Daily Water Availability Model
for the Lavaca River Basin

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CHAPTER 1
INTRODUCTION

The Texas Commission on Environmental Quality (TCEQ) Water Availability Modeling (WAM) System consists of simulation input datasets for the generalized Water Rights Analysis Package (WRAP) modeling system for all river basins of Texas and related information. The TCEQ WAM System WRAP input dataset for a particular river basin is called a water availability model (WAM). The term "Lavaca WAM" refers to the WRAP simulation input dataset for the Lavaca River Basin in the TCEQ WAM System and variations thereof.

The WAM System was originally implemented by the TNRCC/TCEQ and its partner agencies and contractors during 1997-2003 pursuant to water management legislation enacted by the Texas Legislature in 1997 as Senate Bill 1 (SB1). The Texas Natural Resource Conservation Commission (TNRCC) was renamed the TCEQ effective September 2002. Capabilities provided by the WRAP/WAM system have been expanded over the years since its initial implementation. The WRAP/WAM modeling system is based on a monthly computational time step. Development of auxiliary daily modeling features was motivated by the need to improve capabilities for incorporating into the modeling system the environmental flow standards (EFS) established pursuant to the 2007 Senate Bill 3 (SB3).

WRAP software, manuals, other related publications, training courses, and a link to the TCEQ WAM website are available at the WRAP website (https://wrap.engr.tamu.edu/). The latest versions of the various components of the WRAP modeling system are documented by a set of manuals [1, 2, 3, 4, 5, 6]. [Numbers in brackets refer to the list of references at the end of this report.] New daily modeling capabilities were incorporated in the May 2019 version of WRAP and further improved in January 2021 and July 2022 modifications to the WRAP daily simulation model *SIMD* [7].

Lavaca Daily and Modified Monthly WAMs

Environmental flow standards (EFS) have been adopted by the TCEQ through the process created by the 2007 Senate Bill 3 (SB3). A strategy for modeling the SB3 EFS is explored, adopted, and demonstrated with the Brazos, Trinity, Neches, and Colorado WAMs documented in May 2019, December 2019, June 2020, and March 2022 reports [8, 9, 10, 11]. This methodology consists of: (1) converting monthly WAMs to daily, (2) computing daily targets for environmental flow standards using the daily simulation model *SIMD*, and (3) incorporating monthly summations of the daily instream flow targets into the input datasets read by the monthly simulation model *SIM*. This general strategy is employed to develop the daily and modified monthly Lavaca WAMs documented by this report. Daily SB3 EFS targets computed in daily full authorization and current use scenario Lavaca WAM simulations are summed to monthly EFS targets and incorporated in the monthly WAM simulation input datasets.

SB3 EFS for the Colorado and Lavaca Rivers and Matagorda and Lavaca Bays adopted by the TCEQ in August 2012 are documented as Subchapter D of Chapter 298 of the Texas Administrative Code [12]. The SB3 EFS for the five sites on the Lavaca River and its tributaries were incorporated in the daily *SIMD* input dataset for the Lavaca WAM employing capabilities provided by sets of instream flow *IF*, environmental standard *ES*, hydrologic condition *HC*, pulse flow *PF*, and *PO* pulse options records. Daily flow targets computed by *SIMD* for each day of a 1940-2021 simulation were summed to 1940-2021 monthly targets for incorporation as target series *TS* records incorporated in the monthly *SIM* input dataset.

The primary component of the conversion of the monthly Lavaca WAM to daily is the disaggregation of monthly naturalized flows to daily within the *SIMD* simulation based on input *DF* record daily flow pattern hydrographs discussed in Chapters 3 and 4. A *JT* record is added to the DAT file to activate daily computations. Negative incremental flow option 7 activated on the *JO* record is designed specifically for daily simulations. The SB3 EFS are incorporated in the daily WAM using sets of *IF*, *ES*, *HC*, and *PF* records as described in Chapters 5 and 6. Target series *TS* records are used to incorporate the SB3 EFS in the monthly WAM. *SIM* and *SIMD* time series input data (*IN*, *EV*, *DF*, and *TS* records) are compiled in a single *SIM/SIMD* input DSS file.

Modeling options adopted for the Brazos, Trinity, Neches, and Colorado WAMs for dealing with various complexities and issues guide creation and application of the daily Lavaca WAM. This strategy is also being applied to develop daily and modified monthly Nueces WAMs.

Forecasting is relevant only if routing is activated. Routing parameters are needed only if routing is activated. Lag and attenuation routing parameters were included in the daily WAM datasets for the Brazos, Trinity, Neches, and Colorado WAMs. Comparative simulations were performed with these previous daily WAMs with and without routing and forecasting [8, 9, 10, 11]. Routing and forecasting were determined to adversely affect accuracy in some cases and to generally not result in improvements in simulation results. The routing parameters were included in the datasets to allow comparative analyses but were generally not employed in final adopted simulations. The Lavaca River Basin is much smaller than these other basins making routing and forecasting much less relevant. Routing and forecasting options are not activated in the Lavaca WAM, and routing parameters are considered unnecessary.

Daily WAMs can also be employed directly for various other studies in which EFS and/or reservoir operations for flood control are important without summing daily SB3 EFS targets for input to monthly WAMs. Various issues of integrated multiple-objective water management can be investigated applying daily WAMs. Capabilities for satisfying the instream flow requirements reflected in SB3 EFS can be assessed directly using a daily WAM. Effects of EFS on unappropriated flows available for municipal, industrial, and agricultural water use can be quantified either directly from daily *SIMD* simulations or using a monthly WAM with monthly EFS targets computed in a daily *SIMD* simulation.

Creation of the daily simulation *SIMD* input datasets for the full authorization and current use scenarios began with the monthly *SIM* datasets from the TCEQ WAM System. The original monthly full authorization and current use scenario versions of the Lavaca WAM have a hydrologic period-of-analysis of 1940-1996 which was extended through 2021 in the new expanded version. Daily flow pattern (*DF* record) hydrographs for nine control points are added to the simulation input datasets. Hydrology data include monthly naturalized flows (*IN* records) and reservoir net evaporation-precipitation depths (*EV* records) for the same seven control points. A set of 1940-2021 sequences of *DF* record daily flows at nine control points were developed based on combining observed daily flows downloaded from the U.S. Geological Survey (USGS) National Water Information System (NWIS) website with WAM naturalized monthly flows.

Lavaca River Basin

The 2,320 square mile Lavaca River Basin encompasses the smallest area of any of the 15 major river basins of Texas. Its location and size relative to the other major river basins and coastal basins in Texas are shown in Figure 1.1. A basin map of the Lavaca River Basin is provided as Figure 1.2. From its headwaters in Gonzales County, the Lavaca River flows to Lavaca Bay, which is a secondary bay of the Matagorda Bay system. Streams within the basin include the Lavaca and Navidad Rivers, Sandy Creek, and East and West Mustang Creeks. Most of the reservoir storage capacity in the basin is provided by Lake Texana on the Navidad River. The Navidad River, Sandy Creek, and East and West Mustang Creeks flow into Lake Texana. The Navidad and Lavaca Rivers confluence downstream of Texana Dam before flowing into Lavaca Bay.

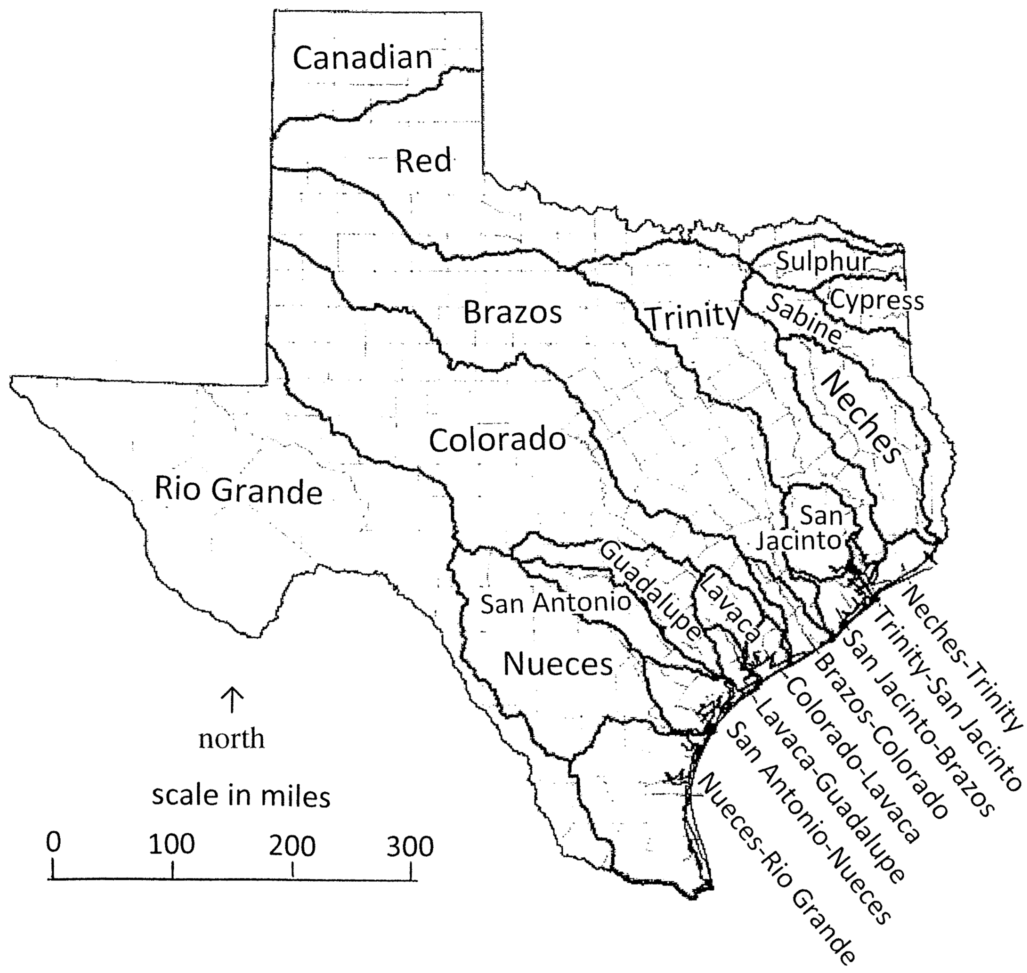

Figure 1.1 Fifteen Major River Basins and Eight Coastal Basins in Texas

Almost all of the reservoir storage capacity in the Lavaca River Basin is contained in Lake Texana owned and operated by the Lavaca-Navidad River Authority (LNRA). Water is transported from Lake Texana by a 101-mile-long pipeline to supply the City of Corpus Christi in the Nueces-Rio Grande Coastal Basin. The LNRA also supplies other water customers in the lower basin and adjoining coastal area. Most water use within the Lavaca River Basin is supplied from groundwater. The observed historical storage plot of Figure 1.3 is from a Texas Water

Development Board (TWDB) website. The top of conservation and top of inactive storage are shown by dashed lines. The reservoir storage capacity was 159,845 acre-feet based on a 2010 TWDB hydrographic survey but has changed with sedimentation. Deliberate impoundment of water in Lake Texana began in May 1980.

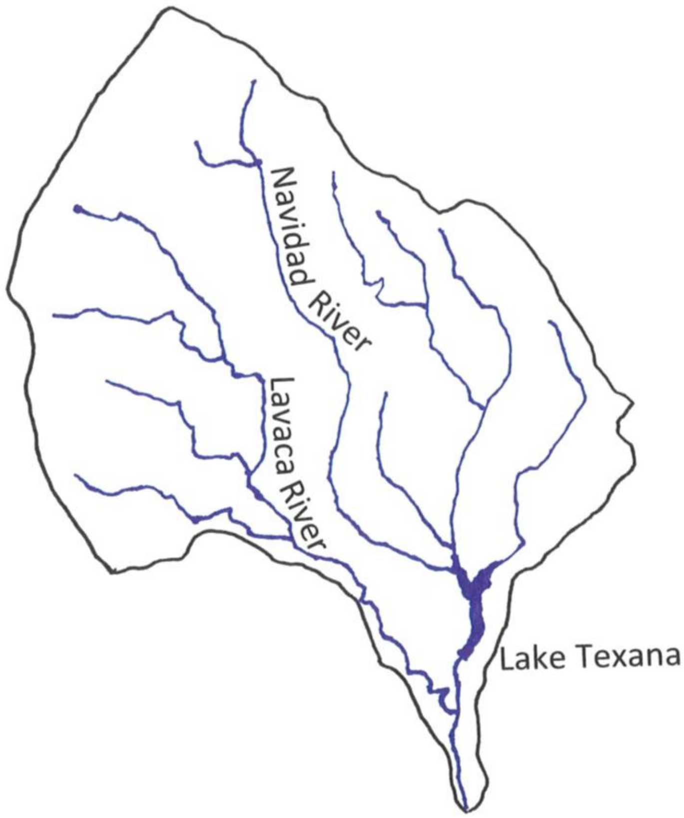

Figure 1.2 Lavaca River Basin

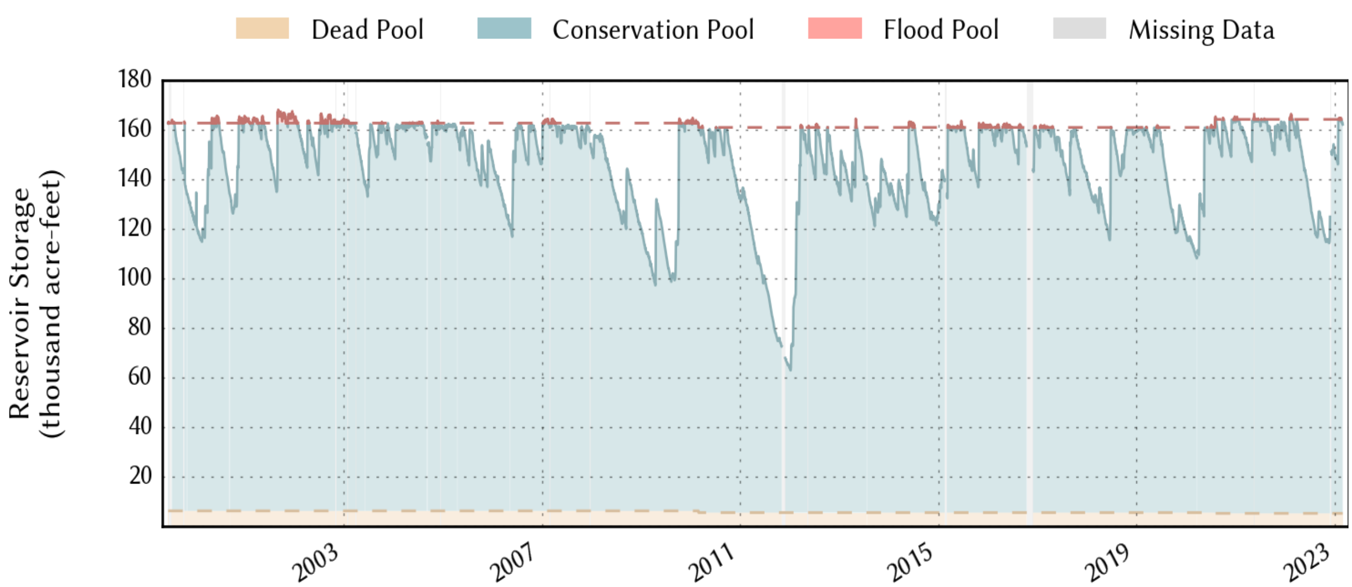

Figure 1.3 Historical Storage in Lake Texana
(https://www.waterdatafortexas.org/reservoirs/individual/texana)

Scope and Organization of this Report

This report documents the development of full authorization and current use scenario versions of the Lavaca WAM that employ a daily computational time step. The report also documents a specific application of the daily model in which the monthly full authorization and current use WAMs are modified by adopting monthly SB3 EFS instream flow targets stored in the monthly *SIM* input datasets that were computed by summing daily targets generated in daily *SIMD* simulations. Data storage system (DSS) files are employed for storing time series input data and simulation results. A single DSS file created in conjunction with this work contains all *SIM* and *SIMD* time series input datasets (*IN*, *EV*, *DF*, and *TS* records) for both daily and monthly simulations with both full authorization and current use scenario DAT files.

Relevant WAM datasets are listed and briefly described in the next section of the present Chapter 1. The alternative versions of the Lavaca WAM are described in Chapter 2. River system hydrology as modeled in the monthly *SIM* and daily *SIMD* is discussed in Chapter 3, including extension of the hydrologic period-of-analysis from 1940-1996 to 1940-2021 and disaggregation of monthly naturalized flows to daily. Chapter 4 covers conversion of the monthly WAM to daily.

The preceding version of the monthly WAM and the new daily and revised monthly WAMs provide capabilities for simulating environmental flow standards (EFS) that have been established by the TCEQ and collaborating science and stakeholder committees through the 1997 Senate Bill 3 (SB3) process. The TCEQ added draft records in 2014 to the monthly WAM based on WRAP capabilities available at that time. Capabilities employing newly created hydrologic condition *HC*, environmental standard *ES*, and pulse flow *PF* records have since been added to the WRAP daily simulation model *SIMD*. The initial records added by the TCEQ in 2014 to model SB3 EFS have been removed and replaced as described in Chapter 5 of this report.

Simulation results generated with the daily and revised monthly full authorization and current use WAMs are presented in Chapter 6. Simulation results from the alternative versions of the WAM are compared. Study results and conclusions are summarized in Chapter 7.

Lavaca WAM Data Files

The initial datasets modified to create the January 2023 daily and monthly WAMs consist of the monthly full authorization and current use WAMs last updated by the TCEQ in 2014 and 2008, respectively, which are discussed in Chapter 2. Daily and monthly versions of the full authorization (run 3) and current use (run 8) WAMs developed as described in this report include the following DSS and DIS files common to monthly *SIM* and daily *SIMD* simulations and separate *SIM* and *SIMD* main input DAT files. A *SIMD* daily input DIF file provides flow disaggregation specifications. The January 2023 daily and monthly WAMs consist of the following simulation input files.

LavacaHYD.DSS − The hydrology DSS file contains 1940-2021 monthly series of *IN* record naturalized flows, *EV* record net reservoir surface evaporation less precipitation depths, *TS* record monthly SB3 EFS instream flow targets, and 1940-2021 *DF* record daily flows. FLO and EVA files were converted to a DSS file and *DF* and *TS* records were added.

Lavaca.DIS − The flow distribution DIS file contains the flow distribution *FD* and watershed parameter *WP* records used to distribute monthly naturalized flows from 7 primary control points to 178 secondary control points the same with the daily versus monthly and authorized versus current use versions of the WAM. The *FD* and *WP* records and DIS file are not changed in the work reported here.

Lavaca3D.DIF and Lavaca8D.DIF − The DIF file contains flow disaggregation specifications on a *DC* record. Optional routing *RT* records are not included.

Lavaca3D.DAT − The daily version of the full authorization scenario (run 3) DAT file with filename Lavaca3D.DAT expands the monthly DAT file with filename lav3.DAT.

Lavaca3M.DAT − The Lavaca3M version of the monthly full authorization DAT file with monthly SB3 EFS targets from a daily simulation replaces the monthly DAT file with filename lav3.DAT.

Lavaca8D.DAT − The daily version of the current use scenario (run 8) DAT file with filename Lavaca8D.DAT expands the monthly DAT file with filename lav8.DAT.

Lavaca8M.DAT − The Lavaca8M version of the monthly current use DAT file with monthly SB3 EFS targets from a daily simulation replaces the monthly DAT file with filename lav8.DAT.

The daily and monthly WAMs created as described in this report are the first versions of the Lavaca WAM to employ DSS (data storage system) files. The *SIM/SIMD* input file with filename LavacaHYD.DSS stores hydrology time series (*IN*, *EV*, *DF* records) and target time series (*TS* records) data as described on the preceding page 5. This DSS file can be called either the hydrology or the time series input file. The same single *SIM/SIMD* hydrology or time series input file with filename LavacaHYD.DSS is read by both *SIM* and *SIMD* for use with either the full authorization or current use DAT files. Model users can read this DSS file, like all DSS files, with *HEC-DSSVue*.

SIM and *SIMD* time series simulation results are also written to a DSS file. The DSS pathname parts A, B, C, D, E, and F labeling conventions adopted for the *IN*, *EV*, *DF*, and *TS* records in the DSS input file and the simulation results variables in the DSS out file are defined in Chapter 6 of the *WRAP Users Manual* [2].

Any data storage system (DSS) files including *SIM* and *SIMD* input and output files are viewed, analyzed, and modified with *HEC-DSSVue*. All other WRAP input and output files are in normal text format read with Microsoft WordPad, NotePad, Word, Excel or other editors. Program *TABLES* is used to organize and display the information in *SIM* and *SIMD* simulation input DAT and output OUT files.

This report is also accompanied by two additional DSS files with the following filenames that contain datasets developed as described in the chapters indicated in parenthesis.

LavacaAuxiliaryData.DSS	(Chapter 3)
LavacaSimulationResults.DSS	(Chapter 6)

CHAPTER 2
WATER AVAILABILITY MODEL FOR THE LAVACA RIVER BASIN

The term *Lavaca WAM* refers to the monthly WRAP simulation model *SIM* input dataset for the Lavaca River Basin from the TCEQ WAM System and modified variations thereof. The original Lavaca WAM was completed by the U.S. Bureau of Reclamation for the TNRCC (TCEQ) in 2001 [13]. The TCEQ has modified the monthly WAM in the past. Daily and revised monthly versions of the WAM datasets were developed as documented by this report.

Previous and Updated Versions of the WAM

Versions of WAM datasets relevant to this chapter are listed as follows.

Full authorization run 3 dataset last modified by TCEQ in June 2008 comprised of the following files: lav3.dat, lav3.dis, lav3.eva, and lav3.inf

Current use run 8 dataset last modified by TCEQ in June 2008 comprised of the following files: lav8.dat, lav8.dis, lav8.eva, and lav8.inf

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Full authorization run 3 dataset last modified by TCEQ in September 2014 comprised of the following files: lav3.dat, lav3.dis, lav3.eva, lav3.flo, and lav3.his

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Daily full authorization run 3 dataset developed as documented by this report comprised of the following files: Lavaca3D.DAT, Lavaca.DIS, Lavaca3D.DIF, and LavacaHYD.DSS.

Daily current use run 8 dataset developed as documented by this report comprised of the following files: Lavaca8D.DAT, Lavaca.DIS, Lavaca3D.DIF, and LavacaHYD.DSS.

Monthly full authorization run 3 dataset developed as documented by this report comprised of the following files: Lavaca3M.DAT, Lavaca.DIS, LavacaHYD.DSS.

Monthly current use run 8 dataset developed as documented by this report comprised of the following files: Lavaca8M.DAT, LavacaDIS, and LavacaHYD.DSS.

The June 2008 lav3 and lav8 datasets do not include SB3 EFS. The September 2014 lav3 dataset includes draft records in the DAT file modeling SB3 EFS and a hydrologic index series HIS file added solely for modeling the SB3 EFS. The HIS file and DAT file records modeling SB3 EFS are removed and replaced in the January 2023 datasets as explained in Chapter 5.

The hydrologic period-of-analysis is January 1940 through December 1996 for the original 2003 Lavaca WAM and versions updated by the TCEQ in June 2008 and September 2014. The hydrologic period-of-analysis has been extended through December 2021 for the four January 2023 versions of the WAM developed as discussed in Chapter 3 of this report.

Negative incremental flow ADJINC option 5 is activated on the *JD* record for monthly versions of the Lavaca WAM, and daily standard ADJINC option 7 is activated for daily WAMs. INMETHOD option 7 is selected on *CP* records to apply the drainage area method for distributing flows to secondary control points using watershed areas from *WP* records in the DIS file.

The WRAP simulation models *SIM* and *SIMD* print a listing in the message (MSS) file of the number of various system components. Program *TABLES* 1RCT, 1SUM, and 1RES records provide summaries of data in a DAT file. Counts and totals for the alternative WAM versions listed above are tabulated in Tables 2.1 and 2.2 for comparison.

Table 2.1
Number of Model Components in Lavaca WAM Datasets

Latest Update of Datasets	2008	2008	2014	2023	2023	2023	2023
Monthly or Daily Time Step	Month	Month	Month	Month	Month	Daily	Daily
Authorized or Current Use	3	8	3	3	8	3	8
Filename Root	lav3	lav8	lav3	Lavaca3M	Lavaca8M	Lavaca3D	Lavaca8D
total number of control points	185	184	342	185	184	185	184
primary control points	7	7	7	7	7	7	7
evap-precip control points	7	7	7	7	7	7	7
number of reservoirs	22	21	22	22	21	22	21
WR record water rights	72	68	212	72	69	72	69
instream flow *IF* record rights	30	30	130	35	35	40	40
system water rights	0	0	48	5	5	10	10
drought index *DI* records	3	3	3	3	3	3	3
FD records in DIS file	167	167	172	167	167	167	167
Total records in DAT file	396	408	1,547	409	421	494	504

The last line in Table 2.1 shows the total number of records in the DAT file excluding comment and title records. The simulation input DAT files for the 2008 and 2014 versions of the full authorization WAM contain totals of 396 and 1,547records, respectively. The additional 1,151 records in the 2014 DAT file update were added to model the SB3 EFS. These 1,151 records were removed in the 2023 daily WAM input DAT file and replaced with 90 *IF*, *HC*, *ES*, and *PF* records.

<u>Reservoirs and Water Rights</u>

Lake Texana on the Navidad River is the only major reservoir in the Lavaca River Basin. Planning studies by the U.S. Bureau of Reclamation (USBR) during the 1960's resulted in proposed construction of a project known as Palmetto Bend Dam and Reservoir, Stages I and II. Stage I was a dam and reservoir on the Navidad River that was actually constructed with initial impoundment in 1980 and renamed Texana Dam and Reservoir. The proposed and permitted Stage II, consisting of an adjacent dam on the Lavaca River has not yet been constructed. Lake Texana was turned over to the Lavaca-Navidad River Authority (LNRA) after completion of construction by the USBR. The City of Corpus City is LNRA's largest water supply customer.

As indicated by Table 2.2, the full authorization scenario WAM includes 22 reservoirs with a total storage capacity of 234,778 acre-feet. This includes Lake Texana with a capacity of 170,300 acre-feet, the permitted but yet constructed Palmetto Bend Stage II Reservoir with a capacity of 62,454 acre-feet, and twenty small reservoirs with a combined total capacity of 2,024 acre-feet. The current use scenario WAM includes 21 reservoirs with a total storage capacity of 167,716 acre-feet, which includes Lake Texana with 165,692 acre-feet and twenty small reservoirs with a combined total storage capacity of 2,024 acre-feet.

The summations of the annual diversion and instream flow amounts from field 2 of the *WR* and *IF* records are also tabulated in Table 2.2. About 77.3 percent of the total *WR/IF* record authorized target amounts of 762,591 acre-feet/year represent diversions or releases from Lake

Texana. A significant portion of these totals reflect artificial accounting computations rather than actual water supply or instream flow target amounts.

Table 2.2
Totals of Reservoir Storage Capacity and Annual Diversion Targets

	2008 Authorized	2008 Current	2014 Authorized	2023 Authorized	2023 Current
number of WR records	72	68	212	72	68
WR & IF record targets (ac-ft/yr)	762,681	665,842	1,749,218	762,591	665,842
number of reservoirs	22	21	22	22	21
reservoir storage capacity (ac-ft)	234,778	167,716	234,778	234,778	167,716

Control Points

The Lavaca WAM has 185 control points defined by *CP* records. Seven are primary control points with naturalized flows provided as *IN* records in the *SIM/SIMD* hydrology input file. Monthly reservoir net evaporation-precipitation depths are input on *EV* records for these same seven control points. Nine of the ten USGS gage sites listed in Table 2.3 serve as control points (seven primary and two secondary) for all versions of the WAM. The USGS gage identifier, location, period-of-record, and watershed drainage area in square miles are included in Table 2.3. Control point identifiers are listed in the last column of Table 2.3 and first column of Table 2.4. "GS" in the control point identifiers means "gage site".

Table 2.3
Ten USGS Gage Sites, Seven Primary and Two Secondary Control Points

USGS No.	Location	Period-of-Record	Area (sm)	CP
08163500	Lavaca River at Hallettsville	Aug 1939 – present	108	GS400
08164000	Lavaca River near Edna	Aug 1938 – present	817	GS300
08164300	Navidad River near Hallettsville	Oct 1961 – present	332	GS600
08164350	Navidad River near Speaks	Oct 1981 – Jan 2022	437	GS550
08164370	Navidad River at Morales	Oct 1996 – Jan 2022	549	-
08164390	Navidad at Strane Park nr Edna	Oct 1996 – present	579	DV501
08164450	Sandy Ck near Ganado	Oct 1978 – present	289	GS1000
08164500	Navidad River near Ganado	Jun 1939 – 5 Jul 1999	1,062	GS500
08164503	West Mustang Creek nr Ganado	Oct 1978 – present	178	WGS800
08164504	East Mustang Creek nr Louise	Oct 1996 – present	53.9	ECB720

DF record daily flows are developed for the nine sites in Table 2.4 as discussed in Chapter 3. The five control points with SB3 EFS are so indicated in the last column of Table 2.4. Primary versus secondary status is indicated in the next-to-last column. Primary control points are locations at which naturalized flows are provided in a *SIM* or *SIMD* input dataset. Naturalized flows at all other sites, called secondary control points, are computed within the simulation based on the naturalized flows at primary control points and watershed parameters provided on DIS file *FD* and *WP* records and/or DAT file *CP* records. Naturalized flows are synthesized during execution of *SIM* for 178 secondary control points in the Lavaca WAM using the drainage area ratio method as specified by flow source option 7 in control point *CP* record field 6. Watershed areas delineated by *FD* record parameters from the DIS file are read from *WP* records in the DIS file.

Table 2.4
WAM Control Points at or near USGS Gage Sites

CP	Location	Drainage Area (sm)	Type CP	EFS
GS400	Lavaca River at Hallettsville	108	Primary	-
GS300	Lavaca River near Edna	817	Primary	EFS
GS600	Navidad River near Hallettsville	332	Primary	-
GS550	Navidad River near Speaks	437	Primary	-
DV501	Navidad at Strane Park near Edna	579	Secondary	EFS
GS1000	Sandy Creek near Ganado	289	Primary	EFS
GS500	Navidad River near Ganado	1,062	Primary	-
WGS800	West Mustang Creek near Ganado	178	Primary	EFS
ECB720	East Mustang Creek near Louise	53.9	Secondary	EFS

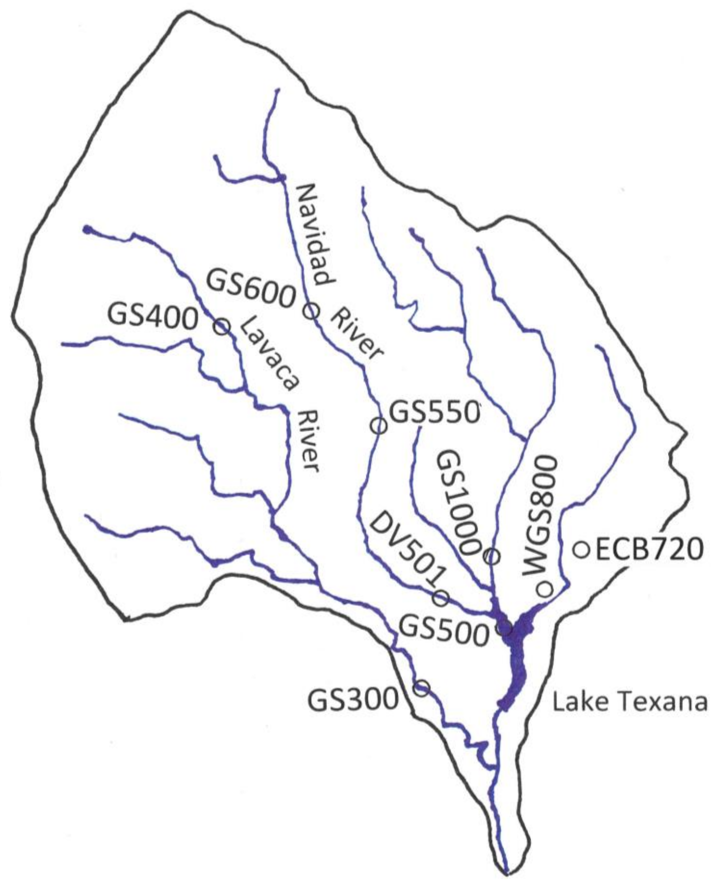

Figure 2.1 Control Points Located at or near USGS Gage Sites

CHAPTER 3
RIVER SYSTEM HYDROLOGY

Chapter 3 describes the general hydrologic characteristics of the Lavaca River Basin and WAM 1940-2021 hydrologic period-of-analysis monthly time series input data, which consists of monthly naturalized flows at seven control points stored on *IN* records and monthly net evaporation-precipitation depths on *EV* records assigned to the same seven control points. Daily flow pattern hydrographs on *DF* records for nine control points are developed in Chapter 4.

River Basin Characteristics

The location and size of the Lavaca River Basin in comparison to the other major river basins and coastal basins of Texas is illustrated in Figure 1.1 on page 3. The general configuration of the river basin is shown in Figure 1.2. The locations of nine USGS gage stations at seven primary and near two secondary control points are shown in Figure 2.1 on the preceding page 10.

Watershed Drainage Areas

The watershed drainage areas of several relevant locations in the river system are tabulated below in Table 3.1. The watershed areas in Table 3.1 are from the watershed parameter *WP* records in the Lavaca WAM DIS file. The watershed areas in Table 2.4 are from the USGS NWIS.

Table 3.1
Watershed Areas

Control Point	Location	Drainage Area (square miles)
GS400	Lavaca River Gage at Hallettsville	107.4
GS300	Lavaca River Gage near Edna	822
GS600	Navidad River Gage near Hallettsville	333
GS550	Navidad River Gage near Speaks	410
DV501	Navidad River Gage at Strane Park near Edna	581
GS500	Navidad River near Ganado	1,062
GS1000	Sandy Creek near Ganado	296
CB510	Confluence of Sandy Creek and Navidad River	1,059
	Sandy Creek Watershed	(475)
	Navidad River Watershed	(584)
WGS800	West Mustang Creek near Ganado	168
ECB720	East Mustang Creek near Louise	54.4
DV221A	Lake Texana Dam	1,406
CB210	Confluence of Lavaca and Navidad Rivers	2,294
	Lavaca River Watershed	(876)
	Navidad River Watershed	(1,418)
EP000	Lavaca River Outlet at Lavaca Bay	2,322

Reservoir Storage Capacity

Most of the reservoir storage capacity in the Lavaca River Basin is contained in Lake Texana. The location of Lake Texana is shown in Figure 1.2 on page 4 of Chapter 1. A TWDB plot of historical observed storage contents of Lake Texana is provided as Figure 1.3.

As noted in Chapter 2, the full authorization scenario WAM includes 22 reservoirs with a total storage capacity of 234,778 acre-feet. Lake Texana with an authorized capacity of 170,300 acre-feet accounts for 72.5% of the permitted total storage capacity. The permitted but not yet constructed Palmetto Bend Stage II Reservoir has a capacity of 62,454 acre-feet, and the other twenty reservoirs have a combined total capacity of 2,024 acre-feet.

The current use scenario WAM includes 21 reservoirs with a total storage capacity of 167,716 acre-feet, which includes Lake Texana with 165,692 acre-feet (98.8% of total) and the same twenty small reservoirs with a combined total storage capacity of 2,024 acre-feet.

Precipitation and Reservoir Evaporation Rates

Monthly precipitation depths extending from January 1940 and monthly reservoir evaporation depths from January 1954 to near the present (currently through 2021) for 92 one-degree by one-degree quadrangles that encompass Texas are accessible at the following TWDB website: https://waterdatafortexas.org/lake-evaporation-rainfall. The TWDB updates the databases each year to extend through the preceding year. Observed monthly precipitation and evaporation depths are spatially averaged by the TWDB over each of the 92 one-degree quadrangles as explained at the website. Each quadrangle covers an area of about 4,000 square miles.

Quadrangles 811 and 911 encompass most of the Lavaca River Basin and all of Lake Texana. Most of Lake Texana is in quadrangle 811, which is south of quadrangle 911. Annual 1940-2021 precipitation depths and 1954-2021 evaporation depths in inches for each of these two quadrangles are tabulated in Table 3.2.

Table 3.2
Annual Precipitation and Reservoir Evaporation Depths

	Quad 811	Quad 911	Average
Annual Precipitation Mean (inches)	41.7	39.8	40.75
Annual Precipitation Minimum (inches)	15.3	17.5	16.40
Annual Precipitation Maximum (inches)	62.1	61.6	61.85
Annual Evaporation Mean (inches)	49.8	50.0	49.90
Annual Evaporation Minimum (inches)	39.5	32.2	35.85
Annual Evaporation Maximum (inches)	61.9	60.6	61.25

The averages of quantities for quadrangles 811 and 911 are considered to be reasonable approximations of precipitation and reservoir evaporation for the Lavaca River Basin. Thus, the basin-wide 1940-2021 annual precipitation in the Lavaca River Basin is estimated have ranged from a minimum of about 16.40 inches to a maximum of about 61.85 inches, with an 82-year average of about 40.75 inches/year. The 1954-2021 average annual reservoir evaporation in the Lavaca River Basin is about 49.9 inches/year, ranging between the minimum and maximum values shown in Table 3.2.

