

# Coastal Hydrology for East Matagorda Bay

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Bays & Estuaries Program  
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## **Purpose**

This technical memo documents the procedure for estimating combined freshwater inflow data for East Matagorda Bay and the specifics related to producing hydrology dataset versions #TWDB201001 and #TWDB201004 for this estuary.

## **Introduction**

The goal of the Texas Water Development Board (TWDB) Coastal Hydrology program is to provide estimates of historical freshwater inflows 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 between 1980 and 1983. Monthly inflows to the seven major estuaries in Texas for the period 1941 - 1976 were estimated in those studies. However, the minor estuaries were not addressed in those early studies. The TWDB began estimating inflows to the minor bay systems including East Matagorda Bay in 2003, while continuing to update inflows to the major estuaries.

This report covers the most recent update of freshwater inflow estimates for East Matagorda Bay and extends the hydrology through 2009. Therefore, complete hydrology is available for this minor estuary for the period of 1977 - 2009 in the form of daily, monthly, or annual estimates.

## **Estimates of Combined Freshwater Inflows**

Detailed studies of hydrology of the areas draining to East Matagorda Bay include only the ungaged portions of eight small coastal basins, as there are no major rivers that drain into East Matagorda Bay. **Combined Freshwater Inflow** to the estuaries is typically estimated by combining Gaged Inflows + Ungaged Inflows + Return Flows - Diversions below the last gage station. Given that there are no major rivers that drain into this system, there are no gaged inflows that are monitored by USGS gages. Hence, in this case, combined freshwater inflow is estimated by the following calculation: Ungaged Inflows + Return Flows – Diversions.

**Freshwater Inflow Balance** then includes the Combined Inflows + Precipitation on the estuary – Evaporation from the estuary.

### 1977 - 2009 Period of Record

This dataset does not use measurements from U.S. Geological Survey (USGS) stream gages, but instead relies on rainfall-runoff estimates from the Texas Rainfall-Runoff (TxRR) model to determine flows in eight ungaged watersheds. These estimates then are adjusted for known agricultural, municipal, and industrial diversion and return flows obtained from the TCEQ (or equivalent agency, such as the Texas Natural Resource Conservation Commission (TNRCC)), and the TWDB Irrigation Water Use estimates. Data on inflows to East Matagorda Bay for 1977 - 2009 are available as daily, monthly, or annual estimates.

## **Gaged Watersheds**

East Matagorda Bay does not have any major rivers flowing into it, and as such, there are no gaged watersheds in this basin.

## **Ungaged Watersheds**

The East Matagorda Bay watershed consists of eight ungaged watersheds, which are used to estimate ungaged inflows into the Bay, including #13101, #13102, #13103, #13104, #13105, 13106, 13107, and 50% of watershed #13108. Figure 1 shows the delineation of the watershed boundaries for the period from 1977 to 2009. TWDB uses the Texas Rainfall-Runoff (TxRR) model to estimate daily stream flows in ungaged watersheds. This model is conceptually similar to the Agricultural Research Service (ARS) rainfall-runoff model which is based on the Soil Conservation Service's curve number method to estimate direct runoff from a precipitation event. TxRR, however, has three key differences: (1) use of a simpler and more straightforward mathematics, (2) introduction of 12 monthly depletion factors, instead of single depletion factor used in the ARS Model, and (3) introduction of a base flow component into the model. TxRR has been used to estimate daily stream flows from over 50 coastal ungaged watersheds as a part of the Bays & Estuaries Coastal Hydrology Program to study freshwater inflows to Texas bays and estuaries.

