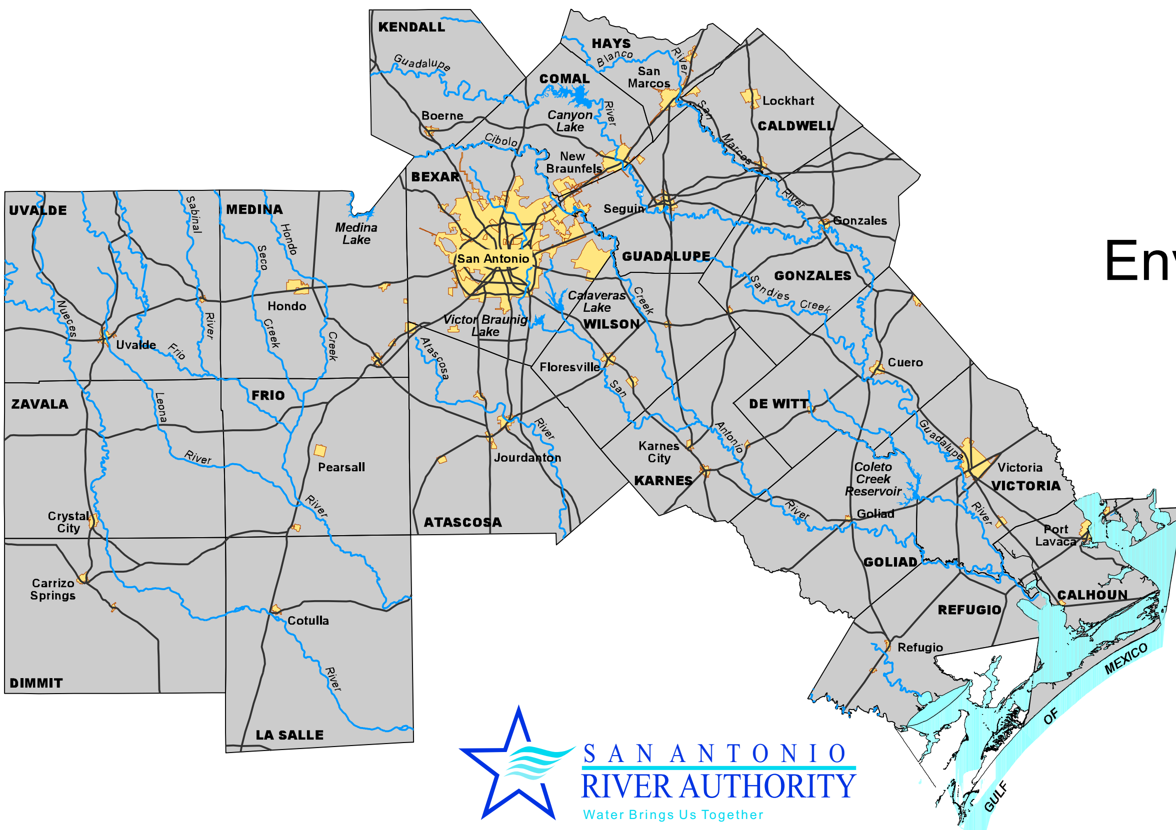
Region L

South Central Texas Regional Water Planning Group

TEXAS WATER DEVELOPMENT BOARD

2011 Regional Water Plan

Study 4
Part A
Environmental Studies



SAN ANTONIO RIVER AUTHORITY
Water Brings Us Together

April 2009

Prepared by:

South Central Texas Regional Water Planning Group

With administration by:

San Antonio River Authority

With technical assistance by:

HDR Engineering, Inc.
Laura Raun Public Relations
Ximenes & Associates

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South Central Texas Regional Water Planning Area

2011 Regional Water Plan

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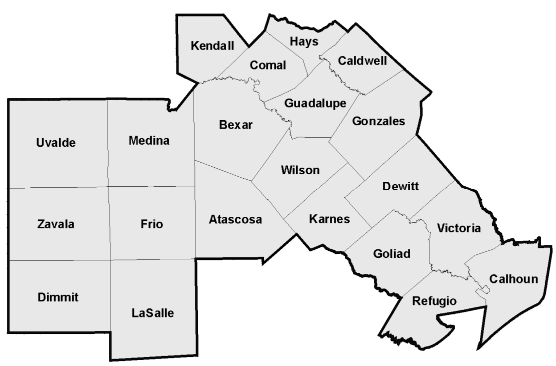

With technical assistance by:

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Executive Summary

ES.1 Introduction

The purpose of Study 4 is to continue environmental studies focused on bays & estuaries, instream flows, bottomland hardwoods, endangered species, and other relevant subjects of interest to the regional water planning group. The results of Study 4 provide information relevant to the potential environmental effects of the regional water plan and will aid planning group members in making decisions regarding water management strategies to be recommended for implementation in the 2011 South Central Texas Regional Water Plan (SCTRWP).

Study 4 Part A (Study 4A) focuses on three tasks:

1. Research and refine estimates of historical diversions and effluent discharges affecting flows in the lower Guadalupe River and freshwater inflows to the Guadalupe Estuary prior to 1977. Evaluate potential effects on fisheries harvest equations for selected species of interest (Blue Crabs, White Shrimp, Brown Shrimp, Eastern Oyster, Black Drum, Red Drum, and Spotted Seatrout).

2. Perform ecologically-based streamflow assessments (similar to those for the Guadalupe Estuary in Section 7 of the 2006 Regional Plan) for the Guadalupe River at Victoria and the San Antonio River at Falls City.

3. Develop and deliver presentation materials and GIS-based graphics to support SCTRWPG and education programs focused on regulatory processes, endangered species habitat ranges, and other factors potentially affecting implementation of planned strategies.

Study 4B consists of on-going work being performed by Texas A&M University (TAMU) and is presented in a separate report. TAMU is developing an ecosystem simulation model that will integrate existing project field data with information from the scientific literature to project possible ecosystem responses to variation in freshwater inflows to the Guadalupe Estuary.

ES.2 Guadalupe Estuary Harvest Equations

ES.2.1 Background

Current fisheries harvest equations for the Guadalupe Estuary were derived by the Texas Water Development Board (TWDB) using diversion and return flow data for only the period after 1976. Prior to 1977, diversions and return flows were not accounted for and the fisheries harvest equations were derived using inflow estimates greater than actual inflows. Objectives of Task 1 include refinement of freshwater inflow estimates prior to 1977, re-derivation of fisheries harvest equations using multi-variable regression techniques and equation formulations identical to the TWDB, and comparisons of equations and resulting historical fisheries harvest estimates in the hope that new equations might prove more robust in estimating fisheries harvest during dry periods.

ES.2.2 Estimates of Historical Inflow to the Guadalupe Estuary

In an effort to improve the historical freshwater estimates derived by the TWDB, diversion and return data for the lower Guadalupe River Basin prior to 1977 were obtained from several sources, including the Texas Water Commission (TWC). Estimates of monthly historical inflow to the Guadalupe Estuary are calculated using TWC net reported surface water use data (including diversions prior to 1977), Victoria return flow data (including return flow prior to 1977), TWDB ungaged run-off estimates from the TxRR Model, and data from the three upstream gages (Guadalupe River at Victoria, Coleto Creek near Victoria, and San Antonio River at Goliad). These updated estuarine inflow estimates are summarized in Table ES-1 in the bimonthly groupings used to derive the fisheries harvest equations. Table ES-2 presents the bimonthly differences in freshwater inflow estimates as a result of accounting for historical diversions and return flows prior to 1977.

ES.2.3. Harvest Equations with Updated Historical Freshwater Inflow Estimates

The original TPWD/TWDB harvest equations were updated using the updated estuarine inflow estimates in Table ES-1. The same bi-monthly periods, annual harvests, and equation formulations used in the original equation derivation were used to perform the re-derivation of the harvest equations using the updated estuarine inflows. Multi-variable regression was performed using Microsoft Excel to re-derive the coefficients of the original harvest equations. The newly calculated bimonthly species coefficients are slightly different from the original coefficients.

Table ES-1.
Updated Estuarine Inflow Estimates (acft)

Year	Bimonthly Periods						Annual Total
	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	
1958	1,376,188	434,608	542,724	152,120	643,083	430,993	3,579,717
1959	413,305	368,125	285,319	225,227	426,252	219,601	1,937,830
1960	265,974	227,739	483,146	478,307	1,288,168	1,080,285	3,823,618
1961	815,196	328,579	682,450	414,765	352,899	296,255	2,890,143
1962	146,114	153,042	217,963	61,901	148,952	176,023	903,996
1963	152,563	109,258	52,113	15,561	45,773	133,747	509,014
1964	166,996	172,819	88,451	90,074	200,825	154,081	873,246
1965	597,435	195,668	839,518	113,973	212,457	463,779	2,422,829
1966	336,176	337,423	525,346	191,374	200,383	142,459	1,733,162
1967	141,335	113,692	112,816	90,432	2,711,544	449,616	3,619,435
1968	1,029,284	427,260	1,116,514	365,635	332,987	301,296	3,572,976
1969	426,760	694,554	493,960	99,700	170,390	278,375	2,163,738
1970	328,035	464,106	676,009	172,560	258,225	118,387	2,017,322
1971	102,520	75,604	76,718	200,138	894,844	530,147	1,879,971
1972	328,322	185,476	1,354,248	264,429	269,061	264,043	2,665,579
1973	230,484	644,568	984,118	873,700	1,595,304	623,364	4,951,538
1974	491,063	274,191	429,124	178,425	560,108	772,721	2,705,631
1975	593,059	453,840	1,342,035	483,224	274,203	233,842	3,380,203
1976	182,159	610,120	897,024	430,115	539,557	1,351,739	4,010,714
1977	685,135	1,132,668	943,254	238,327	230,298	322,486	3,552,168
1978	210,829	186,116	231,700	374,319	667,631	293,293	1,963,888
1979	776,170	841,942	1,288,304	462,238	494,651	167,626	4,030,931
1980	223,205	129,267	349,784	147,870	232,483	152,420	1,235,029
1981	164,986	230,841	1,414,993	572,083	1,166,285	588,801	4,137,989
1982	353,499	187,173	575,205	98,773	109,908	242,609	1,567,167
1983	220,345	303,067	211,877	266,075	224,778	159,619	1,385,761
1984	150,823	129,226	60,777	33,109	164,354	174,640	712,929
1985	301,599	570,844	360,028	299,441	244,304	532,234	2,308,450
1986	264,598	159,207	532,965	155,490	389,204	737,625	2,239,089
1987	692,847	555,264	2,718,643	893,407	330,447	262,478	5,453,086

Table ES-2.
Differences in Estuarine Inflow Estimates (acft)

Year	Bimonthly Periods						Annual Total
	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	
1958	187	-2,070	-10,517	-14,309	-937	222	-27,423
1959	79	-4,358	-12,729	-14,464	-6,709	115	-38,065
1960	253	-449	-14,700	-20,194	-4,473	162	-39,402
1961	202	-718	-8,099	-12,221	-391	152	-21,076
1962	160	-1,828	-12,103	-13,737	-4,257	28	-31,736
1963	2,682	-677	-25,619	-25,889	-6,376	2,596	-53,284
1964	2,800	-7,184	-22,603	-21,402	-5,587	2,776	-51,200
1965	3,316	-4,527	-17,882	-23,241	-11,751	3,255	-50,831
1966	3,188	965	-1,174	-12,492	-3,224	2,861	-9,875
1967	1,751	-8,340	-20,466	-16,560	-1,519	1,635	-43,499
1968	2,956	-3,787	-20,877	-31,415	-10,681	2,930	-60,874
1969	2,866	-4,507	-28,432	-31,371	-14,933	2,780	-73,598
1970	2,277	-2,607	-20,939	-23,999	-5,741	1,029	-49,980
1971	569	-19,136	-25,402	-25,997	-9,923	1,434	-78,455
1972	-427	-9,336	-26,028	-19,291	-19,284	858	-73,508
1973	-1,673	-3,395	-24,972	-36,882	-12,176	-1,666	-80,764
1974	-345	-5,383	-18,632	-20,791	-12,977	-606	-58,735
1975	-1,420	-12,288	-23,157	-18,639	-13,008	-784	-69,296
1976	-334	-6,876	-19,008	-15,522	-13,743	417	-55,066
1977	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0

ES.2.4 Applications of Updated Harvest Equations

An annual fisheries harvest calculation model (ESTUARY1) for the Guadalupe Estuary was developed as part of the Trans-Texas Water Program to calculate theoretical harvests associated with freshwater inflows resulting from implementation of one or more water management strategies. A sample set of freshwater inflows was used as input into versions of the model with the original and updated equations. Use of the updated harvest equations decreased the number of low and high bound excursions for five (White Shrimp, Brown Shrimp, Blue Crabs, Eastern Oyster, and Red Drum) of seven species using the sample inflow data set.

ES.2.5 Conclusions and Recommendations

Freshwater inflow recommendations for the Guadalupe Estuary were developed by the TPWD and the TWDB and published in 1998.[1] These recommendations included a maximum harvest (MaxH) freshwater inflow of 1,147,400 acft/yr and a minimum freshwater inflow (MinQ) of 1,028,800 acft/yr assumed to represent a range within which a flow recommendation consistent with the goal of maintaining a biologically healthy and productive Guadalupe Estuary might be achieved. Comparison of predicted species landings based on the updated and original harvest equations for the Maximum Harvest (MaxH) inflow recommendations reveals that updated equations would predict five (5) percent greater total species landings (klbs), 13 percent greater Red Drum landings, and about 8 percent greater Brown Shrimp, Blue Crab, and Easter Oyster landings. A similar comparison for the MinQ inflow set reveals that updated equations would predict seven (7) percent greater total species landings (klbs), 18 percent greater Blue Crab landings, 16 percent greater Red Drum landings, and about 11 percent greater Brown Shrimp and Easter Oyster landings. Clearly, it is possible that such differences could have affected the outcome of optimization and associated procedures that led to the 1998 freshwater inflow recommendations for the Guadalupe Estuary. It is recommended that the TWDB and TPWD give careful consideration to the updated harvest equations as one element of the broader scientific effort to establish environmental flow standards pursuant to SB3 of the 80th Texas Legislature.

ES.3 Ecologically-Based Streamflow Assessments

The 2006 SCTRWP[2] includes an ecologically-based freshwater inflow assessment of the Guadalupe Estuary considering inflow conditions ranging from natural to the present to the future with implementation of strategies recommended in the plan. Continuing that effort, Task

[1] Pulich, Warren, et al, "Freshwater Inflow Recommendation for the Guadalupe Estuary of Texas," Texas Parks and Wildlife Department and Texas Water Development Board, December 1998.

[2] South Central Texas Regional Water Planning Group, "2006 South Central Texas Regional Water Plan," Texas Water Development Board, San Antonio River Authority, HDR Engineering, Inc., et al., January 2006.

2 of Study 4 was performed to demonstrate a similar type of assessment for instream flows focusing on the Guadalupe River at Victoria and the San Antonio River near Falls City.

ES.3.1 High Flow Criteria

An important aspect of high streamflows is the ability for the stream to maintain aquatic and riparian habitats, and provide for stream connectivity with the floodplain.[3] High flow pulses are short, high flow events following storms that stay within the channel, while overbanking flows are less frequent, high flow flood events in which streamflow rises above the normal channel. Scientists consulted generally suggested that a flood flow consistent with a 2-year return period would be typical of an overbanking event and a good measure for the high flow criteria.

ES.3.2 Low Flow Criteria

The low (subsistence) streamflow criteria needs to be high enough to maintain aquatic habitat sufficient for endemic species to survive transient low flow periods and to maintain dissolved oxygen (DO) in the stream.[4] These low flows are characterized by seasonal periods of infrequent streamflow well below the normal flow. The City of Victoria's Permit #18-5466 "low" flow values are used as the low flow criteria for the Guadalupe River at Victoria. For the San Antonio River near Falls City, a long-standing informal agreement between the San Antonio River Authority (SARA), San Antonio Water System (SAWS), and City Public Service (CPS) of 76 cfs (55,000 acft/yr) is used as the low flow criteria.

ES.3.3 Base Flow Criteria

Guiding principles in selection of base streamflow criteria are that they should reflect the "normal" flow condition in the stream between storm events and ensure adequate habitat conditions, including variability, to support the natural biologic community.[5] Based on noticeable similarities between potential base streamflow criteria and consultation with resource agency scientists, monthly flows from the site-specific study of the Guadalupe River near Gonzales were translated downstream and used as the base streamflow criteria for the Guadalupe River at Victoria. Monthly base streamflow criteria derived by the Modified Lyons Method

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[3] Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, & Texas Water Development Board, "Texas Instream Flow Studies: Technical Overview," TWDB Report 369, May 2008.
[4] Ibid.
[5] Ibid.

were used to perform the ecologically-based assessment of changes in streamflow for the San Antonio River at Falls City.