The monthly precipitation depths plotted in Figures 3.1 and 3.2 illustrate the great temporal variability of rainfall in the Lavaca River Basin and throughout Texas. Reservoir evaporation rates are also highly variable over time as illustrated in Figure 3.3. Although both evaporation and precipitation exhibit seasonality, the within-year seasonal fluctuations in Figure 3.3 are most apparent. Annual depths of precipitation and reservoir evaporation are compared in Figure 3.4. Reservoir surface evaporation rates are significantly higher that rainfall rates. The corresponding statewide average annual precipitation and evaporation rates for Texas are 28.1 and 59.4 inches.

Except for Figure 1.3, all time series plots in this report, including the figures in this chapter, were prepared with *HEC-DSSVue*. The statistics in Table 3.2 were computed using HEC-DSSVue. The WRAP program *HYD* was also includes features for analyzing the TWDB evaporation and precipitation datasets. The WRAP modeling system includes a DSS file developed using *HYD* that contains the TWDB 92-quadrangle monthly precipitation and evaporation datasets updated through 2021.

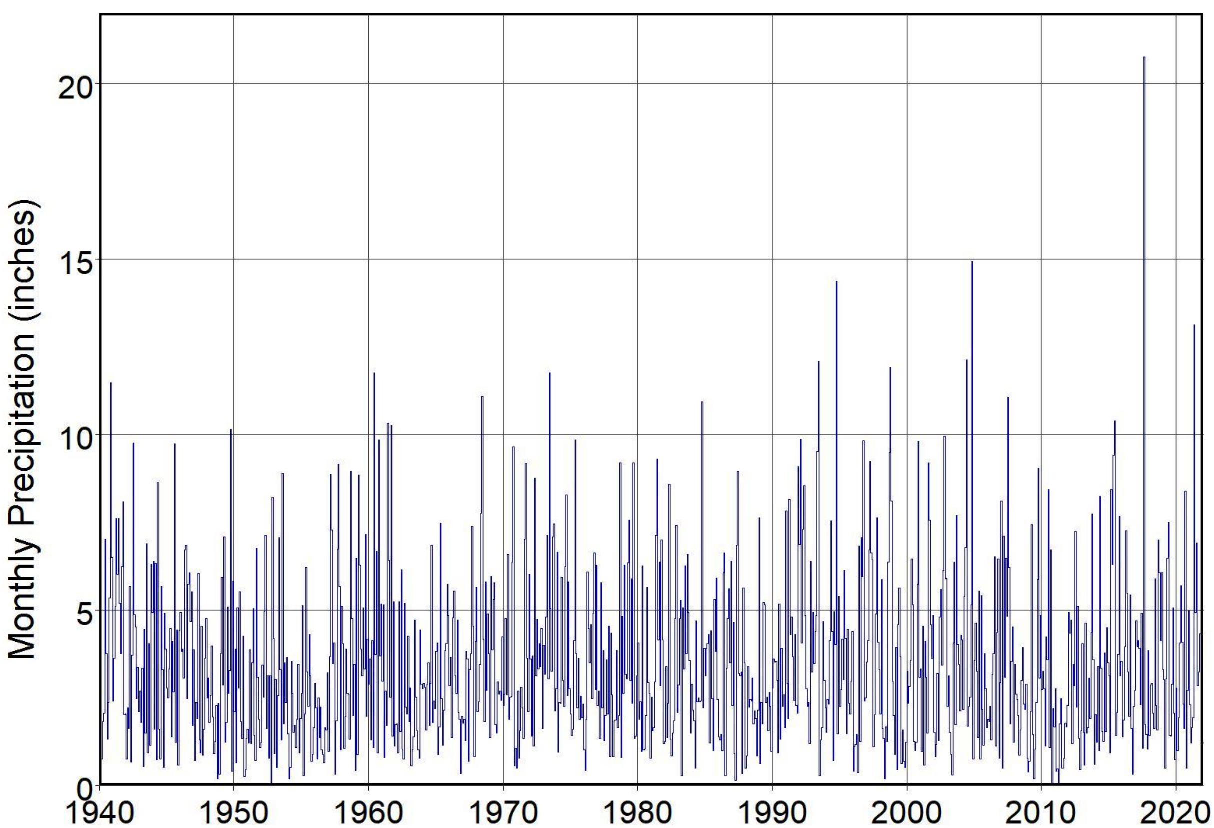

Figure 3.1 Monthly Precipitation for Quadrangle 811

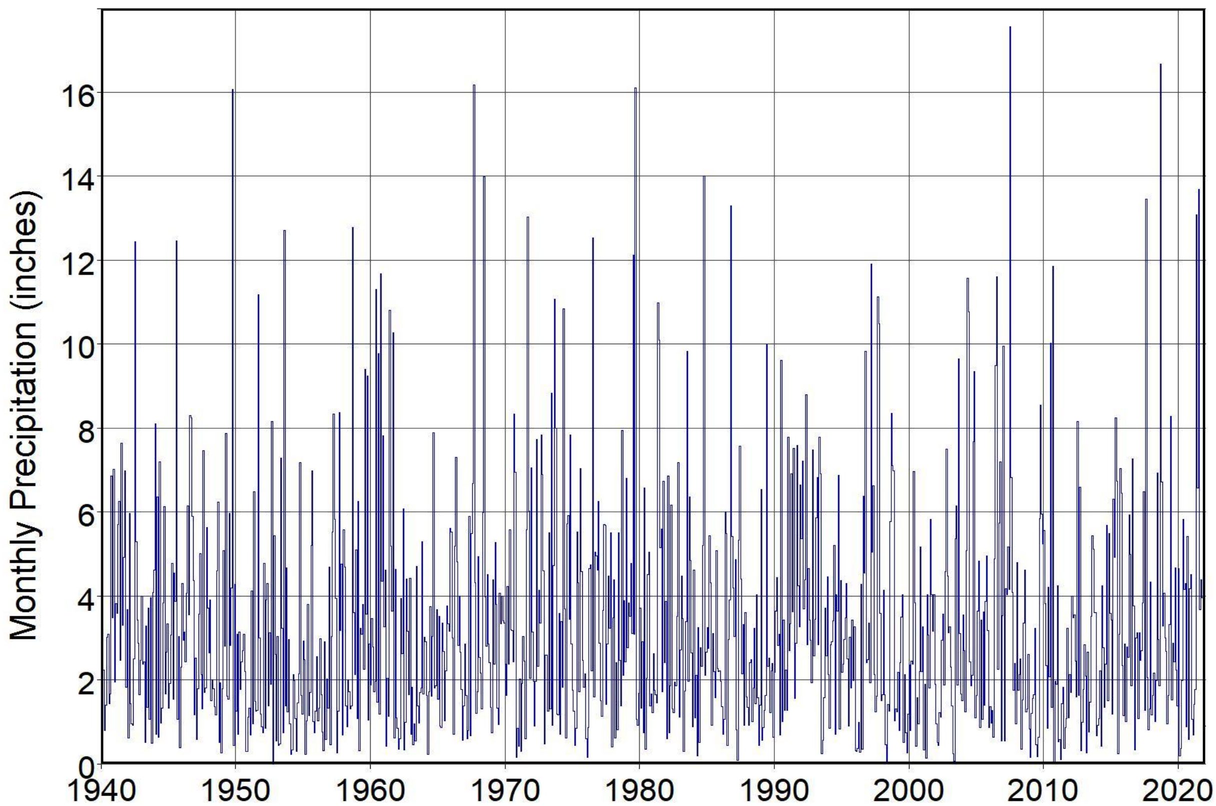

Figure 3.2 Monthly Precipitation for Quadrangle 911

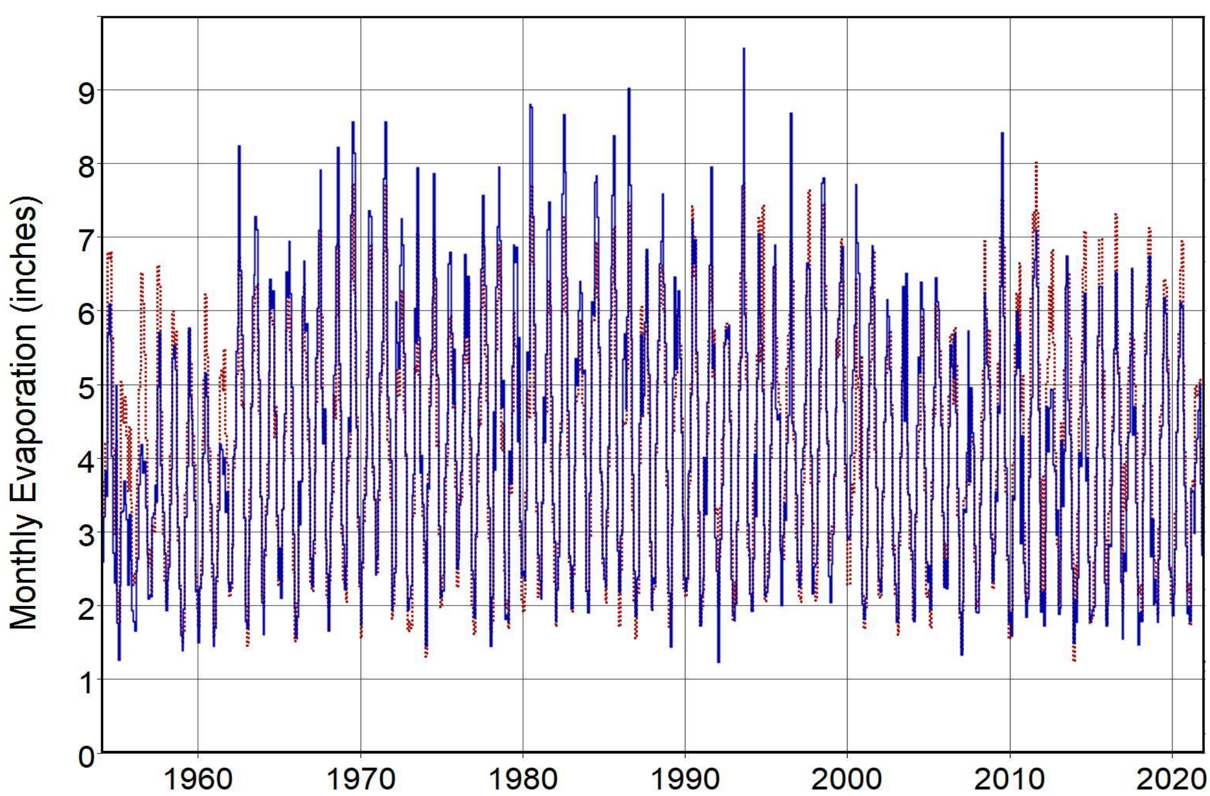

Figure 3.3 Monthly Evaporation for Quadrangles 811 (red dots) and 911 (blue solid line)

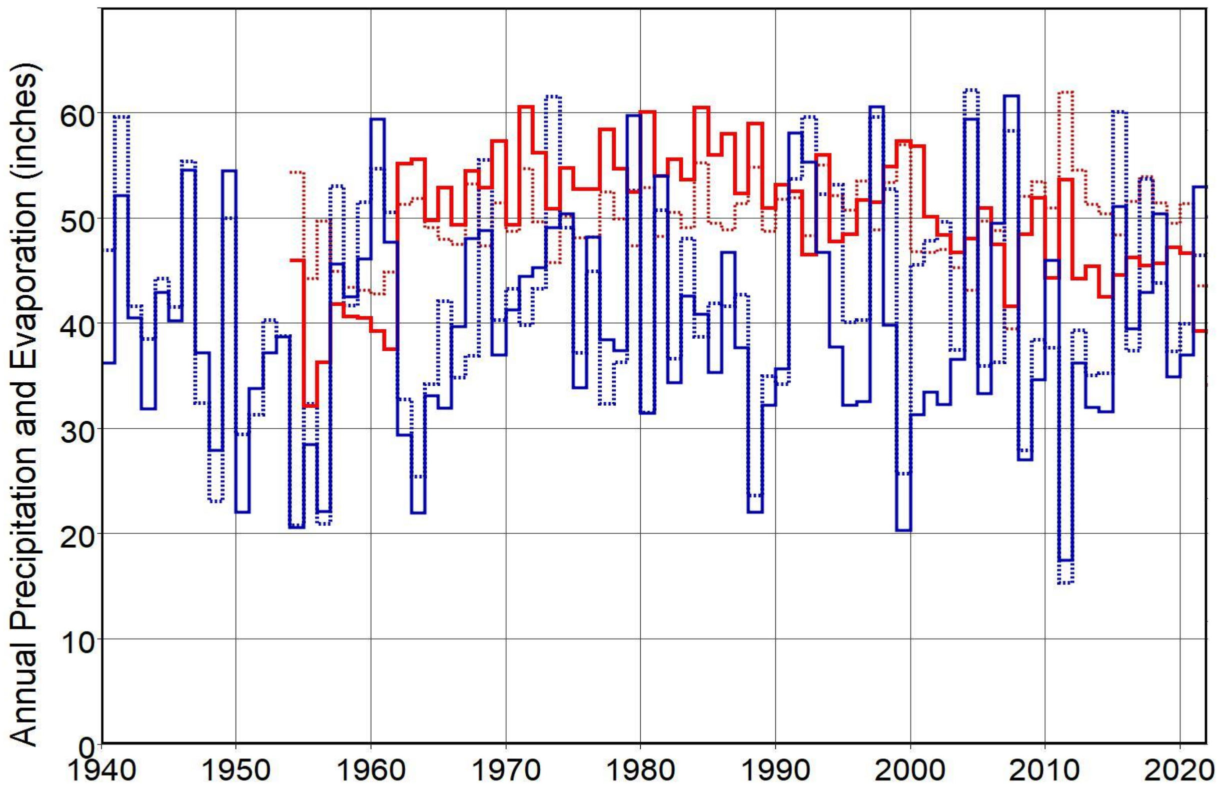

Figure 3.4 Annual Precipitation for Quadrangles 811 (blue dots) and 911 (blue solid line) and Evaporation for Quadrangles 811 (red dots) and 911 (red solid)

WAM Monthly Net Reservoir Evaporation-Precipitation Depths

The original Lavaca WAM developed by the U.S. Bureau of Reclamation (USBR) for the TNRCC (renamed TCEQ) has a hydrologic period-of-analysis of 1940-1996. The 2002 USBR Lavaca WAM report [13] states that historical monthly gross evaporation and precipitation rates for Lake Texana were obtained from the Lavaca-Navidad River Authority. The TWDB quadrangle monthly evaporation and precipitation datasets appeared to have been used for the twenty small reservoirs. The USBR developed *EV* records of net evaporation-precipitation rates by subtracting precipitation from evaporation depths. The WAM includes seven sets of *EV* records assigned the same identifiers as the seven primary control points. The Lake Texana net evaporation-precipitation rates are assigned control point identifier GS300.

The TWDB employs the WAMs in regional and statewide planning studies. The TWDB applies the latest extended monthly naturalized flows (*IN* records) and evaporation-precipitation rates (*EV* records) updated by the TCEQ and its contractors for the WAMs that have recently updated hydrologic periods-of-analysis. TWDB staff has extended the *IN* and *EV* records for WAMs that have not been recently updated by the TCEQ. Sequences of *IN* and *EV* records extended by the TWDB for nine WAMs are available at the following website.

https://www.twdb.texas.gov/surfacewater/data/ExtendedNatFlow/index.asp

TWDB extensions of the *EV* records through 2021 are adopted for the January 2023 Lavaca WAM.

The seven 1940-2021 sequences of monthly net reservoir evaporation less precipitation depths in feet stored on *EV* records for the January 2023 Lavaca WAM consists of the original quantities for 1940-1996 and quantities for 1997-2021 compiled by the TWDB using their quadrangle database. The *EV* record 1940-2021 monthly evaporation less precipitation depths for Lake Texana assigned control point identifier GS300 are plotted in Figure 3.5.

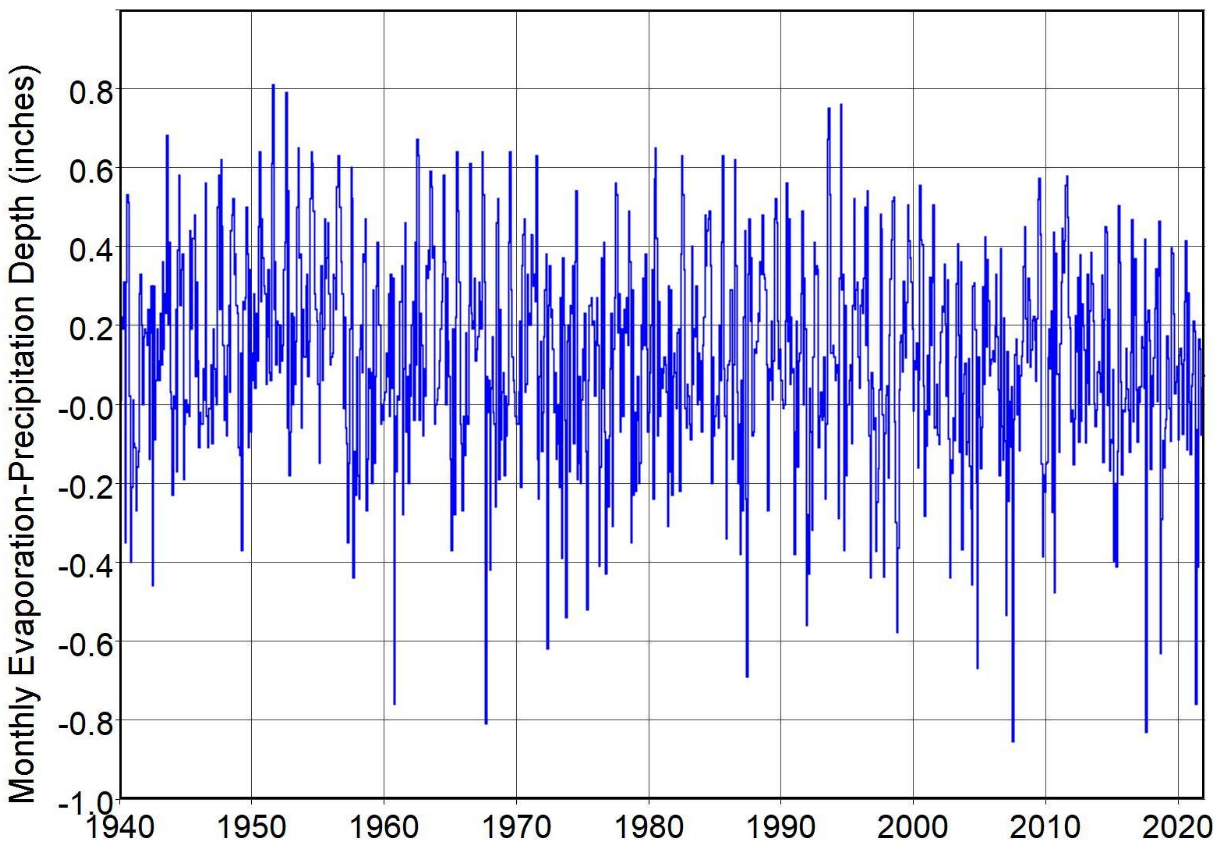

Figure 3.5 Monthly Net Evaporation-Precipitation Rates for Lake Texana
(*EV* Records for Control Point DV221A)

Observed Daily Flows at USGS Gages

Ten gage stations with daily stream flow data available at the U.S. Geological Survey (USGS) National Water Information (NWIS) website are listed in Table 2.3. Daily flows at nine of the ten gages are used to compile *DF* records as discussed later in Chapter 4. These nine sites are listed in Tables 3.3 through 3.5. Seven of the USGS gage sites are primary control points for monthly naturalized flows as indicated in Table 2.4. Two sites are assigned secondary control point identifiers. SB3 EFS are located at five gage sites identified in Tables 2.4 and 5.1.

Daily mean flows in cubic feet per second (cfs) at the sites in Table 2.4 and Tables 3.3-3.5 are plotted in Figures 3.6-3.14. Gage locations are shown in Figure 2.1. Watershed drainage areas, periods-of-record, and other information for each WAM control point (USGS gage site) are provided in Table 2.4 and Tables 3.3-3.5. The period-of-record of each gage covering the 1940-2021 WAM hydrologic period-of-analysis and 1997-2021 extension are shown in Tables 3.4-3.5.

Table 3.3
USGS Gage Sites with Daily Flows Plotted in Figures 3.6 through 3.14

USGS No.	Location	Period-of-Record	Drainage Area (square miles)	CP ID
08163500	Lavaca River at Hallettsville	Aug 1939 – present	108	GS400
08164000	Lavaca River near Edna	Aug 1938 – present	817	GS300
08164300	Navidad River near Hallettsville	Oct 1961 – present	332	GS600
08164350	Navidad River near Speaks	Oct 1981 – Jan 2022	437	GS550
08164390	Navidad at Strane Park nr Edna	Oct 1996 – present	579	DV501
08164450	Sandy Ck near Ganado	Oct 1978 – present	289	GS1000
08164500	Navidad River near Ganado	Jun 1939 – 5 Jul 1999	1,062	GS500
08164503	West Mustang Creek nr Ganado	Oct 1978 – present	178	WGS800
08164504	East Mustang Creek nr Louise	Oct 1996 – present	53.9	ECB720

Table 3.4
Gage Records of Daily Observed Flows within the 1940-2021 Period-of-Analysis

CP	Location	Period-of-Record within 1940-2021	Missing (days)
GS400	Lavaca River at Hallettsville	1Jan1940–30Sep1992, 10Oct2015-31Dec2021	8,400
GS300	Lavaca River near Edna	1 Jan 1940 – 31 Dec 2021	0
GS600	Navidad River nr Hallettsville	1 Oct 1961 – 31 Dec 2021	7,945
GS550	Navidad River near Speaks	1Oct1981–29Sep1989, 1Oct1996-29Sep2000	25,570
DV501	Navidad at Strane Park Edna	1 Oct 1996 – 31Dec2021	20,729
GS1000	Sandy Ck near Ganado	1Oct1978–29Sep2013, 30Sep2014-31Dec2021	14,520
GS500	Navidad River near Ganado	1Jan1940–21May1980, 24Jun1999-5Jul1999	15,188
WGS800	West Mustang Creek Ganado	1 Oct 1977 – 31 Dec2021	13,789
ECB720	East Mustang Creek Louise	1 Oct 1996 – 31 Dec2021	20,728

Table 3.5
Gage Records of Daily Observed Flows within the 1997-2021 Extension Period

CP	Location	Records within 1997-2021	Values (days)	Missing (days)
GS400	Lavaca River at Hallettsville	1 Oct 2015 – 31 Dec 2021	2,284	6,847
GS300	Lavaca River near Edna	1 Jan 1997 – 31 Dec 2021	9,131	0
0GS600	Navidad River nr Hallettsville	1 Jan 1997 – 31 Dec 2021	9,130	1
GS550	Navidad River near Speaks	1 Jan 1997 – 29 Sep 2000	1,368	7,763
DV501	Navidad at Strane Park Edna	1 Jan 1997 – 31 Dec 2021	9,130	1
GS1000	Sandy Ck near Ganado	1 Jan 1997 – 31 Dec 2021	8,764	367
GS500	Navidad River near Ganado	24 Jun 1999 – 5 Jul 1999	12	9,119
WGS800	West Mustang Creek Ganado	1 Jan 1997 – 31 Dec 2021	9,130	1
ECB720	East Mustang Creek Louise	1 Jan 1997 – 31 Dec 2021	9,131	0

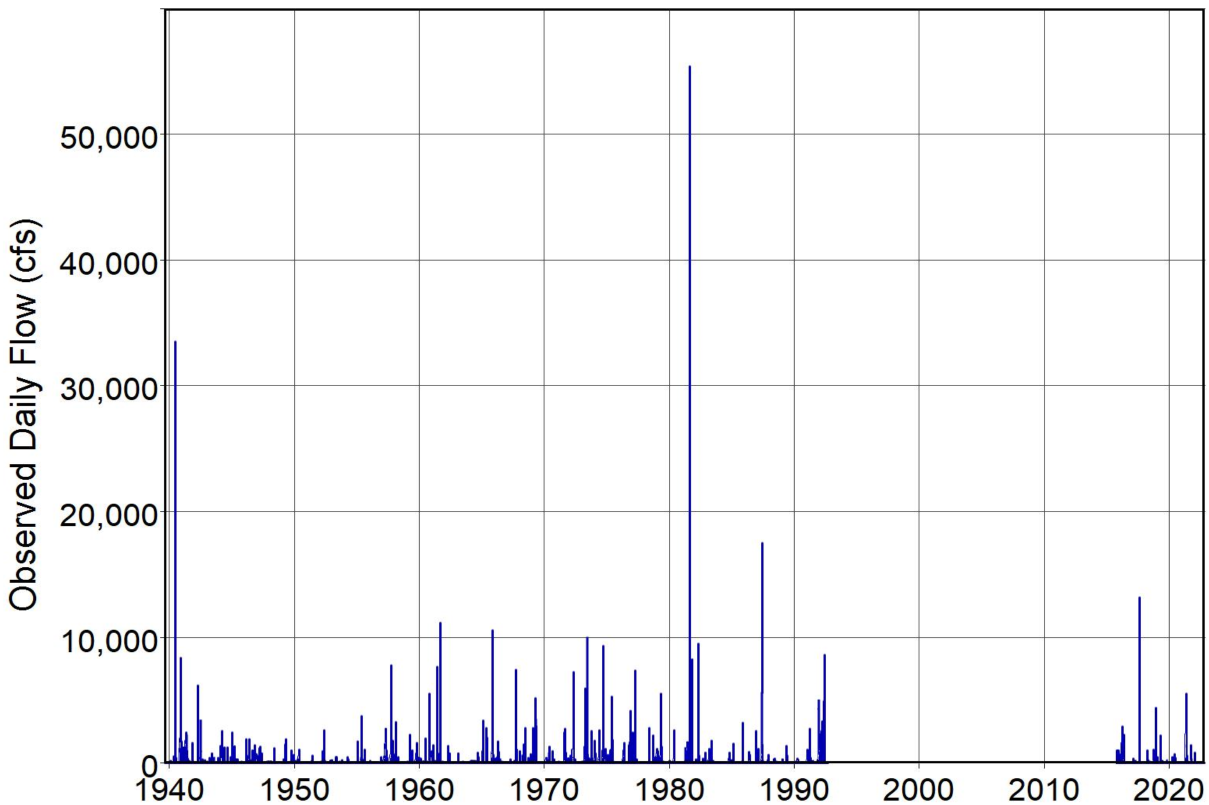

Figure 3.6 Daily Flows of Lavaca River at Hallettsville (control point GS400)

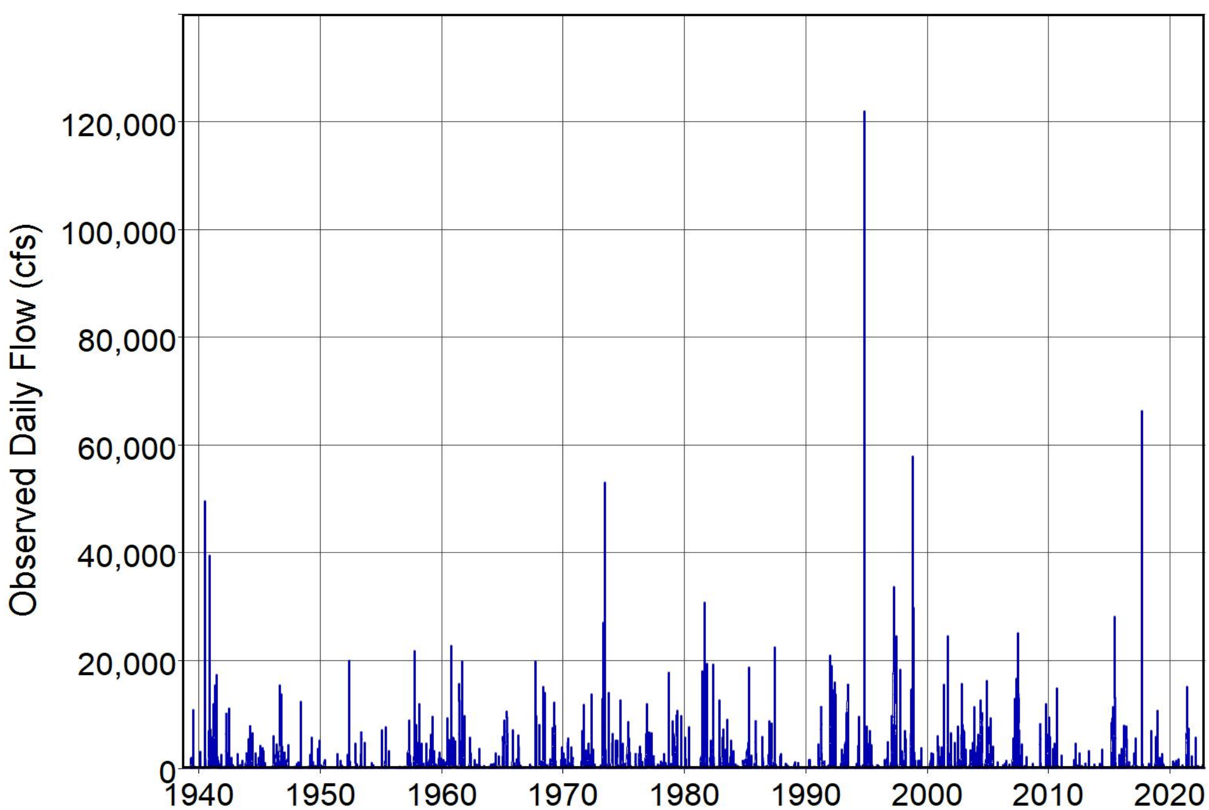

Figure 3.7 Daily Flows of Lavaca River near Edna (control point GS300)

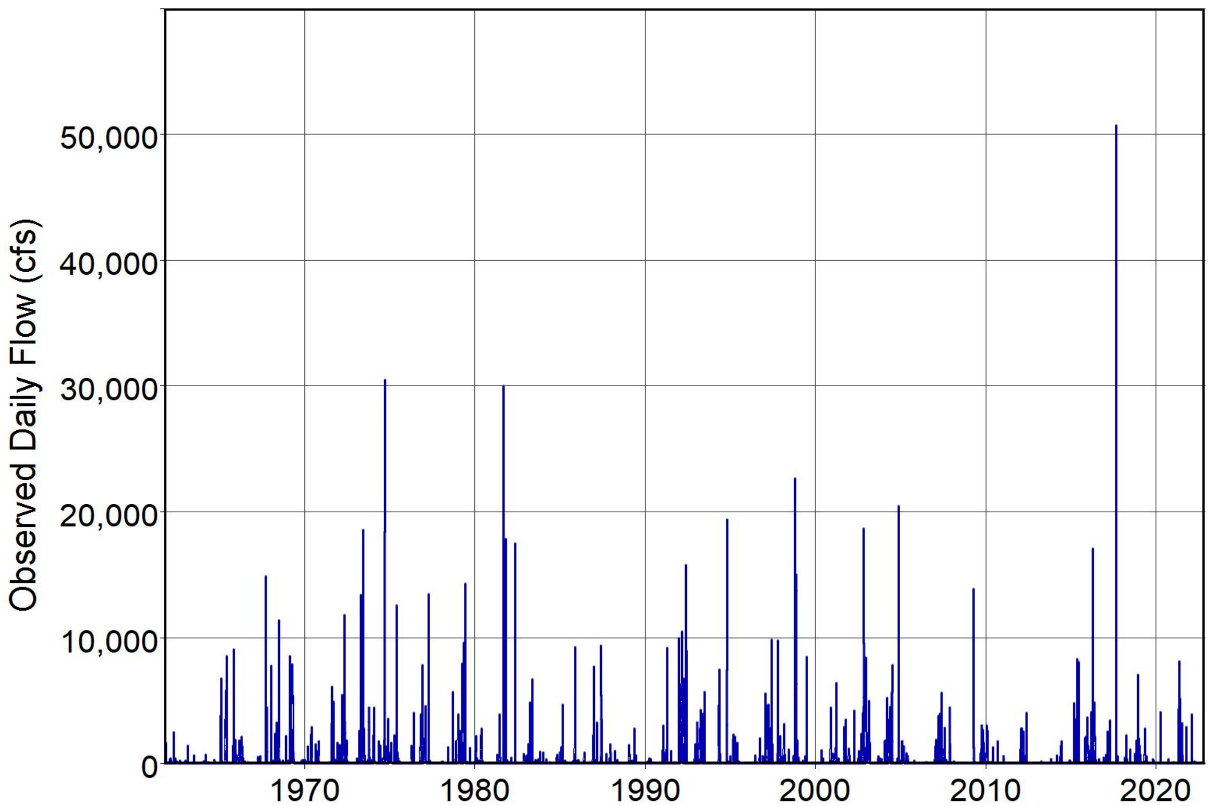

Figure 3.8 Daily Flows of Navidad River near Hallettsville (GS600)

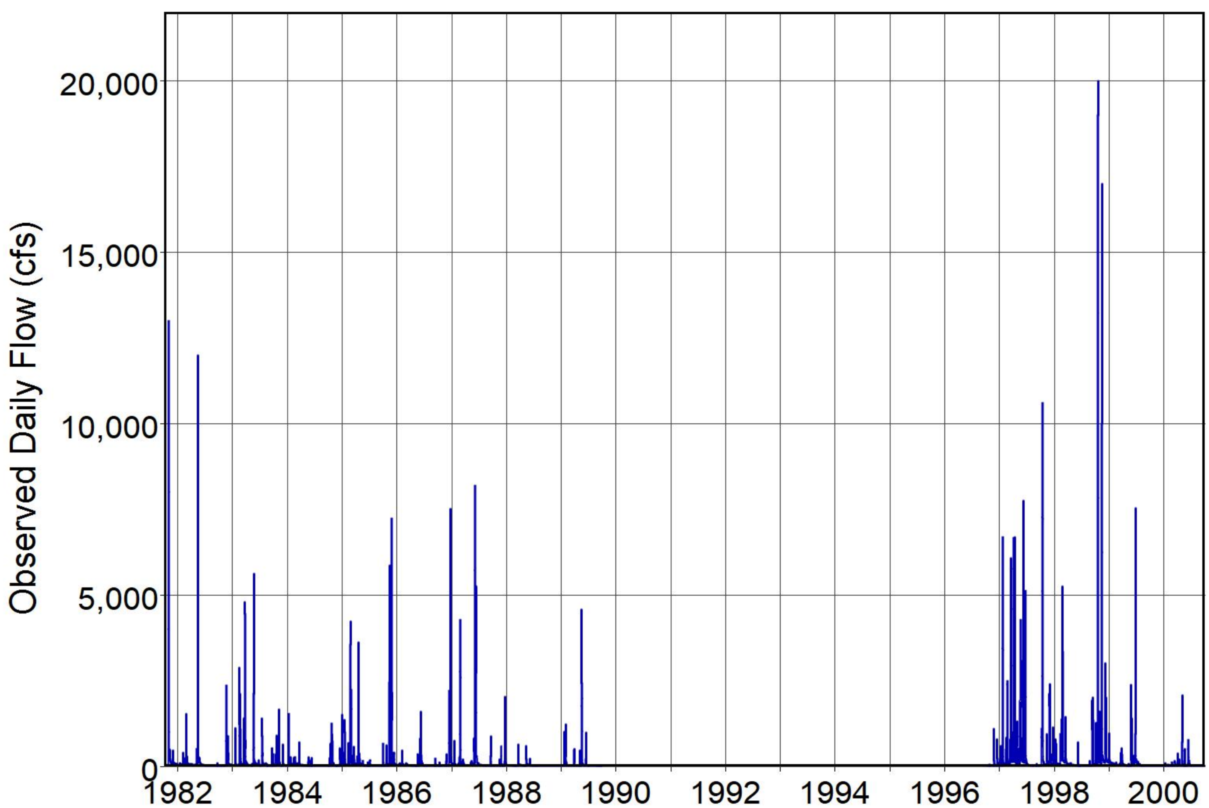

Figure 3.9 Daily Flows of Navidad River near Speaks (GS 550)

