

TO: Sabine-Neches Expert Science Team Technical Committee
FROM: Jon S. Albright, Freese and Nichols, Inc.
SUBJECT: Hydrology-Based Environmental Flow Regime (HEFR) Analyses for Sabine-Neches Bay and Basin Expert Science Team (BBEST)
DATE: September 17, 2009

Introduction

The Senate Bill 3 Science Advisory Committee for Environmental Flows (SAC) developed a draft guidance document *Use of Hydrologic Data in the Development of Instream Flow Recommendations for the Environmental Flows Allocation Process and the Hydrology-Based Environmental Flow Regime (HEFR) Methodology*¹ to guide the basin advisory groups in developing flow recommendations. One of the options in this document is employing the Hydrology-Based Environmental Flow Regime (HEFR) methodology to determine an environmental flow regime based on historical hydrology. The Sabine Neches Bay and Basin Expert Science Team (BBEST) hired Freese and Nichols, Inc. (FNI) to conduct hydrologic analyses at twelve gages in the Sabine and Neches River Basins and inflows into Sabine Lake, including HEFR analyses. Table 1 lists the gages selected by the BBEST.

The HEFR methodology is described in detail in the SAC guidance, so this document contains only a brief description of the method. HEFR is basically a two step process. In the first step, historical daily streamflow data are divided into one of four components or classifications:

- Subsistence flow – minimum streamflow needed during extreme drought conditions
- Base flow – “normal” flow conditions found between storm events
- High flow pulses – short-duration, high flows within the stream channel resulting from a storm event
- Overbank flows –high-flow events that cause flow beyond the riverbanks

Figure 1 is an illustration of the different flow classifications. The flows are displayed using both linear and logarithmic axes in order to illustrate the range of both high and low flows.

¹ Senate Bill 3 Science Advisory Committee for Environmental Flows: *Working Draft: Use of Hydrologic Data in the Development of Instream Flow Recommendations for the Environmental Flows Allocation Process and the Hydrology-Based Environmental Flow Regime (HEFR) Methodology*, April 20, 2009.

Table 1: USGS Stream Gages Selected by the Sabine-Neches BBEST

USGS Gage Name	USGS Gage Number	HUC	County
SABINE BASIN			
Big Sandy Creek nr Big Sandy	8019500	12010002	Upshur
Sabine River nr Gladewater	8020000	12010002	Gregg
Sabine River nr Beckville	8022040	12010002	Panola
Sabine River nr Bon Wier	8028500	12010005	Newton
Big Cow Creek nr Newton	8029500	12010005	Newton
Sabine River nr Ruliff	8030500	12010005	Newton
NECHES BASIN			
Village Creek nr Kountze	8041500	12020006	Hardin
Neches River at Evadale	8041000	12020003	Jasper
Attoyac Bayou nr Chireno	8038000	12020005	San Augustine
Angelina River nr Alto	8036500	12020004	Cherokee
Neches River near Rockland	8033500	12020003	Tyler
Neches River at Neches	8032000	12020001	Cherokee

In the second step, the HEFR model performs a series of statistical and regression analyses on the daily flows and associated classifications. The output of this model is a “flow matrix” of values for the various classifications, grouped by wet, average or dry conditions and season. Wet, average and dry conditions are typically associated with the 25th percentile, median and 75th percentile, respectively, of flow, volume, duration and frequency. Figure 2 is an illustration of the default output of the model. The output is explained in more detail later in this memorandum.

The flow matrix method is a useful tool for conceptualizing different parts of the flow regime and thinking about how those parts contribute to environmental health. The matrix method has been employed for developing instream flow goals for Caddo Lake in Texas, as well as in a variety of other situations elsewhere in the United States. A good source of information on the flow classifications and their functions can be found in the *Texas Instream Flow Studies: Technical Overview*².

² Texas Commission on Environmental Quality, Texas Parks and Wildlife Department and the Texas Water Development Board: *Texas Instream Flow Studies: Technical Overview*, Texas Water Development Board Report 369, May 2008.

Figure 1: Illustration of Flow Components

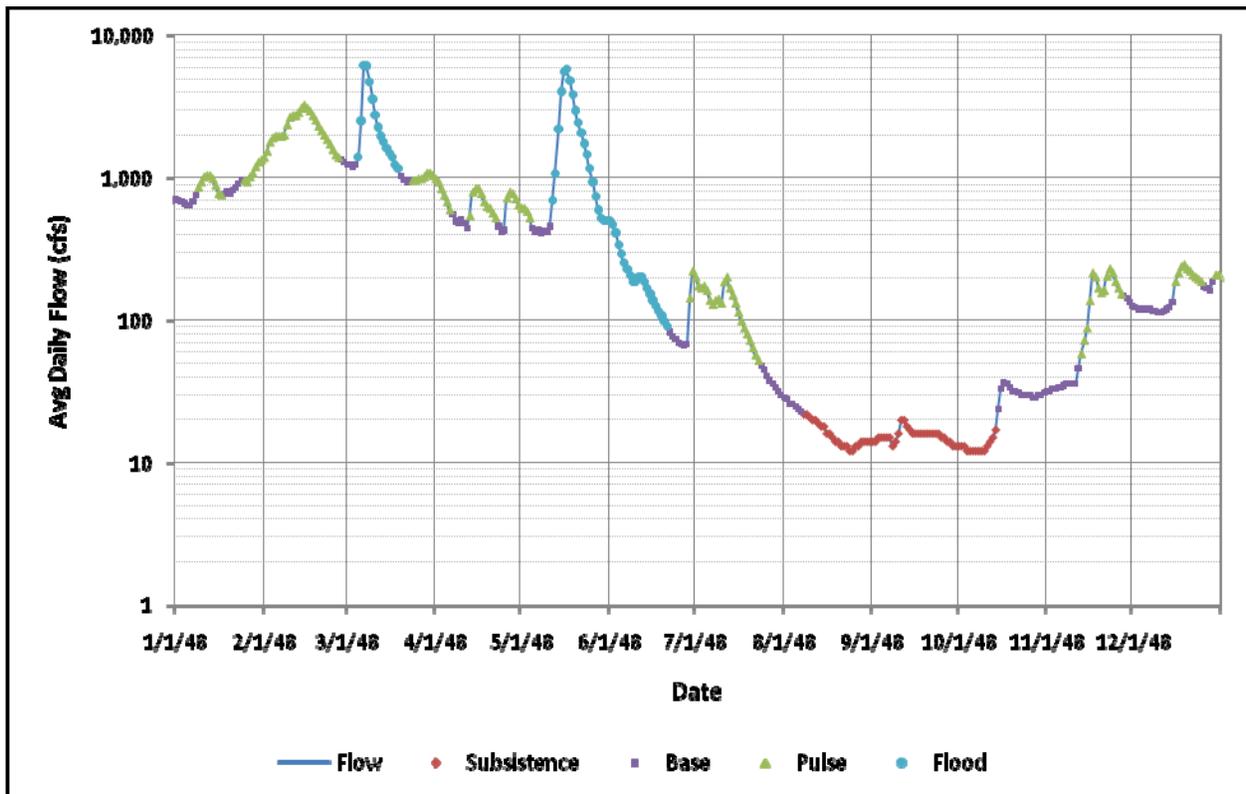
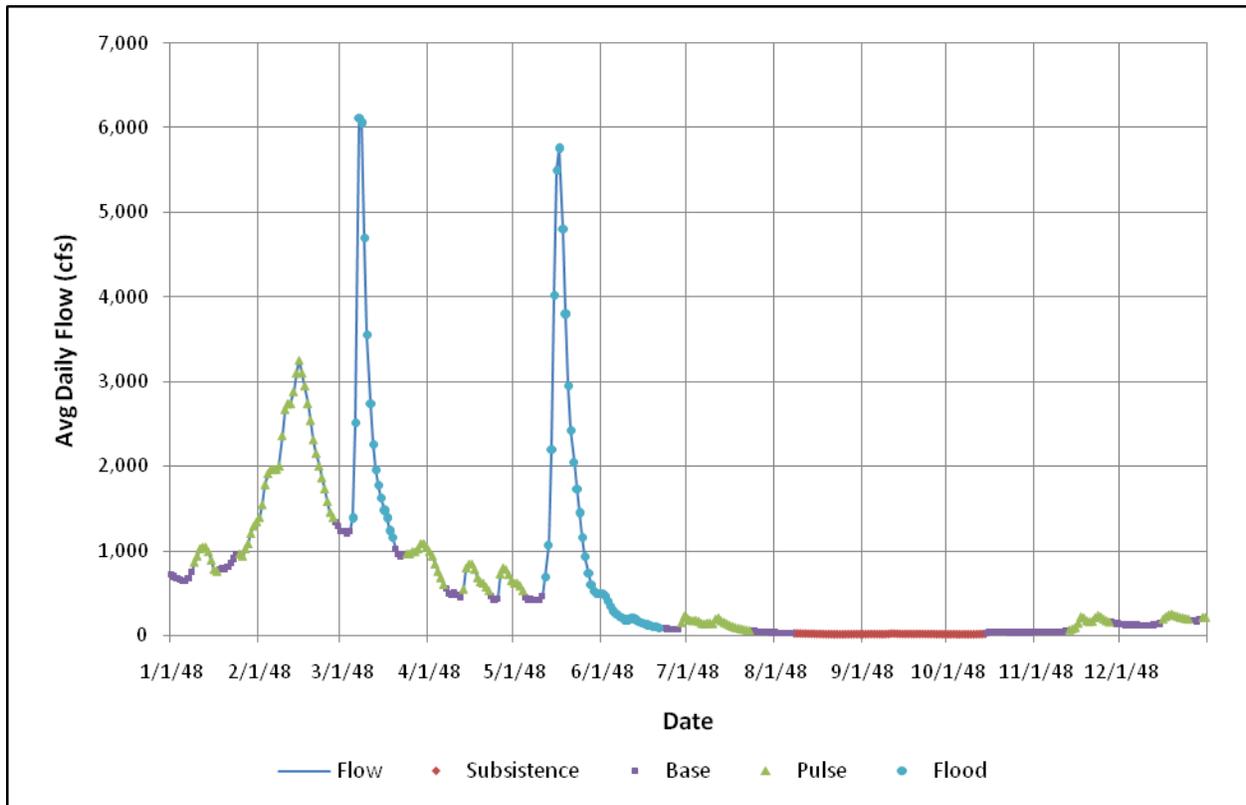




Figure 2: HEFR Output Example

Overbank Flows	Return Period (R) : 1.7 (years)						Duration (D) : 49 (days)					
	Volume (V) : 1068536 (ac-ft)						Peak Flow (Q) : 20800 (cfs)					
High Flow Pulses	F: 0		F: 0		F: 0		F: 1		F: 1		F: 1	
	D: 31		D: 32		D: 25		D: 22		D: 22		D: 22	
	Q: 9738		Q: 8205		Q: 3890		Q: 5320		Q: 5320		Q: 5320	
	V: 300873		V: 256900		V: 96100		V: 119033		V: 119033		V: 119033	
	F: 1		F: 1		F: 1		F: 1		F: 1		F: 1	
	D: 18		D: 19		D: 14		D: 16		D: 16		D: 16	
	Q: 6105		Q: 5580		Q: 2100		Q: 2760		Q: 2760		Q: 2760	
	V: 143799		V: 145101		V: 44625		V: 51194		V: 51194		V: 51194	
	F: 2		F: 2		F: 2		F: 2		F: 2		F: 2	
	D: 8		D: 10		D: 4		D: 4		D: 4		D: 4	
	Q: 2640		Q: 2973		Q: 1005		Q: 1100		Q: 1100		Q: 1100	
	V: 39010		V: 47462		V: 12647		V: 12686		V: 12686		V: 12686	
Base Flows (cfs)	4980		3868		3210		2630		2630		2630	
	2590		3070		2140		1280		1280		1280	
	1760		1553		471		438		438		438	
Subsistence Flows (cfs)	135		266		228		204		204		204	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Winter			Spring			Summer			Fall			

Hydrologic Conditions	Wet (75th %ile)
	Average (50th %ile)
	Dry (25th %ile)
	Subsistence

High Flow Pulse Characteristics	F = Frequency (per season)
	D = Duration (days)
	Q = Peak Flows (cfs)
	V = Volume (ac-ft)

HEFR provides potentially useful information about the statistical distribution of flows. However, the HEFR output by itself is not sufficient to develop a description of a flow regime that defines a sound ecological environment. (The Texas Environmental Flows Advisory Committee defines a sound ecological environment as one that "sustains the full complement of native species in perpetuity, sustains key habitat features required by these species, retains key features of the natural flow regime required by these species to complete their life cycles, and sustains key ecosystem processes and services, such as elemental cycling and the productivity of important plant and animal populations."³) When interpreting the matrix, several issues should be kept in mind, including:

- What is the linkage between the statistics in the matrix (i.e. wet, average and dry) and environmental health (biology, geomorphology, water quality, etc.)?

³ Environmental Flows Advisory Committee: Final Report, prepared for Governor Rick Perry et. al., December, 2006.

- What are the specific goals of the flow matrix? What are we trying to protect? What are the specific functions of the components of the flow matrix?
- How frequently should the flows in the matrix be met to maintain a sound ecological environment?
- Is the flow matrix by itself sufficient to define a flow regime to maintain a sound ecological environment?

HEFR intended to be a starting point for developing environmental flow recommendations. The analyses in this study have been performed using default parameters without regard to site-specific environmental factors that may be important in developing instream flow goals. Other studies commissioned by the BBEST could provide additional insight as to how the flow regime interacts with the environment. The BBEST may wish to rerun HEFR analyses or perform other analyses as other data becomes available.

The remainder of this memorandum describes the analyses performed in this study. The final section includes an evaluation of the result of the study.

Flow Separation

The first step of the HEFR method relies on separation of daily flow into one of the following classifications:

- Subsistence flow – minimum streamflow during extreme drought conditions. According to the Texas Instream Flow Program (TIFP), the primary function of subsistence flows is to maintain water quality.
- Base flow – “normal” flow conditions found between storm events. Primary TIFP functions include maintenance of habitats for the natural community.
- High flow pulses – short-duration, high flows within the stream channel resulting from a storm event. Primary TIFP functions include habitat maintenance and longitudinal connectivity.
- Overbank flows –high-flow events that cause flow beyond the riverbanks Primary TIFP functions include maintenance of riparian areas and lateral connectivity with the active flood plain.

Additional information on the functions of these flow classifications can be found in *Texas Instream Flow Studies: A Technical Overview*².

HEFR employs two different methods for flow separation: the Indicators of Hydrologic Alteration Environmental Flow Components (IHA EFC) method developed by the Nature Conservancy, and the Modified Base Flow Index with Threshold (MBFIT) based on a base flow

separation technique developed by the Bureau of Reclamation. Both of these methods parse the daily flow records and classify each day's flows as subsistence, base, high flow pulse or overbank. Each of these methods is described in detail in the SAC hydrologic methods document¹, so only a brief description will be included here.

IHA EFC Method

The IHA EFC method uses a software package developed by the Nature Conservancy to separate flows. (The IHA software does many other things as well, including comparison of two different periods of record to see how flow has changed. The HEFR method only uses the flow separation component of the software.) IHA EFC uses six parameters to classify each day as an overbank event, pulse event, base flow or subsistence flow:

- An *Increase Rate*, expressed as a percentage. If flow on a particular day exceeds the flow in the previous day by this percentage, it signals the beginning of a pulse event. The default value for HEFR is 50% per day.
- A *Decrease Rate*, also expressed as a percentage. If flows during a pulse event decline by less than this percentage, it signals the end of a pulse event. The default value for HEFR is 5 percent per day.
- An *Upper High Flow Pulse Threshold*, expressed as a percentile of flows during the analysis period. If flows on a particular day exceed this value it is always classified as a pulse or overbank event. This parameter is required because pulse events are not always identified by a rise or fall rate. The default value for HEFR is the 75th percentile flow.
- A *Lower High Flow Pulse Threshold*, expressed as a percentile of flows during the analysis period. If flows on a particular day are less than this amount it is always classified as a base flow or subsistence event. This parameter prevents small-magnitude increases in flow during low-flow periods from being classified as initiating a pulse event. The default value for HEFR is the 25th percentile.
- A *Subsistence Flow Threshold*, expressed as a percentile of initially-classified base flows during the analysis period. Base flows below this value are reclassified as subsistence flows. The default value for HEFR is the 10th percentile of base flows during the analysis period.
- An *Overbank Threshold*, expressed as a peak flow with a specific recurrence interval. Once pulse days have been identified, a second pass through the pulse days classifies a pulse event as either a high flow pulse or an overbank event. If flows exceed the overbank threshold level at any time during a pulse event, the entire pulse event is classified as an overbank event. The HEFR default is an overbank event a 1.5 year recurrence interval.

