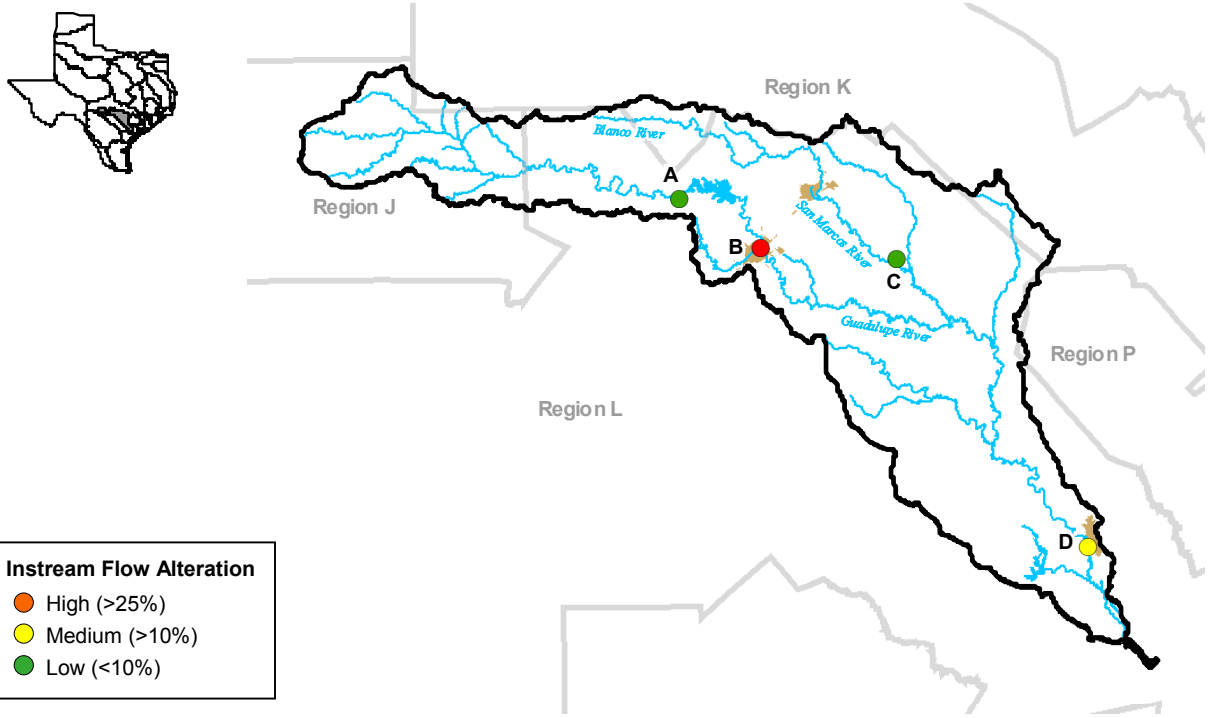
Normal Flow Conditions



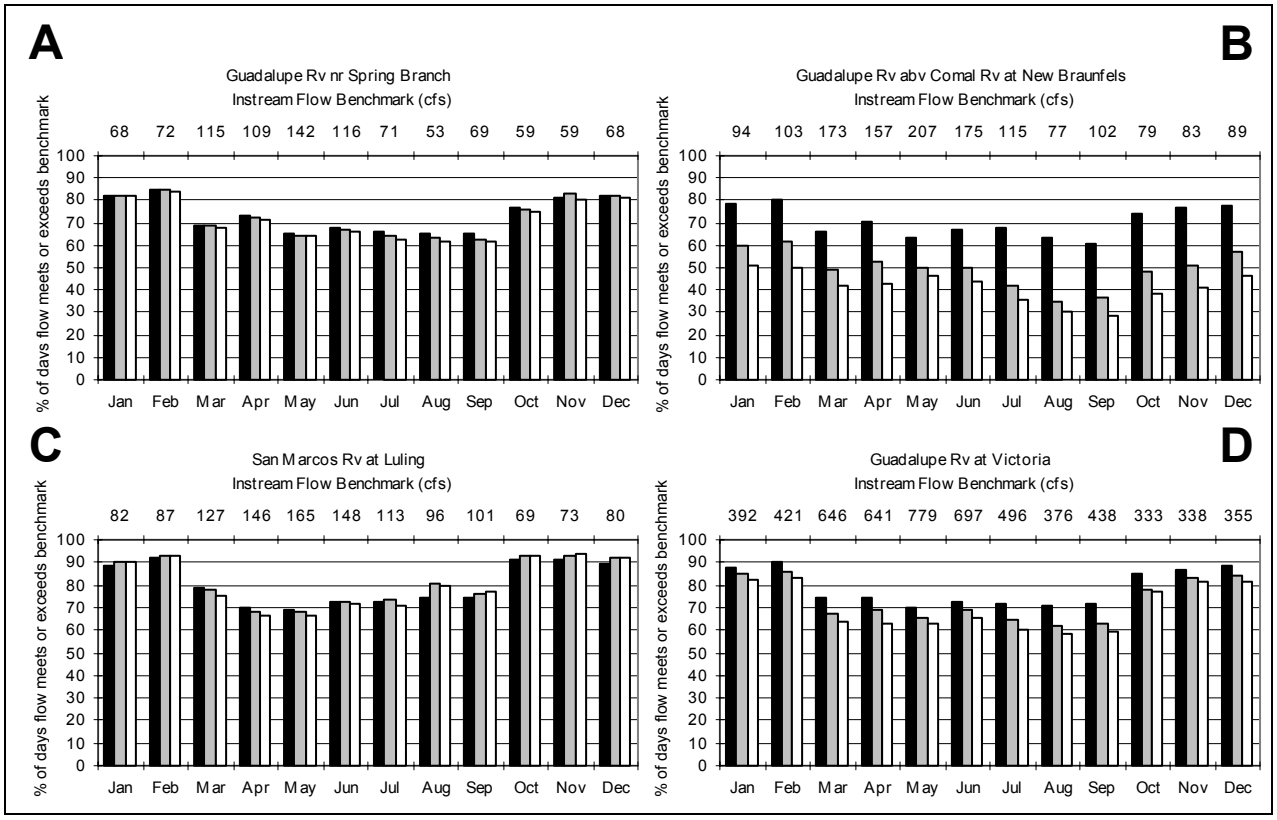
Low Flow Conditions



Guadalupe River Basin

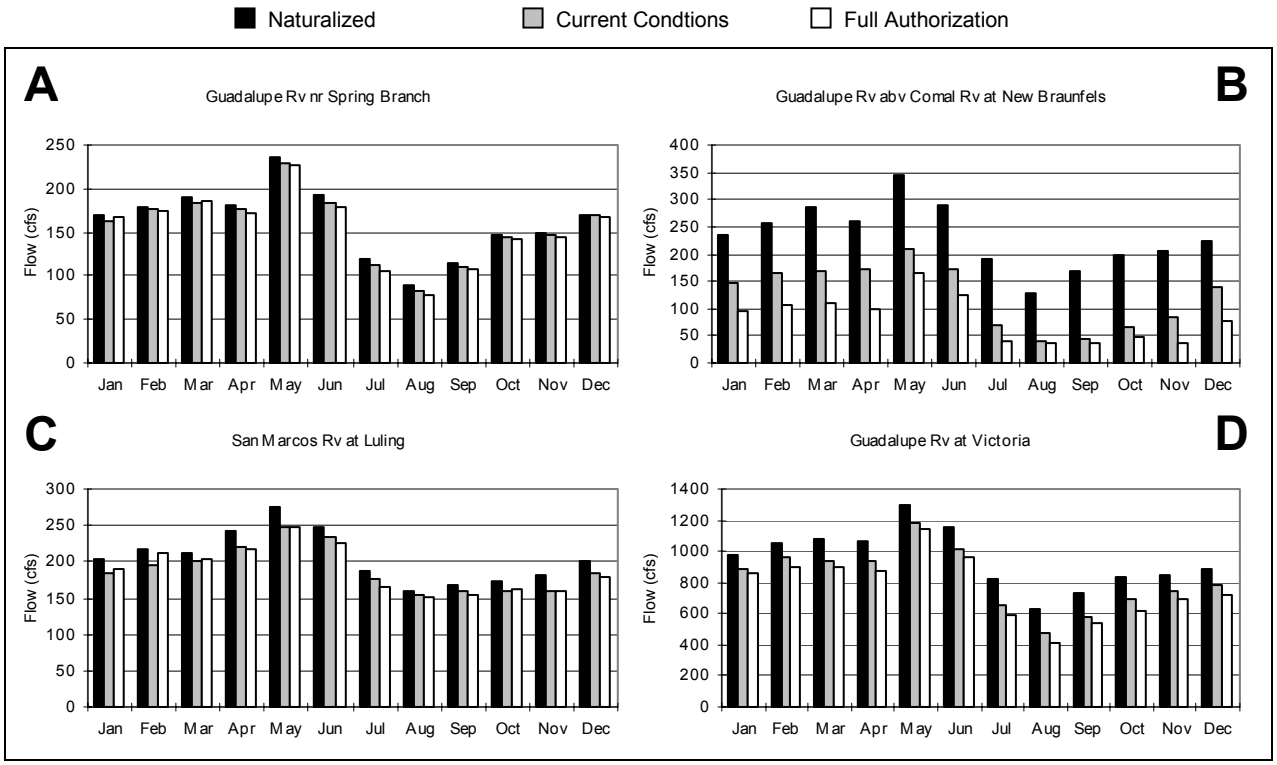


Percent of days when instream flow benchmarks are met or exceeded

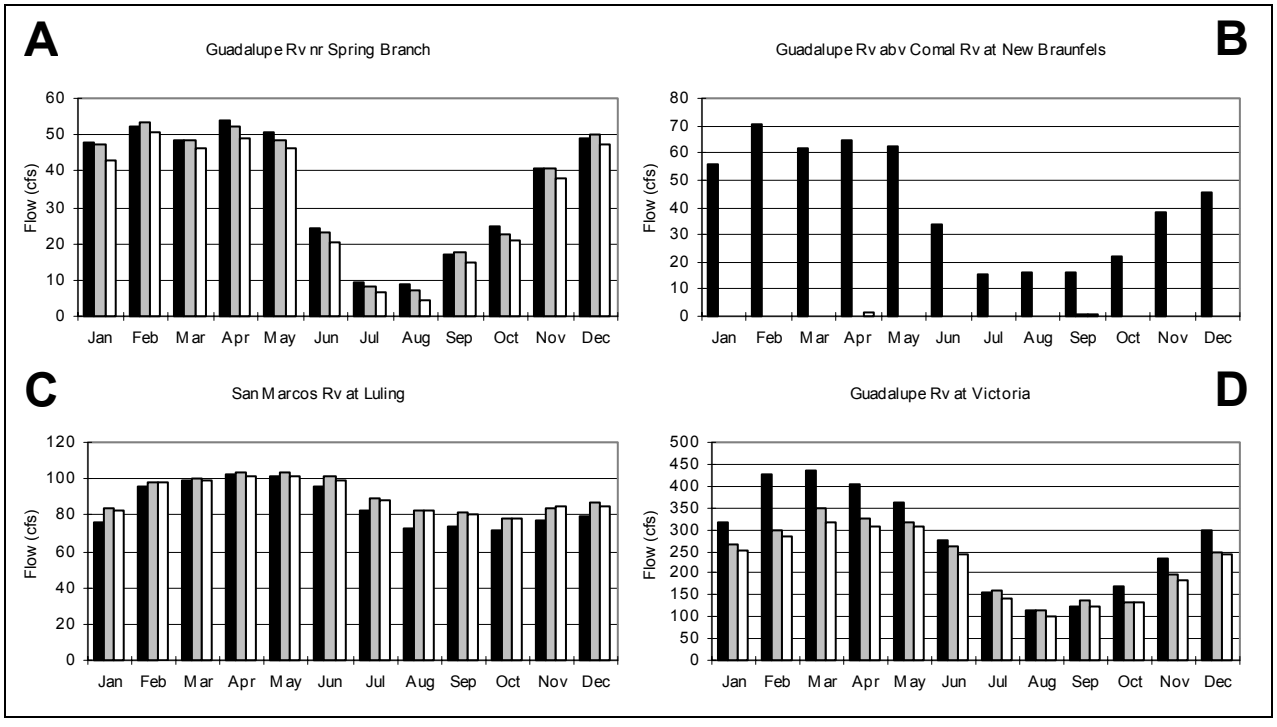


Guadalupe River Basin (cont.)