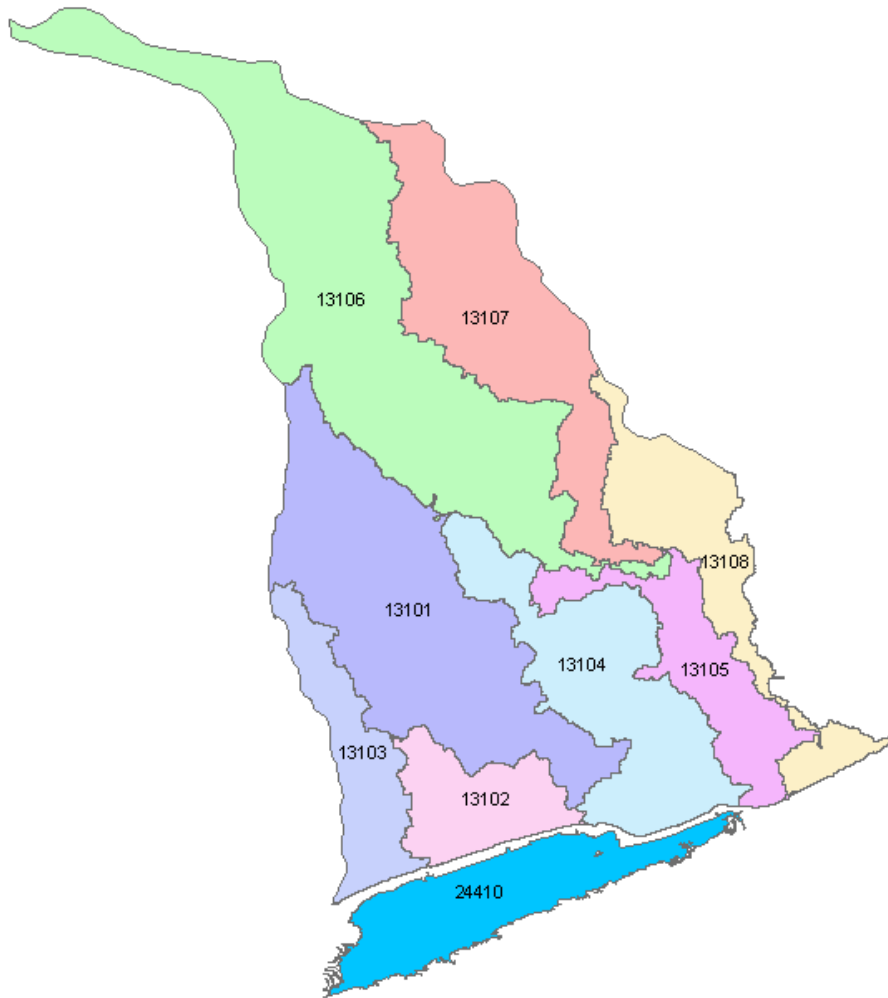


Figure 1. Ungaged watershed delineation used in TxRR to determine unengaged inflows to the East Matagorda Bay system.

### **Diversions and Return Points**

Rainfall-runoff estimates from the TxRR model are adjusted for known diversion and return flows obtained from the TCEQ (or equivalent agency, such as the Texas Natural Resource Conservation Commission, TNRCC) and the TWDB Irrigation Water Use estimates. The major water rights and holders and the major discharge permits and dischargers to East Matagorda Bay are listed in Table 1 and the locations of these permits are shown in Figure 2.

Table 1. Major water rights and discharge permits in the East Matagorda Bay watershed below the lowest USGS stream gages.

<b>DIVERSIONS</b>	<b>Water Right Number</b>	<b>Owner</b>
	3426	John S Runnells III
	3427	Ben H Towler Jr.
	3428	Estate Of P J Reeves Jr.
	3429	D R Alford
	3430	Hudgins Division Of H.D. Hudgins
	3431	Michael J Pruett
	3432	Johnny Wayne & Vicki L Jones
	3433	Hilcorp Energy I LP Et Al
	3434	Donald R & Janice M Kopnicky
	3435	John A. Huebner Jr. Et Al
	3436	Russell & Juanita Matthes
	3437	Francis I Savage
	3438	E Cross Cattle Co Inc.
	3439	E Cross Cattle Co Inc.
	3846	Linda C Moore
	3895	The Minze Land Investments LP
	3992	Runnells Pasture Company LTD
	4122	Julia Holub Et Al
	5438	Matagorda Co Drainage Dist #1
<b>RETURNS</b>	<b>NPDES Number</b>	<b>Owner</b>
	TX0024155	Matagorda County WCID 6
	TX0033910	Boling Municipal Water Dist
	TX0034461	City Of Bay City
	TX0070297	Massey Jimmie Wayne
	TX0087173	Equistar Chemicals, LP
	TX0091561	Wadsworth WSC
	TX0115134	Wharton County Power Partners LP & N American Energy Services Co
	TX0122483	Caney Creek MUD