MBFIT Method

The MBFIT method relies on defining daily flows as either “pulse-dominated” or “base-dominated” using three parameters:

- N – defining an n -day sliding window of local minima. Must be odd, with a typical value being between 5 and 9.
- f – the fraction threshold for a local minimum to be considered a “turning point” and possibly a base-dominated day. Must be between 0 and 1, with a typical value being 0.9.
- *Runoff fraction* – fraction of the flow considered to be runoff for a flow to be classified as a pulse flow. Usually set to 0.2.

Like IHA EFC, another set of threshold parameters can override the initial classification by specifying that flows below a certain level are always classified as a base-dominated and flows above a certain level are always classified as a pulse-dominated. A second step divides the base-dominated days into subsistence or base flows based on a threshold parameter and the pulse-dominated days into either overbank or high flow pulse events based on an overbank threshold parameter. Like the IHA EFC method, an entire event is classified as an overbank event if one or more days during a pulse exceed the overbank threshold. An example of the MBFIT calculation may be found in Attachment A.

For the MBFIT calculations, this study used a spreadsheet method developed by Joe Trungale of Trungale Engineering and Science, which he has graciously made available for use in the Senate Bill 3 studies. FNI modified this spreadsheet to facilitate parameter testing and graphical display of the data.

Evaluation and Selection of Flow Separation Methods

FNI compared the IHA EFC and MBFIT methods using data from the Neches River at Evadale, Neches River near Neches and Sabine River near Ruliff gages. Figure 3 is an example using IHA EFC at the Neches near Neches gage and Figure 4 shows the same data using the MBFIT method. The IHA EFC parameters use the default HEFR values, while the MBFIT parameters use values developed as part of this analysis. In these figures overbank flows are shown with light blue circles, pulse flows with green triangles, base flows with purple diamonds and subsistence flows with red squares. The Overbank Threshold value is shown with the solid light blue line. If

Figure 3: Example of IHA EFC Flow Separation

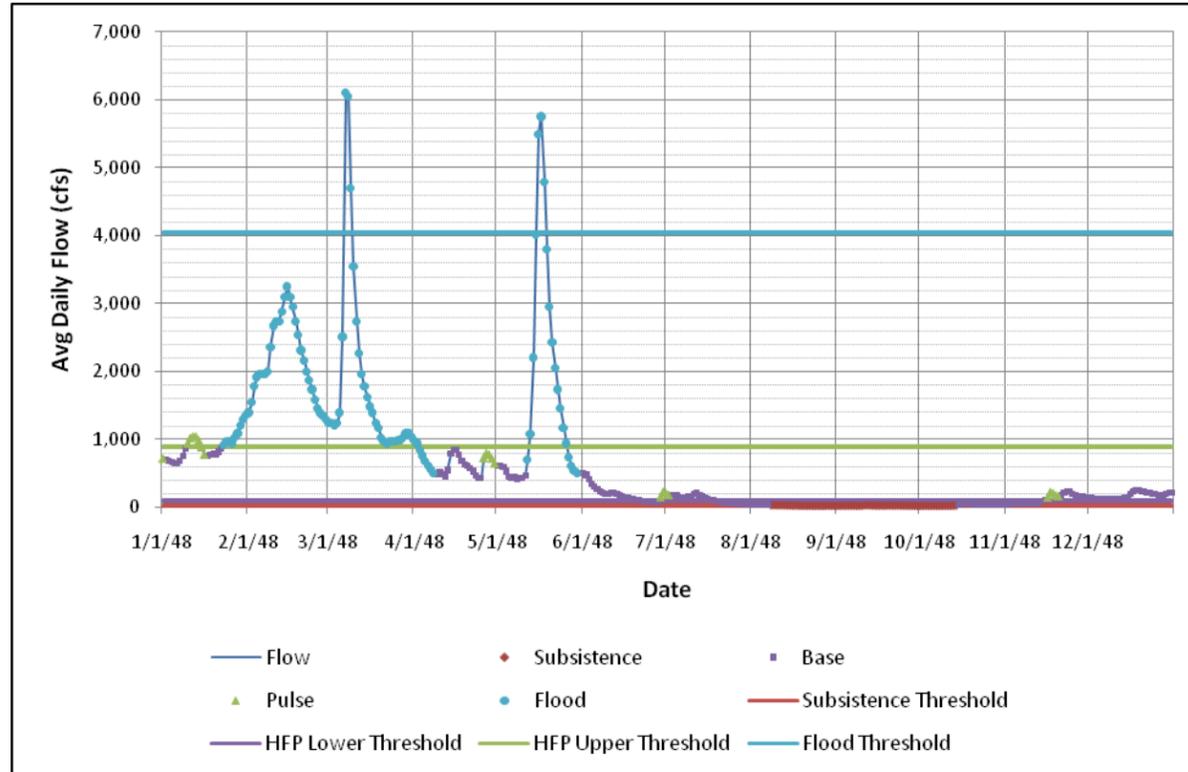
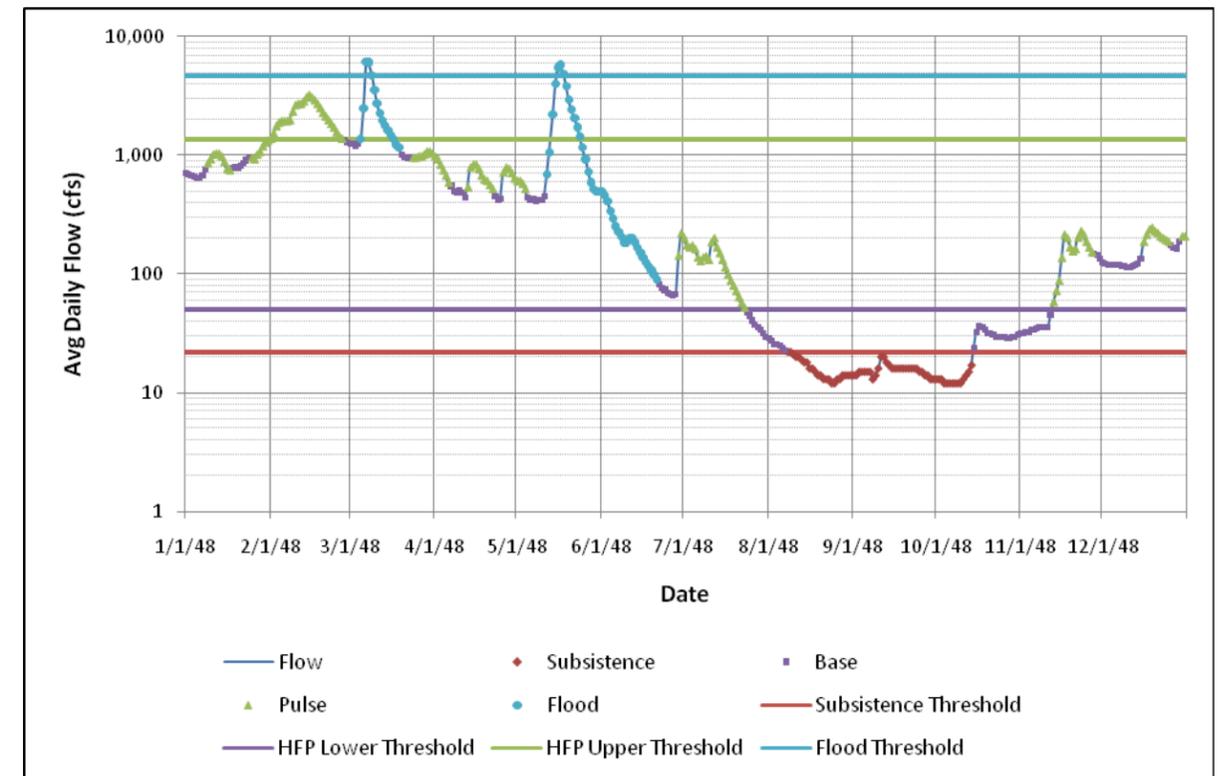
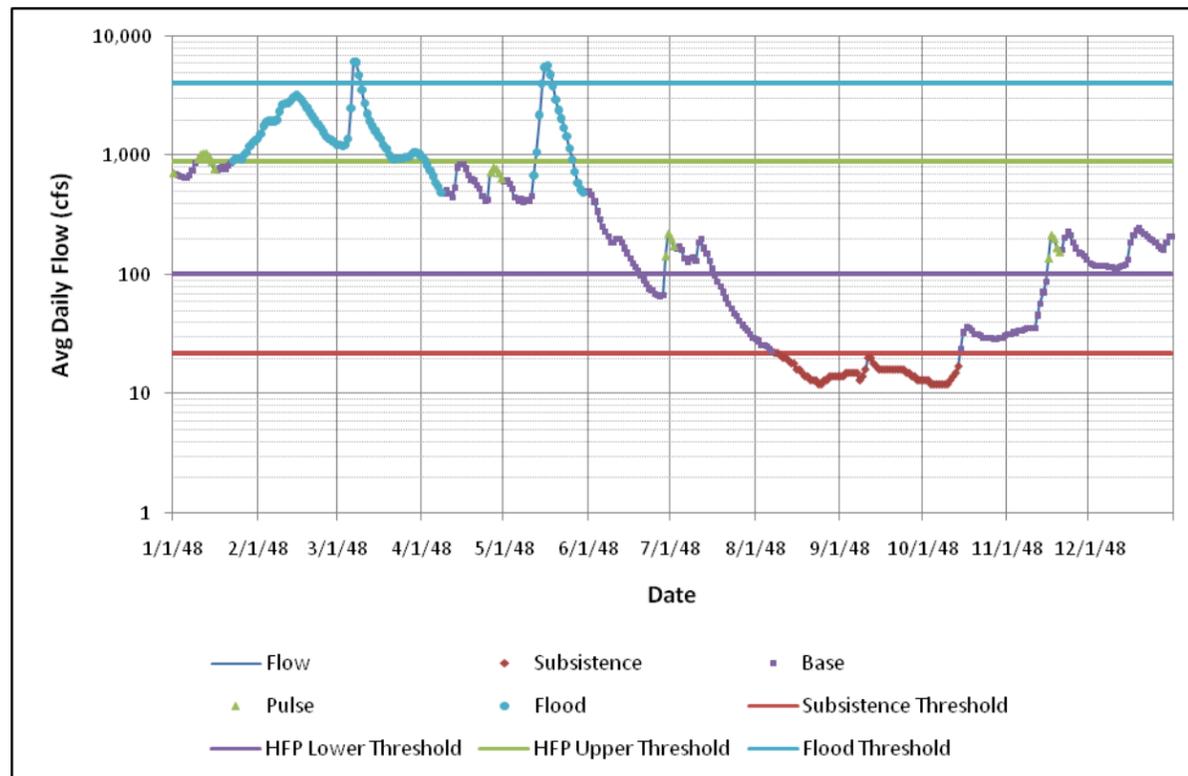
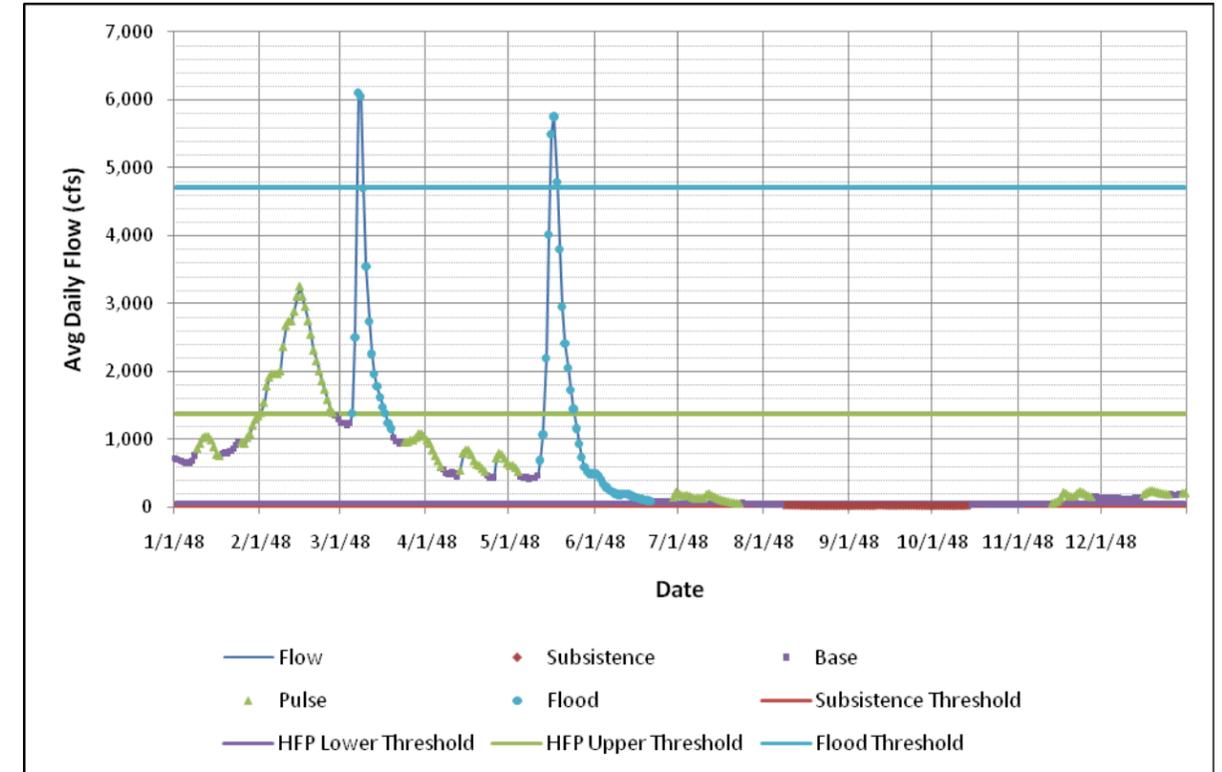


Figure 4: Example of MBFIT Flow Separation



a pulse flow exceeds this threshold at any time during a pulse event, the entire event is classified as an overbank flow. The Upper High Flow Pulse Threshold is shown with a solid green line. If flows are above this value, they are automatically classified as a pulse (or an overbank flow, if the pulse event exceeds the Overbank Threshold). The Lower High Flow Pulse Threshold is shown with the solid purple line. If flows are below this value (but above the Subsistence Threshold), they are always classified as a base flow. The dark red line is the Subsistence Threshold. If flows are below this line, they are automatically classified as subsistence flows. The flow axis is shown at both a linear and logarithmic scale to show both low and high flows.

One of the characteristics of flows in the Sabine and Neches Basins is a season of very high flows from about February through May. Flows during this time are frequently high flow pulses or overbanks flows, with little or no periods of base flow between events. In the example in Figures 3 and 4, there is a fairly large pulse in February followed by an overbank event in March. Note that the IHA EFC method (using this specific parameterization) classifies these two events as one flood event, while the MBFIT method identifies a few days of base flow between the events. Although it is arguable whether these flows really qualify as base flows, one of the benefits of identifying these days as base flows is that the MBFIT method successfully separates the two events into a flood and a pulse event. The IHA EFC method does not separate the two events, classifying the February and March events as a single flood event. The IHA EFC method tends to rely heavily on the Upper High Flow Pulse Threshold to identify pulses, so it can miss higher base flows.

Another characteristic of flows in the Sabine and Neches Basins are persistent low flows beginning around July and continuing through October. Although large pulse events can and do occur during these months, many years are characterized by smaller pulse events that probably serve an important environmental function during these times. The summer flows in Figure 3 and 4 are drier than normal, falling into the subsistence range, so no pulses at all occur from August to October. However, note that the MBFIT method does a better job of identifying the smaller pulses in July and November than IHA EFC method, as well as the two smaller pulses in April and the beginning of May. The IHA EFC method also tends to rely heavily on the Lower High Flow Pulse Threshold to define base flow events, so smaller pulses can be overlooked.