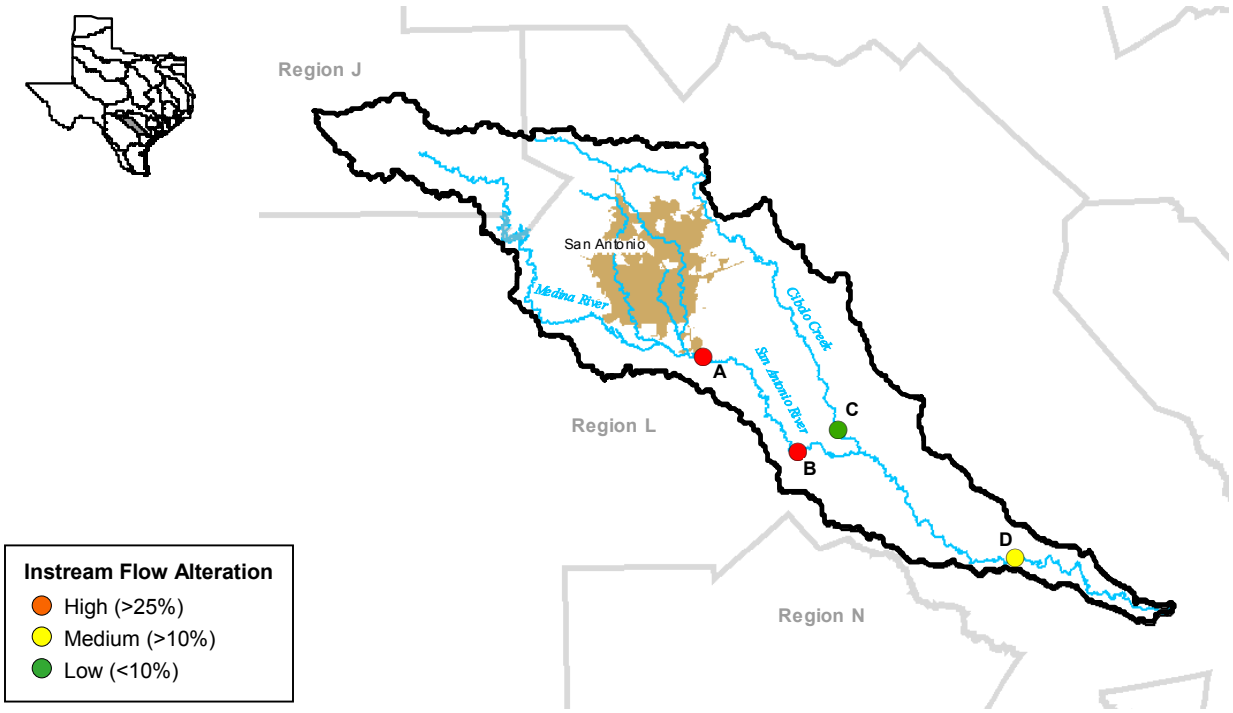
Normal Flow Conditions



Low Flow Conditions

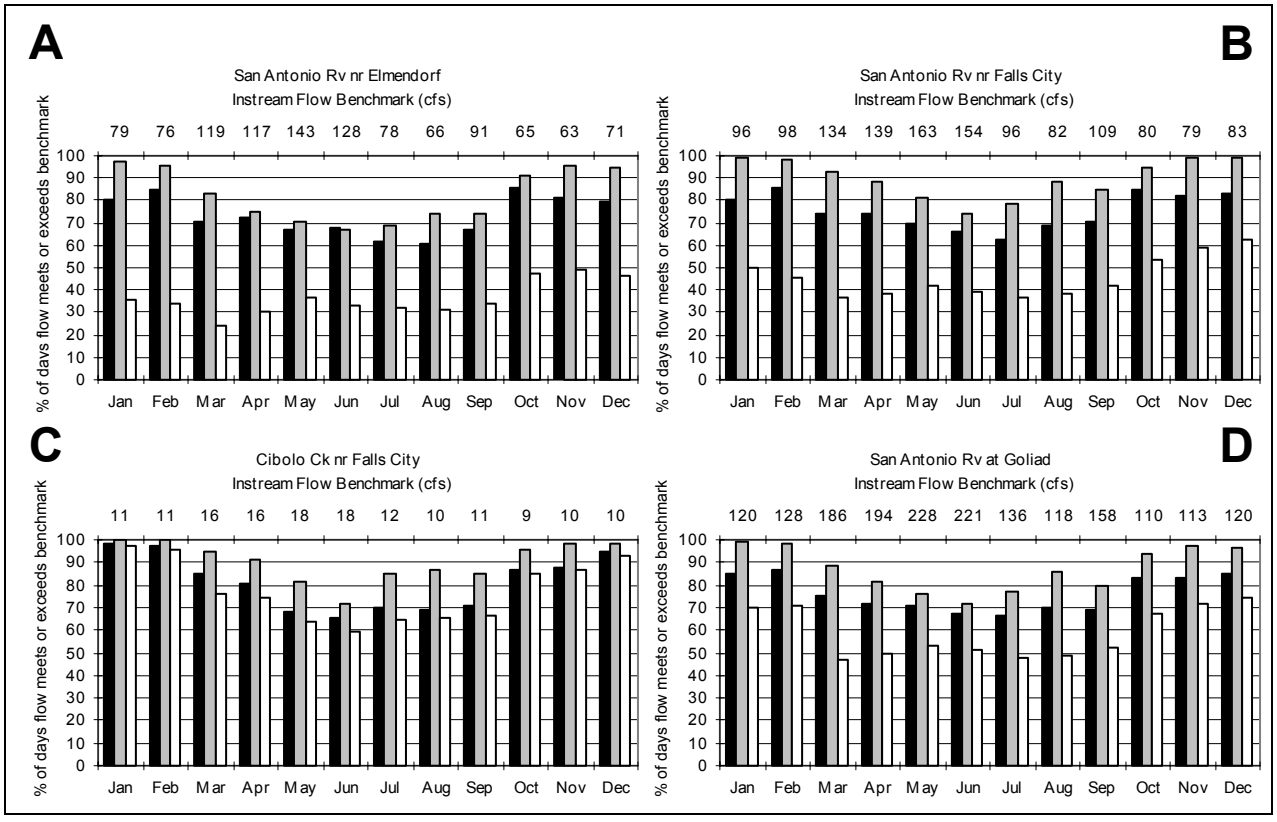


San Antonio River Basin



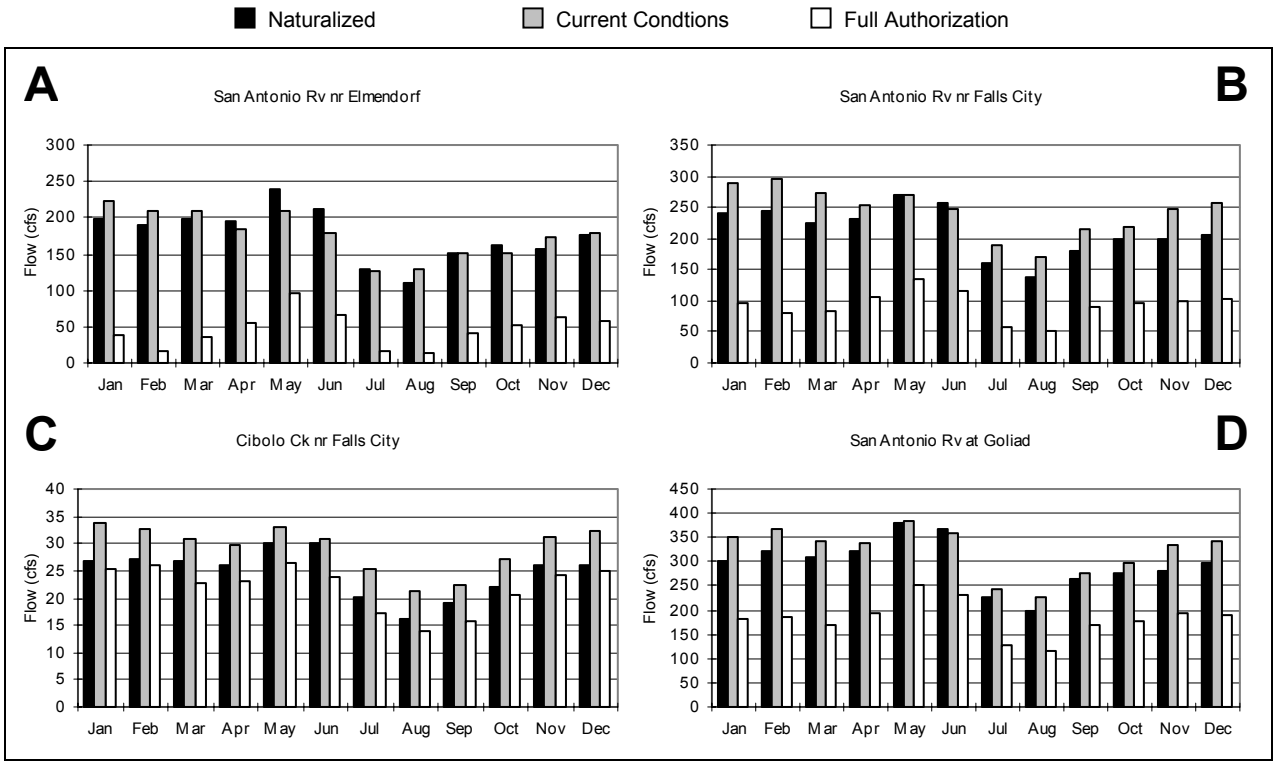
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

