

Coastal Bend Regional Water Planning Area

2011 Regional Water Plan

Study 3

Implementation Analyses for Pipeline from CCR to LCC, Including Channel Loss Study Downstream of Choke Canyon Reservoir

Prepared by:

Coastal Bend Regional Water Planning Group

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Nueces River Authority

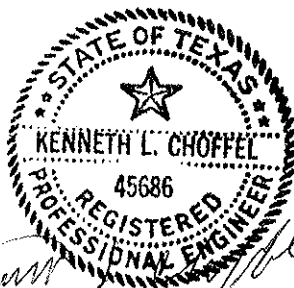
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Study 3
Implementation Analyses for Pipeline from CCR to
LCC, Including Channel Loss Study Downstream of
Choke Canyon Reservoir
(Final)



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List of Acronyms

acft	Acre-Feet
ACDP	Acoustic Doppler Current Profiler
CCR	Choke Canyon Reservoir
CCR/LCC	Choke Canyon Reservoir/ Lake Corpus Christi System
CCWSM	Corpus Christi Water Supply Model
cfs	Cubic Feet per Second
ft-msl	Feet-Mean Sea Level
LCC	Lake Corpus Christi
OWC	Outlet Works and Control
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
USGS	United States Geological Survey

Executive Summary

Choke Canyon Reservoir (CCR) and Lake Corpus Christi (LCC) operate as a system to provide surface water supplies to the City of Corpus Christi and its customers. Water stored in CCR is delivered to LCC using the natural stream channels of the Frio and Nueces Rivers and the yield of the system is affected by channel losses. If water could be delivered by a pipeline that bypasses the stream channels, it would not be subjected to these losses and could result in more water in storage and enhance the system yield. The CCR/LCC pipeline was studied in the 2001 and 2006 Plans, however a detailed channel loss was unavailable prior to this study to quantify reduced streamflow in the Frio and Nueces Rivers when delivering water supplies from CCR to LCC through a pipeline rather than river channel.

The primary objective of this study is to evaluate stream flow interaction with alluvial sands of the Gulf Coast Aquifer downstream of CCR to LCC using data collected during a field channel loss study. A channel loss study was conducted from March 3- 28, 2008, during a fairly wet hydrologic period with LCC water levels ranging from 93.5 ft-msl to 93.8 ft-msl (or 96.1% - 98.3% LCC water storage capacity).

An overall 87 percent delivery rate (or 13 percent channel loss) from CCR to the Nueces River at Three Rivers Gage was measured during the channel loss study. These data agree closely with the City of Corpus Christi's previously estimated 84 percent delivery factor from CCR to Three Rivers.^{1,2} From the Nueces River near Three Rivers to the Nueces River downstream of the confluence with Sulphur Creek near Oakville (a distance of 7.4 river miles), the data indicate between an 11 percent and 13 percent gain in stream flow. The study did not characterize the river segment from the Nueces River near Sulphur Creek to LCC due to backwater influence and it is anticipated that significant losses can occur from the Nueces River segment downstream of the Nueces River near Sulphur Creek to Wesley Seale Dam. During the channel loss study, it was determined that a larger portion of the Nueces River is under the influence of LCC water levels than previously thought, specifically during times when LCC is

¹ HDR, "Updates and Enhancements to Lower Nueces River Basin Bay and Estuary Model and Corpus Christi Water Supply Model", January 2006.

² The March 2008 channel loss survey results reported an 87 percent delivery factor as compared to an 84 percent average delivery factor. This is less than a 4 percent difference, which might be attributable to seasonal differences as discussed in the Model Update report (January 2006).

nearly full. Previous estimates by the TWDB indicated that the most upstream location considered as part of LCC was “at a point where the Nueces River meanders closest to the Missouri-Pacific railroad tract”, which based on this study appears to be underestimating the extent of LCC influence by at least 12 miles. Based on this study, an overall channel loss was estimated to be between 2 and 3 percent for the 17.4 river mile stretch from CCR to the Nueces River near Sulphur Creek. This is significantly less than the results from previous studies which estimated channel losses from CCR to LCC over a distance of about 63 miles at about 37.8 percent (a delivery factor of 62.2 percent). The 45.6 river mile segment downstream of the Nueces River near Sulphur Creek to the Wesley Seale Dam at LCC was not characterized during this study due to the influence of water stored in LCC.

The differences in the channel loss results as compared to previous studies are attributed primarily to the geological setting. A unique geological feature of the Gulf Coast Aquifer system impacts Nueces River streamflow near the Three Rivers Gage. Older clay and sandstone geologic layers are overlain by younger Fluvial terrace and Alluvium layers consisting primarily of gravel, sand, silt, clay, and floodplain deposits. These younger geologic formations impact water movement downstream in two ways: (1) part of the streamflow traveling from CCR towards the Three Rivers Gage becomes underflow in the alluvium system which results in a temporary loss from the stream (i.e. channel losses from CCR toward the Three Rivers Gage), and (2) the alluvium system pinches out downstream of the Three Rivers Gage and the streamflow lost to underflow rejoins the Nueces River after the confluence with Sulphur Creek.

The groundwater and surface water interaction downstream of CCR to LCC is very complex and could vary significantly based on seasonal events, antecedent drought or wet conditions and prolonged drought or wet conditions that could impact storage in LCC. LCC was full or nearly full from 2002 to 2005 and began depleting from May 2005 to September 2006. LCC began filling again in September 2006 and was full or nearly full from June 2007 through March 2008. When LCC is at or near storage capacity (conservation pool elevation of 94 ft-msl), the alluvium system influenced by LCC stores water which would be expected to result in less channel losses from the Three Rivers Gage to LCC. Furthermore, after prolonged drought periods there could be less water stored in LCC and it would be expected that the alluvium system will act somewhat like a sponge and absorb streamflow traveling down the Nueces River towards LCC, resulting in higher channel losses. For example, a previous TWDB water loss study based on data collected from 1958 to 1965 reported a total water loss of 11 percent for

LCC. Based on historical data, the majority of this time period was very dry, with storage of water in LCC at less than 70% capacity from July 1958 through October 1964 and therefore losses during this time would be anticipated to be higher than during wet conditions.

The 2006 Plan showed an estimated firm yield supply of 39,500 acft/yr in Year 2060 attributable to operating a CCR/LCC pipeline project at a 300 cfs delivery rate. This yield was based on the results of previous studies showing a 37.8 percent loss (a delivery factor of 62.2 percent) from CCR to LCC over a distance of about 63 river miles, or a loss of 0.6 percent per river mile. Smaller channel losses may significantly reduce the benefits of delivering water supplies through a pipeline from CCR to LCC. Based on the results of this recent channel loss study, an overall channel loss was estimated to be between 2 and 3 percent for the 17.4 river mile stretch from CCR to the Nueces River near Sulphur Creek, which is about 1/10 of the channel losses from previous studies. Based on the results from previous studies, a channel loss around 10.4% would have been expected for this reach (i.e. 17.4 river miles times 0.6 percent per river mile). If an additional firm yield supply with CCR/LCC pipeline was 1/10 the supply shown in the 2006 Plan, then an annual raw water cost of \$3,103 per acft would be expected. However, the channel loss study was conducted when LCC reservoir was nearly full and during a fairly wet hydrologic cycle and therefore, would not be representative of drought conditions used to calculate firm yield. For this reason, it is important to qualify that data collected during the channel loss study in March 2008 may not represent long-term conditions since the data was collected during wet weather conditions and may not be appropriate for evaluating and assessing modifications or benefits of the CCR/LCC pipeline strategy.

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1.0 Introduction

Choke Canyon Reservoir (CCR) and Lake Corpus Christi (LCC) operate together as a system to provide water supplies to the City of Corpus Christi (City) and their customers. Previous studies have shown that significant channel loss occurs in the Lower Nueces River Basin. This loss affects the ability of the river system to deliver stored water from CCR and LCC to the Calallen Pool, where intakes for regional water supplies are located. CCR is operated to release stored water down the Frio and Nueces Rivers to LCC based on water level conditions in LCC. Channel losses in these river channel segments between CCR to LCC are often large, due in part to these streams being located within the outcrop of the Gulf Coast Aquifer. The river channel segments that affect the ability of the lower Nueces River system to deliver water from CCR and LCC to the Calallen Pool are as follows:

- Frio River from CCR to the Nueces River confluence at Three Rivers (10 miles),
- Nueces River from Three Rivers to LCC (53 miles), and
- Nueces River from LCC to Calallen (39 miles).

Of these three segments, two reaches have been extensively studied by the City and the United States Geological Survey (USGS): Frio River from CCR to the Nueces River confluence at Three Rivers and the Nueces River from LCC to Calallen. However, the 53 mile river reach from the USGS Gage located near Three Rivers (Three Rivers Gage) to LCC is poorly understood due to limited streamflow data and close hydraulic connection with the Goliad Sands of the Gulf Coast Aquifer.

1.1 Background

Previous studies by the City and the USGS have provided a good understanding of channel losses that occur on the Frio River from CCR to the Nueces River near Three Rivers. In a study conducted by the City¹, eleven release events from CCR during the time period from 1987 to 2001 were identified when recorded flow at the USGS Nueces River near Three Rivers Gage (USGS #08210000) consisted primarily of water released from CCR. Delivery factors were calculated for each event by dividing the volume released from CCR by the total volume of

¹ City of Corpus Christi, HDR Engineering, "Updates and Enhancements to Lower Nueces River Basin Bay and Estuary Model and Corpus Christi Water Supply Model," January 2006.

water passing the Three Rivers Gage. The study showed that approximately 84 percent of the water released from CCR will arrive at the Three Rivers Gage. This 84 percent rate resulted in a loss rate of about 1.6 percent per mile for this reach. A slight seasonal variation in channel losses was observed in the general trends of the datasets, which showed a higher percent delivery during the spring (86 percent) than during the winter or summer (82 percent and 84 percent, respectively). This seasonal variation was attributed primarily to antecedent drought or wet conditions prior to the release, gage error, and variations in lag time between CCR and LCC. Based on the City's results, the Corpus Christi Water Supply Model (CCWSM) was updated for a constant delivery factor of 84 percent from CCR to Three Rivers, with enhanced user capabilities to model seasonal variation in the future.

Groundwater and surface water interaction downstream of LCC is dynamic and complex. Previous studies of the Nueces River from LCC to Calallen have shown seasonal fluctuations in stream flow, with the highest losses reported during summer months (average 85 percent delivery) and the lowest losses reported in the winter (average 97 percent delivery). Since the focus of this study is the hydraulic connection with the Goliad Sands of the Gulf Coast Aquifer upstream of LCC, the Nueces River reach downstream of LCC is not reported in greater detail.

In 1970, the Texas Water Development Board (TWDB) conducted a water loss study of LCC² which included a mass balance analysis for data collected from 1949 to 1965. TWDB study results showed a high correlation between impounded water in LCC and groundwater levels, which was most clearly observed in groundwater level data before and after enlargement of LCC in April 1958. The study results showed that from 1958 to 1965, a total water loss of 11 percent was calculated for LCC and estimated to have percolated into the Goliad Sands of the Gulf Coast Aquifer. Based on historical data, the majority of this time period was very dry and stored water in LCC was less than 70% capacity from July 1958 through October 1964.

Several water loss studies have been previously conducted for the Nueces River to LCC but the results have been inconclusive. In consideration of TWDB findings, previous studies by HDR included mass balance calculations using data collected from 1948 to 1989 (or 42 years) downstream of the Nueces River at Three Rivers Gage and showed a delivery factor of 74 percent, or water loss of 26 percent, from the Nueces River near Three Rivers to the Wesley

² Texas Water Development Board, "Water-Loss Studies of Lake Corpus Christi, Nueces River Basin, 1949-1965", Report 104, January 1970.

Seale Dam at LCC.³ However, there was uncertainty in estimations of intervening flows for the area downstream of Three Rivers Gage and upstream of LCC. The streamflow delivery factors included in the CCWSM from Three Rivers Gage to LCC were based on results from the TWDB and HDR analyses.

The Frio and Nueces River segments from CCR to LCC's Wesley Seale Dam are hydraulically complex due to stream flow interaction with the underlying alluvial sands of the Gulf Coast Aquifer. In 1992, the USGS conducted a low flow study⁴ between CCR and LCC and found that groundwater movement was toward the Frio and Nueces Rivers. According to the study, "discharge measurements indicate a hydraulic connection that is most active in the reach between CCR and the Nueces River near the Three Rivers Gage." Two low flow events in December 1991 and November 1992 were evaluated as part of the study and net gains were reported of 1.9 percent and 3.6 percent, respectively, between CCR and the Nueces River near Sulfur Creek at Oakville. However, the USGS qualified the results as "not significant" because the error of the discharge measurements was greater than the estimated gains or losses. In December 2000, the USGS installed a gage on the Nueces River at George West (#08210100) which was intended to help provide more accurate estimates of channel losses from the Three Rivers Gage to LCC.

Based on the combined results of studies by the City, USGS, TWDB, and HDR, the channel loss in the 63- mile reach of the Frio and Nueces Rivers downstream of CCR to LCC's Wesley Seale Dam was estimated at about 37.8 percent (for a delivery factor of 62.2 percent) and simulated in the CCWSM accordingly.

1.2 Need for Study and Project Objectives

Since the majority of the surface water supply from the CCR/LCC System for the City and its customers is stored in CCR and delivered to LCC using the natural stream channel, the yield of the system is affected by channel losses. If water could be delivered by a pipeline that bypasses the stream channels, it would not be subjected to these losses and could result in more water in storage and enhance the system yield.

³ City of Corpus Christi, "Updates and Enhancements to Lower Nueces River Basin Bay and Estuary Model and Corpus Christi Water Supply Model," January 2006.

⁴ USGS, "USGS Study of Stream Flow Losses between Choke Canyon Reservoir and Lake Corpus Christi, Nueces River Basin, Texas", December 18, 1992.

The CCR/LCC pipeline was studied in the 2001 and 2006 Plans, however a detailed channel loss analysis was previously unavailable prior to this study to quantify the reduced streamflow in the Frio and Nueces River when delivering water supplies to LCC through the pipeline rather than river channel. The CCR/LCC pipeline is recommended as a water management strategy in the 2006 Plan to provide additional water supplies for the City of Corpus Christi and their customers by Year 2020. Since the 2006 Plan, the CCWSM has been updated to include a CCR/LCC pipeline water delivery option.

A more detailed analysis of the river channel losses from CCR and LCC is necessary to further evaluate the CCR/LCC pipeline as a recommended water management strategy. The primary objective of this study is to evaluate stream flow interaction with alluvial sands of the Gulf Coast Aquifer from CCR and LCC using field measurement data collected as part of this study. Based on the channel loss study results, optimal pipeline routing and capacity for the CCR/LCC pipeline will be considered in addition to conjunctive operation of an off-channel reservoir with CCR/LCC pipeline.

2.0 Description of the Study

A channel loss study of the Frio and Nueces River stream segments from CCR and LCC was conducted from March 3rd to March 28th, 2008. Six strategic locations were identified on the Atascosa, Frio, and Nueces Rivers for field monitoring during the channel loss study to isolate the reach between CCR and LCC for channel loss analysis. Low flow baseline stream flow measurements were collected prior to scheduled, controlled CCR releases from March 5th to March 21st, with final stream flow measurements collected after CCR releases ended as flow restored to baseline conditions. The field measurements were used to calculate a channel loss (and resulting delivery factor) from CCR to LCC based on field survey conditions and to evaluate the potentials of using a CCR/LCC pipeline to deliver water supplies from CCR to LCC rather than delivery using the natural stream channel.