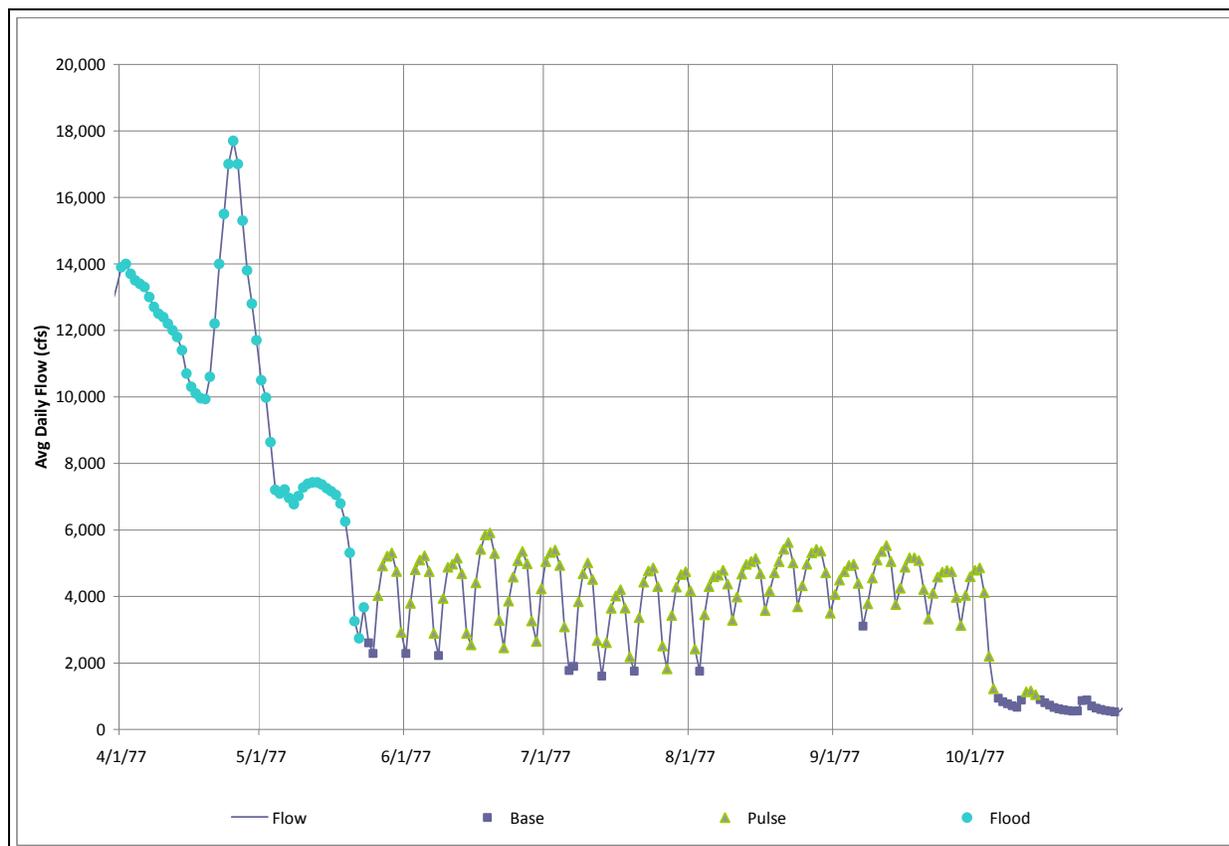
As shown in these examples, the increasing and decreasing rates in the IHA EFC methodology often do not identify the beginning or the end of a pulse event. As a result, the method tends to be sensitive to the upper and lower pulse threshold values when classifying a day as a pulse or base flow. HEFR results tend to be sensitive to the selection of these parameters. The HEFR default is to set these upper and lower thresholds at the 75th and 25th percentiles. Both the IHA EFC and MBFIT tend to have similar results when these parameters are used. However, because MBFIT tends to be more successful at identifying smaller pulse events and larger base flow events, these two thresholds can be set wider, allowing a potentially greater range of flows in each classification. FNI believes that this reduces the tendency of the HEFR results to be influenced by parameter selection.

The flood event in May illustrates another difference between the two methods. The IHA EFC method tends to reclassify the receding limb of a pulse event as a base flow, while the MBFIT method tends to keep these flows as part of the preceding pulse event. It is unclear if inclusion of the receding limb is important to the environmental function of the pulse event.

Although MBFIT works well in this example, it tends to not work well in situations where several short-duration pulse events occur close together. Neither method seems to work well when flow is influenced by hydropower releases, which is the case at the Evadale, Bon Wier and Ruliff gages. Figure 5 shows an example from the Ruliff gage. Note that the summer flows are characterized by small pulse-like events that are induced by hydropower. It is probably not useful to classify all of these cycles as pulse events.

Based on the comparison of the two methods, FNI selected the MBFIT method for the analyses. Table 2 is a summary of the MBFIT parameters used at each gage, as well as the basis used for the threshold parameters. The MBFIT parameters (N , f and the Runoff Fraction) were determined by an analysis at each gage. A range of different N values was evaluated at each gage and visually compared for each year of the analysis. Figure 6 is an example of the graphs used for the evaluation. These graphs were created by adding a constant value to the different time series in the graph. The value of N was selected that appeared to most often correctly define separation of pulse and base flows. In most cases, a limited range of f values was examined as well. Limited tests of the Runoff Fraction showed that the suggested value of 0.2 was adequate for most situations.

Figure 5: Hydropower-Influenced Flow at the Ruliff Gage



Threshold values for subsistence were all set at the 10th percentile of base flows, a suggested default for this parameter. The lower high flow pulse threshold was set at the 10th percentile of all flows, which is lower than the HEFR default value of the 25th percentile. The lower threshold was selected to preserve smaller pulse events during the summer months. The entire period of the gage was used except for the Bon Wier and Evadale gages. Long periods of repeated flows occur in the record at Bon Wier before 1938, so those were eliminated. The pre-dam period at Evadale was used because the influence of hydropower operation artificially increased the 10th percentile statistic. This effect was not as pronounced on the two Sabine River gages (Ruliff and Bon Wier), so the full period of record was used.

Table 2: Flow Separation Parameter Summary

Basin	Gage Name	USGS Gage Number	Published 7Q2 (cfs)	MBFIT Parameters			Threshold Parameters				Basis for Threshold Parameters			
				N	<i>f</i>	Runoff Fraction	Subsistence Threshold (cfs)	Pulse Lower Threshold (cfs)	Pulse Upper Threshold (cfs)	Overbank Threshold (cfs)	Subsistence Threshold	Pulse Lower Threshold	Pulse Upper Threshold	Overbank Threshold
Sabine	Big Sandy Creek nr Big Sandy	8019500	12.4	7	0.90	0.2	10	17	414	1,900	10% of base flows	10% of all flows	90% of all flows	1.5 Year from preliminary analysis
Sabine	Sabine River nr Gladewater	8020000	46.4	9	0.90	0.2	22	54	5,320	10,600	10% of base flows	10% of all flows	90% of all flows	1.5 Year from preliminary analysis
Sabine	Sabine River nr Beckville	8022040	75.9	9	0.90	0.2	31	92	7,230	12,600	10% of base flows	10% of all flows	90% of all flows	NWS flood stage 26 feet
Sabine	Sabine River nr Bon Wier	8028500	703	9	0.90	0.2	306	652	17,800	22,500	10 % of base flows	10th percentile 1938 to 2008	90% of all flows	NWS bankfull 28 feet
Sabine	Big Cow Creek nr Newton	8029500	30	5	0.90	0.2	23	29	230	1,870	10% of base flows	10% of all flows	90% of all flows	No NWS, 1.5 yr from preliminary analysis
Sabine	Sabine River nr Ruliff	8030500	1,121	11	0.90	0.2	450	975	9,880	13,300	10% of base flows	10% of all flows	NWS bankfull 23 feet	NWS flood stage of 24 feet
Neches	Village Creek nr Kountze	8041500	78.9	7	0.90	0.2	51	85	2,070	8,150	10% of base flows	10% of all flows	NWS bankfull 12 feet	1.5 yr from preliminary analysis
Neches	Neches River at Evadale	8041000	1,839	11	0.90	0.2	277	442	8,700	14,200	10% of base flows	10% of 40-60 flows	NWS bankfull 13 feet	Run 1 1.5 year flood 40 to 60
Neches	Attoyac Bayou nr Chireno	8038000	25.6	5	0.90	0.2	13	28	1,200	4,480	10% of base flows	10% of all flows	NWS flood stage 14 ft	1.5 yr from preliminary analysis
Neches	Angelina River nr Alto	8036500	37.7	7	0.90	0.2	20	49	2,340	11,200	10% of base flows	10% of all flows	90% of all flows	NWS flood stage 19 ft
Neches	Neches River near Rockland	8033500	112	11	0.85	0.2	37	94	6,680	19,400	10% of base flows	10% of all flows	90% of all flows	NWS flood stage 26 ft
Neches	Neches River at Neches	8032000	70.7	7	0.90	0.2	22	50	1,370	4,700	10% of base flows	10% of all flows	NWS flood stage 12 ft	1.5 yr from preliminary analysis
	Sabine Lake	N/A	N/A	11	0.90	0.2	1,064	2,759	45,942	115,864	10% of base flows	10% of all flows	90% of all flows	1.5 yr from preliminary analysis

MBFIT Parameters

N – number of days in analysis window

f – fraction of adjacent days to be considered a turning point

Runoff fraction – fraction of runoff for a flow to be considered a base flow

Threshold values

Subsistence – all flows below this value are considered to be subsistence flows

Pulse Lower Threshold – all flows below this value are considered to be a base flow

Pulse Upper Threshold – all flows above this value are considered to be pulse flows

Overbank Threshold – if flows are above this value, the entire pulse event is classified as a flood

NWS = National Weather Service

7Q2 data are from the Texas Surface Water Quality Standards

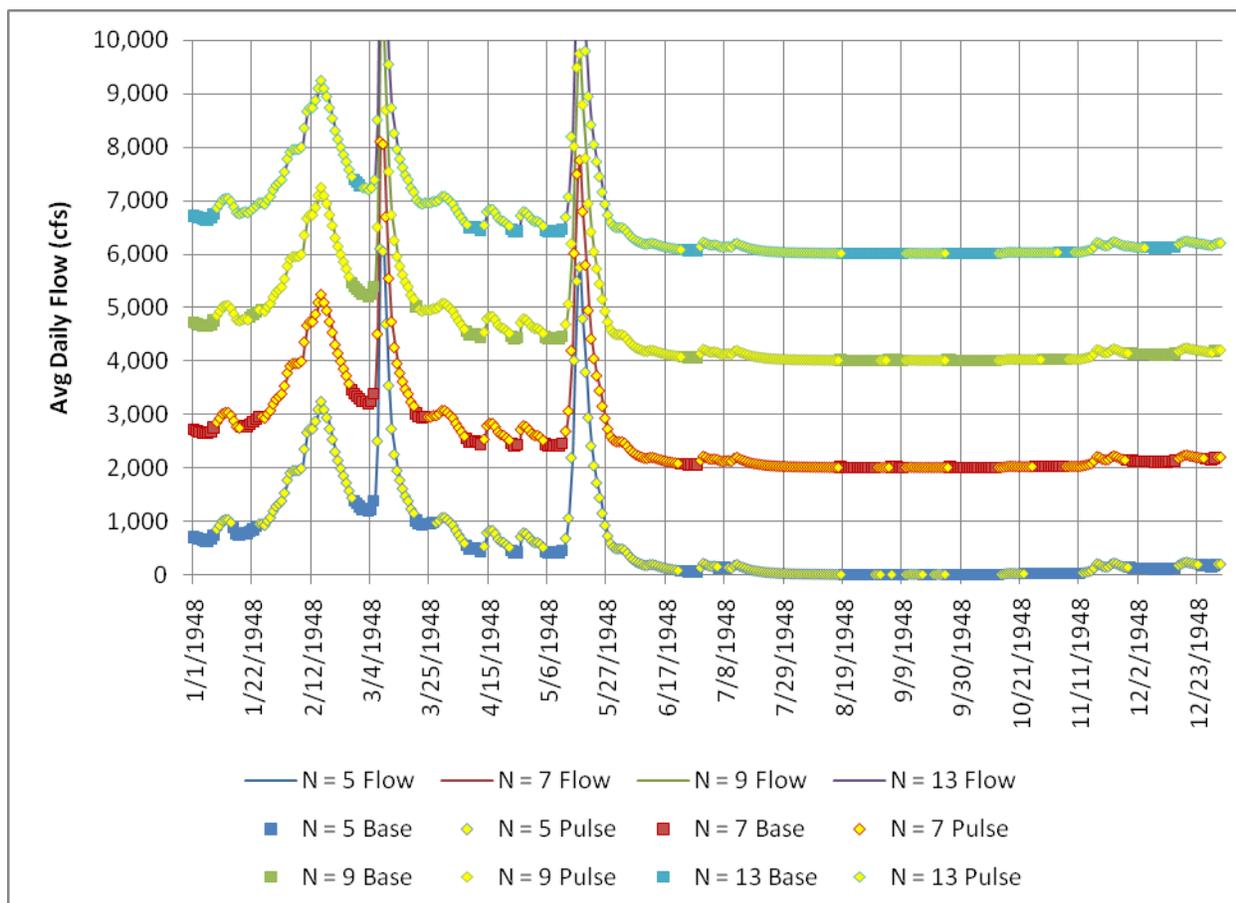
Table 3: National Weather Service Stage Data

River Basin	USGS Stream Gage Name	Flood Categories															Description
		Major Flood Stage			Moderate Flood Stage			Flood Stage			Action Stage			Bankfull Stage			
		Stage (feet)	Flow (kcfs)	Per-centile	Stage (feet)	Flow (kcfs)	Per-centile	Stage (feet)	Flow (kcfs)	Per-centile	Stage (feet)	Flow (kcfs)	Per-centile	Stage (feet)	Flow (kcfs)	Per-centile	
Sabine	Big Sandy Creek n. Big Sandy	21	N/A	N/A	20	N/A	N/A	17	4.8	99.9	16.5	4.22	99.9	N/A	N/A	N/A	17.0 lowlands...along with some secondary roadways...will begin to flood. Ranchers should move livestock and equipment to higher ground.
Sabine	Sabine River n. Gladewater	36	25	99.6	33	13.1	98.3	26	5.72	91.1	25	5.35	90.1	N/A	N/A	N/A	26.0 expect minor lowland flooding with camps and picnic areas near the river suffering some flooding.
Sabine	Sabine River n. Beckville	35	N/A	N/A	30	26.2	99.6	26	12.6	97.6	25.5	12.1	97.1	N/A	N/A	N/A	26.0 expect lowland flooding of the heavily wooded floodplain. In addition...oil field operations in and near the floodplain will be affected and steps should be taken to secure petroleum equipment.
Sabine	Sabine River n. Bon Wier	36	65.2	99.8	33	39.2	99.1	30	28	97.0	30	28	97.0	28	22.5	94.3	30.0 minor lowland flooding will occur along the river between Merryville and Bon Wier. A few roads in southwest Vernon Parish have water over them. 28.0 The river is at its bankfull stage.
Sabine	Big Cow Creek n. Newton	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No NWS data
Sabine	Sabine River n. Ruliff	28	59.5	99.6	26	29.8	96.1	24	13.3	77.8	23	9.88	70.7	23	9.88	70.7	24.0 minor lowland flooding will occur. Low-lying roads in southwestern Beauregard Parish...including Robert Clark Road will have water over them. 23.0 The river is at bankfull stage.
Neches	Neches River n. Neches	24	N/A	N/A	18	13	99.8	12	1.37	85.6	11.5	1.2	82.8	N/A	N/A	N/A	12.0 expect minor lowland flooding of the heavily wooded floodplain. Ranchers that may have cattle and equipment in the river bottoms should move them to higher ground.
Neches	Neches River n. Rockland	33	41.2	99.9	30	31	99.8	26	19.4	99.2	25	17.8	99.0	N/A	N/A	N/A	28.0 water will begin to flood several secondary roadways especially in the Smith's Ferry community.
Neches	Angelina River n. Alto	23	40.9	99.9	21	25.8	99.9	19	11.2	99.7	18.5	8.8	99.4	N/A	N/A	N/A	19.0 expect lowland flooding of the river bottom. Ranchers that have cattle and equipment near the river should move them to higher ground.
Neches	Attoyac Bayou n. Chireno	26	31.7	> his-torical	22	16.1	99.9	14	1.2	91.0	13.5	1.09	89.8	N/A	N/A	N/A	14.0 expect lowland flooding for the next several days of the heavily wooded floodplain. Ranchers that have cattle and equipment near the river should move them to higher ground.
Neches	Neches River @ Evadale	24	96.6	> his-torical	21	62.5	99.9	19	41.5	99.4	19	41.5	99.4	13	8.7	86.1	19.0 minor lowland flooding. Water enters buildings adjacent to gauge. 13.0 The river is at bankfull stage.
Neches	Village Creek n. Kountze	23	21.1	99.9	21	14.5	99.7	17	6.17	98.5	12	2.07	89.3	12	2.07	89.3	17.0 water covers low spots on Willard Lake Road and Village Creek road near Lumberton. 12.0 The river is at bankfull stage.