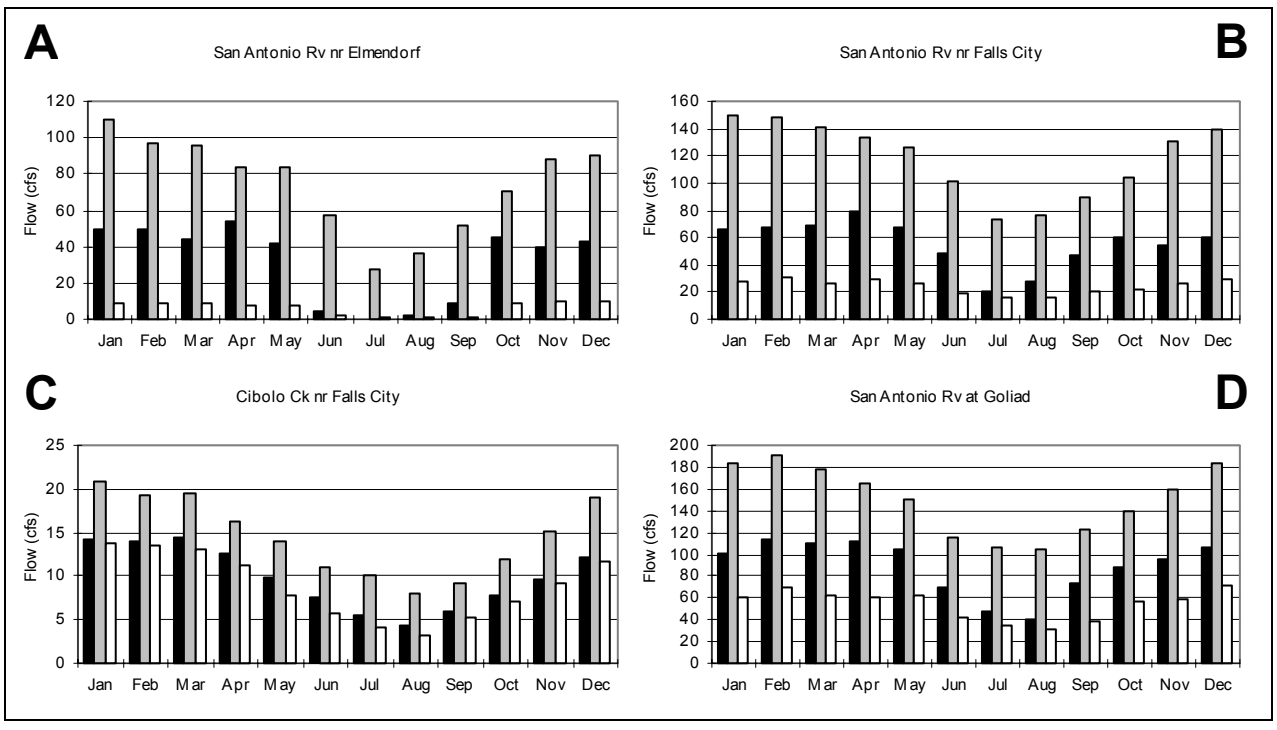


San Antonio River Basin (cont.)

