Coastal Hydrology for the Trinity-San Jacinto Estuary

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Coastal Science Program
Surface Water Division
Texas Water Development Board
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Purpose

This technical memo describes the detailed procedures adopted by the Texas Water Development Board (TWDB) for estimating total freshwater inflow from surface water and the specifics related to producing hydrology dataset version #TWDB201901 for the Trinity-San Jacinto Estuary. This report and dataset version supersede all previous coastal hydrology datasets for the Trinity-San Jacinto Estuary.

Introduction

A primary goal of the TWDB's Coastal Science Program is to provide estimates of historical surface inflow into Texas bays and estuaries to support environmental and water planning studies. The earliest freshwater inflow estimates were compiled in a series of reports published by the Texas Department of Water Resources (TDWR) between 1980 and 1983, in which monthly surface inflow to each of the seven major estuaries of Texas for the period 1941 – 1976 was estimated. The historical estimates and details for the Trinity-San Jacinto Estuary are published in Chapter 4 of LP-113, *Trinity-San Jacinto Estuary: A Study of the Influence of Freshwater Inflows* (TDWR, 1981).

Herein, this report describes the most recent version of freshwater inflow estimates for the Trinity-San Jacinto Estuary which includes hydrology data through 2018. Previous coastal hydrology versions (TWDB201001, TWDB201004, and TWDB201101) are documented in Schoenbaechler *et al*. (2012). Complete hydrology data for the Trinity-San Jacinto Estuary is available for the period between 1941 – 2018, with daily inflow estimates available only from 1977 – 2018 (https://www.waterdatafortexas.org/coastal/hydrology/galveston).

Estimates of Freshwater Inflow

Estimates of hydrology data for the watersheds draining into the Trinity-San Jacinto Estuary include gauged and ungauged portions of the Trinity and San Jacinto river basins and surrounding coastal basins. These estimates do not account for groundwater contributions. The total surface inflow that reaches an estuary at any given time is illustrated in Equation 1. For a typical estuary, the freshwater inflow balance is estimated based on the surface inflow and considers the amount of precipitation onto and rate of evaporation from the estuary, which is represented by a simple relationship as in Equation 2.

$$I^{fw} = \sum Q^{gauged} + \sum Q^{ungauged} - \sum Q^{diversion} + \sum Q^{return} \qquad \text{Equation 1}$$

where I^{fw} is the total freshwater inflow to the estuary, Q^{gauged} is the flow that originated from gauged watersheds, $Q^{ungauged}$ is the flow that originated from ungauged watersheds, $Q^{diversion}$ is the flow diverted from streams in ungauged watersheds, and Q^{return} is the flow returned to streams in ungauged watersheds.

$$WB = I^{fw} - E + P \qquad \text{Equation 2}$$

where WB is the freshwater inflow balance, I^{fw} is the total freshwater inflow, E is the evaporation from the estuary, and P is the precipitation onto the estuary.

1941 – 1976 Period of Record

The 1941 – 1976 period of record used measurements from United States Geological Survey (USGS) stream gauges and one reservoir elevation gauge (Lake Houston) to determine flow from the gauged watersheds. Rainfall-runoff estimates from a water yield model were used to determine flows from ungauged watersheds (TDWR, 1981). Estimates for ungauged watersheds were adjusted for known agricultural, municipal, and industrial diversions and return flows obtained from the TDWR (1981). Municipal and industrial return flows for ungauged watersheds were estimated based on data derived from the TDWR self-reporting system, while irrigation return flows were calculated using agency collected data sourced from rice irrigation return flow studies (TDWR, 1981). Reported diversions for municipal, industrial, and irrigation uses within ungauged watersheds were provided by the TDWR reported water usage system. Total surface inflow, including gauged, modeled, diversion, and return flow data, to the Trinity-San Jacinto Estuary for the period between 1941 – 1976 are available on a monthly and annual basis.

1977 – 2018 Period of Record

The 1977 – 2018 period of record used measurements from USGS stream gauges and one reservoir elevation gauge (Lake Houston) to determine flow from gauged watersheds. Rainfall-runoff estimates from the Texas Rainfall-Runoff (TxRR) model (Matsumoto, 1992) were used to determine flow from ungauged watersheds. Estimates for ungauged watersheds were adjusted for known agricultural, municipal, and industrial diversions and return flows obtained from the Texas Commission on Environmental Quality (TCEQ) and the United States Environmental Protection Agency (US EPA). Agricultural return flow data for the period 1977 – 2007 were obtained from TWDB Irrigation Water Use estimates. In some cases, diversion and return flow data were derived from other sources, such as in the TWDB report on *Coastal Hydrology for the Guadalupe Estuary: Updated Hydrology with Emphasis on Diversion and Return Flow Data for 2000-2009* (Guthrie and Lu, 2010) where diversion and return flow data were obtained from HDR, Inc. Total surface inflow, including gauged, modeled, diversion, and return flow data, to the Trinity-San Jacinto Estuary for the period 1977 – 2018 are available on a daily, monthly, and annual basis.

Gauged Watersheds

Thirteen USGS stream gauges and discharge from Lake Houston were used to generate the gauged inflow component of the total freshwater inflow to the Trinity-San Jacinto Estuary. Among these, three gauging stations (08075000, 08074500, and 08066500) have 78 complete years (1941 – 2018) of daily data that were used to generate the hydrology dataset for the estuary. For hydrology version #TWDB201901, approved USGS stream gauge data at all stations were available through December 2018. Discharge from Lake Houston was calculated using USGS reservoir storage and gauge height data obtained for the 1954 – 2018 period of record. The discharge calculation for Lake Houston was based on an empirical extrapolation that utilizes power regression derived coefficients between reservoir storage and gauge height data. Details of gauging stations, their locations, and corresponding period of record used in estimating total freshwater inflow are presented in Table 1.

Table 1. TWDB watershed number, USGS stream gauges, their location, and period of record used to generate the gauged inflow component of coastal hydrology data for the Trinity-San Jacinto Estuary.

