Coastal Hydrology for the Guadalupe Estuary: Updated Hydrology with Emphasis on Diversion and Return Flow Data for 2000-2009

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Bays & Estuaries Program
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Purpose

This technical memo documents the Texas Water Development Board's (TWDB) procedure for estimating combined freshwater inflow data for the Guadalupe Estuary and the specifics related to producing hydrology datasets version #TWDB201002, version #TWDB201004, and alternative version #HDR201001. Additionally, this technical memo reports on the findings of a review and comparison of TWDB diversion and return flows data, obtained from the Texas Commission on Environmental Quality and the South Texas Water Master, with similar data compiled by HDR based on individual reports from water right holders in the Guadalupe and San Antonio River basins below USGS stream gages #8177500 (Coleto Creek near Victoria), #8176500 (Guadalupe River at Victoria), #81888500 (San Antonio River at Goliad). This comparison focuses on the period from 2000-2009, but includes an alternative version containing HDR diversion and return flow data from 1977-2009. The data provided by HDR was beneficial to developing a more accurate representation of combined inflows to the 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, with estimates for the Guadalupe Estuary published in Chapter 4 of LP-107, *Guadalupe Estuary: A Study of the Influence of Freshwater Inflows* (TDWR 1980, available on the TWDB website or upon request).

Inflow estimates subsequently were extended from 1977-1987 and provided in a daily format in support of further studies on Texas's estuaries (Longley 1994). Finally, inflow records for each of the major estuaries have been updated periodically since, in support of ongoing research and planning studies both within and external to TWDB. This report covers the most recent hydrology updates, which extend

freshwater inflow estimates through 2009 for the Guadalupe Estuary. Therefore, complete hydrology is available for this estuary for 1941-2009, with daily estimates of inflows available only after 1977.

Estimates of Combined Freshwater Inflows

Detailed studies of hydrology of the areas draining to the Guadalupe Estuary include the gaged and ungaged portions of the Guadalupe and San Antonio river basins, as well as other small coastal basins and portions of the Lavaca-Guadalupe and San Antonio-Nueces basins. The combination of Gaged Inflows + Ungaged Inflows + Return Flows - Diversions below the last gage station provide for estimates of ***Combined Freshwater Inflow*** to the estuary. The ***Freshwater Inflow Balance*** then consists of Combined Inflows + Precipitation on the estuary – Evaporation from the estuary. Although inflow estimates are updated on an ongoing basis, there are two distinct periods of estimation. Before 1977, inflow estimates are available only in monthly intervals. Starting in 1977 and thereafter, inflow estimates became available on a daily basis.

1941-1976 Period of Record

This dataset uses measurements from U.S. Geological Survey (USGS) stream gages along with rainfall-runoff estimates from a water yield model to determine flows in gaged and ungaged watersheds (TDWR 1980). In most estimates of coastal hydrology, flows in ungaged areas are adjusted for known municipal and industrial return flows and diversions obtained from the Texas Department of Water Resources (or equivalent agency; e.g., TDWR 1981). However, LP-107, which was the first report developed in this series of freshwater inflow studies of the major estuaries, does not clearly document the treatment of diversion and return flow data in estimating combined inflows to the estuary. Data on inflows to the Guadalupe Estuary for 1941-1976 is available as monthly or annual estimates.

1977-2009 Period of Record

This dataset uses measurements from USGS stream gages along with rainfall-runoff estimates from the Texas Rainfall-Runoff (TxRR) model, adjusted for known diversion and return flows obtained from the TCEQ (or equivalent agency), the South Texas Water Master, and the TWDB Irrigation Water Use estimates. In some cases, diversion and return data may be obtained through other entities, such as in this report where recent diversion and return data were obtained from HDR Engineering, Inc. Data on inflows to the Guadalupe Estuary for 1977-2009 is available as daily, monthly, or annual estimates.

Gaged Watersheds

Four USGS stream gages have been used to develop the gaged inflow component of combined inflows to the Guadalupe Estuary. The stream gage locations at the Guadalupe River at Victoria and the San Antonio River at Goliad have been utilized since 1941. However, the stream gage on Coleto Creek changed twice, with part of the record provided by the stream gage near Victoria and part provided by the gage station near Schroeder. Table 1 lists these USGS stream gages and the corresponding period of record utilized in estimating combined inflows. Gage location and use in estimating inflows also can be seen in Figures 1 - 5. For recently updated hydrology (versions #TWDB201003 and #TWDB201004), approved USGS stream gage data was available through September 2009 and was provisional for the period October to December 2009.

Table 1. USGS stream gages used to develop the gaged inflow component of combined inflows to the Guadalupe Estuary. Gage number, location, and the period of record utilized in developing the combined inflows are shown.

Estuary	Gage Station Number	Gage Location	Utilized Period of Record
Guadalupe	8177500	Coleto Creek near Victoria	1941-1952 & 1978-present
	8177000	Coleto Creek near Schroeder	1953-1978
	8176500	Guadalupe River at Victoria	1941-present
	8188500	San Antonio River at Goliad	1941-present

Ungaged Watersheds

The number of ungaged watersheds for which ungaged inflows are estimated has changed through time. Initial estimates were determined based on five ungaged watersheds (Fig. 1); later estimates were determined using more, finely divided watersheds (Figs. 4-5). Figures 1 - 5 show watershed boundaries for the ungaged watersheds during the period 1941-2009.

The ungaged inflow component of combined inflows is estimated using a rainfall-runoff model. Before 1977, stream flows in ungaged watersheds were obtained using a *water yield model* which required daily precipitation, Soil Conservation Service average curve numbers, and soil depletion index (TDWR 1980). This water yield model provided for monthly estimates of ungaged inflows – not daily. TWDB does not have daily estimates of ungaged inflows for the period prior to 1977.

Since 1977, however, TWDB has used 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 Bays & Estuaries Coastal Hydrology Program to study the effect of freshwater inflows to the Texas bays and estuaries.

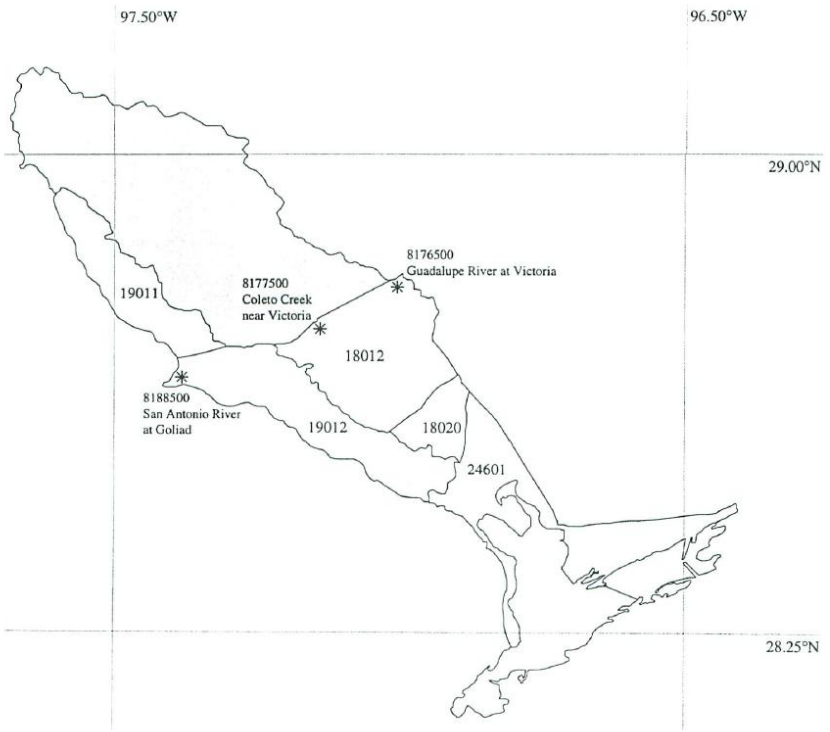

Figure 1. Gaged and ungaged watershed delineation used from January 1, 1941 to December 31, 1952 to determine combined inflows to the Guadalupe Estuary.

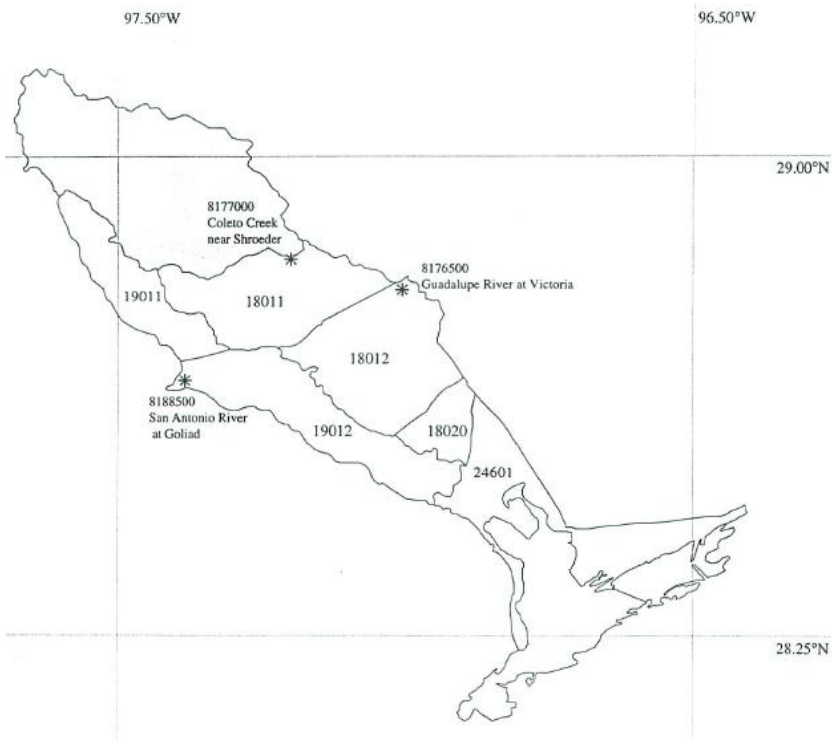

Figure 2. Gaged and ungaged watershed delineation used from January 1, 1953 to December 31, 1965 to determine combined inflows to the Guadalupe Estuary.

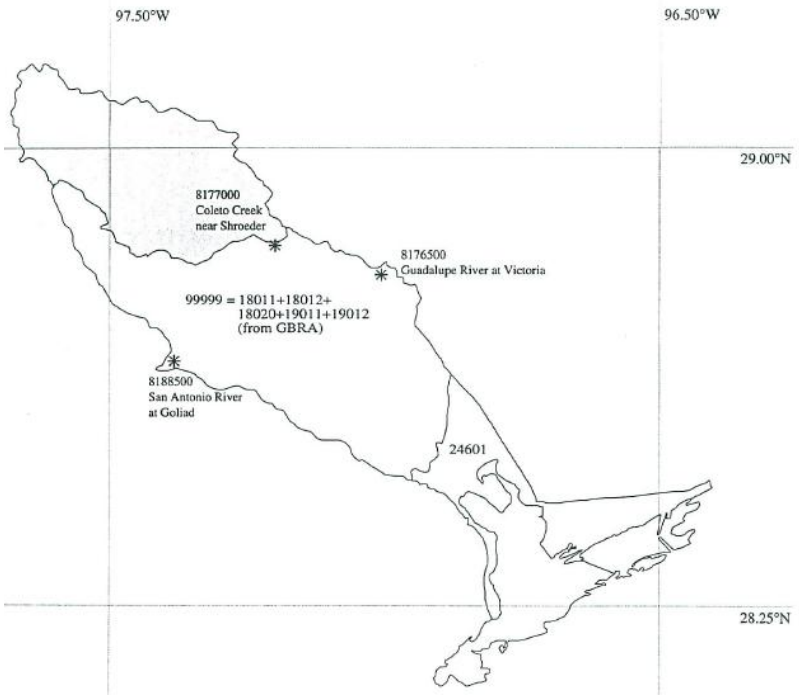

Figure 3. Gaged and ungaged watershed delineation used from January 1, 1966 to December 31, 1976 to determine combined inflows to the Guadalupe Estuary.