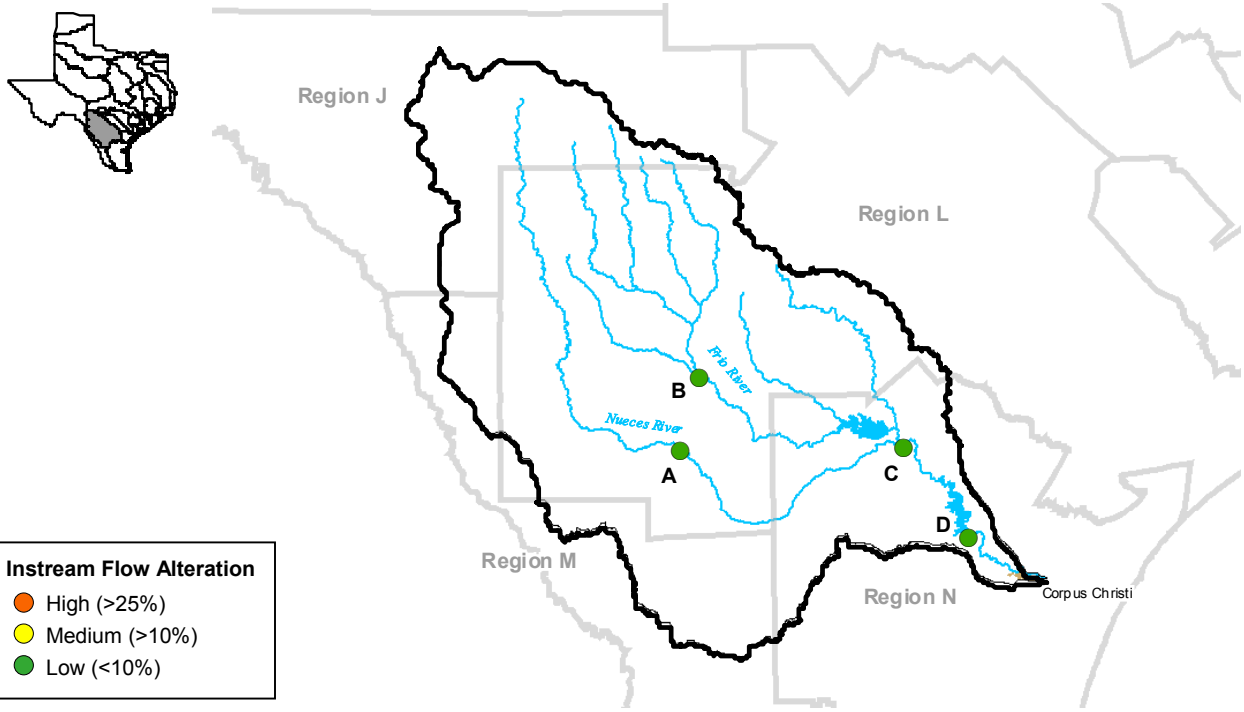
Normal Flow Conditions



Low Flow Conditions

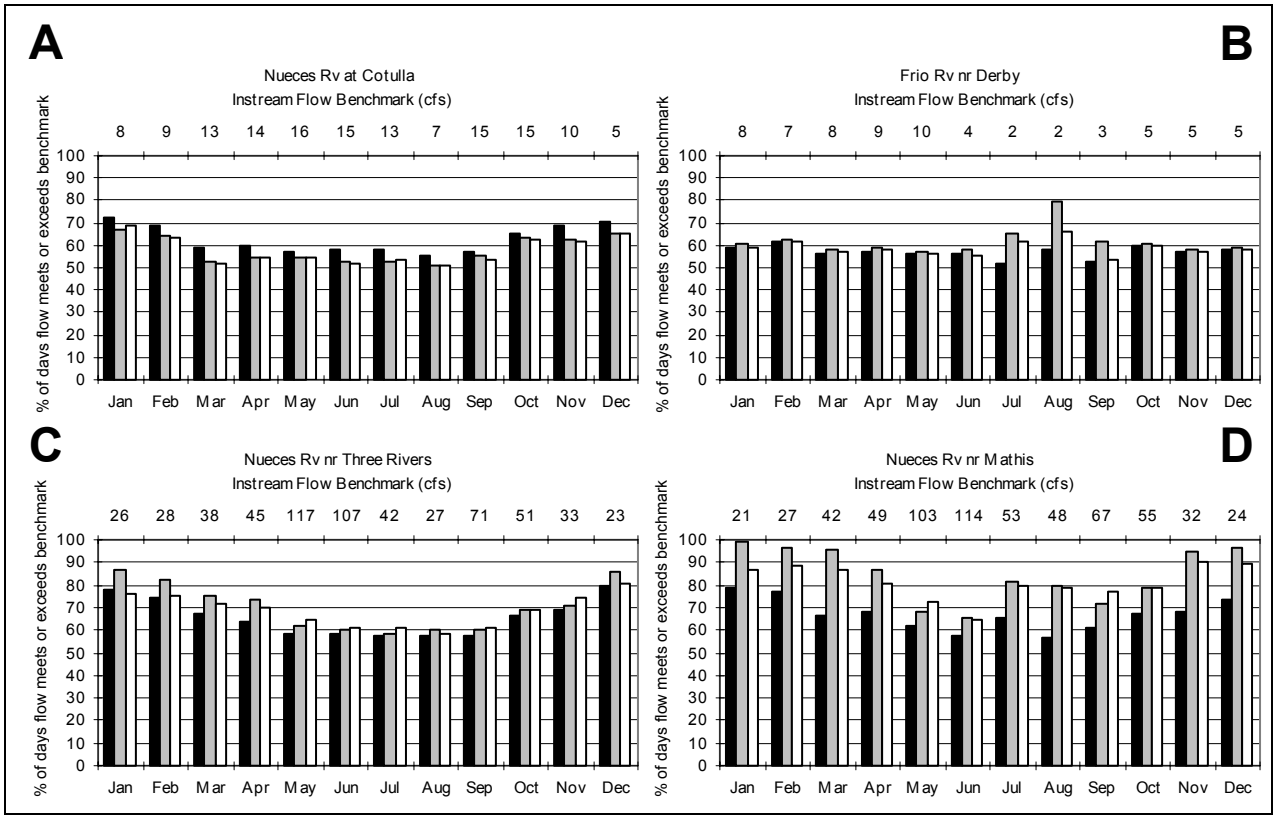


Nueces River Basin



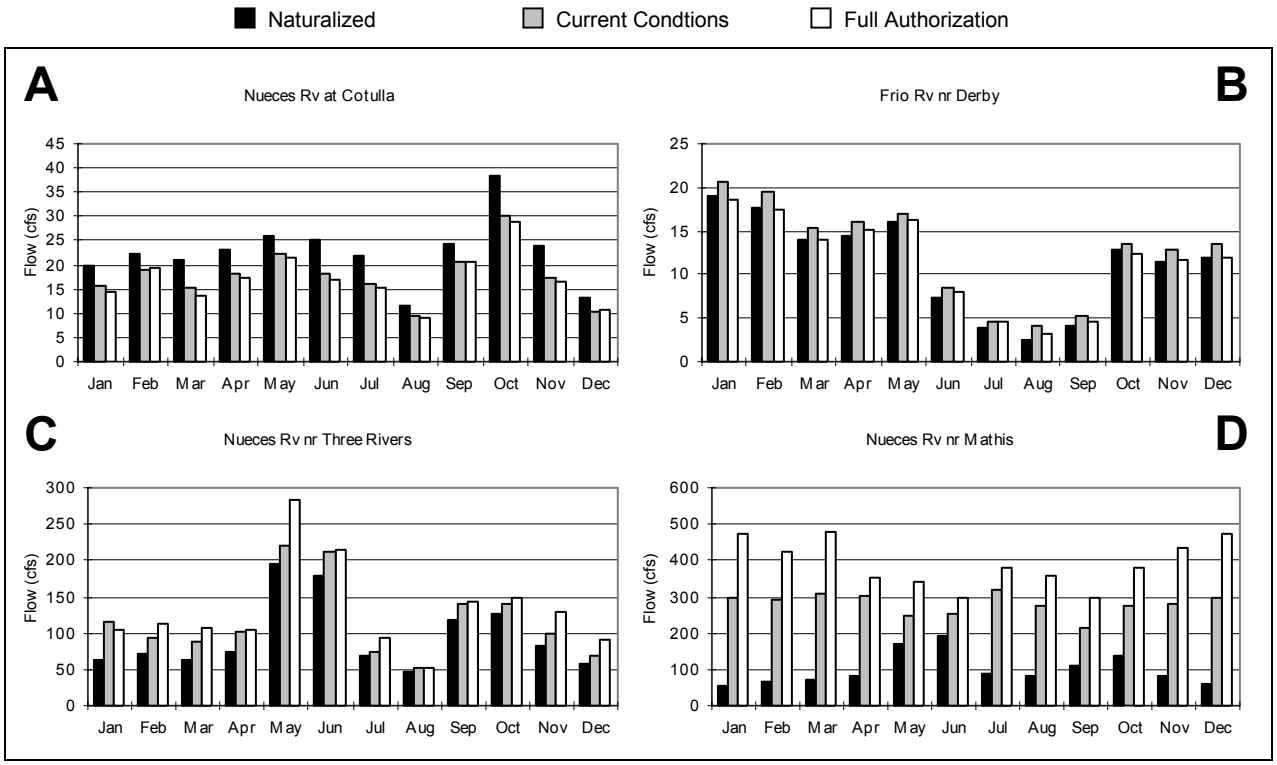