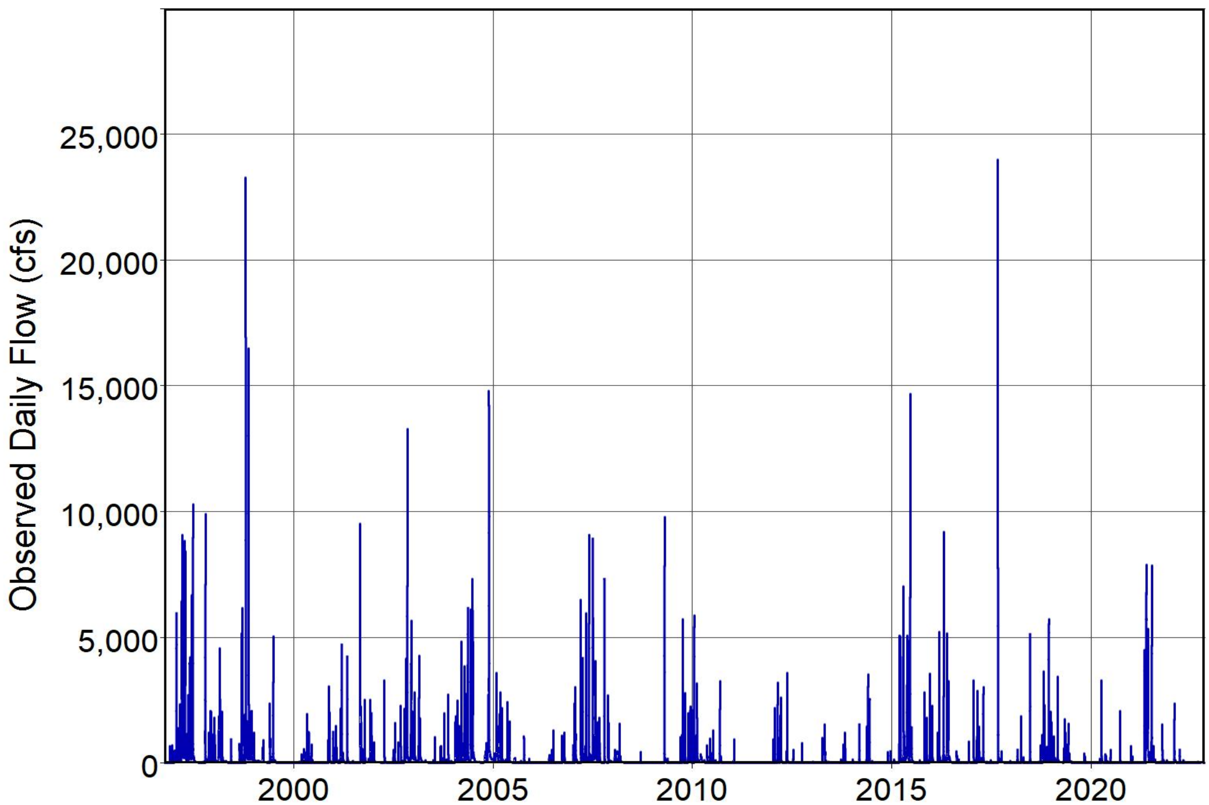

Figure 3.10 Daily Flows of Navidad River near Speaks (DV501)

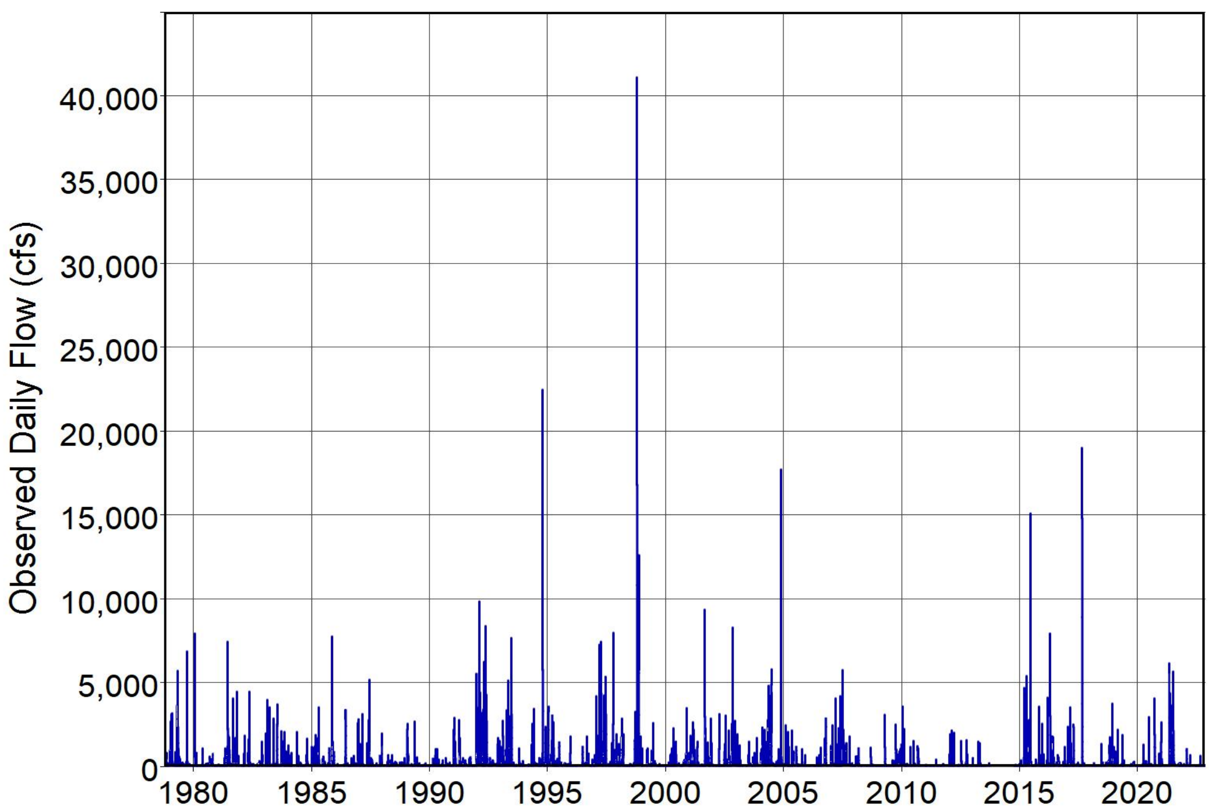

Figure 3.11 Daily Flows of Sandy Creek at Strane Park near Edna (GS1000)

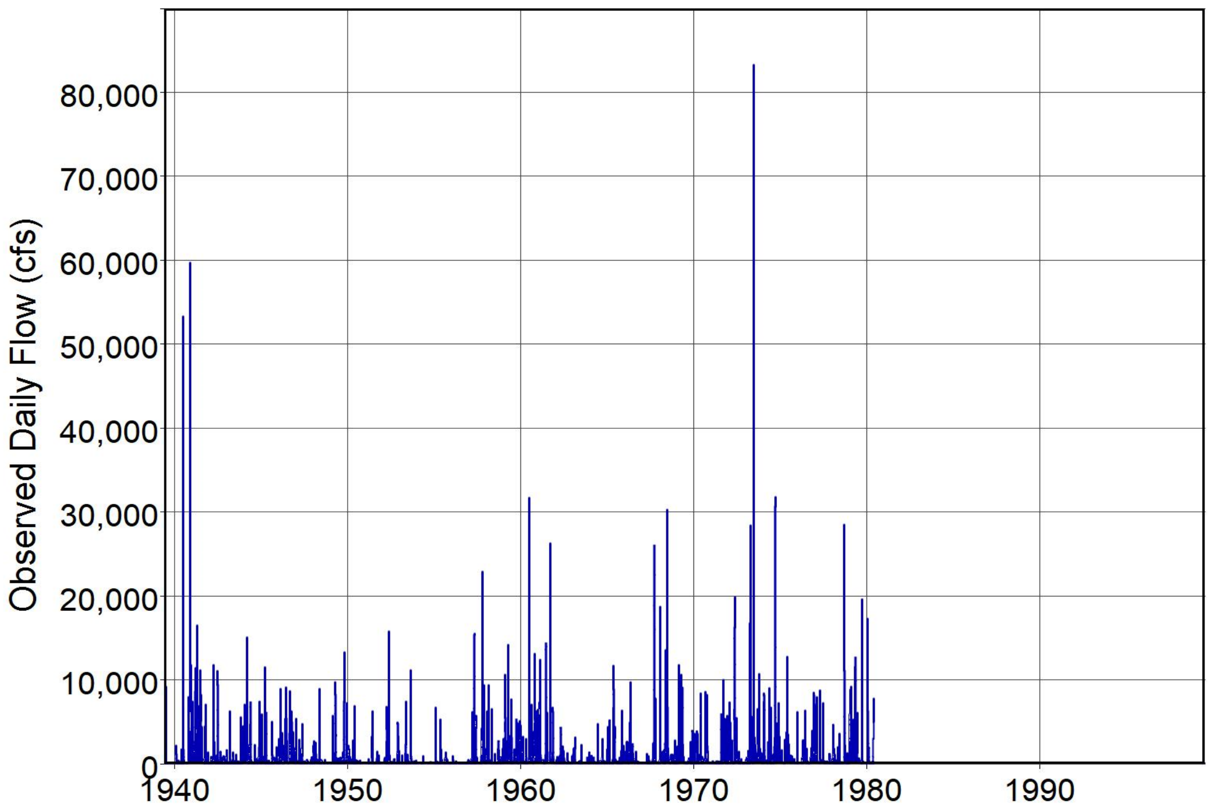

Figure 3.12 Daily Flows of Sandy Creek at Strane Park near Edna (GS500)

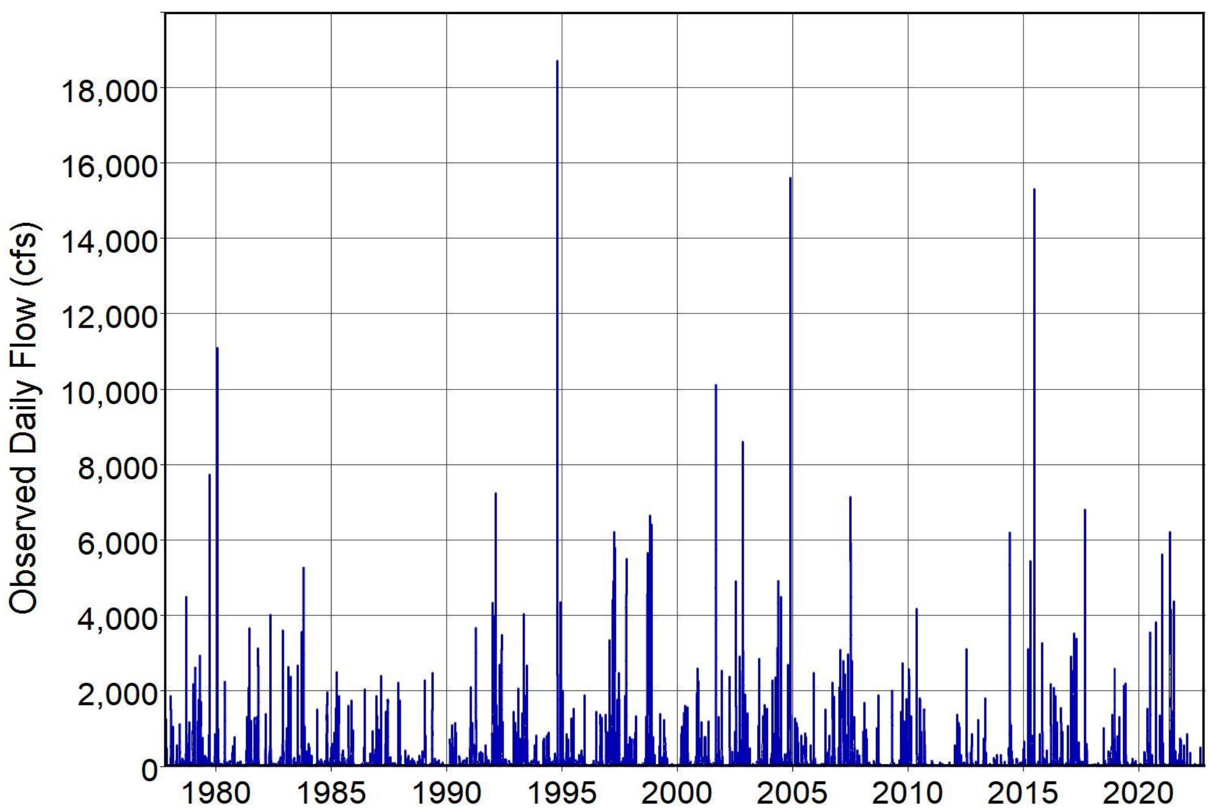

Figure 3.13 Daily Flows of West Mustang Creek near Ganado (WGS800)

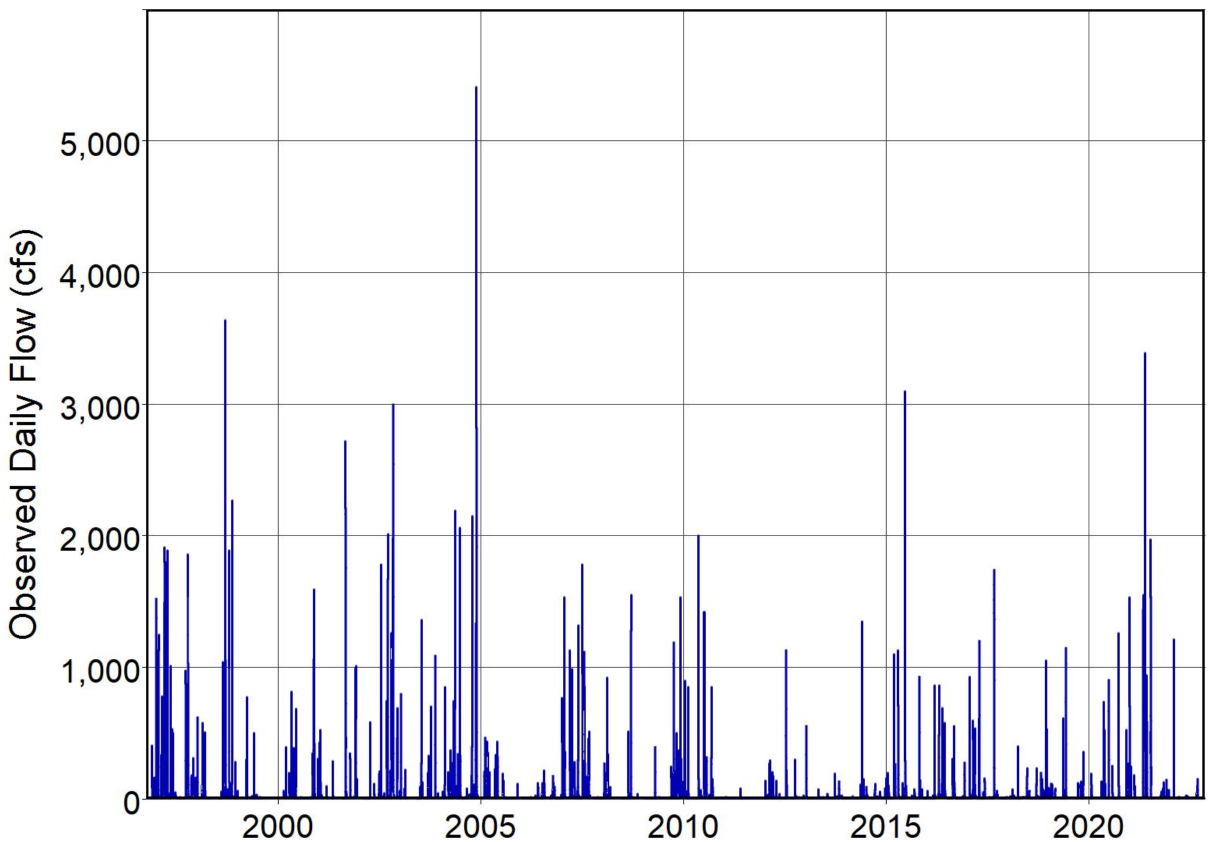

Figure 3.14 Daily Flows of East Mustang Creek near Louise (ECB720)

The daily flows downloaded from the USGS NWIS and other datasets derived therefrom are stored in a DSS file with filename LavacaAuxiliaryData.DSS that accompanies this report. *HEC-DSSVue* was employed to develop the time series plots presented throughout this report and perform computations and analyses discussed in this chapter including aggregating daily mean flows in cfs to monthly flow means in cfs and monthly flow volumes in acre-feet/month.

WAM Monthly Naturalized Flows

The original January 1940 through December 1996 hydrologic period-of-analysis has been updated to extend through December 2021 for the January 2023 daily and monthly Lavaca WAMs. Monthly naturalized flows for 1940-2021 at seven control points are stored on *IN* records in the simulation hydrology input file. The monthly naturalized flows at 178 secondary control points are synthesized during a *SIM* or *SIMD* simulation by applying drainage area ratios to the *IN* record flows at the seven primary control points as specified by *FD* and *WP* records in the DIS file.

As shown in Figure 2.1, none of the primary control points are located downstream of Lake Texana. Almost all reservoir storage capacity in the basin is in Lake Texana. Almost all surface water use is supplied by Lake Texana. Most water supplied from Lake Texana is transported out of the Lavaca Basin. Surface water storage and use have had only minimal impact on observed flows at the seven primary control points, none of which are located downstream of Lake Texana. As previously noted, the current use scenario WAM includes 21 reservoirs with a total storage capacity of 167,716 acre-feet. The Lake Texana capacity of 165,692 acre-feet is 98.8% of the total. Twenty small reservoirs have a combined total storage capacity of 2,024 acre-feet.

The periods-of-record at the USGS gages are shown in Tables 3.3, 3.4, and 3.5. The number of days of missing gage data during the original 1949-1996 WAM hydrologic period-of-analysis and the 1997-2021 extension are tabulated in Table 3.6. The periods 1940-1996 and 1997-2021 are comprised of 20,819 days and 9,131 days, respectively. The gage at control point GS300 on the Lavaca River near Edna is the only gage with a complete 1940-2021 record with no days without recorded daily flows. Gaps in the observed stream flow data is a significant issue in compiling *IN* record monthly naturalized flows and *DF* record daily flow pattern hydrographs.

Table 3.6
Stream Flow Data at Primary Control Points

Control Point	USGS Gage Location River and Nearest Town	Days of Missing Data 1940-1996	Days of Missing Data 1997-2021	Adopted Extension
GS400	Lavaca River at Hallettsville	1,553	6,847	TWDB
GS300	Lavaca River near Edna	0	0	USGS
GS600	Navidad River nr Hallettsville	7,944	1	USGS
GS550	Navidad River near Speaks	17,807	7,763	TWDB
GS1000	Sandy Creek near Ganado	14,513	367	Combined
GS500	Navidad River near Ganado	6,069	9,119	TWDB
WGS800	West Mustang Creek Ganado	13,789	1	USGS

The original *IN* records of 1940-1996 monthly naturalized flows at the seven primary control points were adopted without revision for the January 2023 WAM hydrology dataset. *IN* records of 1997-2021 monthly naturalized flows for the updated January 2023 WAM hydrology dataset were compiled as follows.

- Observed daily flows aggregated to monthly volumes were adopted for control points GS300, GS600, and WGS800. The one day of missing data at GS600 and WGS800 was synthesized by linear interpolation of flows in adjacent days.
- Extensions performed by the TWDB were adopted for control points GS400, GS550, and GS800. TWDB filled in gaps of missing data using linear regression.
- Control point GS550 has a continuous year and several other scattered days of missing data. The TWDB flow extension was adopted for the gaps with missing observed flows. The USGS observed flows were adopted for the remainder of the 1997-2021 extension period.

Strategies for adopting 1997-2021 monthly naturalized flows for incorporation in the hydrology input dataset for the Lavaca WAM are noted in the preceding paragraph and last column of Table 3.6 and discussed later in this chapter. Linear regression analyses between flows at different gages were employed by the USBR to fill in gaps of missing data in compiling the 1940-1996 *IN* record flows and by the TWDB in the 1997-2021 extension of the *IN* record flows.

The following discussions include plots of monthly flows that include the original 1940-1996 naturalized flows, 1997-2021 TWDB extended flows, and 1940-2021 observed flows at the seven primary control points. The monthly flows adopted for *IN* records in the January 2023 WAM hydrology dataset are described on the preceding page. Other datasets are plotted as well for comparative analyses.

TWDB Flow Extensions

TWDB staff have updated the *IN* and *EV* records for nine WAMs including the Lavaca WAM (https://www.twdb.texas.gov/surfacewater/data/ExtendedNatFlow/index.asp). Seven sets of TWDB extended 1997-2021 *EV* records are incorporated in the January 2023 Lavaca WAM as discussed earlier in this chapter. *IN* record monthly flow extensions developed by the TWDB were adopted for several of the control points in the January 2023 Lavaca WAM as noted on the preceding page and discussed later. The extended *IN* record naturalized flow datasets at the TWDB website were generated by TWDB staff using linear regression between historical gaged flow and available existing naturalized flow and between naturalized flows at different locations [14].

The 1940-2021 monthly naturalized flows in acre-feet/month at the seven primary control points plotted in Figures 3.15 through 3.21 combine the original 1940-1996 WAM *IN* record flows with the TWDB 1997-2021 extended flows. The *IN* records were downloaded from the TWDB website and converted into a DSS file for plotting and analysis with *HEC-DSSVue*.

The USGS gage on the Lavaca River at Edna (control point GS300) is the only gage site with a complete record of observed daily flows during 1940-2021. The monthly aggregation of September 1940 through August 2022 observed daily flows at GS300 and the 1940-2021 *IN* record monthly naturalized flows of Figure 3.16 are compared in Figure 3.22 and Table 3.7. Statistics comparing 1940-1996 observed and naturalized flows and 1997-2021 observed and naturalized flows are tabulated in Table 3.7. The 1940-1996 monthly observed flow ranges from 0.20 to 437,699 acre-feet with a mean and median (50% exceedance) of 21,031 and 5,381 acre-feet,

The original 1940-1996 USBR naturalized flows are almost the same as the corresponding USGS observed flows. The 1997-2021 TWDB naturalized flows and observed flows are almost the same except for flows at GS300 on the Lavaca River near Edna. TWDB 1997-2021 naturalized flows are based on linear regression of 1940-1996 naturalized and observed monthly flows.

Table 3.7
Comparison of Observed and Naturalized Flows at Control Point GS300 on Lavaca River

	1940-1996 (684 months)		1997-2021 (300 months)	
	Observed	Naturalized	Observed	Naturalized
mean (acre-feet/month)	21,031	20,914	25,089	14,260
median (acre-feet/month)	5,381	5,261	4,756	3,366
standard deviation (af/m)	42,069	42,059	51,711	29,207
minimum (ac-ft/month)	0.20	0.00	1.94	-81.0
maximum (ac-ft/month)	437,699	437,500	346,360	206,729

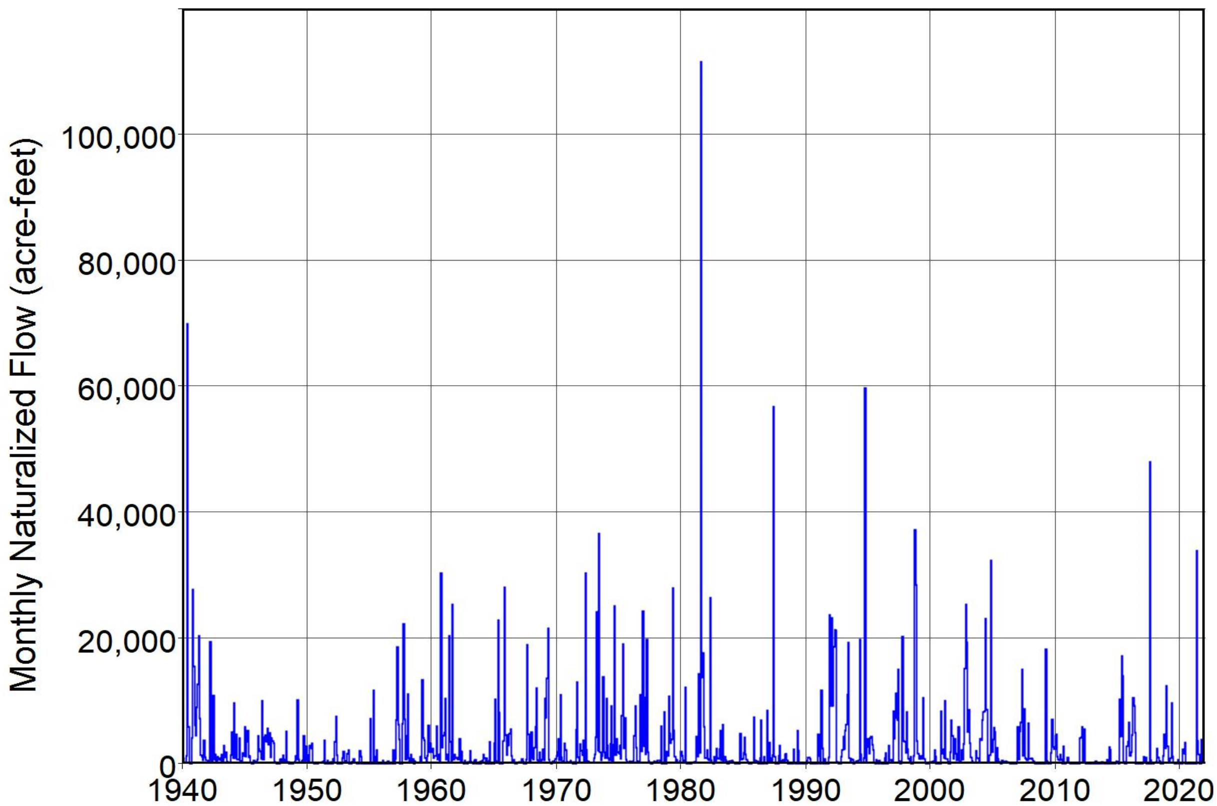

Figure 3.15 Monthly Naturalized Flows of Lavaca River at Hallettsville (GS400)

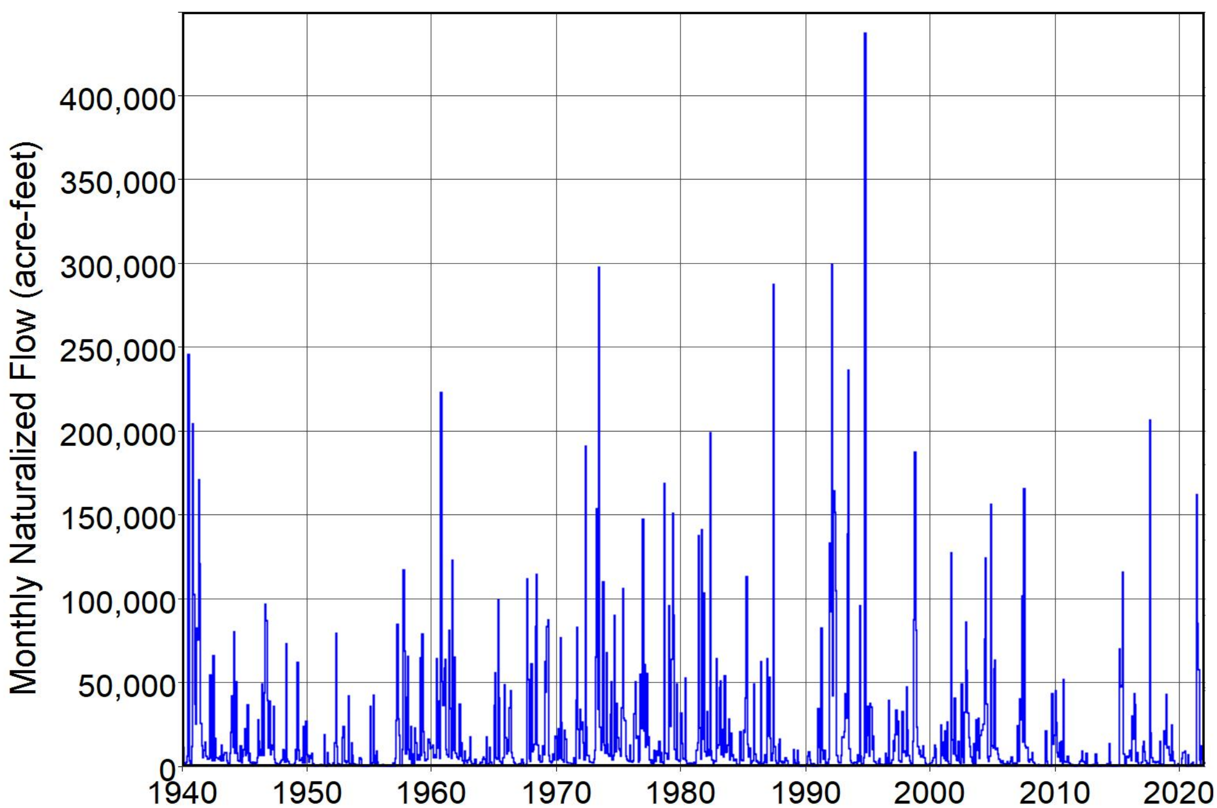

Figure 3.16 Monthly Naturalized Flows of Lavaca River near Edna (GS300)

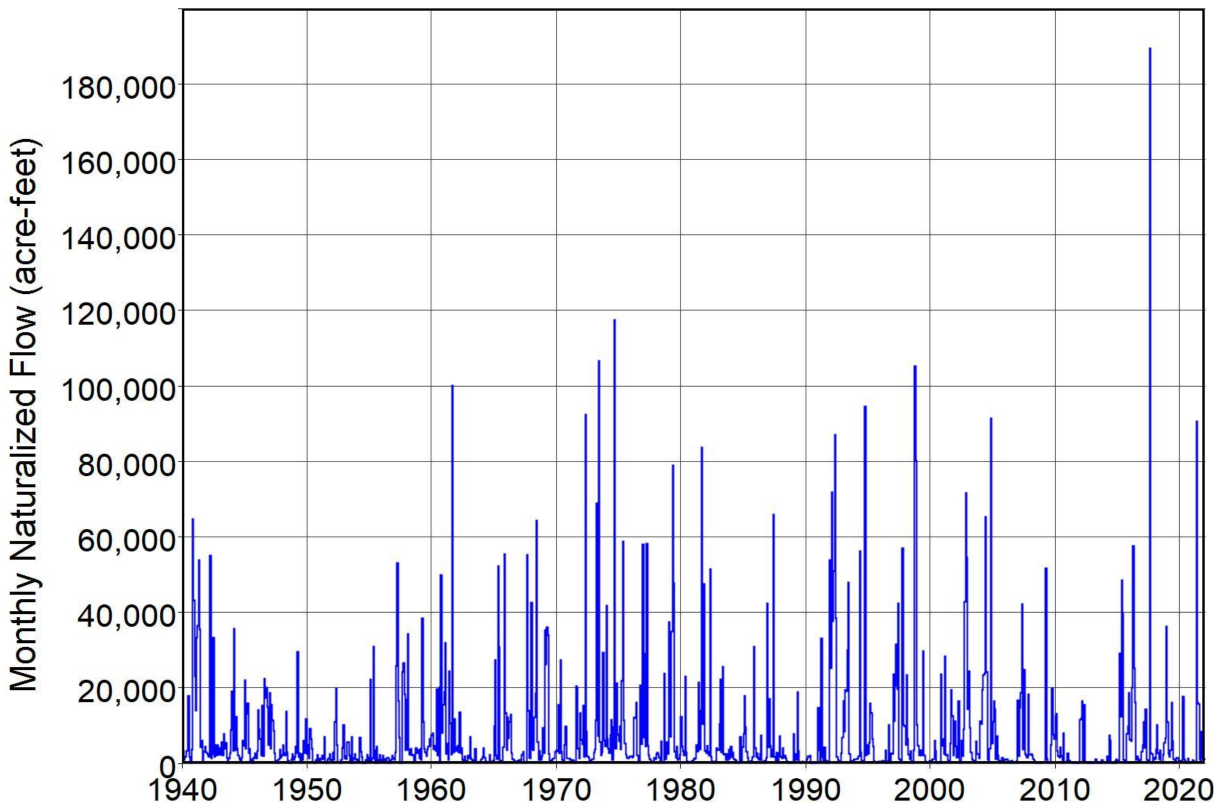

Figure 3.17 Monthly Naturalized Flows of Navidad River at Hallettsville (G600)

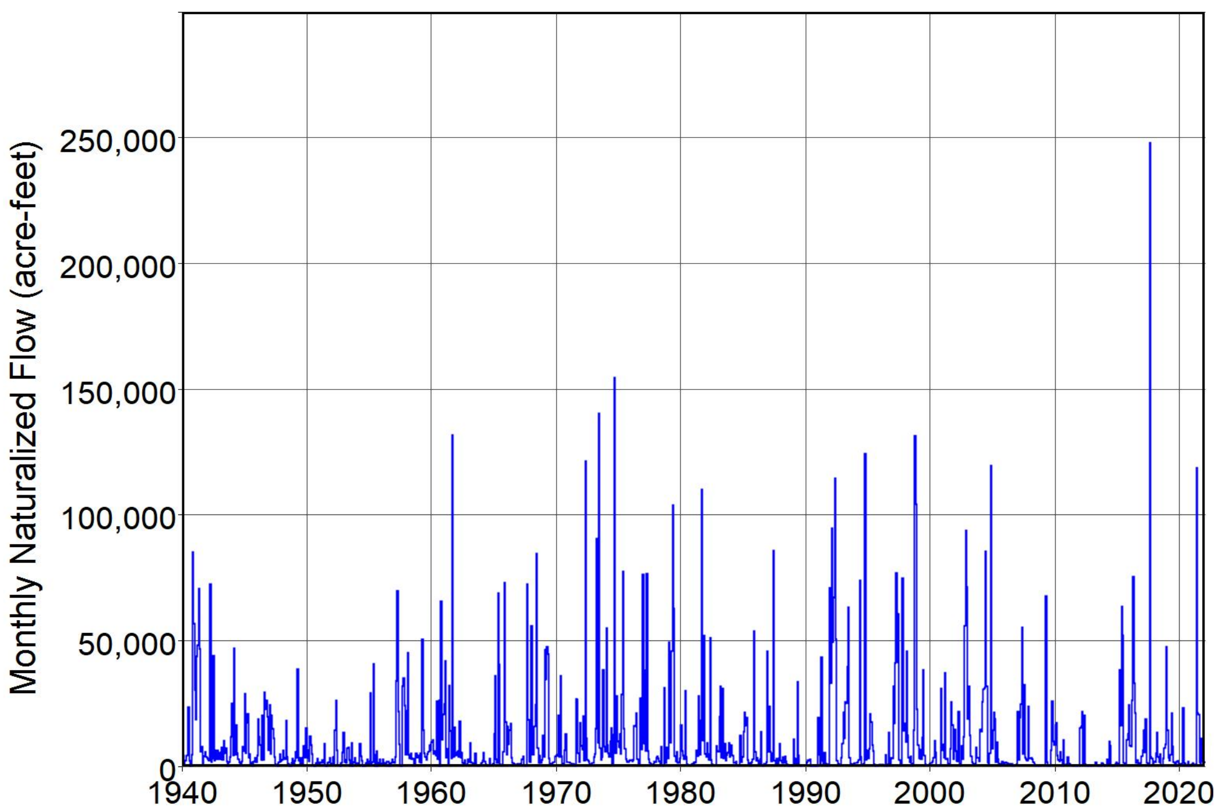

Figure 3.18 Monthly Naturalized Flows of Navidad River near Hallettsville (GS550)

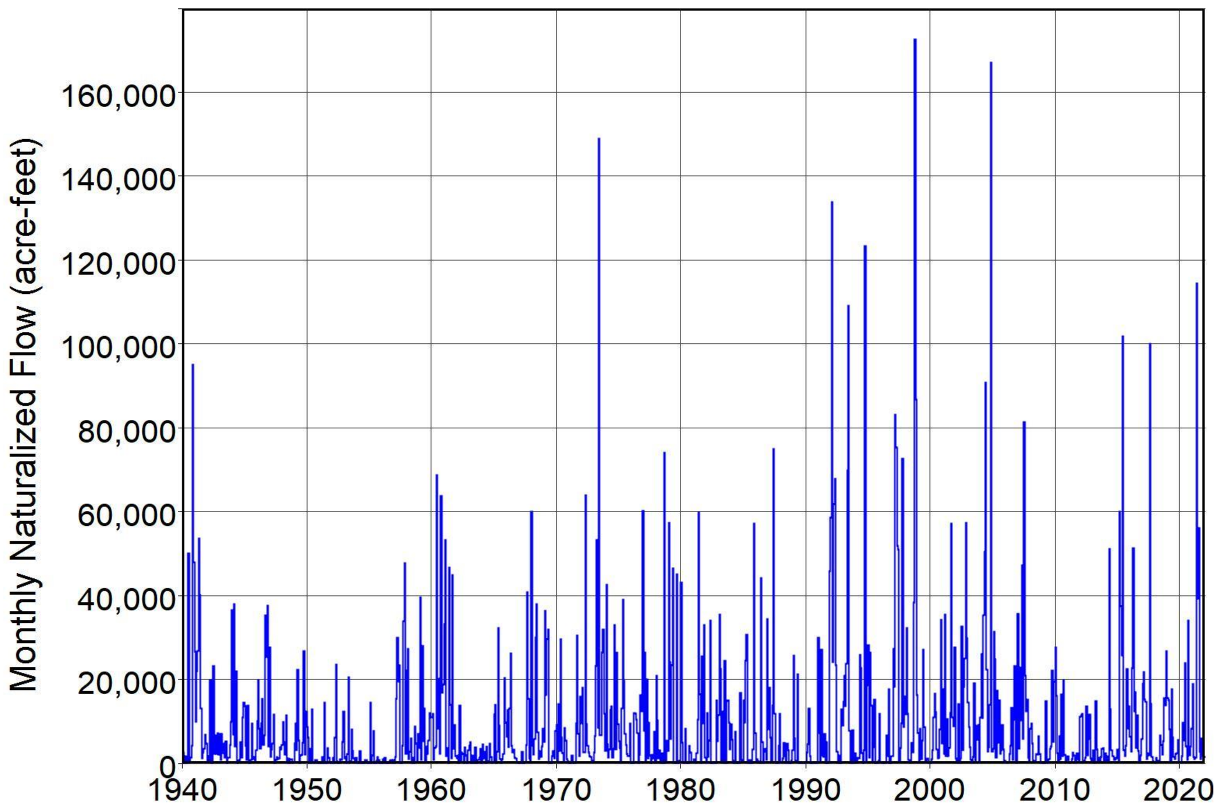

Figure 3.19 Monthly Naturalized Flows of Sandy Creek near Ganado (GS1000)