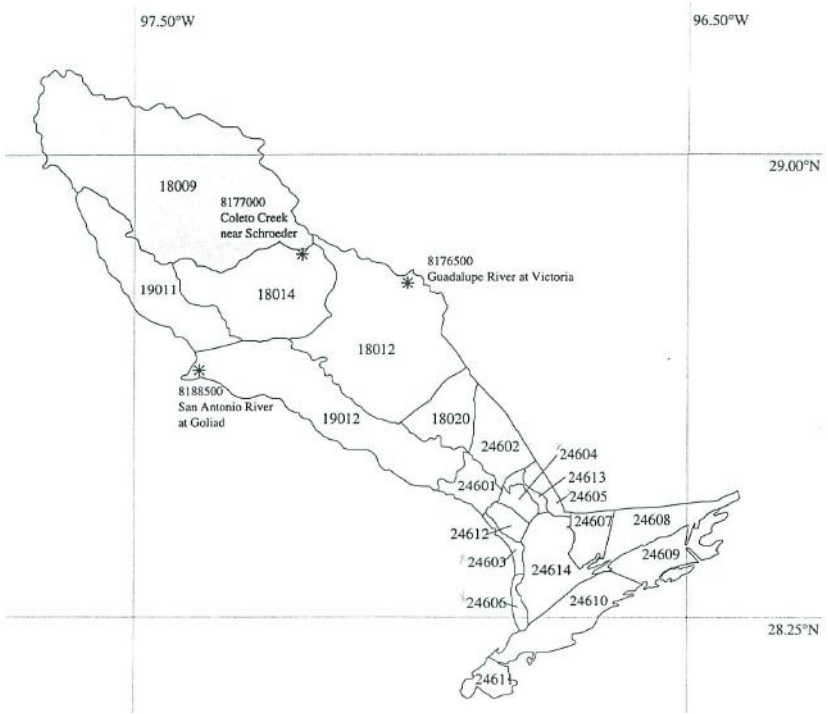

Figure 4. Gaged and ungaged watershed delineation used from January 1, 1977 to June 30, 1978 to determine combined inflows to the Guadalupe Estuary.

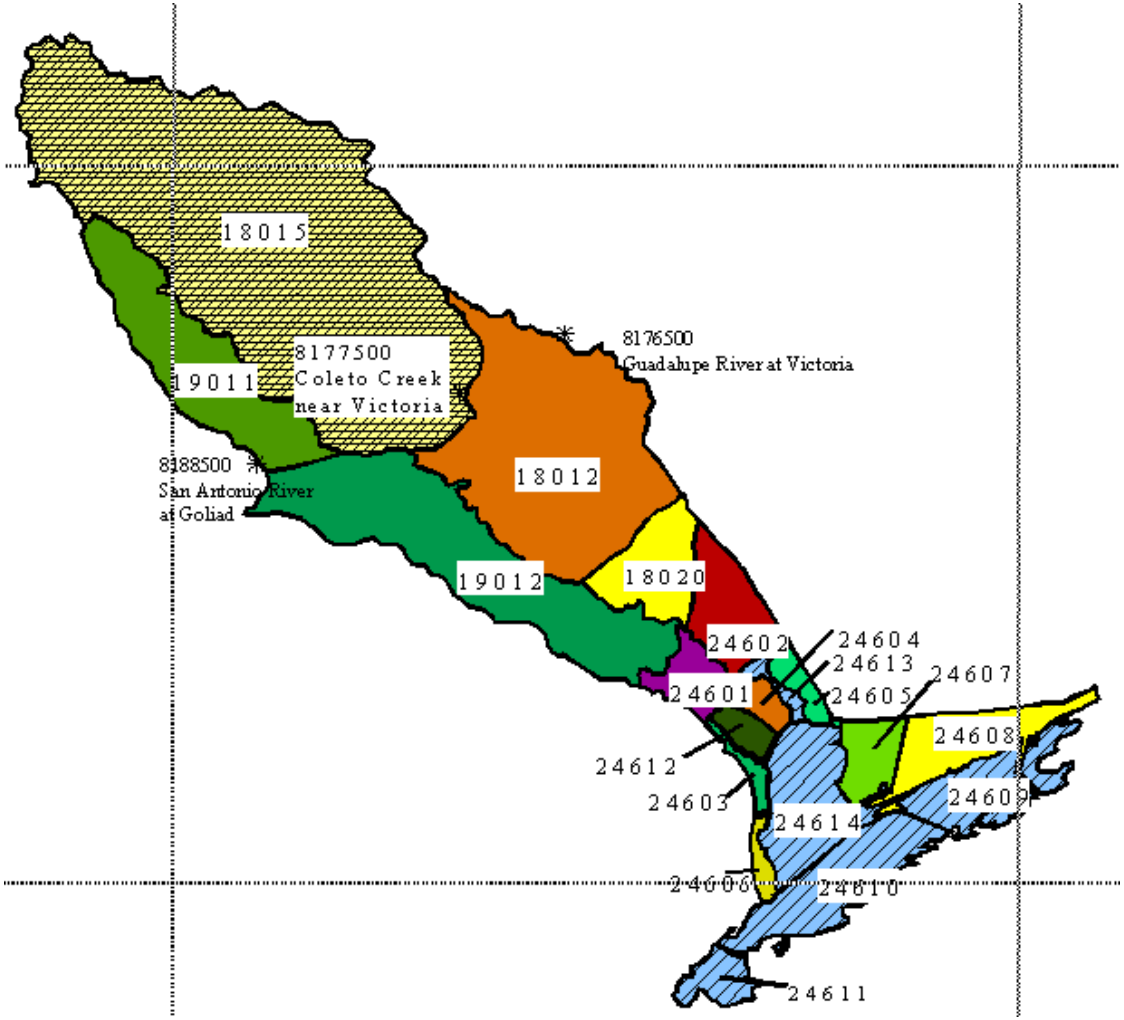

Figure 5. Ungaged watershed delineation used in TxRR from July 1, 1978 to present to determine ungaged flows to the Guadalupe Estuary.

Diversion and Return Points

The major water rights and holders and the major discharge permits and dischargers are listed in Table2, with a map showing the location of diversion points and wastewater outfalls shown in Figure 6.

Table 2. Major water rights and discharge permits in the Guadalupe/San Antonio basin below USGS stream gages #8177500 (Coleto Creek near Victoria), #8176500 (Guadalupe River at Victoria), #81888500 (San Antonio River at Goliad).

	Water Right Number	**Owner**
DIVERSIONS	3861	INVISTA
	3863	Guadalupe-Blanco River Authority
	5173	Guadalupe-Blanco River Authority
	5174	Guadalupe-Blanco River Authority
	5175	Guadalupe-Blanco River Authority
	5176	Guadalupe-Blanco River Authority
	5177	Guadalupe-Blanco River Authority
	5178	Guadalupe-Blanco River Authority
	NPDES Number	**OWNER**
RETURNS	TX0002844	Union Carbide Corp
	TX0003603	Victoria WLE, LP
	TX0006050	INVISTA S.A.R.L. LIMITED
	TX0023477	Quail Creek Mud
	TX0025186	Guadalupe-Blanco River Authority
	TX0025194	City of Victoria & Guadalupe-Brazos River Authority
	TX0026671	City of Seadrift
	TX0054101	Refugio County WCID 1
	TX0075744	Devereux Foundation
	TX0077577	BP AMOCO Chemical CO
	TX0079286	The Fordyce LTD
	TX0086398	Air Liquide Large Industries US LP
	TX0090948	76 Seadrift Coke LP
	TX0112151	Port O'Connor MUD
	TX0116190	City of Seadrift

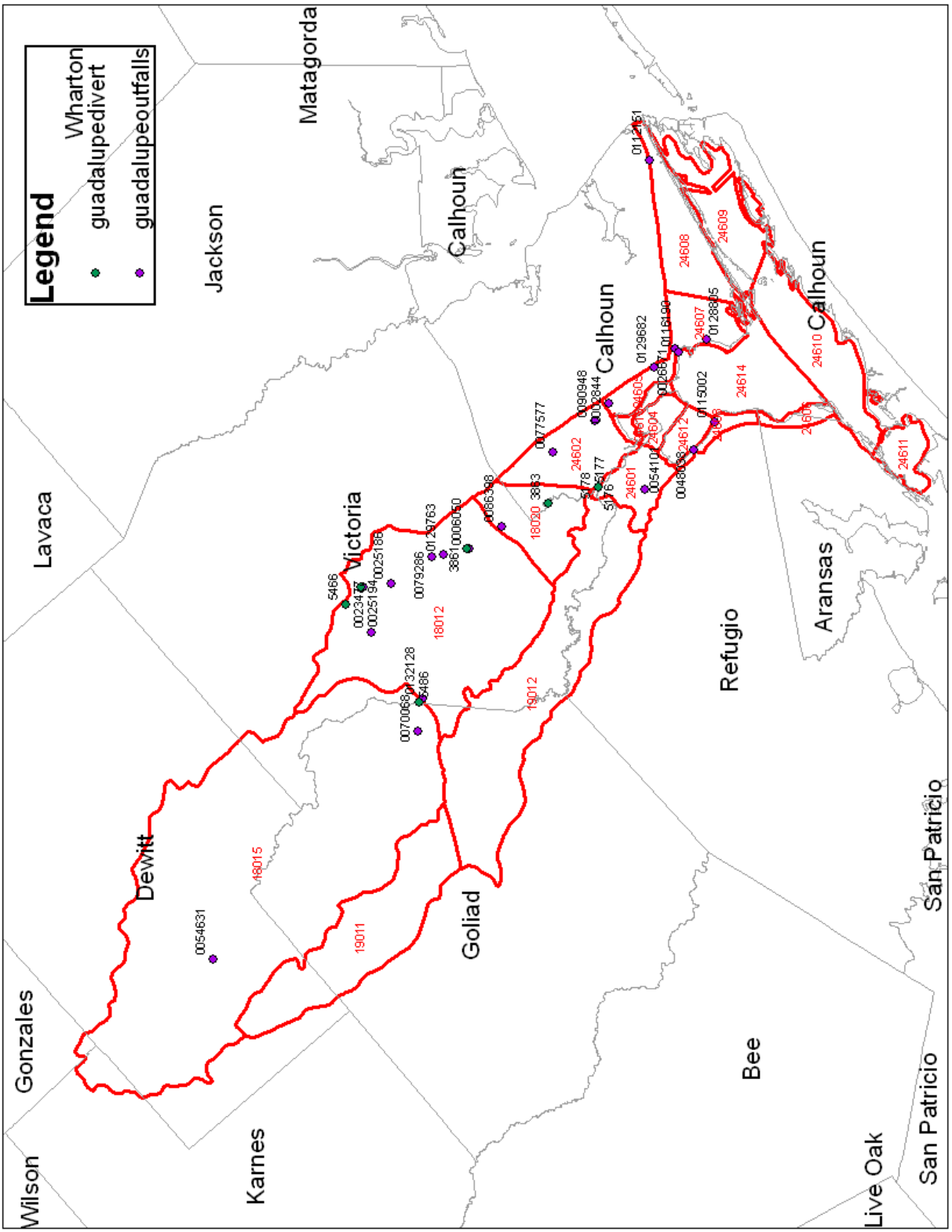

Figure 6. Location of permitted diversion points and wastewater outfalls in the lower Guadalupe and San Antonio River basins. Locations below USGS stream gages #8177500 (Coleto Creek near Victoria), #8176500 (Guadalupe River at Victoria), #81888500 (San Antonio River at Goliad) are used to determine the diversions and returns components of estimating combined inflows

Hydrology: Version #TWDB201002

TWDB coastal hydrology update version #TWDB201002 for the Guadalupe Estuary included updates to gaged and ungaged inflows (through December 2009). However, approved USGS stream gage data was available only through September 2009 and was provisional for the period October to December 2009. Similarly, ungaged inflows were estimated using daily precipitation from the National Weather Service, which had complete records through May 2009 and incomplete records for June to December 2009.