3.0 Methodology and Approach

3.1 Channel Loss Schedule

On February 14, 2008, HDR met with the City, Nueces River Authority, and other interests to discuss the schedule for the channel loss study including weather forecast, current and projected stream flows and reservoir levels, recently recorded USGS gage stream flows, and

other issues for consideration. The USGS gage stations of interest for the channel loss study are shown in Table 3-1, including statistical data considered during development of the field survey and CCR release schedule. At the time of the meeting, the only gages in the study area that reported streamflows greater than the historical median flow for the February and March timeframe were the Nueces River near Tilden (USGS # 08194500) and the Frio River at Tilden (USGS # 08206600) gages. The CCR and LCC water levels were reported on February 14, 2008 at 219.7 ft-msl (97.1 percent capacity) and 93.8 ft-msl (98.4 percent capacity), respectively.

Table 3-1.
Summary of USGS Gage Data Used for Channel Loss Study Schedule

Name	USGS ID	Currently Records Real-Time Data	Active Gage Period	Recorded Streamflow Measurement on 2/13/08 (cfs)	Median February and March Streamflow Over Past 15 Years since 1992(cfs)
Streamflow Stations					
Nueces Rv nr Tilden, TX	08194500	YES	12/1/1942 - Current	66	37
Nueces Rv at Simmons, TX	08194600	NO	4/1/1965 - 10/17/1977	Not Available	Not Available
Frio Rv at Tilden, TX	08206600	YES	7/14/1978 - Current	82	35
Choke Canyon Res OWC nr Three Rivers, TX	08206910	YES	11/19/1991 - Current	29	38
Atascosa Rv at Whitsett, TX	08208000	YES	6/1/1932 - Current	11	11
Nueces Rv nr Three Rivers, TX	08210000	YES	7/1/1915 - Current	102	140
Nueces Rv at George West, TX	08210100	IN PROGRESS	12/13/2000 - Current (Gage Height Only)	Not Available	Not Available

Name	USGS ID	Currently Records Reservoir Stage	Active Gage Period	Recorded Reservoir Stage Measurement on 2/13/08	Stage Level When Full	Percent (%) Full
Reservoir Level Stations						
Choke Canyon Reservoir nr Three Rivers TX	08206900	YES	10/1/1984 - Current	219.7	220.5	97.10%
Lake Corpus Christi nr Mathis TX	08210500	YES	9/1/1948 - Current	93.8	94	98.40%

With LCC nearly full, it was important to consider adequate storage availability in LCC to capture the water released from CCR for the channel loss study. Elevation-area-capacity relationships from the 2002 TWDB Volumetric Survey of LCC were used to determine the amount of storage available in LCC at the following water levels:

- LCC water level at 93.8 ft-msl = 3,643 acft storage available,
- LCC water level at 93.6 ft-msl = 7,272 acft storage available, and
- LCC water level at 93.4 ft-msl = 10,885 acft storage available.

Water supply delivery factors from previous studies (84 percent from CCR to Three Rivers Gage and 74 percent from Three Rivers Gage to LCC) were used to develop five potential

CCR release schedules for the channel loss study as shown in Table 3-2. Previous historic water level trends for LCC were evaluated to estimate water level declines that may be expected during the months of March and April as shown in Figure 3-1. Additional information that was considered in determining the preferred time for the channel loss study, the duration of study and the CCR release schedule is summarized in Appendix A.

Table 3-2.
Alternative CCR Release Schedules Considered Based on LCC Water Levels

Alternative CCR Release Schedules Considered	Release from CCR (acft)	Estimated Delivery To Three Rivers (acft)	Estimated Delivery To LCC (acft)
400 cfs release from CCR for 3 weeks	16,660	13,994	10,356
400 cfs release from CCR for 2 weeks	11,110	9,332	6,906
300 cfs release from CCR for 2 weeks	4,170	3,503	2,592
300 cfs release from CCR for 3 weeks	12,500	10,500	7,770
200 cfs release from CCR for 2 weeks	5,550	4,662	3,450

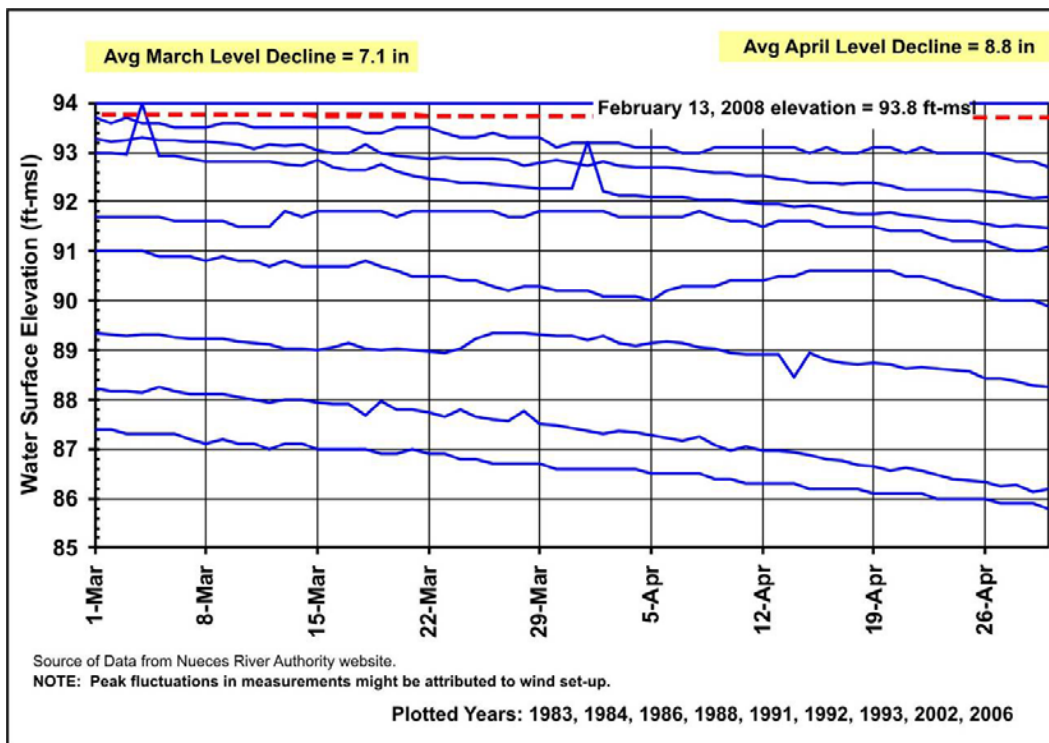


Figure 3-1. Lake Corpus Christi Water Surface Elevations (March-April)

Based on information gathered, it was determined that the channel loss study would commence when LCC water levels were at or below 93.5 ft-msl (0.5 foot below conservation pool elevation) with CCR releases maintained at 300 cfs for a 2 to 3 week period (similar to Alternative 3 or 4 in Table 3-2) based on LCC water levels and weather conditions. During a conference call on February 29th, the City, Nueces River Authority, and City of Three Rivers discussed the CCR release schedule and approved the plan to conduct a channel loss study in early March 2008 contingent on LCC water levels and weather conditions. The City issued a press release on February 29th notifying the Live Oak County area of managed water supply releases for a channel loss study.

3.2 Field Measurement Protocol

Two site reconnaissance trips were conducted to assist in developing the field measurement protocol, identify small contributing tributary inflows and springs that may affect quantities of flow, and determine desirable locations for obtaining measurements for the channel loss study. On February 15, 2008, a small motorized boat used by the Nueces River Authority for sample collection for the TCEQ Clean Rivers Program was launched at the Live Oak County Public Boat Ramp on Airport Road to survey the Nueces River upstream of the City of George West. The boat encountered shallow waters and log jams on the Nueces River about 3 miles downstream of Sulphur Creek making it impossible to reach the Three Rivers Gage by boat. On February 29, 2008, a second field reconnaissance survey of the channel loss study area was conducted by kayak from the Frio River on Hwy 72 near TIPS Park to the Nueces River Live Oak County Public Boat Ramp on Airport Road (about 15 river miles). During the field survey, several challenges were noted that were anticipated to impact data collection including: limited road access, debris and log jams along the Frio and Nueces Rivers, possible impacts of backwater from LCC, and no real-time streamflow monitoring gage between the Three Rivers Gage and LCC.

After evaluating data gathering limitations, the following six strategic measurement locations were identified for collecting flow measurements on the Atascosa, Frio, and Nueces Rivers between CCR and LCC. These locations are shown in Figure 3-2.

- Site # 1: Atascosa River near Good Hope Road;
- Site # 2: Frio River downstream of CCR at end of County Road 401;
- Site # 3: Frio river near TIPS park at Highway 72;

- Site # 4: Nueces River near former USGS gage site at Simmons;
- Site # 5: Nueces River downstream of Sulphur Creek tributary; and
- Site # 6: Nueces River at Live Oak County Public Boat Ramp (Airport Road).

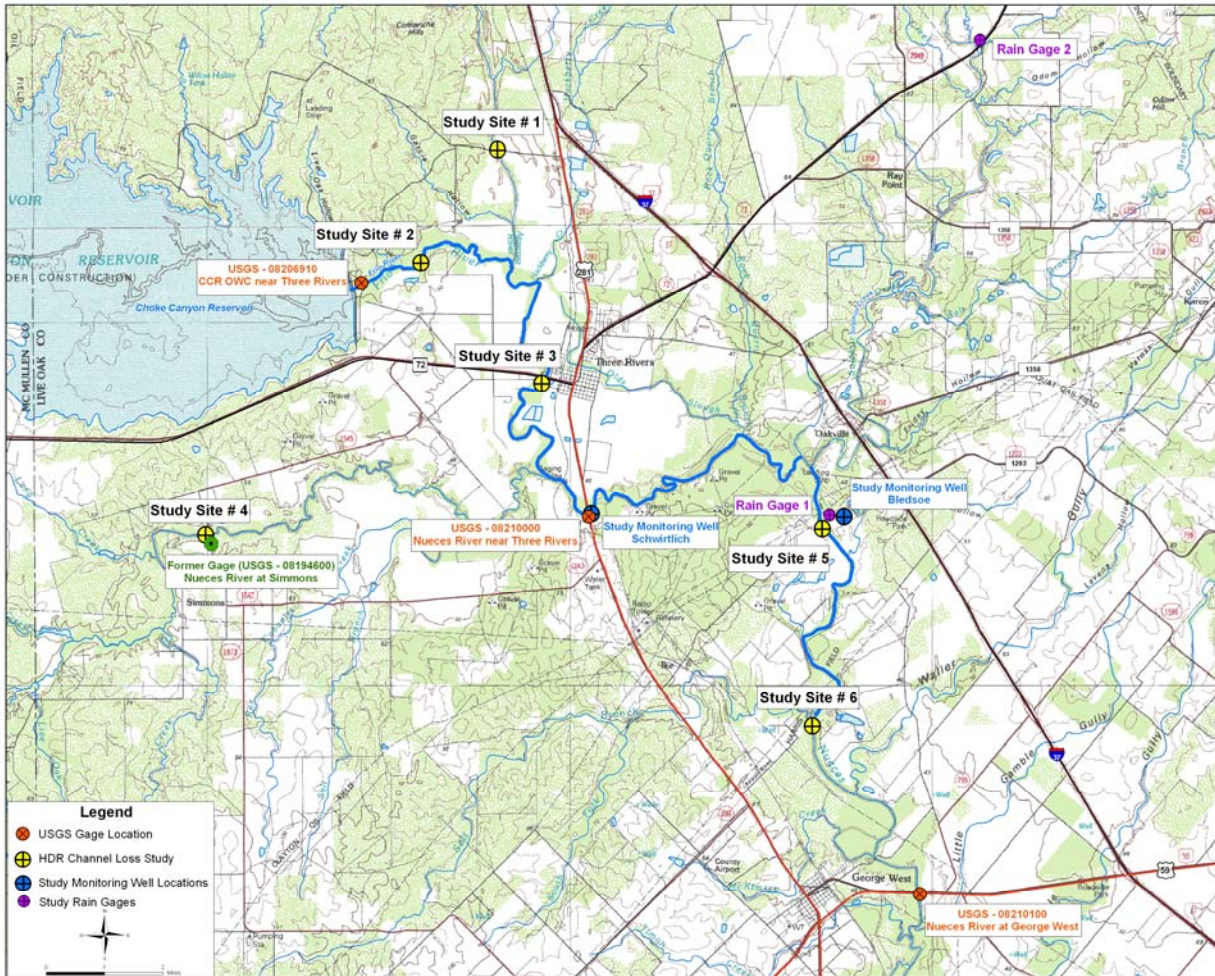


Figure 3-2. Measurement Locations for Channel Loss Study

Based on hydrologic conditions and data collection needs, a preliminary field measurement schedule was established to include at least eight measurements for each study location:

- One low flow (baseline) measurement collected prior to the scheduled, controlled releases from CCR;
- Five measurement events during the CCR releases; and
- Two measurement events after CCR releases end, as streams restore to baseline conditions.

An acoustic Doppler current profiler (ADCP) was used to measure stream flow at five of the six locations. For Site # 1 (Atascosa River near Good Hope Road), a point Doppler velocity meter was used for measuring stream flow since flow conditions were not suitable for the application

of an ADCP. Streamflow velocity was measured at each location following standard USGS practices.

The TWDB, Live Oak Underground Water Conservation District, and the City of Three Rivers were contacted to determine if any wells within 5 miles of the study area were monitored regularly. It did not appear that any wells were monitored regularly in the area. It was determined that accessing local wells for water level measurement during the study would be difficult. Mr. Scott Bledsoe, Co-Chair of the Coastal Bend Regional Water Planning Group, provided access to his personal well near Oakville during this study for obtaining water level measurements. A second well off IH 281 near Three Rivers Gage was monitored from March 20th to March 28th for three measurement events. Access to the second well was provided by Mr. Lonnie Schwirtlich. These two groundwater wells were monitored during measurement events to assist in characterizing groundwater and surface water interaction for the channel loss study.

Two temporary rain gages were installed near the project area and monitored during the study. The USGS Atascosa near Whitsett gage was also monitored to identify nearby rainfall events that may impact study results. A pressure transducer was installed to record river stage in the Nueces River near the Live Oak County Public Boat Ramp on Airport Road.

4.0 Field Data Collection Activities

On March 3, 2008, the LCC water level reached the previously agreed-upon trigger level of 93.5 ft-msl for the channel loss study to commence. As shown in Figure 4-1, LCC had started filling in October 2006 and LCC water levels had been continuously at or above 93.6 ft-msl since June 2007.⁵ Therefore, it was critical that measurements begin promptly.

Low flow (baseline) measurements were collected on March 3rd and March 4th at the six strategic streamflow locations on the Atascosa, Frio, and Nueces Rivers between CCR and LCC (Figure 3-2). Prior to collecting low flow measurements, the USGS serviced their gages located within the study area.

CCR began releasing at 300 cfs at noon on March 5th. Field measurements were collected at each of the six strategic locations for five events from March 7th to March 20th while CCR sustained releases at about 300 cfs. LCC water levels increased to 93.8 ft-msl on March 19th and the City stopped releasing 300 cfs from CCR at noon on March 21st. Prior to ending the CCR releases, it was determined that sufficient data had been collected for the channel loss

⁵ TWDB contracts for Phase I studies for 2011 Plan were signed in May 2007.

analysis. Two follow-up measurement events occurred on March 25th and March 28th at the six locations as stream flows were returning to baseline conditions. Due to local rainfall events near the end of March, the final measurements were collected on March 28th. During the channel loss study, the lowest LCC water level was measured at 93.5 ft-msl (or 96.1% LCC water storage capacity). Channel loss progress reports were prepared and submitted to the City, Nueces River Authority, and the City of Three Rivers during the field survey and are included in Appendix B.