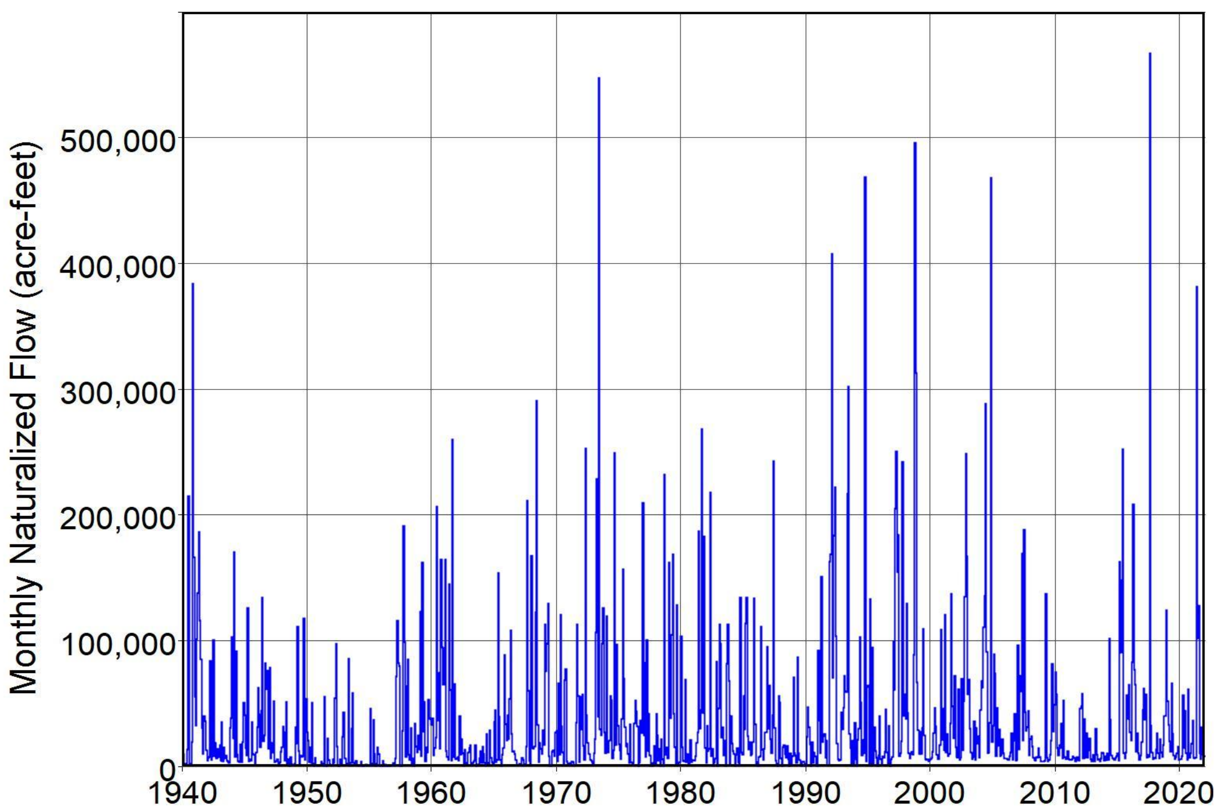

Figure 3.20 Monthly Naturalized Flows of Navidad River near Ganado (GS500)

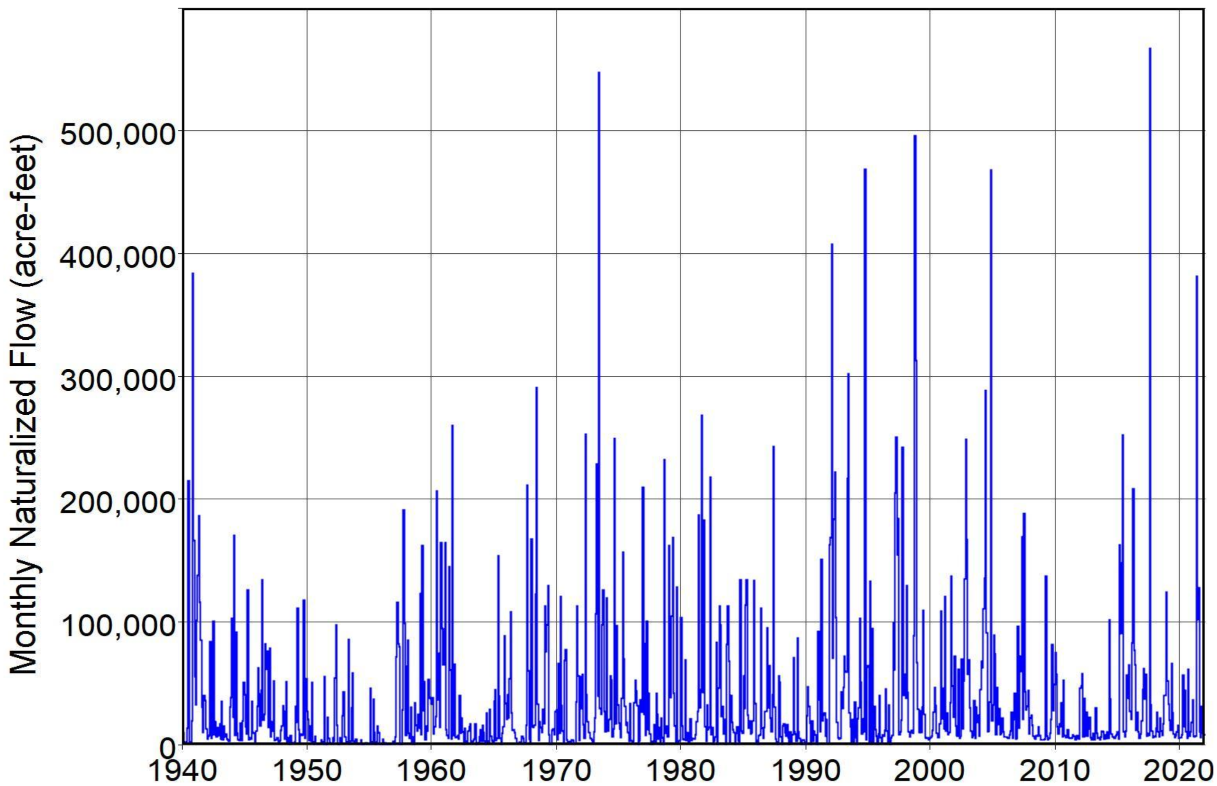

Figure 3.21 Monthly Naturalized Flows of West Mustang Creek near Ganado (WGS800)

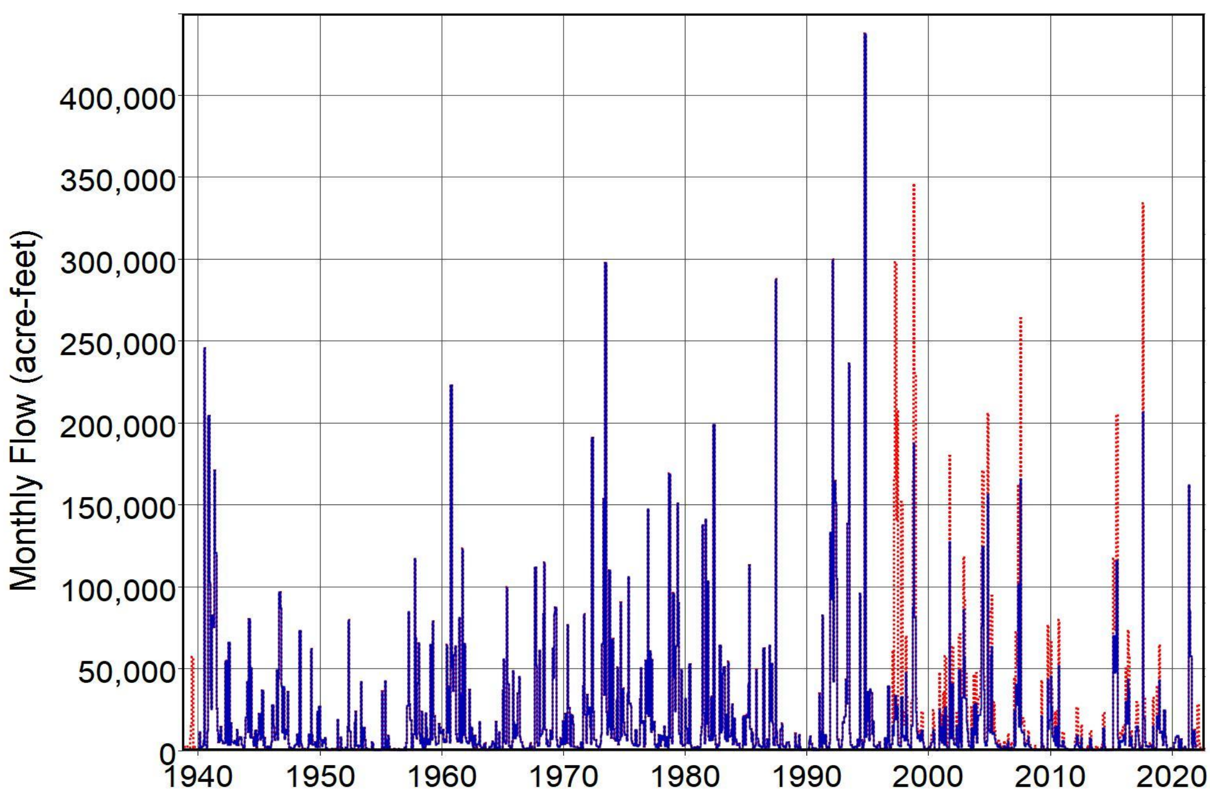

Figure 3.22 Monthly Observed (red dots) and Naturalized (blue solid line) Flows of Lavaca River near Edna (GS300)

Monthly Naturalized Flows in the January 2023 WAM

As previously discussed, the last column of Table 3.6 indicates which strategy is adopted for extending the *IN* records from 1997 through 2021 at each of the seven primary control points.

- Observed daily flows aggregated to monthly volumes are adopted for control points GS300, GS600, and WGS800 and, with the exception of one year, for control point GS1000. These sites have complete or almost complete observed flows during 1997-2021. The adopted monthly naturalized flows on *IN* records for the complete 1940-2021 hydrologic period-of-analysis are at these control points are plotted in Figures 3.23-3.26.
- The TWDB 1997-2021 extended monthly naturalized flows are adopted for control points GS400, GS550, and GS500 due to the large number of days with missing data in the gage records that must be filled in using regression. The adopted monthly naturalized flows on *IN* records for the complete 1940-2021 hydrologic period-of-analysis at these three control points are plotted in the previously presented Figures 3.15, 3.18, and 3.20.

The TWDB extended 1997-2021 monthly naturalized flows at control points GS300, GS600, and WGS800 plotted in Figures 3.16, 3.17, and 3.21 are not actually incorporated in the January 2023 WAM dataset. TWDB extended flows for only one year are adopted for GS1000 *IN* record flows plotted in Figure 3.19.

Figures 3.23-3.26 include the original 1940-1996 monthly naturalized flows and observed flows available from the USGS gage record during 1940-2021. Naturalized flows for 1940-1996 are almost the same as observed flows.

Sites relevant to the following discussion are listed in Tables 3.3, 3.4, and 3.5. Gage periods-of-records and gaps with missing data are identified in these tables. Daily flows were downloaded into a DSS file from the USGS NWIS website and aggregated to monthly flows within *HEC-DSSVue*. TWDB extended monthly naturalized flows were downloaded from the TWDB website and also stored in the DSS file. *HEC-DSSVue* was employed to perform comparative analyses of relevant observed and computed streamflow datasets. Findings of these analyses include the following observations.

The 1940-1996 monthly naturalized flows compiled by the USBR for the TCEQ are almost identical to USGS observed flows at all sites. TWDB 1997-2021 extended monthly naturalized flows are almost the same as observed flows at all sites except control point GS300 on the Lavaca River near Edna. The 1997-2021 observed flows versus flows computed by linear regression at this site are compared in Table 3.7 and Figure 3.22.

Surface water storage and use has had only minimal impact on observed flows at the seven primary control points, none of which are located downstream of Lake Texana. Almost all reservoir storage capacity in the basin is in Lake Texana. Almost all surface water use is supplied by Lake Texana. Most water supplied from Lake Texana is transported out of the Lavaca Basin.

Gaps in the observed stream flow data is an important consideration in compiling *IN* record monthly naturalized flows. Flows during days and months with missing observed data during 1940-2021 are synthesized by linear regression.

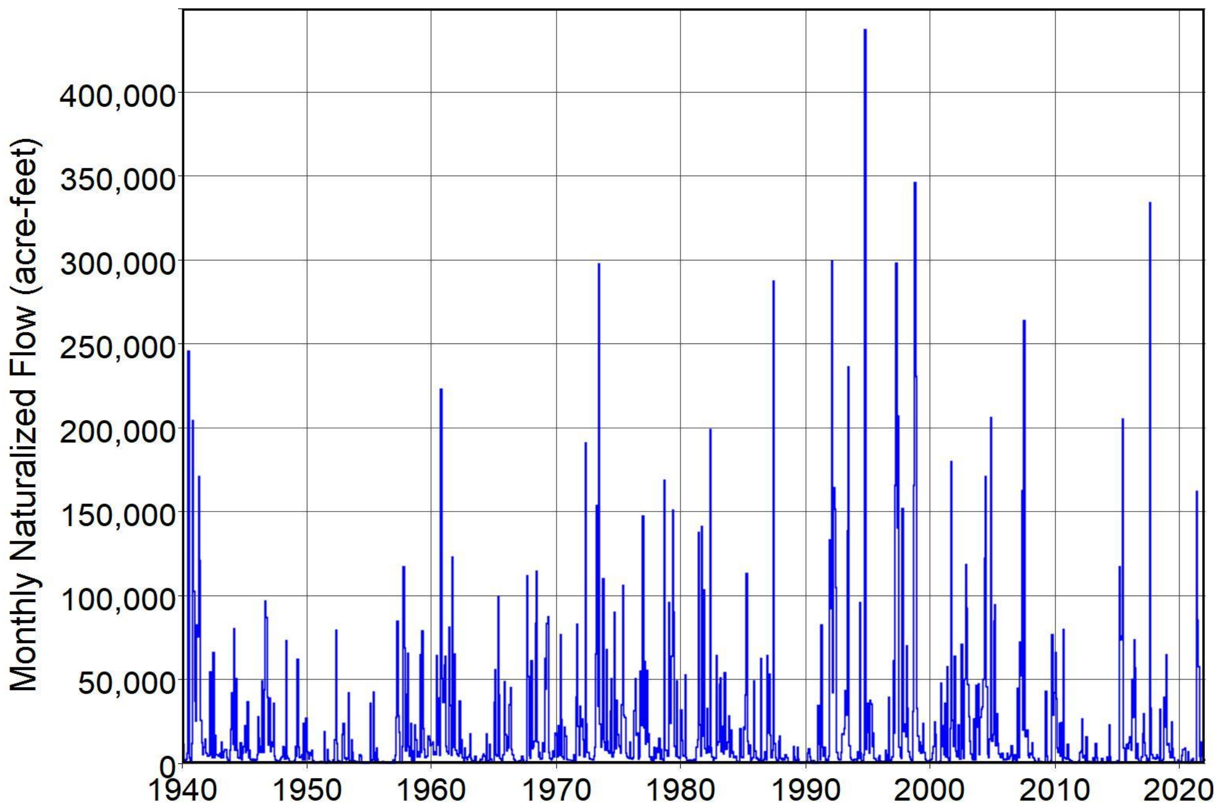

Figure 3.23 Monthly Naturalized Flows of Lavaca River near Edna (GS300)

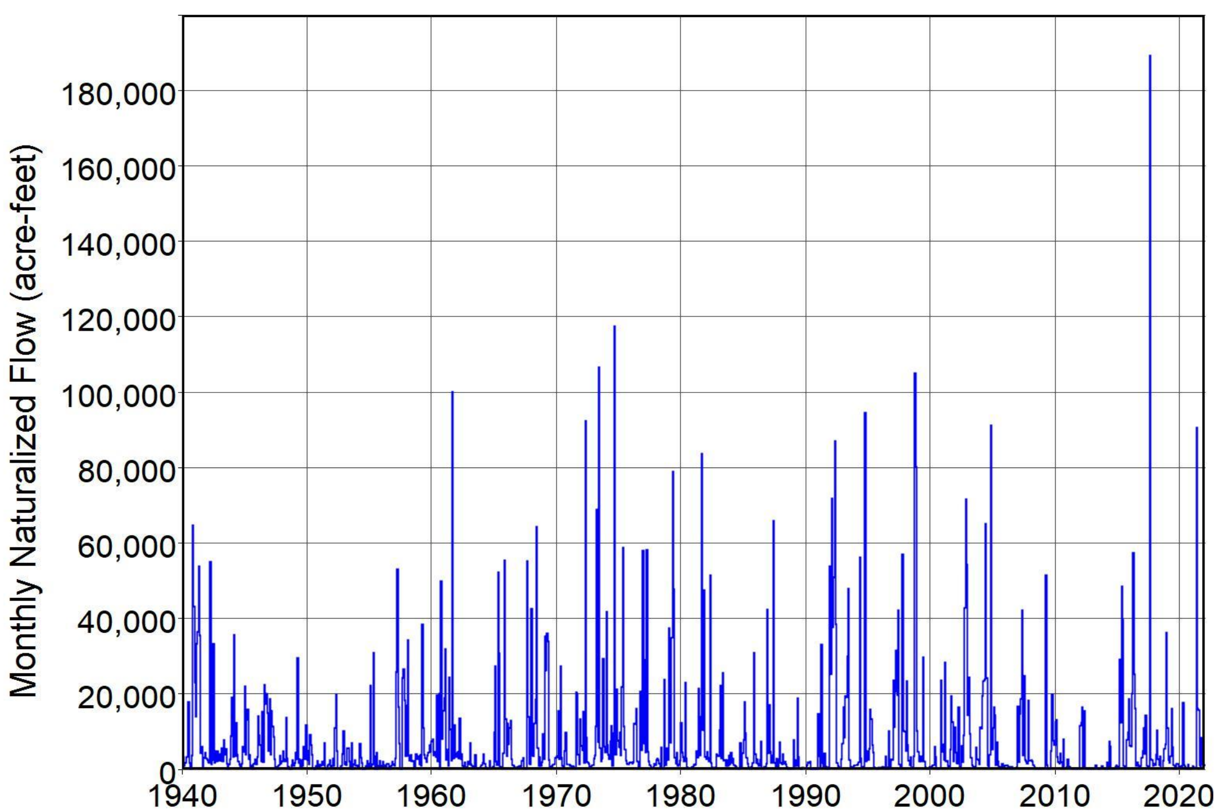

Figure 3.24 Monthly Naturalized Flows of Navidad River at Hallettsville (GS600)

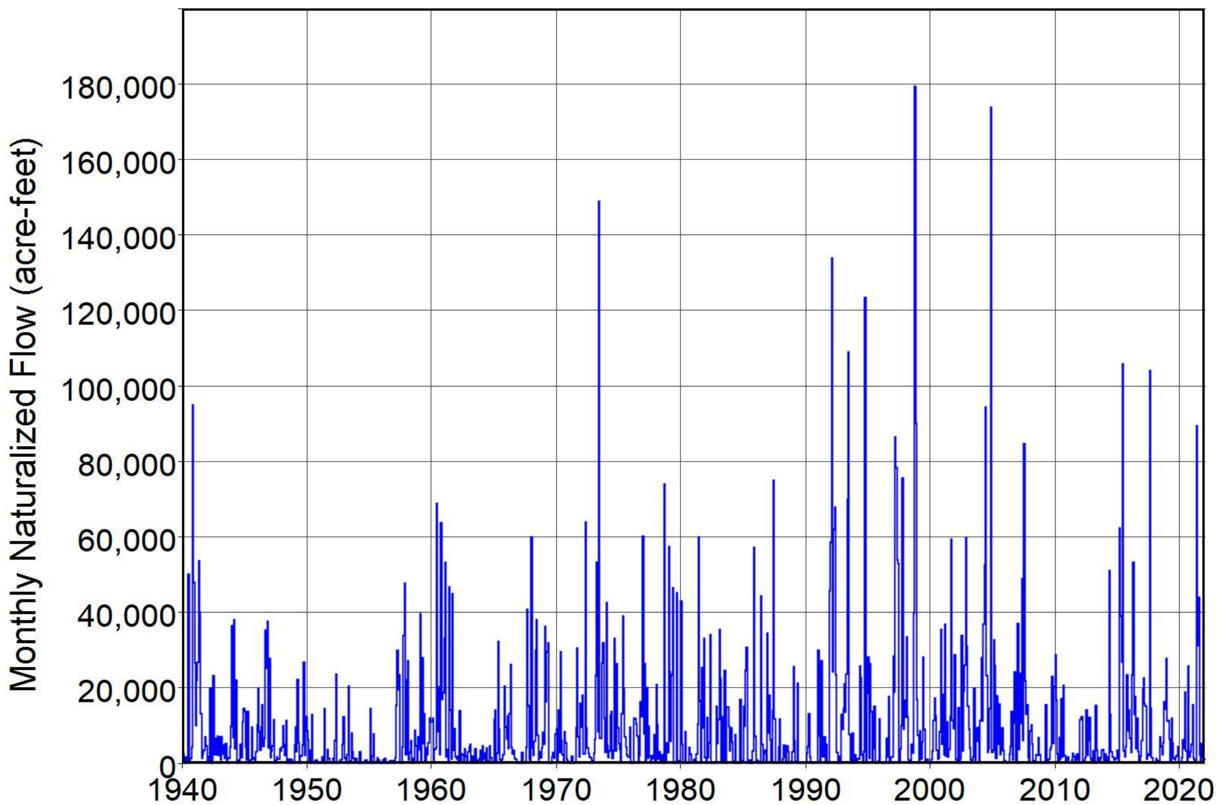

Figure 3.25 Monthly Naturalized Flows of Sandy Creek near Ganado (GS1000)

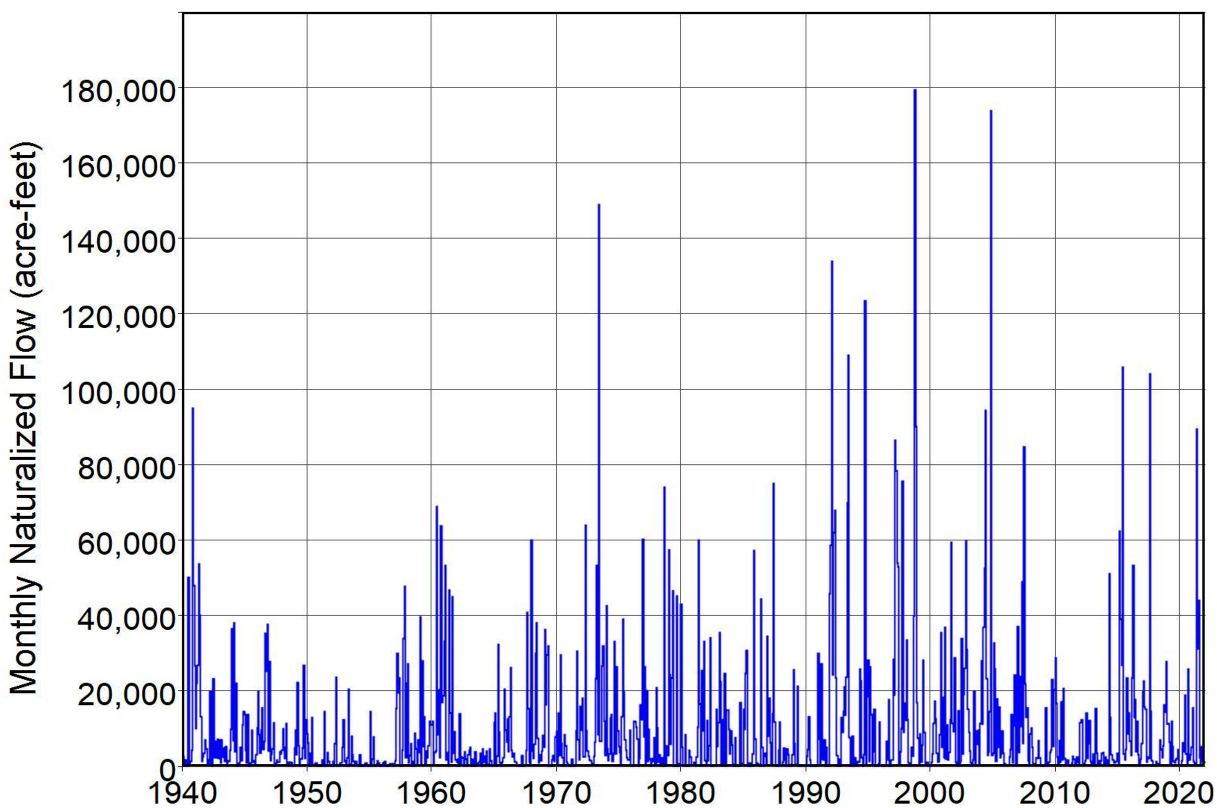

Figure 3.26 Monthly Naturalized Flows of West Mustang Creek near Granado (WGS800)

The gage at control point GS300 on the Lavaca River near Edna is the only gage with a complete 1940-2021 record with no days without recorded daily flows. The TWDB applied standard least-squares linear regression between flows at different sites to compute *IN* record monthly flows for periods of missing observed flow data. Likewise, the USBR previously applied standard linear regression computations to estimate *IN* record monthly flows for periods of missing data for the original 1940-1996 dataset.

The USGS observed daily flow record during 1997-2021 at control points GS400, GS550, and GS500 contain numerous days of missing data as indicated by Tables 3.5 and 3.6. Regression analyses were required to fill in the missing flow data. The TWDB extended 1997-2021 IN record monthly flows at these three control points were adopted for the January 2023 WAM. The 1940-2021 *IN* record flows for control points GS400, GS550, and GS500 are plotted in Figures 3.15, 3.18, and 3.20.

Observed flows were adopted for the 1997-2021 *IN* record monthly flow extension at control points GS300, GS600, GS1000, and WGS800. These gage sites have only minimal numbers of periods with missing data. The 1940-2021 *IN* record flows for control points GS300, GS600, GS1000, and WGS800 are plotted in Figures 3.23, 3.24, 3.25, and 3.20.

CHAPTER 4
CONVERSION OF MONTHLY LAVACA WAM TO DAILY

Actual real-world stream flow and other variables simulated in water availability modeling fluctuate continuously over time. Simulation computations dealing with continually varying variables are necessarily performed based on a fixed computational time interval. The monthly *SIM* employs a monthly computational time step, ignoring within-month variability. The daily *SIMD* employs a daily computational time step, ignoring within-day variability. The effects of computational time step choice on simulation results vary with different water management modeling situations and applications. Due to the extreme variability characteristic of stream flow, daily models are particularly relevant for modeling both the high flow pulse components of environmental flow standards and reservoir operations during floods [4].

Chapter 4 explains the conversion of the Lavaca WAM described in Chapter 2 from a monthly to daily time step. Chapter 5 describes the addition of environmental flow standards (EFS) adopted by the TCEQ in 2012 following procedures established by the 2007 Senate Bill 3 (SB3). Daily and monthly WAM simulation results are presented in Chapter 6.

The completed daily WAM is used to compute daily instream flow targets for SB3 EFS that are summed to monthly targets within the *SIMD* simulation. The monthly instream flow targets are stored in the shared DSS input file as time series *TS* records which are used by *IF* record instream flow rights in the monthly *SIM* simulation model as described in Chapters 5 and 6.

Daily *SIMD* Simulation Input Dataset

All of the *SIM* input records in the monthly Lavaca WAM dataset except records used to model SB3 EFS are also included in the daily Lavaca WAM dataset to be read by *SIMD*. Additional "*daily-only*" input records are added in the conversion of the monthly WAM to daily. Daily-only *SIMD* input records are explained in Chapter 4 of the *Users Manual* [2]. The only record required to switch a monthly WAM to daily is the *JT* record. All other records are optional, with defaults activated for blank fields or missing records.

The following daily records are included in the daily Lavaca WAM: *JT* and *JU* (daily options), *DC* (flow disaggregation), *DF* (daily flows), and *PF* (pulse flow component of environmental flow standards). *HC* and *ES* records are also used in modeling SB3 EFS in the daily Lavaca WAM. However, though not applied in the monthly Lavaca WAM, *HC* and *ES* records can be included in monthly *SIM* simulations and thus are covered in Chapter 3 rather than Chapter 4 of the WRAP *Users Manual*. The output file options *OF* record generally applicable to both monthly *SIM* and daily *SIMD* simulations includes options applicable to only daily simulations.

Flood control operations (*FR*, *FF*, *FV*, and *FQ* records) are not included in the daily Lavaca WAM since there is no designated flood control storage pool in Lake Texana or any other reservoirs in the Lavaca River Basin.

Based on experience with daily WAMs for other river basins [8, 9, 10, 11] and the small size of the Lavaca River Basin, lag and attenuation routing and forecasting are not activated in the Lavaca WAM. The purpose of routing is to adjust flow changes for the lag and attenuation effects of stream reaches with lag times that are significantly long relative to the computational time interval of one day. Forecasting is relevant only if routing is activated. Routing was concluded to not positively contribute to model accuracy for the Lavaca River system and was not adopted.

Stream flow is extremely variable. Capturing within-month daily variability in the monthly-to-daily disaggregation of naturalized stream flow is the key central component of converting a monthly WAM to daily. The monthly-to-daily naturalized flow disaggregation is highly non-uniform reflecting the great natural variability of stream flow.

All other monthly time series input data in the daily Lavaca WAM are uniformly disaggregated from monthly to daily. *SIMD* includes no alternative other than a uniform distribution for monthly-to-daily disaggregation of *EV* record net evaporation-precipitation depths or *CI* record constant inflows. These quantities are uniformly disaggregated by *SIMD* in proportion to the number of days (28, 29, 30, or 31) in each month.

Monthly water supply diversion targets are uniformly disaggregated to daily. Daily diversion targets in acre-feet/day are computed by *SIMD* by dividing monthly diversion target volumes by the number of days in each month. Likewise, with the exception of the instream flow targets for the SB3 EFS added as discussed in Chapter 5, *IF* record instream flow targets are uniformly distributed from monthly to daily. *SIMD* includes options for non-uniformly disaggregating monthly diversion and instream flow targets to daily, activated by input parameters on *JU*, *DW*, and *DO* records, but these options are not employed in the daily Lavaca WAM.

The daily Lavaca WAM *SIMD* input dataset is composed of DAT, DIS, DIF, and DSS files. The original flow distribution DIS file (*FD* and *WP* records) is used without modification in both the daily and expanded monthly versions of the WAM. The same DSS hydrology input file is shared by both the daily and expanded monthly versions of the WAM. The only differences between the current use and full authorization versions of the Lavaca WAM are reflected in the different DAT files.

A monthly simulation can be performed with *SIM* with a DAT file containing input records for a daily simulation. *SIM* skips over daily input records in the DAT file, does not read the DIF file, and ignores the *DF* records in the DSS time series input file. However, the daily *SIMD* has no option for skipping over the daily-only records in the DAT file, other than manually commenting (**) them out. *SIMD* can perform a monthly simulation if and only if no daily-only records are included in the input dataset.

Simulation Input DAT File Records

The records replicated as Table 4.1 are found at the beginning of the daily DAT file. The *JT*, *JU*, and *OF* records control daily simulation input, output, and computation options. The *SIMD* *JT* and *JU* records are analogous to the *SIM/SIMD JD* and *JO* records. *SIM/SIMD* input records applicable in both monthly and daily simulations are covered in Chapter 3 of the *Users Manual* [2]. *SIMD* input records applicable only in a daily *SIMD* simulation are explained in Chapter 4 of the *Users Manual* [2]. Although *OF* record field 4 entry DSS(3) has options that are relevant only to a daily simulation, the file options *OF* record is described in Chapter 3 of the *Users Manual*.

Table 4.1
SIMD DAT File Input Records for Controlling Daily Simulation Options

```
**      1       2       3       4       5       6       7       8
**3456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
JD    82    1940       1       0       0               6
JO     6
JT                                             0
JU     1   1
CO         GS300   DV501  GS1000  WGS800  ECB720
DF         GS300   GS400   GS500   GS550   GS600  GS1000  WGS800   DV501  ECB720
OF     0   0   2   1                                       Lavaca
OFV   15
```

The following options activated on the records shown in Table 4.1 contribute to the conversion of the monthly WAM to daily.

- ADJINC option 7 in *JD* record field 8 (column 56) is the recommended standard negative incremental flow adjustment option for daily simulations with forecasting as explained in *Daily Manual* Chapter 3 [4]. *JO* record *ADJINC* options 4 or 6 are the recommended standards for monthly simulations or daily simulations without forecasting. Option 5 was adopted in the original monthly Lavaca WAM.
- INEV option 6 in *JO* record field 2 (column 8) instructs *SIM* and *SIMD* to read *IN* and *EV* records from the hydrology DSS input file.
- DSS(3) option 2 is selected in *OF* record field 4 (column 16) to instruct *SIMD* to record both daily and monthly simulation results in a DSS output file. A one in *OF* record field 4 (column 20, DSS(4)=1) and variable 15 (instream flow target) on the accompanying *OFV* record results in instream flow targets for the five control points listed on the *CO* record being included in the simulation results DSS file.
- The input filename root Lavaca is entered in *OF* record field 12 to connect to the time series input file with filename LavacaHYD.DSS and hydrology files with filenames Lavaca.DIS and Lavaca.DIF. With field 12 blank, by default, the filename of the DSS, DIS, and DIF input files is the hydrology filename entered in *WinWRAP* which by default is the same as the DAT file.
- The *JT* record is required for a daily simulation, and the *JU* record activates certain daily options. Defaults are activated for blank fields or entries of zero on the *JT* and *JU* records.
- All fields of the *JT* record in Table 4.1 are blank. Several of these fields allow optional output tables to be created in the annual flood frequency AFF file and daily message SMM file. An entry of 1 for SUBFILE in field 11 (column 44) would activate the daily output SUB file.
- Flow disaggregation DFMETH option 1 (uniform) is set as the global default in *JU* record field 2 used for computational control points that do not reflect actual real stream flow sites. A *DC* record placed in the DIF file with REPEAT and DFMETHOD options 2 and 4 activate disaggregation option 4 based on *DF* record pattern hydrographs for all control points on the Lavaca River and its tributaries that have actual monthly naturalized stream flows.
- DFFILE option 1 is selected in *JU* record field 3 (column 12), meaning daily flow *DF* records are read from the hydrology input DSS file for the nine control points listed on the DAT file *DF* record in Table 4.1.

Environmental flow standards at five sites established by the TCEQ in collaboration with a science team and stakeholder committee through a process created by the 2007 Senate Bill 3 are modeled by adding *IF*, *ES*, *HC*, and *PF* records to the DAT file as described in Chapter 5.

Daily flows for the control points listed on a *DF* record in Table 4.1 are stored on *DF* records in the time series DSS input file along with the *IN* and *EV* records. The *DF* record daily flows are used by *SIMD* for disaggregating monthly naturalized stream flows to daily. Naturalized flow volumes in acre-feet/month are distributed to daily volumes in acre-feet/day in proportion to the daily flow pattern hydrographs recorded on *DF* records in the DSS file as explained in the next section.

Disaggregation of Monthly Naturalized Stream Flow to Daily

SIM and *SIMD* read monthly naturalized stream flow volumes from inflow *IN* records for the seven primary control points (Table 2.4). Both monthly *SIM* and daily *SIMD* simulations synthesize monthly naturalized flows at the 178 other secondary control points based on the monthly naturalized flows at the seven primary control points and parameters read from control point *CP*, flow distribution *FD*, and watershed parameter *WP* records. *SIMD* distributes the monthly naturalized flow volumes at each of the 185 control points to the 28, 29 (February of leap years), 30, or 31 days in each of the 984 months of the 1940-2021 hydrologic period-of-analysis.

Ungaged primary control point EP000 represents the outlet of the Lavaca River Basin at Lavaca Bay. GS300 is the most downstream gaged control point on the Lavaca River. DFMETHOD option 4 employing daily flows from *DF* records is applied to all control points upstream of the outlet at control point EP000 and at control point EP000. *JU* record DFMETH option 1 (uniform) applies to all other control points including disconnected artificial control points. The procedure described in the next paragraph is activated by the following DIF input file *DC* record which activates REPEAT and DFMETHOD options 2 and 4.

```
DC   EP000   2   4   GS300
```

Monthly naturalized stream flows at control point EP000 and all other control points located upstream of EP000 are disaggregated to daily using 1940-2021 daily flows at nine control points stored as *DF* records in the hydrology input DSS file. Monthly volumes are distributed to daily volumes in proportion to daily flows while maintaining the monthly volumes. The automated procedure in *SIMD* for repeating daily flows at multiple control points is described on page 28 of Chapter 2 of the *Daily Manual* [4]. The automated procedure consists of using flows at the nearest downstream control point if available, otherwise finding flows at the nearest upstream control point, and lastly if necessary using flows from another tributary.