ES.3.4 Simulation Descriptions

The Guadalupe - San Antonio River Basin Water Availability Model (GSA WAM)[6] was used to simulate monthly streamflows for four (4) scenarios. The four scenarios, consistent with those used in the ecologically-based assessment of changes in freshwater inflow to the Guadalupe Estuary in the 2006 SCTRWP, are Natural Conditions, Present Conditions, Baseline (Full Permits), and Regional Water Plan.

ES.3.5 Discussion of the Ecologically-Based Streamflow Assessments

The results of the ecologically-based streamflow assessments for the Guadalupe River at Victoria show that the regional plan would have virtually no effect on streamflow. For the San Antonio River near Falls City, implementation of the regional water plan would have limited effects in all three flow regimes considered (high, base, and low). Such limited effects could be considered positive with respect to the Baseline (flows increase due to increased San Antonio effluent) and negative with respect to Present Conditions (flows decrease due to increased diversions under existing water rights). The ecological significance of these limited effects is unknown and further complicated by the significant differences between Natural Conditions and the other three scenarios considered. Ongoing instream flow studies on the San Antonio River will likely yield additional information regarding appropriate criteria for ecologically-based streamflow assessments. It is anticipated that, with continued refinement in the assessment criteria and improved knowledge of the instream flow needs, the SCTRWPG will be able to further consider this issue in a future round of planning.

ES.4 Interactive, Web-Based Graphics and Presentation Materials

The South Central Texas Regional Water Planning Group (SCTRWPG) is interested in communicating potential interactions between recommended water management strategies and the natural environment, particularly with respect to endangered species. Furthermore, the SCTRWPG seeks to summarize and communicate the range of processes, in addition to regional water planning, necessary for implementation of water management strategies. Hence, the

SCTRWPG has developed interactive, web-based graphics and presentation materials to support SCTRWPG and education programs focused on these subjects. The reader is encouraged to visit the South Central Texas Regional Water Planning Area website (http://www.regionltexas.org/) and explore available information regarding endangered species using the graphical interface.

Beginning with project conception, or identification as a potentially feasible water management strategy, there are many elements involved in the development of a water supply project. Regional water planning, pursuant to SB1 of the 75th Texas Legislature, can be a critical element in project development, as it represents one of the first opportunities for project sponsors to receive public comment on a concept for future water supply. Figure ES-1 provides a graphical summary of many of the elements typically involved in the project development process, from conception to implementation. Although regional water planning may be engaged relatively early, it can affect project development throughout the permitting phase and into the implementation phase. Examples may include consistency with a regional water plan in order to obtain new surface water rights or groundwater production permits, referencing regional water planning for consideration of project alternatives in permitting, and/or recommendation in an approved regional water plan to obtain loans from the Texas Water Development Board for project construction.

[6] HDR Engineering, Inc., "Water Availability in the Guadalupe – San Antonio River Basin," Texas Natural Resource Conservation Commission, December 1999.

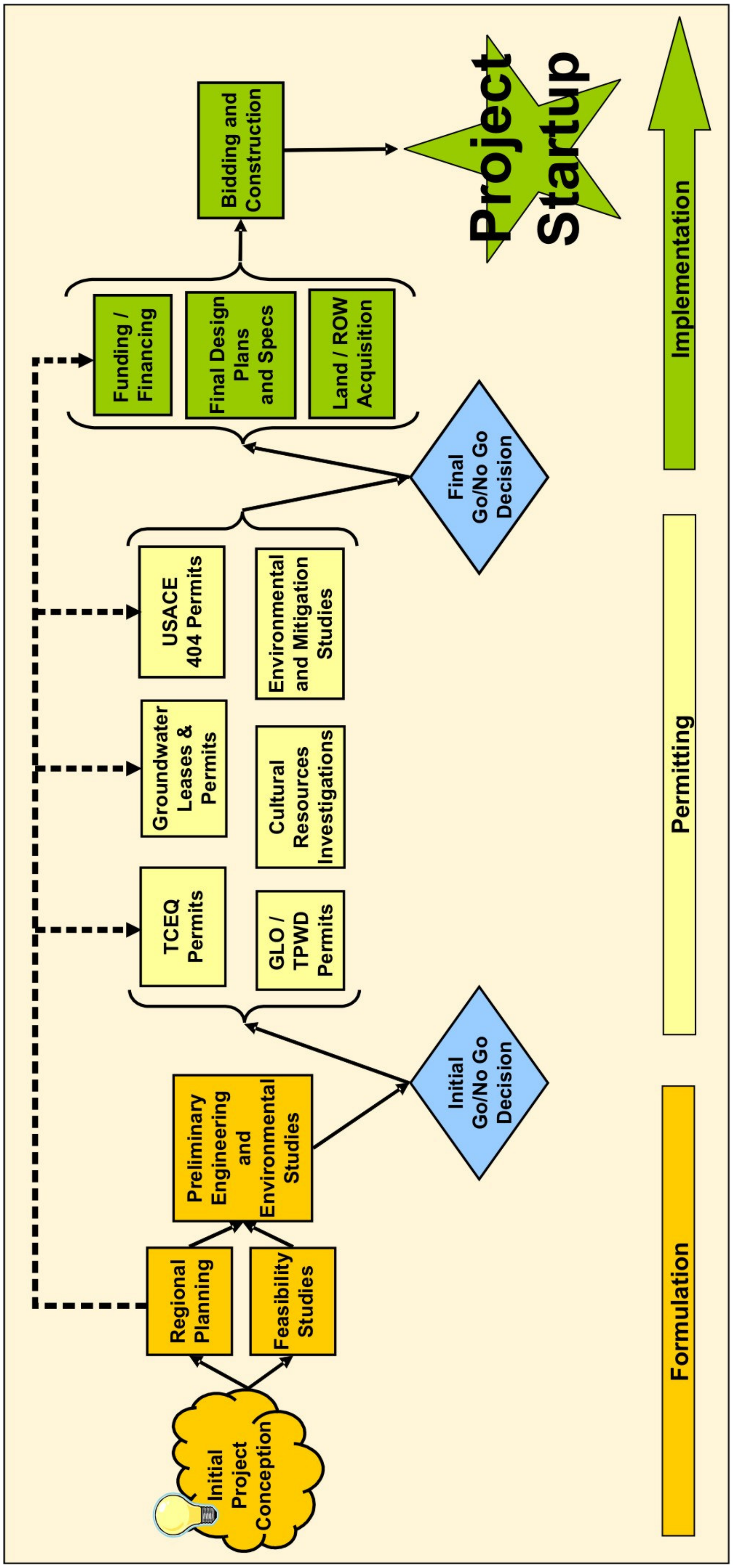

Figure ES-1. Project Development from Conception to Implementation

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1.0 Introduction

Study 4, Part A (Study 4A), Environmental Studies of the First Biennium of the 2011 South Central Texas Regional Water Plan (SCTRWP) is the continuation of environmental studies focused on bays & estuaries, instream flows, bottomland hardwoods, endangered species, and other relevant subjects of interest to the South Central Texas Regional Water Planning Group (SCTRWPG). Study 4A focuses on three tasks, presented in this report, and introduced below. Study 4B consists of on-going work performed by Texas A&M University (TAMU) and is presented in a separate report. TAMU is developing an ecosystem simulation model that will integrate existing project field data with information from the scientific literature to project possible ecosystem responses to variation in freshwater inflows to the Guadalupe Estuary.

Task 1, Guadalupe Estuary Harvest Equations (Presented in Section 2) – Research and refine estimates of historical diversions and effluent discharges affecting flows in the lower Guadalupe River and freshwater inflows to the Guadalupe Estuary prior to 1977. Evaluate potential effects on fisheries harvest equations for selected species of interest (Blue Crabs, White Shrimp, Brown Shrimp, Eastern Oyster, Black Drum, Red Drum, and Spotted Seatrout).

Task 2, Ecologically-Based Streamflow Assessments (Presented in Section 3) – Perform ecologically-based streamflow assessments (similar to those for the Guadalupe Estuary in Section 7 of the 2006 South Central Texas Regional Water Plan) for the Guadalupe River at Victoria and the San Antonio River at Falls City.

Task 3, Interactive, Web-Based Graphics and Presentation Materials (Presented in Section 4) – Develop and deliver presentation materials and GIS-based graphics to support SCTRWPG and education programs focused on regulatory processes, endangered species habitat ranges, and other factors potentially affecting implementation of planned strategies.

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2.0 Guadalupe Estuary Harvest Equations

Ecological health of Texas estuaries is of great concern for many reasons including protection of the wildlife that live in and depend upon the estuary, protection of commercial fisheries harvest, and preservation of natural recreation areas. The Texas Water Code provides for studies of Texas estuaries and how freshwater inflow affects them. Perhaps the most comprehensive summary of such studies to-date is found in a report entitled "Freshwater Inflows to Texas Bays and Estuaries: Ecological Relationships and Methods for Determination of Needs."[1] Senate Bill 3 of the 80th Texas Legislature (2007) authorized ongoing studies and created a process for defining environmental flow regimes that "reflect seasonal and yearly fluctuations that typically would vary geographically, by specific location in a watershed, and that are shown to be adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies."

A sound ecological environment and fundamental species viability are dependent on many factors, including salinity levels and gradients within an estuary. Commercial harvest of species within bays and estuaries depends, in part, on these salinity levels, which are directly affected by the amount of freshwater inflow entering the bay and estuary. In this study, as in the Texas Parks and Wildlife Department (TPWD) / Texas Water Development Board (TWDB) study[2], seven commercially harvested species are of interest, including White Shrimp, Brown Shrimp, Blue Crab, Eastern Oyster, Black Drum, Red Drum, and Spotted Seatrout.

Current fisheries harvest equations for the Guadalupe Estuary were derived by the TWDB using diversion and return flow data for only the period after 1976. Prior to 1977, diversions and return flows were not accounted for and, because diversions exceeded return flows, the fisheries harvest equations were derived using inflow estimates greater than actual inflows (see Figure 2-1 for a schematic illustration of major diversions and returns in the lower Guadalupe River Basin). Objectives of Task 1 include refinement of freshwater inflow estimates prior to 1977, re-derivation of fisheries harvest equations using multi-variable regression techniques and equation formulations identical to the TWDB, and comparisons of equations and

[1] Longley, W.L., "Freshwater Inflows to Texas Bays and Estuaries: Ecological Relationships and Methods for Determination of Needs," Texas Parks and Wildlife Department and Texas Water Development Board, 1994.
[2] Pulich, Warren et al, "Freshwater Inflow Recommendation for the Guadalupe Estuary of Texas," Texas Parks and Wildlife Department and Texas Water Development Board, December 1998.

resulting historical fisheries harvest estimates in the hope that new equations might prove more robust in estimating fisheries harvest during dry periods.

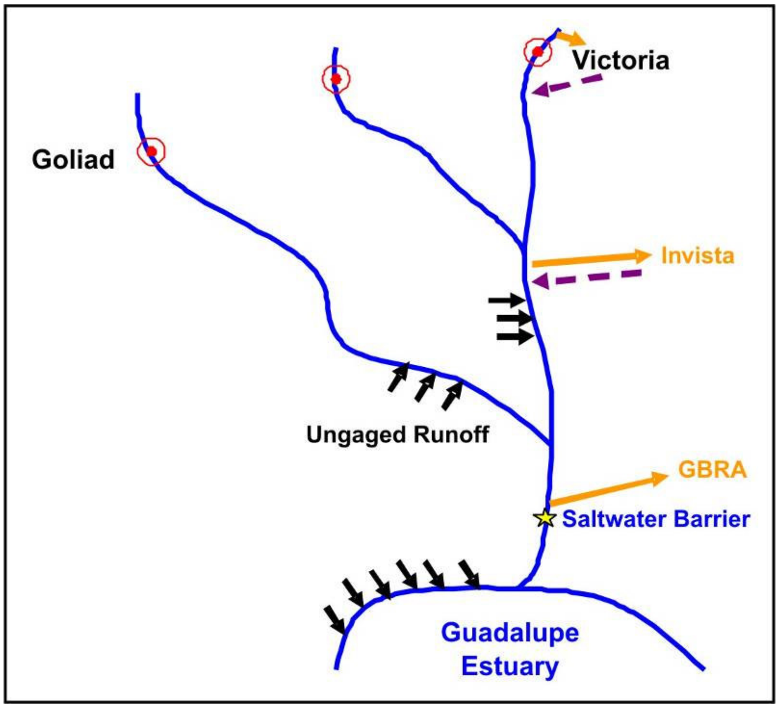

Figure 2-1. Lower Guadalupe-San Antonio River Basin Schematic

2.1 Supplemental Diversion and Return Data

In an effort to improve the historical freshwater estimates derived by the TWDB, diversion and return data for the lower Guadalupe River Basin prior to 1977 were obtained from several sources, including the Texas Water Commission (TWC).

2.1.1 Diversion Data

Monthly and annual diversion data were acquired from the Texas Water Commission (TWC) for the development of natural streamflows used in the Guadalupe-San Antonio River Basin Model[3] (GSA Model) and, ultimately, the Guadalupe-San Antonio River Basin Water Availability Model[4] (GSA WAM). The TWC database and query techniques available at the time provided historical diversion data for multiple water rights aggregated by stream segment delineated by river order numbers. This TWC data was used with the understanding that it

[3] HDR Engineering, Inc., "Guadalupe-San Antonio River Basin Recharge Enhancement Study," Vol. 2, Edwards Underground Water District, September 1993.
[4] HDR Engineering, Inc., "Water Availability in the Guadalupe-San Antonio River Basin," Texas Natural Resource Conservation Commission, December 1999.

included only consumptive use or net diversions for major industrial users. The stream segment grouping of interest for the purposes of this study extends from the following streamflow gaging stations down to the Guadalupe-Blanco River Authority (GBRA) Saltwater Barrier and Diversion Dam near Tivoli:

1. Guadalupe River at Victoria;
2. Coleto Creek near Victoria; and
3. San Antonio River at Goliad.

Reported diversions in this area were summarized monthly and include municipal, industrial, irrigation, mining, steam-electric power generation, and recreational types of use. Unfortunately, consultations with the Texas Commission on Environmental Quality (TCEQ) during the last few years reveal that the referenced TWC database is no longer accessible.

The largest surface water rights in this portion of the Guadalupe-San Antonio River Basin are held by GBRA, Dow Chemical Company (formerly Union Carbide Corporation), and Invista (formerly DuPont). The GBRA and Dow water rights are held jointly and total 172,501 acft/yr in authorized diversions. Invista's water rights include authorized diversions of 60,000 acft/yr with consumptive use limited to 33,000 acft/yr and the balance returned to the Guadalupe River. Authorized diversions for other water rights in this portion of the basin having priority dates prior to 1977 total about 3,900 acft/yr.

Annual historical diversions by GBRA and Dow through the Calhoun Canal System for the period of interest were gathered from GBRA records (1947-1976) and from Parshall flume measurements in the Calhoun Canal System reported by the U.S. Geological Survey (USGS) (1969-1976). Data from these two sources are consistent with one another and with the TWC data, recognizing that the TWC data includes diversions by others located upstream of the Calhoun Canal System.

Diversion data for Invista, as reported to the TWC, are reasonably consistent with the aggregated TWC data when considered in combination with the Calhoun Canal System diversions. It is observed that potential discrepancies may exist in some years as a result of uncertainty in accounting for total diversions versus consumptive use by Invista. Research in the central filing system of the TCEQ, however, reveals that neither hardcopy, nor microfiche/microfilm, versions of annual water use reports by Invista are available for years prior to 1977.

Since the aggregated diversion data originally provided by the TWC remains the basis for natural streamflows in the GSA WAM and is reasonably supported by available data from other sources, it has been used for development of updated historical freshwater inflow estimates prior to 1977 herein and is recommended for consideration by the TWDB.

2.1.2 Return Flow Data

Return flow data in the lower Guadalupe-San Antonio River Basin prior to 1977 consisted primarily of effluent from the Victoria wastewater treatment plant, as Invista return flows were accounted for as net consumptive use in the diversion data. Monthly Victoria return flow estimates used in the development of natural streamflows for the GSA WAM for the period prior to 1973 were calculated using population records and a linear regression relationship between population and reported effluent based on the 1973 through 1991 historical period.