Diversion Data – TWDB obtained raw diversion data (dated 11/22/2005) from the South Texas Water Master (STWM) for the period January 2000 to October 2005. Raw diversion data contained monthly diversions for water rights within the STWM's jurisdiction. Version #TWDB201002 therefore included diversion data through October 2005.

Return Flow Data – Similarly, industrial and municipal return flow data was obtained from TCEQ for the period January 1987 to December 2007. Additional return flow data was obtained from TWDB's agricultural return flow estimates through December 2005.

NOTE: This version of hydrology was used as the basis for hydrology in the TxBLEND model calibration and simulations documented in the July 2010 report of the *TxBLEND Model Calibration and Validation for the Guadalupe and Mission-Aransas Estuaries (TWDB 2010)* and presented to the Guadalupe-San Antonio Basin & Bay Expert Science Team (BBEST).

Hydrology: Version #TWDB201003

TWDB coastal hydrology update version #TWDB201003 for the Guadalupe Estuary includes approved gaged data through November 2009, with provisional data for December 2009. Ungaged inflows were updated using approved daily precipitation data from the National Weather Service through November 2009, with provisional data for December 2009. Diversion data remained the same as in version #TWDB201002. Return flow data obtained from TCEQ was updated through December 2009. Agricultural return flows data obtained from TWDB were extended to December 2007.

Recent Updates to Hydrology: Version #TWDB201004

TWDB coastal hydrology update version #TWDB201004 for the Guadalupe Estuary includes the same data for gaged and ungaged inflows as in version #TWDB201003, but includes updates of both diversion and return flow data, as described below.

Diversion Data – This version of hydrology includes an update of diversion data through December 2009. Data was obtained from the STWM and from HDR Engineering, Inc. HDR has been working to compile diversion and return data for this basin based on individual reports from water right holders. Thus, TWDB was able to obtain diversion data for the period 2000 – 2009 which allowed for the comparison of data previously obtained from the STWM, and used in official estimates of hydrology, to the data compiled by HDR. Figure 7 shows annual diversion data used by TWDB (in version #TWDB200901) as compared to data compiled by HDR for the Guadalupe and San Antonio river basins below the lowest USGS stream gages (#8177500 (Coleto Creek near Victoria), #8176500 (Guadalupe River at Victoria), #81888500 (San Antonio River at Goliad).

It is apparent in Figure 7 that after 2001 TWDB diversion data is much less than that compiled by HDR. However, an examination of the individual permitted diversion records showed that records obtained by TWDB from the STWM were missing diversion right #5188, a major water right held by the Guadalupe-Blanco River Authority (GBRA) with a permitted diversion amount of 106,000 ac-ft/yr. Additionally, GBRA water right #5177, with a permitted amount of 32,615 ac-ft/yr., was missing from the data provided by the STWM, except for the years 2000 and 2001. Yet for year 2000, the STWM database showed a constant diversion amount of 1,113.92 (ac-ft) for all 12 months, rather than the actual diversion amount as reported by HDR (Table 3). Data errors also were found in the Invista Corporation water right #3861 diversion records provided by the STWM. They were corrected using data compiled by HDR.

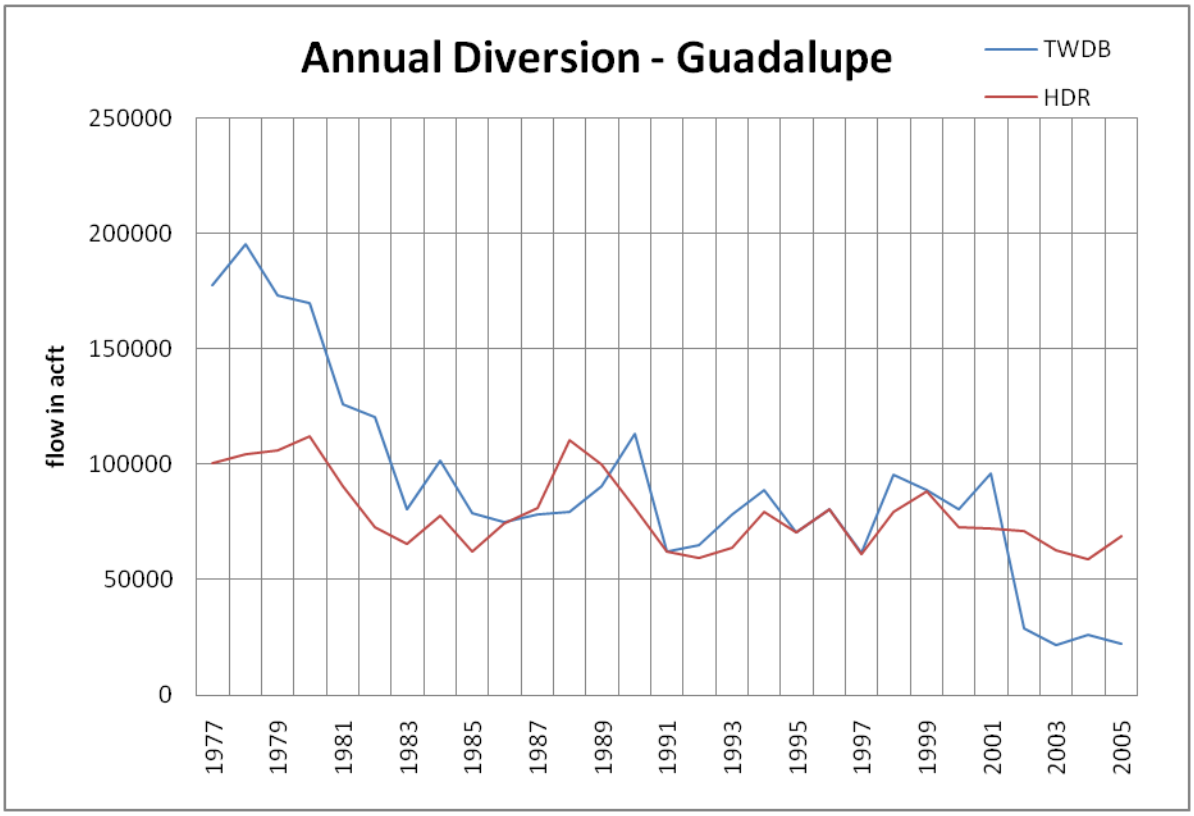

Figure 7. Annual diversion data in the Guadalupe and San Antonio river basins as compiled by TWDB (blue line; based on data obtained from the STWM for hydrology version #TWDB200901) and as compiled by HDR (red line) from records provided by water right holders in the basin.

Table 3. Diversion data for the Guadalupe-Blanco River Authority water right #5177 for the years 2000 and 2001. Data for this water right, except for these two years, was missing from the dataset provided to TWDB. In a comparison to diversion data obtained by HDR, it is clear that the reported diversion data for year 2000 was in error (showing a constant diversion amount of 1,113.92 (ac-ft) for all 12 months). HDR's data records instead show actual reported diversions. Data reported by the STWM for year 2001 was corrected with records compiled by HDR. The GBRA water right #5177 has a permitted amount of 32,615 ac-ft/yr.

Account #	Year	Month	HDR	TWDB	Account #	Year	Month	HDR	TWDB
5177-400	2000	1	2139	1113.92	5177-400	2001	1	1187	1187
5177-400	2000	2	1083	1113.92	5177-400	2001	2	1195	1195
5177-400	2000	3	834	1113.92	5177-400	2001	3	1424	1424
5177-400	2000	4	608	1113.92	5177-400	2001	4	2064	2064
5177-400	2000	5	672	1113.92	5177-400	2001	5	2156	2156
5177-400	2000	6	938	1113.92	5177-400	2001	6	4618	4618
5177-400	2000	7	1220	1113.92	5177-400	2001	7	2615	2615
5177-400	2000	8	1182	1113.92	5177-400	2001	8	2934	2934
5177-400	2000	9	969	1113.92	5177-400	2001	9	2097	2097
5177-400	2000	10	1255	1113.92	5177-400	2001	10	1374	1374
5177-400	2000	11	1401	1113.92	5177-400	2001	11	984	984
5177-400	2000	12	1068	1113.92	5177-400	2001	12	954	954

HDR's endeavor to obtain the most accurate diversion data for this river basin is greatly appreciated and was essential to allowing TWDB to re-construct and update the diversion data with greater confidence. Missing and inaccurate data obtained from the STWM database were able to be corrected using the diversion data compiled by HDR. Figure 8 shows the results of this effort, where after 1999 the two datasets now are consistent. Differences remain in the diversion records obtained by TWDB from the STWM as compared to the data compiled by HDR for earlier years in the period of record (pre-1999). At this time, these discrepancies cannot be reconciled. TWDB hydrology data will continue to use the official records, as reported by the STWM, for this earlier time period. TWDB diversion data represented in Figure 8 were used to develop hydrology for version #TWDB201004.