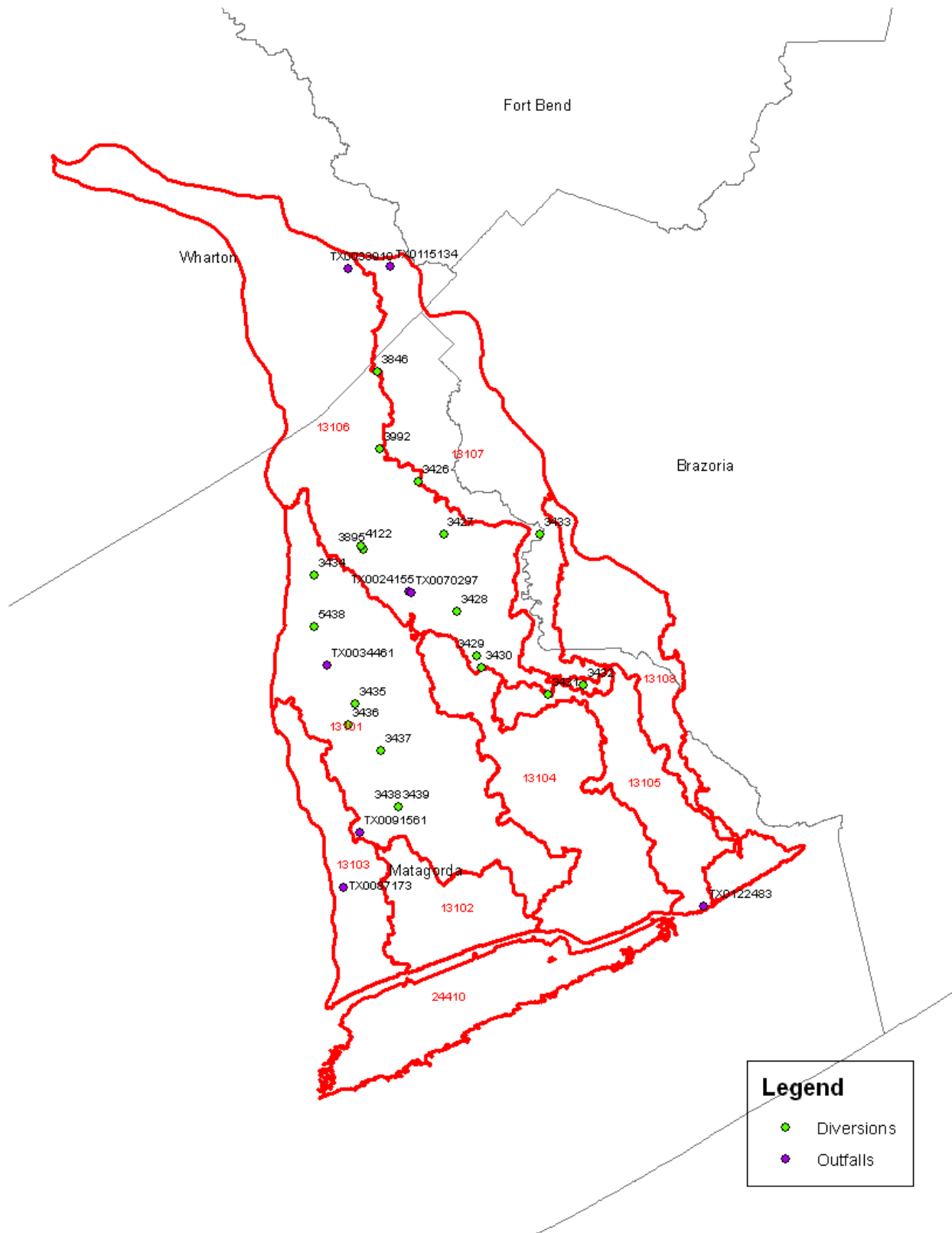


Figure 2. Location of permitted diversion points and wastewater outfalls in the East Matagorda Bay watershed.