Percent of days when instream flow benchmarks are met or exceeded

Naturalized Current Condtions Full Authorization

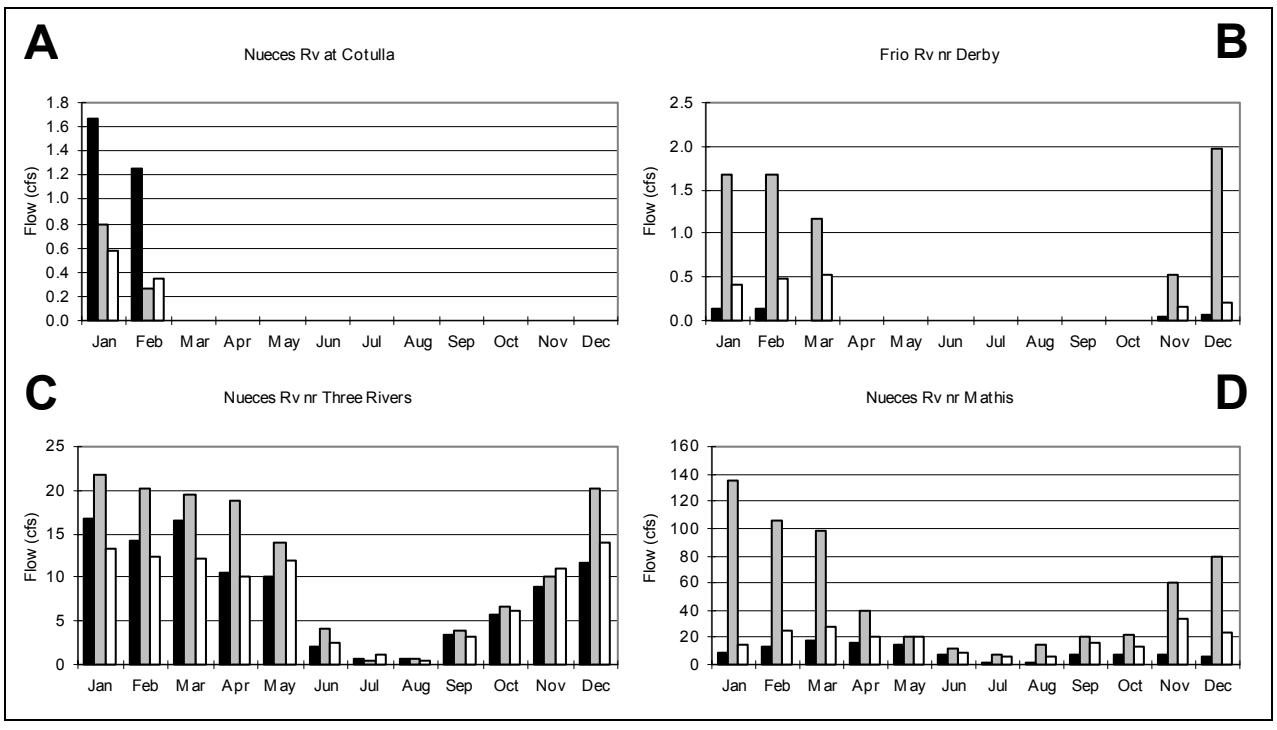


Nueces River Basin (cont.)