Annual net diversions (diversions minus return flows) for the 1958 through 1987 historical period on which the fisheries harvest equations were based are plotted in Figure 2-2. Review of Figure 2-2 indicates that the TWC data is in reasonable agreement with the TPWD/TWDB data, with the exceptions of a few years (1977-1979). With regard to net diversions in the years 1977-1979, USGS flow records for the Calhoun Canal System tend to support the higher net diversion figures based on the TWC data.

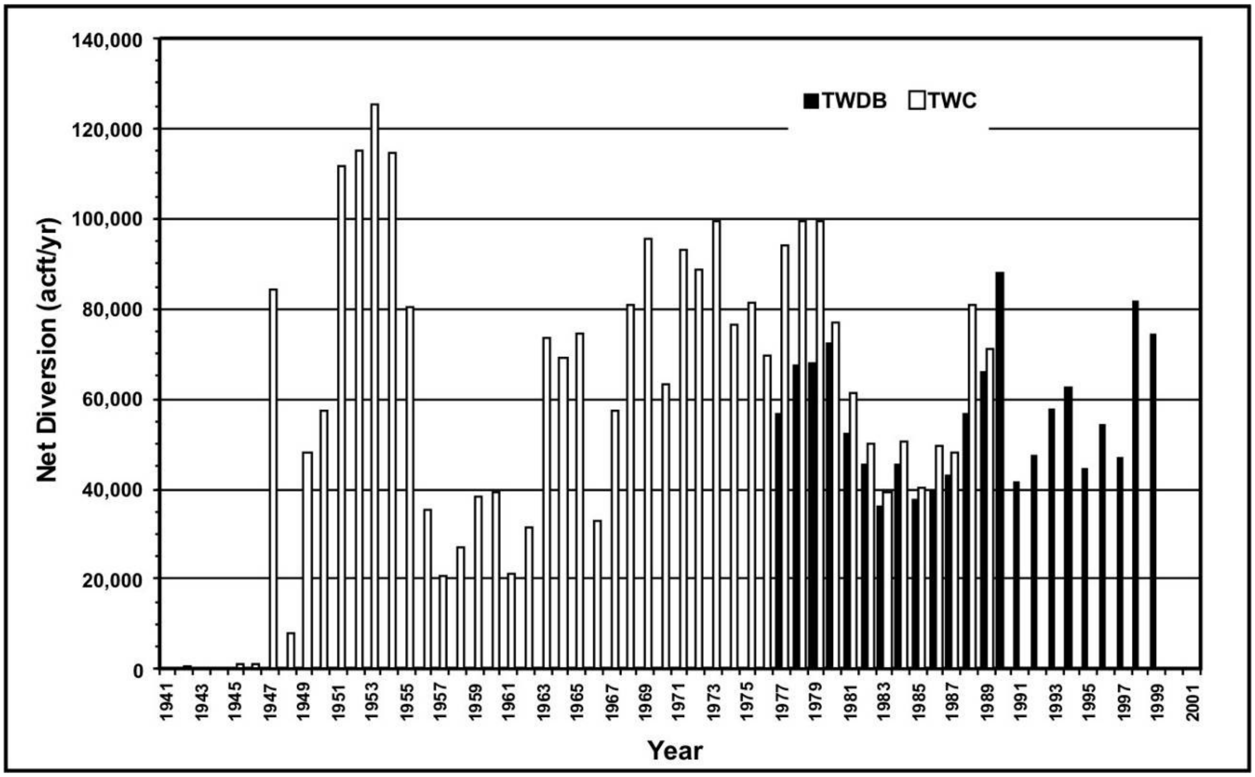

Figure 2-2. Comparison of TWC and TWDB Net Diversion Data

2.2 Estimates of Historical Inflow to the Guadalupe Estuary

Estimates of monthly historical inflow to the Guadalupe Estuary are calculated using Equation 2-1 (see Figure 2-1). Updated Guadalupe Estuary inflow estimates were calculated using TWC net reported surface water use data, Victoria return flow data, TWDB ungaged run-off estimates from the TxRR Model, and data from the three upstream gages (Guadalupe River at Victoria, Coleto Creek near Victoria, and San Antonio River at Goliad). These updated estuarine inflow estimates are summarized in Table 2-1 in the bimonthly groupings used to derive the fisheries harvest equations. Table 2-2 presents the bimonthly differences in freshwater inflow estimates as a result of accounting for historical diversions and return flows prior to 1977.

Estuarine Inflow = Gaged Streamflow – Diversions + Returns + Ungaged Run-off **(Eq. 2-1)**

The original data used by TPWD/TWDB resulted in a set of upper and lower estuarine inflow bounds for each species, within which equations would produce reasonable harvest estimates. In other words, the harvest equations are only applicable to the same range of flows from which they were developed. The updated estuarine inflows reflect lower bimonthly inflow bounds than TPWD/TWDB's original inflow estimates, therefore resulting in more robust fisheries harvest equations during dry periods.

2.3 Verification of Existing Harvest Equations

Prior to updating the TPWD/TWDB diversion and return flow data and deriving new harvest equations, the original harvest equations were verified using the same data from the TPWD/TWDB study.[5] The same bi-monthly flows, bi-monthly periods, annual harvests, and equation formulations were used to perform the verification. Multi-variable regression was performed using Microsoft Excel, producing coefficients very similar to those reported in 1998 study. Table 2-3 shows the similarity between the original and the verified equations for each of the species.

[5] Pulich, Warren et al, "Freshwater Inflow Recommendation for the Guadalupe Estuary of Texas," Texas Parks and Wildlife Department and Texas Water Development Board, December 1998.

Table 2-1.
Updated Estuarine Inflow Estimates (acft)

Year	Bimonthly Periods						Annual Total
	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	
1958	1,376,188	434,608	542,724	152,120	643,083	430,993	3,579,717
1959	413,305	368,125	285,319	225,227	426,252	219,601	1,937,830
1960	265,974	227,739	483,146	478,307	1,288,168	1,080,285	3,823,618
1961	815,196	328,579	682,450	414,765	352,899	296,255	2,890,143
1962	146,114	153,042	217,963	61,901	148,952	176,023	903,996
1963	152,563	109,258	52,113	15,561	45,773	133,747	509,014
1964	166,996	172,819	88,451	90,074	200,825	154,081	873,246
1965	597,435	195,668	839,518	113,973	212,457	463,779	2,422,829
1966	336,176	337,423	525,346	191,374	200,383	142,459	1,733,162
1967	141,335	113,692	112,816	90,432	2,711,544	449,616	3,619,435
1968	1,029,284	427,260	1,116,514	365,635	332,987	301,296	3,572,976
1969	426,760	694,554	493,960	99,700	170,390	278,375	2,163,738
1970	328,035	464,106	676,009	172,560	258,225	118,387	2,017,322
1971	102,520	75,604	76,718	200,138	894,844	530,147	1,879,971
1972	328,322	185,476	1,354,248	264,429	269,061	264,043	2,665,579
1973	230,484	644,568	984,118	873,700	1,595,304	623,364	4,951,538
1974	491,063	274,191	429,124	178,425	560,108	772,721	2,705,631
1975	593,059	453,840	1,342,035	483,224	274,203	233,842	3,380,203
1976	182,159	610,120	897,024	430,115	539,557	1,351,739	4,010,714
1977	685,135	1,132,668	943,254	238,327	230,298	322,486	3,552,168
1978	210,829	186,116	231,700	374,319	667,631	293,293	1,963,888
1979	776,170	841,942	1,288,304	462,238	494,651	167,626	4,030,931
1980	223,205	129,267	349,784	147,870	232,483	152,420	1,235,029
1981	164,986	230,841	1,414,993	572,083	1,166,285	588,801	4,137,989
1982	353,499	187,173	575,205	98,773	109,908	242,609	1,567,167
1983	220,345	303,067	211,877	266,075	224,778	159,619	1,385,761
1984	150,823	129,226	60,777	33,109	164,354	174,640	712,929
1985	301,599	570,844	360,028	299,441	244,304	532,234	2,308,450
1986	264,598	159,207	532,965	155,490	389,204	737,625	2,239,089
1987	692,847	555,264	2,718,643	893,407	330,447	262,478	5,453,086

Table 2-2.
Differences in Estuarine Inflow Estimates (acft)

Year	Bimonthly Periods						Annual Total
	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec	
1958	187	-2,070	-10,517	-14,309	-937	222	-27,423
1959	79	-4,358	-12,729	-14,464	-6,709	115	-38,065
1960	253	-449	-14,700	-20,194	-4,473	162	-39,402
1961	202	-718	-8,099	-12,221	-391	152	-21,076
1962	160	-1,828	-12,103	-13,737	-4,257	28	-31,736
1963	2,682	-677	-25,619	-25,889	-6,376	2,596	-53,284
1964	2,800	-7,184	-22,603	-21,402	-5,587	2,776	-51,200
1965	3,316	-4,527	-17,882	-23,241	-11,751	3,255	-50,831
1966	3,188	965	-1,174	-12,492	-3,224	2,861	-9,875
1967	1,751	-8,340	-20,466	-16,560	-1,519	1,635	-43,499
1968	2,956	-3,787	-20,877	-31,415	-10,681	2,930	-60,874
1969	2,866	-4,507	-28,432	-31,371	-14,933	2,780	-73,598
1970	2,277	-2,607	-20,939	-23,999	-5,741	1,029	-49,980
1971	569	-19,136	-25,402	-25,997	-9,923	1,434	-78,455
1972	-427	-9,336	-26,028	-19,291	-19,284	858	-73,508
1973	-1,673	-3,395	-24,972	-36,882	-12,176	-1,666	-80,764
1974	-345	-5,383	-18,632	-20,791	-12,977	-606	-58,735
1975	-1,420	-12,288	-23,157	-18,639	-13,008	-784	-69,296
1976	-334	-6,876	-19,008	-15,522	-13,743	417	-55,066
1977	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0

Table 2-3.
Guadalupe Estuary Harvest Equations Using Original Inflows

Species	***Constant***	***Jan-Feb***	***Mar-Apr***	***May-Jun***	***Jul-Aug***	***Sep-Oct***	***Nov-Dec***
White Shrimp							
Original H =	545.59	+ 160.9 $\ln Q_{JF}$		+ 279.1 $\ln Q_{MJ}$	- 155.1 $\ln Q_{JA}$		- 277.9 $\ln Q_{ND}$
Verified H =	547.23	+ 161.2 $\ln Q_{JF}$		+ 278.7 $\ln Q_{MJ}$	- 154.9 $\ln Q_{JA}$		- 278.2 $\ln Q_{ND}$
Brown Shrim							
Original $\ln H$ =	6.5679				+ 0.6707 $\ln Q_{JA}$	- 0.7486 $\ln Q_{SO}$	
Verified $\ln H$ =	6.5499				+ 0.6715 $\ln Q_{JA}$	- 0.7460 $\ln Q_{SO}$	
Blue Crab							
Original H =	110.64	- 145.3 $\ln Q_{JF}$			+ 332.5 $\ln Q_{JA}$	- 141.4 $\ln Q_{SO}$	
Verified H =	106.01	- 144.8 $\ln Q_{JF}$			+ 332.4 $\ln Q_{JA}$	- 141.1 $\ln Q_{SO}$	
Eastern Oyster							
Original H =	3000.7		+ 180.4 $\ln Q_{MA}$	- 963.3 $\ln Q_{MJ}$	+ 710.0 $\ln Q_{JA}$	- 231.5 $\ln Q_{SO}$	
Verified H =	2989.1		+ 180.3 $\ln Q_{MA}$	- 962.6 $\ln Q_{MJ}$	+ 711.6 $\ln Q_{JA}$	- 231.6 $\ln Q_{SO}$	
Black Drum							
Original H =	- 18.087	+ 0.2411 Q_{JF}	- 0.1734 Q_{MA}				+ 0.0850 Q_{ND}
Verified H =	- 18.114	+ 0.2410 Q_{JF}	- 0.1733 Q_{MA}				+ 0.0850 Q_{ND}
Red Drum							
Original H =	32.786			+ 0.0797 Q_{MJ}	+ 0.2750 Q_{JA}		- 0.2010 Q_{ND}
Verified H =	32.811			+ 0.0796 Q_{MJ}	+ 0.2754 Q_{JA}		- 0.2011 Q_{ND}
Spotted Seatrout							
Original $\ln H$ =	2.6915		- 0.7185 $\ln Q_{MA}$	+ 1.860 $\ln Q_{MJ}$			- 1.086 $\ln Q_{ND}$
Verified $\ln H$ =	2.6904		- 0.7185 $\ln Q_{MA}$	+ 1.860 $\ln Q_{MJ}$			- 1.086 $\ln Q_{ND}$

2.4 Harvest Equations with Updated Historical Freshwater Inflow Estimates

The original TPWD/TWDB harvest equations were updated using the updated estuarine inflow estimates in Table 2-1. Guadalupe Estuary inflows were calculated using Equation 2-1 and the flows were used in multi-variable regressions to re-derive the coefficients of the original harvest equations. The newly calculated bimonthly species coefficients are slightly different from the original coefficients (Table 2-4).

Table 2-4.
Guadalupe Estuary Harvest Equations Using Updated Inflows

Species	Constant	Jan-Feb	Mar-Apr	May-Jun	Jul-Aug	Sep-Oct	Nov-Dec
White Shrimp							
Original H =	545.59	+ 160.9 $\ln Q_{JF}$		+ 279.1 $\ln Q_{MJ}$	- 155.1 $\ln Q_{JA}$		- 277.9 $\ln Q_{ND}$
Updated H =	532.74	+ 154.7 $\ln Q_{JF}$		+ 257.4 $\ln Q_{MJ}$	- 121 $\ln Q_{JA}$		- 278.3 $\ln Q_{ND}$
Brown Shrimp							
Original lnH =	6.5679				+ 0.6707 $\ln Q_{JA}$	- 0.7486 $\ln Q_{SO}$	
Updated lnH =	7.0587				+ 0.5901 $\ln Q_{JA}$	- 0.7468 $\ln Q_{SO}$	
Blue Crab							
Original H =	110.64	- 145.3 $\ln Q_{JF}$			+ 332.5 $\ln Q_{JA}$	- 141.4 $\ln Q_{SO}$	
Updated H =	342.87	- 139 $\ln Q_{JF}$			+ 280.7 $\ln Q_{JA}$	- 135.1 $\ln Q_{SO}$	
Eastern Oyster							
Original H =	3000.7		+ 180.4 $\ln Q_{MA}$	- 963.3 $\ln Q_{MJ}$	+ 710.0 $\ln Q_{JA}$	- 231.5 $\ln Q_{SO}$	
Update H =	3232.1		+ 153.2 $\ln Q_{MA}$	- 946.8 $\ln Q_{MJ}$	+ 677.6 $\ln Q_{JA}$	- 226.5 $\ln Q_{SO}$	
Black Drum							
Original H =	- 18.087	+ 0.2411 Q_{JF}	- 0.1734 Q_{MA}				+ 0.0850 Q_{ND}
Updated H =	- 18.573	+ 0.2407 Q_{JF}	- 0.174 Q_{MA}				+ 0.0853 Q_{ND}
Red Drum							
Original H =	32.786			+ 0.0797 Q_{MJ}	+ 0.2750 Q_{JA}		- 0.2010 Q_{ND}
Updated H =	43.893			+ 0.0831 Q_{MJ}	+ 0.2832 Q_{JA}		- 0.2199 Q_{ND}
Spotted Seatrout							
Original lnH =	2.6915		- 0.7185 $\ln Q_{MA}$	+ 1.860 $\ln Q_{MJ}$			- 1.086 $\ln Q_{ND}$
Updated lnH =	3.4667		- 0.6779 $\ln Q_{MA}$	+ 1.735 $\ln Q_{MJ}$			- 1.112 $\ln Q_{ND}$

While the updated harvest equations do not drastically alter the harvests calculated by the original equations, the addition of the diversion and return flow data prior to 1977 does result in lower bimonthly inflow bounds above which the equations are valid, lending somewhat greater utility to the harvest equations.

In order to observe the accuracy of the original and updated harvest equations, it is necessary to compare computed harvest values to the reported harvests from the historical records. Figures 2-3 through 2-9 show the harvests, as calculated using the original and updated equations, compared to the reported harvests for each species. The average annual harvests calculated using the updated equations more closely approximate the average reported harvests than do the average harvest values calculated using the original equations for six of the seven species of interest. However, estimated harvest values actually improve in more than 50 percent of the years considered for only three of the seven species. As is apparent in Figures 2-3 through 2-9, predicted or calculated harvests can deviate significantly from reported values for individual years.