## Estimates of Freshwater Inflow Balance

*Total Freshwater Inflow* to the estuary may include estimates of **Combined Freshwater Inflow** to the estuary + Precipitation on the Estuary. The **Freshwater Inflow Balance** then considers the effect of Evaporation from the estuary. Due to limitations on estimates of evaporation throughout the period of record, estimates of the freshwater inflow balance are available only in monthly intervals.

### Precipitation

Direct precipitation onto the surface of East Matagorda Bay is calculated using Thiessen-weighted precipitation techniques as described in LP-106 (TDWR 1980). Station based rainfall data are obtained from the National Weather Service (NWS) and processed using Arc/Info Macro Language. Figure 3 shows the Thiessen polygons that were drawn to be coincident with rainfall stations to calculate watershed rainfall. The bay watershed #24410 then is used to calculate precipitation on the bay by summing the area-weighted rainfall of the Thiessen polygon fragment over the bay.

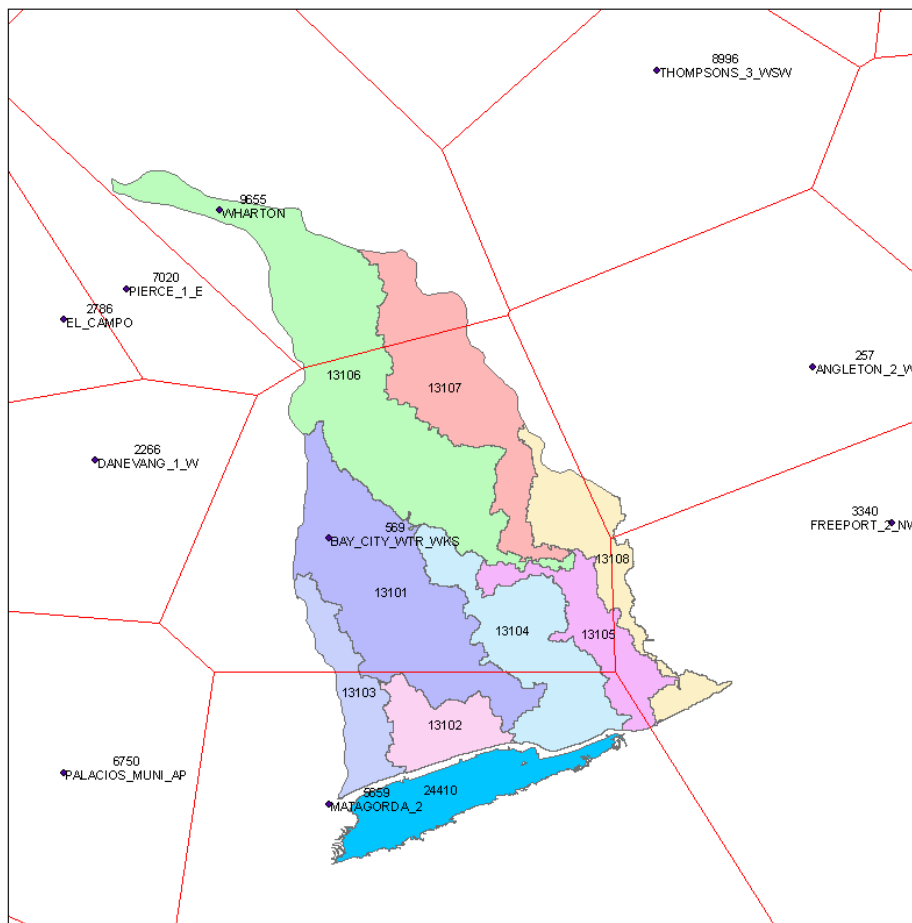


Figure 3. Rainfall stations (◆) and Thiessen polygons (red lines) used to estimate direct precipitation onto East Matagorda Bay.