Data are from the National Weather Service Western Gulf River Forecast Center

No data available for Big Cow Creek

Figure 6: Example of MBFIT Parameter Analysis



The pulse upper threshold and flood threshold values are based on a comparison of National Weather Service (NWS) stage data and a frequency analysis of historical gage flows⁴. The NWS publishes flood stages and discharges for all BBEST gages except for Big Cow Creek nr Newton and bankfull stages and discharges for the Sabine River near Bon Wier, Sabine River near Ruliff, Neches River at Evadale and Village Creek near Kountze gages. Although the NWS data appear to focus on potential damage to define flood stages, the information does give some potentially useful information about overbanking flows. In particular, it appears that overbanking events occur at Ruliff and Evadale on a fairly regular basis. In most cases the 90th percentile of all flows was used for the pulse upper threshold, and the 1.5 year event from a preliminary HEFR analysis was used for the overbank threshold (the final 1.5 year event may be different because of changed parameters). At Ruliff, the NWS bankfull flow was used as the upper pulse

⁴ National Weather Service River Forecast Center, West Gulf RFC, available on-line at <http://www.srh.noaa.gov/wgrfc/>

threshold and the NWS flood stage for the overbank threshold. These values are the 71st and 78th percentile of all historical flows, respectively, and appear to happen quite regularly. At Kountze, the NWS bankfull flow is about the 90th percentile so it was used as the upper pulse threshold to be consistent with other gages. At Evadale, the NWS bankfull stage is about the 76th percentile, so it was used as the upper pulse threshold. At Chireno the NWS flood stage is very close to the 90th percentile, so the flood stage was used for the upper pulse threshold and the 1.5 year event for an overbank. At the Neches near Neches gage the bankfull flow is about the 90th percentile, so it was used as the upper pulse threshold to be consistent with other analyses.

Although a NWS bankfull flow is available at Bon Wier, the flow is around the around the 95th percentile of all flows. This is very different than the next downstream gage at Ruliff, where the bankfull flow is around the 71st percentile. At Bon Wier the 90th percentile flow was used for the upper pulse threshold and the bankfull flow for the overbank threshold.

HEFR Parameters

The output of the MBFIT flow separation was used as input for the HEFR model. Each location was analyzed using both the original percentile-based approach and the frequency approach for up to three different time periods. This makes a maximum of six runs for each gage plus Sabine Lake. This section discusses the parameters used in the HEFR runs.

Period of Record

The BBEST selected three periods of record for the analysis:

- Full Period – the full period of record for each gage. HEFR must use full years, so partial years at the beginning and the end of the record were dropped. Some gages with data in the 1920s and 1930s had incomplete records or extended periods of repeated daily data, so those years were dropped as well.
- Pre-Dam conditions – the period from 1940 to 1960, prior to the construction of most major reservoirs
- Post-Dam conditions – the period from 1971 to 2008, after the construction of most major reservoirs

A few gages do not have complete records for all analyses. The Big Sandy near Big Sandy gage only has records through 2007, so it is missing the last year of the Post-Dam period. The first full year for Big Cow Creek near Newton is 1953. The Pre-Dam condition from 1953 to 1960

was not included for this gage because it is too short for a meaningful analysis. The first full year for the Angelina River near Alto is 1960, so the Pre-Dam condition is not available. Attoyac Bayou near Chireno has full years of data only from 1940 to 1953 and from 1960 to 1984. Therefore these two periods were substituted for the three conditions used at the other gages. All of these gages have little or no upstream development, so differences in the results are probably the result of climatic variability rather than diversions or return flows.

Seasons

The BBEST divided the year into simple quarters based on historical flow records:

- Winter – January through March
- Spring – April through June
- Summer – July through September
- Fall – October through December

The BBEST considers these seasons as best describing the seasonal flow trends in the Sabine and Neches River Basins.

Use of 7Q2

HEFR provides the option to specify a minimum “water quality protection flow”. If this parameter is specified, base or subsistence flow statistics produced by HEFR may never fall below this value. HEFR guidance suggest using a 7Q2 (a historical 7-day average low flow with a 2-year recurrence interval) as this limit. In Texas, a 7Q2 is used as the flow below which water quality standards do not apply. It is also considered when determining stream loading for wastewater discharges. Other states, including Louisiana, use a 7Q10 (a 7-day low flow with a 10-year recurrence interval) for similar purposes. The 7Q2 is also used as a minimum flow limit in other desktop environmental flow methods such as the Lyons or Consensus methods described in the SAC hydrologic methods¹. Table 4 lists the 7Q2 values for the BBEST gages published in the Texas Surface Water Quality Standards⁵.

One of the issues with using a 7Q2 for a minimum discharge is the influence of hydropower at the Ruliff, Bon Wier and Evadale gages. Table 5 compares 7Q2 and 7Q10 values at these three

⁵ Texas Administrative Code Chapter 307: Texas Surface Water Quality Standards, available on-line at <http://www.sos.state.tx.us/tac/index.shtml>

gages calculated using the Environmental Protection Agency's DFLOW model⁶. (7Q10 values are used in the State of Louisiana and are included for comparison purposes.) The periods in this table include the period prior to the construction of Sam Rayburn Reservoir for the Evadale gage and Toledo Bend Reservoir for the Ruliff and Bon Wier gages. Note that the pre-dam 7Q2 values are significantly lower than the published 7Q2 values. The reason for the discrepancy between the published 7Q2 and the DFLOW output for the Ruliff gage is unknown.

Table 4: Published 7Q2 Values

USGS Stream Gage Name	USGS#	7Q2 (cfs)
Big Sandy Creek n. Big Sandy	8019500	12.4
Sabine River n. Gladewater	8020000	46.4
Sabine River n. Beckville	8022040	75.9
Sabine River n. Bon Wier	8028500	703.1
Big Cow Creek n. Newton	8029500	30
Sabine River n. Ruliff	8030500	1,121.3
Neches River n. Neches	8032000	70.7
Neches River n. Rockland	8033500	111.7
Angelina River n. Alto	8036500	37.7
Attoyac Bayou n. Chireno	8038000	25.6
Neches River @ Evadale	8041000	1,838.6
Village Creek n. Kountze	8041500	78.9

Data are from the Texas Surface Water Quality Standards

Table 5: Comparison of Published 7Q2 to DFLOW 7Q2 and 7Q10 for Hydropower Influenced Gages

(Values in cfs)

Gage	Published 7Q2	Period	DFLOW Output								
			Pre-Dam			TCEQ Published Period			Full Period		
			7Q2	7Q10	Period	7Q2	7Q10	Period	7Q2	7Q10	Period
Evadale	1,838.6	'66-'96	308	138	'22-'64	1,839	361	'66-'96	497	167	'22-'08
Ruliff	1,121.3	'68-'96	683	349	'25-'65	1,109	584	'68-'96	895	417	'25-'08
Bon Wier	703.1	'68-'96	399	218	'24-'65	703	371	'68-'96	545	250	'24-'08

⁶ U.S. Environmental Protection Agency DFLOW 3.1, available on-line at <http://www.epa.gov/waterscience/models/dflow/>

Using a 7Q2 as a minimum flow recommendation primarily affects subsistence criteria. Subsistence flows are infrequently occurring low flows during extremely dry periods. However, with a 2-year recurrence interval, a 7Q2 is not a particularly rare occurrence. When considering recommendations for subsistence criteria, the BBEST should balance the function of subsistence flows (the minimum flow to sustain life) and the presence of waste loading in the stream with the natural occurrence of extremely low flows. In the case of hydropower influenced gages, the BBEST should consider how hydropower operations affect biology, as well as the potential for hydropower operations to cease or be reduced in the future.

The BBEST elected not to use a 7Q2 as a limit in the HEFR runs because it can easily be added as a limit later in the process if needed.

HEFR Results

The output matrices of the HEFR runs may be found in Attachment B. Tables 6 through 10 compare the results of the various gages. A maximum of six different matrices was produced for each gage plus Sabine Lake. Each gage was analyzed for three different periods of record: the Full Period of record for the gage, a Pre-Dam period from 1940 to 1960 and a Post-Dam period from 1971 to 2008. (Some gages do not have complete periods of record and only have a subset of the three periods.) Each period was analyzed using both the original percentile-based method and the frequency-based method. In the matrices in Attachment B, the original method results are at the top and the frequency-based results are at the bottom.

The two bottom panels of each matrix in Attachment B contains the subsistence and base flow recommendations for each season and flow condition (wet, average or dry). These flow recommendations are constant throughout the season.

The middle panel of each HEFR matrix in Attachment B describes pulse events, which are episodic and only occur during part of a season. Both statistical methods describe pulses in terms of peak discharge (Q or Q_p) in cfs, volume (V) in acre-feet, and duration (D or Duration) of the event in days. The original percentile-based method matrices also contain the frequency for pulse events (F), or the number of times the event is expected to occur during a season. Occasionally the frequency of the event is zero, which indicates that an event meeting these criteria would not be expected to occur every year. The frequency-based method reports these

Table 6: HEFR Overbank Results

Basin	USGS Gage Name	USGS Gage Number	NWS Flood Stage Discharge (cfs)	NWS Bankfull Stage Discharge (cfs)	Flow Statistic	Original			Frequency		
						Full Period	Pre-Reservoir	Post-Reservoir	Full Period	Pre-Reservoir	Post-Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	4,800	-	Peak Discharge (cfs)	2,875	3,360	2,820	2,930	4,000	2,930
					Volume (Ac-Ft)	32,695	33,461	32,563	35,703	43,877	36,806
					Duration (Days)	23	22	21	30	30	31
					Return Period (Years)	4.9	3.0	4.1	2.0	2.0	2.0
Sabine	Sabine River nr Gladewater	8020000	5,720	-	Peak Discharge (cfs)	18,100	19,400	16,700	18,100	34,600	15,900
					Volume (Ac-Ft)	553,068	456,865	584,547	483,275	703,975	535,070
					Duration (Days)	39	35	44	44	52	44
					Return Period (Years)	4.2	2.6	4.8	2.0	2.0	2.0
Sabine	Sabine River nr Beckville	8022040	12,600	-	Peak Discharge (cfs)	17,300	28,100	15,800	16,100	29,800	15,200
					Volume (Ac-Ft)	773,375	833,246	710,023	541,644	799,357	570,487
					Duration (Days)	42	39	42	45	52	44
					Return Period (Years)	5.4	3.5	4.8	2.0	2.0	2.0
Sabine	Sabine River nr Bon Weir	8028500	28,000	22,500	Peak Discharge (cfs)	29,400	27,900	29,900	36,500	37,500	36,700
					Volume (Ac-Ft)	942,288	989,950	935,207	1,200,452	1,627,017	1,009,374
					Duration (Days)	26	32	23	32	40	28
					Return Period (Years)	1.9	1.4	1.8	2.0	2.0	2.0
Sabine	Big Cow Creek nr Newton	8029500	-	-	Peak Discharge (cfs)	3,150	-	3,000	3,180	-	3,350
					Volume (Ac-Ft)	17,048	-	17,040	18,325	-	19,792
					Duration (Days)	13	-	13	17	-	17
					Return Period (Years)	3.7	-	2.7	2.0	-	2.0
Sabine	Sabine River nr Ruliff	8030500	13,300	9,880	Peak Discharge (cfs)	26,050	26,800	27,250	41,300	52,000	40,600
					Volume (Ac-Ft)	1,209,868	1,017,035	1,358,499	2,581,061	3,530,854	2,511,832
					Duration (Days)	48	46	51	82	90	93
					Return Period (Years)	1.2	0.9	1.4	2.0	2.0	2.0
Neches	Village Creek nr Kountze	8041500	6,170	2,070	Peak Discharge (cfs)	12,100	11,600	11,850	12,400	13,800	13,000
					Volume (Ac-Ft)	175,168	185,347	157,589	170,313	184,922	178,562
					Duration (Days)	22	22	22	29	31	28
					Return Period (Years)	3.8	7.0	2.9	2.0	2.0	2.0
Neches	Neches River at Evadale	8041000	41,500	8,700	Peak Discharge (cfs)	20,800	21,400	21,400	26,800	34,600	25,900
					Volume (Ac-Ft)	1,068,535	1,022,083	1,289,216	1,762,388	2,030,727	2,052,809
					Duration (Days)	49	49	56	46	57	44
					Return Period (Years)	1.7	1.4	1.7	2.0	2.0	2.0
Neches	Attoyac Bayou nr Chireno	8038000	1,200	-	Peak Discharge (cfs)	-	8,130	7,280	-	9,310	7,520
					Volume (Ac-Ft)	-	89,740	85,178	-	110,273	91,536
					Duration (Days)	-	20	23	-	24	27
					Return Period (Years)	-	2.3	2.9	2.0	2.0	2.0
Neches	Angelina River nr Alto	8036500	11,200	-	Peak Discharge (cfs)	13,650	-	13,650	9,690	-	9,690
					Volume (Ac-Ft)	242,645	-	233,432	204,931	-	205,699
					Duration (Days)	28	-	28	29	-	29
					Return Period (Years)	8.2	-	6.3	2.0	2.0	2.0
Neches	Neches River near Rockland	8033500	19,400	-	Peak Discharge (cfs)	26,400	30,550	24,400	18,500	16,000	20,300
					Volume (Ac-Ft)	950,303	1,131,262	788,834	661,717	590,921	706,179
					Duration (Days)	54	45	53	41	38	42
					Return Period (Years)	10.9	7.0	38.0	2.0	2.0	2.0
Neches	Neches River at Neches	8032000	1,370	-	Peak Discharge (cfs)	6,835	7,610	6,650	7,280	10,700	6,650
					Volume (Ac-Ft)	175,539	178,367	174,906	172,590	208,786	185,208
					Duration (Days)	36	34	37	38	40	38
					Return Period (Years)	4.3	3.0	4.2	2.0	2.0	2.0

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 7a: Winter Pulse Flows (Original Method)

Basin	USGS Gage Name	USGS Gage Number	Flow Statistic	Winter 25th Percentile (Dry)			Winter Median (Average)			Winter 75th Percentile (Wet)		
				Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	Peak Discharge (cfs)	128	142	136	223	246	240	574	584	591
			Volume (Ac-Ft)	1,513	2,059	1,531	4,143	4,999	4,322	9,546	10,486	9,695
			Duration (Days)	7	9	7	11	12	11	16	17	17
			Frequency (# per Season)	4	4	4	3	2	3	1	1	1
Sabine	Sabine River nr Gladewater	8020000	Peak Discharge (cfs)	741	800	953	2,000	2,520	2,060	5,035	5,290	5,030
			Volume (Ac-Ft)	12,474	13,684	14,224	49,989	54,860	52,092	135,646	129,017	157,924
			Duration (Days)	13	12	13	17	16	18	28	26	27
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1
Sabine	Sabine River nr Beckville	8022040	Peak Discharge (cfs)	1,113	1,185	1,115	3,140	3,720	2,865	6,428	6,083	7,215
			Volume (Ac-Ft)	14,357	20,792	10,849	75,531	89,921	66,081	206,207	201,972	189,248
			Duration (Days)	12	11	11	18	20	17	29	30	25
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1
Sabine	Sabine River nr Bon Weir	8028500	Peak Discharge (cfs)	3,318	6,690	2,690	9,655	10,500	9,680	16,600	15,150	17,300
			Volume (Ac-Ft)	39,069	122,856	30,902	129,081	223,775	94,869	393,099	406,542	394,314
			Duration (Days)	5	8	3	14	15	13	22	23	20
			Frequency (# per Season)	3	3	3	2	2	2	0	0	1
Sabine	Big Cow Creek nr Newton	8029500	Peak Discharge (cfs)	126	-	150	293	-	358	676	-	761
			Volume (Ac-Ft)	828	-	1,014	2,002	-	2,506	4,316	-	5,227
			Duration (Days)	4	-	4	7	-	7	9	-	9
			Frequency (# per Season)	6	-	5	4	-	4	2	-	1
Sabine	Sabine River nr Ruliff	8030500	Peak Discharge (cfs)	1,788	4,570	1,390	4,655	8,020	2,675	8,185	11,400	7,263
			Volume (Ac-Ft)	12,322	58,076	5,217	111,640	199,775	43,676	228,050	512,906	165,342
			Duration (Days)	3	8	2	16	20	12	25	34	24
			Frequency (# per Season)	1	1	2	1	1	1	0	0	0
Neches	Village Creek nr Kountze	8041500	Peak Discharge (cfs)	723	730	776	1,490	1,510	1,650	2,940	2,835	3,620
			Volume (Ac-Ft)	9,203	9,897	9,189	22,885	23,554	26,826	50,836	46,758	67,795
			Duration (Days)	9	9	8	12	12	12	20	19	20
			Frequency (# per Season)	4	5	4	3	3	3	1	1	1
Neches	Neches River at Evadale	8041000	Peak Discharge (cfs)	2,640	2,848	3,220	6,105	5,505	6,480	9,738	10,660	10,750
			Volume (Ac-Ft)	39,010	57,630	22,145	143,799	121,954	143,459	300,873	299,574	308,261
			Duration (Days)	8	14	3	18	18	17	31	34	28
			Frequency (# per Season)	2	2	2	1	1	1	0	1	0
Neches	Attoyac Bayou nr Chireno	8038000	Peak Discharge (cfs)	-	509	245	-	814	598	-	1,800	948
			Volume (Ac-Ft)	-	5,675	2,554	-	13,749	8,180	-	31,016	18,051
			Duration (Days)	-	7	7	-	11	10	-	17	15
			Frequency (# per Season)	-	4	5	-	3	3	-	1	1
Neches	Angelina River nr Alto	8036500	Peak Discharge (cfs)	696	-	834	1,385	-	1,655	3,200	-	3,400
			Volume (Ac-Ft)	10,616	-	13,339	29,002	-	35,381	72,590	-	76,168
			Duration (Days)	10	-	10	14	-	15	22	-	22
			Frequency (# per Season)	4	-	3	2	-	2	1	-	1
Neches	Neches River near Rockland	8033500	Peak Discharge (cfs)	2,040	1,850	2,695	4,280	4,320	4,490	7,605	7,580	8,050
			Volume (Ac-Ft)	22,274	22,770	28,691	104,569	92,172	103,279	257,841	268,031	277,469
			Duration (Days)	8	8	11	18	18	18	35	36	31
			Frequency (# per Season)	3	2	2	2	2	2	1	1	1
Neches	Neches River at Neches	8032000	Peak Discharge (cfs)	378	440	337	705	985	635	1,258	1,680	1,205
			Volume (Ac-Ft)	2,521	8,289	1,687	11,437	18,906	7,517	29,166	43,839	23,767
			Duration (Days)	6	9	2	12	15	10	19	23	18
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 7b: Spring Pulse Flows (Original Method)