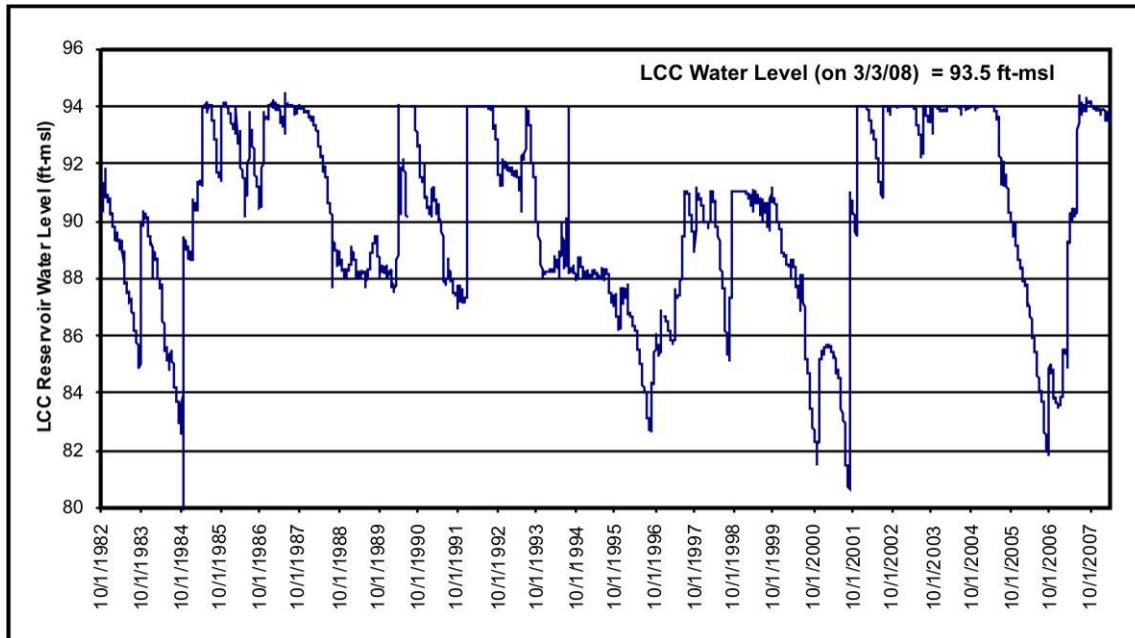


Figure 4-1. Lake Corpus Christi Reservoir Water Levels (October 1982 to March 2008)

5.0 Results of Study

On March 3rd and 4th, low flow (baseline) measurements were recorded and in good agreement with data reported by nearby USGS gages. Baseline measurements were obtained during desirable conditions, with Nueces and Atascosa River streamflows generally at or below median flow conditions and LCC water level at or below 93.5 ft-msl (i.e., ½ foot storage available). After controlled CCR releases of 300 cfs began at noon on March 5th, the USGS gages at CCR OWC near Three Rivers (USGS # 8206910) and Nueces River at Three Rivers (USGS # 8210000) were monitored in real-time fifteen minute intervals to determine the lag time for the first CCR release waters to reach the gage at Three Rivers. As shown in Figure 5-1, it took about eight hours for the released flow to reach the Nueces River at Three Rivers Gage. The Three Rivers Gage recorded increased flow over the next twenty-one hours

before stabilizing about 5:00 pm on March 6, 2008. This delay in stabilizing channel flow is primarily attributable to streamflow interaction with alluvial sands of the Gulf Coast Aquifer, and to a lesser extent the physical obstructions (i.e. log jams) in the Frio River. A discussion of the unique geologic setting impacting channel losses downstream of CCR is presented later in the report.

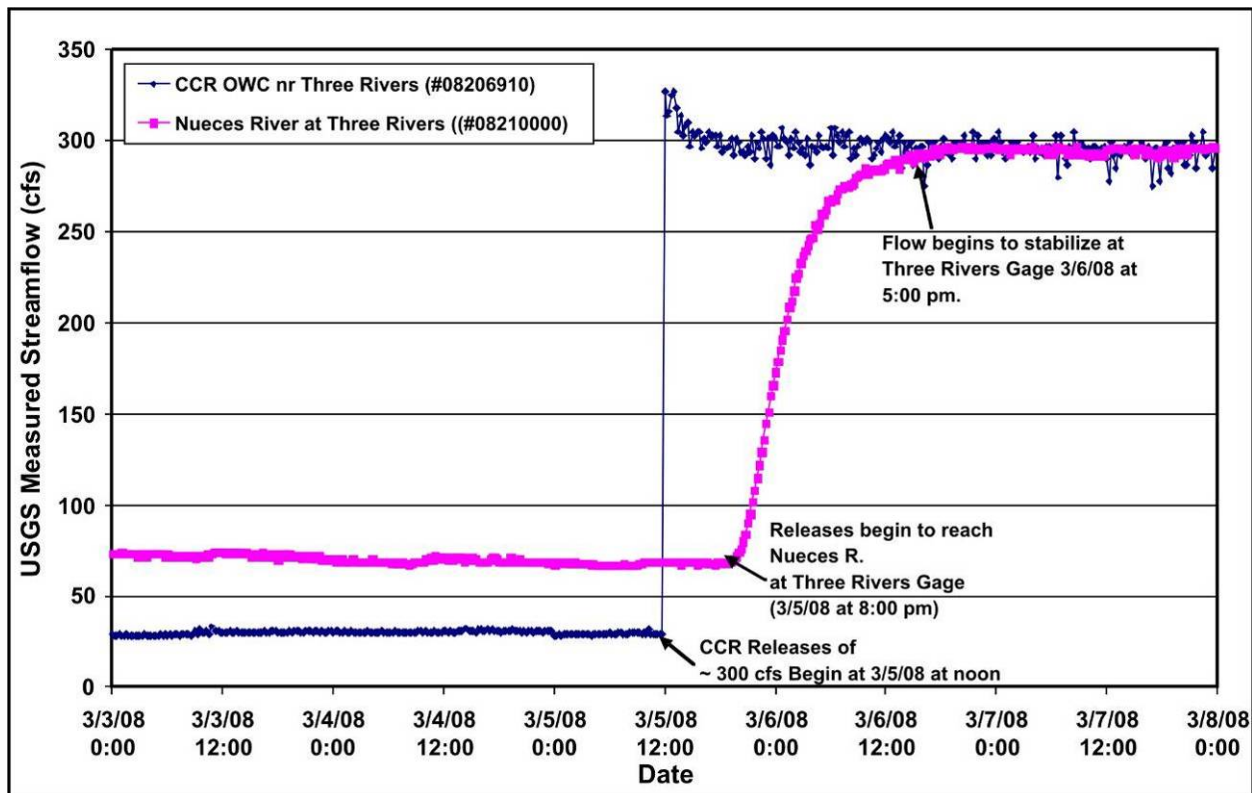


Figure 5-1. USGS Gage Recorded Streamflow (First 5 Days of Channel Loss Study)

From March 7th to March 20th, five measurement events were conducted at the six study sites. After CCR releases ended at noon on March 21st, two measurement events occurred on March 25th and March 28th as streamflows returned to baseline conditions. The streamflow measurements obtained during the channel loss study are shown in Table 5-1. There was good confidence in the results, with less than 5 percent coefficient of variation for most samples collected.⁶

⁶ Due to windy conditions, it was difficult to collect streamflow measurements at Study Site #6 (Nueces River at Live Oak County Public Boat Ramp- Airport Road). Although there was reasonable confidence in results, the coefficient of variation was slightly higher than 5 percent for a couple of measurements.

Table 5-1.
Summary of Streamflow Measurements Obtained During Channel Loss Study

Site #	Baseline (cfs)		During 300 cfs CCR Releases (cfs)					After 300 cfs CCR ended (cfs)	
	3-Mar	4-Mar	7-Mar	8-Mar	12-Mar	15-Mar	20-Mar	25-Mar	28-Mar
1		10.8	12.5	14.2	17.1	15.4	10.6	9.3	9.9
2		29.2	312	315	280	278	276	29.8	31.6
3	33		283	300	310	315	288	39.2	36.8
4		34.2	32.1	32.2	22.2 ^b	18.97	9.8	6.9	11.6
5		83.5	313	340	322	311	303	61.3	50.7
6	89.6 ^a		297 ^a	344 ^a	334	334	326	186 ^a	73

^a very windy, difficult to maintain boat track

^b An instantaneous flow measurement was collected at Nueces River at Highway 281 bridge (near Three Rivers) of 326 cfs and compared to the USGS Three Rivers Gaged flow. The flow indicated in the table was calculated for Nueces River near Simmons gage based on based on flow relationship with Nueces River at Tilden USGS gage.

During the field collection effort, precipitation and groundwater levels were also monitored. On March 6th, the USGS Atascosa near Whitsett Gage (USGS # 8208000) reported 0.24 inches of rainfall and the Nueces River Authority's website reported 0.37 inches of rainfall at CCR and 0.01 inches at LCC. This short-term rain event was monitored and did not appear to have a noticeable impact on streamflows. On March 9th, the USGS Atascosa near Whitsett Gage reported nearly 0.5 inch of rainfall and Nueces River Authority's website reported 0.19 inch at CCR and 0.10 inch at LCC. This rainfall event primarily occurred west and south of the channel loss study. On March 18th, the Nueces River Authority's website reported 0.08 inch of rainfall at CCR and no rainfall at LCC. Overall, about 2/3 of an inch of rainfall was reported at CCR and 1/10 of an inch at LCC during the field collection effort from March 3rd to March 28th. In response to the March 6th precipitation event, two temporary rain gages were installed on March 8th and monitored for the duration of the field study. The first gage (Rain Gage 1) was installed near Site 5 along the Nueces River; and the second gage (Rain Gage 2) near the town of Oaks on Highway 72 to indicate if precipitation from storm events were possibly contributing to runoff to Sulphur Creek. From March 8th to March 28th, only 0.1 inch precipitation was measured at Rain Gage 1 and no precipitation was recorded at Rain Gage 2. Based on the data analysis, it was determined that the small precipitation events in the watershed during the data collection period (March 3rd to March 28th) did not have an overall impact on field measurements.

Groundwater level measurements were collected at a shallow, livestock well about 1/8 mile from the Nueces River near Oakville (Well 2) during the entire data collection period. Water level measurements were collected a second shallow well (Well 1) off Interstate Highway 281 near Three Rivers Gage for three measurement events from March 20th to March 28th. The groundwater level measurements obtained during the study are shown in Table 5-2. The results reported a distinct groundwater and surface water interaction, as indicated by the water level rising about 0.3 foot (or 4 inches) in Well 2 during CCR releases and declining after CCR releases ended. Water levels in Well 1 increased over 1 foot after the CCR releases ended on March 20th, and these groundwater level increases were assumed to sustain past March 28th when measurement collection ended.

Table 5-2.
Summary of Groundwater Level Measurements Collected for Channel Loss Study

	<i>Depth to Water Level (from top of well casing, near land surface) (feet)</i>								
	<i>3-Mar</i>	<i>4-Mar</i>	<i>7-Mar</i>	<i>8-Mar</i>	<i>12-Mar</i>	<i>15-Mar</i>	<i>20-Mar</i>	<i>25-Mar</i>	<i>28-Mar</i>
Well 2		22.08	22.08	22.02	21.98	21.79	22.25	22.13	21.96
Well 1							35.85	36.64	36.91

5.1 Interpretation of Field Data

After field measurements were collected, the data were evaluated to calculate channel losses for the study period from March 3rd to March 28th. Data collected during the eight, individual measurement events were interpolated by study site during the study period when no data were collected to estimate total flow volume at each of the six study sites. For the Three Rivers Gage (USGS # 08210000), real-time and daily streamflow records from the USGS were used to calculate total flow volume during the study period. The estimated total volume by site for the study period from March 3rd to March 28th is shown in Figure 5-2. Graphs that compare actual measurements to interpolated daily flows are presented by study site in Appendix C.

Based on data results, Site 6 (Nueces River at Live Oak County Public Boat Ramp) showed nearly 2,000 acft more water as compared to Site 5 (Nueces River downstream of Sulphur Creek tributary). The average width of the Nueces River at Site 6 was observed during the study to be about 80 feet, with an average depth of 8 to 10 feet in the center of the channel. Real-time stage height data recorded by the pressure transducer on the Nueces River near the

Live Oak County Public Boat Ramp on Airport Road were evaluated with LCC water level data to determine if Site 6 was influenced by LCC water levels. Site 6 is located about 12 miles upstream of the Missouri-Pacific Railroad near the Gussettville Bridge, a location previously identified in the TWDB Volumetric Survey of LCC as the most upstream location of LCC influence. As shown in Figure 5-3, the stage increase at Site 6 during CCR releases from March 5th to March 21st correlates to increases in LCC over the same time period. Due to wind set-up when LCC water level peaks, the stage level at Site 6 is lower as can be expected with water level oscillations caused by wind. Based on these results, it appears Site 6 is influenced by LCC during conditions when LCC water levels are high (i.e. 93.5 ft-msl, or 98% full). Previous estimates by the TWDB had indicated that the most upstream location considered part of LCC was “at a point where the Nueces River meanders closest to the Missouri-Pacific railroad tract”, which based on this study appear to be underestimating the extent of LCC influence.

Due to LCC influence, Site 6 was removed from channel loss calculations. Based on total flows presented in Figure 5-2, the flow contribution from the Atascosa River and Nueces River upstream of the confluence with the Frio River were subtracted from total flow calculations to focus on channel losses associated with the Frio and Nueces reaches from CCR to Site 5 (Nueces River downstream of Sulphur Creek Tributary). A 98 percent delivery factor (or 2 percent channel loss) was observed from CCR to Site 2 (Nueces River near TIPS Park), with an overall 87 percent delivery rate (or 13 percent channel loss) from CCR to the Three Rivers Gage. These data agree closely with the City’s previously estimated 84 percent delivery factor from CCR to Three Rivers.^{7,8}

From the Three Rivers Gage to Site 5 (a distance of 7.4 river miles), the data indicate between an 11 percent and 13 percent gain in stream flow. As shown in Figure 5-4, a unique geological feature of the Gulf Coast Aquifer system impacts Nueces River streamflow near the Three Rivers Gage. The Fleming Formation and Oakville Sandstone (shown in dark purple and green) formations of the Miocene and Pliocene Era are primarily composed of clay and sandstone. Overlaying this formation are Fluvial terrace deposits (shown in orange) and

⁷ HDR, “Updates and Enhancements to Lower Nueces River Basin Bay and Estuary Model and Corpus Christi Water Supply Model”, January 2006.

⁸ The March 2008 channel loss survey results reported an 87 percent delivery factor as compared to an 84 percent average delivery factor. This is less than a 4 percent difference, which might be attributable to seasonal differences as discussed in the Model Update report (January 2006).