Normal Flow Conditions



Low Flow Conditions



Reference Gages for Daily Streamflow Estimation

#	USGS	Name	Basin	Start	End	Missing	Reservoir	Start	End	Ref USGS	Ref Name	Reason for using (or not using) reference gage
1	7233500	Palo Duro Ck nr Spearman	Canadian	1/1/48	12/31/98	10/79 - 12/98		1/1/48	9/30/79	7233500	Palo Duro Ck nr Spearman	
								10/1/79	12/31/98	7235000	Wolf Ck at Lipscomb	Fill in missing gage data
2	7235000	Wolf Ck at Lipscomb	Canadian	1/1/48	12/31/98	1/48 - 9/61		1/1/48	9/30/61	7233500	Palo Duro Ck nr Spearman	Fill in missing gage data
								10/1/61	12/31/98	7235000	Wolf Ck at Lipscomb	
3	7227500	Canadian Rv nr Amarillo	Canadian	1/1/48	12/31/98			1/1/48	12/31/98	7227500	Canadian Rv nr Amarillo	
4	7228000	Canadian Rv nr Canadian	Canadian	1/1/48	12/31/98		Meredith 1/65	1/1/48	12/31/64	7228000	Canadian Rv nr Canadian	
								1/1/65	12/31/98	7227500	Canadian Rv nr Amarillo	Adjust for Meredith
5	7299540	Pr Dog Twn Fk Red Rv nr Childress	Red	1/1/48	12/31/98	1/48 - 9/65		1/1/48	9/30/65	7312500	Wichita Rv at Wichita Falls	Fill in missing gage data
								10/1/65	12/31/98	7299540	Pr Dog Twn Fk Red Rv nr Childress	
6	7312500	Wichita Rv at Wichita Falls	Red	1/1/48	12/31/98		Kemp 10/22	1/1/48	12/31/98	7312500	Wichita Rv at Wichita Falls	Ignore Kemp and Diversion Lake, no tributary with long term records in basin
7	7316000	Red River near Gainesville	Red	1/1/48	12/31/98			1/1/48	12/31/98	7316000	Red River near Gainesville	
8	7337000	Red River at Index	Red	1/1/48	12/31/98		Texoma 10/43	1/1/48	12/31/98	7337000	Red River at Index	Ignore Texoma
9	7343000	N Sulphur Rv nr Cooper	Sulphur	1/1/40	12/31/96	1/40 - 9/49		1/1/40	5/31/42	7344000	Sulphur Rv nr Darden	Fill in missing gage data
								6/1/42	9/30/49	7342500	S Sulphur Rv nr Cooper	Fill in missing gage data
								10/1/49	12/31/96	7343000	N Sulphur Rv nr Cooper	
10	7342500	S Sulphur Rv nr Cooper	Sulphur	1/1/40	12/31/96	1/40 - 5/42	Cooper 9/91	1/1/40	5/31/42	7344000	Sulphur Rv nr Darden	Fill in missing gage data
								6/1/42	8/31/91	7342500	S Sulphur Rv nr Cooper	
								9/1/91	12/31/96	7343000	N Sulphur Rv nr Cooper	Adjust for Cooper
11	7343200	Sulphur Rv nr Talco	Sulphur	1/1/40	12/31/96	1/40 - 9/56 & 10/96 - 12/96	Cooper 9/91	1/1/40	9/30/56	7344000	Sulphur Rv nr Darden	Fill in missing gage data
								10/1/56	8/31/91	7343200	Sulphur Rv nr Talco	
								9/1/91	12/31/96	7343000	N Sulphur Rv nr Cooper	Adjust for Cooper
12	SRSL	Sulphur Rv at State Line	Sulphur	1/1/40	12/31/96	All	Wright Patman 6/56	1/1/40	9/30/56	7344000	Sulphur Rv nr Darden	No gage at this site
								10/1/56	8/31/91	7343200	Sulphur Rv nr Talco	
								9/1/91	12/31/96	7343000	N Sulphur Rv nr Cooper	

Reference Gages for Daily Streamflow Estimation

#	USGS	Name	Basin	Start	End	Missing	Reservoir	Start	End	Ref USGS	Ref Name	Reason for using (or not using) reference gage
13	7344500	Big Cypress Ck nr Pittsburg	Cypress	1/1/48	12/31/98	1/63 - 9/67 & 10/89-12/98		1/1/48	12/31/62	7344500	Big Cypress Ck nr Pittsburg	
								1/1/63	9/30/67	7346050	Little Cypress Ck nr Ore City	Fill in missing gage data
								10/1/67	9/30/89	7344500	Big Cypress Ck nr Pittsburg	
								10/1/89	12/31/98	7346050	Little Cypress Ck nr Ore City	Fill in missing gage data
14	7346000	Big Cypress Ck nr Jefferson	Cypress	1/1/48	12/31/98	1/60 - 9/79	Lake O' The Pines 8/57	1/1/48	7/31/57	7346000	Big Cypress Ck nr Jefferson	
								8/1/57	12/31/62	7344500	Big Cypress Ck nr Pittsburg	Adjust for Lake O' The Pines
								1/1/63	9/30/67	7346070	Little Cypress Ck nr Jefferson	
								10/1/67	9/30/89	7344500	Big Cypress Ck nr Pittsburg	
								10/1/89	12/31/98	7346050	Little Cypress Ck nr Ore City	
15	7346070	Little Cypress Ck nr Jefferson	Cypress	1/1/48	12/31/98	10/60 - 9/61 & 10/98 - 12/98		1/1/48	9/30/60	7346070	Little Cypress Ck nr Jefferson	
								10/1/60	9/30/61	7344500	Big Cypress Ck nr Pittsburg	Fill in missing gage data
								10/1/61	9/30/98	7346070	Little Cypress Ck nr Jefferson	
								10/1/98	12/31/98	7346050	Little Cypress Ck nr Ore City	Fill in missing gage data
16	DSCL	Downstream of Caddo Lake	Cypress	1/1/48	12/31/98	All	Caddo 12/14	1/1/48	12/31/98	7346000	Big Cypress Ck nr Jefferson	No gage at this site
										7346070	Little Cypress Ck nr Jefferson	
										7346045	Black Cypress Bayou at Jefferson	
										7344500	Big Cypress Ck nr Pittsburg	
										7346050	Little Cypress Ck nr Ore City	
17	8020000	Sabine Rv nr Gladewater	Sabine	1/1/40	12/31/98		Tawakoni 10/60	1/1/40	12/31/98	8020000	Sabine Rv nr Gladewater	Ignore Tawakoni & Lake Fork
							Lake Fork 6/79					
18	8022040	Sabine Rv nr Beckville	Sabine	1/1/40	12/31/98			1/1/40	12/31/98	8022040	Sabine Rv nr Beckville	
19	8025360	Sabine Rv at Toledo Bd Res nr Burkeville	Sabine	1/1/40	12/31/98	1/40 - 9/71	Toledo Bend 10/66	1/1/40	9/30/66	8028500	Sabine Rv nr Bon Wier	Fill in missing gage data
								10/1/66	12/31/98	8022040	Sabine Rv nr Beckville	Adjust for Toledo Bend
20	8030500	Sabine Rv nr Ruliff	Sabine	1/1/40	12/31/98		Toledo Bend 10/66	1/1/40	12/31/98	8030500	Sabine Rv nr Ruliff	
								10/1/66	12/31/98	8022040	Sabine Rv nr Beckville	Adjust for Toledo Bend
21	8032000	Neches Rv nr Neches	Neches	1/1/40	12/31/96		Palestine 5/62	1/1/40	12/31/96	8032000	Neches Rv nr Neches	Ignore Palestine
22	8033500	Neches Rv nr Rockland	Neches	1/1/40	12/31/96			1/1/40	12/31/96	8033500	Neches Rv nr Rockland	
23	8039300	Sam Rayburn Res nr Jasper	Neches	1/1/40	12/31/96	All	Sam Rayburn 3/65	1/1/40	12/31/96	8033500	Neches Rv nr Rockland	No gage at this site
24	8041000	Neches Rv at Evadale	Neches	1/1/40	12/31/96		Steinhagen 4/51	1/1/40	12/31/96	8041000	Neches Rv at Evadale	Ignore Stienhagen