Basin	USGS Gage Name	USGS Gage Number	Flow Statistic	Spring 25th Percentile (Dry)			Spring Median (Average)			Spring 75th Percentile (Wet)		
				Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	Peak Discharge (cfs)	96	126	98	219	266	212	569	637	465
			Volume (Ac-Ft)	1,270	2,108	1,252	4,255	5,005	3,745	8,592	10,301	7,595
			Duration (Days)	10	10	10	14	14	15	21	22	20
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1
Sabine	Sabine River nr Gladewater	8020000	Peak Discharge (cfs)	649	1,080	643	2,340	2,820	2,500	4,655	4,555	4,655
			Volume (Ac-Ft)	9,579	22,951	10,112	44,846	57,511	44,223	131,931	127,502	140,556
			Duration (Days)	13	13	13	21	22	23	33	29	36
			Frequency (# per Season)	2	2	2	2	1	2	0	1	0
Sabine	Sabine River nr Beckville	8022040	Peak Discharge (cfs)	1,130	1,758	1,105	3,320	3,520	3,840	6,470	6,535	6,893
			Volume (Ac-Ft)	16,913	39,314	17,468	74,880	79,258	82,403	191,107	190,708	192,119
			Duration (Days)	13	13	13	23	21	25	34	33	36
			Frequency (# per Season)	2	2	2	1	1	1	0	0	1
Sabine	Sabine River nr Bon Weir	8028500	Peak Discharge (cfs)	3,240	4,475	3,165	5,730	9,660	4,920	10,700	14,350	8,218
			Volume (Ac-Ft)	34,213	51,937	34,099	90,135	222,387	73,271	256,264	388,398	177,927
			Duration (Days)	6	6	6	13	17	13	23	33	19
			Frequency (# per Season)	3	2	3	2	1	2	1	1	1
Sabine	Big Cow Creek nr Newton	8029500	Peak Discharge (cfs)	68	-	73	123	-	124	356	-	350
			Volume (Ac-Ft)	379	-	409	940	-	956	2,703	-	2,717
			Duration (Days)	3	-	3	5	-	5	9	-	9
			Frequency (# per Season)	6	-	6	4	-	4	2	-	1
Sabine	Sabine River nr Ruliff	8030500	Peak Discharge (cfs)	2,863	4,715	2,960	4,730	6,655	4,380	9,013	10,275	7,520
			Volume (Ac-Ft)	32,326	37,755	35,742	111,352	208,364	100,721	269,445	358,304	236,826
			Duration (Days)	5	7	6	17	26	17	27	40	27
			Frequency (# per Season)	2	1	2	1	0	1	0	0	1
Neches	Village Creek nr Kountze	8041500	Peak Discharge (cfs)	401	434	401	1,040	970	1,145	2,300	2,260	2,455
			Volume (Ac-Ft)	5,345	5,538	5,743	15,632	13,962	18,758	38,144	37,412	41,295
			Duration (Days)	9	9	9	14	14	14	20	20	20
			Frequency (# per Season)	4	4	3	2	2	2	1	1	1
Neches	Neches River at Evadale	8041000	Peak Discharge (cfs)	2,973	3,238	3,458	5,580	7,035	5,575	8,205	9,340	7,740
			Volume (Ac-Ft)	47,461	42,873	43,716	145,101	177,749	118,126	256,899	285,030	212,975
			Duration (Days)	10	11	6	19	20	16	32	32	22
			Frequency (# per Season)	2	2	2	1	1	1	0	0	0
Neches	Attoyac Bayou nr Chireno	8038000	Peak Discharge (cfs)	-	289	204	-	532	491	-	1,225	811
			Volume (Ac-Ft)	-	2,182	2,371	-	7,262	5,754	-	19,164	15,493
			Duration (Days)	-	7	7	-	10	12	-	16	19
			Frequency (# per Season)	-	4	4	-	3	2	-	1	1
Neches	Angelina River nr Alto	8036500	Peak Discharge (cfs)	432	-	431	997	-	1,010	2,410	-	2,365
			Volume (Ac-Ft)	6,060	-	5,812	19,035	-	20,184	59,201	-	59,173
			Duration (Days)	11	-	11	16	-	16	24	-	24
			Frequency (# per Season)	4	-	4	2	-	2	1	-	1
Neches	Neches River near Rockland	8033500	Peak Discharge (cfs)	1,165	1,135	1,150	3,115	2,845	3,440	6,345	6,663	5,780
			Volume (Ac-Ft)	12,357	9,566	10,453	75,472	82,031	65,375	201,424	237,922	187,636
			Duration (Days)	5	4	4	22	21	19	38	36	37
			Frequency (# per Season)	2	3	3	1	2	1	1	1	1
Neches	Neches River at Neches	8032000	Peak Discharge (cfs)	272	524	209	748	794	706	1,398	1,560	1,385
			Volume (Ac-Ft)	3,058	6,240	1,718	13,352	18,054	11,980	35,313	35,806	37,572
			Duration (Days)	6	11	5	14	16	12	24	25	23
			Frequency (# per Season)	3	2	4	2	1	2	1	1	1

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 7c: Summer Pulse Flows (Original Method)

Basin	USGS Gage Name	USGS Gage Number	Flow Statistic	Summer 25th Percentile (Dry)			Summer Median (Average)			Summer 75th Percentile (Wet)		
				Full Period	Pre-Reservoir	Post-Reservoir	Full Period	Pre-Reservoir	Post-Reservoir	Full Period	Pre-Reservoir	Post-Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	Peak Discharge (cfs)	25	31	25	40	59	42	112	134	130
			Volume (Ac-Ft)	146	369	144	545	791	587	1,720	2,087	1,906
			Duration (Days)	3	7	3	10	11	10	15	15	16
			Frequency (# per Season)	4	4	4	3	3	3	1	1	1
Sabine	Sabine River nr Gladewater	8020000	Peak Discharge (cfs)	113	174	101	276	492	228	991	1,738	838
			Volume (Ac-Ft)	1,130	2,078	834	5,052	10,213	4,318	17,558	30,198	14,967
			Duration (Days)	6	12	4	14	19	14	22	26	21
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1
Sabine	Sabine River nr Beckville	8022040	Peak Discharge (cfs)	165	250	149	420	735	272	1,270	2,080	1,195
			Volume (Ac-Ft)	775	3,496	630	6,805	15,605	4,588	25,658	40,571	18,612
			Duration (Days)	3	10	2	13	20	12	24	26	20
			Frequency (# per Season)	3	3	4	2	2	2	1	1	1
Sabine	Sabine River nr Bon Weir	8028500	Peak Discharge (cfs)	1,795	1,048	3,968	4,750	2,125	5,860	6,725	5,200	7,115
			Volume (Ac-Ft)	24,947	6,630	44,172	65,117	51,336	72,417	135,699	126,307	144,007
			Duration (Days)	6	2	6	13	16	13	19	24	17
			Frequency (# per Season)	5	3	6	3	2	3	1	1	1
Sabine	Big Cow Creek nr Newton	8029500	Peak Discharge (cfs)	46	-	52	73	-	81	127	-	139
			Volume (Ac-Ft)	228	-	263	559	-	637	1,203	-	1,337
			Duration (Days)	2	-	3	5	-	5	8	-	8
			Frequency (# per Season)	6	-	6	4	-	4	2	-	2
Sabine	Sabine River nr Ruliff	8030500	Peak Discharge (cfs)	1,780	1,595	3,340	4,270	2,920	5,900	6,663	5,215	7,390
			Volume (Ac-Ft)	25,140	9,650	45,144	90,456	85,993	134,420	220,160	157,502	276,555
			Duration (Days)	6	3	6	17	18	18	27	26	28
			Frequency (# per Season)	3	2	3	2	1	2	1	1	1
Neches	Village Creek nr Kountze	8041500	Peak Discharge (cfs)	146	161	143	270	381	263	699	1,113	699
			Volume (Ac-Ft)	1,413	1,397	1,389	3,790	4,492	3,896	10,739	14,117	10,636
			Duration (Days)	5	5	5	10	11	10	17	19	17
			Frequency (# per Season)	4	4	4	3	3	3	1	1	1
Neches	Neches River at Evadale	8041000	Peak Discharge (cfs)	1,005	1,045	3,065	2,100	1,640	3,800	3,890	3,125	4,890
			Volume (Ac-Ft)	12,647	16,589	26,648	44,624	48,754	64,205	96,099	112,188	111,818
			Duration (Days)	4	12	4	14	19	11	25	30	18
			Frequency (# per Season)	2	2	3	1	2	1	0	1	1
Neches	Attoyac Bayou nr Chireno	8038000	Peak Discharge (cfs)	-	66	50	-	108	103	-	235	226
			Volume (Ac-Ft)	-	382	363	-	1,233	1,109	-	2,873	3,052
			Duration (Days)	-	4	4	-	7	7	-	10	13
			Frequency (# per Season)	-	6	6	-	5	4	-	2	2
Neches	Angelina River nr Alto	8036500	Peak Discharge (cfs)	86	-	81	154	-	172	401	-	420
			Volume (Ac-Ft)	1,051	-	1,064	2,598	-	3,099	7,502	-	7,992
			Duration (Days)	6	-	7	12	-	12	18	-	19
			Frequency (# per Season)	4	-	4	3	-	3	1	-	1
Neches	Neches River near Rockland	8033500	Peak Discharge (cfs)	159	181	151	319	344	368	950	1,250	1,050
			Volume (Ac-Ft)	1,081	1,131	758	4,423	5,500	4,881	20,043	24,061	18,493
			Duration (Days)	3	3	3	12	12	12	24	27	23
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1
Neches	Neches River at Neches	8032000	Peak Discharge (cfs)	88	65	99	139	128	150	294	248	386
			Volume (Ac-Ft)	470	329	504	1,581	2,198	1,488	4,590	5,266	4,132
			Duration (Days)	3	3	2	9	11	7	14	18	10
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 7d: Fall Pulse Flows (Original Method)

Basin	USGS Gage Name	USGS Gage Number	Flow Statistic	Fall 25th Percentile (Dry)			Fall Median (Average)			Fall 75th Percentile (Wet)		
				Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	Peak Discharge (cfs)	47	53	49	94	90	110	239	237	297
			Volume (Ac-Ft)	525	660	511	1,402	1,299	1,809	4,522	5,167	5,076
			Duration (Days)	7	7	7	11	10	11	15	15	16
			Frequency (# per Season)	4	4	4	3	3	3	1	1	1
Sabine	Sabine River nr Gladewater	8020000	Peak Discharge (cfs)	239	288	201	649	730	650	2,540	2,650	2,840
			Volume (Ac-Ft)	3,396	3,731	3,556	10,683	16,677	12,296	54,732	55,666	62,360
			Duration (Days)	12	7	11	17	18	17	24	25	24
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1
Sabine	Sabine River nr Beckville	8022040	Peak Discharge (cfs)	231	429	169	768	885	707	3,235	3,020	3,380
			Volume (Ac-Ft)	2,409	4,776	914	14,418	20,231	13,029	73,518	72,447	82,638
			Duration (Days)	7	8	3	14	16	14	23	22	22
			Frequency (# per Season)	3	3	4	2	2	2	1	1	1
Sabine	Sabine River nr Bon Weir	8028500	Peak Discharge (cfs)	1,085	1,270	1,025	1,720	3,310	1,600	5,160	7,890	4,248
			Volume (Ac-Ft)	5,722	8,430	4,816	17,564	67,736	15,382	90,228	148,683	61,711
			Duration (Days)	3	4	3	6	13	6	17	21	15
			Frequency (# per Season)	4	3	6	3	2	3	1	1	2
Sabine	Big Cow Creek nr Newton	8029500	Peak Discharge (cfs)	82	-	97	162	-	182	412	-	463
			Volume (Ac-Ft)	504	-	575	1,170	-	1,297	3,039	-	3,247
			Duration (Days)	3	-	3	6	-	7	8	-	8
			Frequency (# per Season)	5	-	5	4	-	3	2	-	2
Sabine	Sabine River nr Ruliff	8030500	Peak Discharge (cfs)	1,400	1,250	1,395	2,060	2,770	2,000	4,580	5,595	3,735
			Volume (Ac-Ft)	7,676	7,597	5,484	24,674	52,026	17,812	95,742	184,884	82,463
			Duration (Days)	3	3	2	7	14	6	18	27	16
			Frequency (# per Season)	3	2	4	2	2	3	1	1	1
Neches	Village Creek nr Kountze	8041500	Peak Discharge (cfs)	238	190	325	557	489	693	1,790	1,230	2,080
			Volume (Ac-Ft)	2,724	1,709	3,302	7,449	5,972	8,805	27,057	19,576	36,456
			Duration (Days)	6	4	7	10	10	11	15	15	15
			Frequency (# per Season)	4	4	4	2	2	2	1	1	1
Neches	Neches River at Evadale	8041000	Peak Discharge (cfs)	1,100	767	2,740	2,760	1,880	3,435	5,320	3,890	6,425
			Volume (Ac-Ft)	12,685	11,786	18,347	51,193	51,193	55,547	119,032	110,364	155,395
			Duration (Days)	4	10	3	16	17	11	22	28	19
			Frequency (# per Season)	2	2	2	1	1	1	1	1	1
Neches	Attoyac Bayou nr Chireno	8038000	Peak Discharge (cfs)	-	117	120	-	265	219	-	602	683
			Volume (Ac-Ft)	-	1,163	1,167	-	2,602	2,856	-	8,300	9,313
			Duration (Days)	-	6	6	-	7	8	-	12	13
			Frequency (# per Season)	-	3	5	-	3	3	-	2	1
Neches	Angelina River nr Alto	8036500	Peak Discharge (cfs)	182	-	196	535	-	595	1,440	-	1,505
			Volume (Ac-Ft)	2,408	-	2,463	9,457	-	10,852	31,763	-	32,799
			Duration (Days)	10	-	10	13	-	13	19	-	19
			Frequency (# per Season)	4	-	4	3	-	3	1	-	1
Neches	Neches River near Rockland	8033500	Peak Discharge (cfs)	253	232	287	811	986	1,035	3,000	3,775	3,435
			Volume (Ac-Ft)	2,945	4,278	3,010	13,920	18,207	18,796	70,691	90,086	78,533
			Duration (Days)	5	5	5	16	17	16	26	25	25
			Frequency (# per Season)	3	3	3	2	2	2	1	1	1
Neches	Neches River at Neches	8032000	Peak Discharge (cfs)	162	192	157	310	485	274	647	965	579
			Volume (Ac-Ft)	1,125	2,481	934	4,318	8,820	3,326	11,445	24,343	8,745
			Duration (Days)	4	10	2	10	15	9	16	19	13
			Frequency (# per Season)	4	3	4	3	2	3	1	1	1

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 8a: Annual Pulse Flows (Frequency Method)