TWDB Watershed	USGS gauge	Location	Data starting period	Data continuity	Data ending period	Data status
09030	08067500	Cedar Bayou nr Crosby, TX	10/1/1971	*Missing data	12/31/2018	Approved thru 2018
10061	08075000	Brays Bayou at Houston, TX	1/1/1941	No missing data	12/31/2018	Approved thru 2018
10062	08075500	Sims Bayou at Houston, TX	10/1/1952	No missing data	9/30/1995	Approved thru 1995
10063	08076000	Greens Bayou nr Houston, TX	10/1/1952	No missing data	12/31/2018	Approved thru 2018
10064	08076500	Halls Bayou at Houston, TX	10/1/1952	*Missing data	12/31/2018	Approved thru 2018
10065	08075770	Hunting Bayou at IH 610, Houston, TX	4/14/1964	*Missing data	12/31/2018	Approved thru 2018
10066	08075730	Vince Bayou at Pasadena, TX	10/1/1971	No missing data	12/31/2018	Approved thru 2018
10073	08074500	Whiteoak Bayou at Houston, TX	1/1/1941	No missing data	12/31/2018	Approved thru 2018
10074	08073600	Buffalo Bayou at W Belt Dr, Houston, TX	9/1/1971	No missing data	12/31/2018	Approved thru 2018
11021_a	08077000	Clear Ck nr Pearland, TX	8/1/1944	*Missing data	9/4/1994	Approved thru 1994
11021_b	08076997	Clear Ck at Mykawa St nr Pearland, TX	10/1/2006	No missing data	12/31/2018	Approved thru 2018
11081	08078000	Chocolate Bayou nr Alvin, TX	3/1/1959	No missing data	12/31/2018	Approved thru 2018
lkhouston	08072000	Lk Houston nr Sheldon, TX	4/1/1954	No missing data	12/31/2018	Approved thru 2018
trinity	08066500	Trinity Rv at Romayor, TX	1/1/1941	No missing data	12/31/2018	Approved thru 2018

Note: *Where gauged data are missing, streamflow values were estimated using the TxRR model. (Missing data points: 08067500: 1/1/2000 – 9/30/2001; 08075500: 1/1/2000 – 12/31/2018; 08076500: 1/1/2000 – 6/13/2001; 08075770: 9/30/2004 – 9/29/2005; and 08077000: 1/1/2000 – 9/30/2006)

Ungauged Watersheds

The number of ungauged watersheds for the Trinity-San Jacinto Estuary has changed over time as new USGS gauges are installed or removed, and watersheds have been re-delineated and re-numbered through time (Schoenbaechler *et al.* 2012). Initial estimates for 1941 – 1976 were determined using 18 ungauged watersheds. Subsequent estimates for 1977 – 1999 were determined using 23 ungauged watersheds. The most recent estimates for 2000 – 2018 were determined using 26 ungauged watersheds. An increase in the number of ungauged watersheds over the period of record occurred due to sub-division of large watersheds into smaller ones, as well as the addition of new watersheds. The delineation of watershed boundaries for generating the hydrology dataset for the period between 1977 and 2018 are illustrated in Figure 1.

Surface inflows from ungauged watersheds are estimated using a rainfall-runoff model and thus form the modeled component of the freshwater inflow estimates. Before 1977, stream flows in ungauged watersheds across the Texas coast were obtained using a *water yield model* which required daily precipitation, Soil Conservation Service (SCS) average curve numbers, and soil depletion index (TDWR, 1981). This water yield model provided for monthly estimates of ungauged inflows, thus TWDB does not have daily estimates of ungauged inflows for the period prior to 1977.

Since 1977, the ungauged inflow component has been estimated using the TxRR model. The model is conceptually similar to the Agricultural Research Service (ARS) rainfall-runoff model which is based on the Soil Conservation Service's curve number approach to estimate direct runoff from a precipitation event. The TxRR model, however, has four key differences: (1) use of simple and more straightforward mathematics, (2) introduction of 12 monthly depletion factors instead of a single depletion factor, (3) introduction of a baseflow component, and (4) simulation modeling capabilities on a daily basis. The TxRR model has been applied to estimate daily streamflow for 118 ungauged watersheds across the Texas coast.