Reference Gages for Daily Streamflow Estimation

#	USGS	Name	Basin	Start	End	Missing	Reservoir	Start	End	Ref USGS	Ref Name	Reason for using (or not using) reference gage
25	8048000	W Fk Trinity Rv at Ft Worth	Trinity	1/1/40	12/31/96		Bridgeport 4/32	1/1/40	12/31/96	8047500	Clear Fk Trinity Rv at Ft Worth	Ignore Return Flows
26	8049500	W Fk Trinity Rv at Grand Prairie	Trinity	1/1/40	12/31/96			1/1/40	12/31/96	8047500	Clear Fk Trinity Rv at Ft Worth	Ignore Return Flows
27	8057000	Trinity Rv at Dallas	Trinity	1/1/40	12/31/96		Lewisville 11/54	1/1/40	12/31/96	8057000	Trinity Rv at Dallas	Ignore Return Flows
28	8062500	Trinity Rv nr Rosser	Trinity	1/1/40	12/31/96		Ray Hubbard 12/68	1/1/40	12/31/96	8062500	Trinity Rv nr Rosser	Ignore Return Flows
29	8065000	Trinity Rv nr Oakwood	Trinity	1/1/40	12/31/96		Richland-Chambers 11/87	1/1/40	12/31/96	8065000	Trinity Rv nr Oakwood	Ignore Return Flows
30	8065500	Trinity Rv nr Midway	Trinity	1/1/40	12/31/96	11/70 - 12/96		1/1/40	10/31/70	8065500	Trinity Rv nr Midway	
								11/1/70	12/31/96	8065350	Trinity Rv nr Crockett	Fill in missing gage data
31	8066000	Trinity Rv at Riverside	Trinity	1/1/40	12/31/96	10/68 - 12/96		1/1/40	9/30/68	8066000	Trinity Rv at Riverside	
								10/1/68	12/31/96	8065350	Trinity Rv nr Crockett	Fill in missing gage data
32	8066500	Trinity Rv at Romayor	Trinity	1/1/40	12/31/96		Livingston 10/68	1/1/40	9/30/68	8066500	Trinity Rv at Romayor	
								10/1/68	12/31/96	8065350	Trinity Rv nr Crockett	Adjust for Lingston
33	8068000	W Fk San Jacinto Rv nr Conroe	SanJacinto	1/1/40	12/31/96		Conroe 1/73	1/1/40	12/31/72	8068000	W Fk San Jacinto Rv nr Conroe	
								1/1/73	12/31/96	8068500	Spring Ck nr Spring	Adjust for Conroe
34	8070000	E Fk San Jacinto Rv nr Cleveland	SanJacinto	1/1/40	12/31/96			1/1/40	12/31/96	8070000	E Fk San Jacinto Rv nr Cleveland	
35	8068500	Spring Ck nr Spring	SanJacinto	1/1/40	12/31/96			1/1/40	12/31/96	8068500	Spring Ck nr Spring	
36	8075000	Brays Bayou at Houston	SanJacinto	1/1/40	12/31/96			1/1/40	12/31/96	8075000	Brays Bayou at Houston	

Reference Gages for Daily Streamflow Estimation

#	USGS	Name	Basin	Start	End	Missing	Reservoir	Start	End	Ref USGS	Ref Name	Reason for using (or not using) reference gage
37	8082000	Salt Fk Brazos Rv nr Aspermont	Brazos	1/1/40	12/31/97			1/1/40	12/31/97	8082000	Salt Fk Brazos Rv nr Aspermont	
38	8080500	DMF Brazos Rv nr Aspermont	Brazos	1/1/40	12/31/97			1/1/40	12/31/97	8080500	DMF Brazos Rv nr Aspermont	
39	8085500	Clear Fk Brazos Rv at Ft Griffin	Brazos	1/1/40	12/31/97			1/1/40	12/31/97	8085500	Clear Fk Brazos Rv at Ft Griffin	
40	8088000	Brazos Rv nr South Bend	Brazos	1/1/40	12/31/97			1/1/40	12/31/97	8088000	Brazos Rv nr South Bend	
41	8089000	Brazos Rv at Morris Sheppard Dam nr Graford	Brazos	1/1/40	12/31/97	1/40 - 9/76 & 10/94 - 12/97	Possum Kindom 3/41	1/1/40	12/31/97	8088000	Brazos Rv nr South Bend	Adjust for Possum Kingdom
42	8091000	Brazos Rv nr Glen Rose	Brazos	1/1/40	12/31/97		Granbury 9/69	1/1/40	8/31/69	8091000	Brazos Rv nr Glen Rose	
								9/1/69	12/31/97	8090800	Brazos Rv nr Dennis	Adjust for Granbury
43	8096500	Brazos Rv at Waco	Brazos	1/1/40	12/31/97		Whitney 12/51	1/1/40	11/30/51	8096500	Brazos Rv at Waco	
								12/1/51	8/31/69	8091000	Brazos Rv nr Glen Rose	Adjust for Whitney
								9/1/69	12/31/97	8090800	Brazos Rv nr Dennis	Adjust for Granbury
44	8106500	Little Rv at Cameron	Brazos	1/1/40	12/31/97		Belton 3/54	1/1/40	2/28/54	8102500	Leon Rv nr Belton	
							Stillhouse 2/68	3/1/54	12/31/97	8100500	Leon Rv at Gatesville	Adjust for Belton
							Granger 1/80					
45	8109000	Brazos Rv nr Bryan	Brazos	1/1/40	12/31/97			1/1/40	9/30/93	8109000	Brazos Rv nr Bryan	
								10/1/93	12/31/97	8108700	Brazos Rv at SH 21 nr Bryan	
46	8110500	Navasota Rv nr Easterly	Brazos	1/1/40	12/31/97		Limestone 10/78	1/1/40	9/30/78	8110500	Navasota Rv nr Easterly	
								10/1/78	12/31/97	8110325	Navasota Rv abv Groesbeck	Adjust for Limestone
47	8111500	Brazos Rv nr Hempstead	Brazos	1/1/40	12/31/97			1/1/40	12/31/97	8111500	Brazos Rv nr Hempstead	
48	8114000	Brazos Rv at Richmond	Brazos	1/1/40	12/31/97			1/1/40	12/31/97	8114000	Brazos Rv at Richmond	