USGS Gage Name	Flow Statistic	1 per 2 Years			1 per Year			2 per 3 Years			2 per Year		
		Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Big Sandy Creek nr Big Sandy	Peak Discharge (cfs)	2,930	4,000	2,930	1,920	2,100	2,100	1,420	1,550	1,460	1,170	1,260	1,220
	Volume (Ac-Ft)	35,703	43,877	36,806	24,536	25,150	28,694	18,665	19,224	21,188	15,644	16,008	18,092
	Duration (Days)	30	30	31	26	24	27	23	22	23	21	20	21
Sabine River nr Gladewater	Peak Discharge (cfs)	18,100	34,600	15,900	10,600	17,000	8,800	7,440	10,600	7,150	6,220	8,100	6,220
	Volume (Ac-Ft)	483,275	703,975	535,070	291,042	361,760	305,608	206,844	232,391	248,298	173,829	181,142	215,334
	Duration (Days)	44	52	44	36	39	34	31	33	32	29	30	30
Sabine River nr Beckville	Peak Discharge (cfs)	16,100	29,800	15,200	11,800	12,700	12,300	9,640	10,000	10,600	8,270	8,550	8,650
	Volume (Ac-Ft)	541,644	799,357	570,487	400,063	354,109	471,064	327,118	281,228	409,271	280,219	241,798	335,194
	Duration (Days)	45	52	44	38	35	39	34	31	36	32	29	32
Sabine River nr Bon Weir	Peak Discharge (cfs)	36,500	37,500	36,700	28,700	27,700	30,200	24,300	24,300	25,700	21,600	22,200	22,800
	Volume (Ac-Ft)	1,200,452	1,627,017	1,009,374	931,140	1,151,824	834,847	778,690	989,598	710,449	684,952	890,079	628,732
	Duration (Days)	32	40	28	28	33	25	25	30	23	24	28	21
Big Cow Creek nr Newton	Peak Discharge (cfs)	3,180	-	3,350	1,870	-	2,280	1,480	-	1,680	1,260	-	1,400
	Volume (Ac-Ft)	18,325	-	19,792	11,168	-	13,829	8,975	-	10,387	7,725	-	8,756
	Duration (Days)	17	-	17	14	-	14	13	-	13	12	-	12
Sabine River nr Ruliff	Peak Discharge (cfs)	41,300	52,000	40,600	29,000	33,100	27,900	22,700	27,300	22,000	16,800	21,400	16,000
	Volume (Ac-Ft)	2,581,061	3,530,854	2,511,832	1,760,073	2,175,046	1,692,669	1,337,897	1,751,573	1,304,349	941,501	1,317,231	904,395
	Duration (Days)	82	90	93	60	63	64	49	53	51	37	44	37
Village Creek nr Kountze	Peak Discharge (cfs)	12,400	13,800	13,000	8,150	8,050	9,100	6,180	5,800	6,580	5,050	4,500	5,590
	Volume (Ac-Ft)	170,313	184,922	178,562	118,176	115,871	131,318	92,022	85,981	98,166	76,452	67,975	84,577
	Duration (Days)	29	31	28	25	25	24	22	22	22	21	20	20
Neches River at Evadale	Peak Discharge (cfs)	26,800	34,600	25,900	19,500	22,800	19,200	15,800	19,000	14,800	13,000	15,300	12,700
	Volume (Ac-Ft)	1,762,388	2,030,727	2,052,809	1,242,210	1,314,691	1,288,788	974,359	1,077,767	860,628	769,783	843,682	676,846
	Duration (Days)	46	57	44	38	45	35	33	41	28	30	36	25
Attoyac Bayou nr Chireno	Peak Discharge (cfs)	-	9,310	7,520	-	5,750	4,480	-	4,090	3,260	-	3,240	2,330
	Volume (Ac-Ft)	-	110,273	91,536	-	75,392	61,455	-	56,095	46,734	-	45,467	34,492
	Duration (Days)	-	24	27	-	21	22	-	19	20	-	17	18
Angelina River nr Alto	Peak Discharge (cfs)	9,690	-	9,690	6,900	-	6,930	5,200	-	5,330	3,920	-	4,040
	Volume (Ac-Ft)	204,931	-	205,699	153,429	-	154,659	118,681	-	121,916	90,835	-	93,832
	Duration (Days)	29	-	29	26	-	26	24	-	24	21	-	22
Neches River near Rockland	Peak Discharge (cfs)	18,500	16,000	20,300	13,000	11,900	14,700	9,840	9,500	11,200	7,460	7,270	8,300
	Volume (Ac-Ft)	661,717	590,921	706,179	471,924	436,782	535,721	357,420	345,631	416,254	268,550	260,326	309,730
	Duration (Days)	41	38	42	35	33	36	31	30	32	27	26	27
Neches River at Neches	Peak Discharge (cfs)	7,280	10,700	6,650	4,880	5,760	4,640	3,430	4,220	3,300	2,440	3,340	2,370
	Volume (Ac-Ft)	172,590	208,786	185,208	118,357	116,577	134,806	84,058	86,823	97,411	59,977	69,606	69,675
	Duration (Days)	38	40	38	30	31	30	25	27	25	21	24	20

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 8b: 1 per Season Pulse Flows (Frequency Method)

USGS Gage Name	Flow Statistic	1 per Season Winter			1 per Season Spring			1 per Season Summer			1 per Season Fall		
		Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Big Sandy Creek nr Big Sandy	Peak Discharge (cfs)	942	865	1,080	950	1,120	923	132	140	151	367	376	432
	Volume (Ac-Ft)	14,544	13,378	14,931	12,852	13,838	14,072	2,054	2,175	2,500	6,055	6,387	7,012
	Duration (Days)	16	17	16	19	19	20	11	13	12	14	13	15
Sabine River nr Gladewater	Peak Discharge (cfs)	5,570	5,790	5,470	5,070	8,180	4,600	730	1,410	714	2,240	2,290	2,770
	Volume (Ac-Ft)	194,743	163,437	176,257	140,612	183,526	141,941	13,480	26,786	13,226	66,875	59,491	96,621
	Duration (Days)	24	24	25	25	26	25	17	24	16	21	19	23
Sabine River nr Beckville	Peak Discharge (cfs)	7,200	5,970	8,330	7,030	8,550	6,630	1,120	1,260	1,180	3,250	2,670	4,250
	Volume (Ac-Ft)	302,174	210,126	378,918	220,513	234,879	237,367	19,863	30,776	19,886	100,717	85,995	132,399
	Duration (Days)	24	21	26	27	26	27	16	19	16	21	19	23
Sabine River nr Bon Weir	Peak Discharge (cfs)	20,600	18,000	22,800	16,500	18,500	15,500	7,360	4,700	7,800	8,960	7,900	10,300
	Volume (Ac-Ft)	690,800	536,946	659,704	483,992	687,013	418,139	175,009	148,553	183,207	249,617	84,084	251,422
	Duration (Days)	17	21	15	21	24	17	14	16	14	17	15	18
Big Cow Creek nr Newton	Peak Discharge (cfs)	1,080	-	1,300	862	-	1,010	191	-	223	790	-	1,040
	Volume (Ac-Ft)	7,387	-	8,761	6,075	-	7,588	1,447	-	1,650	5,038	-	6,527
	Duration (Days)	10	-	10	10	-	10	7	-	8	9	-	10
Sabine River nr Ruliff	Peak Discharge (cfs)	14,800	16,200	12,000	10,600	14,200	9,060	6,600	3,980	7,560	6,030	4,680	7,510
	Volume (Ac-Ft)	923,041	672,419	891,358	489,092	683,919	281,109	182,343	123,614	234,720	161,358	113,910	221,092
	Duration (Days)	32	32	29	23	30	19	19	13	20	15	13	17
Village Creek nr Kountze	Peak Discharge (cfs)	4,170	3,330	5,000	3,250	3,150	3,860	804	1,240	841	2,400	1,780	2,830
	Volume (Ac-Ft)	78,857	62,045	89,150	46,002	44,156	56,506	11,418	19,272	12,263	35,862	25,582	41,595
	Duration (Days)	18	17	19	18	18	18	13	16	13	14	12	14
Neches River at Evadale	Peak Discharge (cfs)	10,900	11,800	10,700	9,500	13,800	8,090	3,390	1,860	4,440	3,820	3,520	6,480
	Volume (Ac-Ft)	617,583	544,871	419,772	456,832	652,700	193,548	73,933	59,057	103,201	90,628	98,061	169,349
	Duration (Days)	27	28	26	24	30	17	13	14	10	13	18	12
Attoyac Bayou nr Chireno	Peak Discharge (cfs)	-	2,790	1,850	-	2,350	1,550	-	322	390	-	854	898
	Volume (Ac-Ft)	-	46,539	29,620	-	30,739	23,048	-	4,098	5,384	-	12,064	16,133
	Duration (Days)	-	18	14	-	14	17	-	10	12	-	11	12
Angelina River nr Alto	Peak Discharge (cfs)	3,530	-	3,770	2,760	-	2,760	397	-	420	1,500	-	1,640
	Volume (Ac-Ft)	89,332	-	97,268	59,278	-	59,755	7,129	-	7,597	34,291	-	37,070
	Duration (Days)	18	-	18	20	-	19	13	-	13	16	-	16
Neches River near Rockland	Peak Discharge (cfs)	6,910	5,920	7,430	5,600	6,580	5,570	615	622	857	2,240	2,050	3,050
	Volume (Ac-Ft)	256,523	235,673	234,661	167,866	209,493	165,766	13,365	16,535	22,183	72,600	47,704	100,255
	Duration (Days)	22	19	24	23	25	20	11	11	13	17	16	17
Neches River at Neches	Peak Discharge (cfs)	1,750	2,220	1,750	1,830	3,610	1,660	248	222	279	782	865	771
	Volume (Ac-Ft)	53,526	63,336	53,209	41,351	68,399	46,632	4,029	4,164	4,171	19,996	23,985	17,551
	Duration (Days)	15	18	14	18	23	18	7	9	6	12	15	11

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 8c: 2 per Season Pulse Flows (Frequency Method)

USGS Gage Name	Flow Statistic	2 per Season Winter			2 per Season Spring			2 per Season Summer			2 per Season Fall		
		Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Big Sandy Creek nr Big Sandy	Peak Discharge (cfs)	358	339	484	313	376	301	50	70	54	130	128	171
	Volume (Ac-Ft)	5,932	6,525	7,055	5,062	6,155	4,905	671	1,081	623	2,189	2,233	2,812
	Duration (Days)	10	11	11	13	14	13	6	9	6	9	9	10
Sabine River nr Gladewater	Peak Discharge (cfs)	1,880	2,260	1,770	1,580	2,820	1,390	168	238	172	380	422	517
	Volume (Ac-Ft)	48,599	61,528	43,834	51,150	81,030	33,802	2,752	4,070	2,908	1,098	7,920	2,902
	Duration (Days)	15	16	15	16	17	15	7	8	7	11	10	12
Sabine River nr Beckville	Peak Discharge (cfs)	2,900	3,530	3,020	2,160	2,720	1,890	285	492	272	628	615	886
	Volume (Ac-Ft)	84,998	111,620	89,502	72,092	90,188	34,297	5,436	8,732	4,031	7,245	8,617	15,286
	Duration (Days)	15	16	14	15	14	15	6	10	5	9	9	9
Sabine River nr Bon Weir	Peak Discharge (cfs)	13,800	11,600	17,100	6,700	7,360	6,660	5,880	1,440	6,900	2,590	2,350	3,300
	Volume (Ac-Ft)	421,966	253,913	472,075	151,163	143,294	145,449	132,571	15,323	155,752	40,957	45,713	66,672
	Duration (Days)	14	16	13	12	12	11	13	6	13	7	6	8
Big Cow Creek nr Newton	Peak Discharge (cfs)	693	-	799	350	-	393	109	-	127	322	-	405
	Volume (Ac-Ft)	4,911	-	5,615	2,545	-	3,017	873	-	1,022	2,232	-	2,777
	Duration (Days)	8	-	8	7	-	7	5	-	5	7	-	7
Sabine River nr Ruliff	Peak Discharge (cfs)	1,600	2,390	1,460	3,250	#N/A	3,530	3,380	1,610	6,010	2,020	1,220	2,250
	Volume (Ac-Ft)	#N/A	#N/A	#N/A	#N/A	#N/A	79,096	108,505	8,950	187,343	33,993	38,612	40,386
	Duration (Days)	3	7	3	8	#N/A	9	11	6	16	5	4	5
Village Creek nr Kountze	Peak Discharge (cfs)	2,010	2,010	2,540	1,380	1,110	1,630	341	394	393	712	568	1,020
	Volume (Ac-Ft)	36,927	35,379	45,535	23,093	19,584	26,496	6,159	5,384	7,135	11,426	9,262	16,312
	Duration (Days)	13	13	14	13	12	14	8	8	8	9	8	10
Neches River at Evadale	Peak Discharge (cfs)	2,000	2,240	1,290	3,440	4,500	4,110	1,190	1,000	3,380	1,150	550	3,030
	Volume (Ac-Ft)	#N/A	#N/A	5,754	#N/A	36,118	68,584	28,078	20,901	58,511	4,918	42,738	44,291
	Duration (Days)	6	9	2	12	13	10	8	9	9	6	6	7
Attoyac Bayou nr Chireno	Peak Discharge (cfs)	-	1,140	837	-	840	690	-	204	146	-	446	405
	Volume (Ac-Ft)	-	19,313	13,871	-	12,241	10,618	-	2,483	1,888	-	6,722	6,353
	Duration (Days)	-	11	10	-	11	13	-	8	7	-	9	9
Angelina River nr Alto	Peak Discharge (cfs)	1,620	-	1,930	1,100	-	1,270	146	-	177	588	-	645
	Volume (Ac-Ft)	37,114	-	45,570	24,117	-	27,812	2,632	-	3,250	12,038	-	12,923
	Duration (Days)	13	-	14	14	-	14	8	-	8	12	-	12
Neches River near Rockland	Peak Discharge (cfs)	3,080	2,740	3,420	1,720	2,500	2,200	195	228	287	515	448	800
	Volume (Ac-Ft)	82,195	74,886	85,689	39,935	67,562	48,282	#N/A	548	191	649	13,921	13,668
	Duration (Days)	14	13	15	12	12	13	5	5	6	8	8	9
Neches River at Neches	Peak Discharge (cfs)	833	990	800	820	890	820	113	90	136	345	338	365
	Volume (Ac-Ft)	19,104	25,161	17,618	20,405	20,370	19,781	1,339	1,085	1,019	5,391	3,704	5,900
	Duration (Days)	10	12	8	12	13	11	4	5	4	8	10	7

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

2 per season regression failed for Spring season for pre-reservoir conditions at the Sabine River near Ruliff

Table 9a: Base Flows (Winter)

(Values in cfs)

Basin	USGS Gage Name	USGS Gage Number	Winter 25th Percentile (Dry)			Winter Median (Average)			Winter 75th Percentile (Wet)		
			Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	66	72	71	106	113	116	163	165	166
Sabine	Sabine River nr Gladewater	8020000	277	274	266	472	422	525	836	770	939
Sabine	Sabine River nr Beckville	8022040	438	448	511	807	766	923	1,580	1,580	1,710
Sabine	Sabine River nr Bon Weir	8028500	1,460	1,890	1,210	5,870	3,615	10,200	15,400	9,275	16,200
Sabine	Big Cow Creek nr Newton	8029500	56	-	66	78	-	91	106	-	119
Sabine	Sabine River nr Ruliff	8030500	1,520	2,350	1,303	2,565	2,890	1,685	5,063	4,600	3,618
Neches	Village Creek nr Kountze	8041500	240	205	315	424	344	521	672	666	717
Neches	Neches River at Evadale	8041000	1,760	1,840	1,750	2,590	2,420	2,505	4,980	5,160	3,070
Neches	Attoyac Bayou nr Chireno	8038000	-	195	107	-	348	188	-	516	339
Neches	Angelina River nr Alto	8036500	252	72	259	581	-	610	971	-	955
Neches	Neches River near Rockland	8033500	548	503	422	1,390	1,070	1,365	2,500	2,860	2,335
Neches	Neches River at Neches	8032000	178	240	165	408	438	351	814	762	700

Table 9b: Base Flows (Spring)

Basin	USGS Gage Name	USGS Gage Number	Spring 25th Percentile (Dry)			Spring Median (Average)			Spring 75th Percentile (Wet)		
			Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	30	38	26	51	75	51	111	127	106
Sabine	Sabine River nr Gladewater	8020000	119	198	100	283	332	325	664	616	910
Sabine	Sabine River nr Beckville	8022040	232	326	197	526	598	589	1,260	1,220	1,533
Sabine	Sabine River nr Bon Weir	8028500	856	1,440	755	1,590	3,210	1,195	6,680	6,980	8,808
Sabine	Big Cow Creek nr Newton	8029500	38	-	43	52	-	60	74	-	82
Sabine	Sabine River nr Ruliff	8030500	1,208	2,018	1,130	1,795	2,860	1,480	3,035	4,488	2,250
Neches	Village Creek nr Kountze	8041500	106	101	121	189	177	229	335	285	382
Neches	Neches River at Evadale	8041000	1,553	1,380	2,940	3,070	2,480	3,410	3,868	5,000	3,968
Neches	Attoyac Bayou nr Chireno	8038000	-	96	49	-	189	96	-	276	178
Neches	Angelina River nr Alto	8036500	82	-	85	206	-	231	518	-	520
Neches	Neches River near Rockland	8033500	382	738	349	1,020	1,260	837	2,160	2,473	2,225
Neches	Neches River at Neches	8032000	87	122	80	194	262	134	524	520	463

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 9c: Base Flows (Summer)

(Values in cfs)