## **Evaporation**

Evaporation is calculated for the surface area of the bay using TWDB and NWS pan evaporation data to estimate evaporation rates. Bay watershed #24410, which is located within quadrangle 912, is used to calculate evaporation (Figure 4). Total water evaporated from this watershed is calculated by multiplying the watershed area by the evaporation rates obtained from the TWDB. Evaporation rates are determined with a GIS based program, *ThEvap*, using TWDB and NWS pan evaporation data. The *ThEvap* program replaced an older program, *WD0300*, previously run by the Texas Department of Water Resources (<http://midgewater.twdb.state.tx.us/Evaporation/evap.html>).

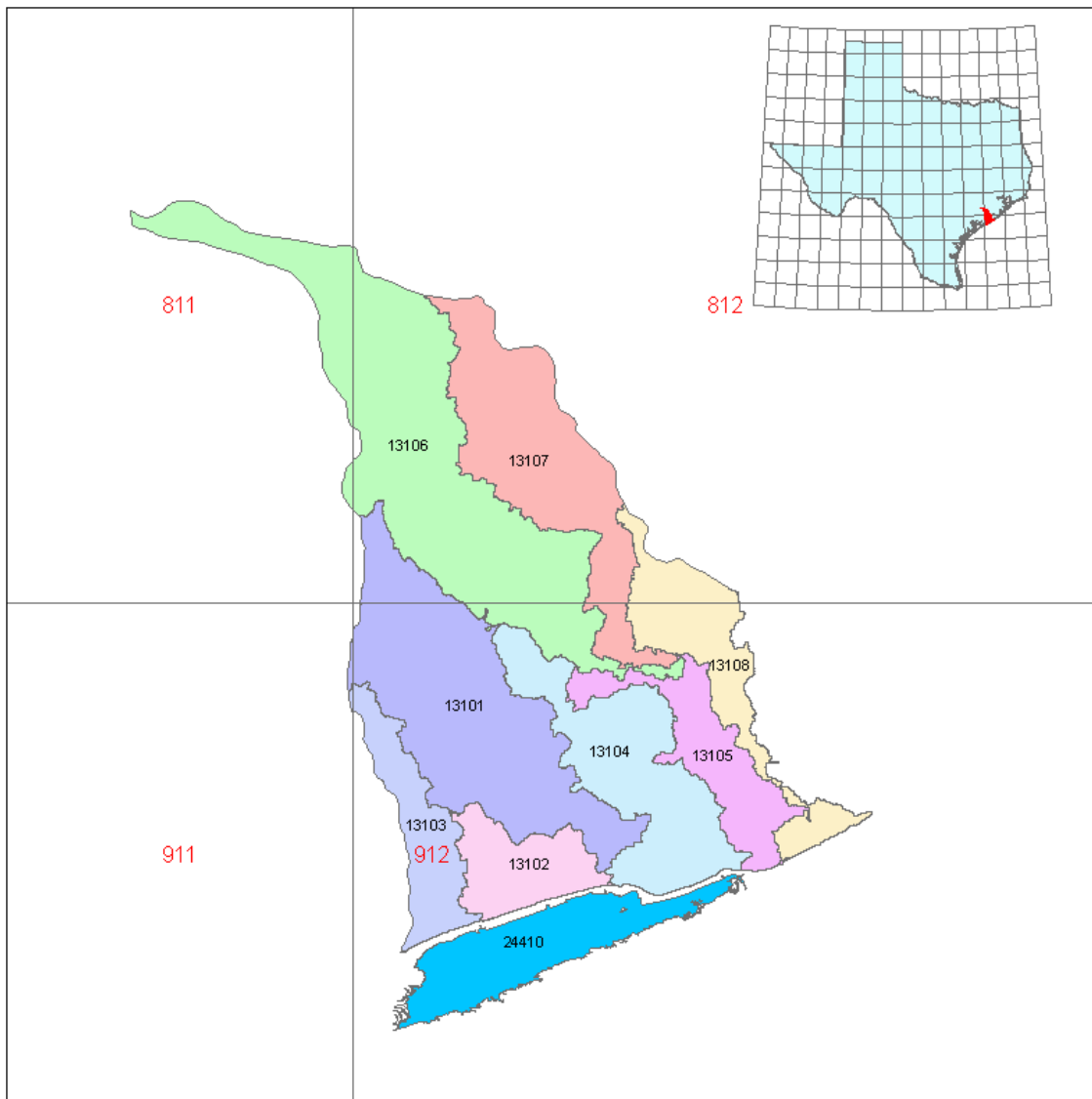


Figure 4. TWDB evaporation quadrangles used to estimate evaporation for East Matagorda Bay. Quadrangle 912 is used to estimate evaporation from the East Matagorda Bay segment #24410.