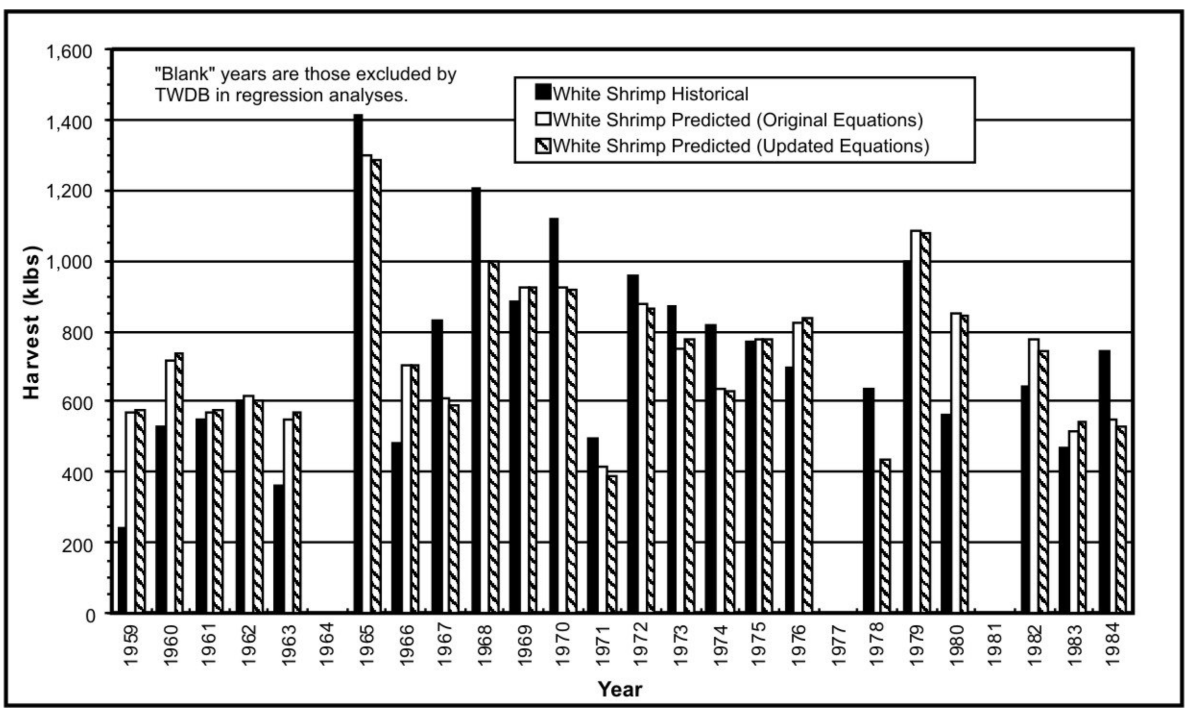

Figure 2-3. White Shrimp Actual Harvests Compared to Calculated Harvests from Original and Updated Equations

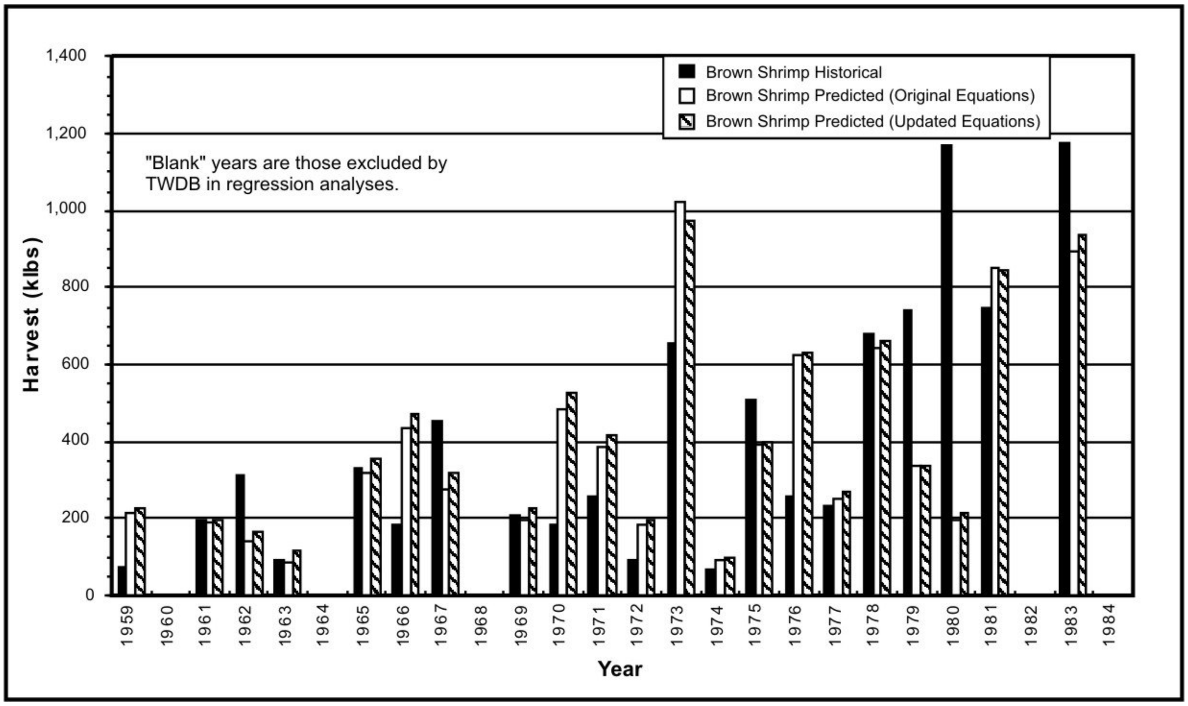

Figure 2-4. Brown Shrimp Actual Harvests Compared to Calculated Harvests from Original and Updated Equations

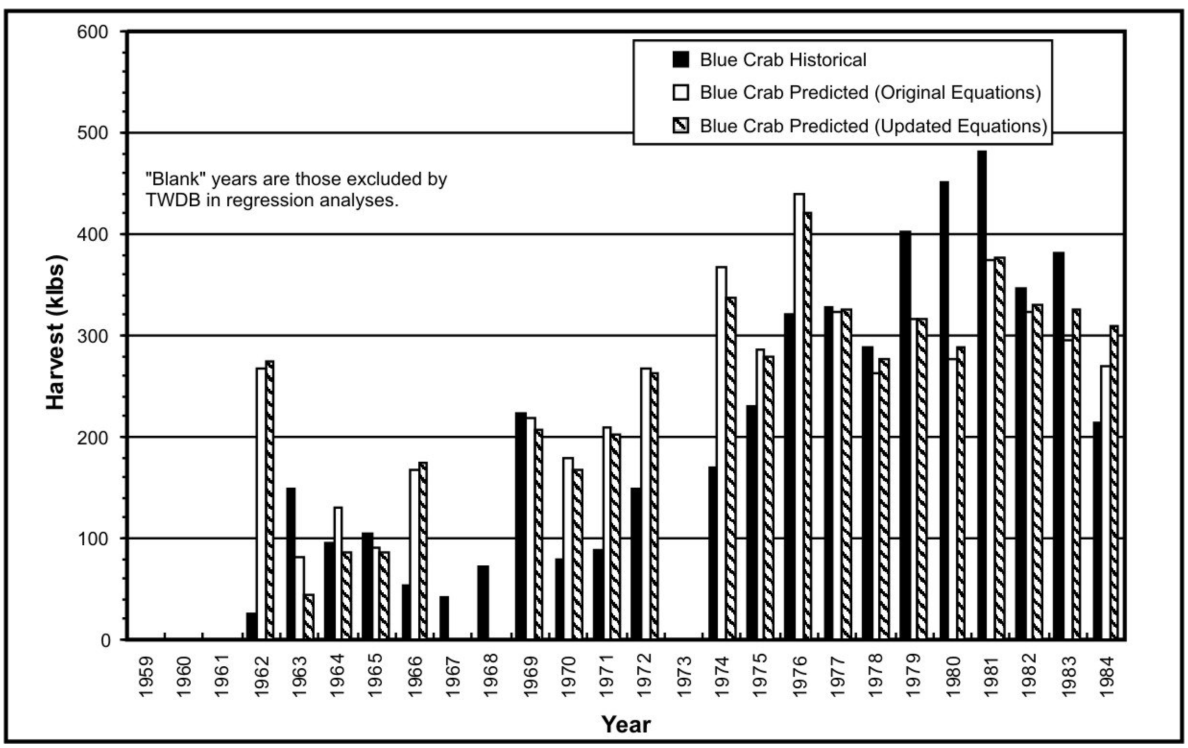

Figure2-5. Blue Crab Actual Harvests Compared to Calculated Harvests from Original and Updated Equations

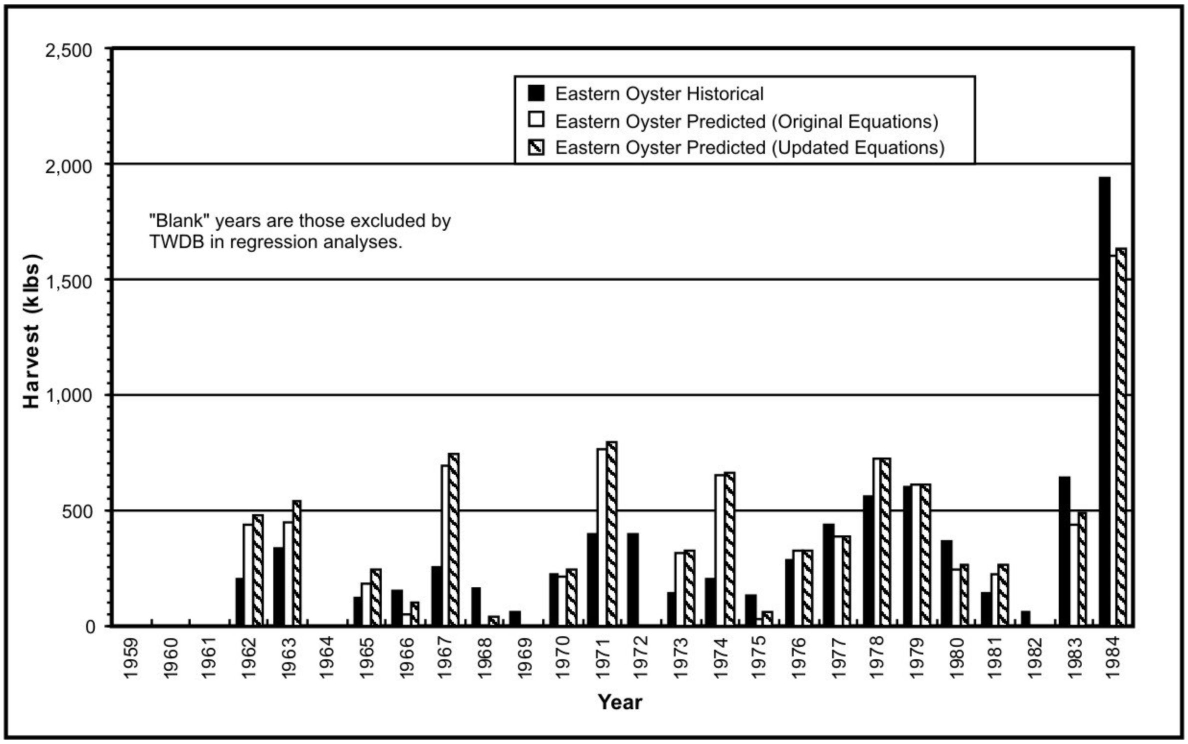

Figure 2-6. Eastern Oyster Actual Harvests Compared to Calculated Harvests from Original and Updated Equations

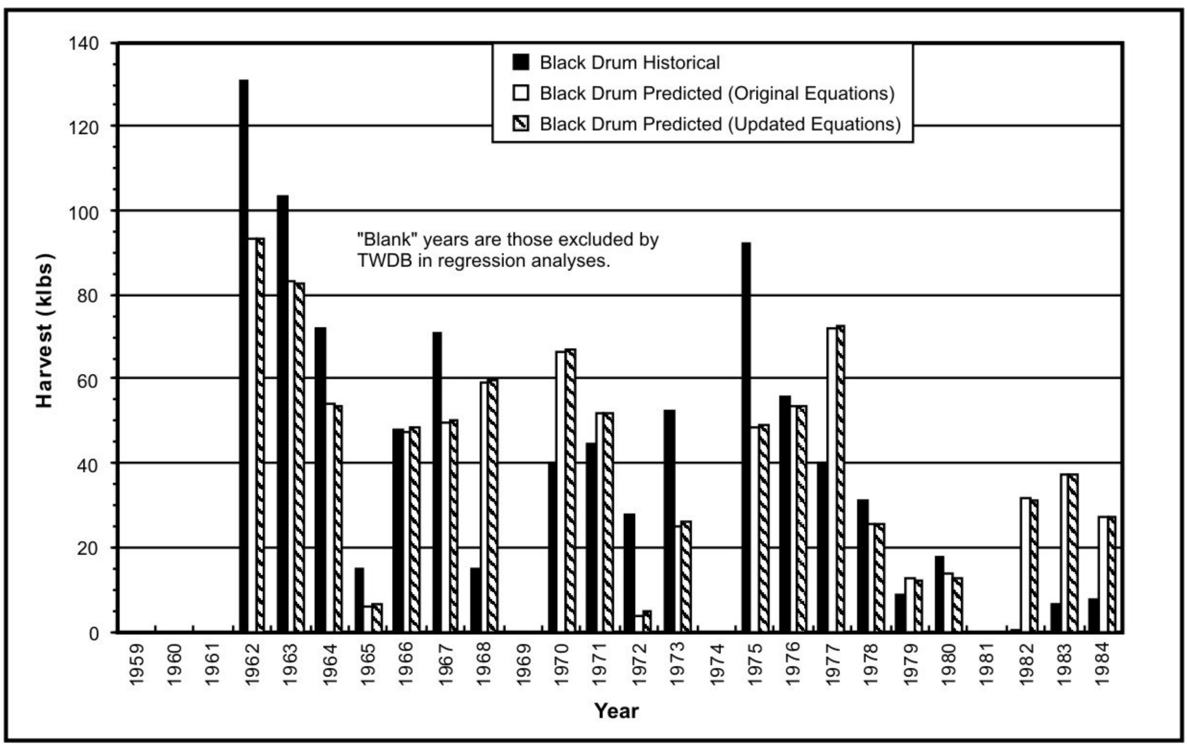

Figure 2-7. Black Drum Actual Harvests Compared to Calculated Harvests from Original and Updated Equations

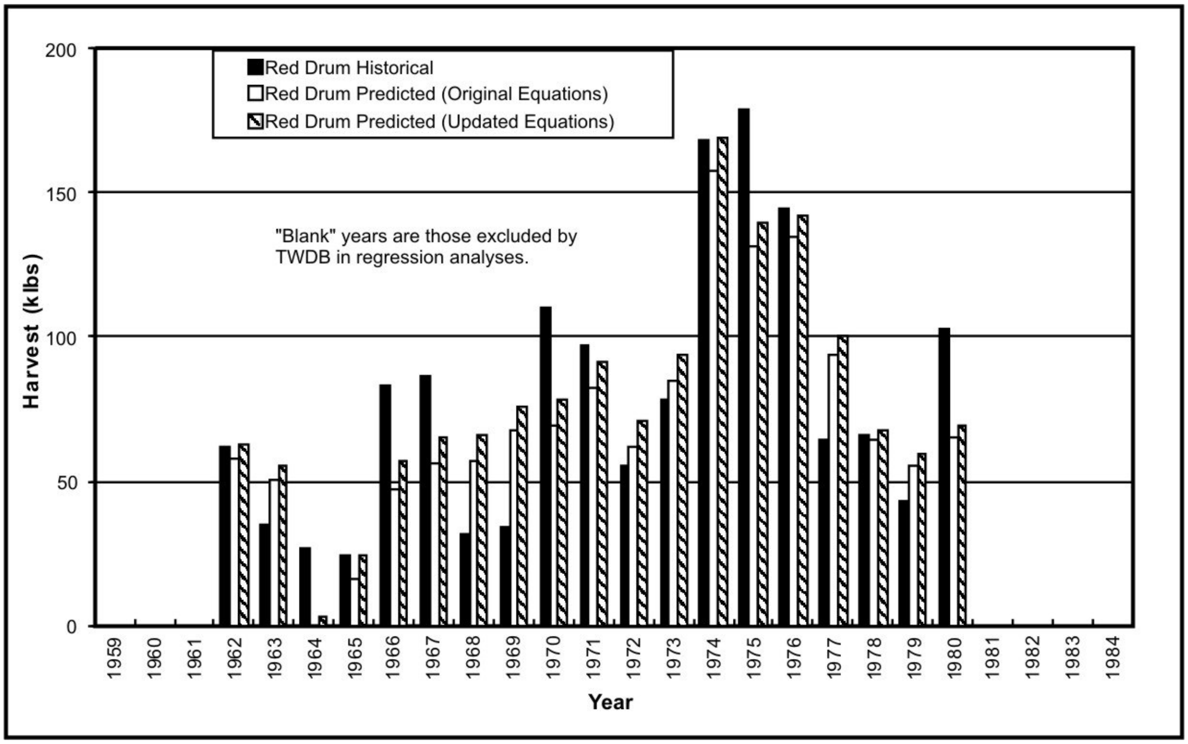

Figure 2-8. Red Drum Actual Harvests Compared to Calculated Harvests from Original and Updated Equations