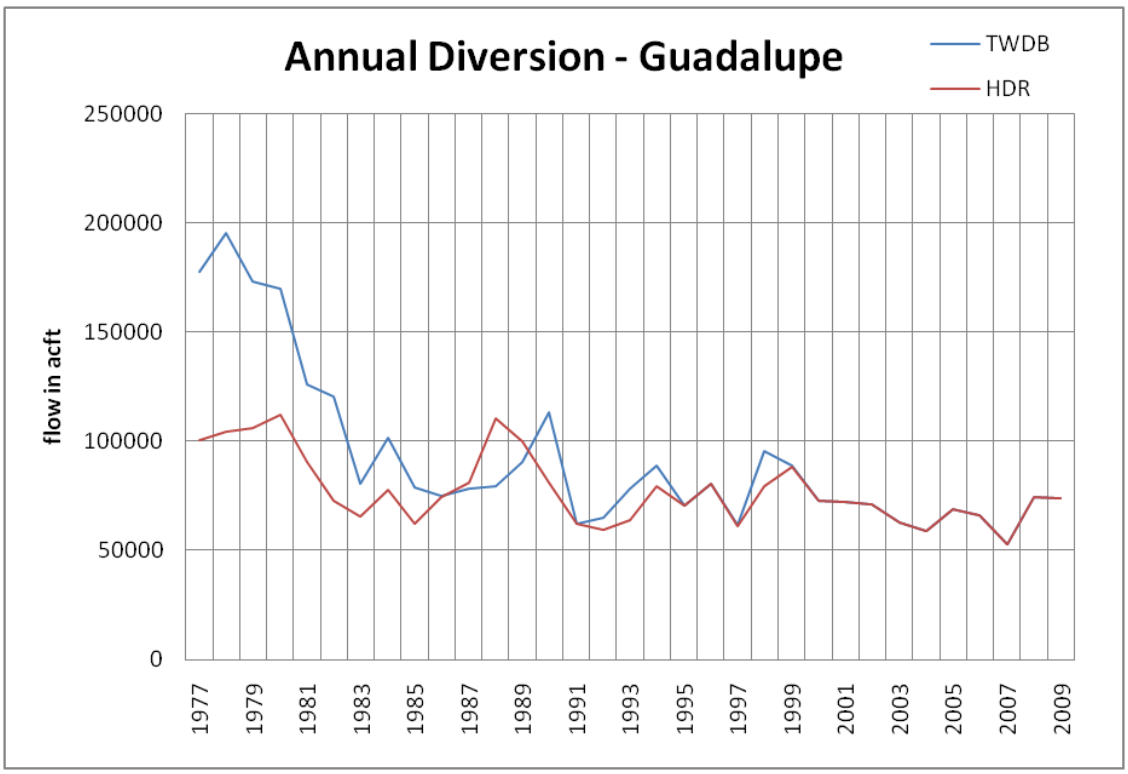

Figure 8. Annual diversion data as compiled by HDR (red line) and as compiled by TWDB (blue line; using records provided by the STWM and also by HDR for cases with missing or inaccurate information for hydrology version #TWDB201004). After 1999, diversion data obtained by HDR and by TWDB are identical (blue line hidden by red line in figure). Prior to 1999, differences exist in the diversion data which cannot be reconciled at this time. TWDB, therefore, will continue to rely on previously reported data obtained from the STWM for estimates of hydrology prior to 1999.

Return Data – The #TWDB201004 version of hydrology includes an extension of return flows data obtained from TCEQ and the TWDB for the period January 2000 to December 2009. The TCEQ wastewater database contains self-reported data, which have limited quality control. As mentioned above, HDR has compiled more recent diversion and return flow data for this basin based on individual reports from water right holders. Their efforts allowed for a comparison of return flow data obtained from TCEQ, and used in official TWDB estimates of hydrology (version #TWDB201003), to discharge data compiled by HDR for the Guadalupe and San Antonio river basins below the lowest USGS stream gages (#8177500 (Coleto Creek near Victoria), #8176500 (Guadalupe River at Victoria), #81888500 (San Antonio River at Goliad). The comparison revealed a difference in reported return flows data throughout the period of record (Figure 9).

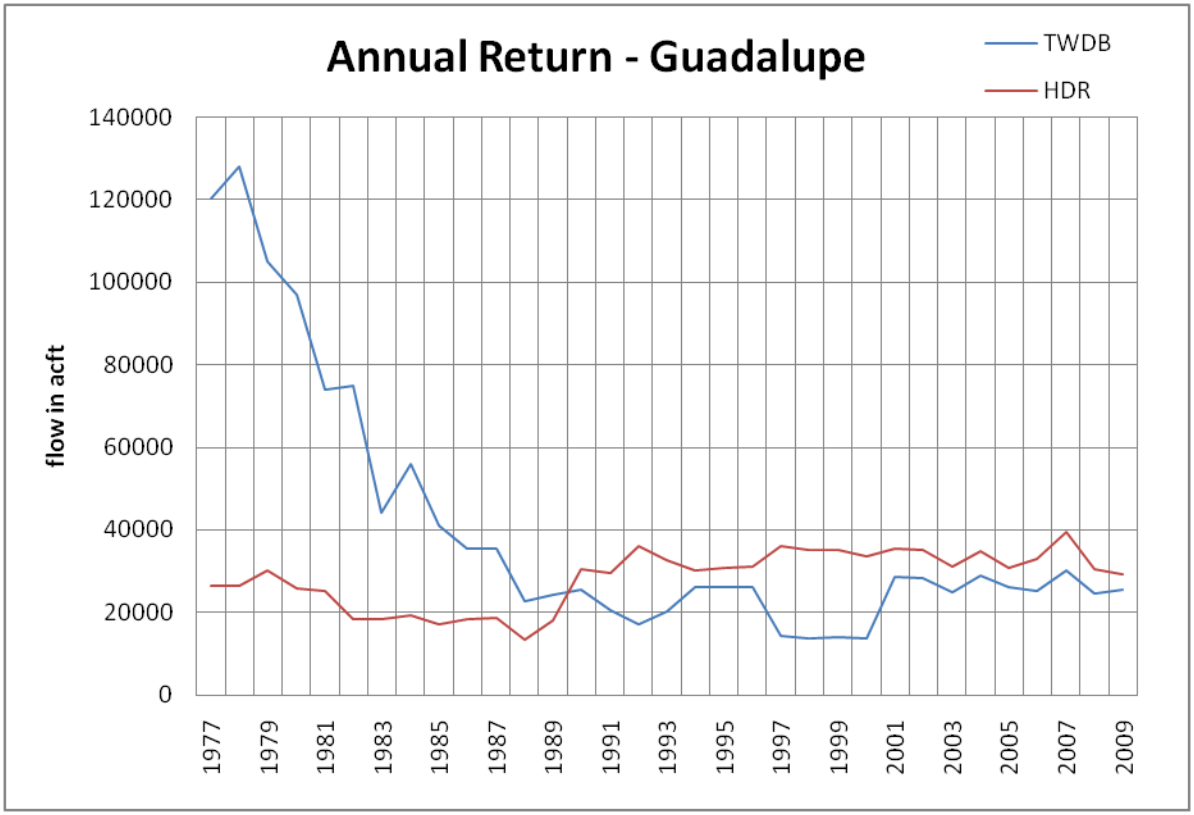

Figure 9. Annual return flows data in the Guadalupe and San Antonio river basins as compiled by TWDB (blue line; based on data obtained from TCEQ for hydrology version #TWDB201003) and as compiled by HDR (red line) from records provided by permitted dischargers in the basin.

A discrepancy in the return flows data reported by TCEQ has the Union Carbide Corporation (TX0002844) discharge located within a gaged watershed, rather than in its correct location within an ungaged watershed. This discrepancy caused the return flow data to not be included in the calculation of return flows. This discrepancy was identified and corrected for hydrology version #TWDB201004.

Additional problems arise when wastewater facilities have multiple outfalls with no indication of whether an outfall is external or internal. Internal outfalls are coded differently in the TCEQ wastewater database and should not be counted in the return flow calculation. However, if a code was not entered properly (e.g., denoting an external outfall instead of an internal outfall and vice-versa) then a miscalculation will cause an error in the estimate of return flows. For example, the TCEQ wastewater database identifies six outfalls for the Invista Corp. discharge (TX0006050), which are coded 001A, 002A, 003A, 004A, 005A, and 006A, respectively, in which only discharge for outfall 001A (presumably an external outfall) was used by HDR. Raw data for these outfalls are shown in Table 4, where the reporting unit was converted from million gallons per day to acre-feet. Additionally, it is evident from Table 4 that the TCEQ wastewater database is missing discharge data for outfall 001A in all months of 2000, in September of 2004, and in May of 2008. Data obtained from Invista Corp. and compiled by HDR were used to fill in these data gaps for discharge permit TX0006050 and reconstruct return flow data for the Guadalupe Estuary.

HDR's effort to obtain the most accurate discharge data for this river basin was important to allowing TWDB to re-construct and update return flows with greater confidence. Once data errors and omissions were corrected in the return flow dataset obtained by TWDB, a comparison to the compiled HDR data for return flows shows that TWDB estimated return flows are slightly greater from 2000 to 2009 due to small discharges which were not accounted for in the HDR dataset (Figure 10). TWDB return flows data represented in Figure 10 were used to develop hydrology for version #TWDB201004.

Table 4. Return flow data for six outfalls under the Invista Corp. discharge permit (TX0006050). Discharge outfall 001A was included in the return flow data compiled by HDR Engineering, Inc., but data for all six are available from the TCEQ wastewater database. Data shown is in acre-feet, converted from million gallons per day.

Year	Month	001A	002A	003A	004A	005A	006A	INVISTA(HDR)
2000	1	0	0	0	0	0	0	1172
2000	2	0	0	0	0	0	0	1218
2000	3	0	0	0	0	0	0	1176
2000	4	0	0	0	0	0	0	1103
2000	5	0	0	0	0	0	0	1209
2000	6	0	0	0	0	0	0	1274
2000	7	0	0	0	0	0	0	1295
2000	8	0	0	0	0	0	0	1508
2000	9	0	0	0	0	0	0	1536
2000	10	0	0	0	0	0	0	1692
2000	11	0	0	0	0	0	0	1433
2000	12	0	0	0	0	0	0	1308
2001	1	1408	13	0	17	6	10	1406
2001	2	1435	0	0	0	0	0	1437
2001	3	1494	11	0	0	6	2	1495
2001	4	1482	0	0	6	0	0	1479
2001	5	1322	75	0	26	83	15	1320
2001	6	1243	0	0	0	0	0	1243
2001	7	1475	16	0	0	4	29	1478
2001	8	1751	29	0	92	0	6	1746
2001	9	1574	29	0	7	2	5	1576
2001	10	1579	16	0	10	2	3	1578
2001	11	884	17	0	14	2	5	885
2001	12	1028	10	0	76	1	2	1030
2002	1	1075	10	0	0	1	2	1078
2002	2	1169	0	0	0	0	0	1166
2002	3	1303	0	0	0	0	0	1302
2002	4	1289	8	0	0	1	2	1289
2002	5	1303	10	0	0	1	2	1305
2002	6	1317	28	0	727	5	10	1313
2002	7	1484	15	0	209	3	5	1481
2002	8	1294	29	0	381	3	15	1295
2002	9	1574	9	0	138	1	2	1571
2002	10	1808	19	0	162	2	76	1778
2002	11	1298	9	0	175	1	6	1299
2002	12	1132	11	0	48	1	2	1129
2003	1	1275	20	0	0	2	4	1278
2003	2	1143	9	0	249	1	3	1139
2003	3	1246	19	0	409	2	4	1246
2003	4	1151	0	0	0	0	0	1146