DFMETH option 1 is selected in *JU* record field 2 (column 8 in Table 4.1) to apply the uniform monthly-to-daily naturalized flow disaggregation option for all of the other control points not located upstream of control point EP000. Thus, the selected default uniform disaggregation option (DFMETH=1) is applied to artificial control points employed in computational water accounting schemes that are not connected in the model to the actual outlet. Since GS300 is entered in field 5 of the *DC* record shown above, the *DF* record daily flow pattern hydrograph for control point GS300 found in the hydrology input file will also be applied for control point EP000.

Daily Flow Pattern Hydrographs

The dataset of *DF* records of daily 1940-2021 naturalized flow volumes in acre-feet at nine control points stored in the *SIMD* hydrology DSS input file with filename LavacaHYD.DSS are developed from daily means in cubic feet per second (cfs) of observed flow rates at USGS gages. The daily quantities on *DF* records are used in the *SIMD* simulation to determine the proportion of monthly naturalized flow volume to distribute to each of the 28, 29, 30, or 31 days in each of the 984 months of the 1940-2021 hydrologic period-of-analysis at all relevant control points.

The daily flow *DF* records are employed in the *SIMD* simulation for the sole purpose of serving as pattern hydrographs used in disaggregating monthly naturalized flows to daily. Therefore, only the pattern of the quantities on the *DF* records within each of the 984 months, not the actual magnitude of the individual quantities for each day, affect *SIMD* simulation results. The *DF* record daily flows can be in any units and are not required to reflect a specific single site. However, the *DF* records for the Lavaca WAM contain daily naturalized flows in acre-feet/day. The *DF* records of daily naturalized flows can be easily tabulated or plotted in *HEC-DSSVue*.

The following tasks were performed in developing the dataset of *DF* records of 1940-2021 daily flows at nine control points.

1. Available daily observed flow data were explored to select control points for inclusion in the dataset of *DF* records. A determination was made to develop *DF* records for each of the nine primary control points listed in Tables 2.3 and 2.4 and shown in Figure 2.1.
2. Observed flows at relevant USGS gages as daily means in cfs were compiled as a DSS file from the U.S. Geological Survey (USGS) National Water Information System (NWIS) website using the data import feature of *HEC-DSSVue*.
3. Periods-of-record for each of the USGS gages is listed in Tables 3.3-3.5. Eight of the nine gage sites do not have periods-of-record covering the entire WAM 1940-2021 hydrologic period-of-analysis. Gage records at two or more sites were combined as necessary to develop complete 1940-2021 sequences of observed daily flows in cfs.
4. The 1940-2021 daily flows in cfs at the nine control points were converted within *HEC-DSSVue* to a *SIMD* input dataset of *DF* records with flows in cfs. *SIMD* was executed with this dataset. The *SIMD* simulation results included naturalized daily flows in acre-feet/day.
5. The daily naturalized flows recorded by *SIMD* in its simulation results DSS file were converted within *HEC-DSSVue* to another dataset of *DF* records. This final dataset of *SIMD* input *DF* records consists of 1940-2021 daily naturalized flows in acre-feet/day at nine control points.

<u>Observed Daily Flows at USGS Gages</u>

DF record daily flows are developed from observed flows at the USGS gages listed in Table 4.2. The daily observed flows are discussed in Chapter 3 and plotted in Figures 3.6-3.14. Periods-of-record are tabulated in Tables 3.3, 3.4, and 3.5. The number of days of missing data during the WAM 1940-2021 hydrologic period-of-analysis is shown in the last column of Table 4.2. The January 1, 1940 through December 31, 2021 hydrologic period-of-analysis consists of 29,951 days. USGS gage 08164000 on the Lavaca River near Edna is the only gage station that has a complete record covering the 29,951 days of the 1940-2021 period-of-analysis with no missing data. The other gages have multiple days of missing data during 1940-2021 ranging from 7,944 to 25,570 days. Filling in gaps of missing daily flows is discussed later in this chapter.

Table 4.2
USGS Gage Sites Used in Developing the *DF* Record Daily Flow Dataset

CP	USGS Gage.	Location	Drainage Area (square miles)	Missing (days)
GS400	08163500	Lavaca River at Hallettsville	108	8,400
GS300	08164000	Lavaca River near Edna	817	0
GS600	08164300	Navidad River near Hallettsville	332	7,944
GS550	08164350	Navidad River near Speaks	437	25,570
DV501	08164390	Navidad at Strane Park nr Edna	579	20,728
GS1000	08164450	Sandy Ck near Ganado	289	14,520
GS500	08164500	Navidad River near Ganado	1,062	15,188
WGS800	08164503	West Mustang Creek nr Ganado	178	13,788
ECB720	08164504	East Mustang Creek nr Louise	53.9	20,728

The observed daily flow records were downloaded from the U.S. Geological Survey (USGS) National Water Information System (NWIS) website using the data import feature of *HEC-DSSVue* Version 7. The NWIS import feature no longer works in the old version 6 of *HEC-DSSVue*. The data manipulations employed to develop the *DF* records of daily pattern hydrographs were performed using *HEC-DSSVue*. The data are stored in a DSS file.

WAM Daily Pattern Hydrographs on *DF* Records

Daily observed flows in cfs recorded at the USGS gages listed in Tables 4.2 and 4.3 are used to develop the dataset of *DF* records of daily naturalized flows. Daily gaged flow records are incomplete with gaps of missing data, which are synthesized as discussed later in this section. The final *DF* record daily flow volumes in acre-feet sum to *IN* record monthly volumes in acre-feet.

The final dataset of *DF* records consists of January 1940 through December 2021 daily naturalized stream flows at the nine control points. The first column of Table 4.3 is the WAM identifier for each control point. The last column shows the selected control points of the USGS gage sites for which observed daily flows were adopted for use in filling in gaps of missing data. In only one case (GS300), a complete record of 1940-2021 daily flows is provided by a single gage. In the eight other cases, observed flows at two or three gages are combined as necessary to cover the entire 29,951-day 1940-2021 period. Flows at a control point are adopted for that control point. For control points (first column of Table 4.3) with gaps of missing data, the data available at sites listed in the last column are used to fill in gaps. Data at the first gage listed in the last column of Table 4.4 is used to fill in data gaps to the extent possible. The flows at the next gage listed in the last column are used if additional gaps still remain. All flows in a particular month are from the same source site.

The resulting dataset of 1940-2021 observed daily flows in cfs at nine control points were converted to *DF* records within *HEC-DSSVue*. *SIMD* was executed with this dataset. The *SIMD* simulation results included naturalized daily flows in acre-feet/day. The daily naturalized flows recorded by *SIMD* in the *SIMD* simulation results DSS file were converted within *HEC-DSSVue* to a dataset of *DF* records. This final dataset of *SIMD* input *DF* records consists of 1940-2021 daily naturalized flows in acre-feet/day at nine control points. The *DF* record daily flows are plotted in Figures 4.1 through 4.9.

Table 4.3
Gage Sites for Developing Daily Flows
on *DF* Records for the Nine Primary Control Points

CP	Gage and Control Point Location	Control Points for Gaps
GS400	Lavaca River at Hallettsville	GS600
GS300	Lavaca River near Edna	complete with no gaps
GS600	Navidad River near Hallettsville	GS400
GS550	Navidad River near Speaks	GS600, DV501, GS500
DV501	Navidad at Strane Park at Edna	GS500, GS600
GS1000	Sandy Ck near Ganado	WGS800, GS500
GS500	Navidad River near Ganado	DV501, GS300
WGS800	West Mustang Creek near Ganado	GS500
ECB720	East Mustang Creek near Louise	WGS800, GS500

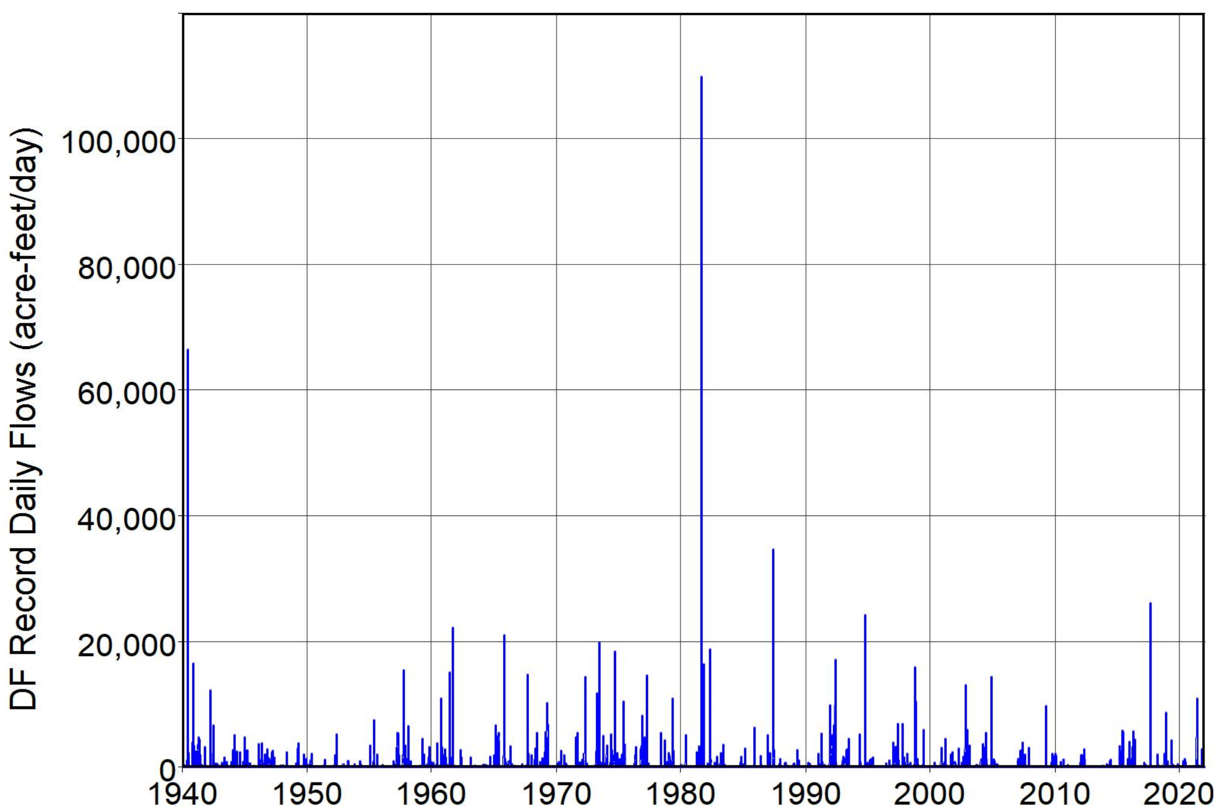

Figure 4.1 *DF* Record Daily Flows for Control Point GS400

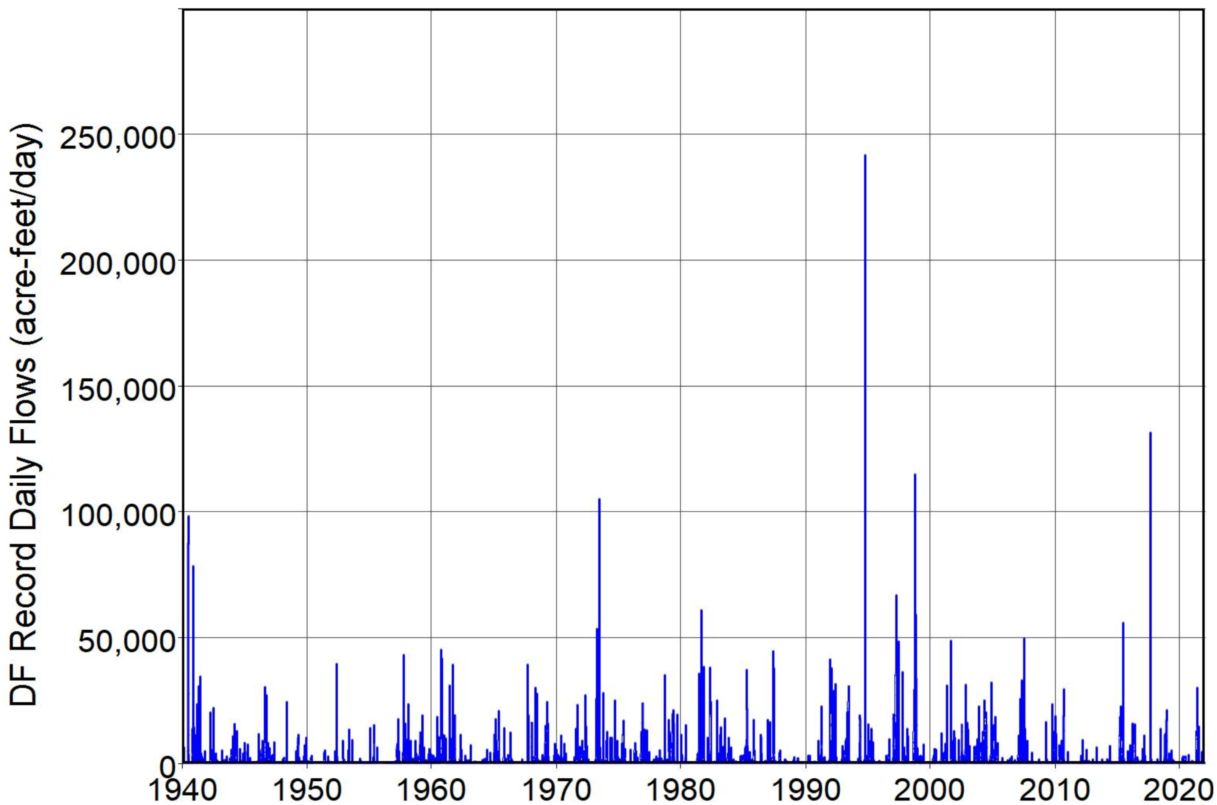

Figure 4.2 *DF* Record Daily Flows for Control Point GS300

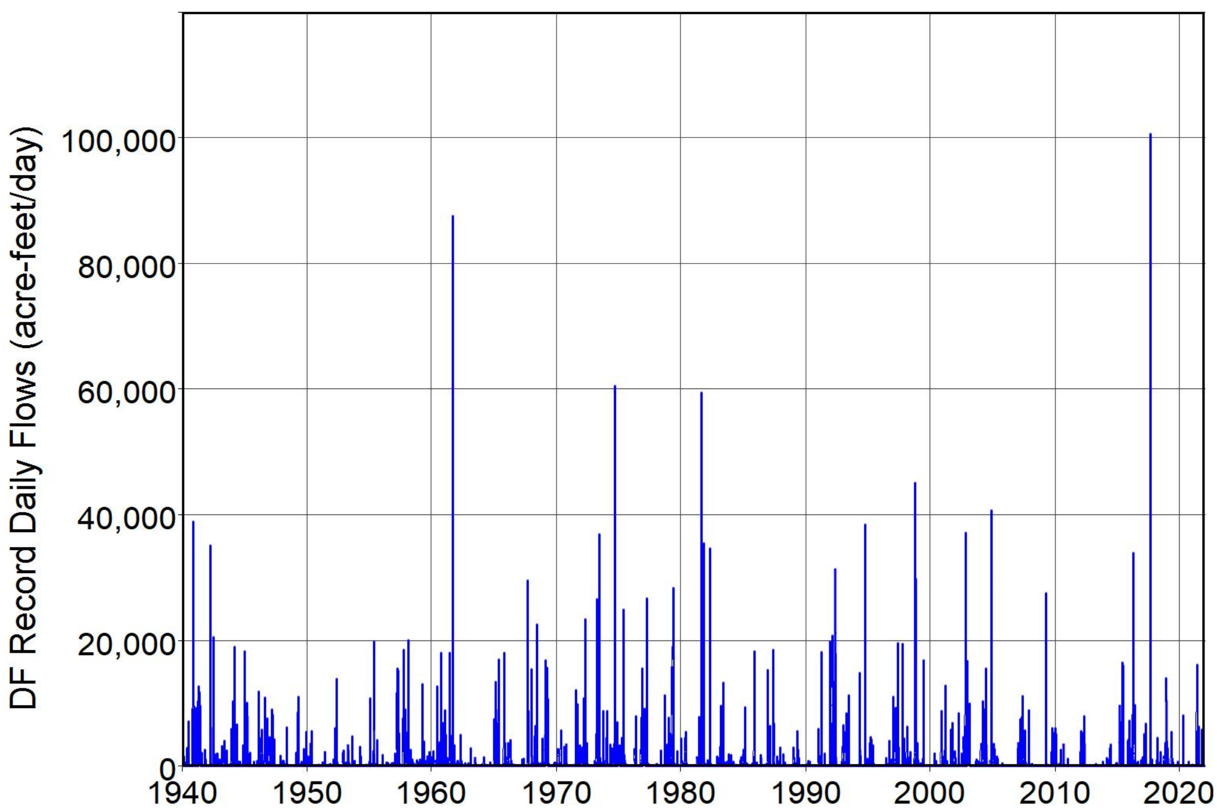

Figure 4.3 *DF* Record Daily Flows for Control Point GS600

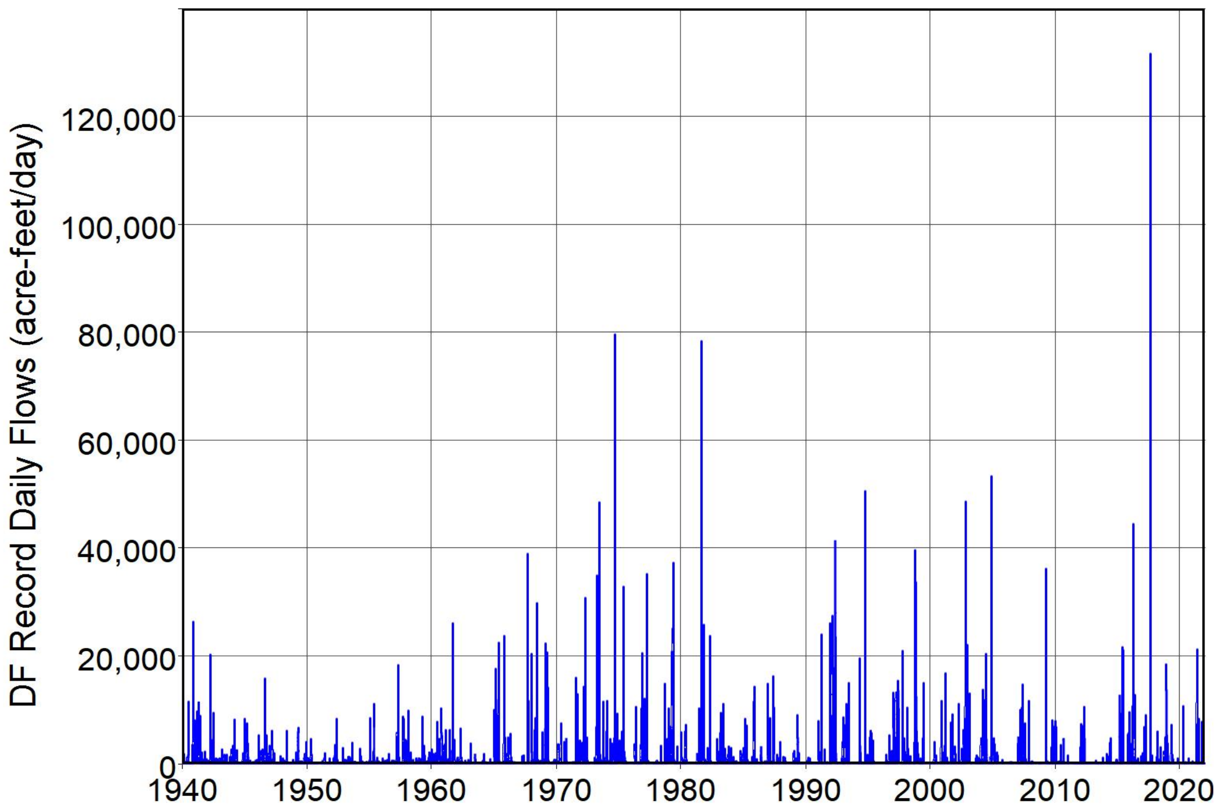

Figure 4.4 *DF* Record Daily Flows for Control Point GS550

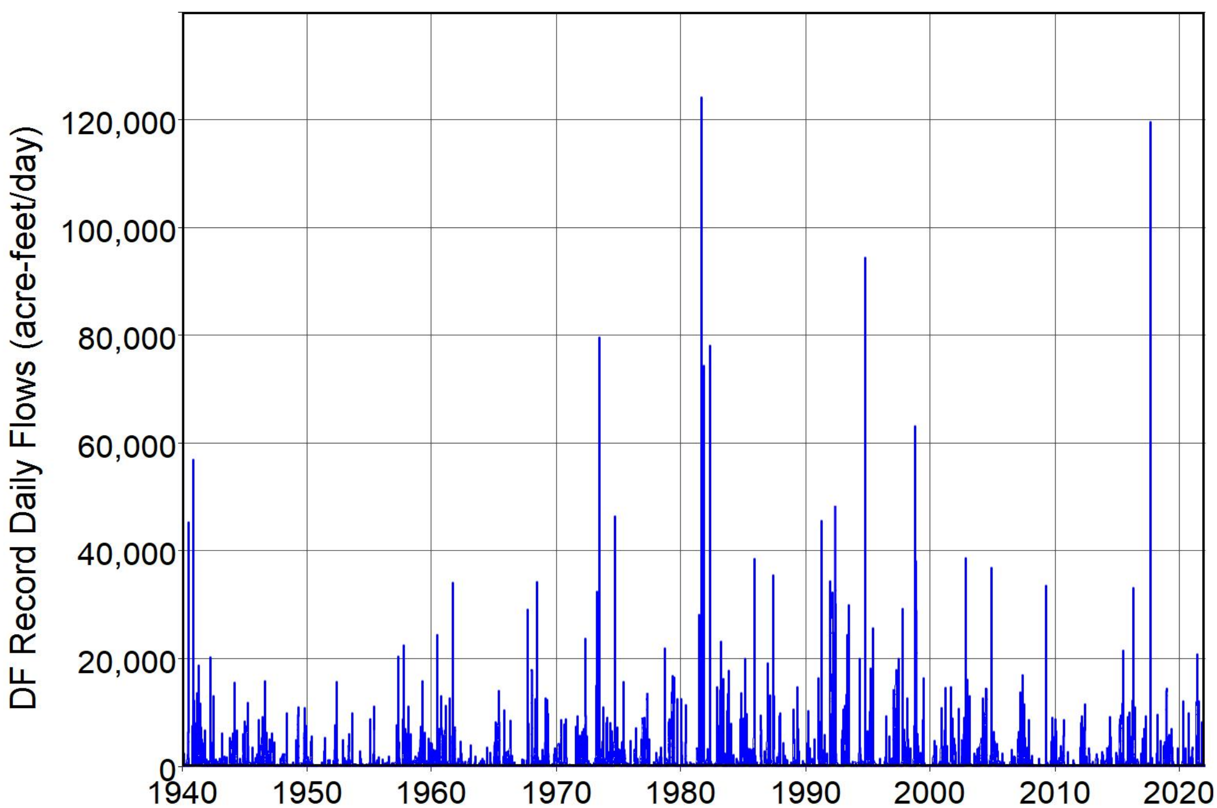

Figure 4.5 *DF* Record Daily Flows for Control Point DV501

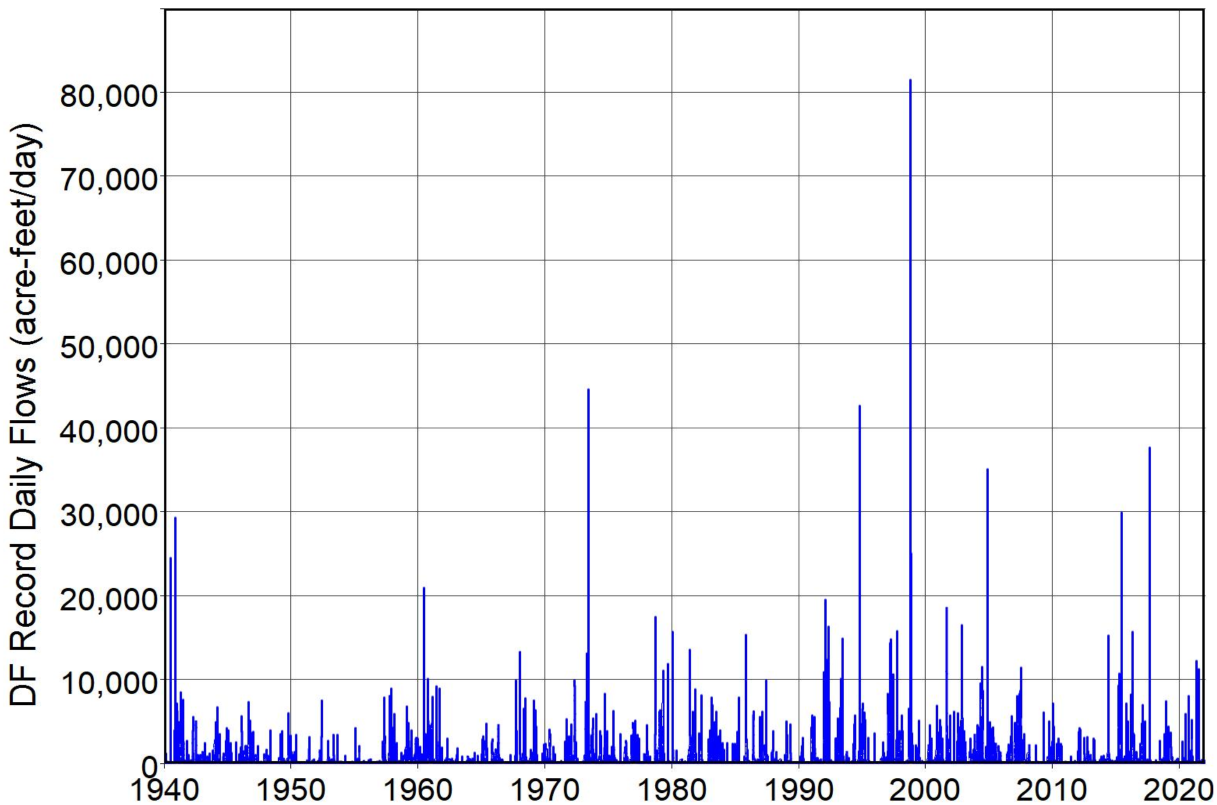

Figure 4.6 *DF* Record Daily Flows for Control Point GS1000

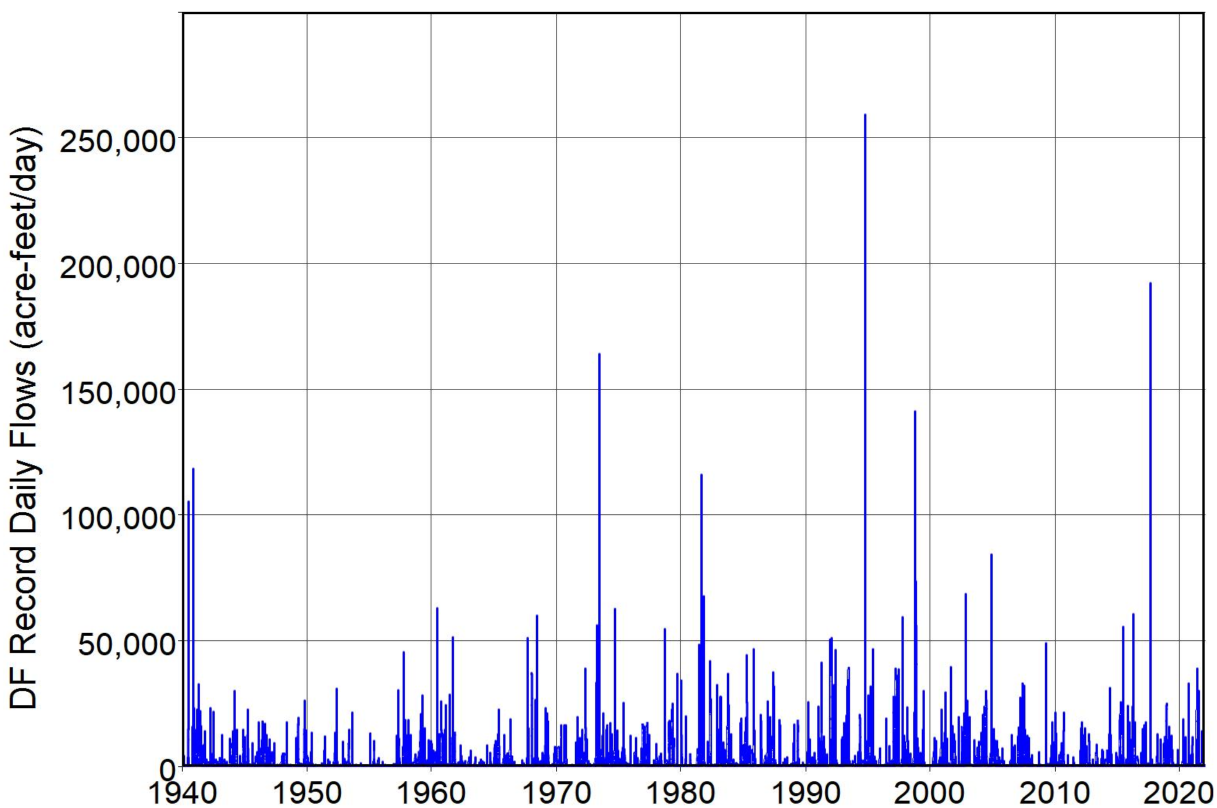

Figure 4.7 *DF* Record Daily Flows for Control Point GS500

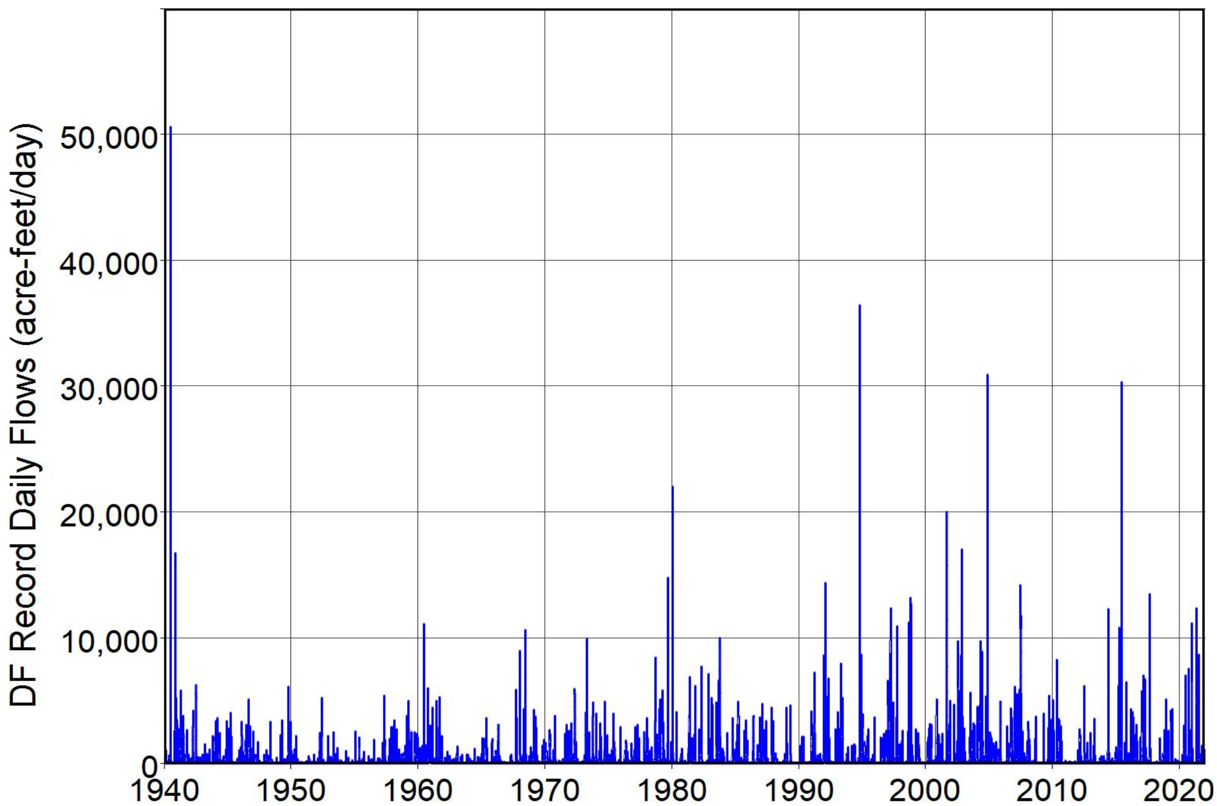

Figure 4.8 *DF* Record Daily Flows for Control Point WGS800

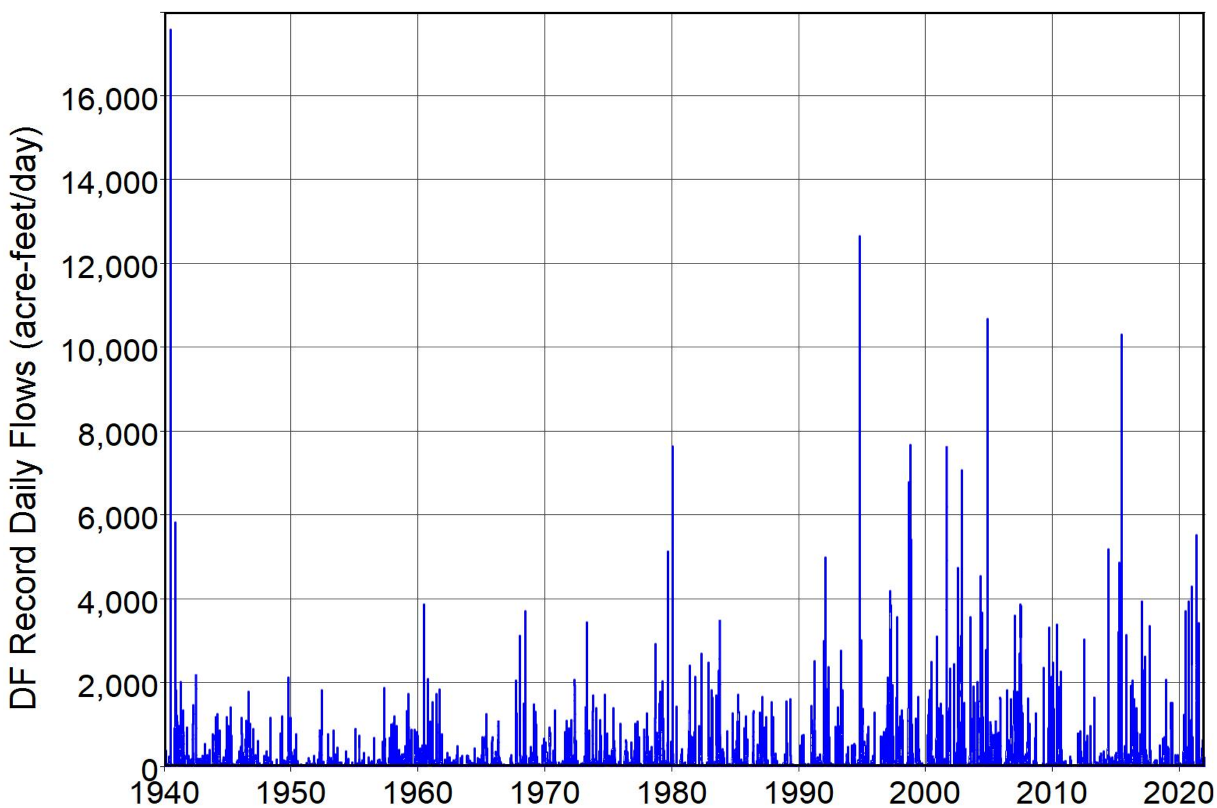

Figure 4.9 *DF* Record Daily Flows for Control Point ECB720

CHAPTER 5
ENVIRONMENTAL FLOW STANDARDS

The following topics are covered in this chapter.

1. Environmental flow standards (EFS) at five gage sites in the Lavaca River Basin established by the TCEQ in collaboration with a science team and stakeholder committee following procedures established by the 2007 Senate Bill 3 (SB3) are described.
2. Modeling of the SB3 EFS to the daily Lavaca WAM using *IF*, *HC*, *ES*, and *PF* input records inserted in the *SIMD* input DAT file is explained.
3. A procedure is outlined in which daily *IF* record instream flow targets for the SB3 EFS computed in a daily *SIMD* simulation are summed to monthly totals and incorporated in the monthly *SIM* input dataset for the Lavaca WAM. This procedure is applied in Chapter 6.