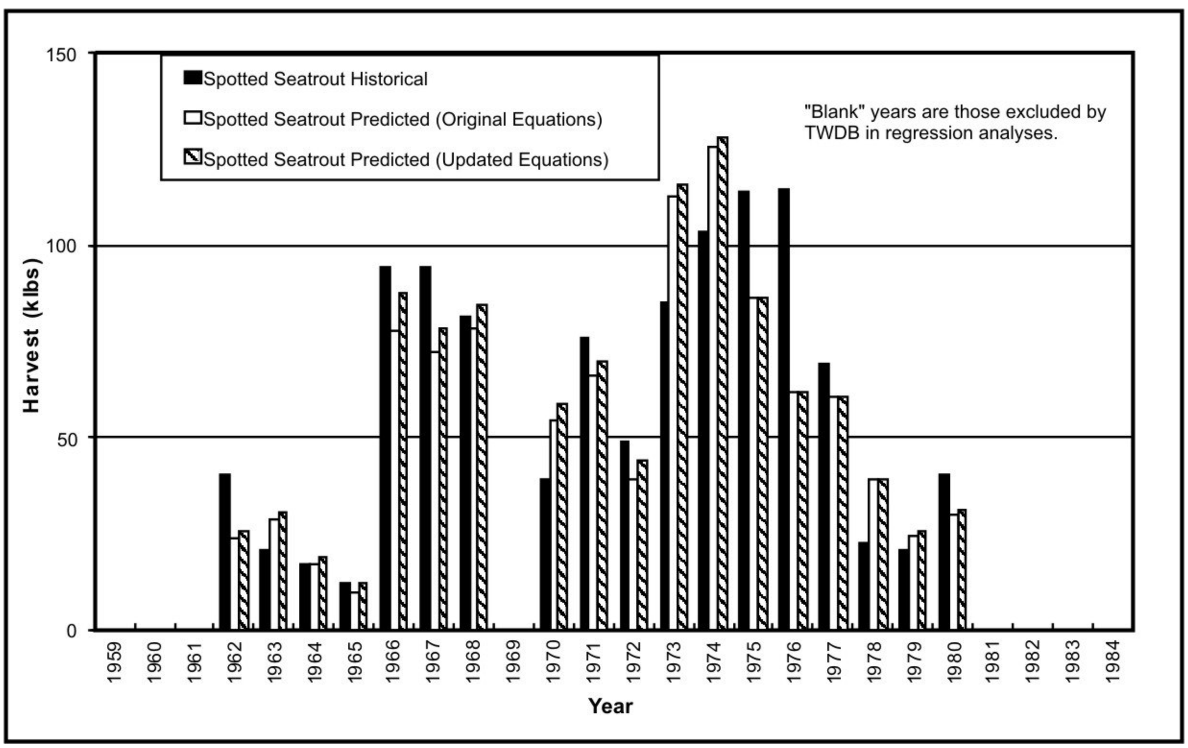

Figure 2-9. Spotted Seatrout Actual Harvests Compared to Calculated Harvests from Original and Updated Equations

2.5 Applications of Updated Harvest Equations

An annual fisheries harvest calculation model (ESTUARY1) for the Guadalupe Estuary was developed as part of the Trans-Texas Water Program to calculate theoretical harvests associated with freshwater inflows resulting from implementation of one or more water management strategies. A sample set of freshwater inflows was used as input into versions of the model with the original and updated equations. Use of the updated harvest equations decreased the number of low and high bound excursions for five (White Shrimp, Brown Shrimp, Blue Crabs, Eastern Oyster, and Red Drum) of seven species using the sample inflow data set. For Brown Shrimp, the number of bounds excursions decreased nearly by half, from 31 years to 17 years. Bounds excursions for Red Drum decreased from 36 years to 29 years, or about 19 percent. Finally, bounds excursions for White Shrimp, Blue Crabs, and Eastern Oysters decreased from about 5 to 15 percent.

2.6 Conclusions and Recommendations

While the updated harvest equations only marginally improve attempts to replicate reported harvest data, the updated harvest equations do improve the robustness of the equations by broadening the flow bounds within which the equations are applicable. However, there are still a sufficient number of low flow bounds excursions during drought periods to discourage use of the annual harvest calculation model for assessment of potential ecological effects of water management strategy implementation in the regional water planning process.

Freshwater inflow recommendations for the Guadalupe Estuary were developed by the TPWD and the TWDB and published in 1998.[6] These recommendations included a maximum harvest (MaxH) freshwater inflow of 1,147,400 acft/yr and a minimum freshwater inflow (MinQ) of 1,028,800 acft/yr assumed to represent a range within which a flow recommendation consistent with the goal of maintaining a biologically healthy and productive Guadalupe Estuary might be achieved. Comparison of predicted species landings based on the updated and original harvest equations for the Maximum Harvest (MaxH) inflow recommendations reveals that updated equations would predict five (5) percent greater total species landings (klbs), 13 percent greater Red Drum landings, and about 8 percent greater Brown Shrimp, Blue Crab, and Easter Oyster landings. A similar comparison for the MinQ inflow set reveals that updated equations would predict seven (7) percent greater total species landings (klbs), 18 percent greater Blue Crab landings, 16 percent greater Red Drum landings, and about 11 percent greater Brown Shrimp and Easter Oyster landings. Clearly, it is possible that such differences could have

[6] Ibid.

affected the outcome of optimization and associated procedures that led to the 1998 freshwater inflow recommendations for the Guadalupe Estuary. It is recommended that the TWDB and TPWD give careful consideration to the updated harvest equations as one element of the broader scientific effort to establish environmental flow standards pursuant to SB3 of the 80th Texas Legislature.

3.0 Ecologically-Based Streamflow Assessments

The 2006 SCTRWP[7] includes an ecologically-based freshwater inflow assessment of the Guadalupe Estuary considering inflow conditions ranging from natural to the present to the future with implementation of strategies recommended in the plan. This ecologically-based freshwater inflow assessment included two measures—a freshwater inflow pulse measure and a low-flow (drought) measure. The results of the ecologically-based freshwater inflow assessment are included in the Section 7 of the 2006 SCTRWP. Continuing that effort, Task 2 of Study 4 was performed to demonstrate a similar type of assessment for instream flows focusing on the Guadalupe River at Victoria and the San Antonio River near Falls City.

3.1 Streamflow Criteria

Similar to the ecologically-based freshwater inflow assessment in the 2006 SCTRWP, the ecologically-based streamflow assessment includes high and low streamflow criteria. In addition, a normal (or base) streamflow criterion is incorporated to more fully assess streamflow changes at the two locations. Scientists from the Texas Water Development Board, Texas Parks and Wildlife Department, National Wildlife Federation, and San Antonio River Authority were consulted in selection of appropriate assessment criteria for low, base, and high streamflow conditions. Each of those consulted is a participant in ongoing efforts by the state to implement the Texas Instream Flows Program (Senate Bill 2 of the 77th Texas Legislature)[8] and establish instream flow standards (Senate Bill 3 of the 80th Texas Legislature). Ultimate selection of streamflow criteria or standards is part of statewide programs defined by the Texas Legislature. All criteria applied herein may be considered "placeholder" values until such time that the SB2 and SB3 processes are complete.

3.1.1 High Flow Criteria

An important aspect of high streamflows is the ability for the stream to maintain aquatic and riparian habitats, and provide for stream connectivity with the floodplain.[9] These natural processes are accomplished through high flow pulses and overbanking flows. High flow pulses

[7] South Central Texas Regional Water Planning Group, "2006 South Central Texas Regional Water Plan," Texas Water Development Board, San Antonio River Authority, HDR Engineering, Inc., et al., January 2006.
[8] National Research Council of the National Academies, "The Science of Instream Flows, A Review of the Texas Instream Flow Program," The National Academies Press, 2005.

are short, high flow events following storms that stay within the channel, while overbanking flows are less frequent, high flow flood events in which streamflow rises above the normal channel. Scientists consulted generally suggested that a flood flow approximating a 2-year return period would be typical of an overbanking event and a good measure for the high flow criteria. Therefore, flood flow statistics were analyzed for both the Guadalupe River at Victoria and the San Antonio River near Falls City to determine the 2-year flood event. These flows are shown in Table 3-1.

Table 3-1.
Flow Criteria for Ecologically-Based Streamflow Assessment

Criteria	*Month*	*Guadalupe River at Victoria*	*San Antonio River near Falls City*
High Flow (cfs)	**Any**	16,043	4,366
Base Flow (cfs)	**Jan**	565	92
	Feb	578	93
	Mar	617	139
	Apr	710	130
	May	779	155
	Jun	674	142
	Jul	466	93
	Aug	367	82
	Sept	363	99
	Oct	389	70
	Nov	372	76
	Dec	602	84
Low Flow (cfs)	**Jan**	150	76
	Feb	150	76
	Mar	200	76
	Apr	250	76
	May	200	76
	Jun	250	76
	Jul	300	76
	Aug	300	76
	Sept	200	76
	Oct	150	76
	Nov	150	76
	Dec	150	76

[9] Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, & Texas Water Development Board, "Texas Instream Flow Studies: Technical Overview," TWDB Report 369, May 2008.

3.1.2 Low Flow Criteria

The low (subsistence) streamflow criteria needs to be high enough to maintain aquatic habitat sufficient for endemic species to survive transient low flow periods and to maintain dissolved oxygen (DO) in the stream.[10] These low flows are characterized by seasonal periods of infrequent streamflow well below the normal flow. The minimum accepted DO level, as established by the TCEQ for the stream locations considered herein, is 5 mg/L.[11] A statistic such as 7Q2 (seven day low flow with a return period of 2 years), the state-wide default low flow standard, may not necessarily be an accurate measure of the flow a particular stream needs in order to meet DO standards. Furthermore, in a base flow dominated stream, the 7Q2 may be substantially greater than that necessary to sustain aquatic habitat sufficient for endemic species to survive transient low flow periods. For example, the published 7Q2 values for the Guadalupe River at Victoria and San Antonio near Falls City locations are 607 cfs and 188 cfs, respectively, while site-specific studies, permit conditions, and informal agreements indicate that substantially less flow is necessary to meet environmental needs for short stress periods.

Figure 3-1 shows candidate low flow criteria considered for the Guadalupe River at Victoria. As shown in Figure 3-1, the published 7Q2 is approximately twice the flow necessary to meet the dissolved oxygen standard and special conditions regarding "low" flows in the surface water right permit (Permit #18-5466) held by the City of Victoria. Water quality modeling of the Guadalupe River performed in the Trans-Texas Water Program[12] indicates that a flow of approximately 320 cfs is sufficient to meet the dissolved oxygen standard during summer stress periods subject to current wastewater treatment standards. This result is consistent with monthly low flow criteria in Permit #18-5466 which range from 150 cfs in the cooler months to 300 cfs in July and August. Permit #18-5466 states that these low flow criteria *protect water quality in the river and protect, on a short-term basis, dissolved oxygen levels for fish and wildlife species*. For this streamflow assessment, the Permit #18-5466 "low" flow values, listed in Table 3-1, are used as the low flow criteria for the Guadalupe River at Victoria.

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[10] Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, & Texas Water Development Board, "Texas Instream Flow Studies: Technical Overview," TWDB Report 369, May 2008.
[11] Texas Commission on Environmental Quality, Texas Surface Water Quality Standards - Section 307.7, August 2000.
[12] HDR Engineering, Inc., "Trans-Texas Water Program, West Central Study Area, Phase II, Guadalupe-San Antonio River Basin Environmental Criteria Refinement," Texas Water Development Board, San Antonio River Authority, et al., March 1998.

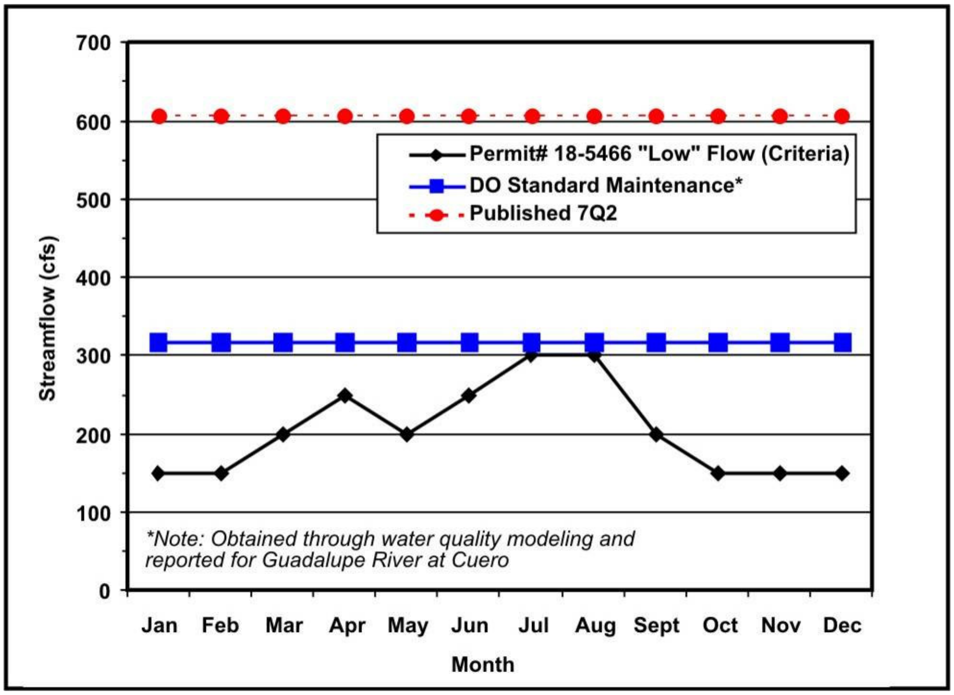

Figure 3-1. Guadalupe River at Victoria – Low Flow Criteria Selection

Water quality modeling in the Trans-Texas Water Program[13] indicated that the low flow necessary to maintain a DO of 5 mg/L in the San Antonio River at and below Falls City is less than10 cfs. This is due, in large part, to advanced treatment standards and consistent performance of the Dos Rios WWTP in San Antonio. As shown in Figure 3-2, 10 cfs is more than an order of magnitude less than the published 7Q2 of 188 cfs, which is a result of effluent dominance of San Antonio River flows. However, factors other than DO maintenance dictate that the low flow criteria greater than 10 cfs be used for this assessment. These factors include protection of downstream water rights, sustainable aquatic habitat, and long-standing informal agreement between the San Antonio River Authority (SARA), San Antonio Water System (SAWS), and City Public Service (CPS). Therefore, 76 cfs (55,000 acft/yr), is used as the low flow criteria for the San Antonio River near Falls City.

[13] Ibid.