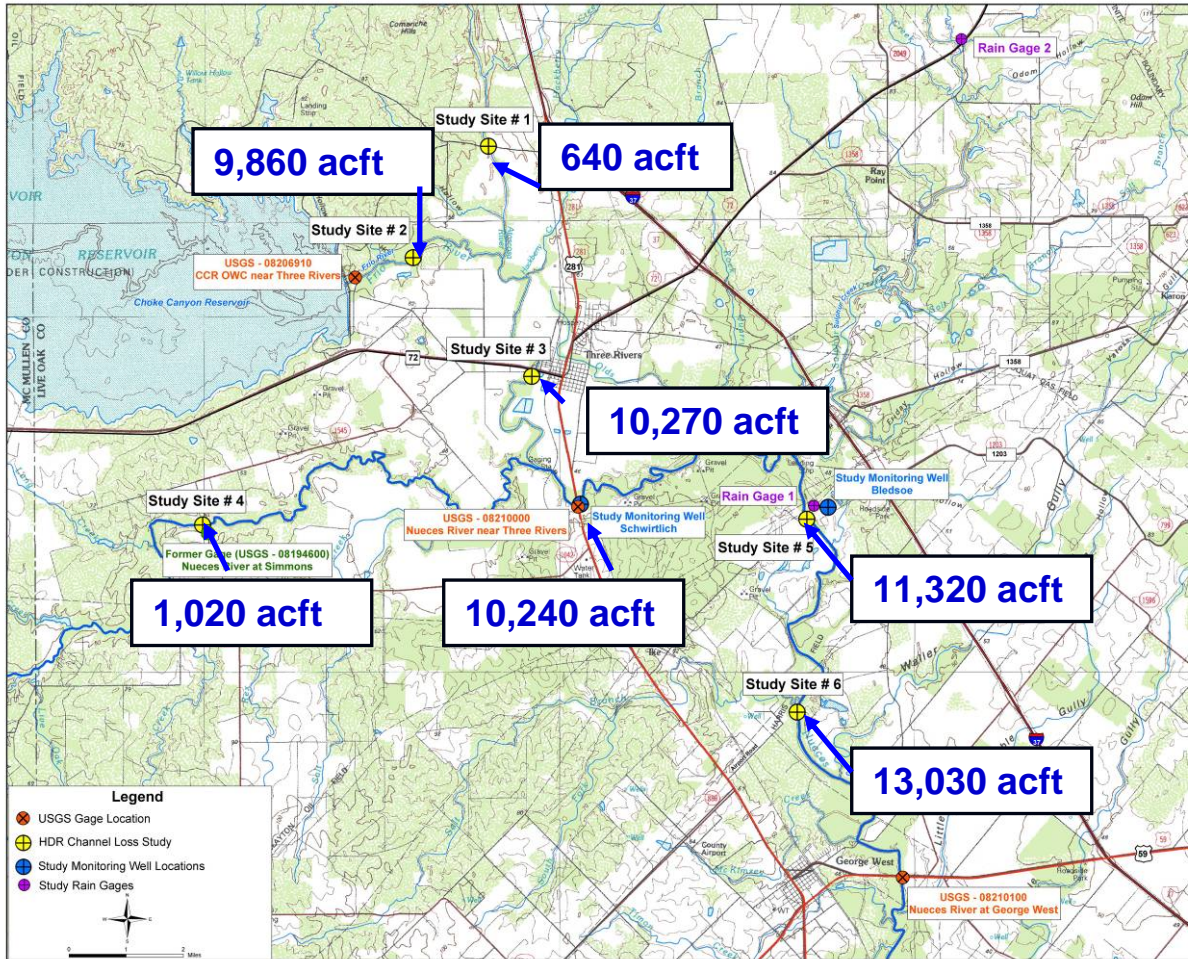


Figure 5-2. Estimated Flow Volume During Channel Loss Study (March 3 – 28, 2008)

Alluvium (shown in yellow) of the more recent, Holocene Era consisting primarily of gravel, sand, silt, clay, and floodplain deposits. These younger geologic formations impact water movement downstream in two ways: (1) part of the streamflow traveling from CCR towards the Three Rivers Gage becomes underflow in the alluvium system which results in a temporary loss from the stream (i.e. channel losses from CCR toward the Three Rivers Gage), and (2) the alluvium system pinches out downstream of the Three Rivers Gage and the streamflow lost to underflow rejoins the Nueces River after the confluence with Sulphur Creek.

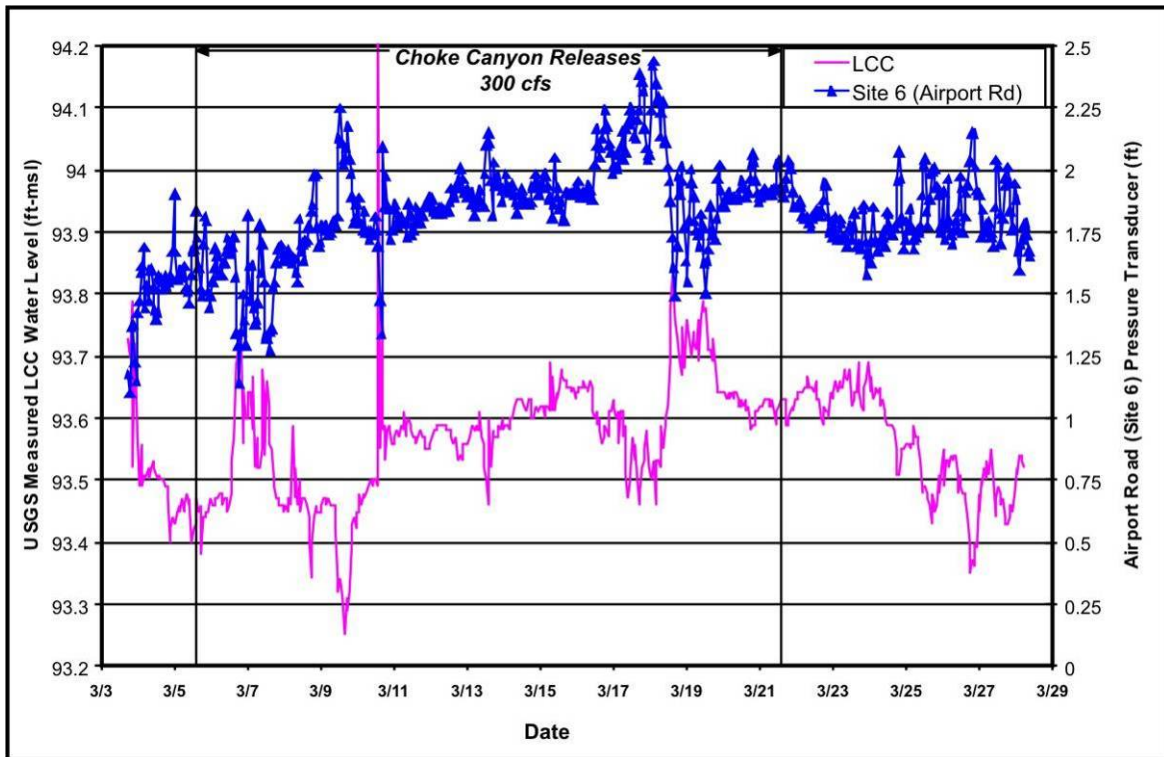


Figure 5-3. Comparison of Water Levels at Study Site # 6 (Airport Road) and LCC

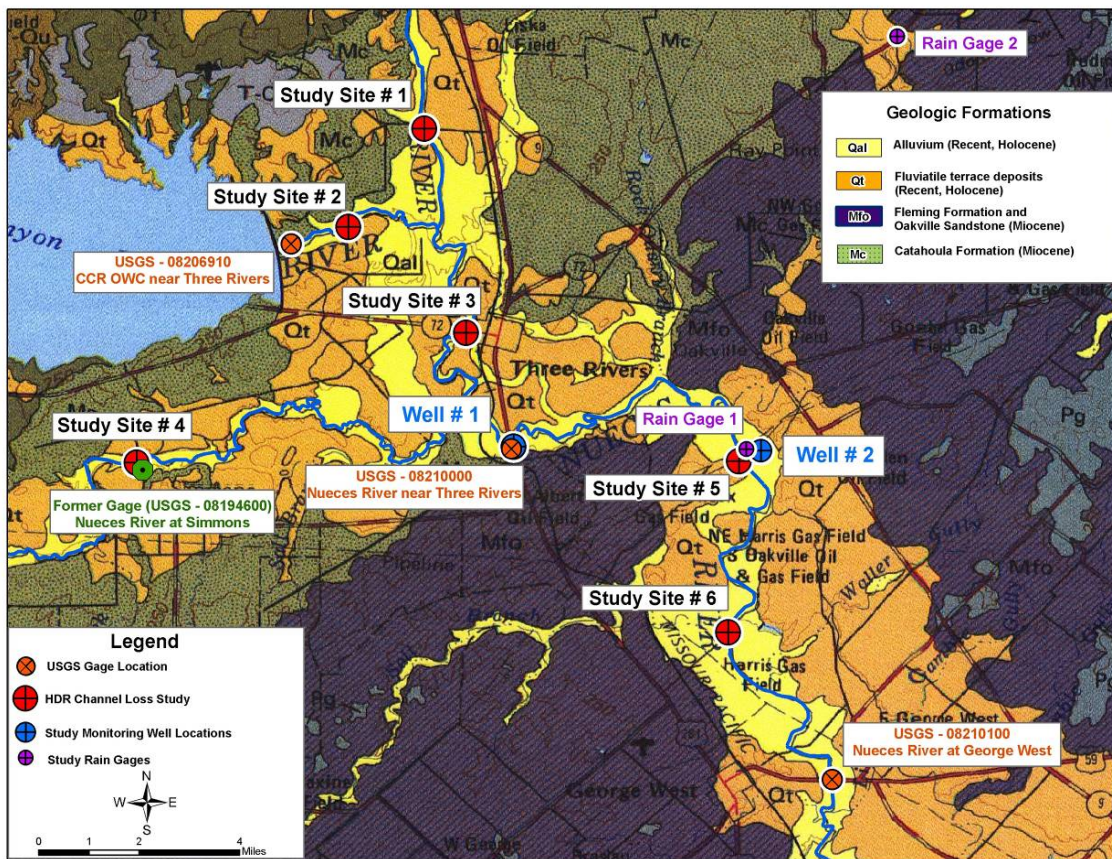


Figure 5-4. Geologic Map of Study Area (source: Bureau of Economic Geology, 1976)

5.2 Calculations of Delivery Factors and Channel Losses between CCR and LCC Based on Channel Loss Study Results

Based on this study, an overall channel loss was estimated to be between 2 and 3 percent for the 17.4 river mile stretch from CCR to the Nueces River near Sulphur Creek as shown in Table 5-3. This is significantly less than results from previous studies which estimated channel losses from CCR to LCC over a distance of about 63 river miles at about 37.8 percent (a delivery factor of 62.2 percent), or a loss of 0.6 percent per river mile. Based on the results from previous studies, a channel loss around 10.4% would have been expected for the reach from CCR to the Nueces River near Sulphur Creek (i.e. 17.4 river miles times 0.6 percent per river mile). The 45.6 river mile segment downstream of the Nueces River near Sulphur Creek to LCC's Wesley Seale Dam was not characterized during this study due to the influence of water stored in LCC.

Table 5-3.
Calculated Channel Loss Based on Flow Volumes during Flow Study
(March 3 – 28)

Study Site Locations	Total Volume of Flow from March 3 - 28 (acft), Calculated by Interpolating Field Measurements		
Site 1	640		
Site 2	9,860		
Site 3	10,270		
Site 4	1,020		
Three Rivers Gage (USGS)	10,240		
Site 5	11,320		
Site 6	13,030		

Calculated Losses	Total Volume of Flow from March 3 - 28 (acft), Calculated by Interpolating Field Measurements	Delivery Factor (%)	Channel Loss (%)
Site 3 (i.e. Site 3 - Site 1)	9,630	97.7%	2.3%
Three Rivers (i.e. Three Rivers - Site 1 - Site 4)	8,580	87.0%	13.0%
Site 5 (i.e. Site 5 - Site 1 - Site 4)	9,660	98.0%	2.0%

The differences in the channel loss results as compared to previous studies are attributed primarily to the geological setting and hydrologic conditions discussed earlier. The groundwater and surface water interaction downstream of CCR to LCC is very complex and could vary significantly based on seasonal events, antecedent drought or wet conditions and prolonged drought or wet conditions that could impact storage in LCC. As shown earlier in Figure 4-1, LCC was full or nearly full from 2002 to 2005 and began depleting from May 2005 to September 2006.

LCC began filling again in September 2006 and has been full since June 2007. When LCC is full (conservation pool elevation of 94 ft-msl) or nearly full, the alluvium system influenced by LCC stores water which would be expected to result in less channel losses from the Three Rivers Gage to LCC. Furthermore, after prolonged drought periods there would be less water stored in LCC and it would be expected that the alluvium system will act somewhat like a sponge and absorb streamflow traveling down the Nueces River towards LCC, resulting in higher channel losses.

During the channel loss study, it was determined that a larger portion of the Nueces River is under the influence of LCC water levels than previously thought, specifically during times when LCC is nearly full. The channel loss monitoring site on the Nueces River near Airport Road (Site 6) appeared to be influenced by LCC water levels which is located about 12 miles upstream of the Missouri-Pacific Railroad near the Gussettville Bridge, a location previously identified in the TWDB Volumetric Survey of LCC as the most upstream location of LCC influence. The measurement study location at Site 6 was not included in the channel loss analysis. All channel loss study results were based on flows from CCR to Site 5 (Nueces River downstream of Sulphur Creek Tributary).

The CCWSM includes channel losses that are used to calculate surface water availability for the CCR/LCC/Lake Texana system and currently reflects the results of previous studies showing 37.8 percent loss (a delivery factor of 62.2 percent) from CCR to LCC. It is important to appropriately simulate channel losses in the model since adjustments to these modeled parameters may have substantial impacts to simulated water supply availability. The results of the channel loss study were considered to determine if any model updates are warranted. Since previous studies were based on analysis of long-term data, it was determined that updates should not be made at this time. Data collected during the channel loss study may not represent long-term conditions since the data was collected during wet weather conditions and may not be appropriate for evaluating and assessing the feasibility of the CCR/LCC pipeline strategy. The channel loss study successfully provides a “snapshot” of groundwater and surface water interaction between CCR and LCC, and this information could be used to extend mass balance analyses for a longer period of record to update the CCWSM model code in the future. Additional studies are needed to justify changing the delivery factors used in the CCWSM as further described in Section 7.0.

6.0 Impact of Channel Loss Results on CCR/LCC Pipeline Water Management Strategy

The 2006 Plan showed an estimated firm yield supply of 39,500 acft/yr in Year 2060 attributable to operating a CCR/LCC pipeline project at a 300 cfs delivery rate. This increase in the yield of the CCR/LCC system was attributed to a pipeline eliminating losses now incurred by transporting CCR releases to LCC via natural river channels. Based on cost estimates, the annual cost of raw water was expected to be \$222 per acft (second quarter 2002 U.S. Dollars). The annual cost of raw water is \$310 per acft when updated to second quarter 2007 U.S. Dollars.