Environmental Flow Standards Established Pursuant to Senate Bill 3 Process

Senate Bill 3 enacted by the 80th Texas Legislature in 2007 established a new regulatory approach to provide for environmental needs for certain stream flow conditions through the use of standards developed through a stakeholder process culminating in TCEQ rulemaking. Water right permits in effect prior to the effective date of September 1, 2007 are not impacted. Only new water rights and water right amendments that are submitted after this date are subject to the new requirements established pursuant to the 2007 Senate Bill 3. Information regarding the process created by the 2007 Senate Bill 3 (SB3) for establishing environmental instream flow standards (EFS) and the EFS that have been adopted to date can be found at the following TCEQ website.

https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/eflows

The SB3 EFS established to date are published as Subchapters B through F of Chapter 298 of Title 30 of the Texas Administrative Code. EFS for different river systems are published as subsections of Chapter 298. Modifications to existing standards and establishment of standards for additional regions and river reaches are expected in the future. The SB3 EFS for the Lavaca River Basin are found in "*Subchapter D: Colorado and Lavaca Rivers and Matagorda and Lavaca Bays*" which was adopted August 8, 2012 and became effective on August 30, 2012 [12]. The priority date for these EFS and the associated set-asides to be incorporated in the water availability modeling system is March 1, 2011.

The expanded regulatory process created by the 2007 SB3 results in determination of environmental flow needs and establishment of set-asides to satisfy the environmental flow needs. *Set-asides* refer to commitment of previously unappropriated water in the TCEQ WAM System to meet specified environmental flow standards. Environmental flow standards (requirements, needs, or targets) for particular locations in particular stream systems are defined in terms of flow regimes. SB3 defines an environmental flow regime as: *A schedule of flow quantities that reflects seasonal and yearly fluctuations that typically would vary geographically, by specific location in a watershed, and that are shown to be adequate to support a sound ecological environment and to maintain the productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies.* Environmental flow standards (EFS) established through the Senate Bill 3 (SB3) process are based on flow regimes that include subsistence flows, base flows, and high flow pulses.

The geographic area covered by "*Subchapter D* of Chapter 298 of Title 30 of the Texas Administrative Code [12] consists of the Colorado and Lavaca Rivers and their tributaries, bays, and estuaries. SB3 EFS have been established at the locations of 21 USGS stream flow gages, including 14 sites in the Colorado River Basin, five in the Lavaca River Basin, and two sites in the Colorado-Lavaca and Lavaca-Guadalupe Coastal Basins. The TCEQ established the EFS based on recommendations submitted by an expert science team and stakeholder committee in reports [15, 16] available at the TCEQ website shown below. The priority date for the EFS is March 1, 2011, the date the Basin and Bay Expert Science Team submitted its recommendations [15].

Colorado and Lavaca Rivers and Matagorda and Lavaca Bays: Stakeholder Committee and Expert Science Team - Texas Commission on Environmental Quality - www.tceq.texas.gov

SB3 EFS at Five USGS Gaging Stations in the Lavaca River Basin

The EFS for the five locations in the Lavaca River Basin are incorporated in the daily Lavaca WAM as described later in this chapter. The five locations with SB3 EFS in the Lavaca River Basin are listed with descriptive information in Table 5.1. The five gage sites with SB3 EFS are all included in the nine sites in Table 2.2 with locations shown in Figure 2.1 of Chapter 2.

Table 5.1
Locations of SB3 EFS in the Lavaca River Basin

CP	USGS Gage	Location	Drainage Area (square miles)	
			USGS	WAM WP
GS300	08164000	Lavaca River near Edna	817	822
DV501	08164390	Navidad at Strane Park near Edna	579	581
GS1000	08164450	Sandy Creek near Ganado	289	296
WGS800	08164503	West Mustang Creek near Ganado	178	168
ECB720	08164504	East Mustang Creek near Louise	53.9	54.4

The EFS established through the process created by the 2007 SB3 consist of subsistence flow, base flow, and high flow pulse components that may vary seasonally and with hydrologic conditions [12]. Seasons are defined in Table 5.2. Hydrologic conditions are defined as a function of storage level in Lake Texana as shown in Table 5.3. The hydrologic condition for a season is determined based on conditions on the last day of the preceding season. The hydrologic condition determined at the beginning of each season is applied for the entire season.

Table 5.2
Seasons Defined in the EFS

Season	Months
Winter	December, January, February
Spring	March, April, May, June
Summer	July, August
Fall	September, October, November

Table 5.3
Lake Texana Metrics Defining Hydrologic Conditions

Hydrologic Condition	Elevation (feet msl)	Reservoir Storage (acre-feet)		
		2020 TWDB	Full Authorization	Current Use WAM
Severe	Less than 39.95	Less than 126,903	Less than 134,509	Less than 129,901
Dry	39.95 – 43.00	126,903 – 153,367	134,509 – 160,973	129,901 – 156,365
Average	43.00 – 44.00	153,367 – 162,694	160,973 – 170,300	156,365 – 165,692
Wet	Greater than 44.00	≥ 162,694	≥ 170,300	≥ 165,692

Hydrologic condition is defined in the SB3 EFS as a function of the storage elevations shown in the second column of Table 5.3 and incorporated in the full authorization and current use scenario WAMs as a function of the corresponding storage volumes in the last two columns of Table 5.3. The hydrologic condition parameters were selected by the science team and stakeholder committee such that severe conditions occur approximately 5% of the time, dry conditions occur approximately 20% of the time, average conditions occur approximately 50% of the time, and wet conditions occur approximately 25% of the time [12, 15, 16].

Subsistence and Base Flow Standards

The subsistence standards with flow limits tabulated in Table 5.5 are applicable during severe hydrologic conditions when flow at a gage site is less than the dry base flow standards. If actual flow is below the designated dry base flow limit and above the defined subsistence flow limit during severe hydrologic conditions, a water right holder may divert water as long as the diversion does not cause the flow to drop below the subsistence flow level [12].

Table 5.4
Flow Limits (cfs) in the Subsistence Flow Standards
for the Severe Hydrologic Condition

WAM Control Point	Seasonal Flow Limits (cfs)			
	Winter (cfs)	Spring (cfs)	Summer (cfs)	Fall (cfs)
GS300	8.5	10	1.3	1.2
DV501	1.0	2.8	1.2	2.2
GS1000	1.0	1.0	1.0	1.0
WGS800	1.0	1.0	1.0	1.0
ECB720	1.0	1.0	1.0	1.0

The flow criteria defining base flow levels are tabulated in Table 5.5 [12]. The base flow standards vary seasonally and between the four hydrologic conditions (severe, dry, average, and wet). If flow at a control point is below applicable high flow pulse trigger levels and above the applicable base flow standard, a water right holder may divert water as long as the diversion does not cause the flow to drop below the applicable base flow standard.

Table 5.5
Stream Flow Limits (cfs) Defining Base Flow Standards

WAM	Winter				Spring				Summer				Fall			
CP ID	Sev	Dry	Avg	Wet	Sev	Dry	Avg	Wet	Sev	Dry	Avg	Wet	Sev	Dry	Avg	Wet
GS300	30	30	55	94	30	30	55	94	20	20	48	33	20	20	33	58
DV501	14	14	35	71	18	18	35	71	24	24	47	84	17	17	35	71
GS1000	5	5	14	30	5	5	14	30	9	9	21	39	9	9	21	39
WGS800	4	4	9	20	5	5	11	20	10	10	18	32	6	6	14	26
ECB720	1	1	2	6	1	1	3	6	2	2	5	8	1	1	3	8

High Flow Pulse Standards

The high flow pulse components of the SB3 EFS are outlined in Table 5.6 [12]. The high pulse criteria are specified for a two-per-season pulse, a one-per-season pulse, and an annual pulse. When the high flow pulse trigger level is reached, that flow level is protected by curtailing junior water rights until either the specified volume or duration criteria in Table 5.6 is met. Junior rights can appropriate excess stream flow exceeding the trigger level at any of the five sites.

For all five gage locations, high flow pulses are independent of hydrologic conditions, and each season is independent of other seasons. If a requirement for a pulse event is satisfied during a season, a high flow pulse requirement is considered to be satisfied for each smaller event in that season. For example, if an annual pulse flow requirement is met in a season, then a one-per-season pulse flow requirement and a two-per-season pulse flow requirement are met for that season.

Water right holders are not required to cease diverting water or release stored water to produce a high flow pulse event if the trigger criterion is not met during a season. High flow pulses are preserved but not created. Water that was previously stored as authorized by a water right may be diverted or released regardless of applicable environmental flow requirements.

Applicability of Instream Flow Requirements (EFS) Established Pursuant to Senate Bill 3 (SB3)

The priority date for the SB3 EFS for the Lavaca River Basin and the associated set-asides to be incorporated by the TCEQ in the water availability modeling system is March 1, 2011. Existing water rights with priorities senior to March 1, 2011 are not regulated to protect the SB3 EFS. The SB3 EFS may constrain water availability for diversions and storage authorized by permits with priority dates junior to March 1, 2011. The SB3 EFS may constrain curtailment of stream flow appropriations for diversions and refilling depleted storage capacity, but do not require releases of water from already in storage,

Administrative Code Chapter 298, Subchapter D, Section §298.335 entitled "*Water Right Permit Conditions*" requires that water right permits or amendments issued after the effective date of the EFS to store or divert water from the Lavaca River and its tributaries contain flow restriction special conditions that are adequate to protect the EFS of Subchapter D [12].

Table 5.6
High Flow Pulse Standards

WAM CP ID	Season	Pulse Flow Criteria	Frequency		
			2 per season	1 per season	Annual
GS300	Winter	Trigger (cfs)	2,000	4,500	4,500
		Volume (ac-ft)	8,000	18,400	18,400
		Duration (days)	6	7	7
	Spring	Trigger (cfs)	4,500	4,500	
		Volume (ac-ft)	18,400	18,400	
		Duration (days)	7	7	
	Summer	Trigger (cfs)	88	420	
		Volume (ac-ft)	370	1,800	
		Duration (days)	4	6	
	Fall	Trigger (cfs)	1,600	4,500	
		Volume (ac-ft)	6,100	18,000	
		Duration (days)	5	6	
DV501	Winter	Trigger (cfs)	2,000	2,500	2,500
		Volume (ac-ft)	9,000	11,250	11,250
		Duration (days)	6	7	7
	Spring	Trigger (cfs)	2,500	2,500	
		Volume (ac-ft)	11,250	11,250	
		Duration (days)	7	7	
	Summer	Trigger (cfs)	200	610	
		Volume (ac-ft)	1,000	3,400	
		Duration (days)	5	6	
	Fall	Trigger (cfs)	2,000	2,500	
		Volume (ac-ft)	8,700	11,250	
		Duration (days)	6	7	
GS10000	Winter	Trigger (cfs)	800	1,800	2,200
		Volume (ac-ft)	4,000	10,000	12,200
		Duration (days)	6	8	10
	Spring	Trigger (cfs)	1,400	2,200	
		Volume (ac-ft)	7,300	12,200	
		Duration (days)	6	10	
	Summer	Trigger (cfs)	91	260	
		Volume (ac-ft)	500	1,600	
		Duration (days)	4	7	
	Fall	Trigger (cfs)	630	1,800	
		Volume (ac-ft)	3,100	9,200	
		Duration (days)	6	7	

Table 5.6 (Continued)
High Flow Pulse Standards

WAM CP ID	Season	Pulse Flow Criteria	Frequency 2 per season	1 per season	Annual
WGS800	Winter	Trigger (cfs) Volume (ac-ft) Duration (days)	470 2,400 6	1,000 5,600 8	1,000 5,600 8
	Spring	Trigger (cfs) Volume (ac-ft) Duration (days)	810 4,400 6	1,000 5,600 8	
	Summer	Trigger (cfs) Volume (ac-ft) Duration (days)	75 420 4	190 1,200 6	
	Fall	Trigger (cfs) Volume (ac-ft) Duration (days)	470 2,200 6	2,200 5,600 8	
ECB720	Winter	Trigger (cfs) Volume (ac-ft) Duration (days)	150 680 5	340 1,700 8	1,000 6,000 10
	Spring	Trigger (cfs) Volume (ac-ft) Duration (days)	280 1,400 7	550 3,000 9	
	Summer	Trigger (cfs) Volume (ac-ft) Duration (days)	20 100 5	60 310 6	
	Fall	Trigger (cfs) Volume (ac-ft) Duration (days)	150 650 6	430 2,100 7	

Other *IF* Record Instream Flow Requirements

The 2008 versions of the full authorization and current use Lavaca WAMs have 30 *IF* record instream flow rights with priorities ranging from 19720515 (May 15, 1972) to 2001001 (October 10, 2000). These *IF* records were in the WAMs before the SB3 EFS were created. None are located at the same control points assigned to the SB3 EFS. These existing *IF* record water rights are not altered in the conversion to a daily WAM other than uniformly distributing the monthly instream flow targets to the 28, 29, 30, or 31 days in each month.

The SB3 EFS were added to the monthly full authorization Lavaca WAM in 2014 prior to development of new WRAP modeling capabilities employing newly created *ES*, *HC*, *PF*, and *PO* records. The *WR*, *TO*, and other records and accompanying HIS file set of *HI* records used in 2014 to add the SB3 EFS were removed and replaced with the records discussed in the next section.

Modeling SB3 Environmental Flow Standards

Environmental flow standards (EFS) established pursuant to the 2007 Senate Bill 3 (SB3) are based on a flow regime that includes subsistence, base, and high pulse flows as explained in Chapter 4 of the *WRAP Reference Manual* [1] and Chapter 6 of the *Daily Manual* [4] and illustrated by the SB3 EFS for the Lavaca River Basin as described in this chapter.

Environmental standard *ES*, hydrologic condition *HC*, pulse flow *PF*, and pulse flow supplemental options *PO* records are designed specifically to model *IF* record instream flow rights in the format of SB3 EFS. Chapter 3 of the *Users Manual* [2] defines the input parameters entered on the types of input records that are applicable to both the monthly *SIM* and daily *SIMD*, which includes the *ES* and *HC* records. Chapter 4 of the *Users Manual* covers additional daily *SIMD* input records that are not applicable to the monthly *SIM*, including the *PF* and *PO* records.

An example of modeling SB3 EFS is presented in Chapter 8 of the *Daily Manual* [4]. SB3 EFS have been previously added to the Brazos, Trinity, Neches, and Colorado daily WAMs [8, 9, 10, 11] using the same methodologies applied with the daily Lavaca WAM described here in Chapter 5. Daily and monthly instream flow targets for *IF* record rights representing SB3 EFS computed in *SIMD* simulations are presented in Chapter 6 of this report.

The *SIMD* DAT file input records reproduced as Table 5.7 control the computation of daily instream flow targets at the five control points in the Lavaca WAM representing the SB3 EFS gage sites. These *IF* record instream flow targets are minimum flow limits that may constrain appropriation of stream flow by *WR* record water rights with junior priorities.

Table 5.7
Instream Flow Rights that Model the SB3 EFS in the Daily Lavaca WAM DAT File

```
**       1         2         3         4         5         6         7         8         9        10
**34567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456
**     !       !       !       !       !       !       !       !       !       !       !       !       !
**
IF GS300     -9.        20110301   2            IF-GS300-ES
HC GS300   1  ST       M   J S  D      0. 134509. 160973. 170300.     -9.
ES SUBS1     8.5     8.5    10.0    10.0    10.0    10.0     1.3     1.3     1.2     1.2     1.2     8.5
ES BASE1    30.0    30.0    30.0    30.0    30.0    30.0    20.0    20.0    20.0    20.0    20.0    30.0
ES BASE2    30.0    30.0    30.0    30.0    30.0    30.0    20.0    20.0    20.0    20.0    20.0    30.0
ES BASE3    55.0    55.0    55.0    55.0    55.0    55.0    48.0    48.0    33.0    33.0    33.0    55.0
ES BASE4    94.0    94.0    94.0    94.0    94.0    94.0    33.0    33.0    58.0    58.0    58.0    94.0
IF GS300     -9.        20110301   2            IF-GS300-PF
ES PFES
PF   1 0   2000.   8000.   6   2      12   2           2
PF   1 0   4500.  18400.   7   2       3   6           2
PF   1 0     88     370.   4   2       7   8           2
PF   1 0   1600    6100.   5   2       9  11           2
PF   1 0   4500.  18400.   7   1      12   2           2
PF   1 0   4500.  18400.   7   1       3   6           2
PF   1 0    420    1800.   6   1       7   8           2
PF   1 0   4500   18400.   6   1       9  11           2
PF   1 0   4500.  18400.   7   1       1  12           2
**
IF DV501     -9.        20110301   2            IF-DV501-ES
HC DV501   1  ST       M   J S  D      0. 134509. 160973. 170300.     -9.
ES SUBS1     1.0     1.0     2.8     2.8     2.8     2.8     1.2     1.2     2.2     2.2     2.2     1.0
```

```
ES BASE1    14.0    14.0    18.0    18.0    18.0    18.0    24.0    24.0    17.0    17.0    17.0    14.0
ES BASE2    14.0    14.0    18.0    18.0    18.0    18.0    24.0    24.0    17.0    17.0    17.0    14.0
ES BASE3    35.0    35.0    35.0    35.0    35.0    35.0    47.0    47.0    35.0    35.0    35.0    35.0
ES BASE4    71.0    71.0    71.0    71.0    71.0    71.0    48.0    48.0    71.0    71.0    71.0    71.0
IF DV501     -9.        20110301   2            IF-DV501-PF
ES PFES
PF   1 0   2000.   9000.   6   2      12   2           2
PF   1 0   2500.  11250.   7   2       3   6           2
PF   1 0    200.   1000.   5   2       7   8           2
PF   1 0   2000.   8700.   6   2       9  11           2
PF   1 0   2500.  11250.   7   1      12   2           2
PF   1 0   2500.  11250.   7   1       3   6           2
PF   1 0    610.   3400.   6   1       7   8           2
PF   1 0   2500   11250.   7   1       9  11           2
PF   1 0   2500.  11250.   7   1       1  12           2
**
IFGS1000     -9.        20110301   2            IF-GS1000-ES
HCGS1000   1  ST       M   J S  D      0. 134509. 160973. 170300.     -9.
ES SUBS1     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0
ES BASE1     5.0     5.0     5.0     5.0     5.0     5.0     9.0     9.0     9.0     9.0     9.0     5.0
ES BASE2     5.0     5.0     5.0     5.0     5.0     5.0     9.0     9.0     9.0     9.0     9.0     5.0
ES BASE3    14.0    14.0    14.0    14.0    14.0    14.0    21.0    21.0    21.0    21.0    21.0    14.0
ES BASE4    30.0    30.0    30.0    30.0    30.0    30.0    39.0    39.0    39.0    39.0    39.0    30.0
IFGS1000     -9.        20110301   2            IF-GS1000-PF
ES PFES
PF   1 0    800.   4000.   6   2      12   2           2
PF   1 0   1400.   7300.   6   2       3   6           2
PF   1 0     91.    500.   4   2       7   8           2
PF   1 0    630.   3100.   6   2       9  11           2
PF   1 0   1800.  10000.   8   1      12   2           2
PF   1 0   2200.  12200.  10   1       3   6           2
PF   1 0    260.   1600.   7   1       7   8           2
PF   1 0   1800    9200.   7   1       9  11           2
PF   1 0   2200.  12200.  10   1       1  12           2
**
IFECB720     -9.        20110301   2            IF- ECB720-ES
HCECB720   1  ST       M   J S  D      0. 134509. 160973. 170300.     -9.
ES SUBS1     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0
ES BASE1     1.0     1.0     1.0     1.0     1.0     1.0     2.0     2.0     1.0     1.0     1.0     1.0
ES BASE2     1.0     1.0     1.0     1.0     1.0     1.0     2.0     2.0     1.0     1.0     1.0     1.0
ES BASE3     2.0     2.0     3.0     3.0     3.0     3.0     5.0     5.0     3.0     3.0     3.0     2.0
ES BASE4     6.0     6.0     6.0     6.0     6.0     6.0     8.0     8.0     8.0     8.0     8.0     6.0
IFECB720     -9.        20110301   2            IF- ECB720-PF
ES PFES
PF   1 0    150.    680.   5   2      12   2           2
PF   1 0    280.   1400.   7   2       3   6           2
PF   1 0     20.    100.   5   2       7   8           2
PF   1 0    150.    650.   6   2       9  11           2
PF   1 0    340.   1700.   8   1      12   2           2
PF   1 0    550.   3000.   9   1       3   6           2
PF   1 0     60.    310.   5   1       7   8           2
PF   1 0    150     650.   6   1       9  11           2
PF   1 0   1000.   6000.  10   1       1  12           2
**
IFWGS800     -9.        20110301   2            IF-WGS800-ES
HCWGS800   1  ST       M   J S  D      0. 134509. 160973. 170300.     -9.
ES SUBS1     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0     1.0
ES BASE1     4.0     4.0     5.0     5.0     5.0     5.0    10.0    10.0     6.0     6.0     6.0     4.0
ES BASE2     4.0     4.0     5.0     5.0     5.0     5.0    10.0    10.0     6.0     6.0     6.0     4.0
ES BASE3     9.0     9.0    11.0    11.0    11.0    11.0    18.0    18.0    14.0    14.0    14.0     9.0
ES BASE4    20.0    20.0    20.0    20.0    20.0    20.0    32.0    32.0    26.0    26.0    26.0    20.0
IFWGS800     -9.        20110301   2            IF-WGS800-PF
ES PFES
PF   1 0    470.   2400.   6   2      12   2           2
```

```
PF   1 0    810.   4400.   6   2       3   6           2
PF   1 0     75.    420.   4   2       7   8           2
PF   1 0    470.   2200.   6   2       9  11           2
PF   1 0   1000.   5600.   8   1      12   2           2
PF   1 0   1000.   5600.   8   1       3   6           2
PF   1 0    190.   1200.   6   1       7   8           2
PF   1 0   1000.   5600.   8   1       9  11           2
PF   1 0   1000.   5600.   8   1       1  12           2
**
```

The records replicated in Table 5.7 are identically the same for both the full authorization and current use scenario DAT files except for the five hydrologic condition *HC* records. As indicated in Table 5.3, hydrologic conditions are defined in the SB3 EFS as a function of water surface elevations in Lake Texana, which are converted to storage volumes for incorporation in the WAM *HC* records. The storage volumes in Table 5.3 employed in the *HC* records are different between the full authorization and current use scenarios due to reservoir sedimentation.

The *IF* record targets are managed in the same manner as all water right targets within the *SIMD* simulation computations and output files. Options controlled by *IF* record field 3 and *PF* record field 15 create tables in the MSS and SMM message files that provide supplemental information that facilitates tracking the *ES* and *PF* record computations. These message file options are not activated in the dataset of Table 5.7 but can be easily activated whenever needed.

The set of input records replicated in Table 5.7 are inserted with the other sets of *WR* and *IF* record water rights in the *SIMD* input DAT file. Each *IF* record instream flow right in Table 5.7 has a set of *HC*, *ES*, and *PF* records that provide the metrics found in Tables 5.2, 5.3, 5.4, 5.5, and 5.6. The subsistence/base flows and pulse flows are organized as separate water rights in Table 5.7 but can be combined as discussed in the next section of this chapter.

<u>Multiple Instream Flow Targets or Target Components at the Same Control Point</u>

The sets of *IF*, *HC*, *ES*, *PF*, and *PO* records replicated in Table 5.7 are inserted in the DAT file employed in the daily *SIMD* simulations presented in Chapter 6. In the dataset of Table 5.7 and simulation studies of Chapter 6, the pulse flow components are modeled as separate *IF* record rights to facilitate recording pulse flow targets in the simulation results separately from the subsistence and base flow targets. This does not affect the total target quantities but rather allows the components of each target to be recorded separately in output files [2, 4].

Table 5.7 includes ten *IF* record water rights since the pulse flow components of the five EFS are separated from the subsistence/base flow components. However, subsidence flows, base flows, and high flow pulses can be combined reducing the SB3 EFS to five *IF* record water rights simply by removing the *IF* and *ES* records for each of the high flow pulse components. For example, the first two water rights in Table 5.7 labeled with water right identifiers IF-GS300-ES and IF-GS300-PF are instream flow requirements at control point GS300. These two water rights are combined into a single water right in Table 5.8. With this format, all components of the SB3 EFS at a site can be modeled as a single *IF* record water right, with the only difference in simulation results being that combined rather that separate water right targets and target shortages are recorded in the *SIMD* output OUT and DSS files.

Table 5.8
Instream Flow Right that Models the SB3 EFS at Control Point GS300
with *ES* and *PF* Record Components Combined as a Single *IF* Record Right

```
IF GS300     -9.        20110301   2           IF-GS300-ES
HC GS300   1  ST       M   J S  D      0. 134509. 160973. 170300.     -9.
ES SUBS1    0.85     0.85     10.0     10.0     10.0     10.0      1.3      1.3      1.2      1.2      1.2     0.85
ES BASE1    30.0     30.0     30.0     30.0     30.0     30.0     20.0     20.0     20.0     20.0     20.0     30.0
ES BASE2    30.0     30.0     30.0     30.0     30.0     30.0     20.0     20.0     20.0     20.0     20.0     30.0
ES BASE3    55.0     55.0     55.0     55.0     55.0     55.0     48.0     48.0     33.0     33.0     33.0     55.0
ES BASE4    94.0     94.0     94.0     94.0     94.0     94.0     33.0     33.0     58.0     58.0     58.0     94.0
ES PFES
PF   1 0   2000.   8000.   6   2      12   2            2
PF   1 0   4500.  18400.   7   2       3   6            2
PF   1 0     88     370.   4   2       7   8            2
PF   1 0   1600    6100.   5   2       9  11            2
PF   1 0   4500.  18400.   7   1      12   2            2
PF   1 0   4500.  18400.   7   1       3   6            2
PF   1 0    420    1800.   6   1       7   8            2
PF   1 0   4500   18400.   6   1       9  11            2
PF   1 0   4500.  18400.   7   1       1  12            2
```

The table on page 47 of the WRAP *Users Manual* [2] lists 43 time series variables that may be included in *SIM* and *SIMD* simulation results output files. Five of these variables are forms of instream flow targets or shortages in meeting instream flow targets. These five instream flow targets and shortage quantities are listed in the first column of Table 5.9 below. The second column of Table 5.9 refers to the *OF* record labels listed on page 47 of the *Users Manual* that are used to select variables for inclusion in the *SIM/SIMD* output DSS file. The labels in DSS pathname part C of the output records are listed in the third column. The corresponding *TABLES* monthly and daily time series input records are listed in the last two columns of Table 5.9. The DSS pathname part C labels in the third column are adopted in the following discussion for referring to the quantities listed in Table 5.9.

Table 5.9
Instream Flow Targets and Shortages in *SIM/SIMD* Simulation Results

Instream Flow Target or Shortage	*SIM/SIMD* *OR* Record	DSS Record Part C	*TABLES* Monthly	*TABLES* Daily
final target at control point	15. IFT	IFT-CP	2IFT	6IFT
shortage for final control point target	16. IFS	IFS-CP	2IFS	6IFS
combined target for IF water right	27. IFT	IFT-WR	2IFT	6IFT
shortage for IF water right	28. IFS	IFS-WR	2IFS	6IFS
individual target for IF water right	29. TIF	TIF-WR	2TIF	6TIF

With only one *IF* record instream flow water right located at a control point, the IFT-CP, IFT-WR, and TIF-WR targets are the same. IFT-CP, IFT-WR, and TIF-WR instream flow targets are different only in the case of two or more *IF* record rights located at the same control point. An IFT-CP target refers to the final target at the control point at the completion of the priority sequenced simulation computations. TIF-WR refers to the instream flow target computed for an individual *IF* record right without consideration of any other *IF* record rights located at the same control point. IFT-WR refers to the instream flow target for an *IF* record right after combining with the target for the preceding *IF* record right in the water rights priority sequence.

Any number of instream flow *IF* record water rights can be located at the same WAM control point regardless of the various records used with the *IF* records for computing instream flow targets. Various options can be employed to combine targets computed for multiple *IF* records. With two or more *IF* record rights at the same control point, the target for a junior right is combined with the target from the preceding senior right as specified by IFM(IF,2) in *IF* record field 7. The *IF* record IFM(IF,2) target combining options are listed in Table 5.10.

The computation of a SB3 target consists of computing a subsistence and base flow target as specified by *ES* records and a pulse flow target as specified by *PF* records. Pulse flow *PF* and subsistence/base flow *ES* records can be defined separately or alternatively combined as a single *IF* record instream flow water right at a control point as discussed in the preceding paragraphs. With pulse flow *PF* and subsistence/base flow *ES* records for the same *IF* record right, the instream flow targets are combined as specified in *PF* record field 14 as indicated in Table 5.10. The options for combining consecutive *PF* record targets for a single *IF* record right are also listed in Table 5.10. Multiple instream flow targets at the same control point are combined in the Lavaca WAM always using the option of adopting the largest target.

Table 5.10
Options for Combining Targets for Instream Flow Rights at the Same Control Point

IF record field 7	*PF* record field 14	Method for combining junior and senior targets.
1 (default)	1	The junior target replaces the senior target.
2	2 (default)	The largest target is adopted.
3	3	The smallest target is adopted.
−	4	The two targets are added together.

<u>Monthly WAM with Instream Flow Targets from the Daily WAM</u>

A strategy for incorporating monthly instream flow targets computed in a daily *SIMD* simulation into the *SIM* input for a monthly WAM is introduced in the last section of Chapter 6 of the *Daily Manual* [4]. The methodology is illustrated in an example in *Daily Manual Chapter 8* and has been employed with the Brazos, Trinity, Neches, and Colorado daily WAMs [8, 9, 10, 11] The methodology is applied with the Lavaca WAM as described in Chapter 6 of this report.

Daily instream flow targets in acre-feet/day for the SB3 EFS computed in the daily *SIMD* simulation are summed by *SIMD* to monthly totals in acre-feet/month that are included in the *SIMD* simulation results. These time series of monthly targets are converted to target series *TS* records within *HEC-DSSVue* and incorporated in the input DSS file read in a monthly *SIM* simulation.

The target series *TS* records of monthly instream flow targets in acre-feet/month stored in the DSS file have the pathname identifiers listed in Table 5.11. The target series *TS* records in the DSS file are referenced by *TS* records in the DAT file which are replicated in Table 5.12.

Table 5.11
Pathnames for *TS* Records for the SB3 EFS in the Hydrology Input DSS File

Part A	Part B	Part C	Part D	Part E
Lavaca	GS300	TS	01Jan1940-31Dec2021	1MON
Lavaca	DV501	TS	01Jan1940-31Dec2021	1MON
Lavaca	GS1000	TS	01Jan1940-31Dec2021	1MON
Lavaca	WGS800	TS	01Jan1940-31Dec2021	1MON
Lavaca	ECB720	TS	01Jan1940-31Dec2021	1MON

A daily *SIMD* simulation is performed with the set of *IF*, *ES*, *PF*, and *PO* records in Table 5.7 inserted in the DAT file to control computation of IFT and TIF (Table 5.9) daily instream flow targets for the SB3 EFS at the five USGS gaging stations (WAM control points). The daily TIF instream flow targets in acre-feet/day are summed to monthly quantities in acre-feet/month, which are included in the simulation results DSS file. The DSS records of monthly targets are copied from the daily *SIMD* simulation results DSS output file to the *SIM/SIM* hydrology input DSS file and the pathnames are revised using *HEC-DSSVue*.

The DSS file pathnames for the target series *TS* records are listed in Table 5.11. The *TS* records in the monthly *SIM* DAT file replicated in Table 5.12 reference the DSS file target series employed by the *IF* record water rights. IFM(if,2) option 2 in *IF* record field 7 activates the option to combine multiple *IF* record instream flow targets at the same control point by selecting the largest. With only one *IF* record at a control point, the IFM(if,2) option is not relevant. The results for daily and monthly simulations presented in Chapter 6 include daily and aggregated monthly instream flow targets for the SB3 EFS.

Table 5.12
Instream Flow Rights that Model the SB3 EFS in the DAT File of the Monthly WAM

```
IF GS300                 20110301   2            GS300ES
TS       DSS
IF DV501                 20110301   2            DV501ES
TS       DSS
IFGS1000                 20110301   2            GS1000ES
TS       DSS
IFWGS800                 20110301   2            WGS800ES
TS       DSS
IFECB720                 20110301   2            ECB720ES
TS       DSS
```

Parameter DSSTS on the *JO* record activates reading of *TS* records from the DSS input file. Control point identifiers can be included on the *TS* records. However, blank control point fields on the *TS* records of Table 5.12 default to assigning the control points from the *IF* records.

CHAPTER 6
SIMULATION RESULTS

Results from simulations with daily and monthly full authorization and current use scenario water availability models (WAMs) are presented in this chapter. Daily SB3 environmental flow standard (EFS) instream flow targets are summed to monthly quantities within the daily *SIMD* simulation for incorporation in the monthly *SIM* simulation time series input dataset.

Full authorization scenario WAMs are based on the premise that all water right holders store and divert the full amounts of stream flow for which they are legally entitled subject to water availability. The current use scenario replicates water use quantities that are representative of water use during recent years. The terms run 3 and run 8 have been applied since the beginning of WAM development in the late 1990's to the full authorization and current use, respectively, simulation datasets maintained at the TCEQ WAM website that reflect specified sets of premises.

The January 2023 daily and monthly full authorization (run 3) and current use (run 8) Lavaca WAMs employed in the simulations discussed in this chapter are comprised of simulation input files with the filenames listed in Table 6.1. Selected results from multiple simulations are compiled in a DSS file with filename LavacaSimulationResults.DSS. DSS pathname labeling conventions are described in Chapter 6 of the WRAP Users Manual [2].

Table 6.1
WAM Simulation Input Data Files

Full Authorization Scenario		Current Use Scenario	
Daily *SIMD*	Monthly *SIM*	Daily *SIMD*	Monthly *SIM*
Lavaca3D.DAT Lavaca.DIS LavacaHYD.DSS Lavaca.DIF	Lavaca3M.DAT Lavaca.DIS LavacaHYD.DSS	Lavaca8D.DAT Lavaca.DIS LavacaHYD.DSS Lavaca.DIF	Lavaca8M.DAT Lavaca.DIS LavacaHYD.DSS

All plots and statistical metrics in this chapter were developed with *HEC-DSSVue* from the results of *SIMD* and *SIM* simulations. Daily and monthly time series quantities for selected simulation results are presented in this chapter. The January 1940 through December 2021 hydrologic period-of-analysis has a length spanning 82 years, 984 months, or 29,951 days.

Daily Full Authorization WAM

The full authorization WAM has 22 reservoirs with a total storage capacity of 234,778 acre-feet. Lake Texana has an authorized capacity of 170,300 acre-feet. The permitted but not yet constructed Palmetto Bend Stage II Reservoir has a capacity of 62,454 acre-feet. The other twenty reservoirs have a combined total capacity of 2,024 acre-feet.

Storage plots in Figure 6.1 from a daily full authorization simulation include: (1) end-of-month total storage in the 22 reservoirs, (2) end-of-month storage in the Lake Texana, and (3) end-of-day storage in Lake Texana. The reservoirs are full to capacity at the beginning of the simulation. Since the beginning-of-simulation and simulated 984 end-of-month storage volumes are the same as the beginning-of-simulation and 984 of 29,951 computed end-of-day storage volumes in Lake Texana, the daily and monthly plots appear to be almost the same.

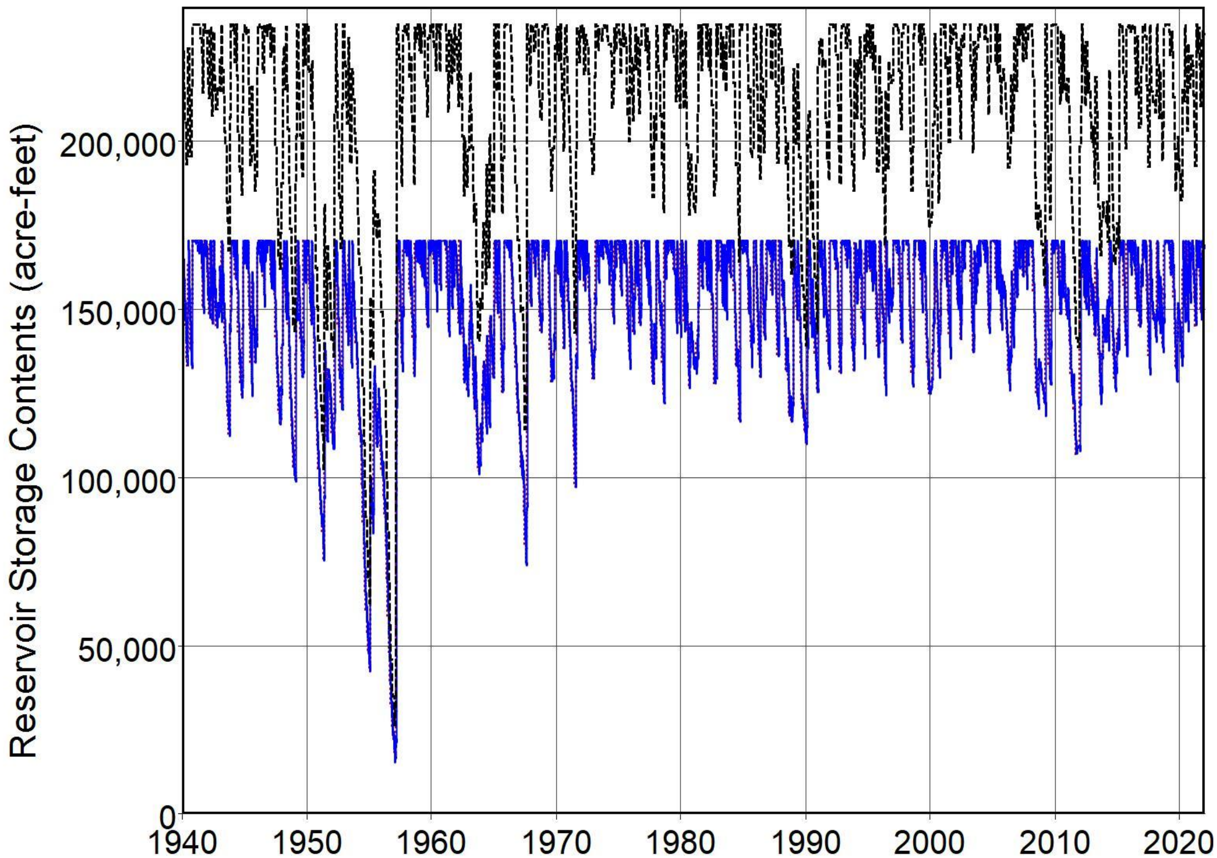

Figure 6.1 Total Monthly (dashed black line), Texana Monthly (blue solid line), and Daily Texana (red dots) Storage for Daily Full Authorization Simulation

Control point EP000 represents the outlet of the river basin where the Lavaca River flows into Lavaca Bay. Simulated daily regulated flows of the Lavaca River at control point EP000 are plotted in Figure 6.2. Frequency statistics for daily naturalized, regulated, and unappropriated flows in cfs at control point EP000 are tabulated in Table 6.2. The regulated and unappropriated flows at control point EP000 are the same since no *WR* or *IF* record water rights are located at or downstream of control point EP000.