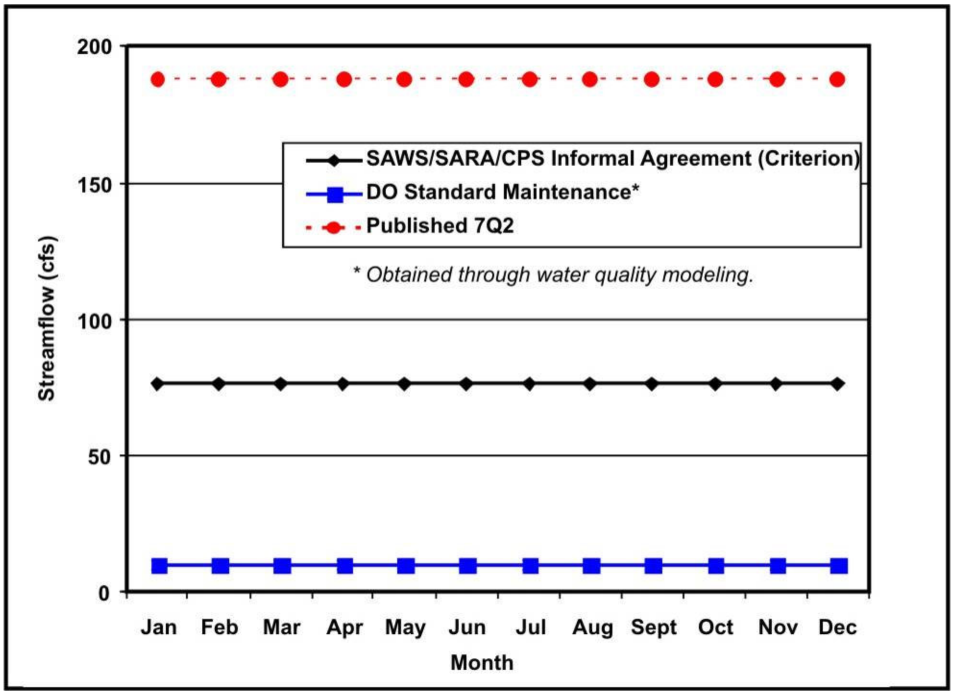

Figure 3-2. San Antonio River near Falls City – Low Flow Criteria Selection

3.1.3 Base Flow Criteria

Like the high and low streamflow criteria, the base streamflow criteria are yet to be uniformly defined among stream basin stakeholders, researchers, and resource agency staff in Texas. Guiding principles in selection of base streamflow criteria are that they should reflect the "normal" flow condition in the stream between storm events and ensure adequate habitat conditions, including variability, to support the natural biologic community.[14]

Figure 3-3 shows several monthly sets of base streamflow criteria considered for performance of an ecologically-based assessment of streamflow changes in the Guadalupe River at Victoria.. Among these criteria are the Modified Lyons Method[15] (the current default method used by TCEQ in the absence of site-specific studies), the "normal" flow values found in Permit #18-5466 held by the City of Victoria, and unpublished results of a site-specific study by TPWD on the Guadalupe River near Gonzales (referenced in Certificate of Adjudication #18-2074E) translated downstream. Also shown for reference in Figure 3-3 are the natural monthly median

[14] Texas Commission on Environmental Quality, Texas Parks and Wildlife Department, & Texas Water Development Board, "Texas Instream Flow Studies: Technical Overview," TWDB Report 369, May 2008.
[15] Bounds, R.L. and B.W. Lyons, "Existing Reservoir and Stream Management Recommendations, Statewide Minimum Streamflow Recommendations," Federal Aid Project F-30-R-4, Texas Parks and Wildlife Department, Austin, TX, 1979.

and quartile flows referenced in the Consensus Criteria for Environmental Flow Needs (CCEFN) used in regional water supply planning. Based on consultation with resource agency scientists and noticeable similarities between potential base streamflow criteria, monthly flows from the site-specific study of the Guadalupe River near Gonzales were translated downstream and used as the base streamflow criteria for the Guadalupe River at Victoria. These monthly base flow criteria are listed in Table 3-1.

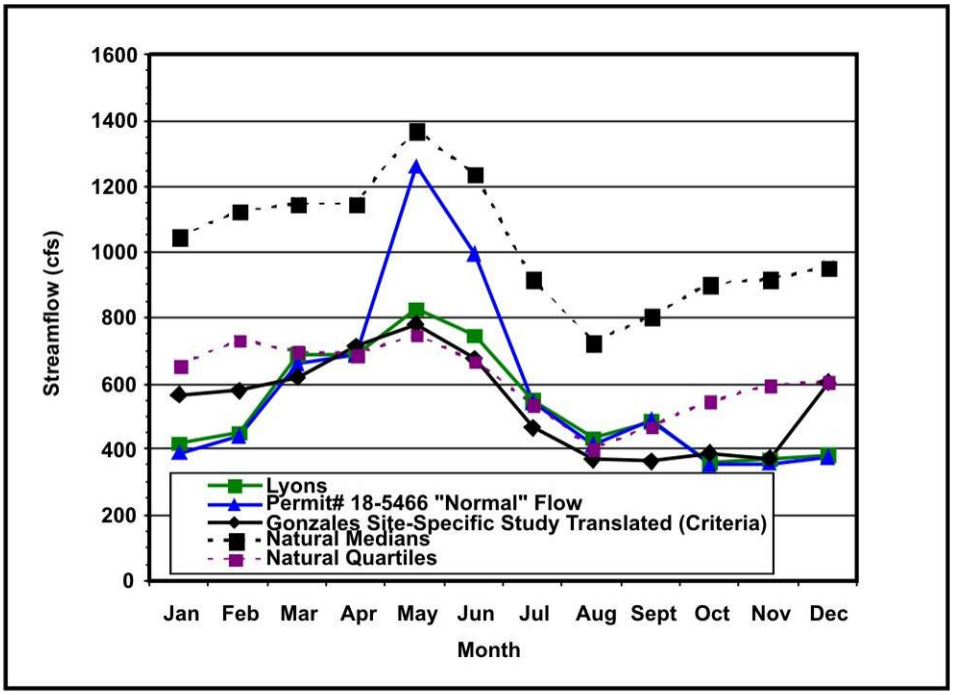

Figure 3-3. Guadalupe River at Victoria – Base Flow Criteria Selection

The primary alternative for derivation of base streamflow criteria for the San Antonio River at Falls City, is the Modified Lyons Method[16] for which monthly values are plotted along with natural monthly median and quartile flows referenced in the CCEFN in Figure 3-4. Site-specific studies including this segment of the San Antonio River are underway, but results are not available at this time. Hence, monthly base streamflow criteria derived by the Modified Lyons Method and listed in Table 3-1 were used to perform the ecologically-based assessment of changes in streamflow for the San Antonio River at Falls City.

[16] Ibid.

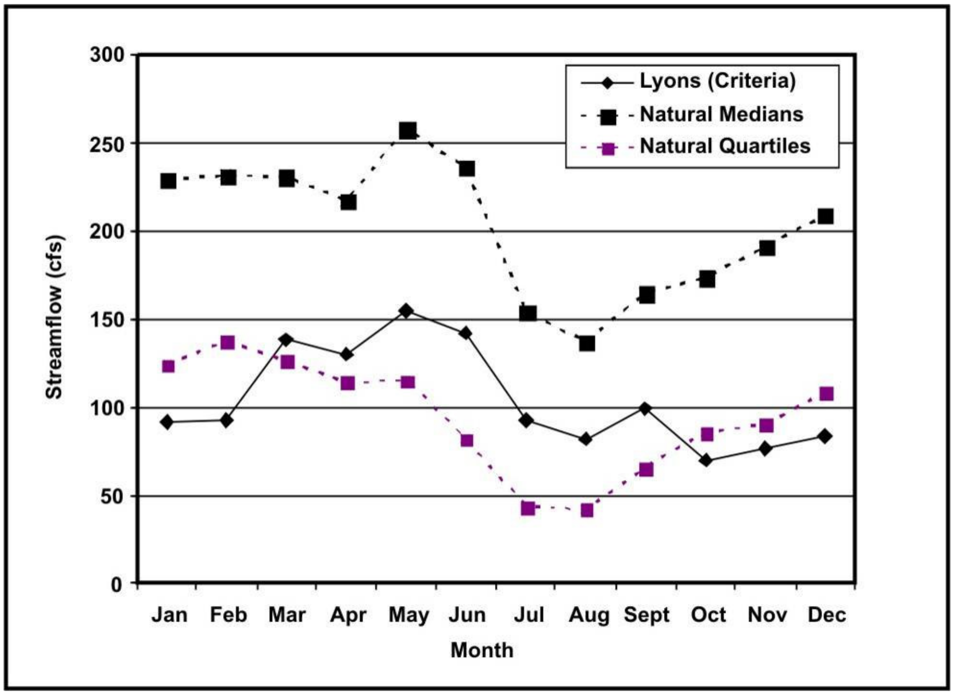

Figure 3-4. San Antonio River near Falls City – Base Flow Criteria Selection

3.2 Simulation Descriptions

The Guadalupe-San Antonio River Basin Water Availability Model (GSA WAM)[17] was used to simulate monthly streamflows for four (4) scenarios. Monthly streamflows are then distributed to daily estimates of streamflow using a MS Excel post-processing model and representative daily patterns for the Guadalupe River at Victoria and the San Antonio River near Falls City locations. The four scenarios, consistent with those used in the ecologically-based assessment of changes in freshwater inflow to the Guadalupe Estuary in the 2006 SCTRWP, are described in the following sections.

3.2.1 Natural Conditions

The Natural Condition is an historical set of theoretical streamflows and estuarine inflows in which the effects of mankind on the water resource have been removed. While the effects of historical reservoir operations, diversions, and treated effluent have been accounted for, it is noted that these natural flows reflect historical pumpage and spring discharges from the Edwards Aquifer. Thus, while other effects of mankind on surface water flows have been removed, spring

[17] HDR Engineering, Inc., "Water Availability in the Guadalupe-San Antonio River Basin," Texas Natural Resource Conservation Commission, December 1999.

discharges, which have direct bearing on surface water flows, reflect historical pumping levels from the Edwards Aquifer. More conceptually appropriate estimates of natural flows could have been based upon simulated natural springflows with zero Edwards Aquifer pumpage, however, such simulated natural springflows were not deemed sufficiently accurate for release by TWDB technical staff at the time when natural flows throughout the Guadalupe-San Antonio River Basin were developed.

3.2.2 Present Conditions

The Present Conditions simulation is intended to be a realistic, but somewhat conservative, portrayal of present conditions with respect to springflows, water rights use, and effluent discharges. The present condition scenario was derived based on Texas Commission on Environmental Quality (TCEQ) Run 8 analyses with appropriate modifications. With the exception of the major water rights discussed below, the values found in the Run 8 data file are used as the present level of water rights use and treated wastewater discharges. The modifications below were made to reflect likely usage levels in the near-term (2-5years) if the South Central Texas Region were to experience a severe drought.

1. *Canyon Reservoir (CA# 18-2074E)* – GBRA has contracts for approximately 65,000 acft/yr. For the Present Conditions simulation, each of these contracts is modeled at its diversion location along the Guadalupe River. In addition, GBRA has an agreement with Guadalupe River Trout Unlimited that is in effect until the year 2018 that was modeled as well. Canyon operations are in accordance with CA#18-2074E.

2. *GBRA Lower Basin Water Rights (CA# 18-5173 through CA# 18-5178 and CA# 18-3863)* – GBRA has water rights totaling 175,501 acft/yr in the lower basin authorized for municipal, industrial, and irrigation use. During the period of 1996 through 2003, the municipal portion of these rights had a maximum annual use of 10,400 acft, the industrial portion had a maximum annual use of 26,600 acft, and the irrigation portion had a maximum annual use of 36,700 acft. Cumulatively, this totals 73,700 acft/yr. For the Present Conditions simulation, 73,700 acft/yr for these water rights, allocated by use type as listed has been simulated. Available information indicates that wastewater due to the municipal diversion does not return to the Guadalupe Estuary. Effluent discharges for the industrial portion of the GBRA Lower Basin water rights are included, as these industries

discharge to the estuary via the Victoria Barge Canal. An estimated return flow of 50 percent is included for these industrial diversions.

3. *Invista/DuPont (CA# 18-3861)* – Information gathered from the South Texas Watermaster indicates that Invista/DuPont diverted 25,254 acft in 1999, their highest in the period of 1998 - 2003. This amount is included in the Present Conditions simulation for Invista/DuPont. It is important to note that Invista/DuPont has a return factor of 45 percent on the diversions, which is derived from the ratio of 27,000 acft/yr (total permitted diversion of 60,000 acft/yr minus permitted consumption of 33,000 acft/yr) over 60,000 acft/yr (total permitted diversion). Thus, the consumptive amount associated with the 25,254 acft/yr is 13,890 acft/yr.

4. *City of Victoria (Permit# 18-5466)* – Data from the City of Victoria indicates that their maximum diversion during the period of 1997-2004 was 9,854 acft in 2003. This amount is used in the Present Conditions simulation.

5. *Braunig & Calaveras Lakes (CA# 19-2161 & CA# 19-2162, respectively)* – Historical data received from City Public Service (CPS), which operates the steam-electric power generation facilities using these reservoirs, indicates that the maximum water use (from forced evaporation) during the period of 1992-2004 occurred in 1999 for Calaveras (13,365 acft) and in 2000 for Braunig (4,057 acft). These amounts are used in the Present Conditions simulation.

6. *Coleto Creek Reservoir (CA# 18-5486)* – Data from the report entitled "Power Generation Water Use for the Years 2000 through 2060 - Final Report," prepared for the TWDB in 2003 indicates that the 2000 consumptive use for Coleto Creek Reservoir (from forced evaporation) was 9,027 acft. For the Present Conditions simulation, this consumptive amount is used.

7. *Medina Lake System (CA# 19-2130)* – The Medina Lake System has used its full permitted amount in the recent past. Thus, the current use associated with the Medina Lake System is its authorized use.

In addition, springflows consistent with an Edwards pumpage of 400,000 acft/yr (plus domestic & livestock use of about 12,000 acft/yr) subject to EAA Critical Period Rules in force at the time of adoption of the 2006 SCTRWP are used to represent present conditions. Except as noted above, effluent discharges, as reported for 1997 and adjusted for SAWS direct recycled water use of about 26,700 acft/yr (based on contracts for consumptive use), are also used in the Present Conditions simulation.

3.2.3 Baseline (Full Permits)

The Baseline simulation is the product of hydrologic assumptions and operational procedures for the assessment of surface water supply (2006 SCTRWP, Section 3.2.3.1) as adopted by the SCTRWPG and approved by the TWDB. These assumptions reflect Edwards Aquifer permitted pumpage of 400,000 acft/yr subject to Critical Period Management rules, full utilization of existing water rights, and treated effluent discharge representative of current conditions (1997 reported discharges adjusted for SAWS direct recycled water program). These are the same assumptions as used to determine surface water supply reliability and perform technical evaluations of surface water management strategies in the 2006 SCTRWP.

3.2.4 Regional Water Plan

The Regional Water Plan simulation attempts to portray the potential cumulative effects of all recommended water management strategies on streamflow and estuarine inflow. Starting with the baseline simulations, the water management strategies of the Edwards Aquifer are incorporated into the GWSIM-IV groundwater model. Resulting springflows from the Edwards Aquifer are then integrated into the GSA WAM data files. Streamflow impacts due to water management strategies in the Carrizo-Wilcox and Gulf Coast Aquifers are estimated using the South-Central Carrizo System (SCCS) Model and the Gulf Coast Groundwater Availability Models, respectively. These streamflow changes are also incorporated into the GSA WAM data files. Finally, the surface water management strategies are added to the GSA WAM to form the Regional Water Plan simulation.

3.3 Results of the Ecologically-Based Streamflow Assessments

Streamflows under each of the four scenarios are compared to the three criteria for both the Guadalupe River at Victoria and the San Antonio River near Falls City. For the high flow criteria, the daily modeled streamflow is evaluated to see how many flood events exceeded the criteria flow during the 56-year simulation period (1934 – 1989). When evaluating scenario streamflow against the base flow criteria, the total number of days in which the streamflow is below the base flow criteria is calculated. Likewise, using the low flow criteria, the total number of days in which the streamflow is below the low flow criteria is calculated. In addition, the maximum number of consecutive days per year in which the streamflow is below the low flow criteria is calculated. A summary and discussion of the results is presented below for each location.

3.3.1 Results for Guadalupe River at Victoria

As shown in Table 3-2, the Guadalupe River at Victoria has between 45 and 46 high flow events during the simulation period, depending on the scenario. There is no significant difference in the number of events among the four scenarios. Occurrences vary between zero and two events in any given year. The low variation indicates that existing and planned impoundments, diversions, returns, and groundwater withdrawals have had no significant effect on the occurrence of high flow events in the Guadalupe River at Victoria.