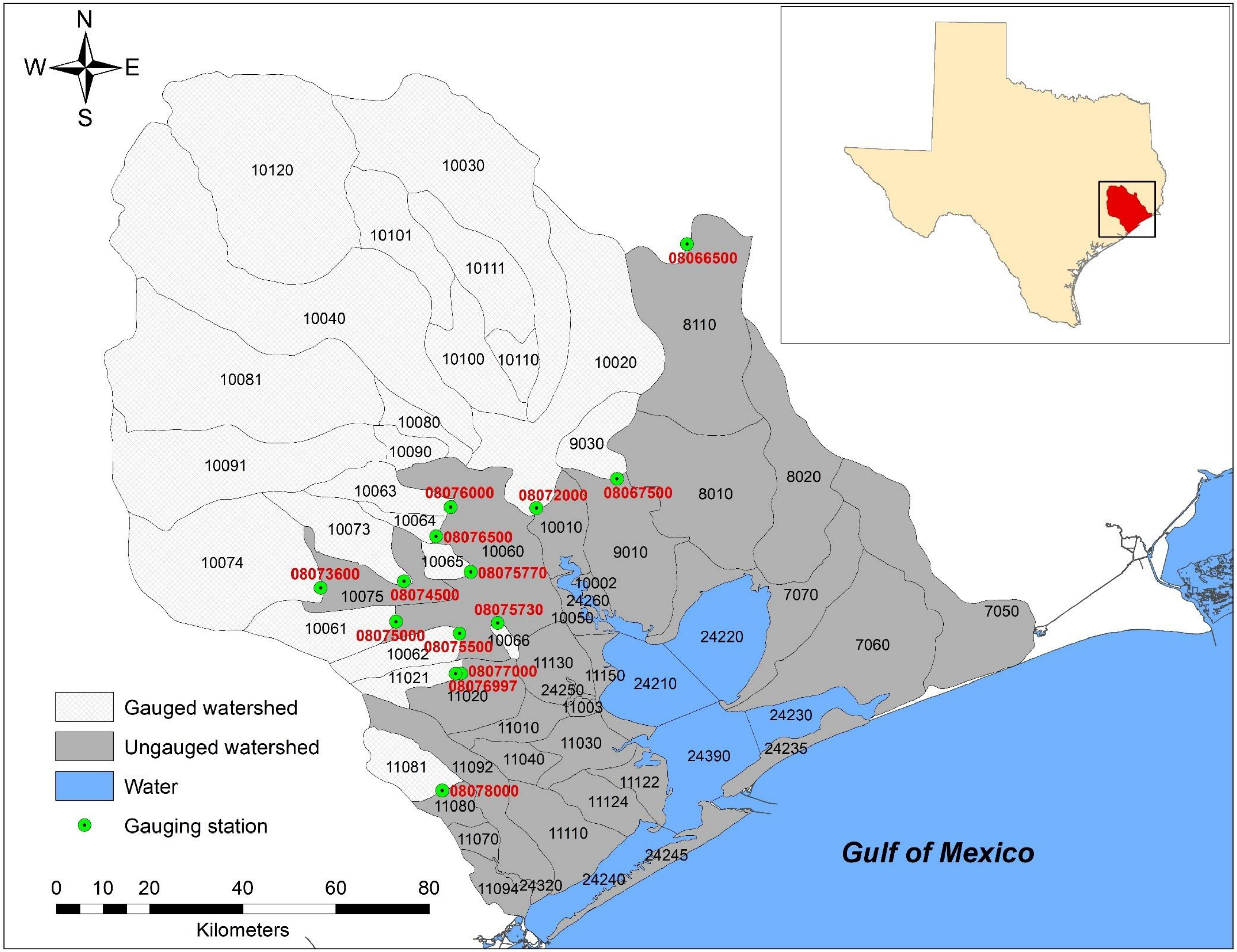

Figure 1. The Trinity-San Jacinto Estuary with gauged (cross-hatched areas) and ungauged (grey areas) watersheds. Gauging stations are indicated with green circles, and bay segments are colored blue.

Diversion and Return Flow Data

Rainfall-runoff estimates from the TxRR model were adjusted for known diversions and return flows within the ungauged watersheds. The major diversion and return flow locations in the watersheds surrounding the Trinity-San Jacinto Estuary are shown in Figure 2. As mentioned above, diversion and return flow data for the 1941 – 1976 period of record were primarily derived from TDWR (1981). For the 1977 – 2018 period of record, diversion and return flow data were obtained from the TCEQ (https://tceq.maps.arcgis.com/home/webmap/viewer.html?webmap=796b001513b9407a9818897b4dc1ec4d) and US EPA's National Pollutant Discharge Elimination System (NPDES; https://echo.epa.gov/tools/data-downloads/icis-npdes-dmr-and-limit-data-set), respectively. This report has the complete diversion and return annual flow data for the period between 1941 – 2018; however, the daily and monthly data can be provided upon request.

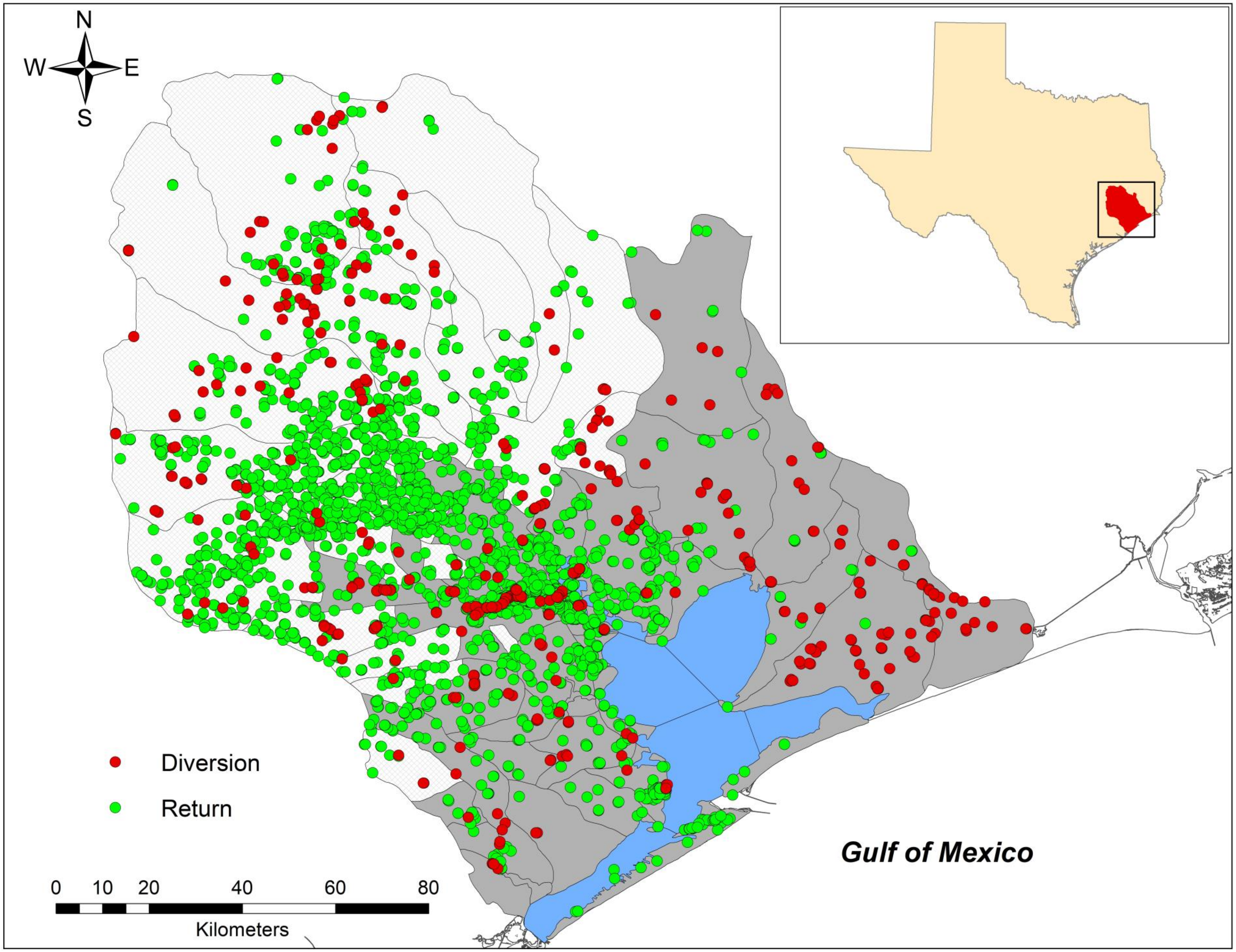

Figure 2. Location of diversion and return flow points within the lower Trinity-San Jacinto watershed. Diversion and return flow data were used to estimate the surface inflow component for ungauged watersheds. Diversion data were obtained from the TCEQ and return flow data were obtained from the US EPA. Water right and discharge permit numbers and owners can be provided upon request.