### Hydrology: Version #TWDB201001

TWDB coastal hydrology version #TWDB201001 for East Matagorda Bay includes ungaged inflows through December 2008 adjusted for diversion and return flows as follows. Raw diversion data was obtained from TCEQ or its equivalent agency TNRCC for the period from 1977 to 2008. Industrial and municipal return flow data was obtained from TCEQ for the period from 1977 to 2008. Additional return flow data was obtained from TWDB's agricultural return flow estimates through December 2005.

### Hydrology: Version #TWDB201004

TWDB coastal hydrology version #TWDB201004 for East Matagorda Bay extends estimates of ungaged inflows through December 2009, using approved daily precipitation data from the NWS through November 2009 but provisional data for December 2009. Diversions were the same as in version #TWDB201001, but additional data from TCEQ extended the dataset to 2009. Return flows were the same as in version #TWDB2010001 with additional data obtained from TCEQ extending the data through December 2009. Agricultural return flow data obtained from TWDB were extended to December 2007. Data on inflows to East Matagorda Bay for the 1977-2009 period are available as daily, monthly, or annual estimates. Figure 5 shows annual combined surface inflow to East Matagorda Bay as calculated by this version. Note that while this version of hydrology extends estimates of freshwater inflow from 1977 through 2009, not all components were updated through 2009. Precipitation data was provisional for December 2009 and agricultural return flows were not considered complete after 2007.

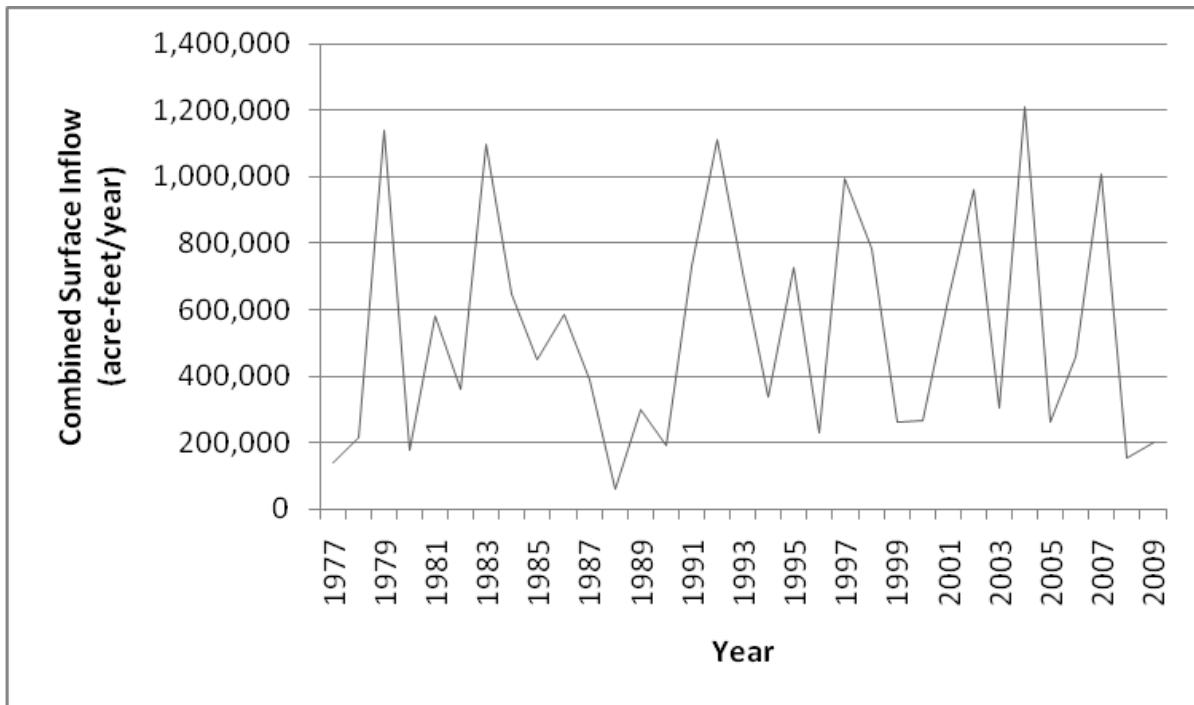


Figure 5. Annual estimates of combined freshwater inflow to East Matagorda Bay as calculated by version #TWDB201004 for the period 1977 – 2009.