Table 3-2.
Guadalupe River at Victoria – High Flow Events

	Natural Conditions	*Present Conditions*	*Baseline (Full Permits)*	*Regional Water Plan*
Flood Events	46	45	45	45

Throughout the 56-year simulation period, the Guadalupe River at Victoria would experience between 4,054 days (Natural Conditions) and 6,200 days (Baseline) below the base flow criteria (Table 3-3), depending on simulation scenario. While the percent of time the streamflow is less than or equal to the base flow criteria for the Natural Conditions scenario is considerably less than that for the Regional Water Plan, differences between the Present Conditions, Baseline (Full Permits), and Regional Water Plan scenarios are very small. Hence, implementation of the strategies recommended in the 2006 SCTRWP would be expected to have very limited effects on base flows in the Guadalupe River at Victoria relative to those under present conditions.

Table 3-3.
Guadalupe River at Victoria – Occurrences of Flows below the Base Criteria

	Natural Conditions	Present Conditions	Baseline (Full Permits)	Regional Water Plan
Total Days Less Than	4,054	5,729	6,200	5,870
Percent of Time Less than or Equal To	20%	28%	30%	29%

There are at least two important measures to consider when comparing simulated streamflows under the specified scenarios to the low flow criteria – the total number of days below the criteria and the maximum number of consecutive days below the criteria in a given year. Table 3-4 summarizes the total number of days less than the low flow criteria and Table 3-5 summarizes the maximum number of consecutive days below the low flow criteria by year, for each of the four scenario simulations. Review of Tables 3-4 and 3-5 indicates that implementation of water management strategies in the 2006 SCTRWP would not be expected to cause significant changes in the frequency or duration of low periods in the Guadalupe River at Victoria relative to present conditions.

Table 3-4.
Guadalupe River at Victoria – Low Flow Occurrences

	Natural Conditions	Present Conditions	Baseline (Full Permits)	Regional Water Plan
Total Days Less Than	1,195	1,571	1,700	1,592
Percent of Time Less than or Equal To	6%	8%	8%	8%

3.3.2 Results for San Antonio River near Falls City

The San Antonio River near Falls City has between 38 and 54 high flow events during the simulation period (Table 3-6), depending on the scenario. The difference in the number of high flow events between the Natural and Present Conditions scenarios is primarily attributable to the Medina Lake System. The reduction in the simulated number of high flow events from Present Conditions to Baseline and Plan scenarios is due, in large part, to increased diversions for steam-electric power generation uses at Braunig and Calaveras Reservoirs under existing water rights. High flow occurrences vary between zero and three events in any given year.

Throughout the 56-year simulation period, the San Antonio River near Falls City has between 2,074 days (Present Conditions) and 5,746 days (Natural Conditions) below the base flow criteria (Table 3-7). The effects of San Antonio effluent are apparent in Table 3-7, as the Natural Condition simulation has the most days below the base flow criteria. Effects of increased effluent projected in the SCTRWP are evident in the decrease in number of days below the base flow criteria between the Baseline and Regional Water Plan scenarios.

Table 3-5.
Guadalupe River at Victoria – Maximum Consecutive Days below the Low Flow Criteria

Year	Natural Conditions	Present Conditions	Baseline (Full Permits)	Regional Water Plan
1934	0	0	0	0
1935	0	0	0	0
1936	0	0	0	0
1937	0	0	0	0
1938	0	0	0	0
1939	0	16	33	16
1940	0	0	3	0
1941	0	0	0	0
1942	0	0	0	0
1943	0	0	0	0
1944	0	0	0	0
1945	0	0	0	0
1946	0	0	0	0
1947	0	0	0	0
1948	1	30	30	30
1949	0	1	4	4
1950	0	30	35	30
1951	36	67	69	69
1952	37	47	39	48
1953	17	26	47	24
1954	120	136	98	120
1955	90	91	91	91
1956	151	151	151	151
1957	30	36	36	36
1958	0	0	0	0
1959	0	0	0	0
1960	0	0	0	0
1961	0	0	0	0
1962	2	14	19	13
1963	26	66	35	66
1964	24	33	33	33
1965	0	0	0	0
1966	0	0	0	0
1967	39	42	43	41
1968	0	0	0	0
1969	0	0	0	0
1970	0	0	0	0
1971	22	30	31	29
1972	0	0	0	0
1973	0	0	0	0

Table 3-5.
Guadalupe River at Victoria – Maximum Consecutive Days below the Low Flow Criteria (Concluded)

Year	Natural Conditions	Present Conditions	Baseline (Full Permits)	Regional Water Plan
1974	0	0	0	0
1975	0	0	0	0
1976	0	0	0	0
1977	0	0	0	0
1978	0	0	0	0
1979	0	0	0	0
1980	0	0	3	0
1981	0	0	0	0
1982	0	0	3	0
1983	0	0	0	0
1984	67	70	79	70
1985	0	0	0	0
1986	0	0	0	0
1987	0	0	0	0
1988	0	0	0	0
1989	30	93	93	54

Table 3-6.
San Antonio River near Falls City – High Flow Events

	Natural Conditions	Present Conditions	Baseline (Full Permits)	Regional Water Plan
Flood Events	54	43	38	40

Table 3-7.
San Antonio River near Falls City – Occurrences of Flows below the Base Criteria

	Natural Conditions	Present Conditions	Baseline (Full Permits)	Regional Water Plan
Total Days Less Than	5,746	2,074	3,594	2,610
Percent of Time Less than or Equal To	28%	10%	18%	13%

Tables 3-8 and 3-9 summarize total days and consecutive days within a calendar year below the low flow criteria, respectively, for each of four simulation scenarios. Low flow occurrences are most frequent and typically of greatest duration under Natural Conditions because of the absence of effluent and the influences of historical Edwards Aquifer pumpage on San Antonio and San Pedro Springs. In general, Tables 3-8 and 3-9 indicate that implementation of the 2006 SCTRWP could be expected to increase the frequency and duration of low flow occurrences relative to Present Conditions, but significantly decrease the frequency and duration of low flow occurrences relative to the Baseline and Natural Conditions scenarios.

Table 3-8.
San Antonio River near Falls City – Low Flow Occurrences

	Natural Conditions	***Present Conditions***	***Baseline (Full Permits)***	***Regional Water Plan***
Total Days Less Than	4,481	878	1,726	1,045
Percent of Time Less than or Equal To	22%	4%	8%	5%

3.4 Discussion of the Ecologically-Based Streamflow Assessments

The results of the ecologically-based streamflow assessments for the Guadalupe River at Victoria show that the regional plan would have virtually no effect on streamflow. For the San Antonio River near Falls City, implementation of the regional water plan would have limited effects in all three flow regimes considered (high, base, and low). Such limited effects could be considered positive with respect to the Baseline (flows increase due to increased San Antonio effluent) and negative with respect to Present Conditions (flows decrease due to increased diversions under existing water rights). The ecological significance of these limited effects is unknown and further complicated by the significant differences between Natural Conditions and the other three scenarios considered. Ongoing instream flow studies on the San Antonio River will likely yield additional information regarding appropriate criteria for ecologically-based streamflow assessments. It is anticipated that, with continued refinement in the assessment criteria and improved knowledge of the instream flow needs, the SCTRWPG will be able to further consider this issue in a future round of planning.

Table 3-9.
San Antonio River near Falls City – Maximum Consecutive Days below the Low Flow Criterion

Year	Natural Condition	Present Condition	Baseline (Full Permits)	Regional Water Plan
1934	10	0	19	10
1935	0	0	0	0
1936	0	0	0	0
1937	0	0	0	0
1938	0	0	0	0
1939	27	0	2	0
1940	16	3	10	5
1941	0	0	0	0
1942	0	0	0	0
1943	0	0	0	0
1944	0	0	0	0
1945	0	0	0	0
1946	0	0	0	0
1947	0	0	0	0
1948	34	19	34	26
1949	11	0	1	0
1950	30	1	8	2
1951	59	34	33	12
1952	52	31	42	10
1953	46	45	37	45
1954	95	20	59	17
1955	40	15	40	25
1956	82	37	29	26
1957	49	13	19	19
1958	11	0	17	2
1959	8	0	0	0
1960	25	2	10	11
1961	11	0	0	0
1962	55	17	46	14
1963	69	13	24	20
1964	41	33	16	12
1965	48	2	3	2
1966	24	0	3	2
1967	35	13	26	28
1968	2	0	0	0
1969	59	18	56	57
1970	28	8	27	9
1971	37	23	27	23
1972	3	0	0	0
1973	0	0	0	0

Table 3-9.
San Antonio River near Falls City – Maximum Consecutive Days below the Low Flow Criterion

Year	Natural Condition	Present Condition	Baseline (Full Permits)	Regional Water Plan
1974	8	0	0	0
1975	0	0	0	0
1976	0	0	0	0
1977	0	0	0	0
1978	32	24	29	29
1979	3	0	0	0
1980	38	21	31	31
1981	12	0	0	0
1982	29	7	16	7
1983	3	0	0	0
1984	9	0	0	0
1985	21	0	0	0
1986	6	0	28	0
1987	1	0	0	0
1988	18	11	18	8
1989	33	13	15	10

4.0 Interactive, Web-Based Graphics and Presentation Materials

The South Central Texas Regional Water Planning Group (SCTRWPG) is interested in communicating potential interactions between recommended water management strategies and the natural environment, particularly with respect to endangered species. Furthermore, the SCTRWPG seeks to summarize and communicate the range of processes, in addition to regional water planning, necessary for implementation of water management strategies. Hence, the SCTRWPG has developed interactive, web-based graphics and presentation materials to support SCTRWPG and education programs focused on these subjects. These graphics and presentation materials are briefly described in the following sections.

4.1 Water Management Strategies and Endangered Species Habitat Ranges

The technical evaluation of each potentially feasible water management strategy recommended for implementation in the 2006 South Central Texas (Region L) Regional Water Plan includes the identification of both federal and state listed endangered and threatened species, and other rare species that may be affected. Using geographical and biological information available from the regional water plan, the Texas Parks & Wildlife Department Natural Diversity Database, and other sources, a graphical interface has been prepared to facilitate the recognition of listed endangered species and their habitats which may be affected by the recommended water management strategies. Screen shots of the base Region L map and four sub-regional maps are presented in Figures 4-1 through 4-5. The reader is encouraged to visit the South Central Texas Regional Water Planning Area website (http://www.regionltexas.org/) and explore available information regarding endangered species using the graphical interface.

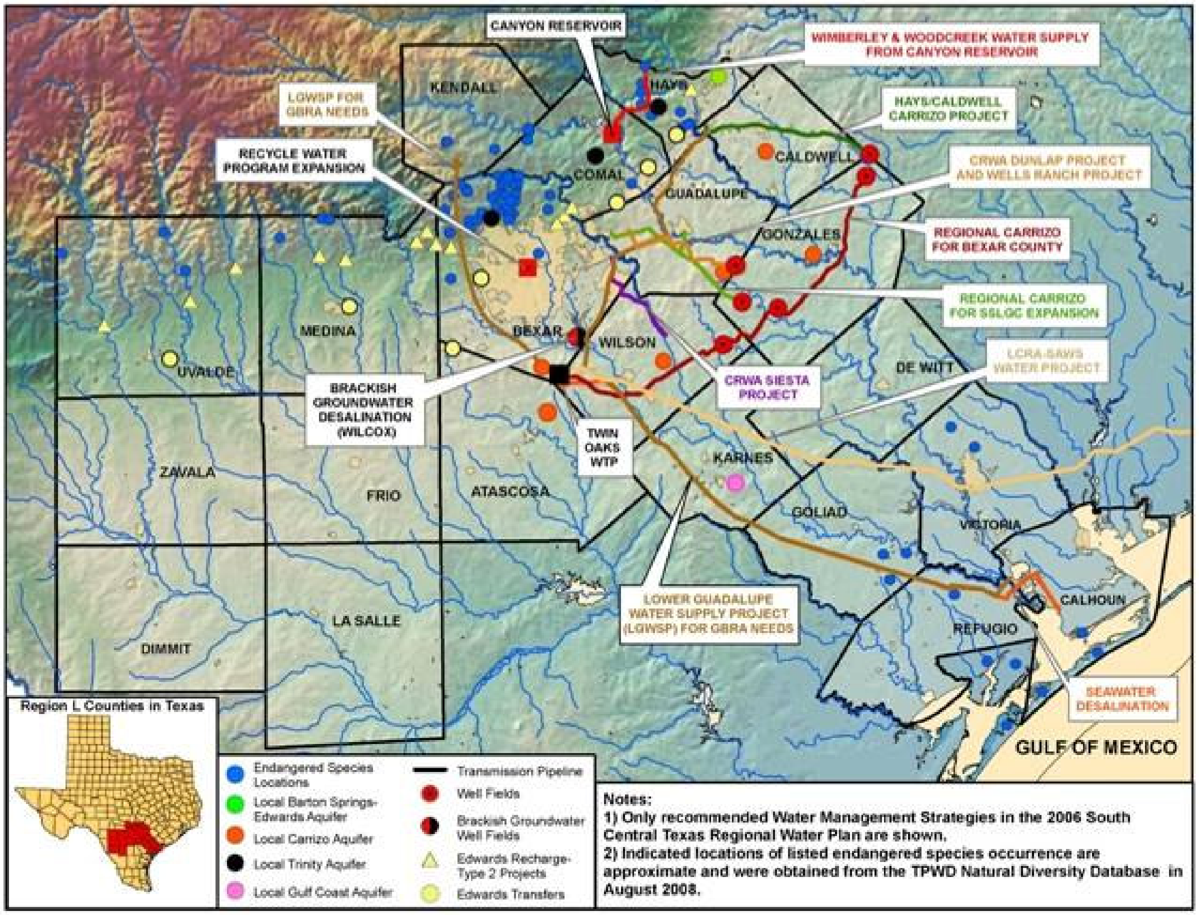

Figure 4-1. Region L with Recommended Water Management Strategies and Endangered Species

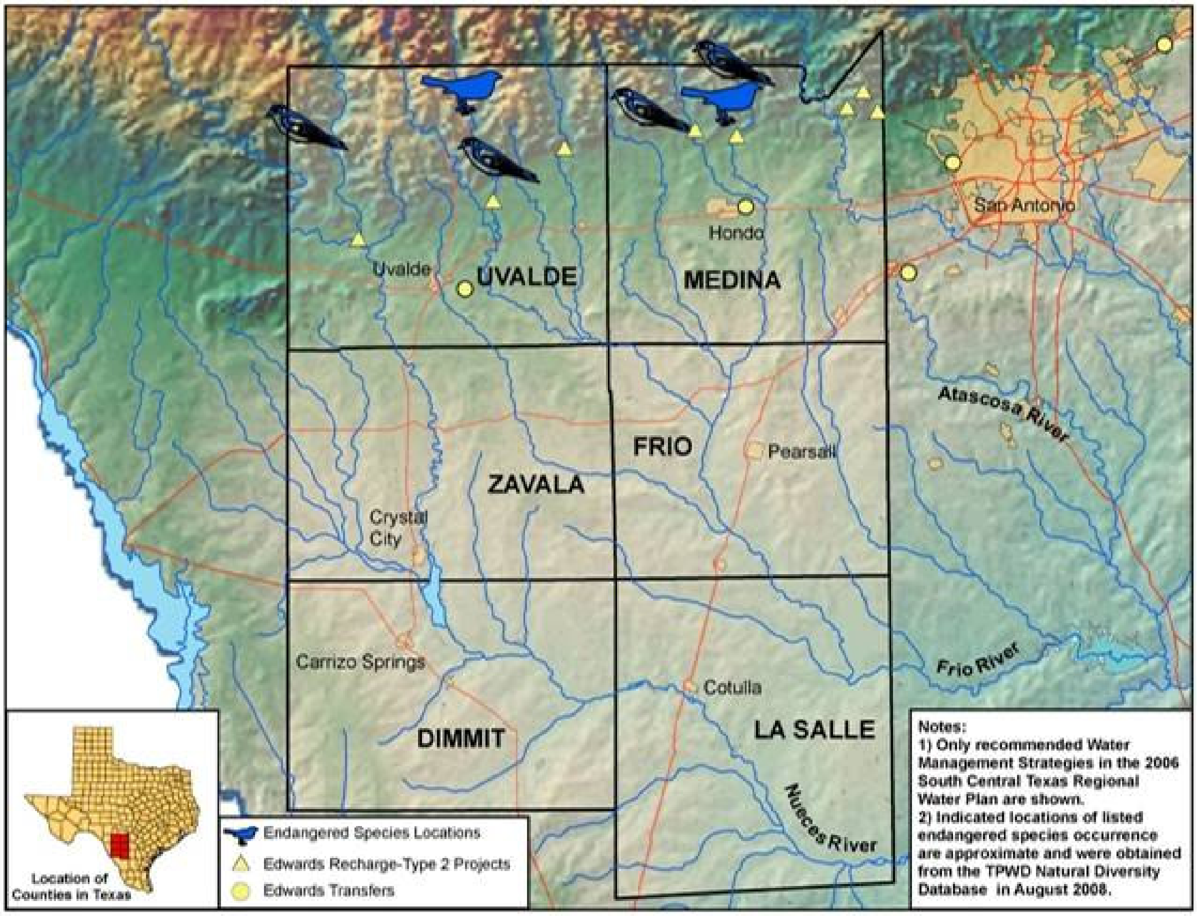

Figure 4-2. Western Area of Region L with Recommended Water Management Strategies and Endangered Species