Estimates of Freshwater Inflow Balance

Total freshwater inflow includes an estimation of surface inflow to the estuary plus precipitation onto the surface of the estuary. The freshwater balance further considers the effect of evaporation from the estuary. Therefore, the freshwater inflow balance of an estuary includes estimates of surface inflow, precipitation, and evaporation as shown in Equation 2. Due to a lack of ungauged daily inflow data prior to 1977 and daily estimates of evaporation throughout the period of record, freshwater inflow balance estimates are available only on a monthly basis.

The bay surface area used to calculate precipitation and evaporation has changed over time resulting from slight adjustments to the number and size of bay segments. Total bay surface area for this version was 474 mi^2 which was used to calculate precipitation and evaporation in order to estimate the freshwater inflow balance.

Precipitation

The amount of precipitation that occurred on the surface of the Trinity-San Jacinto Estuary was calculated using a Thiessen-weighted precipitation technique as described in LP-113 (TDWR, 1981). Station-based precipitation data were obtained from the National Centers for Environmental Information (NCEI; https://www.ncdc.noaa.gov/cdo-web/datatools/findstation) and processed using ARC Macro Language (AML). These datasets were also used as the primary inputs to the TxRR model to generate the surface inflow component from ungauged watersheds. Seven bay segments with the TWDB numbers 24210, 24220, 24230, 24240, 24250, 24320, and 24390 (internally defined by TWDB) were used to calculate precipitation on the bay by summing area-weighted rainfall of the Thiessen polygon segments within the watersheds. The polygons that were generated to be coincident with precipitation stations are shown in Figure 3. To improve the inflow component for ungauged watersheds, the TWDB is exploring the potential use of higher-resolution multi-sensor processed precipitation data.

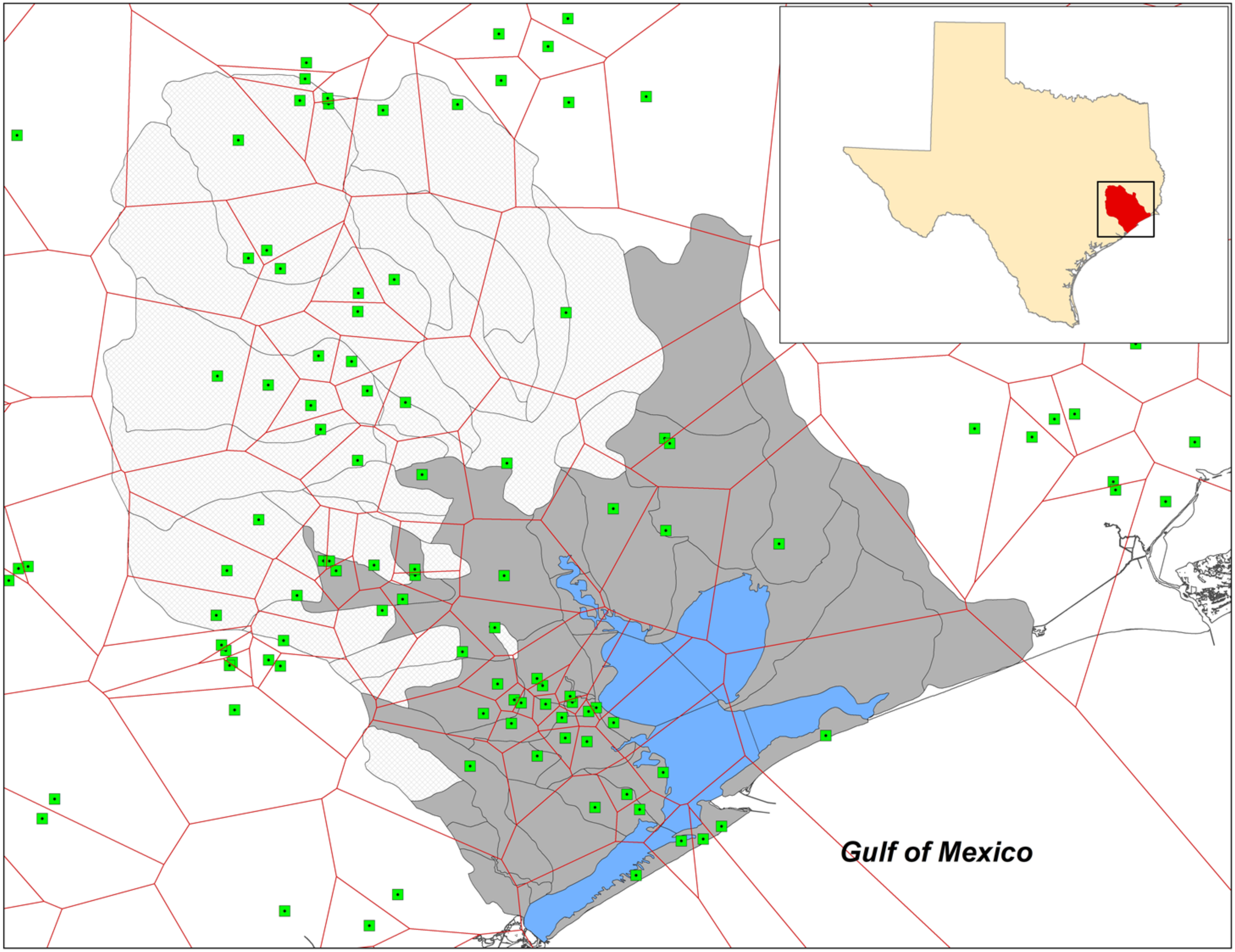

Figure 3. Precipitation stations (green rectangles) and Thiessen polygons (polygons with red lines) used to estimate precipitation as input to the TxRR model to generate the ungauged inflow component for the Trinity-San Jacinto Estuary.

Evaporation

The rate of evaporation in the Trinity-San Jacinto Estuary was estimated by applying the TWDB's monthly gross lake evaporation rates which are compiled for Texas at a broad spatial scale, specifically at a gridded one-degree latitude by one-degree longitude quadrangles (https://www.waterdatafortexas.org/lake-evaporation-rainfall). The Trinity-San Jacinto Estuary falls within quadrangles 812 and 813 (Figure 4), and the evaporation rates for these quadrangles were applied to the total area of seven bay segments (24210, 24220, 24230, 24240, 24250, 24320, and 24390; internally defined by TWDB) to estimate total water evaporated from the estuary. This estuary-wide estimate of gross evaporation was then used in calculating the freshwater inflow balance for the Trinity-San Jacinto Estuary.