Year	Month	001A	002A	003A	004A	005A	006A	INVISTA(HDR)
2003	5	1161	0	0	0	0	0	1157
2003	6	1215	29	0	187	3	6	1216
2003	7	1303	20	0	297	2	5	1302
2003	8	1208	11	0	0	7	8	1206
2003	9	1335	24	0	561	3	5	1336
2003	10	1246	10	0	0	2	3	1243
2003	11	921	18	0	110	2	6	922
2003	12	761	13	0	0	1	3	757
2004	1	980	9	0	0	2	4	982
2004	2	952	9	0	0	1	2	953
2004	3	1265	4	0	0	1	1	1266
2004	4	1197	2863	0	4	147	3	1194
2004	5	1389	8401	0	73	431	14	1392
2004	6	1841	6141	0	161	315	6	1837
2004	7	1427	695	0	88	44	1	1429
2004	8	1275	1570	0	0	81	3	1277
2004	9	0	0	0	0	30	0	1278
2004	10	1437	4234	0	675	217	7	1437
2004	11	1225	2928	0	64	150	5	1228
2004	12	989	2264	0	0	116	0	985
2005	1	1008	1969	0	0	101	3	1009
2005	2	980	2062	0	180	106	3	977
2005	3	1227	3473	0	124	178	6	1231
2005	4	902	1169	0	0	60	2	901
2005	5	1018	1798	0	0	92	4	1014
2005	6	1004	1906	0	212	98	3	999
2005	7	1532	2493	0	0	127	5	1533
2005	8	1589	0	0	0	0	0	1587
2005	9	1492	976	0	0	43	3	1487
2005	10	1408	3473	0	0	178	7	1408
2005	11	1225	1611	0	0	83	4	1228
2005	12	1199	590	0	0	23	2	1196
2006	1	923	0	0	0	23	1	919
2006	2	842	0	0	0	18	0	840
2006	3	1037	1636	0	0	84	3	1040
2006	4	1731	0	0	0	0	0	1731
2006	5	1789	6270	0	4589	322	35	1787
2006	6	1519	5764	0	4216	296	32	1521
2006	7	1579	5623	0	4666	288	31	1581
2006	8	1284	2293	0	1681	118	13	1281
2006	9	1261	4281	0	3135	220	24	1259
2006	10	1370	3358	0	2455	172	19	1367
2006	11	1142	0	0	0	0	0	1137
2006	12	1123	2236	0	0	101	11	1121
2007	1	1456	2949	0	2156	151	16	1455
2007	2	1014	0	0	0	3	0	1012
2007	3	1598	2626	0	3029	135	14	1599
2007	4	1436	1970	0	1445	101	11	1436
2007	5	1570	3140	0	3792	130	14	1574
2007	6	1584	1040	0	1	42	5	1586
2007	7	2131	10275	0	7519	527	58	2133
2007	8	1446	3539	0	2588	182	20	1441
2007	9	1086	1363	0	995	70	7	1085

Year	Month	001A	002A	003A	004A	005A	006A	INVISTA(HDR)
2007	10	1722	2512	0	1835	128	14	1723
2007	11	1298	1068	0	781	54	6	1293
2007	12	1532	5	0	0	0	0	1535
2008	1	1532	2074	0	1062	105	11	1533
2008	2	1540	1344	0	0	69	7	1540
2008	3	1684	1693	0	1239	87	10	1681
2008	4	1869	2191	0	0	112	12	1872
2008	5	0	0	0	0	0	0	1846
2008	6	1657	0	0	0	9	0	1657
2008	7	1406	1313	0	0	68	8	1406
2008	8	1513	2493	3387	0	127	14	1510
2008	9	1234	672	0	0	34	3	1231
2008	10	1028	675	0	0	35	4	1027
2008	11	1188	2560	0	0	132	15	1186
2008	12	999	828	0	0	43	5	1001
2009	1	1056	0	0	0	0	0	1055
2009	2	1194	0	0	0	11	0	1196
2009	3	1418	1208	0	0	62	7	1415
2009	4	1206	1510	0	0	77	8	1208
2009	5	1123	2417	4167	0	124	13	1126
2009	6	1289	2403	4125	0	123	14	1293
2009	7	1570	0	0	0	19	2	1571
2009	8	1617	1151	0	0	57	7	1613
2009	9	1528	3600	0	0	184	20	1529
2009	10	1703	2150	3710	0	114	12	1701
2009	11	1436	6040	3971	0	313	34	1434
2009	12	980	2150	2145	0	114	12	980

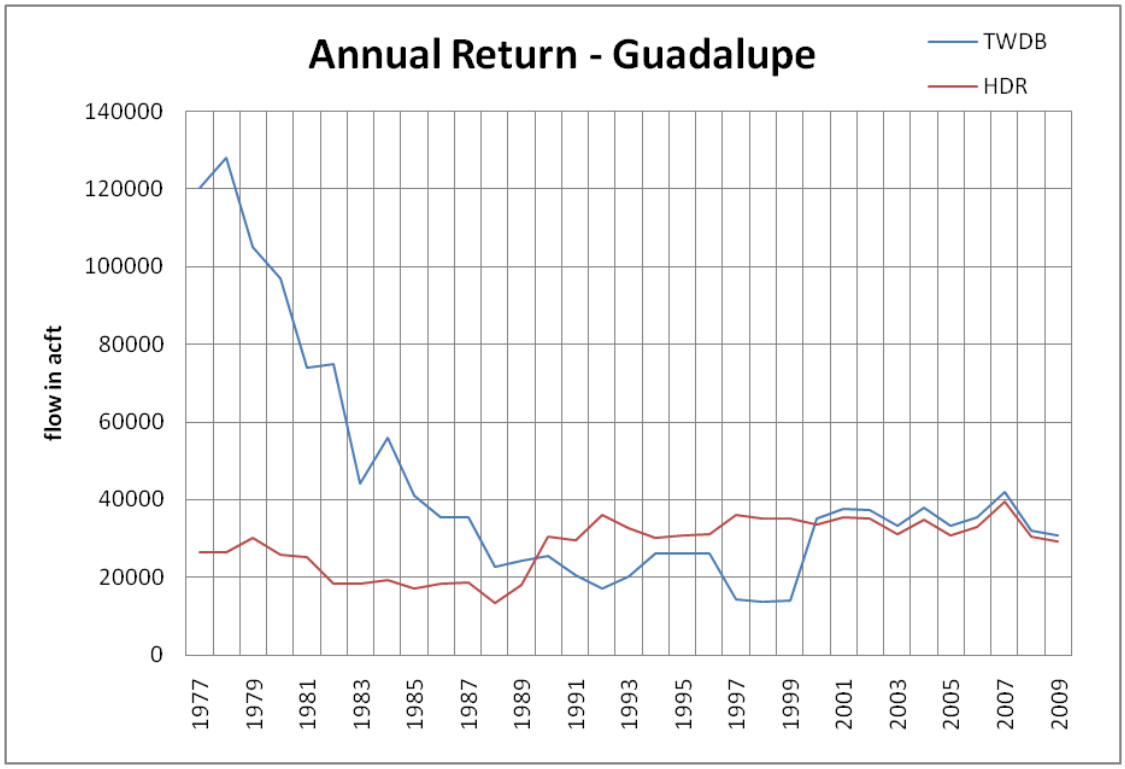

Figure 10. Annual return flows data in the Guadalupe and San Antonio river basins as compiled by TWDB (blue line; based on data obtained from TCEQ and HDR for hydrology version #TWDB201004) and as compiled by HDR (red line) from records provided by permitted dischargers in the basin. After 1999, return flow data obtained by HDR and by TWDB are comparable, with the exception of small discharges which were not accounted for in the HDR dataset. However, prior to 2000, differences exist in the diversion data which have not been reconciled at this time.

HDR and TWDB Net diversions Comparison

HDR presented a net diversion analysis in a recent study for the 2011 Regional Water Plan for Region L. Their analysis reported the net diversions, or difference between diversion and return flow, for the period 1941-2009. In comparing the diversion and discharge data compiled by HDR to that used by TWDB for estimating combined freshwater inflows to the estuary, it is clear there is generally good agreement between the two datasets during the period 1979 to 2001 (Figure 11). For the most recent period, the diversion and discharge data provided by HDR enabled TWDB to update estimates of hydrology such that agreement also was achieved after 2001 (Figure 12). However, TWDB is still working to reconcile differences in the data record obtained by HDR with that obtained by TWDB for the period 1977-1999. Once these differences are reconciled, TWDB will consider updating the hydrology for the 1977-1999 period. In the meantime, and at the request of the Guadalupe-San Antonio BBEST, an alternative hydrology was developed utilizing the HDR diversion and return flow data as provided to TWDB (see the section, *Alternative Hydrology: Version #HDR201001*).

The best documentation of pre-1977 estimates of hydrology are found in LP-107 (TDWR 1980). However, the text does not clearly address the treatment of diversion data (pg. IV-4) in estimating

combined inflows for the period 1941-1976, and the accompanying table (Table 4-1, pg. IV-3 of LP-107) does not explicitly list diversion or return flow data. As such, TWDB is reluctant to incorporate known diversion data for this period at this time until better clarification of the original methodology can be obtained. Therefore in Figures 11 and 12, TWDB net diversion data is not shown.

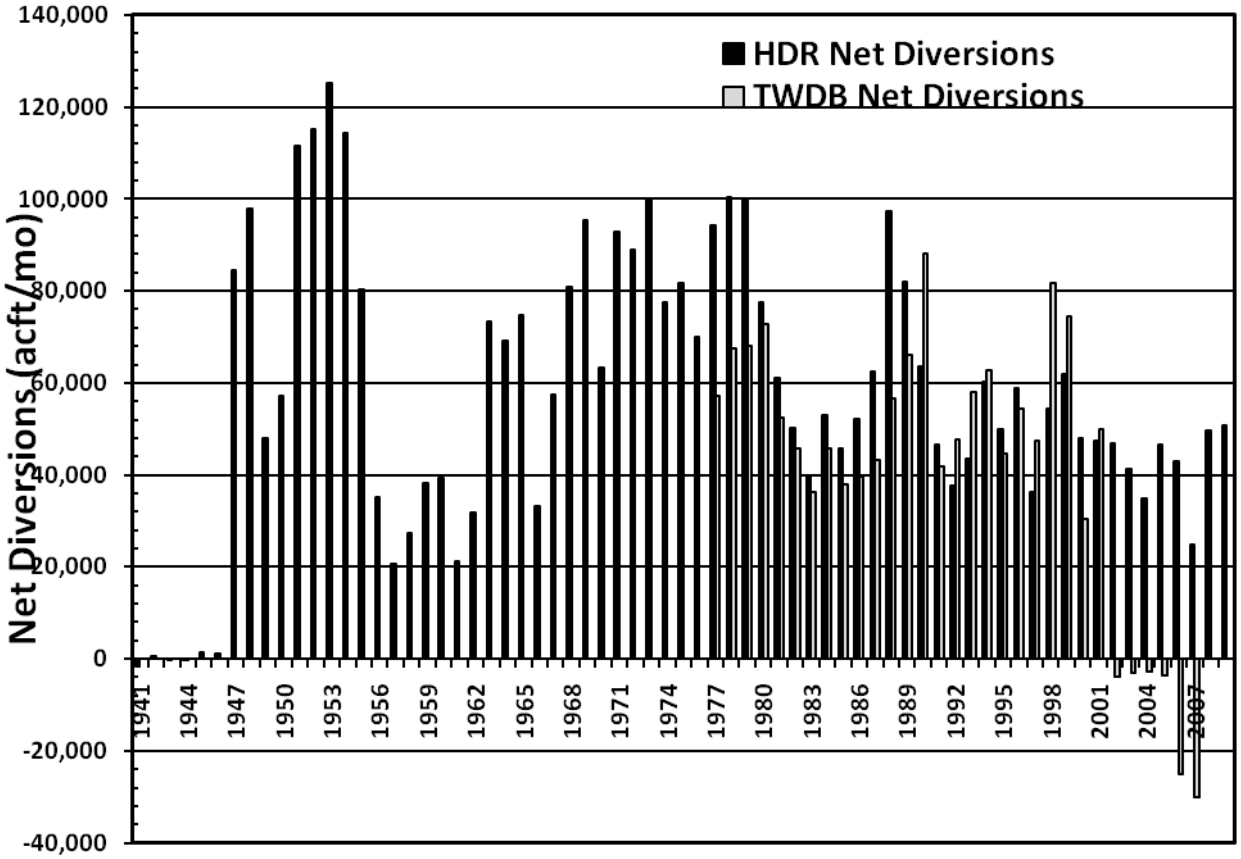

Figure 11. Monthly net diversion (difference between monthly diversion and return flow) calculated for the Guadalupe and San Antonio river basins from 1941 to 2009 based on diversion and discharge data compiled by HDR and similar data used by TWDB (version #TWDB201003) for calculating combined freshwater inflows to the Guadalupe Estuary. Note lack of agreement prior to 1977 and after 2001; see text for explanation.