## Conclusion

Version #TWDB201004 of coastal hydrology for East Matagorda Bay, presented herein, is the most up-to-date data set representing not only combined freshwater inflows but also the individual components of inflows (*i.e.*, ungaged flows, diversions, return flows) for this estuary. Appendix A summarizes recent updates to hydrology, by version, for East Matagorda Bay. Appendix B lists annual combined inflow along with the inflow components, as well as estimates for evaporation and precipitation on the estuary and the total freshwater inflow balance of East Matagorda Bay. Appendix C lists summary statistics for the inflow components over the 1977 through 2009 period.

During the period from 1977 to 2009, there was no gaged inflow to East Matagorda Bay, and thus gaged inflows accounted for 0 percent of total combined inflow, while ungaged flows accounted for 98.14 percent of total combined inflow. In general, net diversions accounted for only a few percent in the total combined inflow to the bay. In the small coastal basin of East Matagorda Bay, average diversions totaled 0.87 percent of combined freshwater inflow, while average return flows totaled 2.73 percent of inflows. The difference then between diversions and returns accounted for about 1.86 percent of combined inflows. Average combined surface inflow to East Matagorda Bay over the study period was 536,165 acre-feet per year, and varied from a minimum of 61,705 acre-feet in 1988 to a maximum of over 1.2 million acre-feet in 2004.

Finally, when considering the total freshwater inflow balance, evaporation from and precipitation onto the surface of the estuary also must be considered. During the 1977 through 2009 period, the freshwater inflow balance varied from a minimum of 4,059 acre-feet in 1988 to a maximum of almost 1.3 million acre-feet in 1979, and averaged 524,054 acre-feet per year.

## Literature Cited

TDWR. 1980. *Lavaca-Tres Palacios Estuary: A study of the influence of freshwater inflows*. LP-106. Texas Department of Water Resources, Austin, Texas.

**Appendix A:** Record of coastal hydrology versions developed by the TWDB Bays & Estuaries Program for East Matagorda Bay.

Estuary	Version	Date Range	Gaged Flows	Ungaged Flows	Diversions	Return Flows	Creation Date
East Matagorda Bay	TWDB201001	1977-2008	none	1977-2008	1977-10/2005 TCEQ	1977-2007  TCEQ 1977 - 12/2007  TWDB 1977 - 12/2005 (Agricultural)	01/2010
	TWDB201002	Dataset does not exist					
	TWDB201003	Dataset does not exist					
	TWDB201004	1977-2009	none	1977-2009, Precipitation data provisional for 12/09	1977-2009 TCEQ	1977-2009  TCEQ 1977 - 12/2009  TWDB 1977 - 12/2007 (Agricultural)	09/2010

**Appendix B:** Annual Hydrology for East Matagorda Bay, version #TWDB201004. Included are estimates of gaged and ungaged (modeled) inflows, diversions and return flows, combined surface inflow to the estuary, as well as evaporation and direct precipitation on the estuary and the total freshwater balance of the estuary. All values are in units of acre-feet.