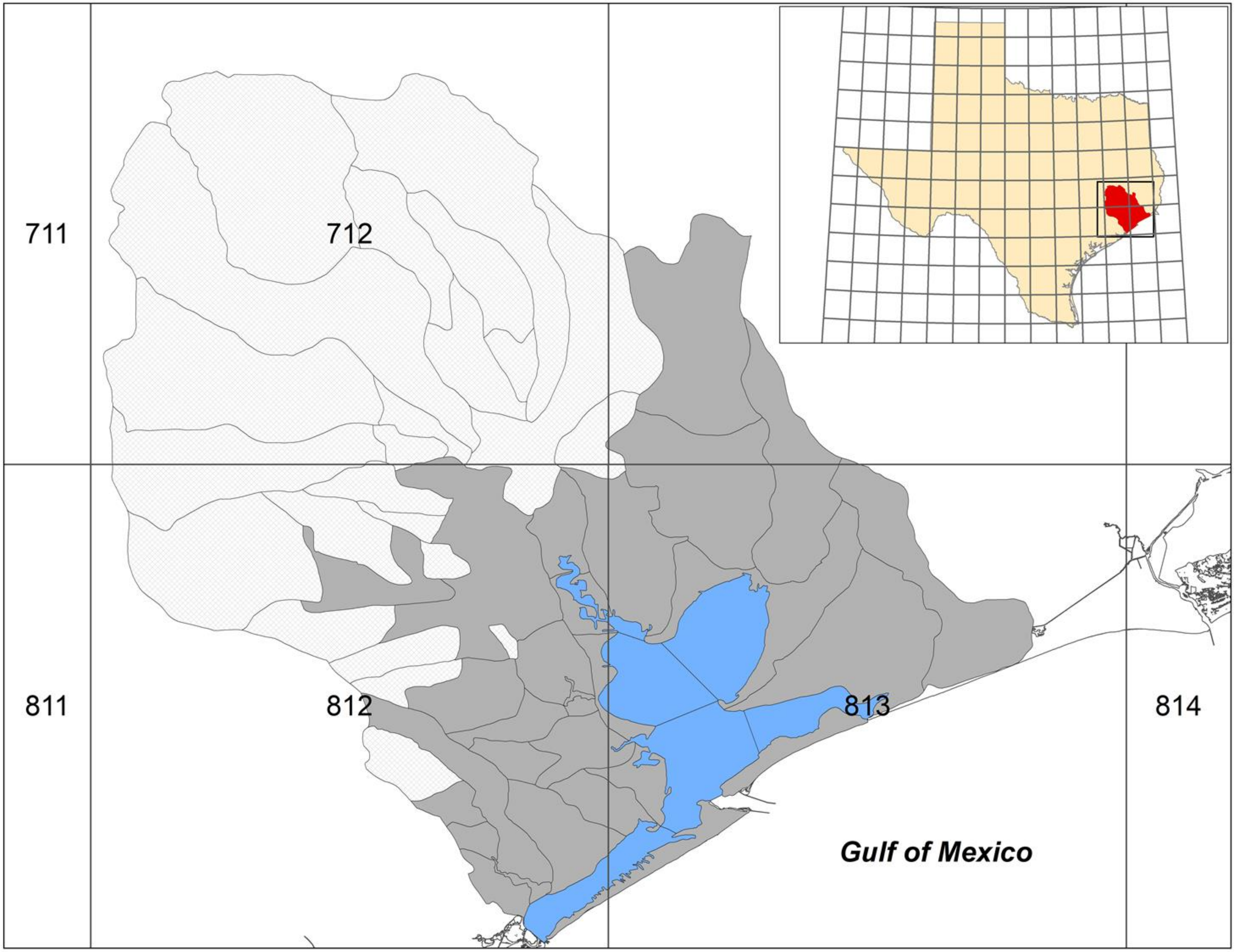

Figure 4. Texas Water Development Board numbered quadrangles within which gross lake evaporation rates are estimated. These rates were then applied to estimate evaporation from the Trinity-San Jacinto Estuary.

Discussion

The TWDB coastal hydrology version #TWDB201901 for the Trinity-San Jacinto Estuary is the most up-to-date complete data set representing total surface inflow values and individual component values for gauged, ungauged, diversions, and return flows as described herein. Appendix A summarizes the data used to develop hydrology version #TWDB201901 for the Trinity-San Jacinto Estuary. Appendix B lists total annual freshwater inflow including the values for seven other components (gauged, ungauged, diversion, return, evaporation, precipitation, and freshwater balance) estimated for the estuary. Appendix C presents summary statistics of all the components for the period between 1941 – 2018.

Figures 5 and 6 display freshwater inflow estimates on an annual and monthly basis, respectively, estimated for the Trinity-San Jacinto Estuary based on version #TWDB201901. During the period from 1941 – 2018, gauged flows into the estuary accounted for approximately 70 percent of total freshwater inflow, while ungauged flow accounted for 28 percent of total inflow. Average annual diversions were 5 percent and return flows were 7 percent of the total freshwater inflow. The long-term mean freshwater inflow for the estuary during the study period was 11.6 million acre-feet per year, ranging from a minimum of 1.9 million acre-feet in 1956 to a maximum of 28.6 million acre-feet in 2015. Despite extreme drought in 2011 which resulted in 2.6 million acre-feet of freshwater inflow, 1956 remains the year with the lowest freshwater inflow on record, delivering only 1.9 million acre-feet of freshwater inflow to the Trinity-San Jacinto Estuary.

Finally, when calculating the total freshwater inflow balance, the amount of precipitation and evaporation occurring upon the bay should be considered. For the period between 1941 – 2018, mean freshwater inflow balance was 11.7 million acre-feet per year, ranging from a minimum of 1.3 million acre-feet in 1954 to a maximum of 29.6 million acre-feet in 2015. Due to the large amount of precipitation and freshwater inflow relative to the amount of evaporation, the Trinity-San Jacinto Estuary has not experienced a negative annual freshwater inflow balance during the period of record.