The *IF* record rights for the SB3 EFS are the most junior water rights in the WAM and thus have no effect on other more senior water rights. The reservoir storage volumes of Figure 6.1 and stream flow metrics of Table 6.2 are the same with or without inclusion of the SB3 EFS *IF* record instream flow requirements in the WAM. Without the SB3 EFS *IF* record water rights, the water right priorities range from 19030930 (September 30, 1903) to 20020703 (July 3, 2002). The *IF* record rights for the SB3 EFS are added with a priority of 20110301 (March 1, 2011).

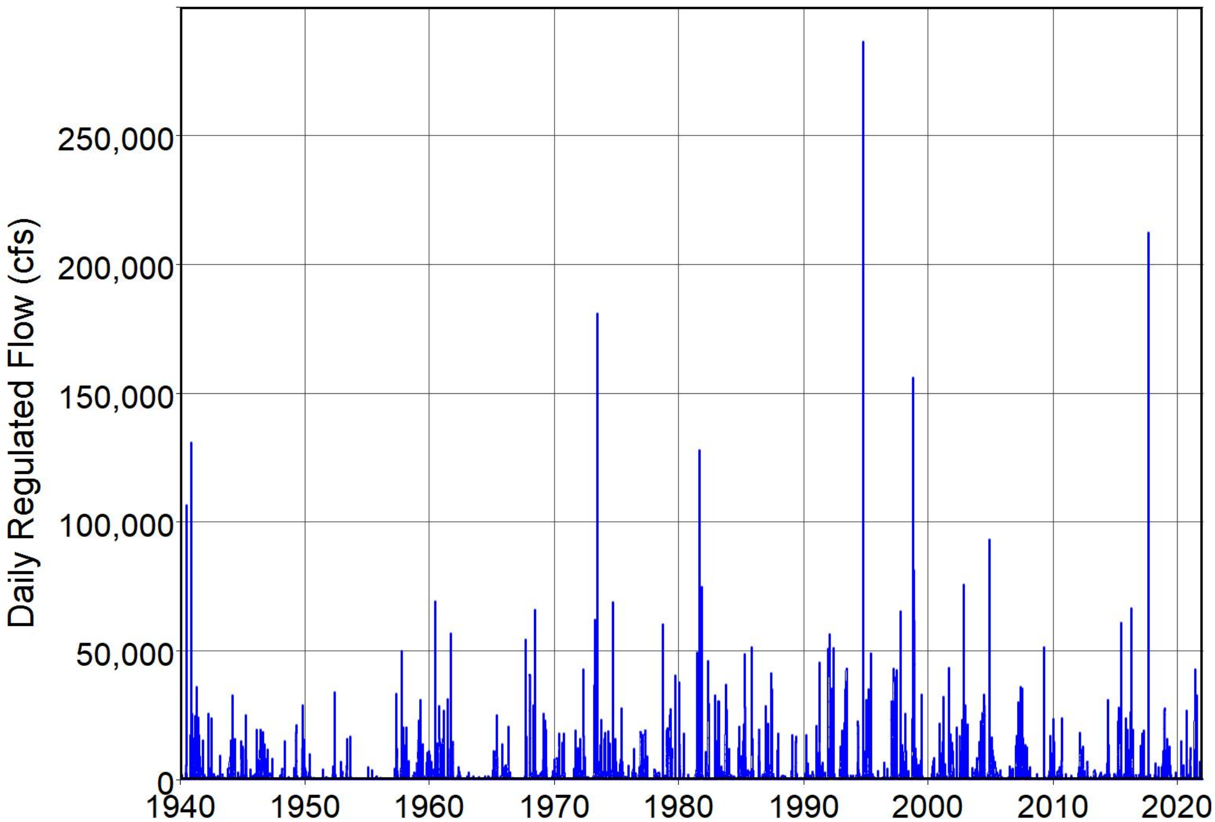

Figure 6.2 Daily Regulated Flow at Outlet (EP000) for Daily Full Authorization Simulation

Table 6.2
Naturalized, Regulated, Unappropriated Flows at the Outlet (EP000)

	Naturalized	Regulated	Unappropriated
Mean Flow (cfs)	1,366	1,151	1,151
Standard Deviation	5,634	5,460	5,460
Minimum (cfs)	0.0	0.0	0.0
Maximum (cfs)	286,696	286,473	286,473
	Daily Flows (cfs) with Specified Exceedance Frequencies		
0.1%	65,628	65,511	65,511
1%	22,993	21,489	21,489
5%	5,999	4,508	4,508
10%	2,115	1,590	1,590
20%	770.5	538.1	538.1
30%	453.2	292.4	292.4
40%	304.1	200.9	200.9
50%	221.2	143.1	143.1
60%	165.2	101.9	101.9
70%	110.2	56.49	56.49
80%	57.93	19.45	19.45
90%	13.68	0.00	0.00
95%	0.00	0.00	0.00

Simulated Regulated Flows at the SB3 EFS Sites

The USGS gage site locations of environmental flow standards (EFS) established following the process created by the 2007 Senate Bill 3 (SB3) are represented in the WAM by the control points listed in Tables 6.3 and 6.4. Watershed drainage areas above the gage sites from the USGS NWIS are tabulated in the third column of the tables. The USGS gage identifiers are included in Table 5.1 of Chapter 5. Locations of the sites are shown in Figure 2.1.

Table 6.3
Statistics for Daily Regulated Flows in cfs at the Control Points of the SB3 EFS

Control	USGS Gage Location	Drainage Area	Regulated Flow (cfs)		
Point	of SB3 EFS	(square miles)	Mean	Median	90%
GS300	Lavaca River near Edna	817	365.8	49.61	6.031
DV501	Navidad at Strane Park near Edna	579	315.2	51.72	5.027
GS1000	Sandy Creek near Ganado	289	161.7	11.23	0.0000
WGS800	West Mustang Creek near Ganado	178	122.0	12.16	0.354
ECB720	East Mustang Creek near Louise	53.9	39.93	3.857	0.0215

Table 6.4
Statistics for Monthly Regulated Flow in acre-feet/month at the Control Points of the SB3 EFS

Control	USGS Gage Location	Drainage Area	Regulated Flow (acre-feet/month)		
Point	of SB3 EFS	(square miles)	Mean	Median	90%
GS300	Lavaca River near Edna	817	22,082	5,081	590.0
DV501	Navidad at Strane Park near Edna	579	19,030	6,218	1,364
GS1000	Sandy Creek near Ganado	289	9,763	2,391	0.000
WGS800	West Mustang Creek near Ganado	178	7,367	2,389	118.0
ECB720	East Mustang Creek near Louise	53.9	2,411	815.8	55.48

The mean and median (50% exceedance) of the regulated flows and the regulated flow quantities equaled or exceeded during 90 percent of the 29,951 days of the *SIMD* simulation are tabulated in the last three columns of Table 6.3. The median is the flow quantity equaled or exceeded during 50 percent of the 29,951 days of the *SIMD* simulation.

The mean, median, and regulated flow quantities equaled or exceeded during 90 percent of the 984 months of the *SIMD* daily simulation are tabulated in the last three columns of Table 6.4. *SIMD* summed the daily regulated flow volumes in acre-feet/day for the 28, 29, 30, or 31 days of each month to monthly totals in acre-feet/month. The metrics in Table 6.4 are in acre-feet/month.

All simulation result variables related to flow rates, including regulated flows and instream flow targets, are computed in a *SIMD* daily simulation in acre-feet/day. Both daily and monthly summations of daily flow volumes in acre-feet/day and acre-feet/month, respectively, can be optionally included in the *SIMD* simulation results. *SIMD* daily computations and simulation results are in units of acre-feet/day which are converted to cubic feet per second (cfs) within *HEC-DSSVue*. An acre-foot/day is equivalent to 1.98347 cfs.

<u>SB3 EFS Instream Flow Targets from a *SIMD* Daily Simulation</u>

The SB3 EFS are modeled as shown in Table 5.7. The subsistence and base flow components of the EFS are modeled as an *IF* record water right. The high pulse flow components are modeled as a separate *IF* record water right. Instream flow targets for the subsistence and base flow components of the EFS are computed in each of the 29,951 days of the *SIMD* simulation. High pulse flow targets are computed during days that satisfy the criteria outlined in Table 5.6. Multiple instream flow targets are computed by *SIMD* in each day. The largest target is adopted.

Statistics for the SB3 EFS instream flow targets for the 29,951 days recorded in the *SIMD* simulation results DSS file are tabulated in Table 6.5. DSS record part C labels TIF-WR and IFT-CP are defined in Table 5.9. TIF-WR and IFT-CP refers to intermediate and final targets. The TIF-WR quantities are the combined subsidence and base flow targets and the combined pulse flow targets. These component targets and the final IFT-CP target are included in Table 6.5.

Table 6.5
Statistics for SB3 EFS Instream Flow Targets

Components of	Daily Instream Flow Targets (cfs)				Shortage
SB3 EFS Targets	Minimum	Median	Mean	Maximum	Mean (cfs)
			Lavaca River near Edna (GS300)		
Subsistence and Base	1.20	20.00	19.69	30.0	0.2332
High Flow Pulse	0.00	0.00	46.29	4,500	-
Final Target	1.20	20.00	65.27	4,500	0.2332
			Navidad River near Edna (DV501)		
Subsistence and Base	1.00	17.00	14.04	24.0	0.1152
High Flow Pulse	0.00	0.00	40.52	2,500	-
Final Target	1.00	17.00	53.94	2,500	0.1152
			Sandy Creek near Ganado (GS1000)		
Subsistence and Base	1.00	5.00	4.160	9.0	0.2933
High Flow Pulse	0.00	0.00	29.52	2,200	-
Final Target	1.00	5.00	33.42	2,200	0.2933
			West Mustang Creek near Ganado (WGS800)		
Subsistence and Base	1.00	4.00	3.928	10.0	0.1131
High Flow Pulse	0.00	0.00	17.99	1,000	-
Final Target	1.00	5.00	21.66	1,000	0.1131
			East Mustang Creek near Louise (ECB720)		
Subsistence and Base	1.00	1.00	1.103	2.0	0.2008
High Flow Pulse	0.00	0.00	7.343	1,000	-
Final Target	1.00	1.00	8.391	1,000	0.2008

Table 6.6
Statistics for SB3 EFS Instream Flow Targets

Exceedance Frequency	GS300	DV501	GS1000	WGS800	ECB720
	Instream Flow Target (cfs) Equaled or Exceeded				
0.1%	4,500	2,500	2,200	1,000	1,000
0.2%	4,500	2,500	2,200	1,000	553.7
0.5%	4,500	2,500	1,800	1,000	340.0
1%	2,000	2,000	1,272	810.0	280.0
2%	204.1	499.6	503.8	371.9	116.6
5%	30.0	24.0	9.0	10.0	2.0
10%	30.0	24.0	9.0	10.0	2.0
15%	30.0	18.0	9.0	6.0	1.0
20%	30.0	18.0	9.0	6.0	1.0
30%	30.0	18.0	5.0	5.0	1.0
40%	30.0	17.0	5.0	5.0	1.0
50%	20.0	17.0	5.0	4.0	1.0
60%	20.0	14.0	1.0	4.0	1.0
70%	10.0	14.0	1.0	1.0	1.0
80%	8.5	2.8	1.0	1.0	1.0
85%	1.3	2.2	1.0	1.0	1.0
90%	1.3	2.2	1.0	1.0	1.0
95%	1.2	1.2	1.0	1.0	1.0
98%	1.2	1.0	1.0	1.0	1.0
99.9%	1.2	1.0	1.0	1.0	1.0

The last column of Table 6.5 shows the mean of the shortages (failures) in meeting the targets during the 29,951 days. Instream flow shortages are labeled IFS-WR and IFS-CP in DSS record part C (Table 5.9). No shortages occur in meeting the high flow pulse targets. Non-zero shortages in meeting the subsistence or base flow targets occur in some days of the simulation.

Combined subsidence and base flow targets in each day at control point GS300 range from 1.20 cfs to 30.0 cfs with a mean and median of 20.0 cfs and 19.69 cfs. The average of shortages is 0.2332 cfs. High flow pulse flow targets range between 0.0 and 4,500 cfs. The highest target is selected in each individual day resulting in final adopted targets that average 65.27 cfs at GS300.

Frequency metrics for the final target in each of the 29,951 days of the 1940-2021 hydrologic period-of-analysis are provided in Table 6.6. The final daily targets adopted each day at a control point are labeled IFT-CP in DSS record part C (Table 5.9).

The daily instream flow targets for the SB3 EFS computed in the daily *SIMD* simulation are plotted in Figures 6.3, 6.5, 6.7, 6.9, and 6.11. The aggregated monthly SB3 EFS instream flow targets computed in the daily *SIMD* simulation by summing daily targets are plotted in Figures 6.4, 6.6, 6.8, 6.10, and 6.12. The monthly targets are converted to target series *TS* records as discussed in the next section for incorporation in the monthly *SIM* input dataset.