Year	Gage	Model	Diversion	Return	Surface Inflow	Evaporation	Precipitation	Freshwater Balance
1977	0	133,993	3,156	9,186	140,023	157,475	112,232	94,780
1978	0	205,715	4,626	13,458	214,547	152,285	118,760	181,022
1979	0	1,130,677	5,198	15,639	1,141,118	150,503	281,235	1,271,850
1980	0	165,569	3,236	17,060	179,393	160,657	114,189	132,925
1981	0	565,977	4,856	17,954	579,075	147,006	176,007	608,076
1982	0	348,810	6,216	18,664	361,258	154,443	111,643	318,458
1983	0	1,088,125	5,093	15,519	1,098,551	151,554	171,252	1,118,249
1984	0	637,420	6,268	17,299	648,451	158,556	172,382	662,277
1985	0	443,250	6,677	14,083	450,656	152,461	148,405	446,600
1986	0	576,933	6,274	13,108	583,767	154,590	170,196	599,373
1987	0	379,965	5,074	14,883	389,774	148,024	107,790	349,540
1988	0	54,125	5,909	13,489	61,705	159,548	101,902	4,059
1989	0	291,192	5,701	13,163	298,654	140,468	125,241	283,427
1990	0	183,090	3,718	12,782	192,154	149,250	118,797	161,701
1991	0	726,270	6,331	13,752	733,691	148,785	197,178	782,084
1992	0	1,104,665	4,458	13,324	1,113,531	130,639	192,660	1,175,552
1993	0	707,288	5,404	10,215	712,099	158,613	146,711	700,197
1994	0	330,438	5,896	14,126	338,668	139,360	117,860	317,168
1995	0	719,181	5,763	14,410	727,828	145,195	142,390	725,023
1996	0	218,847	5,212	13,904	227,539	143,737	80,401	164,203
1997	0	981,670	1,750	15,301	995,221	149,426	183,209	1,029,004
1998	0	771,778	5,509	15,401	781,670	155,989	155,523	781,204
1999	0	251,831	3,524	14,560	262,867	140,060	82,068	204,875
2000	0	254,079	4,501	18,124	267,702	209,985	74,560	132,277
2001	0	620,191	8,054	19,358	631,495	136,270	103,772	598,997
2002	0	941,060	873	21,289	961,476	139,372	143,031	965,135
2003	0	285,221	1,019	20,136	304,338	135,567	119,116	287,887
2004	0	1,191,144	3,576	21,080	1,208,648	135,480	192,891	1,266,059
2005	0	244,935	3,655	18,633	259,913	159,368	104,361	204,906
2006	0	451,383	3,726	13,901	461,558	147,746	162,272	476,084
2007	0	1,002,095	3,602	11,710	1,010,203	152,194	197,197	1,055,206
2008	0	155,839	4,106	3,434	155,167	201,055	81,088	35,200
2009	0	201,371	4,144	3,490	200,717	154,478	114,143	160,382

\*Combined Surface Inflow = Gage + Model - Diversion + Return

\*\*Freshwater Balance = Surface Inflow - Evaporation+ Precipitation

**Appendix C:** Summary statistics for annual freshwater inflow (in acre-feet) over the 1977-2009 period for East Matagorda Bay, version #TWDB201004.

	<b>Gage</b>	<b>Ungaged (Model)</b>	<b>Diversion</b>	<b>Return</b>	<b>Combined Surface Inflow</b>	<b>Evaporation</b>	<b>Precipitation</b>	<b>Freshwater Balance</b>
MIN	0	54,125	873	3,434	61,705	130,639	74,560	4,059
5%ile	0	147,101	1,458	6,908	149,109	135,532	80,813	70,948
10%ile	0	169,073	3,172	10,514	181,945	136,888	86,035	132,407
25%ile	0	244,935	3,655	13,324	259,913	143,737	111,643	181,022
MEDIAN	0	443,250	4,856	14,410	450,656	150,503	125,241	446,600
MEAN	0	526,186	4,640	14,619	536,165	152,125	140,014	524,054
75%ile	0	726,270	5,763	17,299	733,691	155,989	171,252	781,204
90%ile	0	1,070,919	6,273	19,219	1,080,881	159,512	192,845	1,105,640
95%ile	0	1,115,070	6,469	20,514	1,124,566	176,816	197,186	1,211,755
MAX	0	1,191,144	8,054	21,289	1,208,648	209,985	281,235	1,271,850
TOTAL All Years	0	17,364,127	153,105	482,435	17,693,457	5,020,139	4,620,462	17,293,780
% of Total Surface Inflow	0	98.14	0.87	2.73	100.00	-	-	-