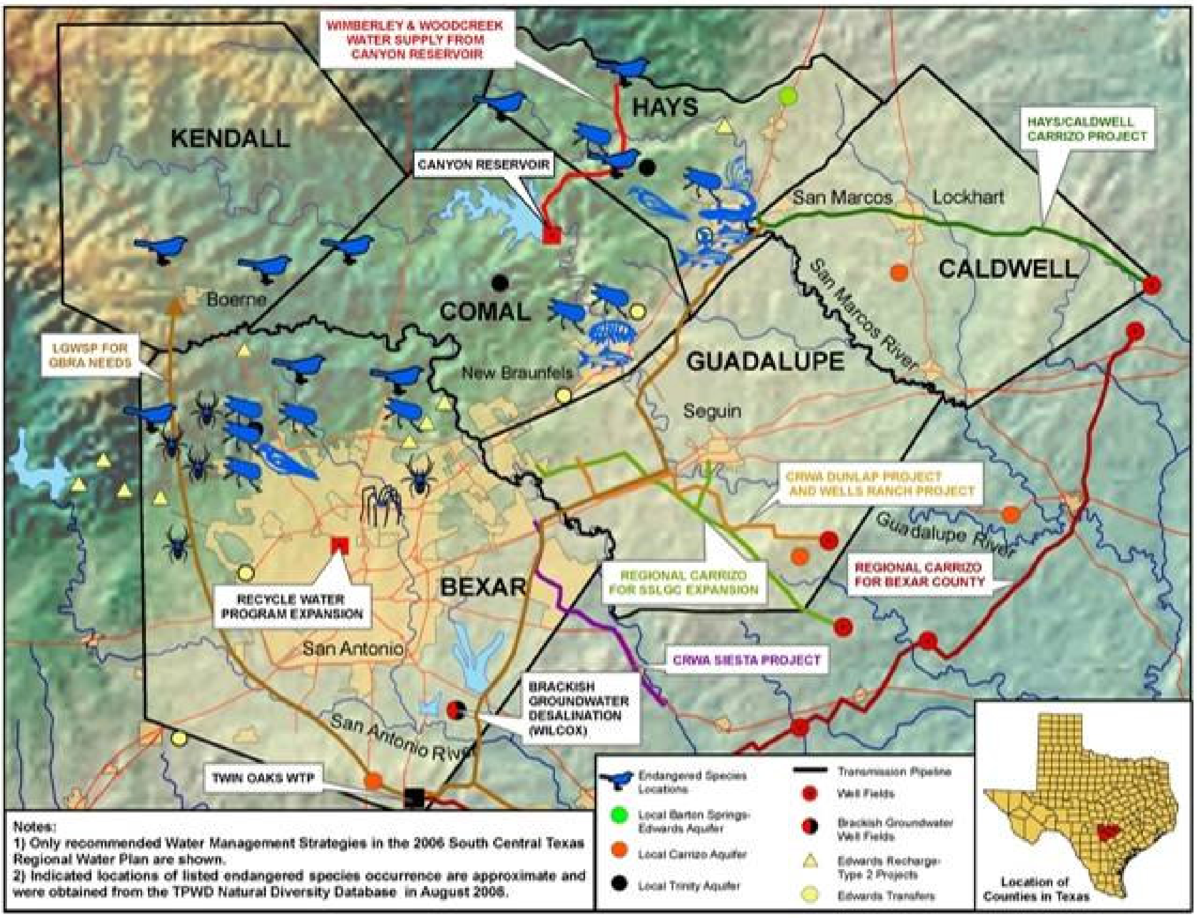

Figure 4-3. Northern Area of Region L with Recommended Water Management Strategies and Endangered Species

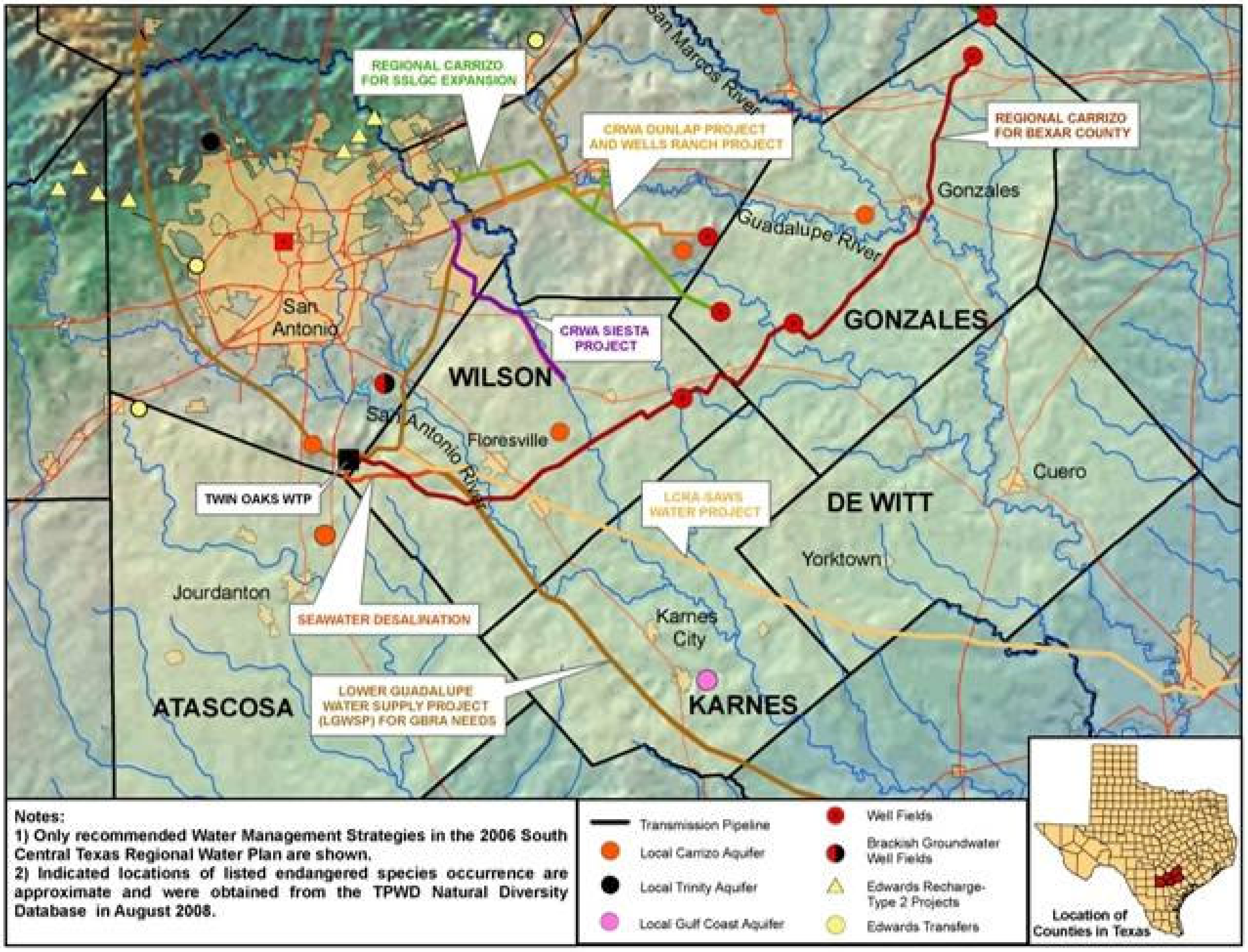

Figure 4-4. Central Area of Region L with Recommended Water Management Strategies and Endangered Species

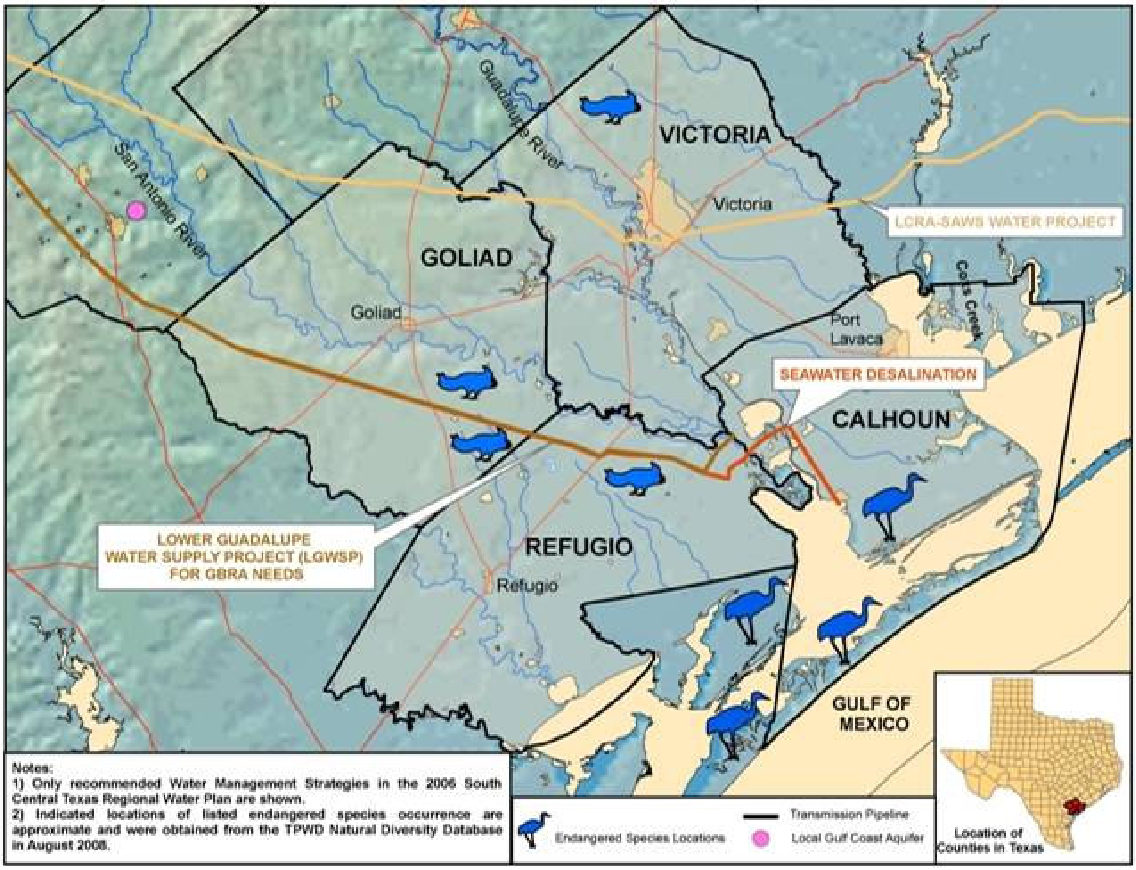

Figure 4-5. Southern Area of Region L with Recommended Water Management Strategies and Endangered Species

4.2 Water Supply Project Development Processes

Beginning with project conception, or identification as a potentially feasible water management strategy, there are many elements involved in the development of a water supply project. Regional water planning, pursuant to SB1 of the 75th Texas Legislature, can be a critical element in project development, as it represents one of the first opportunities for project sponsors to receive public comment on a concept for future water supply. Figure 4-6 provides a graphical summary of many of the elements typically involved in the project development process, from conception to implementation. Although regional water planning may be engaged relatively early, it can affect project development throughout the permitting phase and into the implementation phase. Examples may include consistency with a regional water plan in order to obtain new surface water rights or groundwater production permits, referencing regional water planning for consideration of project alternatives in permitting, and/or recommendation in an approved regional water plan to obtain loans from the Texas Water Development Board for project construction.

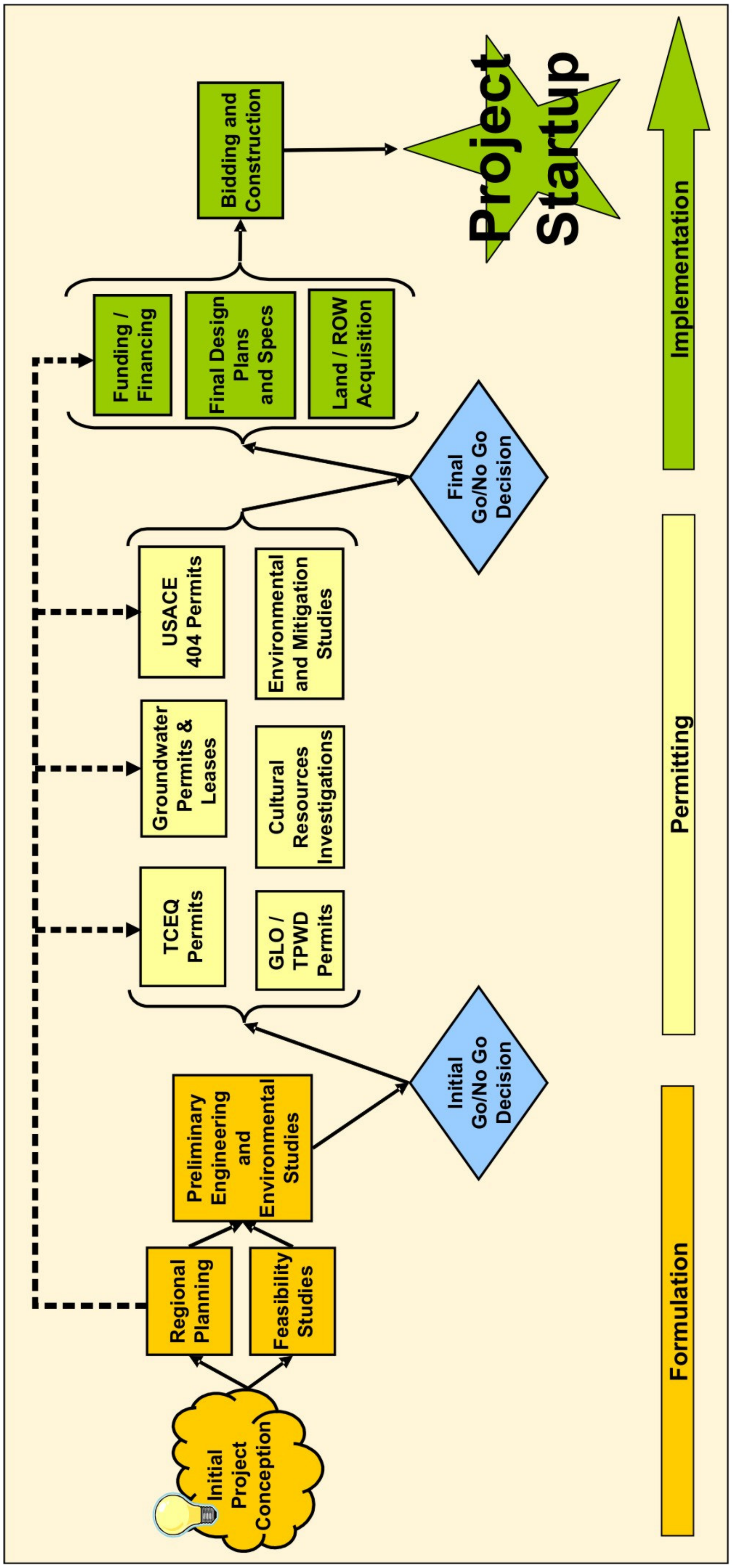

Figure 4-6. Project Development from Conception to Startup

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Appendix A
Comments from Texas Water Development Board and Responses

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ATTACHMENT 1

TWDB Contract No. 0704830697

Region L, Region-Specific Studies 1-5:

TWDB Comments on Draft Final Region-Specific Study Reports:
1) Lower Guadalupe Water Supply Project for GBRA Needs
2) Brackish Groundwater Supply Evaluation
3) Enhanced Water Conservation, Drought Management and Land Stewardship
4) Environmental Studies
5) Environmental Evaluations of Water Management Strategies

Region-Specific Study 4: Environmental Studies

Page ES-3: Data units in Tables ES-1, 2 are not labeled. Please label data units.

Response – The units "acft" will be added to both these tables, as well as the tables in the main body of the text on Pages 9 and 10.

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