The firm yield supply in the 2006 Plan was based on delivery factors included in the CCWSM. If delivery factors from the recent channel loss study were used, then the benefits of a CCR/LCC pipeline would be significantly reduced because the pipeline would be eliminating substantially smaller losses. The channel loss study was conducted when LCC reservoir was nearly full and during a fairly wet hydrologic cycle and therefore, would not be representative of drought conditions used to calculate firm yield. As stated earlier, the channel loss simulated in the CCWSM for the 63.3-mile reach of the Frio and Nueces Rivers downstream of CCR to LCC's Wesley Seale Dam is 37.8 percent (for a delivery factor of 62.2 percent), or 0.6 percent per river mile. The channel loss study estimated the overall channel loss to be between 2 and 3 percent from CCR to the Nueces River near Sulphur Creek, which is about 1/10 of the channel losses from previous studies. Based on the results from previous studies, a channel loss around 10.4% would have been expected for this reach (i.e. 17.4 river miles times 0.6 percent per river mile). If an additional firm yield supply with CCR/LCC pipeline was 1/10 the supply shown in the 2006 Plan, then an annual raw water cost of \$3,103 per acft would be expected. However, the channel loss study was conducted when LCC reservoir was nearly full and during a fairly wet hydrologic cycle and therefore, would not be representative of drought conditions used to calculate firm yield. Data collected during the channel loss study in March 2008 may not represent long-term conditions since the data was collected during wet weather conditions and may not be appropriate for evaluating and assessing modifications or benefits of the CCR/LCC pipeline strategy.

7.0 Summary and Recommendations

The channel loss study results confirmed the previous USGS findings that “hydraulic connection is most active in the reach between CCR and Nueces River near Three Rivers” and corroborated HDR’s previous study results of an 84 percent delivery factor from CCR to the Nueces River at Three Rivers^{9,10}. The channel loss study suggests that impounded waters from LCC influence streamflow further upstream on the Nueces River segment than previously identified, up to at least the Nueces River near Airport Road (a few river miles upstream of the George West Gage). Regarding channel losses, the preliminary results suggest an overall loss of 2 to 3 percent from CCR to Site 5 near Oakville (Nueces River downstream of Sulphur Creek tributary). It is important to note that the study did not characterize the river segment from Nueces River near Sulphur Creek to LCC due to backwater influence and it is anticipated that significant losses can occur in the 45.6 mile river segment from Nueces River near Oakville to Wesley Seale Dam.

Based on the channel loss study results, the geologic setting and surface water interaction with groundwater systems downstream of CCR to LCC is very complex and could vary significantly based on seasonal events, antecedent drought or wet conditions prior to release, and prolonged drought or wet conditions that could impact drainage and storage in LCC. The CCWSM currently reflects an overall channel loss of 37.8 percent from CCR to LCC (84 percent delivery factor from CCR to Three Rivers Gage and 74 percent delivery factor from Three Rivers Gage to LCC) based on previous studies. Since the CCR to Three Rivers Gage has a well-characterized delivery rate of 84 percent, additional effort is needed primarily to characterize the segment from Three Rivers to LCC. The model could then be updated to simulate multiple channel loss amounts based on hydrologic conditions, which may be necessary due to likely seasonal variability and the complexities of groundwater and surface water interaction associated with LCC.

In an attempt to provide a better understanding of channel loss trends and weather-related variations, future follow-up work should include an additional mass balance analysis of the most recent 20 years of hydrologic data (1989 to 2008) to extend the long-term mass balance analysis

⁹ HDR, “Updates and Enhancements to Lower Nueces River Basin Bay and Estuary Model and Corpus Christi Water Supply Model”, January 2006.

¹⁰ The March 2008 channel loss survey results reported an 87 percent delivery factor as compared to 84 percent average delivery factor, which is less than 4 percent difference which could be attributable to seasonal differences as discussed in the Model Update report.

from 1948 to 2008 (or 61 years) which would be useful in further characterizing the channel losses from CCR to LCC.

8.0 Texas Water Development Board Report Formalities

This report was prepared in accordance with the approved Scope of Work pursuant to TWDB Contract No. 0704830699. A portion of the contract scope from Exhibit C related to Task B- Optimization of Pipeline Capacity and Location Towards Project Implementation was not evaluated based on the initial findings of the channel loss study. Upon determining that this task was not needed, the TWDB was notified and the amount previously allocated to this task (\$8,800) was not spent or billed. The following tasks were not performed: (1) series of model runs for up to three pumping rates, (2) preliminary cost estimates for a range of pipeline sizes to optimize size, (3) associated figures to compare the volume of water sent through the pipeline, changes in streamflow downstream of CCR, increase in water supply, and impacts to the Nueces Bay and Estuary; and (4) topographic maps to identify a suitable location for CCR/LCC pipeline; and model run operating the CCR/LCC pipeline conjunctively with the off-channel reservoir.

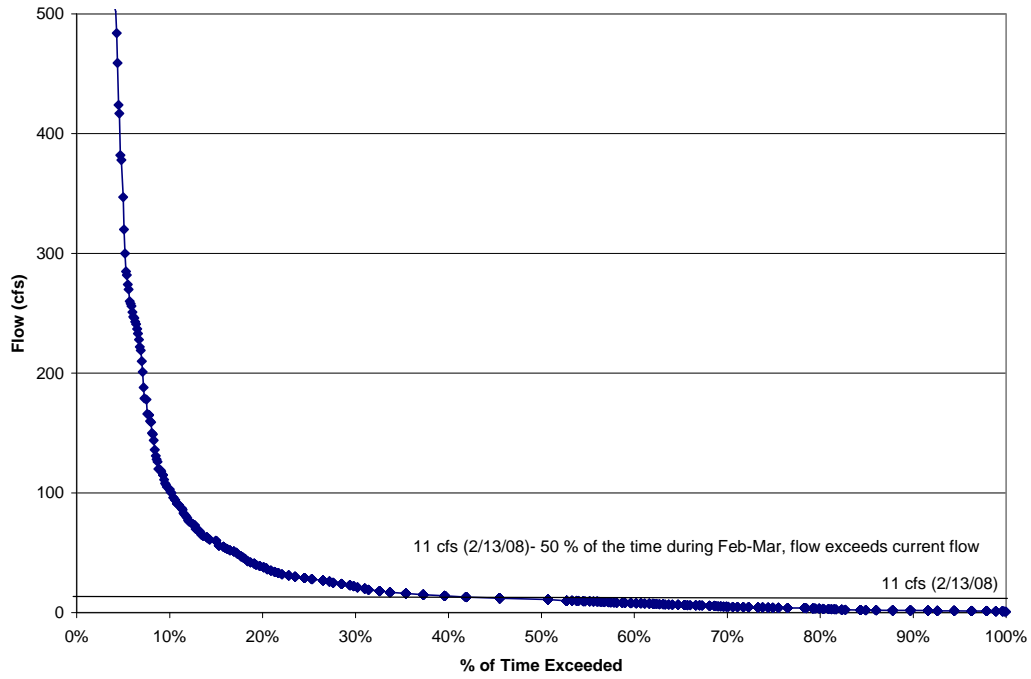
The preliminary draft report was posted in November 2008 on the Nueces River Authority website for Regional Water Planning Group and public comment. All draft report comments were addressed. The draft report was approved by the Coastal Bend RWPG on November 13, 2008 and submitted to the TWDB on December 23, 2008.

The TWDB provided comments on the draft report in March 2009. The Coastal Bend RWPG approved responses to the TWDB comments on March 12, 2009. A copy of TWDB comments on the draft study report and written summary of how the final report addresses these comments is provided in Appendix D.

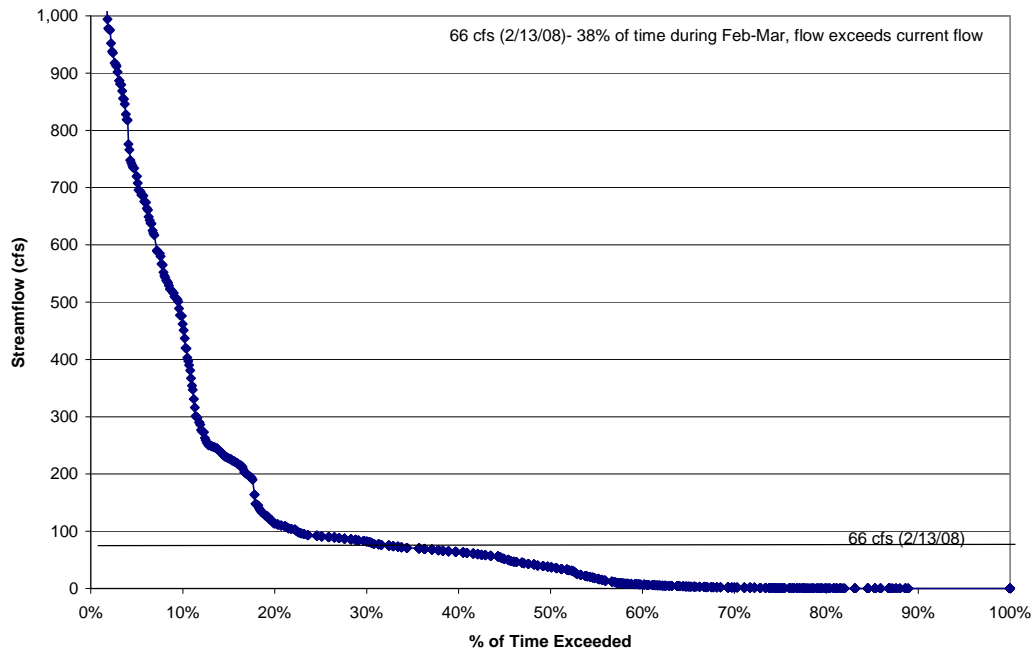
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Appendix A
Information Considered in Determining Channel Loss
and CCR Release Schedule

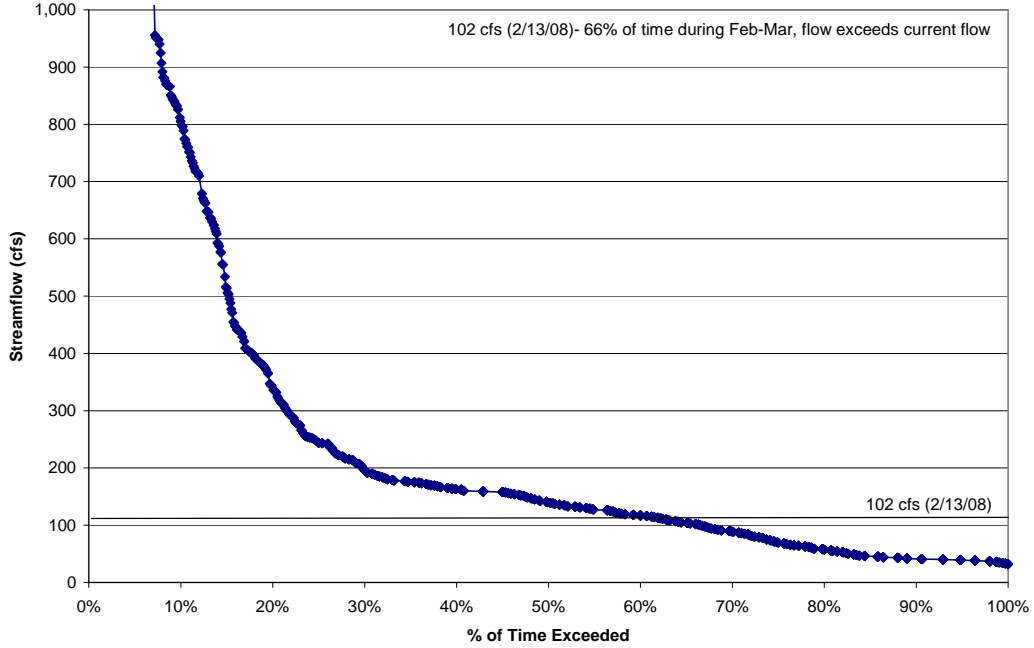
Frequency Distribution of Streamflow at Atascosa River at Whitsett (USGS Gage 08208000)
For FEB - MAR (1992- 2008)



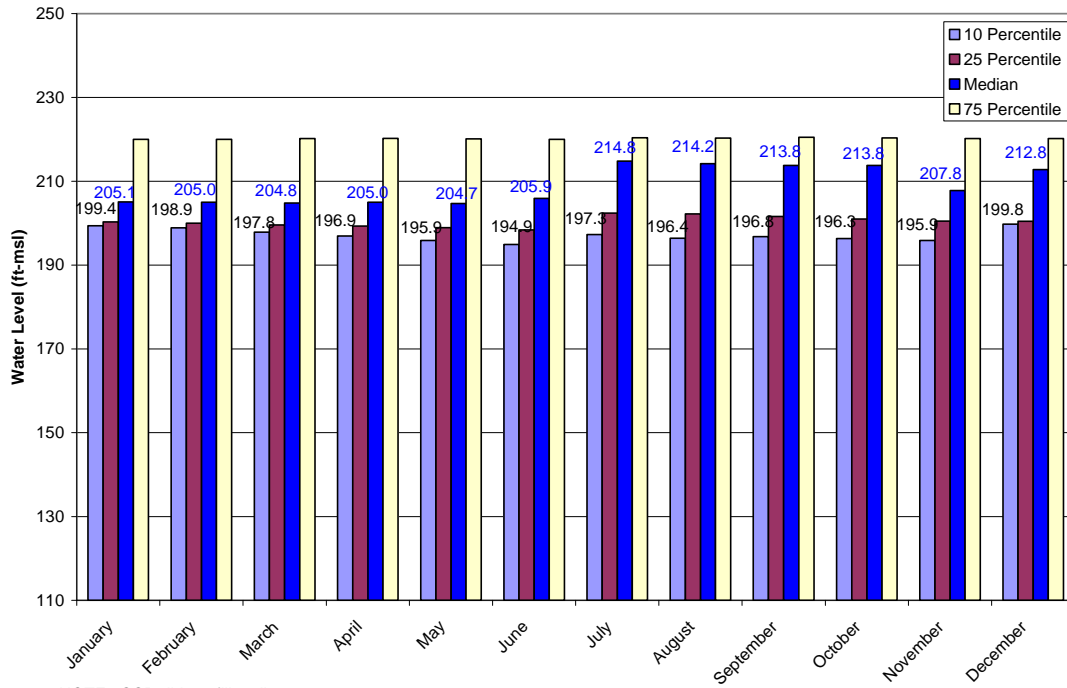
Frequency Distribution of Streamflow at Nueces River nr Tilden (USGS Gage 08194500)
For FEB - MAR (1992- 2008)



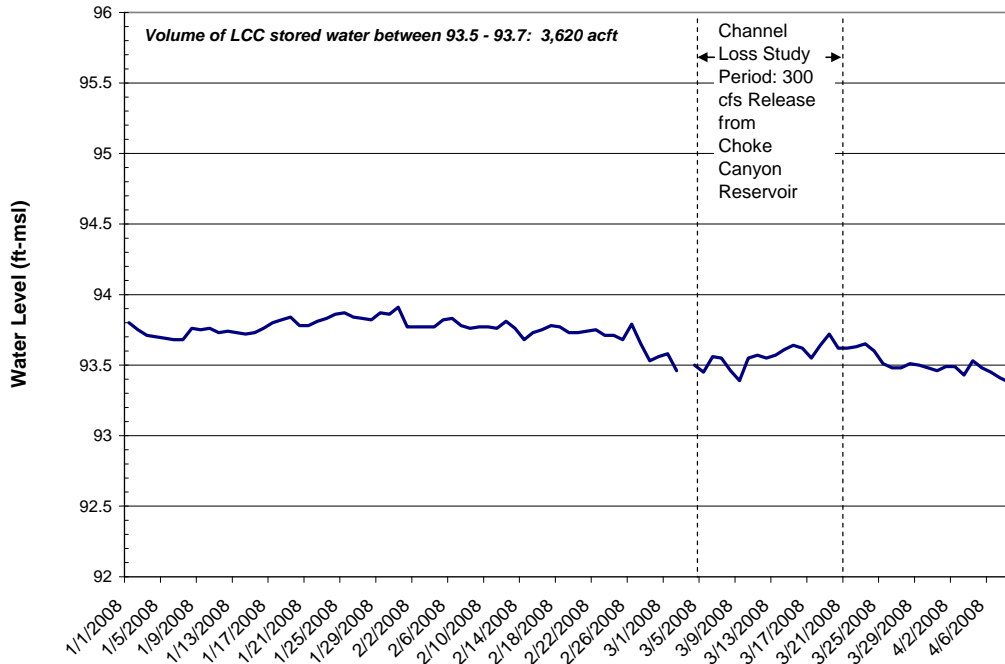
**Frequency Distribution of Streamflow at Nueces River nr Three Rivers (USGS Gage 08210000)
For FEB - MAR (1992- 2008)**