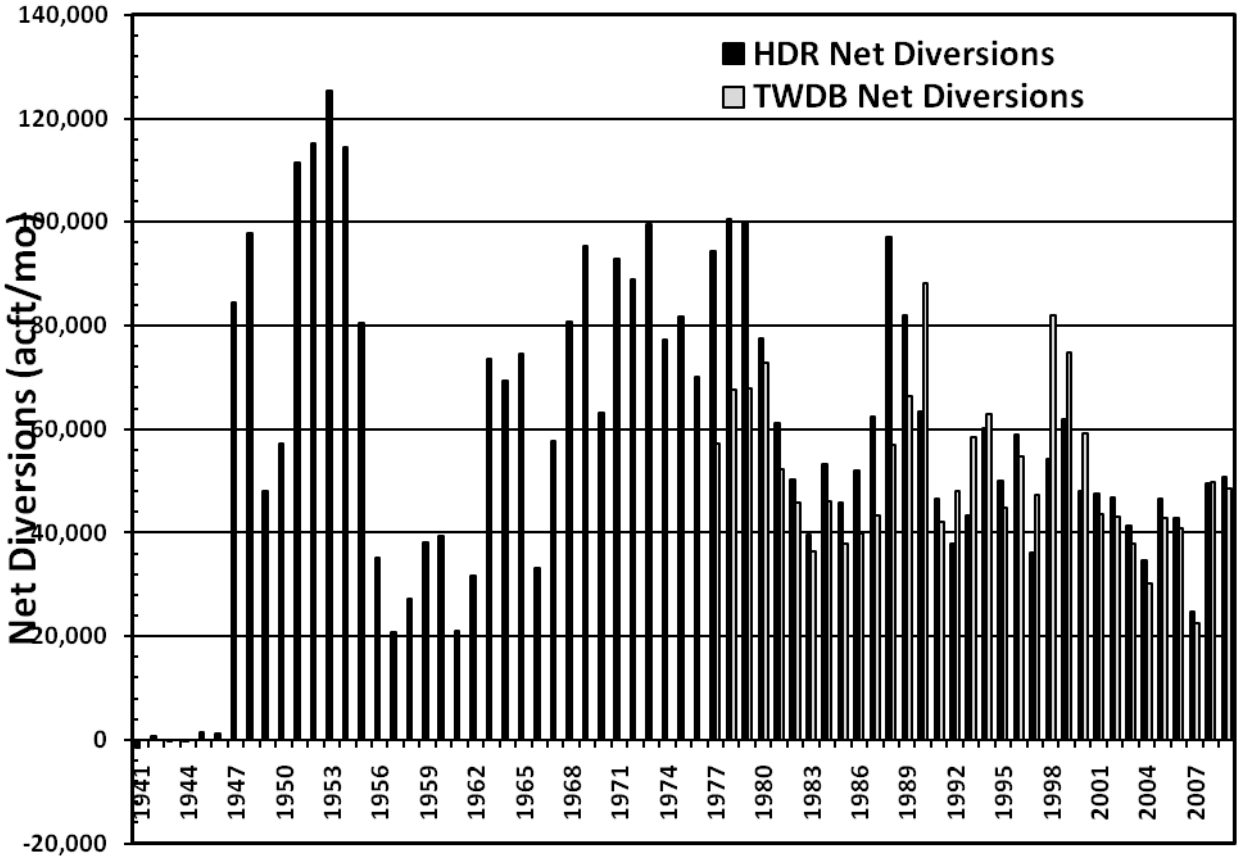

Figure 12. Monthly net diversion (difference between monthly diversion and return flow) calculated for the Guadalupe and San Antonio river basins from 1941 to 2009 based on diversion and discharge data compiled by HDR and similar data compiled by TWDB (version #TWDB201004). Note improved agreement for net diversions after 2000 (as compared to Figure 11).

Alternative Hydrology: Version #HDR201001

At the request of the Guadalupe-San Antonio BBEST, the TWDB prepared a combined inflow hydrology for the Guadalupe Estuary using diversion and return flow data compiled by HDR for the period 1941-2009 (version #HDR201001). This version includes the same data for gaged and ungaged inflows as in version #TWDB201004, but instead, uses the complete record of diversion and return flow data compiled by HDR for the period 1941-2009. HDR obtained this diversion and return data from the entities responsible for the largest diversions and returns (GBRA, Dow Chemical, and Invista Corp.) in the ungaged watersheds. Figure 13 shows a comparison of TWDB hydrology (#TWDB201004) and HDR hydrology (#HDR201001), with Figure 13b specifically displaying differences, as a result of diversion and return data, between the two sets of hydrology.

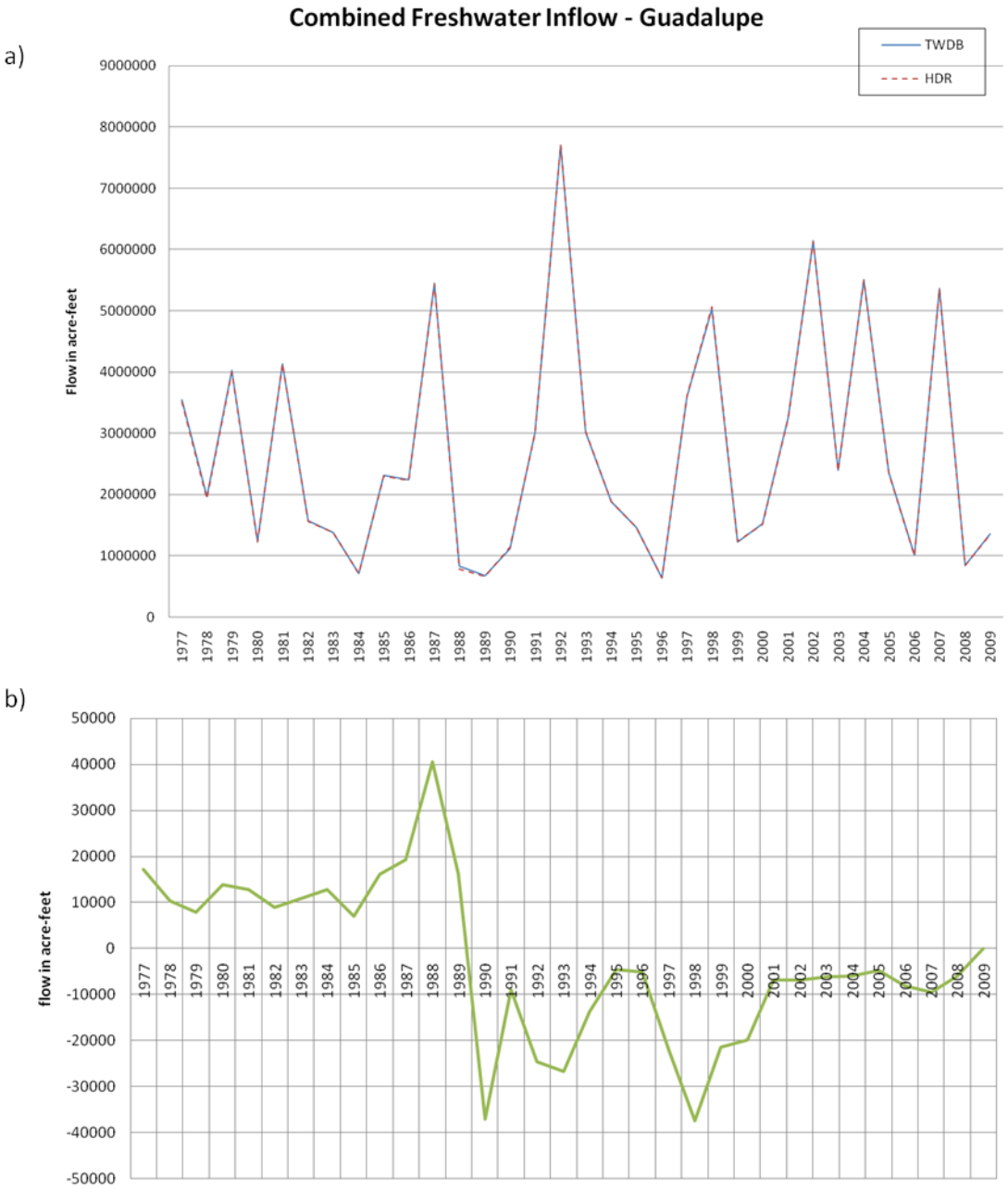

Figure 13. Comparison of hydrology datasets (a) #TWDB201004 versus #HDR201001, where differences primarily are due to differences in diversion and return flow data between 1977-1999, as shown in (b).

Conclusion

Version #TWDB201004 of coastal hydrology for the Guadalupe Estuary, presented herein, is the most up-to-date and accurate data set prepared by the TWDB, representing not only combined freshwater inflows but also the individual components of inflows (*i.e.*, gaged flows, ungaged flows, diversions, return flows) for this estuary. Differences among the versions of hydrology mentioned in this report are a function of extensions or updates to the four components, most recently due to improved information on diversion and return flows data, *e.g.*, Figure 14. Appendix A summarizes recent updates, by version, to hydrology for the Guadalupe Estuary. In addition, Figure 13 displays the effect of the improved diversion and return flows data to the overall estimate of combined inflows as compared to an earlier TWDB version of hydrology. Appendices B and C list annual combined freshwater inflow along with the four components for #TWDB201004 and #HDR20101, respectively, as well as estimates for evaporation and precipitation on the estuary and the total freshwater inflow balance of the estuary. Appendix d provides a table comparing the combined inflows from these two versions of hydrology, and

Alternative hydrologies, such as #HDR201001, represent other equally valuable datasets of coastal hydrology which are available upon request. At the present time, TWDB needs to verify and reconcile the differences in HDR-reported diversion and return flow data for 1987-1999. Once verified against the current TWDB records, TWDB will be able to update version #TWDB20104 to include this additional information.

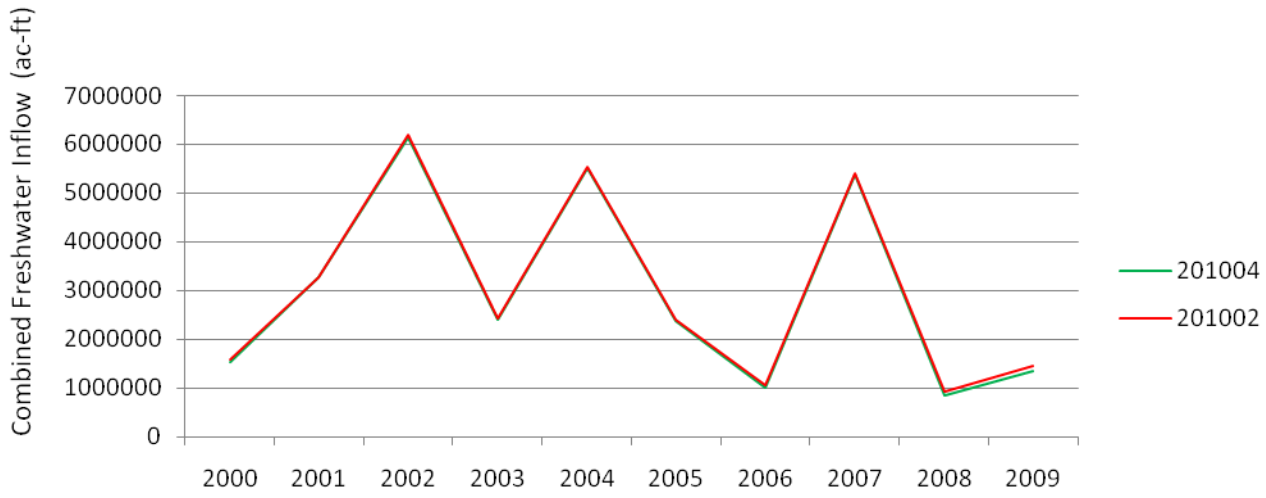

Figure 14. Combined freshwater inflows to the Guadalupe Estuary as calculated for version #TWDB201002 (red) and version #TWDB201004 (green).