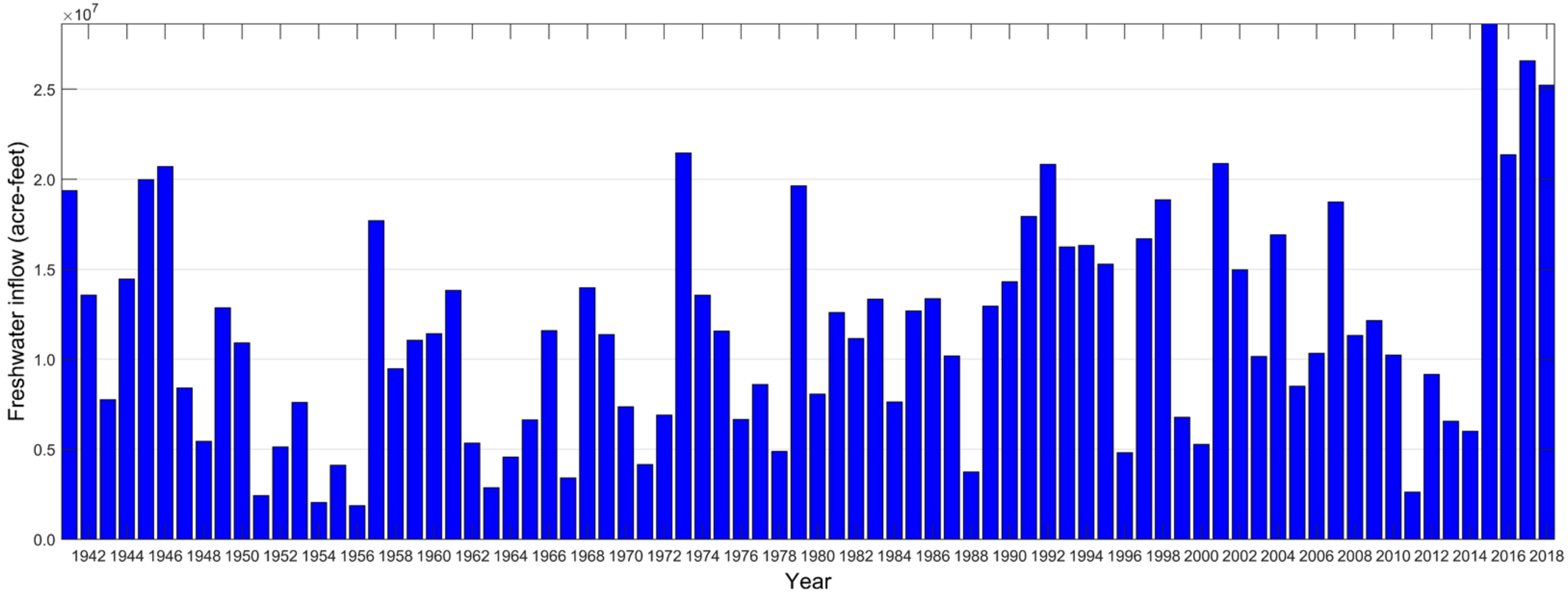

Figure 5. Annual freshwater inflow estimates for the Trinity-San Jacinto Estuary as calculated for version #TWDB201901 for the period between 1941 – 2018. Average annual freshwater inflow for this period was calculated to be 11.6 million acre-feet.

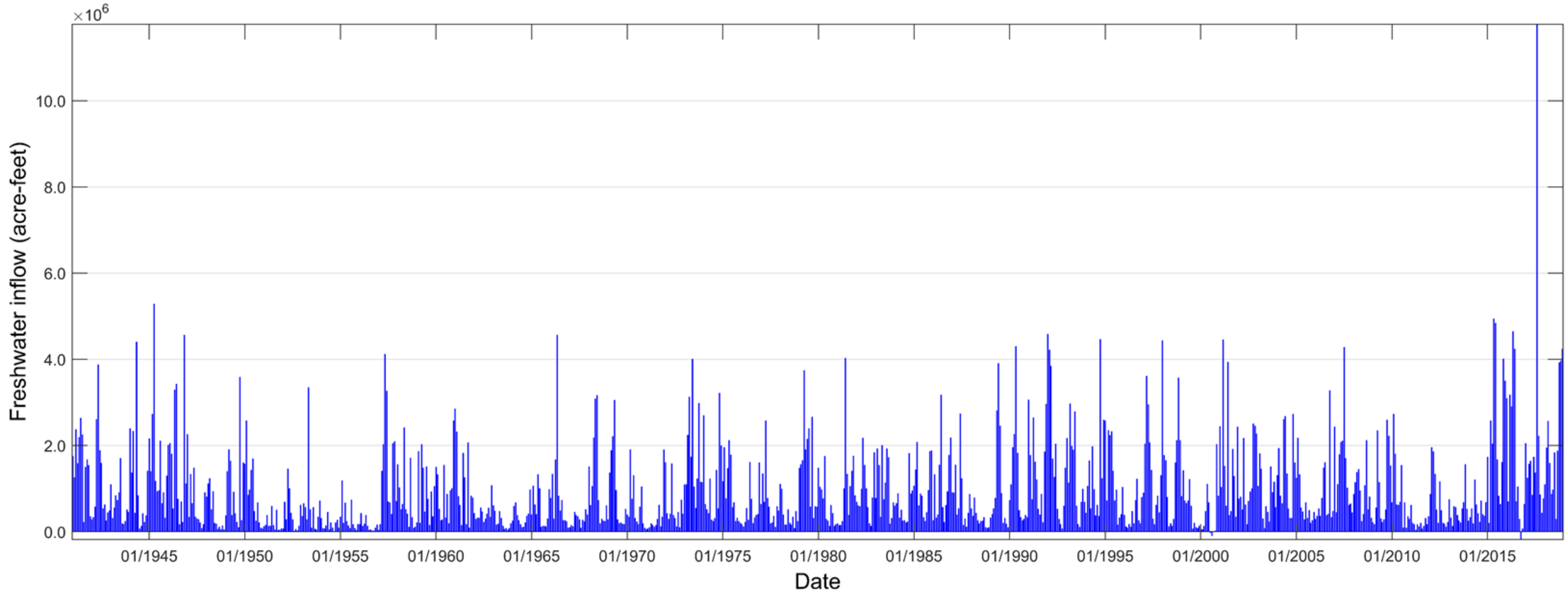

Figure 6. Monthly freshwater inflow estimates for the Trinity-San Jacinto Estuary as calculated for version #TWDB201901 for the period between 1941 – 2018. Monthly average freshwater inflow for this period was calculated to be 0.96 million acre-feet.

References

Guthrie, C.G. and Q. Lu. 2010. *Coastal Hydrology for the Guadalupe Estuary: Updated Hydrology with Emphasis on Diversion and Return Flow Data for 2000-2009.* Texas Water Development Board, Austin, Texas.