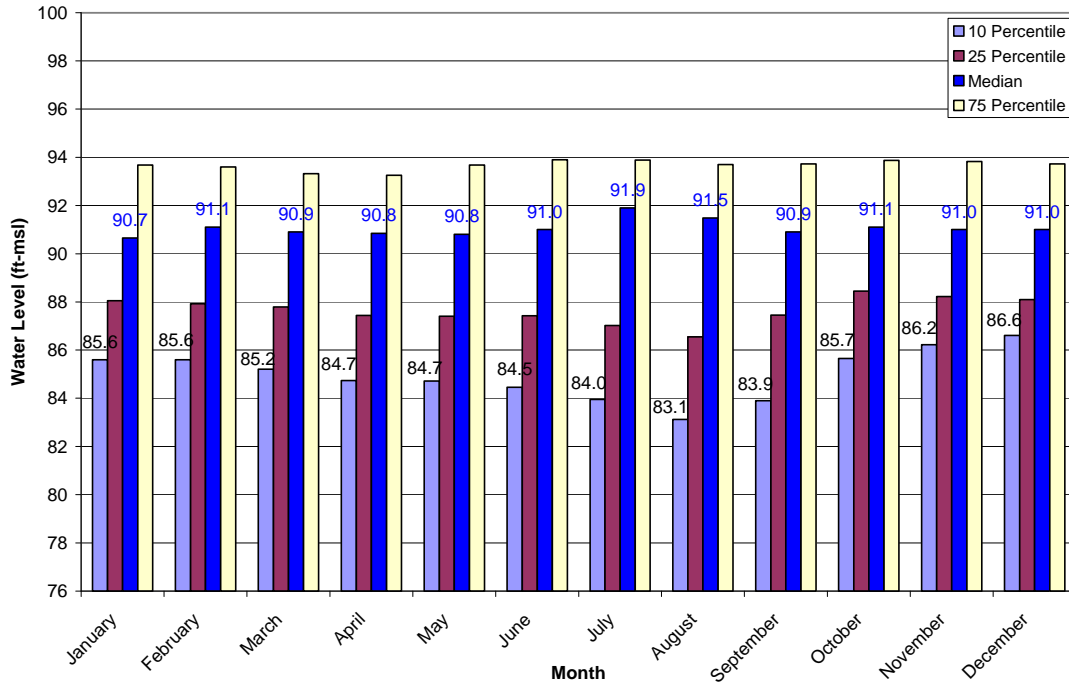
**Summary Statistics for Choke Canyon Reservoir Water Levels (ft-msl)
for Timeperiod from 1987 to 2008**



LCC Historical Water Levels



Summary Statistics for Lake Corpus Christi Water Levels (ft-msl) for Timeperiod from 1959 to 2008



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Appendix B
Progress Reports of Channel Loss Studies

Coastal Bend Regional Water Planning Group Channel Loss Study Progress Report # 1 (for Activities from March 3-March 11, 2008)

General Status: CCR began releases at noon on March 5th at 300 cfs. Since the study began, USGS gages have been serviced, and three measurement events have occurred on the Frio and Nueces Rivers within the Channel Loss Study area. We are in the process of interpreting the first three streamflow measurement events, which will be provided in a later progress report. The project is going well and is on-schedule according to plan. There have been a couple of minor rainfall events in the area (March 6th and March 10th), which are not anticipated to significantly impact streamflow in the study area. Channel losses are anticipated to continue until noon on March 26th. A total of nine measurement events are scheduled to occur during this study at six strategic locations (as described below). USGS gage flow records through March 11th are provided as an Attachment.

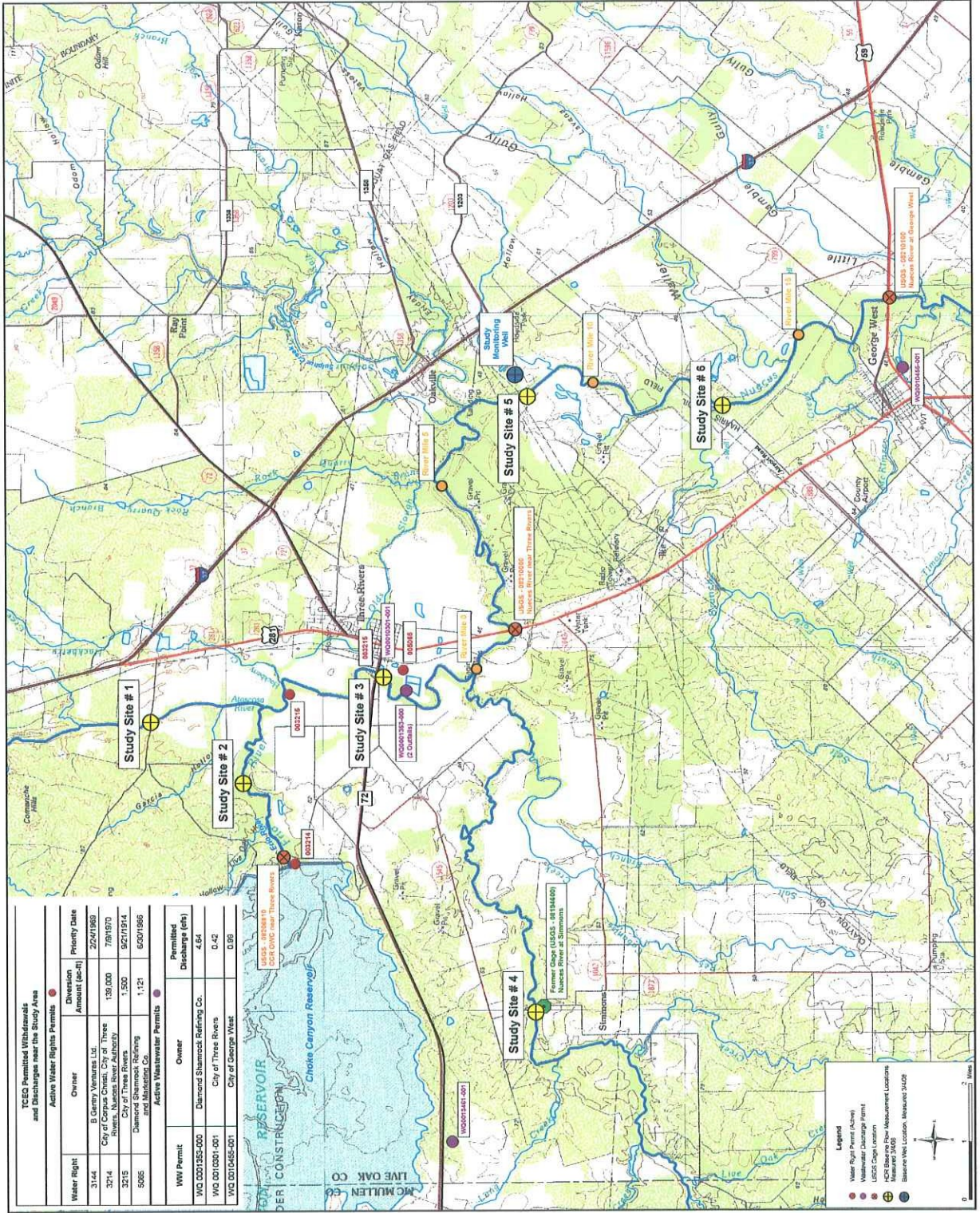
Baseline Activities Prior to CCR Releases (March 3rd and 4th)

The USGS serviced the following gages and obtained discharge measurements. These are in agreement with real-time streamflow measurements:

Gage Description	Gage ID	Date	Time	Instantaneous Streamflow (cfs)
Nueces River at Tilden	8194500	3/3/08	2:25 pm	31.5
Choke Canyon Reservoir OWC	8206910	3/3/08	9:15 am	30.4
Atascosa River nr Whitsett	8208000	3/3/08	4:15 pm	8.63
Nueces River nr Three Rivers	8210000	3/3/08	11:25 am	78.3
		3/4/08	8:45 am	72.8

A pressure transducer to record stage height was installed near Live Oak County Public Boat Ramp on Airport Road. Baseline streamflow measurements were collected at 6 (six) strategic streamflow locations in the study area (shown on Map) as well as baseline groundwater level reading obtained near Oakville:

- (a) Study Site # 1: on Atascosa River near Good Hope Road
- (b) Study Site # 2: on Frio River downstream of CCR at end of CR 401
- (c) Study Site # 3: on Frio River near TIPS park at Hwy 72
- (d) Study Site #4: Nueces River near former USGS Gage Site at Simmons
- (e) Study Site #5: Nueces River downstream of Sulphur Creek tributary
- (f) Study Site #6: Nueces River at Live Oak County Public Boat Ramp (Airport Rd)



TCEQ Permitted Withdrawals and Discharges near the Study Area

Active Water Rights Permits		
Water Right	Owner	Priority Date
3144	B. Glenn Ventures LP	2/24/1995
3214	City of Three Rivers	7/9/1970
3215	City of Three Rivers	9/27/1914
5085	Diamond Shamrock Refining and Marketing Co.	5/30/1995

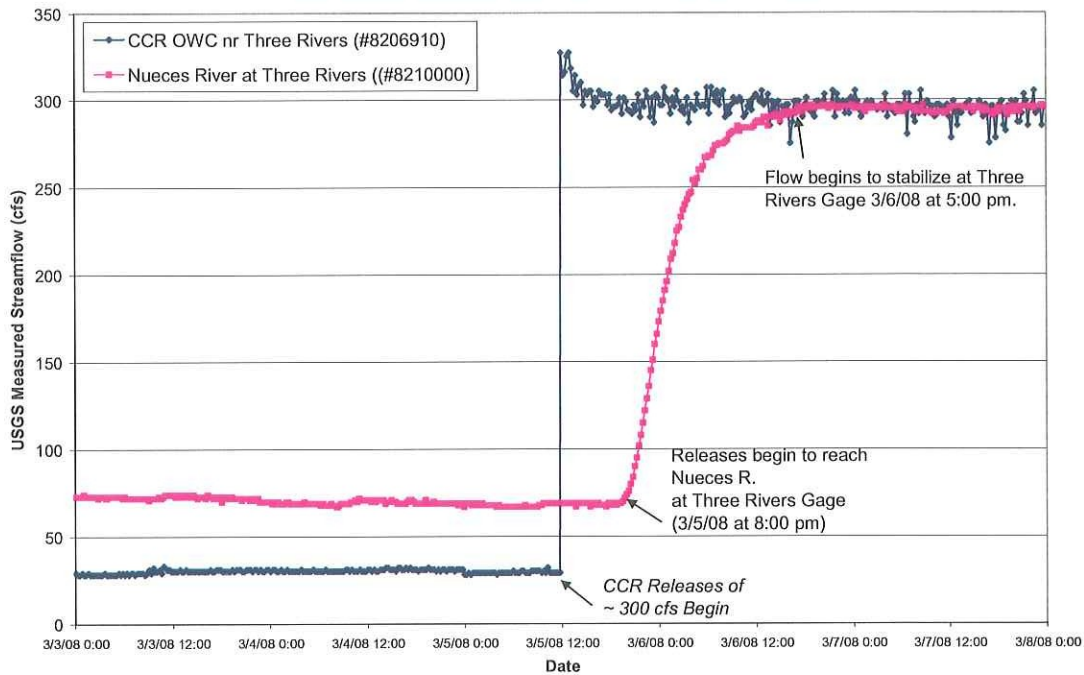
Active Wastewater Permits		
WW Permit	Owner	Permitted Discharge (cfs)
WQ 0011585-000	Diamond Shamrock Refining Co.	4.64
WQ 0010301-001	City of Three Rivers	0.42
WQ 0010485-001	City of George West	0.99

CCR Releases and Short-Term Minor Precipitation Event (March 5th and March 6th)

CCR releases of 300 cfs began at noon on March 5th. Afterwards, it took approximately 8 hours for released flow to reach the Three Rivers USGS Gage. The Nueces River at Three Rivers experienced increased flow over the next 21 hours, before stabilizing at 5:00 pm on March 6th.

On March 6th, the USGS Atascosa near Whitsett gage reported ¼ inch of rainfall, and Choke Canyon Reservoir reported 0.37 inch of rainfall. This rainfall is expected to significantly influence streamflows in study area. Upon completion of the survey, National Climate Data Center hourly and daily precipitation will be compiled, as available, and consulted when interpreting streamflow measurement results and channel losses.

USGS Gage Recorded Streamflow (March 3 - Mar 8, 2008)



First Two Active Channel Loss Study Measurement Events (March 7th and March 8th)

Two streamflow measurement events occurred (one per day) for all six strategic locations in study area, where baseline measurements were obtained on March 4th (see map above). The USGS Gage on the Nueces River at Mathis (downstream of Lake Corpus Christi) reported elevated streamflow levels of 168 cfs and 235 cfs on March 6th and 7th, respectively. The City informed us that windy conditions over Lake Corpus Christi caused water to be pushed over the dam, and intentional releases were not made during those days.

Recent Conditions (March 9th through March 11th)

On March 9th, the USGS Atascosa near Whitsett gage reported nearly ½ inch of rainfall, and Choke Canyon Reservoir reported 0.2 inch of rainfall. The storm appeared to move towards the northeast.