The improved accuracy and representation of the #TWDB201004 hydrology was achieved as a result of the dedicated efforts of HDR to identify the diversions and discharges occurring within this basin. Their effort and willingness to share their findings with TWDB is greatly appreciated. Additionally, this effort highlights factors critical to producing high quality estimates of combined freshwater inflows:

(1) Data availability,
(2) Data accuracy and completeness, and
(3) A thorough understanding of raw diversion and return flow data within a basin.

Data availability is essential for allowing estimates of combined inflow to be developed. Several types of data are required for detailed studies of hydrology, and while it is understood that data processing may take time or data may remain provisional for a short period, it is critical for raw data to be released as soon as possible. Long delays in publishing raw diversion and return flow data frequently delay TWDB's efforts to update to coastal hydrology across the state. Data accuracy and completeness are equally important, as errors in the data impact estimates of hydrology. Without a thorough understanding of the data, significant errors may be introduced into the production of the data, such as in the case of the Invista Corp. discharge data. The problems identified in this technical memo are not unique to the Guadalupe Estuary and TWDB will continue to work to apply similar quality control procedures to other basins in Texas.

In general, net diversions account for only a few percent in the total freshwater inflow to the estuary. In the Guadalupe and San Antonio river basins, annual average diversions total about five percent of combined freshwater inflows, and annual average return flows total about two percent of inflows. The difference then between diversions and returns accounts for about three percent of the total combined freshwater inflow to the estuary. Though in many years, the difference may be relatively small, it is still important to obtain the best data to allow for the most accurate representation of coastal hydrology and total freshwater inflows to the Guadalupe Estuary.

Literature Cited

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Longley, W.L., ed. 1994. *Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs*. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, Tx. 386pp.

TWDB. 2010. *TxBLEND Model Calibration and Validation for the Guadalupe and Mission-Aransas Estuaries.* Texas Water Development Board, Austin, Texas. 45 pp.

APPENDIX A: RECORD OF COASTAL HYDROLOGY VERSIONS DEVELOPED BY THE TWDB BAYS & ESTUARIES PROGRAM

ESTUARY	VERSION #	Date Range	Gaged Flows	Ungaged Flows	Diversions	Return Flows	Creation Date & Application
GUADALUPE	TWDB200901	1941-2005	1941-2005	1941-2005	1941-2005	1941-2005	"old"; published on web
	TWDB201001	1941-2008	1941-2008	1941-2008	1941-10/2005	1941-2007; TCEQ to 12/2007 TWDB to 12/2005	1/2010
	TWDB201002	1941-2009	1941-2009; provisional 10/09-12/09	1941-2009; Provisional precip. data 6/09-12/09	1941-10/2005	1941-2007; TCEQ to 12/2007 TWDB to 12/2005	1/2010; Used to run TxBLEND calibration/validation (GuadalupeJM2009)
	TWDB201003	1941-2009	1941-2009; provisional 12/09	1941-2009; provisional precip. data 12/09	1941-10/2005	1941-2009; TCEQ to 12/2009 TWDB to 12/2007	9/2010
	TWDB201004	1941-2009	1941-2009; provisional 12/09	1941-2009; provisional precip. data 12/09	1941-2009; added STWM data + HDR data (2000-2009)	1941-2009; added HDR data (2000-2009)	9/2010; Used for TxBLEND simulations (Guadalupe2009TWDB2)
	HDR201001	1941-2009	1941-2009; provisional 12/09	1941-2009; provisional precip. data 12/09	1941-2009; using HDR data (1941-2009)	1941-2009; using HDR data (1941-2009)	9/2010; Used for BBEST TxBLEND simulations (Guadalupe2009HDR)

APPENDIX B: Annual Hydrology for the Guadalupe Estuary, based on 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 in units of acre-feet.

Year	Gage	Model	Diversion	Returns	Surface Inflow	Evaporation	Precipitation	Freshwater Balance
1941	3,446,030	694,471	0	0	4,140,501	519,000	582,624	4,204,125
1942	2,504,919	496,639	0	0	3,001,558	532,000	450,840	2,920,398
1943	1,007,186	216,824	0	0	1,224,010	578,000	332,928	978,938
1944	1,762,407	508,217	0	0	2,270,624	554,000	461,244	2,177,868
1945	1,750,135	330,856	0	0	2,080,991	554,000	455,464	1,982,455
1946	2,954,716	499,234	0	0	3,453,950	542,000	561,816	3,473,766
1947	1,461,236	212,026	0	0	1,673,262	553,000	401,132	1,521,394
1948	698,858	226,013	0	0	924,871	567,000	356,048	713,919
1949	1,588,565	424,420	0	0	2,012,985	545,000	586,092	2,054,077
1950	728,389	55,831	0	0	784,220	612,000	223,108	395,328
1951	628,586	212,294	0	0	840,880	636,000	350,268	555,148
1952	1,174,285	240,779	0	0	1,415,064	614,000	364,140	1,165,204
1953	1,049,670	259,299	0	0	1,308,969	636,000	438,124	1,111,093
1954	323,884	52,232	0	0	376,116	659,000	240,448	-42,436
1955	387,369	106,847	0	0	494,216	774,000	312,120	32,336
1956	233,645	41,437	0	0	275,082	763,000	243,916	-244,002
1957	3,137,533	804,601	0	0	3,942,134	682,000	478,584	3,738,718
1958	2,939,089	668,051	0	0	3,607,140	695,000	470,492	3,382,632
1959	1,463,085	512,810	0	0	1,975,895	648,000	519,044	1,846,939
1960	2,852,204	1,010,816	0	0	3,863,020	636,000	676,260	3,903,280
1961	2,362,798	548,421	0	0	2,911,219	624,000	508,640	2,795,859
1962	764,729	171,003	0	0	935,732	693,000	347,956	590,688
1963	521,214	41,084	0	0	562,298	707,000	223,108	78,406
1964	705,584	218,862	0	0	924,446	661,000	336,396	599,842
1965	2,112,635	361,025	0	0	2,473,660	705,000	352,580	2,121,240
1966	1,141,037	602,000	0	0	1,743,037	613,000	457,776	1,587,813
1967	2,410,893	1,252,041	0	0	3,662,934	692,000	593,028	3,563,962
1968	2,896,417	737,433	0	0	3,633,850	706,000	575,688	3,503,538
1969	1,810,305	427,031	0	0	2,237,336	764,000	417,316	1,890,652
1970	1,572,517	494,785	0	0	2,067,302	707,000	458,932	1,819,234
1971	1,237,813	720,613	0	0	1,958,426	763,000	547,944	1,743,370
1972	2,299,824	439,263	0	0	2,739,087	690,000	517,888	2,566,975
1973	4,582,905	449,397	0	0	5,032,302	676,000	514,420	4,870,722
1974	2,219,350	545,016	0	0	2,764,366	676,000	618,460	2,706,826
1975	2,994,227	455,272	0	0	3,449,499	654,000	367,608	3,163,107
1976	3,372,684	693,096	0	0	4,065,780	714,000	597,652	3,949,432

Year	Gage	Model	Diversion	Returns	Surface Inflow	Evaporation	Precipitation	Freshwater Balance
1977	3,144,156	465,133	177,529	120,408	3,552,168	697,839	457,353	3,311,682
1978	1,770,302	261,031	195,384	127,936	1,963,885	655,043	410,585	1,719,427
1979	3,489,254	609,601	173,113	105,189	4,030,931	570,308	685,533	4,146,156
1980	1,148,573	159,145	169,765	97,076	1,235,029	715,384	320,885	840,530
1981	3,617,839	572,470	126,248	73,928	4,137,989	651,834	615,188	4,101,343
1982	1,400,601	212,177	120,679	75,068	1,567,167	676,228	349,682	1,240,621
1983	1,184,332	237,704	80,352	44,077	1,385,761	637,074	442,504	1,191,191
1984	642,702	115,993	101,743	55,977	712,929	730,256	392,461	375,134
1985	2,102,764	243,582	78,830	40,934	2,308,450	664,137	400,924	2,045,237
1986	2,075,230	203,532	75,121	35,448	2,239,089	689,814	474,122	2,023,397
1987	5,235,595	260,591	78,416	35,316	5,453,086	695,482	381,229	5,138,833
1988	861,100	23,721	79,324	22,664	828,161	630,544	202,863	400,480
1989	627,941	110,792	90,275	24,287	672,745	544,636	377,478	505,587
1990	921,547	286,256	113,515	25,477	1,119,765	568,599	390,074	941,240
1991	2,584,803	463,692	62,190	20,431	3,006,736	561,857	635,728	3,080,607
1992	7,060,430	683,878	64,835	17,100	7,696,573	497,453	540,973	7,740,093
1993	2,574,602	506,050	78,221	20,194	3,022,625	598,768	512,868	2,936,725
1994	1,698,467	244,360	88,830	26,031	1,880,028	494,567	385,197	1,770,658
1995	1,332,542	180,989	70,742	26,046	1,468,835	518,104	358,305	1,309,036
1996	603,441	95,122	80,545	26,023	644,041	552,982	248,874	339,933
1997	3,289,802	350,172	61,617	14,314	3,592,671	551,054	616,407	3,658,024
1998	4,915,827	199,060	95,323	13,585	5,033,149	587,540	426,061	4,871,670
1999	1,204,860	93,864	88,590	14,027	1,224,161	1,074,680	175,001	324,482
2000	1,321,072	240,471	72,813	35,179	1,523,909	678,028	520,142	1,366,023
2001	3,010,154	288,998	72,015	37,533	3,264,670	532,885	382,923	3,114,708
2002	5,674,497	507,220	71,291	37,292	6,147,718	523,971	583,794	6,207,541
2003	2,203,662	222,920	62,885	33,139	2,396,836	465,032	483,362	2,415,166
2004	4,879,697	646,635	58,920	37,991	5,505,403	452,577	565,054	5,617,880
2005	2,229,256	172,343	68,869	33,118	2,365,848	558,108	390,496	2,198,236
2006	641,245	397,115	65,925	35,452	1,007,887	521,182	548,814	1,035,519
2007	4,780,141	597,648	52,520	42,090	5,367,359	524,941	686,728	5,529,146
2008	815,915	71,803	74,426	31,901	845,193	646,033	292,248	491,408
2009	1,264,467	129,397	73,970	30,864	1,350,758	533,849	372,498	1,189,407

APPENDIX C: Annual Hydrology for the Guadalupe Estuary, based on Version #HDR201001. Included are estimates of gaged and ungaged (modeled) inflows, diversions and return flows (using HDR data for the period 1941-2007), 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 in units of acre-feet.