Matsumoto, J., 1992. User's Manual for The TWDB's Rainfall-Runoff Model. Texas Water Development Board, Austin, TX. 28pp.

Schoenbaechler, C., Guthrie, C.G., Lu, Q., 2012. Coastal Hydrology for the Trinity-San Jacinto Estuary. Texas Water Development Board, Austin, TX. 29pp.

TDWR. 1981. Trinity-San Jacinto Estuary: A study of the influence of freshwater inflows. LP-113. Texas Department of Water Resources, Austin, TX. 491pp.

Appendix A: Summary of coastal hydrology dataset version #TWDB201901 developed by the Texas Water Development Board Coastal Science Program including the details of data availability for all gauged, modeled, diversion, and return flows for the Trinity-San Jacinto Estuary.

Estuary	Version	Period of record	Gauged flow	Modeled flow	Diversion flow	Return flow	Data generated
Trinity-San Jacinto	TWDB201901	1941 – 2018	1941 – 2018 (USGS)	1941 – 2018 (TxRR)	1941 – 2018 (TDWR) (TCEQ)	1941 – 2007 (TDWR) 1941 – 1976 (TCEQ) 1977 – 2005 (TWDB) 2009 – 2018 (NPDES)	05/2021

Note: Previous coastal hydrology versions (#TWDB201001, #TWDB201004, and #TWDB201101) are documented in Schoenbaechler *et al*. (2012).

Appendix B: Annual hydrology for the Trinity-San Jacinto Estuary, version #TWDB201901. The table presents gauged, modeled, diversion, return, freshwater inflow, evaporation, precipitation, and freshwater balance values for the period between 1941 – 2018. All values are in acre-feet.

Year	Gauged	Modeled	Diversion	Return	Freshwater inflow*	Evaporation	Precipitation	Freshwater balance**
1941	14,476,600	4,899,000	120,000	122,000	19,377,600	1,121,000	2,349,356	20,605,956
1942	11,005,600	2,574,000	145,000	136,000	13,570,600	1,268,000	1,715,592	14,018,192
1943	5,153,210	2,651,000	192,000	152,000	7,764,210	1,267,000	1,756,858	8,254,068
1944	10,633,030	3,860,000	191,000	151,000	14,453,030	1,267,000	1,818,763	15,004,793
1945	15,565,400	4,438,000	184,000	154,000	19,973,400	1,267,000	2,137,119	20,843,519
1946	14,487,350	6,238,000	183,000	160,000	20,702,350	1,238,000	2,885,848	22,350,198
1947	6,872,810	1,561,000	182,000	162,000	8,413,810	1,266,000	1,226,265	8,374,075
1948	4,413,680	1,109,000	240,000	171,000	5,453,680	1,266,000	996,340	5,184,020
1949	8,129,670	4,807,000	259,000	192,000	12,869,670	1,239,000	2,187,233	13,817,903
1950	9,063,520	1,874,000	220,000	187,000	10,904,520	1,414,000	1,267,533	10,758,053
1951	1,777,170	713,000	277,000	206,000	2,419,170	1,385,000	1,176,153	2,210,323
1952	3,157,810	2,019,000	249,000	205,000	5,132,810	1,386,000	1,435,554	5,182,364
1953	5,466,320	2,179,000	230,000	193,000	7,608,320	1,463,000	1,585,891	7,731,211
1954	1,691,350	356,000	279,000	279,000	2,047,350	1,592,000	798,840	1,254,190
1955	2,239,430	1,768,000	214,000	321,000	4,114,430	1,532,000	1,577,046	4,159,476
1956	1,053,280	599,000	106,000	325,000	1,871,280	1,592,000	1,037,608	1,316,888
1957	13,759,230	3,772,000	143,000	321,000	17,709,230	1,443,000	1,680,219	17,946,449
1958	7,004,000	2,312,000	183,000	351,000	9,484,000	1,414,000	1,518,093	9,588,093
1959	6,910,380	3,993,000	191,000	349,000	11,061,380	1,652,000	1,748,019	11,157,399
1960	8,491,920	2,767,000	215,000	374,000	11,417,920	1,534,000	1,518,093	11,402,013
1961	9,596,390	4,070,000	235,000	389,000	13,820,390	1,503,000	1,868,874	14,186,264
1962	4,255,100	939,000	271,000	421,000	5,344,100	1,532,000	1,176,153	4,988,253
1963	2,003,210	677,000	266,000	446,000	2,860,210	1,208,000	869,588	2,521,798
1964	2,937,980	1,395,000	219,000	448,000	4,561,980	1,238,000	1,202,682	4,526,662
1965	5,357,240	1,038,000	238,000	473,000	6,630,240	1,533,000	1,120,147	6,217,387
1966	7,627,190	3,656,000	204,000	514,000	11,593,190	1,031,000	1,930,778	12,492,968
1967	2,330,770	801,000	265,000	543,000	3,409,770	1,295,000	1,099,511	3,214,281
1968	10,370,930	3,295,000	244,000	551,000	13,972,930	1,270,000	1,630,108	14,333,038
1969	8,878,470	2,187,000	252,000	562,000	11,375,470	1,327,000	1,579,994	11,628,464
1970	4,095,940	2,957,000	266,000	575,000	7,361,940	1,358,000	1,733,279	7,737,219
1971	2,697,888	1,109,000	260,000	615,000	4,161,888	1,574,000	1,288,168	3,876,056
1972	4,023,806	2,469,000	220,000	625,000	6,897,806	1,445,000	1,397,233	6,850,039
1973	15,422,740	5,684,000	211,000	559,000	21,454,740	1,408,000	2,231,448	22,278,188
1974	10,357,101	2,822,000	251,000	632,000	13,560,101	1,502,000	1,591,786	13,649,887
1975	8,993,864	2,182,000	221,000	610,000	11,564,864	1,418,000	1,871,823	12,018,687
1976	4,907,017	1,263,000	205,000	695,000	6,660,017	1,485,000	1,385,442	6,560,459
1977	6,077,962	2,275,980	248,486	485,572	8,591,028	1,547,943	1,224,396	8,267,481
1978	2,971,237	1,638,373	283,940	562,888	4,888,558	1,517,345	960,109	4,331,322
1979	12,454,741	6,939,455	365,550	611,712	19,640,358	1,508,969	2,025,941	20,157,330
1980	5,192,354	2,655,061	343,102	573,040	8,077,353	1,623,845	1,180,490	7,633,998
1981	7,749,256	4,630,388	359,094	579,572	12,600,122	1,578,534	1,626,840	12,648,428
1982	8,613,302	2,349,359	348,457	543,654	11,157,858	1,585,170	1,168,877	10,741,565
1983	8,145,502	4,933,877	272,697	537,396	13,344,078	1,542,164	1,731,680	13,533,594
1984	5,649,729	1,761,633	327,768	541,045	7,624,639	1,671,479	1,065,469	7,018,629
1985	8,783,215	3,690,957	315,376	530,182	12,688,978	1,588,343	1,426,017	12,526,652
1986	9,819,130	3,400,504	378,577	533,055	13,374,112	1,566,118	1,327,494	13,135,488
1987	6,816,025	3,280,315	432,417	527,210	10,191,133	1,684,177	1,287,309	9,794,265
1988	2,646,631	1,017,520	411,249	480,247	3,733,149	1,519,940	1,047,656	3,260,865
1989	9,444,965	3,456,164	427,189	484,207	12,958,147	1,375,617	1,408,050	12,990,580