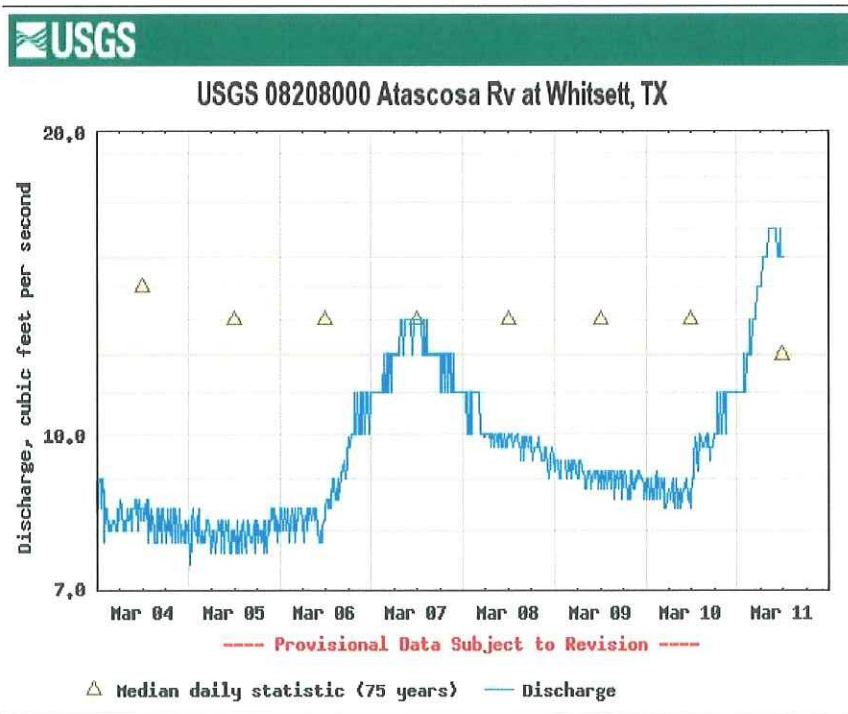
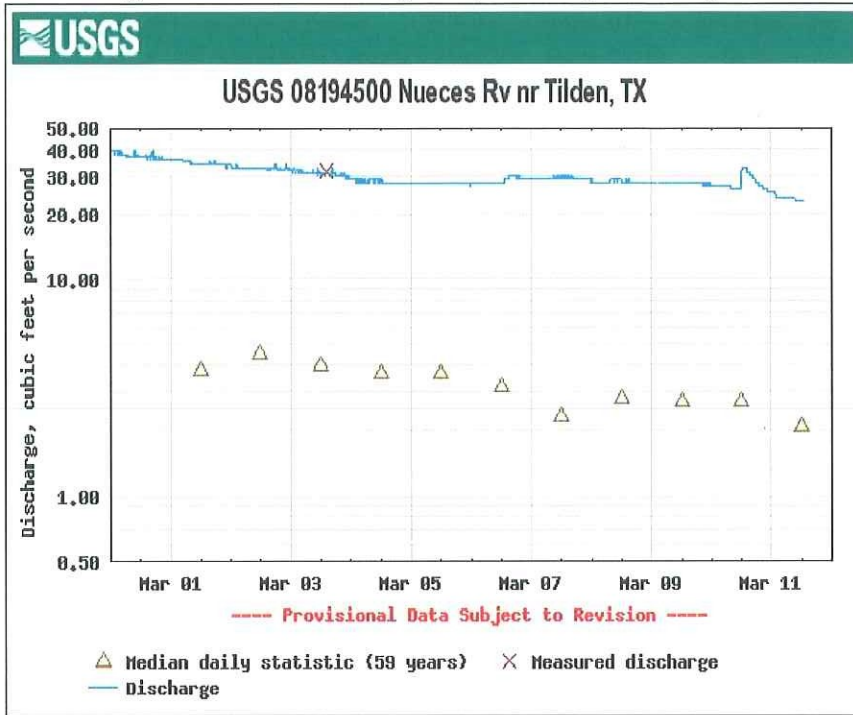
Next Streamflow Measurement Events Scheduled to Occur March 12th and March 15th

During the streamflow measurement event scheduled March 12th, a drive-by visit to Rock Quarry Branch, Sulphur Creek, and Sand Hollow will be conducted to determine if active flood waters are present (or have occurred recently) which will be considered when interpreting streamflow measurements on the Nueces River.

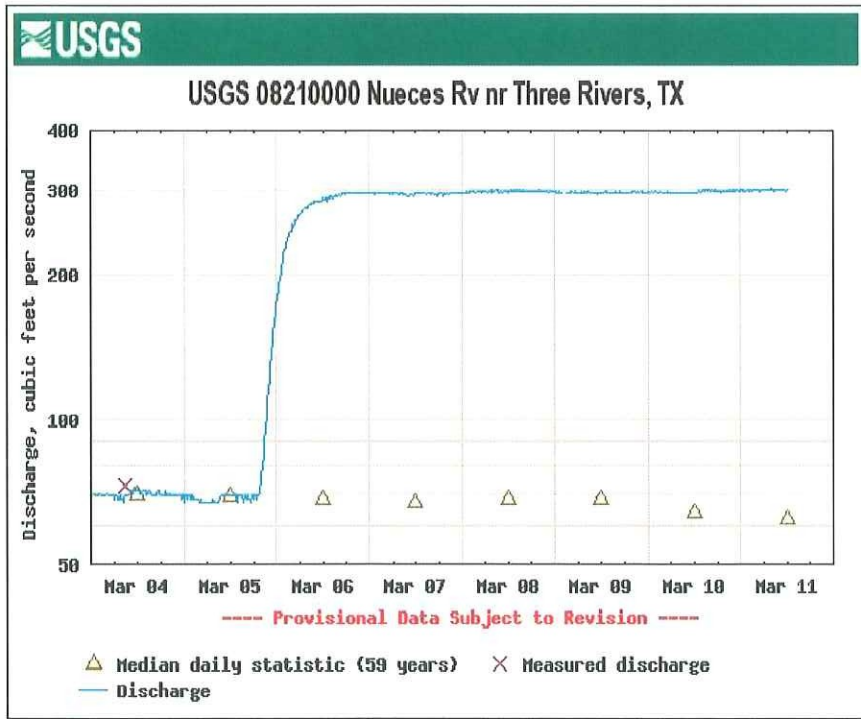
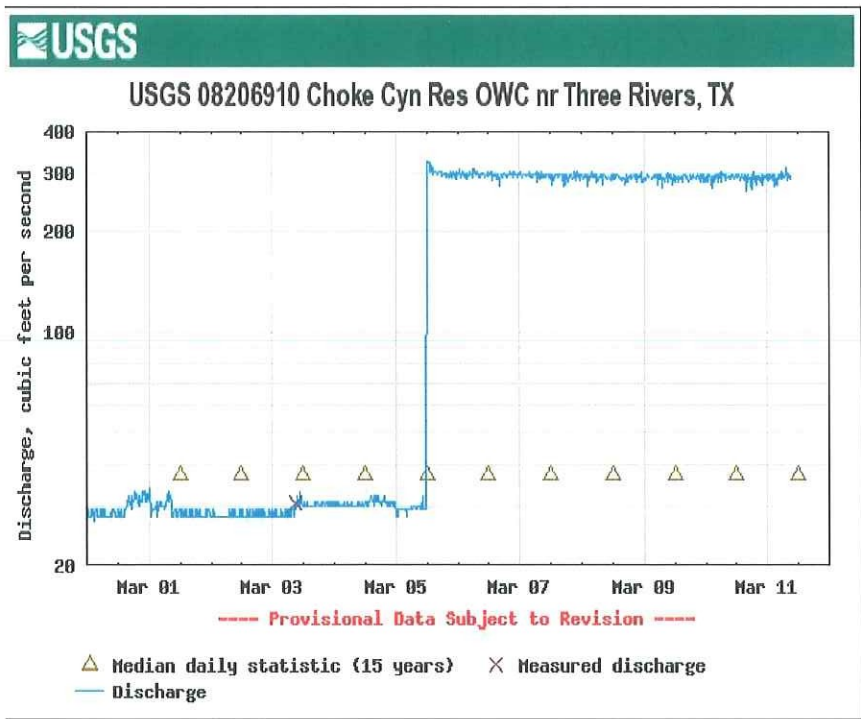
The weather forecast for the next few days looks good, with a 20% chance of precipitation on Thursday, March 13th.

ATTACHMENT

USGS Gages Monitored During Study, and Upstream of Channel Loss Study Area



USGS Gages Monitored During Study, and Within Channel Loss Study Area



Coastal Bend Regional Water Planning Group Channel Loss Study **Progress Report # 2 (for Activities through March 19, 2008)**

General Status: Controlled releases from Choke Canyon Reservoir have been maintained around 300 cfs, since noon on March 5th, 2008. There has been minor, intermittent rainfall in the Channel Loss Study area and 0.1 inch of rainfall was recorded at CCR on March 13, 2008. However, there has been significant rainfall and high winds near Lake Corpus Christi (LCC) with 0.3 ft increase in LCC water level occurring on March 18th. LCC water level as of March 19th is 93.8 ft-msl. Due to the increase in LCC water level, the channel loss study and release schedule will be modified.

Considering the recent increase in LCC water level, HDR proposes that releases from CCR continue at 300 cfs through Friday March 21st at noon to allow another round of measurements on March 20th, and that CCR releases end on March 21st at noon.

To date, five measurements have been collected at each of the six locations, which include one baseline event prior to high flow releases from CCR (collected March 4th) and four events since CCR began releasing at 300 cfs. After releases are returned to normal conditions (30 cfs), additional measurements at the six study locations will be collected for two events.

Preliminary Results

CCR to Nueces River near Three Rivers

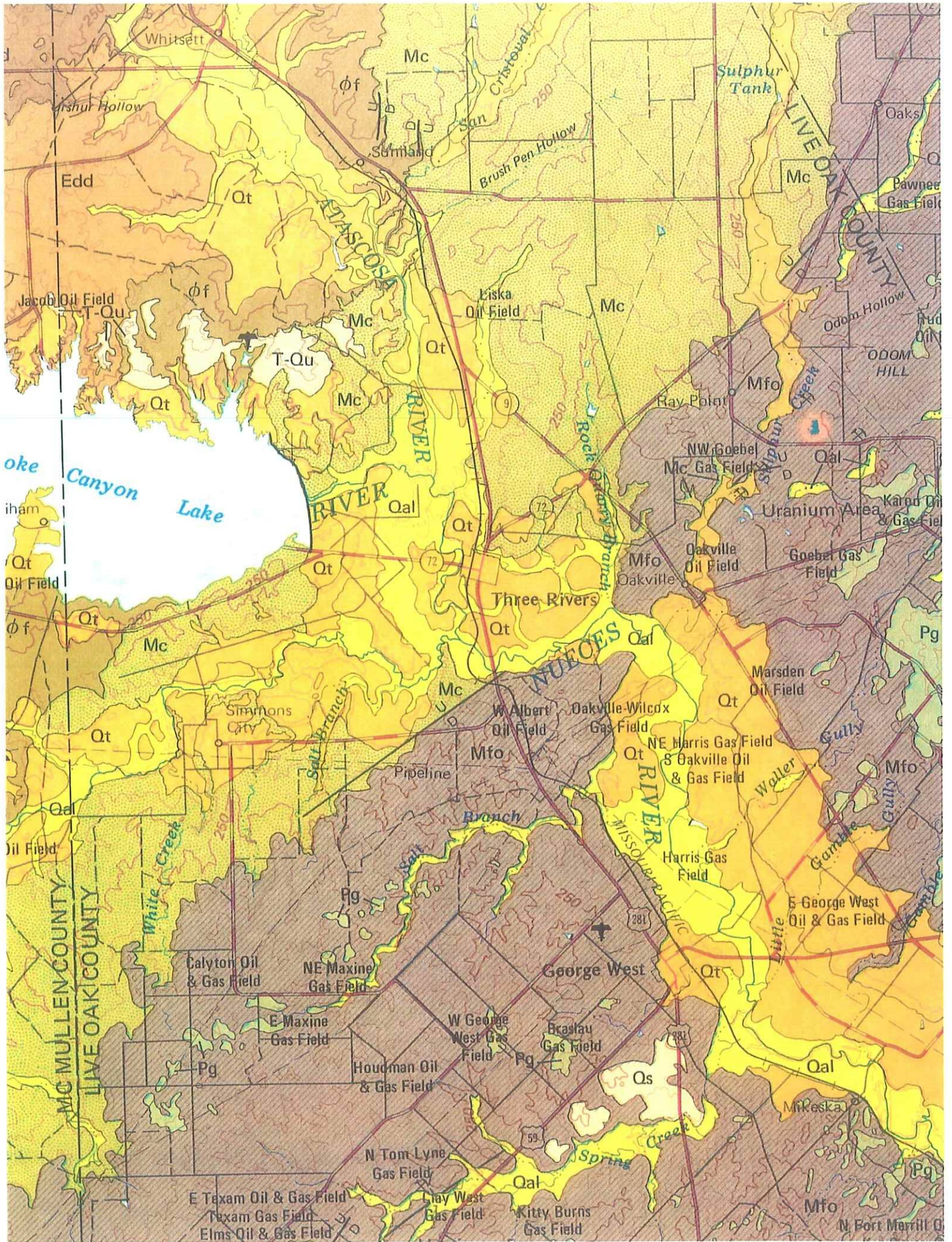
Based on the streamflow measurements collected at the six study locations on the Frio and Nueces Rivers (except for one location on the Atascosa River near Good Hope Road), the estimated channel losses from CCR to the Nueces River near Three Rivers during low flow conditions (prior to CCR releases of 300 cfs) were estimated at about 12% and during high flow conditions the channel losses declined and ranged between 5 and 9.5%. The Frio River with CCR releases at 300 cfs comprises about 90% of the flow at Three Rivers with the remaining 10% contributed from the Nueces and Atascosa Rivers. Considering seasonal weather conditions, the results are consistent with previous results for the river segment between CCR and Nueces River near Three Rivers which indicated channel losses around 14%.

Nueces River near Three Rivers to Airport Road

The Nueces River channel from Three Rivers to Airport Road appears to be gaining streamflow most of the time. The estimated channel gains from the Nueces River near Three Rivers during low flow conditions (prior to CCR releases of 300 cfs) were about 17% and during high flow conditions ranged between 9 and 18%. The high variability in gains is primarily attributable to the local geology (See Map- Next Page) which consists of a large sandy alluvium near Three Rivers (yellow and orange) pinched by the Fleming Formation and Oakville Sandstone (brown) near where Rock Quarry Branch joins the Nueces River. Essentially, a portion of the streamflow from CCR to the Nueces River near Three Rivers is lost from the channel to the alluvium shallow aquifer system, bypasses the Three Rivers Gage at Hwy 281, and travels northeast before re-joining the Nueces River near Oakville. A groundwater well located near Nueces River and Sulphur Creek has reported a water level increase of +0.3 ft since the beginning of the study.