Basin	USGS Gage Name	USGS Gage Number	Summer 25th Percentile (Dry)			Summer Median (Average)			Summer 75th Percentile (Wet)		
			Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	14	16	13	18	21	16	26	29	26
Sabine	Sabine River nr Gladewater	8020000	34	36	36	46	49	49	78	85	96
Sabine	Sabine River nr Beckville	8022040	51	61	52	74	88	76	122	160	128
Sabine	Sabine River nr Bon Weir	8028500	478	440	712	656	615	990	1,120	1,060	2,395
Sabine	Big Cow Creek nr Newton	8029500	28	-	31	36	-	40	48	-	50
Sabine	Sabine River nr Ruliff	8030500	670	688	1,080	870	950	1,600	1,430	1,633	3,485
Neches	Village Creek nr Kountze	8041500	70	70	78	91	95	105	135	141	143
Neches	Neches River at Evadale	8041000	471	392	2,693	2,140	610	3,140	3,210	994	3,478
Neches	Attoyac Bayou nr Chireno	8038000	-	26	20	-	45	28	-	66	48
Neches	Angelina River nr Alto	8036500	36	-	37	48	-	49	69	-	71
Neches	Neches River near Rockland	8033500	61	64	80	88	106	109	151	181	196
Neches	Neches River at Neches	8032000	42	30	63	73	38	88	108	47	120

Table 9d: Base Flows (Fall)

Basin	USGS Gage Name	USGS Gage Number	Fall 25th Percentile (Dry)			Fall Median (Average)			Fall 75th Percentile (Wet)		
			Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir	Full Period	Pre-Reservoir	Post Reservoir
Sabine	Big Sandy Creek nr Big Sandy	8019500	20	23	19	36	39	36	63	70	66
Sabine	Sabine River nr Gladewater	8020000	49	47	74	105	155	110	232	265	223
Sabine	Sabine River nr Beckville	8022040	75	74	90	141	206	140	356	424	372
Sabine	Sabine River nr Bon Weir	8028500	478	471	522	615	640	648	1,110	1,160	1,160
Sabine	Big Cow Creek nr Newton	8029500	36	-	41	46	-	51	64	-	72
Sabine	Sabine River nr Ruliff	8030500	735	840	883	970	1,030	1,130	1,400	1,700	1,460
Neches	Village Creek nr Kountze	8041500	89	86	100	138	122	170	236	200	295
Neches	Neches River at Evadale	8041000	438	400	1,990	1,280	543	2,620	2,630	1,240	3,050
Neches	Attoyac Bayou nr Chireno	8038000	-	37	34	-	78	65	-	139	122
Neches	Angelina River nr Alto	8036500	47	-	50	92	-	101	175	-	238
Neches	Neches River near Rockland	8033500	82	71	124	168	220	220	381	484	455
Neches	Neches River at Neches	8032000	73	42	80	104	136	103	172	238	158

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

Table 10: Subsistence Flows
(Values in cfs)

Basin	USGS Gage Name	USGS Gage Number	7Q2	Winter			Spring			Summer			Fall		
				Full Period	Pre-Reservoir	Post Reservoir									
Sabine	Big Sandy Creek nr Big Sandy	8019500	12.4	#N/A	#N/A	#N/A	9	10	9	8	8	7	8	8	7
Sabine	Sabine River nr Gladewater	8020000	46.4	#N/A	#N/A	#N/A	22	22	22	14	12	18	17	18	22
Sabine	Sabine River nr Beckville	8022040	75.9	#N/A	#N/A	#N/A	28	#N/A	28	20	16	22	19	23	25
Sabine	Sabine River nr Bon Weir	8028500	703.1	#N/A	#N/A	#N/A	279	#N/A	#N/A	241	223	#N/A	234	236	#N/A
Sabine	Big Cow Creek nr Newton	8029500	30	#N/A	-	#N/A	20	-	20	20	-	18	20	-	20
Sabine	Sabine River nr Ruliff	8030500	1121.3	#N/A	#N/A	#N/A	436	#N/A	#N/A	396	360	#N/A	362	350	425
Sabine	Village Creek nr Kountze	8041500	78.9	#N/A	#N/A	#N/A	49	46	49	41	42	37	41	43	46
Neches	Neches River at Evadale	8041000	1838.6	135	132	256	266	#N/A	#N/A	228	238	234	204	171	240
Neches	Attoyac Bayou nr Chireno	8038000	25.6	-	#N/A	#N/A	-	#N/A	0	-	12	9	-	11	7
Neches	Angelina River nr Alto	8036500	37.7	#N/A	-	#N/A	18	-	18	11	-	11	16	-	16
Neches	Neches River near Rockland	8033500	111.7	#N/A	#N/A	#N/A	29	#N/A	#N/A	21	16	26	21	9	#N/A
Neches	Neches River at Neches	8032000	70.7	#N/A	#N/A	#N/A	21	18	21	12	9	19	13	12	#N/A

n/a indicates that a subsistence flow does not occur during this season in the historical record

7Q2 values are from the Texas Surface Water Quality Standards

Full Period analysis not available for Attoyac Bayou nr Chireno

Pre-Reservoir analysis not available for Big Cow Creek nr Newton and Angelina River nr Alto

values somewhat differently. Instead of specifying the number of times an event is expected to occur in a season, the pulse events are given a “recurrence interval”, which is the frequency at which these types of events could be expected to occur over time. These events can be expressed either in terms of years or seasons. The recurrence interval does not mean that these types of events are expected to occur in any particular year. For example, if a pulse event is observed that has a two-year recurrence interval it does not mean that this type of event will not occur until two years later. A similar event could occur later in the same year, or may not occur again for several years. What it does mean is that over relatively long periods of time, these types of events should occur about once every two years. Also notice in the frequency-based results that a single value is reported for discharge (Q_p), but a range of values is specified for volume and duration, with a central tendency value reported in parenthesis. The frequency-based method used regression techniques to identify a typical range of values for volume and duration associated with the historical discharges. Occasionally these regressions produce negative values, and these are reported at #N/A in the output matrix. This seems to occur most often in the volume regressions. Before implementation of the flow regime, all regressions should be examined to evaluate their utility at the recommended flow magnitudes. A reduction in the significance value for the prediction intervals in the regressions could eliminate some of these, but it will also reduce the range of values reported in the matrix.

Looking at the overbank flows in Table 6, it appears that most of the HEFR overbank events exceed the NWS Flood Stage flows, with some even exceeding the Moderate Stage. (See Table 3 for additional NWS data.) The implications of recommending a relatively large flood flow as part of an environmental flow regime are uncertain. The BBEST may wish to refine their definition of overbank flows as additional information becomes available.

It is difficult to discern any general trends in the pulse and base flow data in Tables 7, 8 and 9. In many (but not all) cases the Pre-Dam values are higher than the Full Period and Post-Dam values. FNI recommends caution before making any definite conclusions based on this trend. The Pre-Dam analysis period of 21 years is relatively short compared to the Full Period (variable, but typically at least 70 years) or the Post-Dam period (38 years). The shorter record makes the analysis more easily influenced by individual storm events. Reservoirs typically reduce the number of pulse events and can reduce base flow events, depending on mode of

operation (hydropower typically increases base flows). However, most of the reservoirs in the Sabine and Neches Basins are either relatively small or have not been used to their fullest capacity. The flow records may be examined to see if the analysis could have been influenced by individual storms and verify the Pre-Dam HEFR results.

The gages with the most significant discrepancies are the Sabine River near Bon Wier and the Sabine River near Ruliff. The Bon Wier gage is located about 59 river miles downstream of Toledo Bend Reservoir. The Ruliff is about 58 river miles downstream of Bon Wier and about 40 river miles upstream of Sabine Lake⁷. In most cases, we would expect the downstream gage to have higher values than the upstream gage. However, the HEFR values for Bon Wier are almost always significantly higher than Ruliff. The reason for this discrepancy appears to be the result of using the NWS bankfull and flood stage discharges for the upper pulse threshold and overbank thresholds. The NWS discharges are significantly higher at Bon Wier than at Ruliff. A preliminary test using threshold parameters at Bon Wier that are closer to the Ruliff parameters removes the discrepancy. It is unclear at this time if lower values for the upper pulse and overbank thresholds at Bon Wier are warranted, if higher values at Ruliff should be used, or the results should be left as they are because the environment needs more water at Bon Wier than at Ruliff. Additional information from the current FERC relicensing in this reach may shed light on this issue.

Table 10 compares the HEFR subsistence values to the published 7Q2s for each gage. The subsistence values are uniformly lower than the 7Q2 values except for at the Neches River near Neches gage, where they are higher in the spring and fall for the pre-reservoir condition. Not surprisingly the most significant differences are at the three hydropower-influenced gages: Bon Wier, Ruliff and Evadale.

The HEFR matrices in Attachment B use of the terms “wet,” “average” and “dry” to classify flow conditions. In general, HEFR associates these terms with the 75th percentile, median and 25th percentile of the parameters in the flow matrix. The method does not directly link the results to observed climatic conditions. Figure 7 illustrates how HEFR applies these terms. This particular year is interesting because it includes two overbank events, subsistence flows and

⁷ United State Geological Survey National Water Information System, Surface-Water Data for Texas, available online at <http://waterdata.usgs.gov/tx/nwis/sw>.

Figure 7a: Example of Pulse Classification by Climatic Condition

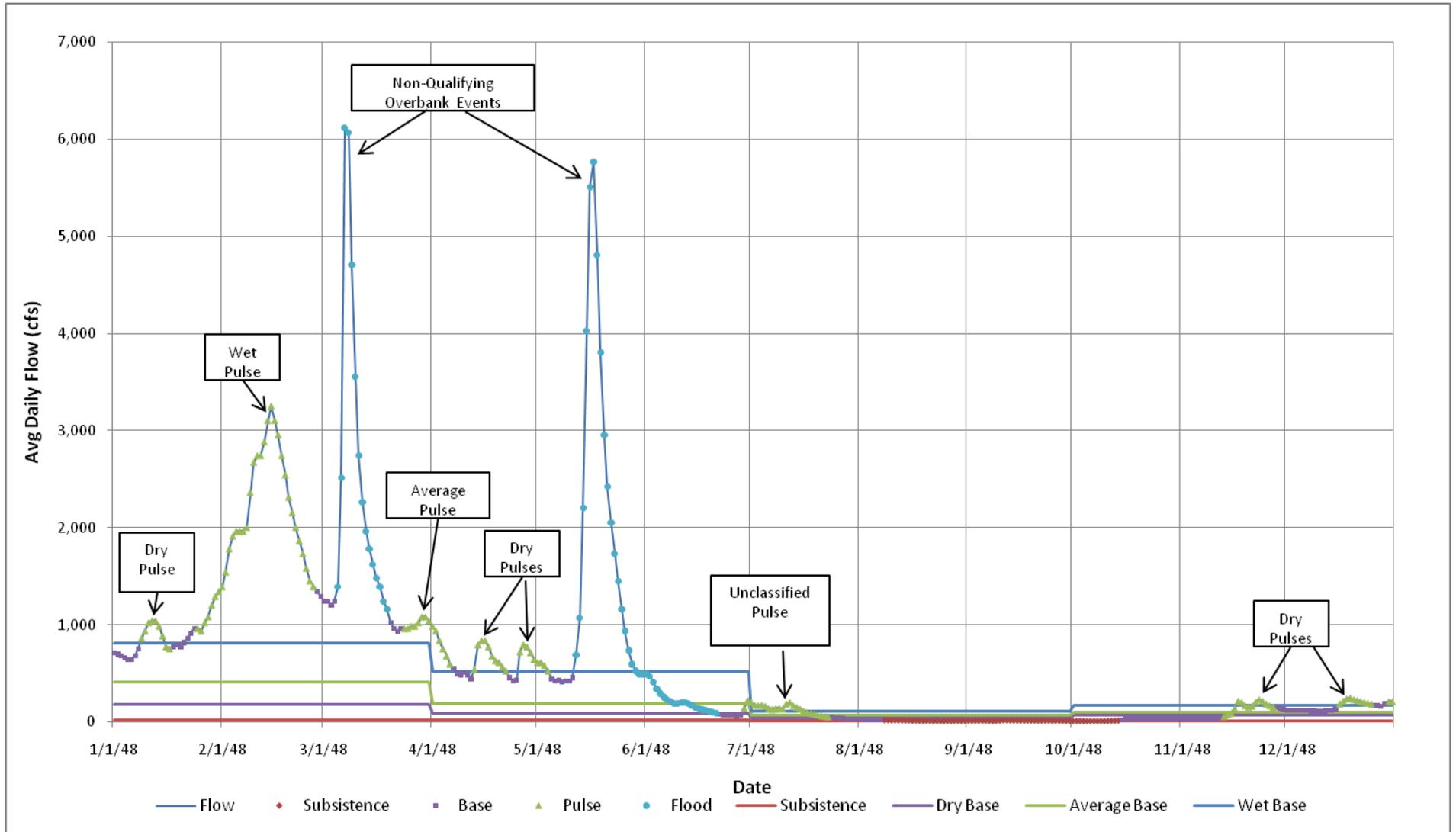
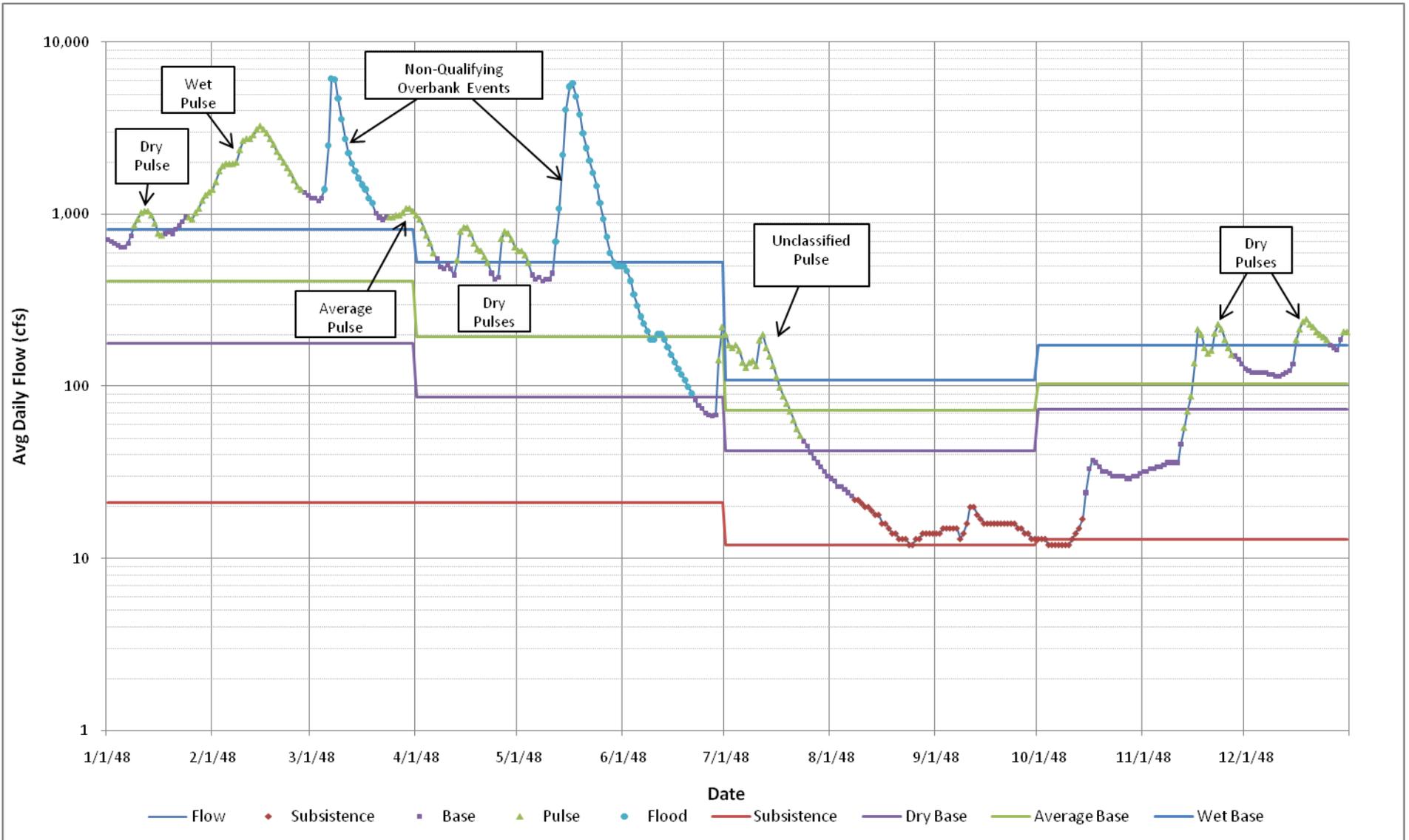


Figure 7b: Example of Pulse Classification by Climatic Condition



several sizes of pulse events. The total flow for this year is slightly below the annual median, so the year could be considered an “average” year. Seasonally, the winter, spring and fall would probably be classified as average while the summer would be classified as dry.