Year	Gauged	Modeled	Diversion	Return	Freshwater inflow*	Evaporation	Precipitation	Freshwater balance**
1990	12,151,089	2,110,414	431,995	478,551	14,308,059	1,414,002	1,284,824	14,178,881
1991	12,160,220	5,850,719	577,096	507,090	17,940,933	1,502,332	1,931,901	18,370,502
1992	16,359,407	4,625,064	621,416	472,844	20,835,899	1,392,356	1,600,708	21,044,251
1993	11,997,802	4,463,188	582,145	364,417	16,243,262	1,660,790	1,481,391	16,063,863
1994	12,350,548	4,102,510	568,981	440,698	16,324,775	1,498,868	1,277,429	16,103,336
1995	10,834,184	4,633,659	646,444	471,686	15,293,085	1,407,081	1,715,593	15,601,597
1996	2,653,800	2,340,702	664,445	478,894	4,808,951	1,459,612	1,223,787	4,573,126
1997	11,684,465	5,271,059	689,092	432,214	16,698,646	1,504,640	1,880,418	17,074,424
1998	13,502,940	5,637,086	729,513	455,408	18,865,921	1,651,077	2,025,985	19,240,829
1999	5,341,183	1,704,491	677,106	417,365	6,785,933	1,318,246	1,110,167	6,577,854
2000	4,810,537	2,244,498	2,056,947	275,493	5,273,581	2,039,035	1,273,709	4,508,256
2001	14,784,051	7,502,001	1,922,805	519,312	20,882,559	1,707,965	2,134,785	21,309,379
2002	10,277,527	5,709,855	1,383,747	370,211	14,973,846	1,682,162	2,448,503	15,740,187
2003	7,267,763	3,688,937	1,209,268	413,817	10,161,249	1,295,304	1,780,756	10,646,700
2004	12,305,170	4,862,938	1,183,192	928,244	16,913,161	1,336,794	2,083,601	17,659,967
2005	6,032,400	1,982,452	907,143	1,399,418	8,507,127	1,615,394	1,342,226	8,233,959
2006	4,068,674	5,644,727	1,076,889	1,703,192	10,339,703	1,599,536	2,232,591	10,972,758
2007	12,711,219	5,208,902	834,270	1,649,039	18,734,891	1,452,624	2,113,939	19,396,206
2008	6,533,195	4,167,550	771,548	1,404,183	11,333,380	1,574,804	1,667,049	11,425,625
2009	8,217,899	3,271,781	753,454	1,422,376	12,158,602	1,565,617	1,746,432	12,339,417
2010	7,634,819	2,574,000	1,311,659	1,345,992	10,243,152	1,565,938	1,431,986	10,109,200
2011	1,861,219	666,895	1,502,871	1,588,355	2,613,598	1,731,048	684,954	1,567,505
2012	5,549,458	3,214,392	1,380,065	1,781,107	9,164,892	1,596,167	1,649,641	9,218,367
2013	3,467,452	2,546,432	1,303,087	1,853,913	6,564,710	1,485,435	1,574,066	6,653,341
2014	3,407,267	2,417,845	1,331,098	1,503,044	5,997,058	1,451,453	1,509,708	6,055,313
2015	20,225,744	7,793,913	2,051,937	2,677,497	28,645,217	1,425,006	2,443,799	29,664,010
2016	19,231,602	5,429,524	3,553,094	262,319	21,370,352	1,461,871	1,649,257	21,557,738
2017	11,331,620	8,764,750	1,239,239	7,723,404	26,580,535	1,445,972	2,740,016	27,874,579
2018	13,934,643	5,568,087	1,199,847	6,933,603	25,236,486	1,398,834	2,401,323	26,238,975

*Freshwater inflow = Gauged + Modeled - Diversion + Return

**Freshwater balance = Freshwater inflow - Evaporation + Precipitation

Appendix C: Annual freshwater inflow statistics (in acre-feet) for the Trinity-San Jacinto Estuary over the period between 1941 – 2018, version #TWDB201901.

	Gauged	**Modeled**	**Diversion**	**Return**	**Freshwater inflow**	**Evaporation**	**Precipitation**	**Freshwater balance**
Minimum	1,053,280	356,000	106,000	122,000	1,871,280	1,031,000	684,954	1,254,190
5%ile	1,857,017	676,495	144,900	151,950	2,603,877	1,236,500	955,583	2,178,182
10%ile	2,615,045	1,009,668	183,900	170,100	4,076,302	1,266,000	1,063,688	3,814,537
25%ile	4,374,035	1,955,339	220,750	343,000	6,652,573	1,371,213	1,257,216	6,573,505
Median	7,692,038	2,889,500	299,658	482,227	11,245,619	1,474,000	1,578,520	11,279,706
Mean	8,105,889	3,295,653	583,401	774,775	11,592,916	1,465,162	1,593,773	11,721,528
75%ile	11,419,831	4,631,206	735,498	610,428	15,530,629	1,574,201	1,869,611	15,821,106
90%ile	14,477,675	5,686,586	1,335,995	1,594,424	20,715,705	1,652,879	2,231,562	21,070,764
95%ile	15,605,100	6,967,582	1,929,262	1,895,092	21,643,827	1,685,366	2,444,035	22,544,637
Maximum	20,225,744	8,764,750	3,553,094	7,723,404	28,645,217	2,039,035	2,885,848	29,664,010
Total	632,259,343	257,060,957	45,505,293	60,432,465	904,247,472	114,282,608	124,314,311	914,279,174