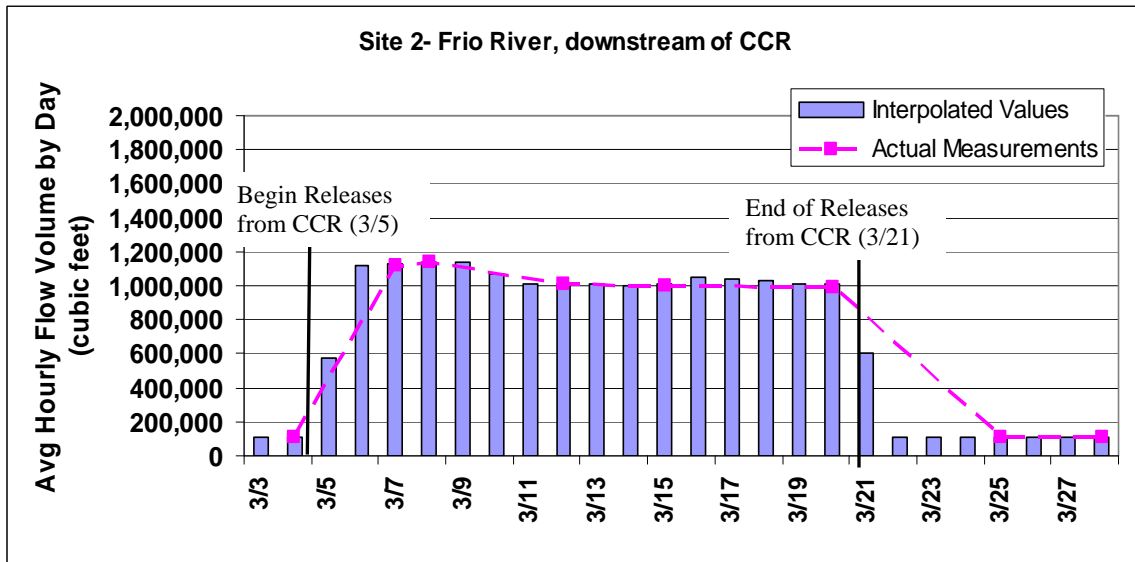
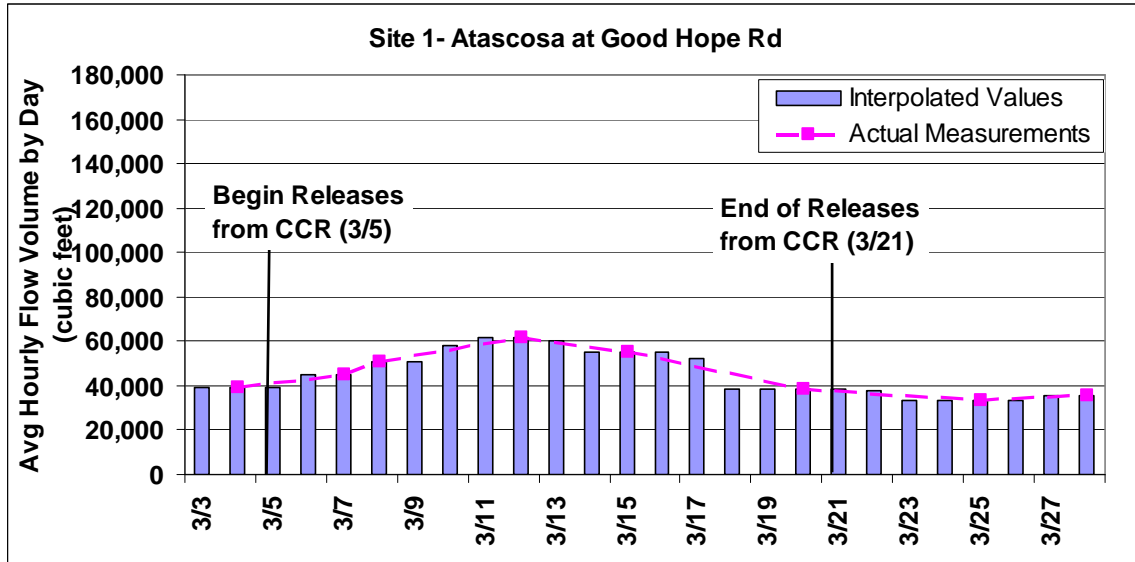
Overall Results from CCR to Nueces River at Airport Road

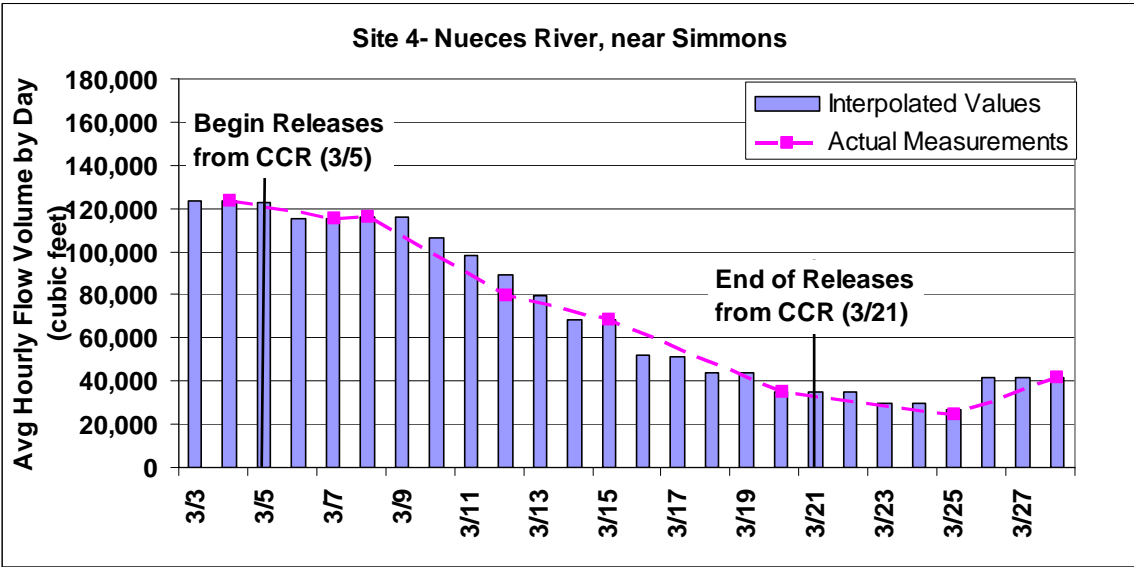
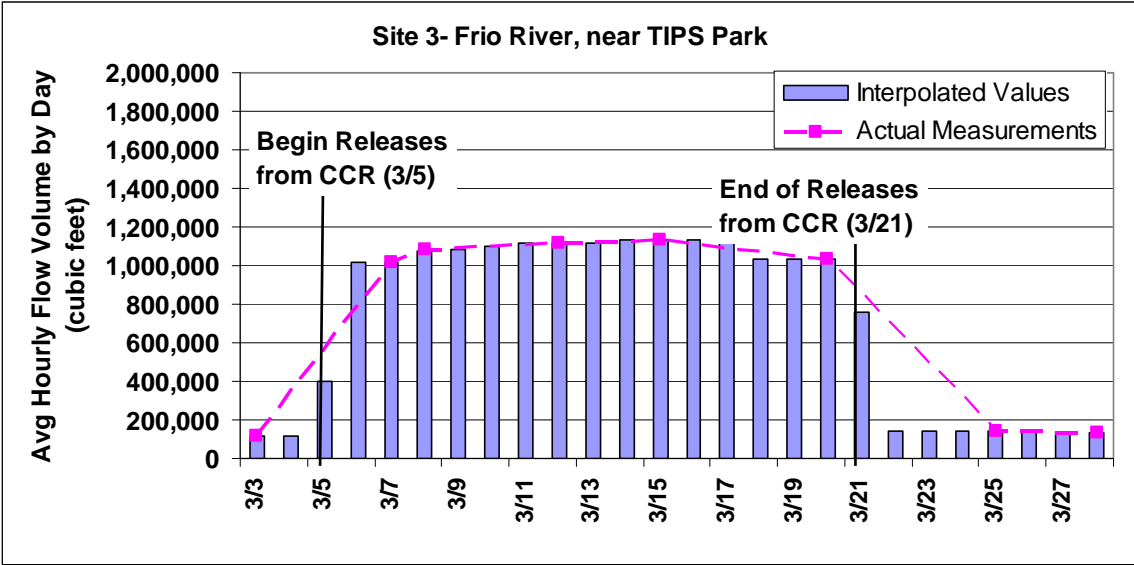
The streamflow channel from CCR to Nueces River at Airport Road gains and loses streamflow and results show an overall increase of as much as 4% and a maximum loss of 8 %.

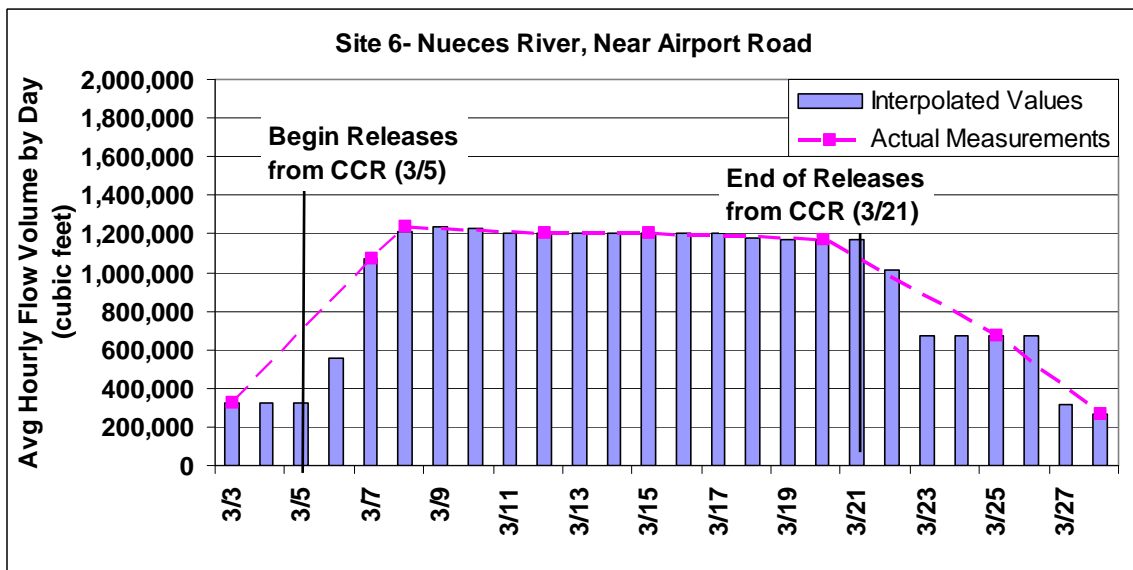
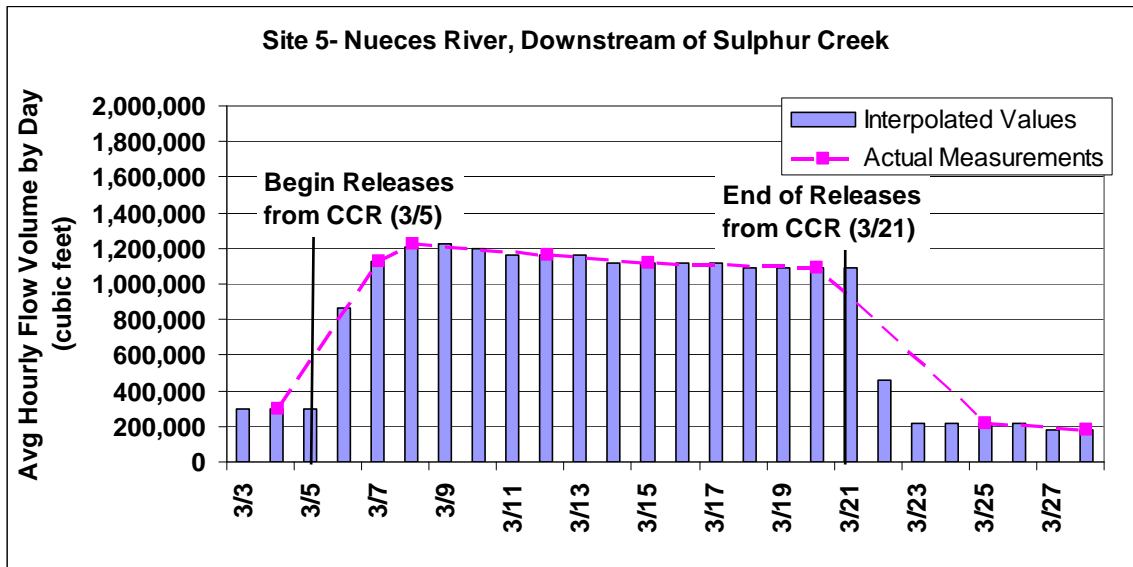


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Appendix C
Data Processing of Streamflow Measurements to
Interpolate Flow Values to Calculate Flow Volume of
Channel Loss Study at Each Study Site







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Appendix D
TWDB Comments and Summary of
Coastal Bend RWPG Responses

TWDB Contract No. 0704830699

Region N, Region-Specific Study 3:

TWDB Comments on Draft Final Region-Specific Study Reports:

3) Implementation Analysis for Pipeline from CCR to LCC, Including Channel Loss Study Downstream of Choke Canyon Reservoir

Region-Specific Study 3: Implementation Analysis for Pipeline from CCR to LCC, Including Channel Loss Study Downstream of Choke Canyon Reservoir

1. Page ES-1: Executive summary does not clearly explain: the reason(s) that the measured stream losses were significantly lower than previous estimates; or, what likely role geologic formations may have played in previous attempts to estimate channel losses.

Response: This information is presented in the main body of the report in Sections 5.1 and 5.2. The executive summary was revised to include a summary of this information, as requested.

2. Page ES-1: Executive summary does not quantitatively describe the impact of the study's conclusion on the estimated yield of the CCR/LCC pipeline as it was recommended in the 2006 Region N Water Plan. Please describe, quantitatively, the potential impact that the report's conclusion may have on the expected yield and unit cost of the previously recommended water management strategy.

Response: This information is presented in the main body of the report in Section 6.0. The executive summary was revised to include a summary of this information, as requested. As stated in the executive summary and Section 6: "Data collected during the channel loss study in March 2008 may not represent long-term conditions since the data was collected during wet weather conditions and may not be appropriate for evaluating and assessing modifications or benefits of the CCR/LCC pipeline strategy."

3. Page 19: The report states that "additional effort is needed primarily to characterize the segment from Three Rivers to LCC." Please further justify this conclusion and elaborate in greater detail in light of the study contract Scope of Work Task A, bullet four, which states that: "Upon completion of this channel loss survey and favorable channel sampling conditions, the referenced reach between CCR and LCC should require no further future channel loss studies by the TWDB" and which was specifically scoped to preclude the need for any further study of the river reach between CCR and LCC.

Response: At the time of scope development, we were unable to anticipate the duration and impact of wet hydrologic conditions that preceded the channel loss study as discussed in the report. Although we were able to get good field measurements during the study, the preceding wet period and high LCC water levels during the study were not considered "favorable channel sampling conditions", included as a qualifier in the referenced statement from the Scope of Work Task A. The study concluded that "the complex geologic setting and surface water interaction with groundwater systems downstream of CCR to LCC could vary significantly based on seasonal events,

antecedent drought or wet conditions prior to release, and prolonged drought or wet conditions that could impact drainage and storage in LCC.” Prior to any channel loss adjustments to the Corpus Christi Water Supply Model, additional channel loss studies are needed to justify changes in delivery factors (if necessary) since adjustments to these modeled parameters may have substantial impacts to simulated water supply availability. Section 7.0 of the report states: “Since the CCR to Three Rivers Gage has a well-characterized delivery rate of 84 percent, additional effort is needed primarily to characterize the segment from Three Rivers to LCC.”

Section 7.0 was revised to more clearly state a recommendation for follow-up work: “In an attempt to provide a better understanding of channel loss trends and weather-related variations, future follow-up work should include an additional mass balance analysis of the most recent 20 years of hydrologic data (1989 to 2008) to extend the long-term mass balance analysis from 1948 to 2008 (or 61 years) which would be useful in further characterizing the channel losses from CCR to LCC.”

4. Certain portions of Task B of the contract Scope of Work were not performed and summarized within the report. Please clarify in report text what specific portions of the contract Scope of Work (e.g. within Task B) were not completed and why (e.g. due to the initial findings of the channel loss portion of the study).

Response: The following text has been added to Section 8.0: “A portion of the contract Scope of Work from Exhibit C related to Task B- Optimization of Pipeline Capacity and Location Towards Project Implementation was not evaluated based on the initial findings of the channel loss study. Upon determining that this task was not needed, the TWDB was notified and the amount previously allocated to this task (\$8,800) was not spent. The following tasks were not performed: (1) series of model runs for up to three pumping rates, (2) preliminary cost estimates for a range of pipeline sizes to optimize size, (3) associated figures to compare the volume of water sent through the pipeline, changes in streamflow downstream of CCR, increase in water supply, and impacts to the Nueces Bay and Estuary; and (4) topographic maps to identify a suitable location for CCR/LCC pipeline; and model run operating the CCR/LCC pipeline conjunctively with the off-channel reservoir.”