Reference Gages for Daily Streamflow Estimation

#	USGS	Name	Basin	Start	End	Missing	Reservoir	Start	End	Ref USGS	Ref Name	Reason for using (or not using) reference gage
49	8126380	Colorado Rv nr Ballinger	Colorado	1/1/40	12/31/98		Spence 12/68	1/1/40	12/31/98	8126380	Colorado Rv nr Ballinger	Ignore Spence
50	8136500	Concho Rv at Paint Rock	Colorado	1/1/40	12/31/98			1/1/40	12/31/98	8136500	Concho Rv at Paint Rock	
51	8136700	Colorado Rv nr Stacy	Colorado	1/1/40	12/31/98	1/40 - 3/68	Ivie 3/90	1/1/40	3/31/68	8126380	Colorado Rv nr Ballinger	Fill in missing gage data
								1/1/40	3/31/68	8136500	Concho Rv at Paint Rock	Fill in missing gage data
								4/1/68	2/28/90	8136700	Colorado Rv nr Stacy	
								3/1/90	12/31/98	8126380	Colorado Rv nr Ballinger	Adjust for Ivie
								3/1/90	12/31/98	8136500	Concho Rv at Paint Rock	Adjust for Ivie
52	8147000	Colorado Rv nr San Saba	Colorado	1/1/40	12/31/98			1/1/40	12/31/98	8147000	Colorado Rv nr San Saba	
53	8151500	Llano Rv at Llano	Colorado	1/1/40	12/31/98			1/1/40	12/31/98	8151500	Llano Rv at Llano	
54	8153500	Pedernales Rv nr Johnson City	Colorado	1/1/40	12/31/98			1/1/40	12/31/98	8153500	Pedernales Rv nr Johnson City	
55	8158000	Colorado Rv at Austin	Colorado	1/1/40	12/31/98		Buchanan 5/37	1/1/40	12/31/98	8147000	Colorado Rv nr San Saba	Adjust for Buchanan
							Travis 9/40	1/1/40	12/31/98	8151500	Llano Rv at Llano	
							Austin 12/39	1/1/40	12/31/98	8153500	Pedernales Rv nr Johnson City	
56	8162500	Colorado Rv nr Bay City	Colorado	1/1/40	12/31/98	1/40 - 4/48		1/1/40	12/31/98	8147000	Colorado Rv nr San Saba	Adjust for Buchanan
								1/1/40	12/31/98	8151500	Llano Rv at Llano	
								1/1/40	12/31/98	8153500	Pedernales Rv nr Johnson City	
57	8164000	Lavaca Rv nr Edna	Lavaca	1/1/40	12/31/96			1/1/40	12/31/96	8164000	Lavaca Rv nr Edna	
58	8164350	Navidad Rv nr Speaks	Lavaca	1/1/40	12/31/96	1/40 - 9/81 & 10/89 - 9/96		1/1/40	9/30/81	8164000	Lavaca Rv nr Edna	Fill in missing gage data
								10/1/81	9/30/89	8164350	Navidad Rv nr Speaks	
								10/1/89	12/31/96	8164000	Lavaca Rv nr Edna	Fill in missing gage data
59	8164500	Navidad Rv nr Ganado	Lavaca	1/1/40	12/31/96	5/80 - 12/96		1/1/40	4/30/80	8164500	Navidad Rv nr Ganado	
								5/1/80	12/31/96	8164000	Lavaca Rv nr Edna	Fill in missing gage data
60	8164503	W Mustang Ck nr Ganado	Lavaca	1/1/40	12/31/96	1/40 - 9/77		1/1/40	9/30/77	8164000	Lavaca Rv nr Edna	Fill in missing gage data
								10/1/77	12/31/96	8164503	W Mustang Ck nr Ganado	

Reference Gages for Daily Streamflow Estimation

#	USGS	Name	Basin	Start	End	Missing	Reservoir	Start	End	Ref USGS	Ref Name	Reason for using (or not using) reference gage
61	8168500	Guadalupe Rv nr Spring Branch	Guadalupe	1/1/34	12/31/89			1/1/34	12/31/89	8167500	Guadalupe Rv nr Spring Branch	
62	8168500	Guadalupe Rv abv Comal Rv at New Braunfels	Guadalupe	1/1/34	12/31/89		Canyon 6/64	1/1/34	5/31/64	8168500	Guadalupe Rv abv Comal Rv at New Braunfels	
								6/1/64	12/31/89	8167500	Guadalupe Rv nr Spring Branch	Adjust for Canyon
63	8172000	San Marcos Rv at Luling	Guadalupe	1/1/34	12/31/89	1/34 - 4/39		1/1/34	4/30/39	8171000	Blanco Rv at Wimberley	Fill in missing gage data
								5/1/39	12/31/89	8172000	San Marcos Rv at Luling	Ignore Aquifer pumping
64	8176500	Guadalupe Rv at Victoria	Guadalupe	1/1/34	12/31/89	1/34 - 11/34		1/1/34	11/30/34	8168500	Guadalupe Rv abv Comal Rv at New Braunfels	Fill in missing gage data
								12/1/34	12/31/89	8176500	Guadalupe Rv at Victoria	
65	8181800	San Antonio Rv nr Elmendorf	SanAntonio	1/1/34	12/31/89	1/34 - 9/62		1/1/34	9/30/62	8183500	San Antonio Rv nr Falls City	Fill in missing gage data
								10/1/62	12/31/89	8181800	San Antonio Rv nr Elmendorf	
66	8183500	San Antonio Rv nr Falls City	SanAntonio	1/1/34	12/31/89			1/1/34	12/31/89	8183500	San Antonio Rv nr Falls City	
67	8186000	Cibolo Ck nr Falls City	SanAntonio	1/1/34	12/31/89			1/1/34	12/31/89	8186000	Cibolo Ck nr Falls City	
68	8188500	San Antonio Rv at Goliad	SanAntonio	1/1/34	12/31/89	1/34 - 2/39		1/1/34	2/28/39	8183500	San Antonio Rv nr Falls City	Fill in missing gage data
								1/1/34	2/28/39	8186000	Cibolo Ck nr Falls City	Fill in missing gage data
								3/1/39	12/31/89	8188500	San Antonio Rv at Goliad	
69	8194000	Nueces Rv at Cotulla	Nueces	1/1/34	12/31/96			1/1/34	12/31/96	8194000	Nueces Rv at Cotulla	
70	8205500	Frio Rv nr Derby	Nueces	1/1/34	12/31/96			1/1/34	12/31/96	8205500	Frio Rv nr Derby	
71	8210000	Nueces Rv nr Three Rivers	Nueces	1/1/34	12/31/96		Choke Canyon 10/82	1/1/34	9/30/82	8210000	Nueces Rv nr Three Rivers	Fill in missing gage data
								10/1/82	12/31/96	8208000	Atascosa Rv at Whitsett	Adjust for Choke Canyon
										8206700	San Miguel Ck nr Tilden	
										8207000	Frio Rv at Calliham	
										8194500	Nueces Rv nr Tilden	
72	8211000	Nueces Rv nr Mathis	Nueces	1/1/34	12/31/96	1/34 - 8/39	Corpus Christi 4/58	1/1/34	8/31/39	8210000	Nueces Rv nr Three Rivers	Fill in missing gage data
								9/1/39	3/31/58	8211000	Nueces Rv nr Mathis	
								4/1/58	12/31/96	8208000	Atascosa Rv at Whitsett	Adjust for Corpus Christi
										8206700	San Miguel Ck nr Tilden	
										8205500	Frio Rv nr Derby	
										8194500	Nueces Rv nr Tilden	