Year	Gage	Model	Diversions	Returns	Surface Inflow	Evaporation	Precipitation	Freshwater Balance
1941	3,446,030	694,471	0	1,608	4,142,109	519,000	582,624	4,205,733
1942	2,504,919	496,639	2,400	1,680	3,000,838	532,000	450,840	2,919,678
1943	1,007,186	216,824	1,667	1,740	1,224,083	578,000	332,928	979,011
1944	1,762,407	508,217	1,500	1,800	2,270,924	554,000	461,244	2,178,168
1945	1,750,135	330,856	3,200	1,860	2,079,651	554,000	455,464	1,981,115
1946	2,954,716	499,234	3,200	1,920	3,452,670	542,000	561,816	3,472,486
1947	1,461,236	212,026	86,376	1,980	1,588,866	553,000	401,132	1,436,998
1948	698,858	226,013	100,000	2,040	826,911	567,000	356,048	615,959
1949	1,588,565	424,420	50,155	2,100	1,964,930	545,000	586,092	2,006,022
1950	728,389	55,831	59,315	2,160	727,065	612,000	223,108	338,173
1951	628,586	212,294	113,856	2,388	729,412	636,000	350,268	443,680
1952	1,174,285	240,779	117,771	2,616	1,299,909	614,000	364,140	1,050,049
1953	1,049,670	259,299	128,077	2,844	1,183,736	636,000	438,124	985,860
1954	323,884	52,232	117,520	3,072	261,668	659,000	240,448	-156,884
1955	387,369	106,847	83,683	3,300	413,833	774,000	312,120	-48,047
1956	233,645	41,437	38,683	3,528	239,927	763,000	243,916	-279,157
1957	3,137,533	804,601	24,430	3,756	3,921,460	682,000	478,584	3,718,044
1958	2,939,089	668,051	31,294	3,984	3,579,830	695,000	470,492	3,355,322
1959	1,463,085	512,810	42,360	4,212	1,937,747	648,000	519,044	1,808,791
1960	2,852,204	1,010,816	43,790	4,440	3,823,670	636,000	676,260	3,863,930
1961	2,362,798	548,421	25,655	4,548	2,890,112	624,000	508,640	2,774,752
1962	764,729	171,003	36,372	4,656	904,016	693,000	347,956	558,972
1963	521,214	41,084	78,241	4,776	488,833	707,000	223,108	4,941
1964	705,584	218,862	74,137	4,884	855,193	661,000	336,396	530,589
1965	2,112,635	361,025	79,653	4,992	2,398,999	705,000	352,580	2,046,579
1966	1,141,037	602,000	38,254	5,100	1,709,883	613,000	457,776	1,554,659
1967	2,410,893	1,252,041	62,811	5,220	3,605,343	692,000	593,028	3,506,371
1968	2,896,417	737,433	86,192	5,328	3,552,986	706,000	575,688	3,422,674
1969	1,810,305	427,031	100,832	5,436	2,141,940	764,000	417,316	1,795,256
1970	1,572,517	494,785	68,762	5,556	2,004,096	707,000	458,932	1,756,028
1971	1,237,813	720,613	98,496	5,676	1,865,606	763,000	547,944	1,650,550
1972	2,299,824	439,263	94,683	5,796	2,650,200	690,000	517,888	2,478,088
1973	4,582,905	449,397	105,292	5,606	4,932,616	676,000	514,420	4,771,036
1974	2,219,350	545,016	82,587	5,190	2,686,969	676,000	618,460	2,629,429
1975	2,994,227	455,272	87,429	5,673	3,367,743	654,000	367,608	3,081,351
1976	3,372,684	693,096	76,870	6,779	3,995,689	714,000	597,652	3,879,341
1977	3,144,156	465,133	100,688	6,440	3,515,041	697,839	457,353	3,274,555

Year	Gage	Model	Diversions	Returns	Surface Inflow	Evaporation	Precipitation	Freshwater Balance
1978	1,770,302	261,031	107,189	6,703	1,930,847	655,043	410,585	1,686,389
1979	3,489,254	609,601	107,074	7,354	3,999,135	570,308	685,533	4,114,360
1980	1,148,573	159,145	85,197	7,743	1,230,264	715,384	320,885	835,765
1981	3,617,839	572,470	68,962	7,891	4,129,238	651,834	615,188	4,092,592
1982	1,400,601	212,177	57,813	7,543	1,562,508	676,228	349,682	1,235,962
1983	1,184,332	237,704	46,738	7,200	1,382,498	637,074	442,504	1,187,928
1984	642,702	115,993	60,996	7,876	705,575	730,256	392,461	367,780
1985	2,102,764	243,582	53,891	8,031	2,300,486	664,137	400,924	2,037,273
1986	2,075,230	203,532	59,443	7,388	2,226,707	689,814	474,122	2,011,015
1987	5,235,595	260,591	81,246	18,754	5,433,694	695,482	381,229	5,119,441
1988	861,100	23,721	110,422	13,231	787,630	630,544	202,863	359,949
1989	627,941	110,792	100,083	17,979	656,629	544,636	377,478	489,471
1990	921,547	286,256	81,313	17,801	1,144,291	568,599	390,074	965,766
1991	2,584,803	463,692	62,190	15,604	3,001,909	561,857	635,728	3,075,780
1992	7,060,430	683,878	59,231	21,457	7,706,534	497,453	540,973	7,750,054
1993	2,574,602	506,050	63,874	20,456	3,037,234	598,768	512,868	2,951,334
1994	1,698,467	244,360	79,287	19,080	1,882,620	494,567	385,197	1,773,250
1995	1,332,542	180,989	70,742	20,722	1,463,511	518,104	358,305	1,303,712
1996	603,441	95,122	80,437	21,516	639,642	552,982	248,874	335,534
1997	3,289,802	350,172	61,029	24,864	3,603,809	551,054	616,407	3,669,162
1998	4,915,827	199,060	79,590	25,311	5,060,608	587,540	426,061	4,899,129
1999	1,204,860	93,864	88,354	26,553	1,236,923	1,074,680	175,001	337,244
2000	1,321,072	240,471	72,811	24,890	1,513,622	678,028	520,142	1,355,736
2001	3,010,154	288,998	72,027	24,547	3,251,672	532,885	382,923	3,101,710
2002	5,674,497	507,220	71,298	24,422	6,134,841	523,971	583,794	6,194,664
2003	2,203,662	222,920	62,892	21,489	2,385,179	465,032	483,362	2,403,509
2004	4,879,697	646,635	58,926	24,171	5,491,577	452,577	565,054	5,604,054
2005	2,229,256	172,343	68,874	22,202	2,354,927	558,108	390,496	2,187,315
2006	641,245	397,115	65,931	22,984	995,413	521,182	548,814	1,023,045
2007	4,780,141	597,648	52,527	27,755	5,353,017	524,941	686,728	5,514,804
2008	815,915	71,803	74,432	24,907	838,193	646,033	292,248	484,408
2009	1,264,467	129,397	73,978	23,160	1,343,046	533,849	372,498	1,181,695

APPENDIX D: Comparison of Annual Hydrology (in units of acre-feet) for Version #TWDB201004 and Version #HDR201001

Year	TWDB	HDR	Difference	% Diff
1941	4,140,501	4,142,109	-1,608	-0.04
1942	3,001,558	3,000,838	720	0.02
1943	1,224,010	1,224,083	-73	-0.01
1944	2,270,624	2,270,924	-300	-0.01
1945	2,080,991	2,079,651	1,340	0.06
1946	3,453,950	3,452,670	1,280	0.04
1947	1,673,262	1,588,866	84,396	5.04
1948	924,871	826,911	97,960	10.59
1949	2,012,985	1,964,930	48,055	2.39
1950	784,220	727,065	57,155	7.29
1951	840,880	729,412	111,468	13.26
1952	1,415,064	1,299,909	115,155	8.14
1953	1,308,969	1,183,736	125,233	9.57
1954	376,116	261,668	114,448	30.43
1955	494,216	413,833	80,383	16.26
1956	275,082	239,927	35,155	12.78
1957	3,942,134	3,921,460	20,674	0.52
1958	3,607,140	3,579,830	27,310	0.76
1959	1,975,895	1,937,747	38,148	1.93
1960	3,863,020	3,823,670	39,350	1.02
1961	2,911,219	2,890,112	21,107	0.73
1962	935,732	904,016	31,716	3.39
1963	562,298	488,833	73,465	13.07
1964	924,446	855,193	69,253	7.49
1965	2,473,660	2,398,999	74,661	3.02
1966	1,743,037	1,709,883	33,154	1.90
1967	3,662,934	3,605,343	57,591	1.57
1968	3,633,850	3,552,986	80,864	2.23
1969	2,237,336	2,141,940	95,396	4.26
1970	2,067,302	2,004,096	63,206	3.06
1971	1,958,426	1,865,606	92,820	4.74
1972	2,739,087	2,650,200	88,887	3.25
1973	5,032,302	4,932,616	99,686	1.98
1974	2,764,366	2,686,969	77,397	2.80
1975	3,449,499	3,367,743	81,756	2.37
1976	4,065,780	3,995,689	70,091	1.72
1977	3,552,168	3,515,041	37,127	1.05
1978	1,963,885	1,930,847	33,038	1.68
1979	4,030,931	3,999,135	31,796	0.79
1980	1,235,029	1,230,264	4,765	0.39
1981	4,137,989	4,129,238	8,751	0.21
1982	1,567,167	1,562,508	4,659	0.30
1983	1,385,761	1,382,498	3,263	0.24
1984	712,929	705,575	7,354	1.03
1985	2,308,450	2,300,486	7,964	0.34
1986	2,239,089	2,226,707	12,382	0.55
1987	5,453,086	5,433,694	19,392	0.36
1988	828,161	787,630	40,531	4.89
1989	672,745	656,629	16,116	2.40
1990	1,119,765	1,144,291	-24,526	-2.19
1991	3,006,736	3,001,909	4,827	0.16
1992	7,696,573	7,706,534	-9,961	-0.13
1993	3,022,625	3,037,234	-14,609	-0.48
1994	1,880,028	1,882,620	-2,592	-0.14
1995	1,468,835	1,463,511	5,324	0.36
1996	644,041	639,642	4,399	0.68
1997	3,592,671	3,603,809	-11,138	-0.31
1998	5,033,149	5,060,608	-27,459	-0.55
1999	1,224,161	1,236,923	-12,762	-1.04
2000	1,523,909	1,513,622	10,287	0.68
2001	3,264,670	3,251,672	12,998	0.40
2002	6,147,718	6,134,841	12,877	0.21
2003	2,396,836	2,385,179	11,657	0.49
2004	5,505,403	5,491,577	13,826	0.25
2005	2,365,848	2,354,927	10,921	0.46
2006	1,007,887	995,413	12,474	1.24
2007	5,367,359	5,353,017	14,342	0.27
2008	845,193	838,193	7,000	0.83
2009	1,350,758	1,343,046	7,712	0.57

	TWDB	HDR	Difference	% Diff
Average	2,454,758	2,420,555	-34,203	-2.81%
Absolute MAX in diff. acre-feet*			125,233	9.57%
Absolute MIN in diff. acre-feet*			73	-0.01%
Absolute MAX in % difference**			114,448	30.43%
Absolute MIN in % difference**			-73 & -300	0.01%

*Absolute maximum difference in acre-feet occurred in 1953; absolute minimum difference occurred in 1943.

**Absolute maximum % difference occurred in 1954; absolute minimum % difference occurred in 1943 and 1944.