The pulse flow events in Table 6 have been marked with the designation of wet, average or dry found in a table generated by HEFR. The model did not give any particular designation to the pulse at the beginning of July, so it is marked as an “unclassified pulse”. The two overbank flows do not meet the HEFR criteria for overbank events because the peak discharge is lower than the matrix criteria, so they have been marked as “non-qualifying overbank events”. Also plotted on the graph are the subsistence and wet, dry and average base flow criteria from the matrix. Note that the winter and spring seasons have a mixture of average, dry, wet and overbank events. Also note that the magnitude of “dry” pulses varies significantly depending on the season. The winter and spring dry pulses are quite a bit larger than the fall dry pulse.

Figure 7 illustrates that even though an event qualifies as “dry” or “wet”, it does not necessarily mean that you would be observing dry or wet conditions. The HEFR statistics are generated without regard to climatic condition, so the use of these terms to describe the statistics can be somewhat misleading. To address this issue, FNI recommends that the BBEST report HEFR results in terms of the statistics as well as the assumed condition. In other words, replace “dry” with the term “25th Percentile (dry)” and so forth. We believe that this will help clarify the statistical nature of the analysis.

Comparison of HEFR results to State Methodology for Sabine Lake

In addition to the HEFR analyses for the twelve stream gages, a HEFR analysis was performed on inflows into Sabine Lake. The flow data consists of historical daily flows from BBEST gages Village Creek near Kountze, Neches River at Evadale and Sabine River near Ruliff, plus the USGS gages Pine Island Bayou near Sour Lake (08041700) and Cow Bayou near Mauriceville (08031000). The historical daily gage flows were added to estimated ungaged inflows obtained from the Texas Water Development Board (TWDB). The ungaged flows consist of monthly data for the period from 1941 to 2005. These flows were distributed to daily using historical flow patterns from the Kountze gage. TWDB also has monthly estimates of diversions and return flows for the ungaged data. These data were distributed evenly throughout the each month and the diversions were subtracted and the return flows added to the daily flows. TWDB also

has historical monthly precipitation and evaporation estimates for Sabine Lake. These data were not included in the inflows. The median net precipitation on Sabine Lake (precipitation – evaporation) for the 1941 to 2005 period averages about 49,000 acre-feet per year, which is less than 1 percent of the average annual flow into the Sabine Lake.

Table 11 compares the annual volume from the HEFR runs using the percentile-based approach for Sabine Lake to the annual volume for MinQ, MaxC and MaxQ⁸ from the State Methodology for bay and estuary inflows. HEFR matrix volumes for each flow condition (25th percentile, median or 75th percentile) are shown for base flows only, base plus pulse flows and with the entire HEFR overbank event added to each condition. (Overbank flows may not occur in any given year.) Subsistence flows have not historically occurred during the winter and spring months. In these months the fall HEFR result was used to calculate volumes.

Comparing HEFR to the State Methodology shows that the HEFR 25th percentile (dry) conditions are less than the MinQ unless an overbank event occurs during the year. Base plus pulse flows for median (average) conditions are less than MinQ for the Full Period and Pre-Dam time periods, but are more than MinQ for the Post-Dam period. MaxC values are only exceeded for the median (average) condition if an overbank event occurs during the year. The 75th percentile (wet) condition is relatively close to the MaxQ even without the occurrence of an overbank flow.

Also note that for the HEFR results in Table 11 most of the volume entering the Lake is included in the base flow component. The base flow by itself is about 70% of the Base + Pulse volume in the 25th percentile (dry) conditions and over 90% for 75th percentile (wet) condition. Also, note that the Post-Dam HEFR results have higher volumes than the Full Period or Pre-Dam results.

Figure 8 compares the seasonal distribution of the HEFR volumes to the seasonal distribution using the State Methodology. (The monthly State Methodology values were summed by the same seasons used in the HEFR analysis.) Note that the distribution for the HEFR volumes without overbank flows is similar to the State Methodology, with the highest flows occurring during the winter months and the lowest during the summer months. The occurrence of an

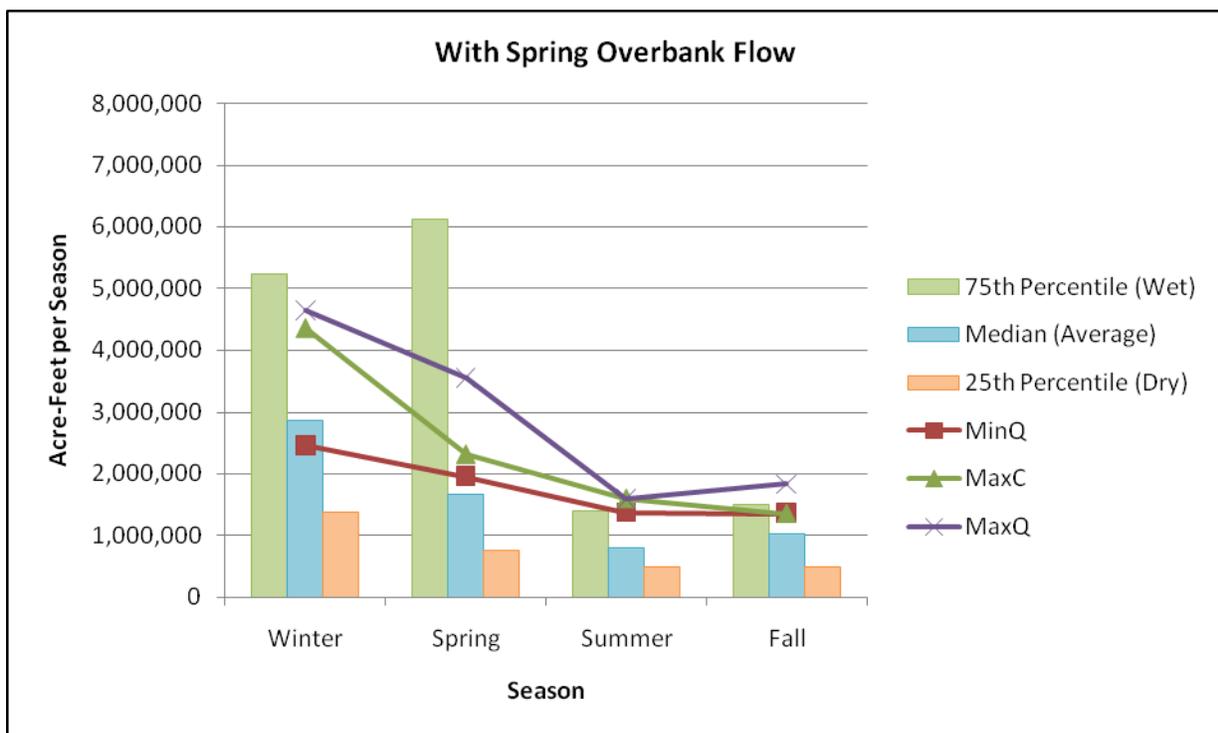
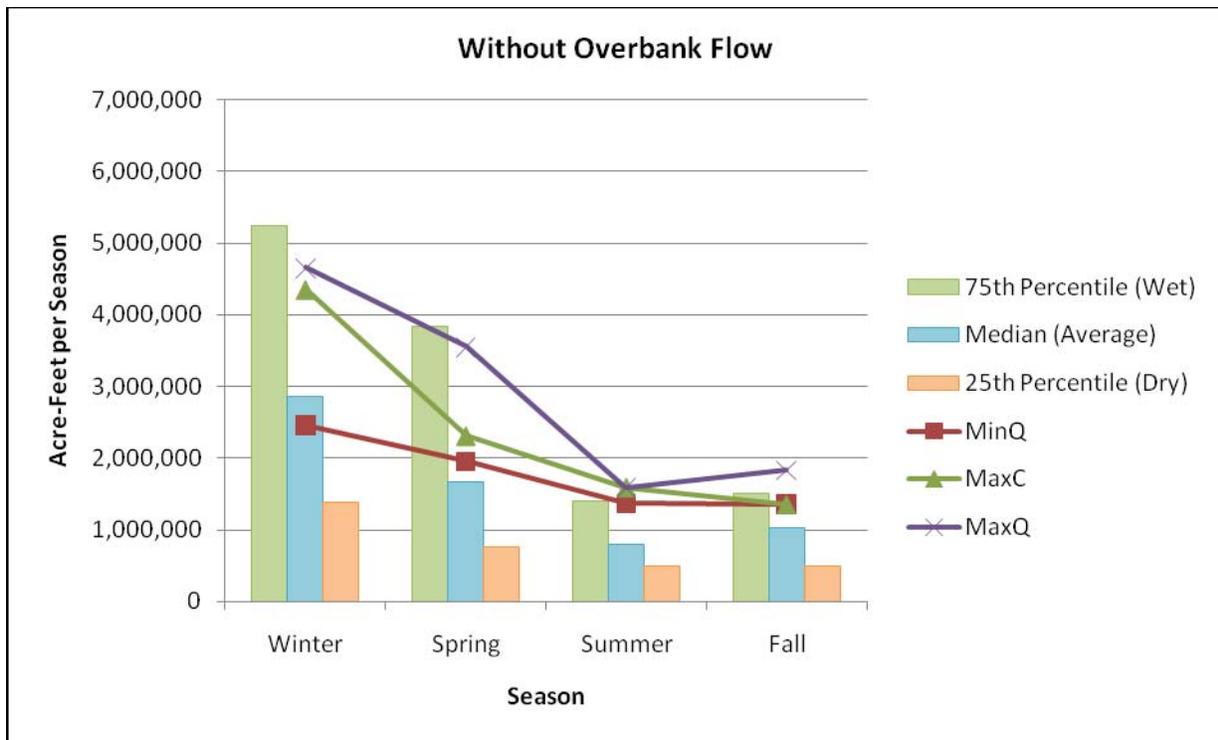
⁸ Texas Parks and Wildlife Department: Freshwater Inflow Recommendation for the Sabine Lake Estuary of Texas and Louisiana, March 2005.

overbank flow can significantly alter the distribution, however. The HEFR volumes are for the Full Period of record. The Pre-Dam and Post-Dam periods have similar results.

Table 11: Comparison of HEFR Annual Volumes to State Methodology for Sabine Lake
 (Values in Acre-Feet per Year)

HEFR Annual Volumes			
	Full Period (41-05)	Pre-Dam (41-60)	Post-Dam (71-05)
Subsistence	549,757	535,467	680,223
25th Percentile (Dry) Condition			
Base Only	2,243,997	2,316,804	3,306,215
Base + Pulse	3,150,508	3,643,588	4,114,963
Base + Pulse + Overbank	6,451,892	8,646,629	7,316,168
Median (Average) Condition			
Base Only	5,018,915	5,013,258	7,240,502
Base + Pulse	6,380,477	6,325,716	8,234,125
Base + Pulse + Overbank	9,467,182	10,719,867	11,271,050
75th Percentile (Wet) Condition			
Base Only	11,076,875	10,520,563	13,694,250
Base + Pulse	11,986,199	11,300,553	14,298,506
Base + Pulse + Overbank	14,266,063	14,416,682	16,359,393
State Methodology			
MinQ	7,114,000		
MaxC	9,596,600		
MaxQ	11,619,300		

Figure 8: Comparison of Seasonal Flow Volumes for Full Period HEFR and State Methodology for Sabine Lake, with and without Overbank Flow



Summary and Conclusions

FNI has performed a series of HEFR analyses for twelve stream gages in the Sabine and Neches Basins and for inflows into Sabine Lake. Where data were available, each gage was evaluated for three different time periods: the Full Period of record for the gage, a Pre-Dam period from 1940 to 1961, and a Post-Dam period from 1971 to 2008. Each period was analyzed using both the original percentile-based approach and frequency based approach available in HEFR. In general these analyses did not stray significantly from default values suggested in the SAC guidance for application of HEFR¹. Major differences from the SAC defaults are the use of NWS stage data to define overbank flows, allowance for a wider range of flow values in pulse and base flow classifications. Subsistence and base flows were not limited to the published 7Q2 in the HEFR analysis. If desired by the BBEST, this limitation can easily be applied to the results. The output flow matrices from the HEFR analyses can be found in Attachment B. Tables 6 through 10 compare the results for the different gages.

The HEFR results for Sabine Lake were compared to the State Methodology MinQ, MaxC and MaxQ values. Table 11 compares the annual volumes. The HEFR 25th percentile (dry) conditions are less than the MinQ unless an overbank event occurs during the year. Base plus pulse flows for median (average) conditions are less than MinQ for the Full Period and Pre-Dam time periods, but are more than MinQ for the Post-Dam period. MaxC values are only exceeded for the median (average) condition if an overbank event occurs during the year. The 75th percentile (wet) condition is relatively close to the MaxQ even without the occurrence of an overbank flow. Most of the flow volume into Sabine Lake in the HEFR matrix occurs as base flows or overbank flows.

HEFR is a “desktop method” for developing streamflow recommendations. Other desktop methods commonly used in Texas are the Lyons Method and Consensus Criteria for Environmental Flow Needs (CCEF). Both of these methods are described in the SAC guidance¹. Both the Lyons Method and CCEF have been used to develop minimum bypass flows in water rights permits and for regional water planning for many years. These methods share some of the concerns associated with the HEFR method, chiefly the lack of a clear link between the recommended flows and environmental health. They have also been employed in a somewhat different fashion than the flow regime that will be recommended by the BBEST. The Lyons and

CCEF methods have been used to determine permit conditions that define a specific lower limit to diversion or impoundment by the water right. They do not specify a flow regime. The flow regime is the result of the interaction of these low-flow conditions with other boundaries such as storage capacity, diversion rates, annual diversion limits and diversions by other water rights, as well as the water provided by nature.

The Legislature has tasked the BBEST with defining a flow regime that defines a sound ecological environment. In FNI's opinion, this assignment has a larger scope than developing boundary conditions that are appropriate for permits. It is likely that a flow regime defining a sound ecological environment will be so complex that permit conditions for new water rights will not be readily apparent from the results. Future permit conditions will need to be developed based on site-specific interactions of existing water rights and the future water rights, taking into consideration flow goals established by the BBEST.

FNI does not believe that the flow matrix, by itself, is sufficient to define a flow regime. Other information that the BBEST should consider as part of its recommendation include a list of the functions of each flow component (for example protection of a specific species or habitat), the frequency with which the different recommendations are expected to be met (at all times, in one of every five years, etc.), and guidance for defining the meaning of the wet, average and dry flow statistics. One potentially misleading aspect of the flow matrix is the specificity of the HEFR output. Often these are reported as a single number, implying that only that flow level is protective of the environment. The precision of the numbers is not justified by the method. The values in the matrix will change depending on the parameters used in the analysis and the period selected, even in cases where the historical flows describe basically natural conditions. In reality, a range of discharges, volumes and duration are not only adequate but probably necessary to maintaining ecological health. Therefore FNI recommends that the BBEST consider a range of values rather than specific numbers in their final recommendations.

The chief limitation of this analysis is the lack of a link between environmental processes and the statistical output generated by the HEFR method. Although it is reasonable to assume that streamflow is linked to the ecological health of a river, it is unclear what part specific statistics play in maintaining a sound ecological environment. For example, it is not clear that the environment will benefit from using the 75th percentile of peak flows as a basis for a pulse flow

recommendation during a wet cycle. Although this may be a reasonable assumption as a starting point, there is no theoretical basis for doing so, and there is no empirical evidence that doing so is effective. Without reference to other environmental factors (biology, water quality and geomorphology for example) it is difficult to have confidence that the tables produced by the HEFR method have any meaning. The SAC is in the process of developing several “overlays” that should help in refining the linkage between HEFR and other environmental factors. Most of these guidance documents are in draft form and should be used by the BBEST to refine the results of these analyses. The HEFR analyses are only the first step in the process.

Because of the lack of linkage to environmental factors, there is no clear recommendation for adopting any particular HEFR analysis based on hydrology alone. FNI recommends the following:

- The BBEST select one or more of the analysis periods and matrix methods as a hypothesis that can be tested as additional data become available. Additional HEFR runs could be made if needed.
- The frequency-based approach is probably more effective in describing an environmental flow regime because of its greater flexibility. The frequency method is not as specific as the percentile-based method and potentially leaves room for more variability. The frequency matrix includes a range of volumes and durations, and using the recurrence interval implies additional variability that is missing from listing a specific number of occurrences in a particular season. The recurrence interval method is similar to the “design flows” used in a variety of other water-oriented applications. FNI is unaware of another application of the percentile approach.
- If the gage location currently has a sound ecological environment, the use of the Post-Dam analysis period may be appropriate. However, because the Post-Dam period includes only 38 years of record it may not effectively describe the full range of flows that can be expected. The Full Period analysis may be more indicative of long-term trends for the gages unimpacted by hydropower. For the gages impacted by hydropower (Ruliff, Bon Wier and Evadale), the flow separation and analyses during periods of hydropower generation is suspect. Therefore for those gages the Pre-Dam period is suggested as a starting point.

These recommendations are not strong recommendations. The BBEST may have other good reasons for adoption of different periods of methods.

In the event that the additional data does not lead to a clear path forward, FNI recommends that the BBEST develop a statement that expresses a relatively low level of confidence in the flow regime provided by the HEFR analysis until such time as the results are verified by other site-specific studies.