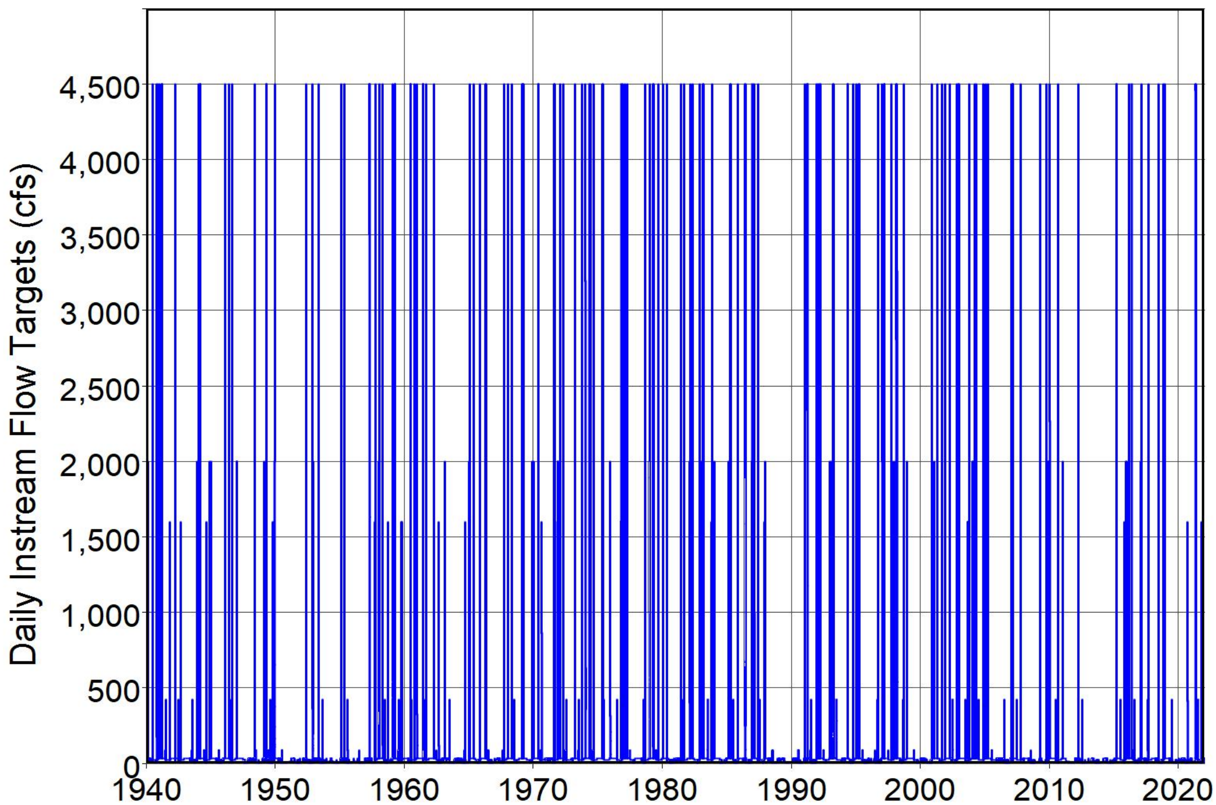

Figure 6.3 Daily SB3 EFS Target (cfs) at GS300

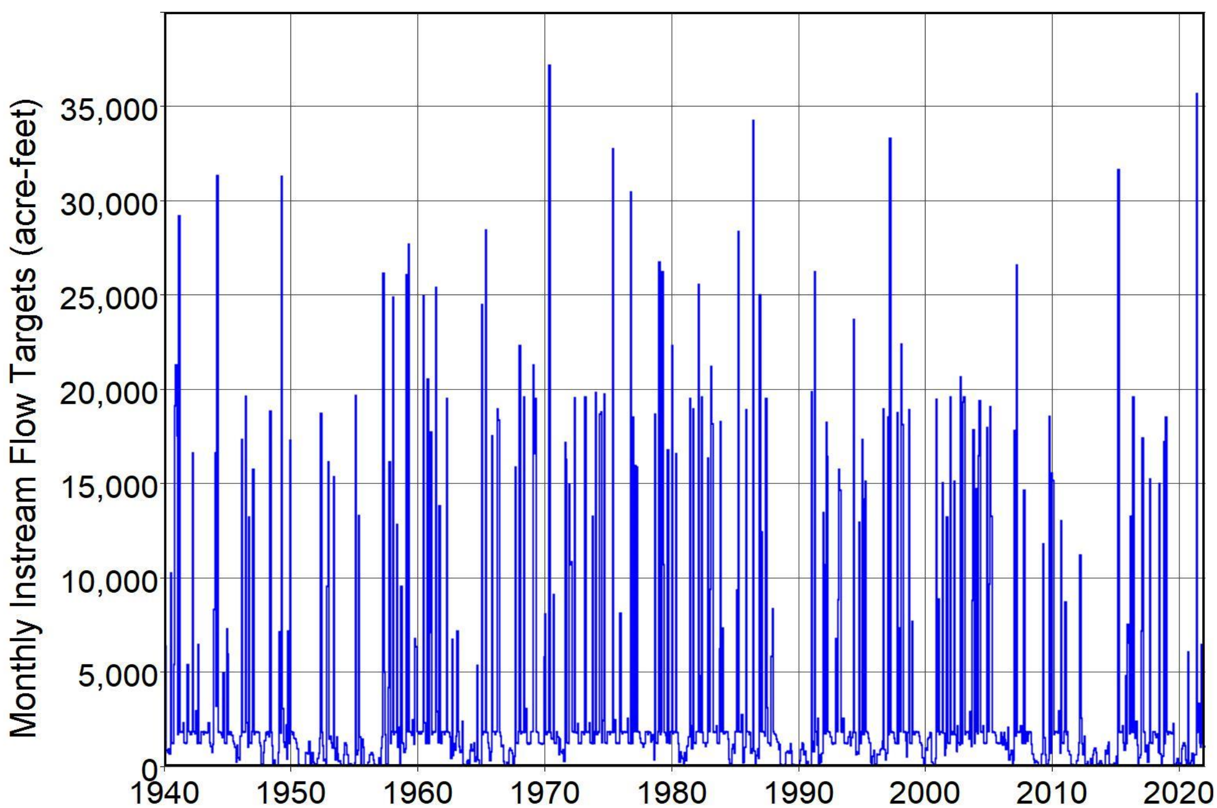

Figure 6.4 Monthly SB3 EFS Target (acre-feet) at GS300

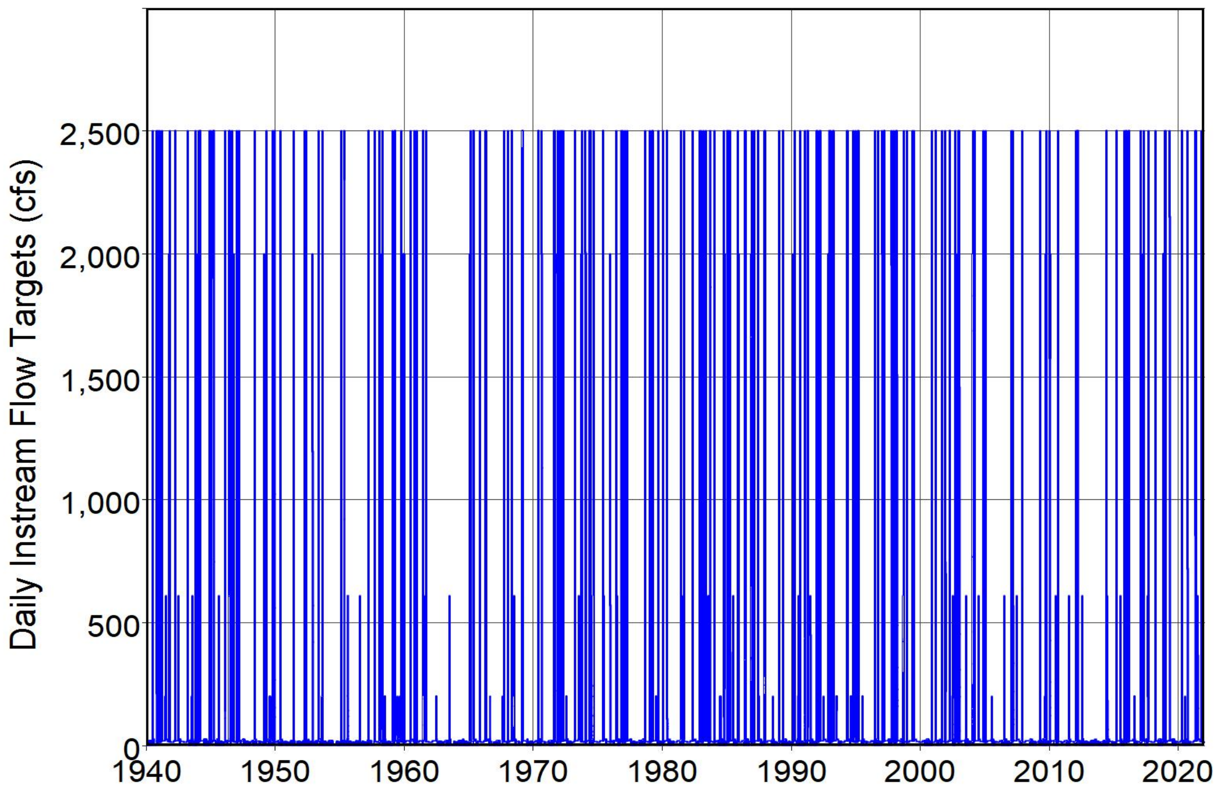

Figure 6.5 Daily SB3 EFS Target (cfs) at DV501

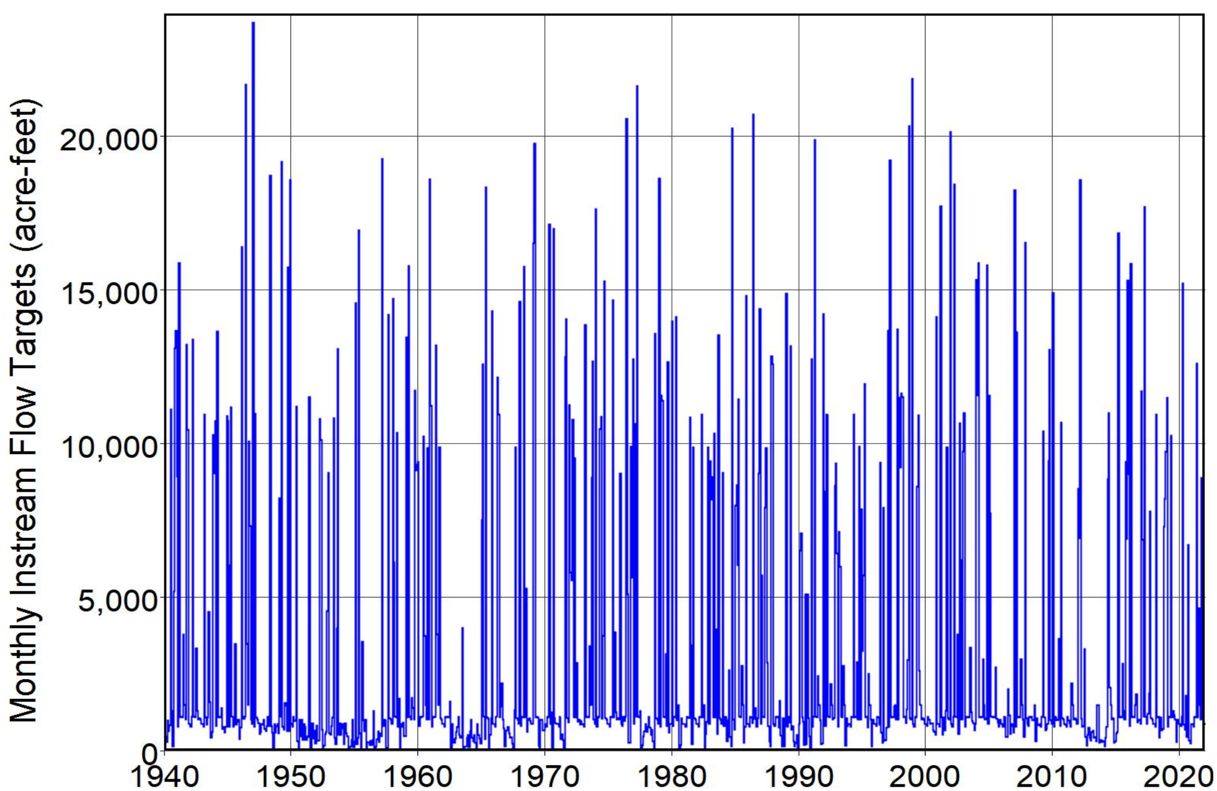

Figure 6.6 Monthly SB3 EFS Target (acre-feet) at DV501

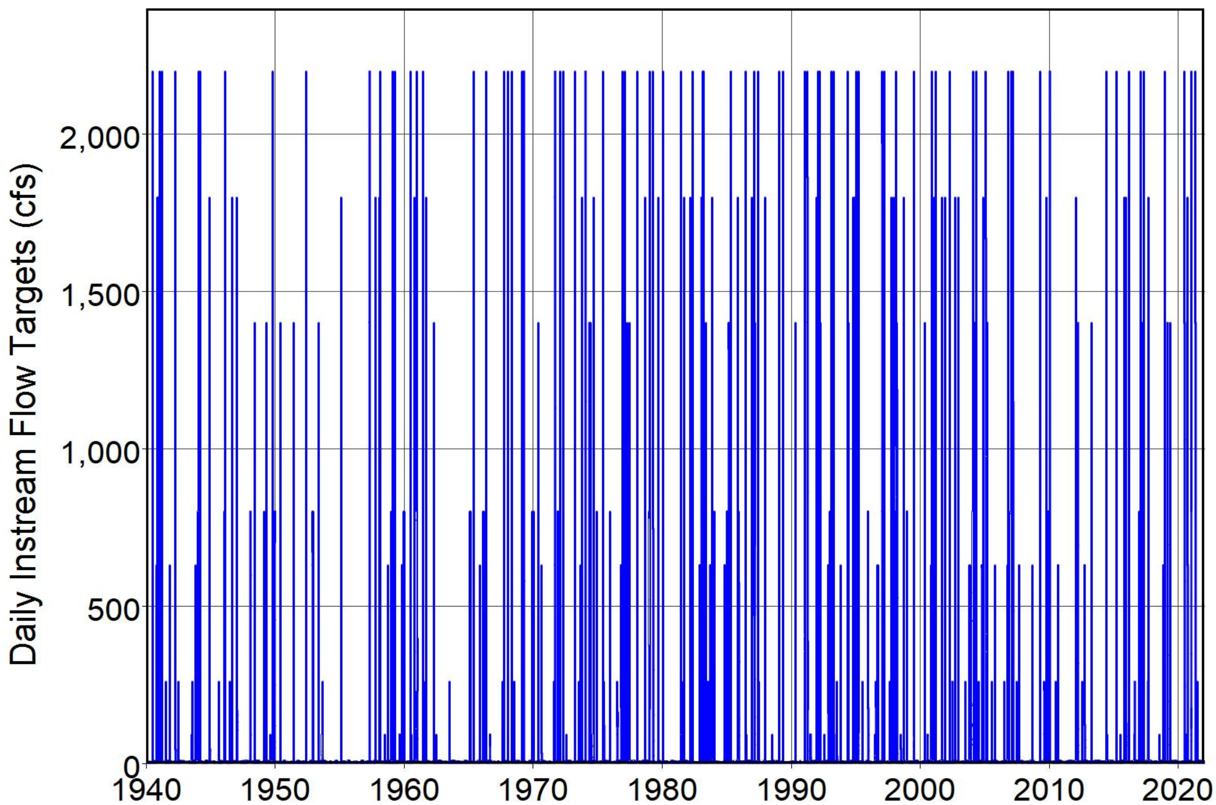

Figure 6.7 Daily SB3 EFS Target (cfs) at GS1000

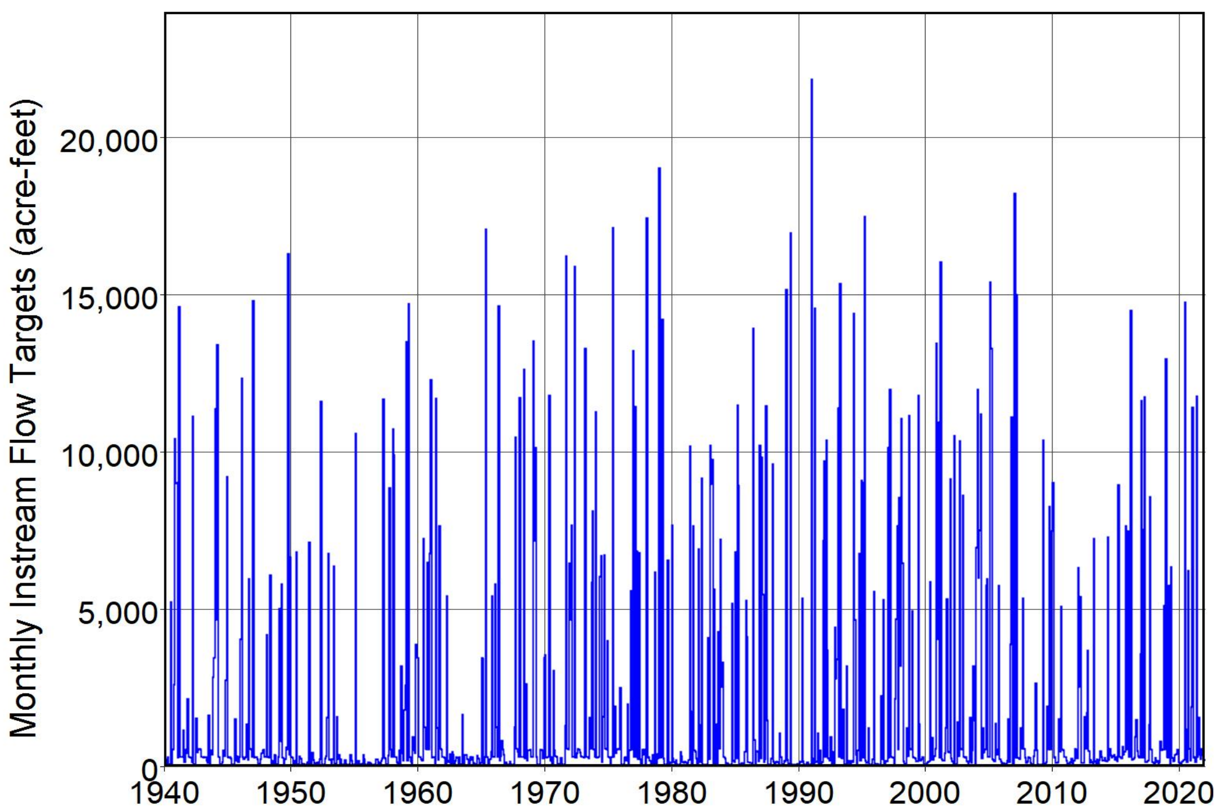

Figure 6.8 Monthly SB3 EFS Target (acre-feet) at GS1000

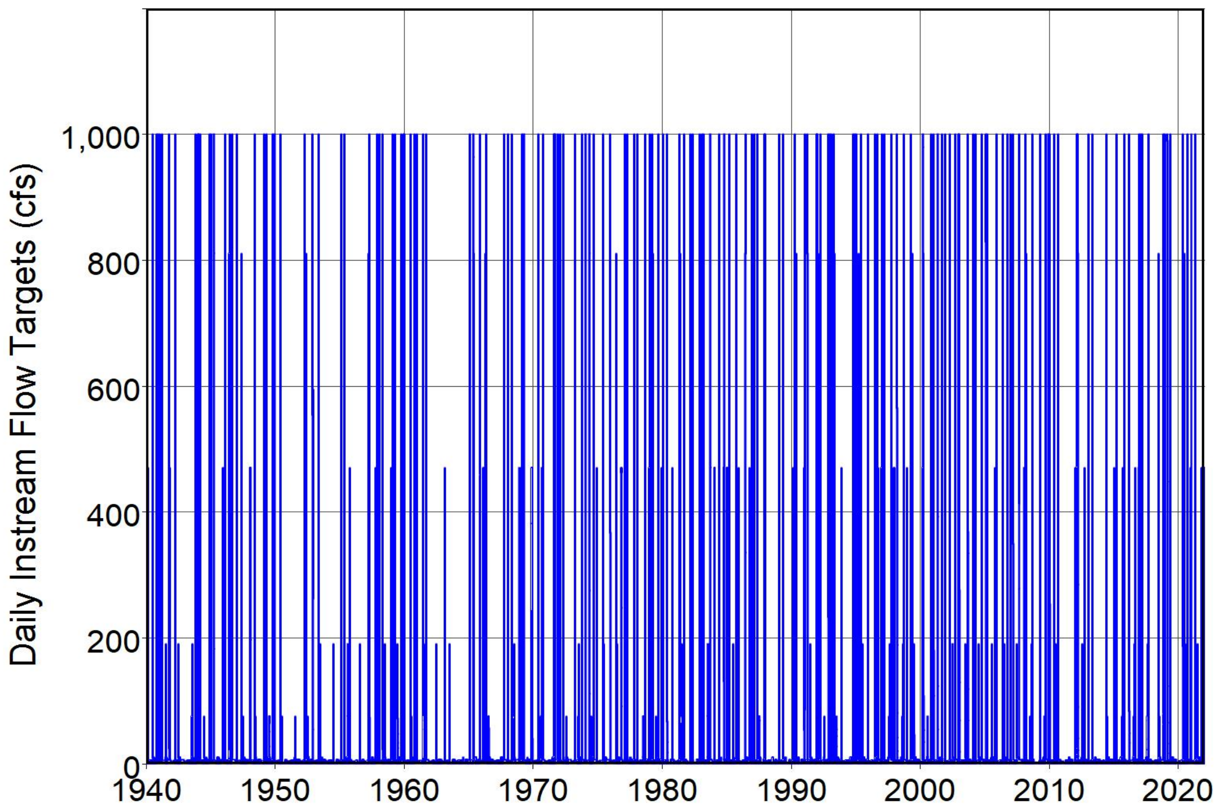

Figure 6.9 Daily SB3 EFS Target (cfs) at WGS800

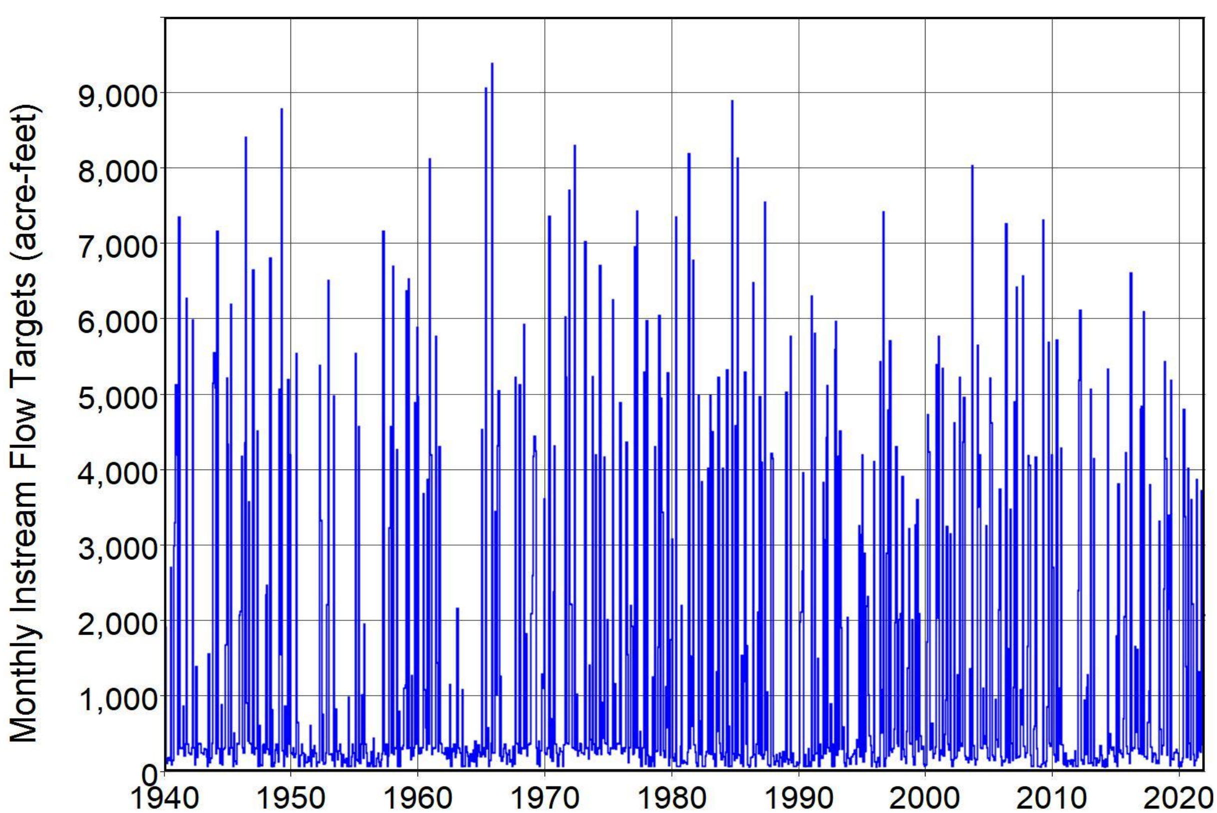

Figure 6.10 Monthly SB3 EFS Target (acre-feet) at WGS800

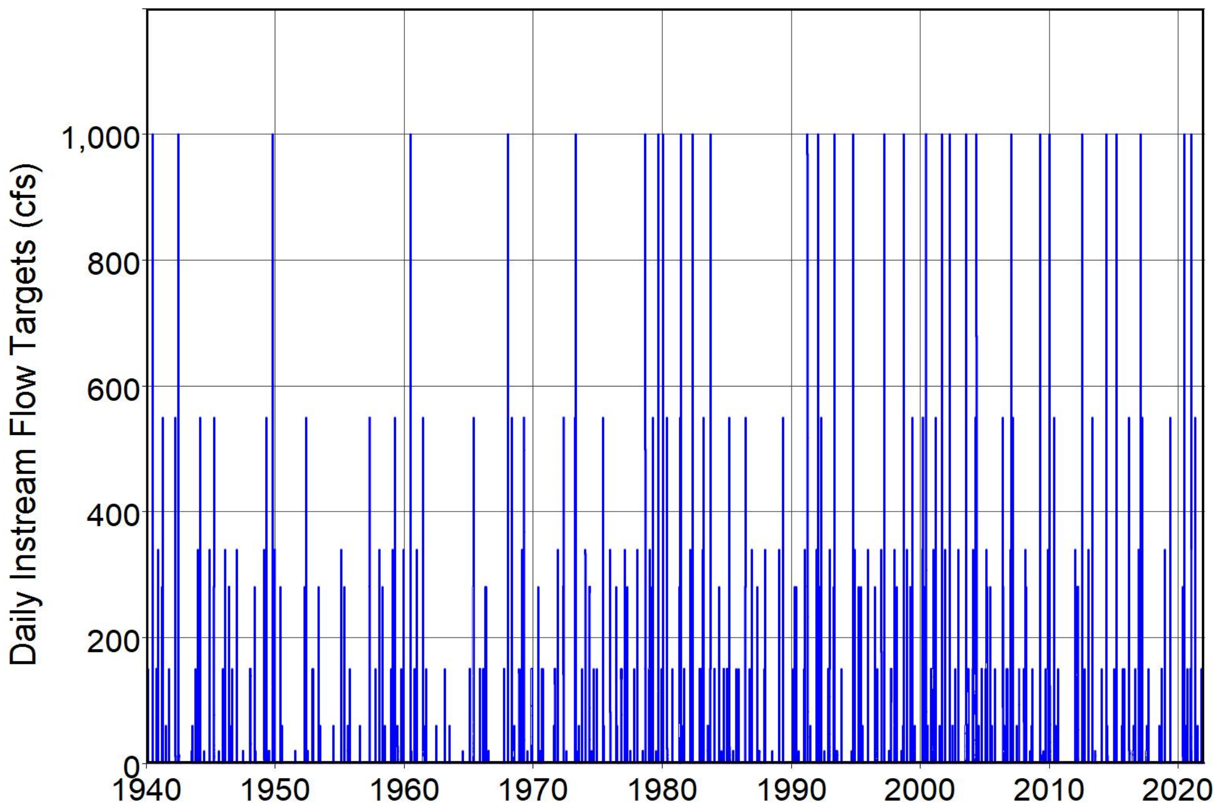

Figure 6.11 Daily SB3 EFS Target (cfs) at ECB720

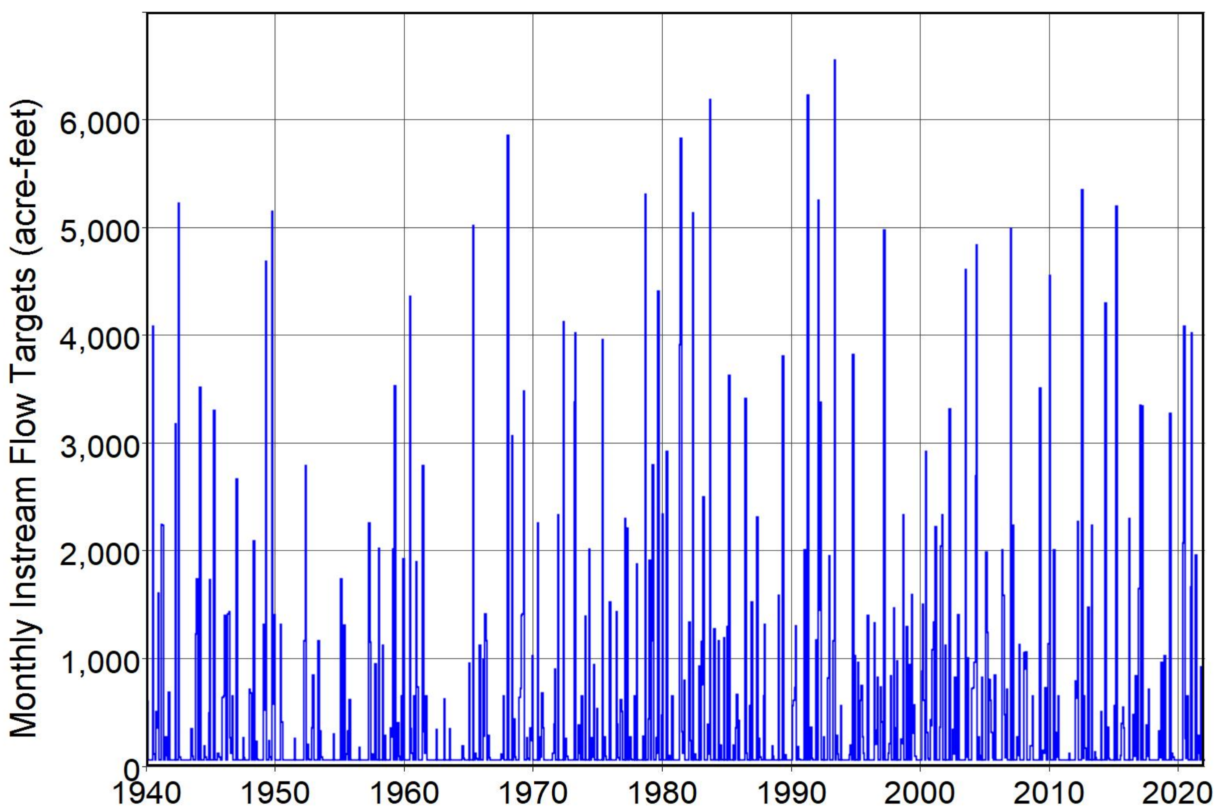

Figure 6.12 Monthly SB3 EFS Target (acre-feet) at ECB720

Monthly Full Authorization WAM

The monthly full authorization Lavaca WAM last updated by the TCEQ in September 2014 includes addition of draft input records modeling the SB3 EFS in an approximate manner. The addition of SB3 EFS in 2014 was before availability of new WRAP modeling capabilities implemented with *ES*, *HC*, and *PF* records. The initial draft addition of SB3 EFS in the September 2014 update has been removed in the January 2023 monthly WAM. The SB3 EFS are now modeled by addition of monthly targets developed in the daily simulation described in the preceding section of this chapter. The records shown in Tables 5.11 and 5.12 are employed to model the SB3 EFS in the January 2023 monthly Lavaca WAM.

Daily instream flow targets in acre-feet/day for the SB3 EFS computed in the daily *SIMD* simulation are summed by *SIMD* to monthly totals in acre-feet/month that are included in the *SIMD* simulation results. The final targets labeled IFT-CP in DSS pathname part C (Table 5.9) are plotted in Figures 6.4, 6.6, 6.8, 6.10, and 6.12. The time series of monthly targets are converted to target series *TS* records (Table 5.11) within *HEC-DSSVue* and incorporated in the input DSS file read in a monthly *SIM* simulation. The target series *TS* records in the DSS file are referenced by *TS* records in the DAT file which are replicated in Table 5.12.

Statistics for the SB3 EFS instream flow targets in acre-feet for the 984 months of the *SIM* simulation are tabulated in Tables 6.7 and 6.8. Table 6.7 includes the minimum, median (50% exceedance), mean (average) , and maximum of the 984 monthly targets and the mean of the shortages in meeting the targets. Table 6.8 is a tabulation of the monthly target amounts that are equaled or exceeded during specified percentages of the 984 months.

Table 6.7
Statistics for SB3 EFS Instream Flow Targets

Control Point	Monthly Instream Flow Targets (acre-feet) Minimum	Median	Mean	Maximum	Mean Shortage (acre-feet) *SIM*	*SIMD*
GS300	47.21	1,500	3,908	37,173	5.148	5.161
DV501	61.49	1,023	3,256	23,699	2.750	1.761
GS1000	55.54	297.5	2,018	21,842	14.27	10.94
WGS800	55.54	289.6	1,308	9,382	4.574	3.891
ECB720	55.54	61.49	506.6	6,554	4.767	4.710

The monthly SB3 EFS instream flow targets recorded in the monthly *SIM* simulation results are identical to the monthly targets computed in the daily *SIMD* simulation since the monthly targets are read by *SIM* as input. The monthly targets are read by *SIM* from *TS* records stored in the time series input DSS file. However, the shortages in meeting the monthly targets in the monthly *SIM* simulation differ from the summation of daily shortages in meeting daily targets computed in the daily *SIMD* simulation reflected in the last two columns of Table 6.7. The next-to-last column in Table 6.7 shows the average of the 984 shortages in meeting the instream flow targets in the monthly *SIM* simulation. The last column lists averages of the 984 monthly shortages computed in the daily *SIMD* simulation by summing daily shortages.

Table 6.8
Statistics for SB3 EFS Monthly Instream Flow Targets

Exceedance Frequency	GS300	DV501	GS1000	WGS800	ECB720
	Monthly Instream Flow Target (acre-feet) Equaled or Exceeded				
0.2%	35,734	21,943	19,120	9,065	6,242
0.5%	32,796	20,775	17,454	8,436	5,830
1%	29,380	19,932	16,241	8,042	5,202
2%	25,698	18,485	14,662	7,191	4,455
5%	19,517	14,600	11,486	5,800	2,796
10%	16,043	11,236	7,665	4,889	1,490
15%	8,170	9,426	5,589	4,097	997.6
20%	2,428	5,792	2,785	2,380	650.6
30%	1,845	1,265	536.0	777.9	244.4
40%	1,785	1,071	331.0	349.1	61.5
50%	1,500	1,023	298.0	289.6	61.5
60%	1190	890.0	220.0	236.0	61.5
70%	975.0	806.0	142.0	194.4	59.5
80%	595.0	659.0	75.0	138.8	59.5
85%	284.0	510.0	61.0	109.1	59.5
90%	80.0	343.0	61.0	72.4	59.5
95%	71.0	177.0	60.0	61.5	56.0
98%	52.0	74.0	60.0	59.5	55.5
99.8%	47.0	61.0	56.0	55.5	55.5

The four reservoir storage plots in Figure 6.13 provide a comparison of:

1. end-of-month total storage in the 22 reservoirs from a monthly *SIM* simulation
2. end-of-month total storage in the 22 reservoirs from a daily *SIMD* simulation
3. end-of-month storage in Lake Texana from a monthly *SIM* simulation
4. end-of-day total storage in Lake Texana from a daily *SIMD* simulation

Statistical metrics for these four 1940-2021 simulated series of monthly and daily reservoir storage volumes are compared in Table 6.9.

Table 6.9
Comparison of Reservoir Storage Volumes from Monthly *SIM* and Daily *SIMD* Simulations

	Totals for All 22 Reservoirs		Lake Texana	
	SIM	*SIMD*/Month	*SIM*	*SIMD*/Day
Minimum (acre-feet)	19,804	26,333	17,492	15,231
Median (acre-feet)	214,830	219,141	157,194	156,886
Mean (acre-feet)	205,592	208,467	150,539	150,432
Maximum (acre-feet)	234,778	234,778	170,300	170,300

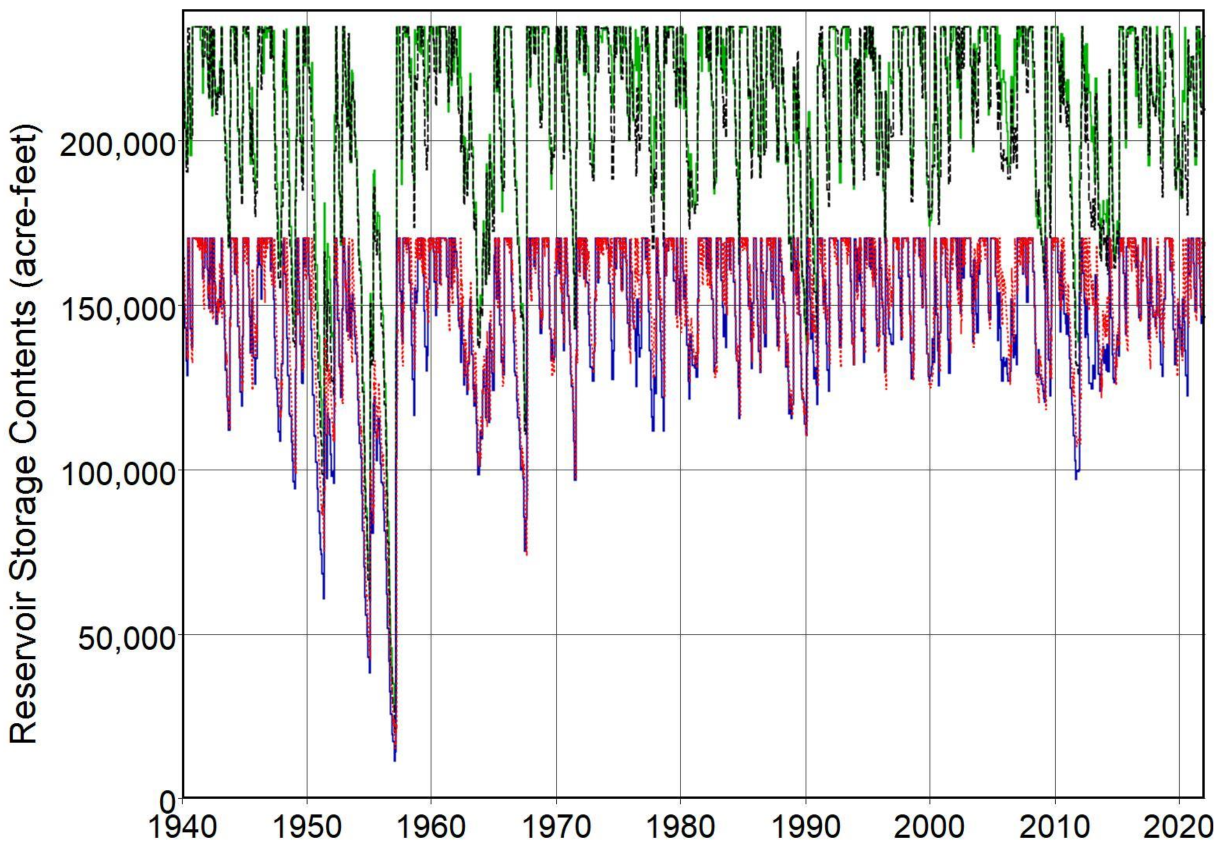

Figure 6.13 Total *SIM* (green solid line), Total *SIMD* Monthly Summations (black dashed line), Texana *SIM* Monthly (blue solid line), and Texana *SIMD* Daily (red dots) Storage

Daily and Monthly Current Use Scenario WAMs

The current use scenario (run 8) monthly Lavaca WAM last updated by the TCEQ in June 2008 was converted to daily and the SB3 EFS was added in essentially the same manner as employed with the full authorization scenario (run 3) WAM. The DIF file and the *IN*, *EV*, and *DF* records in the hydrology input DSS file are the same for the January 2023 current use and full authorization WAMs. The SB3 EFS are modeled the same in both the current use and full authorization daily WAMs except for the differences described in the next two paragraphs.

Hydrologic conditions are defined on *HC* records as a function of storage in Lake Texana. The storage capacity of Lake Texana varies between the full authorization and current use datasets. Storage volumes used in the two alternative versions of the WAM are shown in Table 5.3 of Chapter 5. Hydrologic conditions are defined in the SB3 EFS as a function of water surface elevation in Lake Texana. Elevation versus storage tables last updated by the TWDB in 2020, available at the TWDB website, were combined with storage capacities from the full authorization and current use WAMs to develop the metrics tabulated in Table 5.3.

The SB3 EFS had not been previously added to the current use WAM. Therefore, removal of old records approximating the SB3 EFS was not necessary. The procedures for adding the SB3 EFS to the monthly current use WAM are the same as for the monthly full authorization WAM.

Monthly Current Use Scenario WAM

Daily SB3 EFS instream flow targets are summed to monthly quantities within the daily *SIMD* simulation for incorporation in the monthly *SIM* simulation time series input file with filename LavacaHYD.DSS. The monthly instream flow targets are stored in the *SIM*/*SIMD* shared time series input DSS file as target series *TS* records. The DSS and DAT file records of Tables 5.11 and 5.12 were used with the full authorization WAMs to add the SB3 EFS to the monthly *SIM* input dataset. However, different identifiers are needed in order to store *TS* records for both the current use and full authorization WAMs in the same DSS file. The identifiers on the records of Tables 5.11 and 5.12 are changed to those of Tables 6.10 and 6.11 for the current use WAM. Parameter DSSTS on the *JO* record activates reading of *TS* records from the DSS input file.

Table 6.10
Pathnames for *TS* Records for the SB3 EFS in the Input DSS File

Part A	Part B	Part C	Part D	Part E
Lavaca	CU300	TS	01Jan1940-31Dec2021	1MON
Lavaca	CU501	TS	01Jan1940-31Dec2021	1MON
Lavaca	CU1000	TS	01Jan1940-31Dec2021	1MON
Lavaca	CU800	TS	01Jan1940-31Dec2021	1MON
Lavaca	CU720	TS	01Jan1940-31Dec2021	1MON

Table 6.11
Instream Flow Rights that Model the SB3 EFS in the DAT File of the Monthly WAM

```
IF GS300                 20110301   2            GS300ES
TS       DSS CU300
IF DV501                 20110301   2            DV501ES
TS       DSS CU501
IFGS1000                 20110301   2            GS1000ES
TS       DSSCU1000
IFWGS800                 20110301   2            WGS800ES
TS       DSS CU800
IFECB720                 20110301   2            ECB720ES
TS       DSS CU720
```

Statistics for the daily SB3 EFS instream flow targets in cfs for the 29,951 days of the *SIMD* simulation are tabulated in Table 6.12. These metrics reflect the final instream flow targets in each day after combining subsidence, base flow, and high pulse flow targets. With multiple target components, the highest component target is adopted in each day. Computations are performed and simulation results output in acre-feet/day. Conversions to cfs are performed within *HEC-DSSVue*. The means (averages) of the shortages in meeting the instream flow target during each of the 29,951 days are shown in the last two columns of Table 6.12. The next-to-last column shows the mean daily shortage converted to cfs. The last column shows the mean of the 984 monthly shortages recorded in the *SIMD* time series output for a daily simulation. *SIMD* computes the shortage in each month by summing the daily shortages for each day of that month.

Table 6.12
Statistics for SB3 EFS Instream Flow Targets from Daily *SIMD* Simulation

Control Point	Daily Instream Flow Targets (cfs) Minimum	Median	Mean	Maximum	Daily Shortage (cfs)	Monthly Short (acre-feet)
GS300	1.2	20.0	65.30	4,500	0.1274	5.201
DV501	1.0	17.00	54.04	2,500	0.1065	1.698
GS1000	1.0	5.00	36.86	2,200	0.0691	2.567
WGS800	1.0	5.00	23.93	1,000	0.3746	1.052
ECB720	1.0	1.00	8.506	1,000	0.1969	4.604

Metrics for the SB3 EFS instream flow targets in acre-feet for the 984 months of the *SIM* simulation are tabulated in Tables 6.13 and 6.14. Table 6.13 includes the minimum, median (50% exceedance), mean (average), and maximum of the 984 monthly targets. The two alternative mean monthly shortages in meeting the targets in the last two columns of Table 6.13 are computed differently. The next-to-last column in Table 6.13 is the average of the 984 shortages in meeting the instream flow targets in the monthly *SIM* simulation. The last column lists averages of the 984 monthly shortages computed in the daily *SIMD* simulation by summing the daily shortages. The last column of Table 6.12 is replicated as the last column of Table 13.

Table 6.13
Statistics for SB3 EFS Instream Flow Targets Summed to Monthly

Control Point	Monthly Instream Flow Targets (acre-feet) Minimum	Median	Mean	Maximum	Mean Shortage (acre-feet) *SIM*	*SIMD*
GS300	71.40	1,498	3,942	37,168	4.546	5.201
DV501	61.49	1,023	3,263	23,701	2.585	1.698
GS1000	55.54	488.9	2,225	21,841	2.573	2.567
WGS800	55.54	357.0	1,445	11,032	1.068	1.052
ECB720	55.54	61.49	513.6	6,543	4.727	4.604

Table 6.14 is a tabulation of the monthly target amounts that are equaled or exceeded during specified percentages of the 984 months during the *SIM* current use simulation. These tables for the current use WAM can be compared with Tables 6.7 and 6.8 for the full authorization WAM.

Simulated Storage Contents of Lake Texana

The current use scenario WAM includes 21 reservoirs with a total storage capacity of 167,716 acre-feet, which includes Lake Texana with 165,692 acre-feet (98.8% of the total) and twenty small reservoirs with a combined total storage capacity of 2,024 acre-feet. Thus, Lake Texana dominates the total storage capacity in the current use WAM even more than in the full authorization WAM.

Table 6.14
Statistics for SB3 EFS Monthly Instream Flow Targets in acre-feet

Exceedance Frequency	GS300	DV501	GS1000	WGS800	ECB720
	Monthly Instream Flow Target (acre-feet) Equaled or Exceeded				
0.2%	35,736	21,942	21,737	9,386	6,235
0.5%	32,785	20,774	17,635	8,829	5,801
1%	29,749	19,936	16,011	8,094	5,209
2%	26,026	18,486	14,740	7,273	4,421
5%	19,517	14,599	11,779	5,917	2,934
10%	16,155	11,316	8,582	4,836	1,514
15%	8,134	9,478	5,774	4,145	1,051
20%	2,293	5,792	3,299	2,579	650.6
30%	1,845	1,250	1,078	1,268	262.3
40%	1,785	1,071	553.4	614.9	61.49
50%	1,497	1,023	488.9	357.0	61.49
60%	1,190	890.2	307.4	307.4	61.49
70%	981.8	806.1	297.5	297.52	59.50
80%	614.9	661.7	277.7	245.95	59.50
85%	522.6	515.8	188.4	222.15	59.50
90%	187.2	342.9	109.1	150.74	59.50
95%	79.93	176.5	61.49	89.75	56.03
98%	71.40	73.79	59.50	61.49	55.54
99%	71.40	73.79	59.50	61.49	55.54
99.5%	71.40	73.79	57.37	59.36	55.54
99.8%	71.40	61.49	55.54	55.54	55.54

Statistical metrics for the following four 1940-2021 series of daily and monthly simulated reservoir storage volumes are compared in Table 6.15.

1. Lake Texana end-of-day storage in a daily *SIMD* current use simulation
2. Lake Texana end-of-month storage in a *SIM* current use simulation
3. Lake Texana end-of-day storage in a daily *SIMD* full authorization simulation
4. Lake Texana end-of-month storage in a *SIM* full authorization simulation

Table 6.15
Comparison of Reservoir Storage Volumes from Monthly SIM and Daily SIMD Simulations

	Current Use WAM		Full Authorization WAM	
	Daily	Monthly	Daily	Monthly
Minimum (acre-feet)	117,660	112,292	15,231	11,439
Median (acre-feet)	161,135	158,055	156,886	151,919
Mean (acre-feet)	157,279	155,501	150,432	147,445
Maximum (acre-feet)	165,692	165,692	170,300	170,300

Simulated 1940-2021 storage contents of Lake Texana are compared for alternative simulations in Figures 6.14, 6.15, and 6.16. Daily and monthly WAM simulation result in almost the same storage levels. Storage drawdowns are much greater in the full authorization WAM than the current use WAM. The 1950's drought is the most hydrologically severe drought during the 1940-2021 period-of-analysis in all of the alternative simulations.

Daily *SIMD* simulation results for the full authorization and current use scenario WAMs are compared in Table 6.14. The storage capacity of Lake Texana is 170,300 and 165,692 acre-feet, respectively. Storage drawdowns are much more severe, particularly during the 1950's drought, in the full authorization simulation than in the current use simulation.

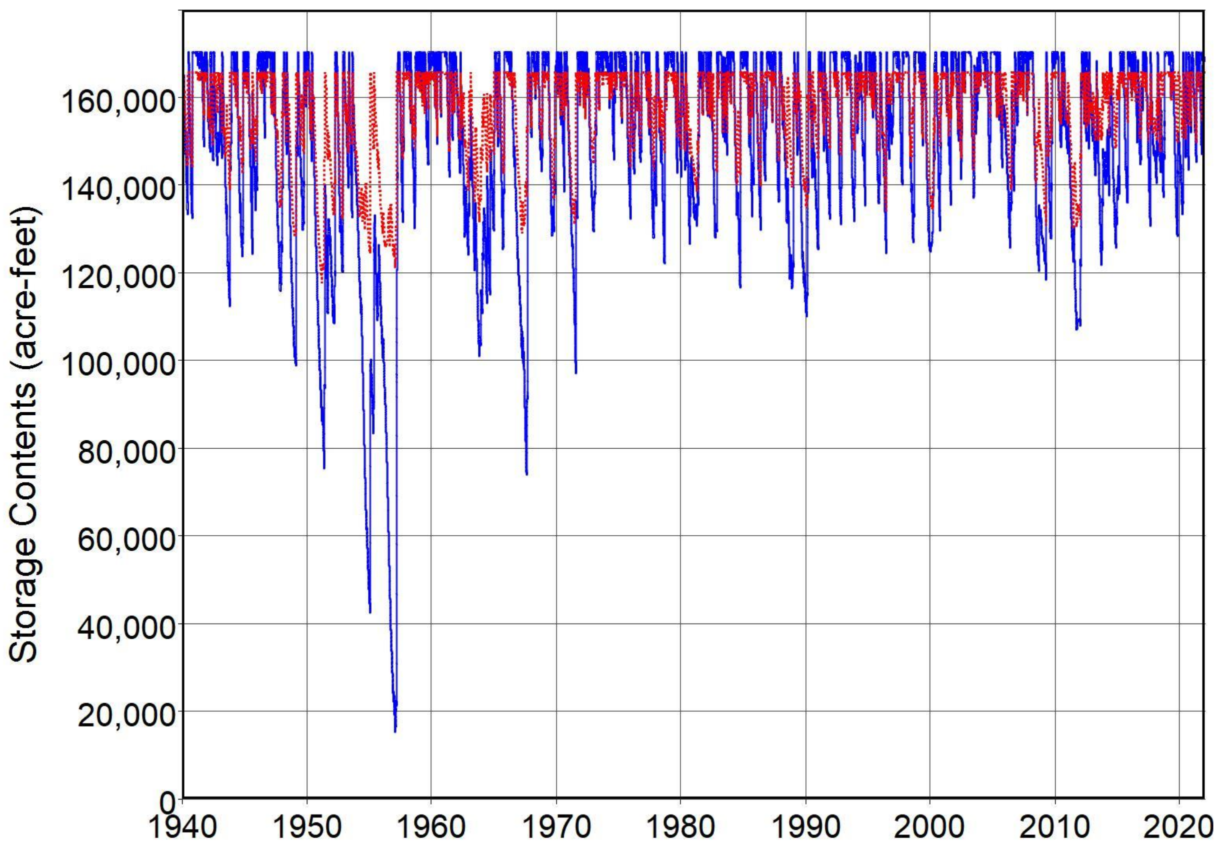

Figure 6.14 Lake Texana Storage for Daily Full Authorization *SIMD* (blue solid) and Daily Current Use *SIMD* (red dots) simulations

Reservoir storage plots comparing daily *SIMD* versus monthly *SIM* simulations for the current use and full authorization WAMs are presented in Figures 6.15 and 6.16. The computed storage volumes are similar using either the daily or monthly WAMs. As indicated in Table 6.15, the minimum storage contents of Lake Texana computed in the current use scenario daily *SIMD* and monthly *SIM* simulations are 117,600 acre-feet and 112,292 acre-feet, respectively. Median storage levels of 161,135 acre-feet and 158,055 acre-feet, respectively, are equaled or exceeded 50 percent of the time in the daily versus monthly current use scenario WAMs.

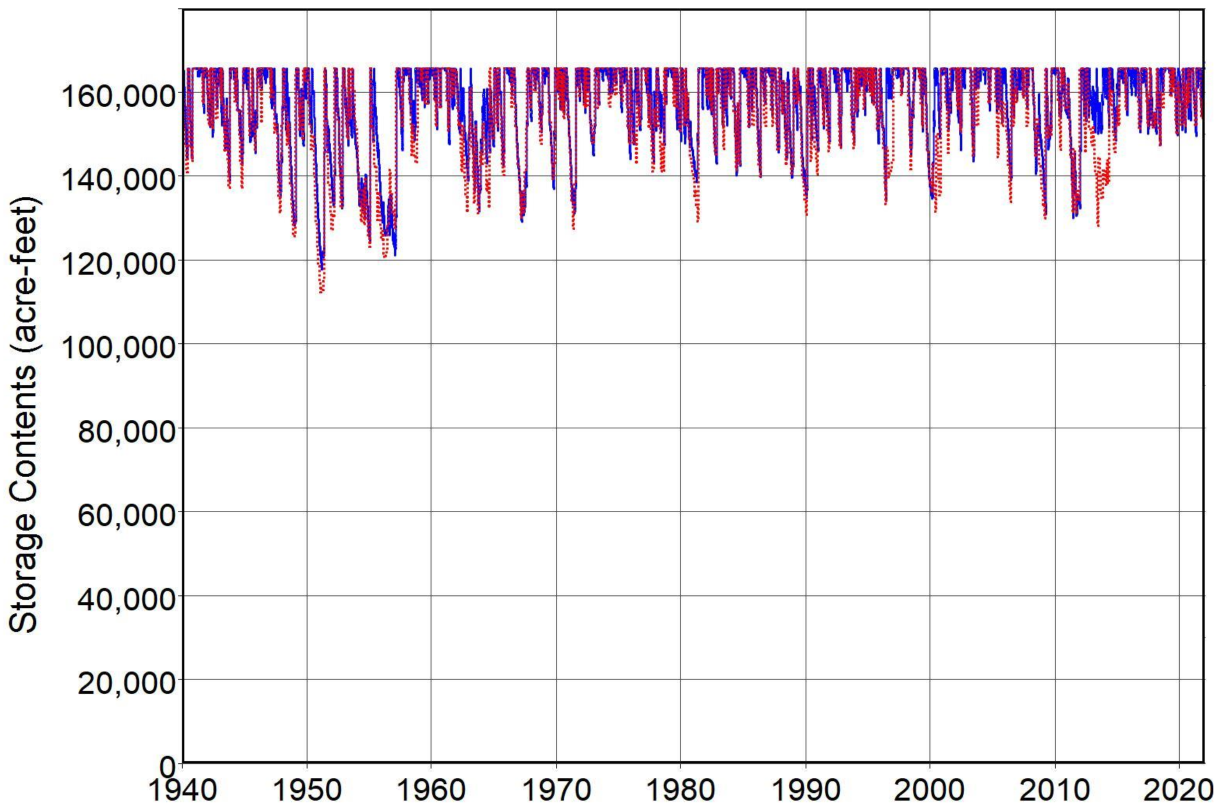

Figure 6.15 Daily (blue solid) and Monthly (red dots) Current Use Lake Texana Storage

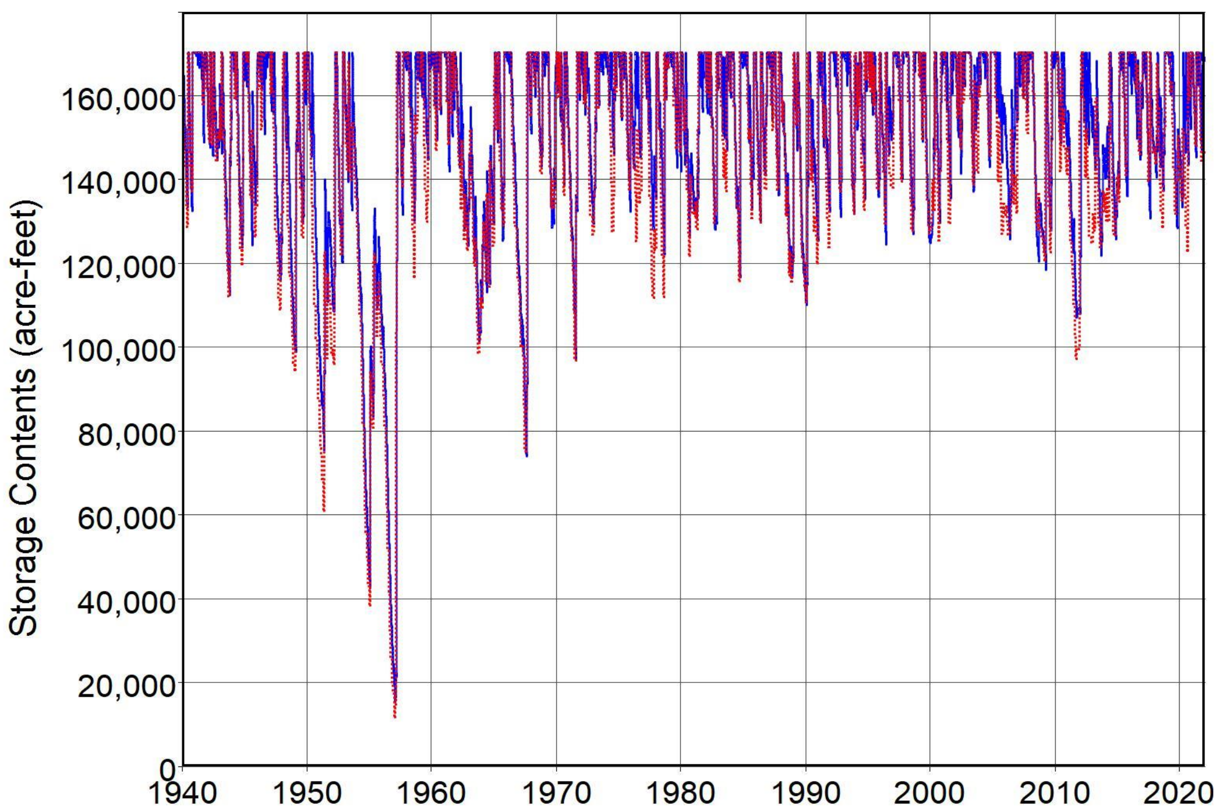

Figure 6.16 Daily (blue solid) and Monthly (red dots) Full Authorization Lake Texana Storage

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