

Appendix 3-D

Water Availability Model Technical Memorandum

The memorandum included as attachment 3-D describes the method used to determine available supplies from the Neches River for the City of Beaumont for regional water planning. Water availability modeling was used to analyze the supply from the Neches run-of-river and the natural flows of the Neches River.

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TO: File

CC: Simone Kiel

FROM: Jon Albright

SUBJECT: Beaumont Supplies from Neches River

DATE: November 21, 2013

PROJECT: Region I PLU12102

Summary

1. This memorandum describes the method used to determine available supplies from the Neches River for the City of Beaumont for regional water planning. The method is based on a daily analysis of flows in 1956 made by Tom Gooch of Freese and Nichols as part of the negotiations between the City of Beaumont and the Lower Neches Valley Authority (LNVA) in 2011. The 2011 analysis was provided to the TCEQ in response to a priority call by the LNVA. A comparison of results using the Neches WAM is part of the analysis.
2. The calculations for the available supply to Beaumont for regional water planning are preliminary. These calculations will be refined once the City of Beaumont and LNVA demands have been finalized.
3. The City of Beaumont owns Certificate of Adjudication (CA) 06-4415, which authorizes 56,467 acre-feet per year of diversion from the Neches River. The City also has supplies of 9,000 acre-feet per year from the Gulf Coast aquifer and a contract with the Lower Neches Valley Authority (LNVA) for 6,000 acre-feet of water from the Neches River and the Steinhagen/Rayburn system.
4. Table 1 compares the available supplies to preliminary demands for the City of Beaumont for the years 2020 and 2070. Table 1a uses supplies from the Neches WAM Run 3 for 1956, the year with the minimum supply available under the City of Beaumont's water rights. Table 1b shows the same analysis using the results of the daily analysis. Note that the daily analysis shows greater shortages than the WAM analysis.
5. In order to properly calculate the need in the database, Beaumont's supply from the Neches River will need to change from year to year. For example, instead of the maximum supply of 22,234 acre-feet per year, the year 2020 Neches River supply will be 15,934 acre-feet per year and the 2070 Neches River supply will be 21,588 acre-feet per year. This is necessary because the analysis uses a shorter time step (monthly) than the database (yearly).

Table 1a: 2020 and 2070 Supply and Demand – Worst Year Supplies from WAM Run 3
 Values in Acre-Feet

Month	CA 4415 Available Supplies from WAM	2020 Conditions				2070 Conditions			
		Beaumont Demand	CA4415 Supplies Used to Meet Demand	Supplies from Other Sources	Shortage	Beaumont Demand	CA4415 Supplies Used to Meet Demand	Supplies from Other Sources	Shortage
Jan-56	4,669	2,723	2,723	0	0	3,962	3,962	0	0
Feb-56	4,132	2,419	2,419	0	0	3,518	3,518	0	0
Mar-56	4,495	2,623	2,623	0	0	3,816	3,816	0	0
Apr-56	4,390	2,579	2,579	0	0	3,749	3,749	0	0
May-56	4,832	2,842	2,842	0	0	4,131	4,131	0	0
Jun-56	26	2,817	26	2,791	0	4,098	26	4,072	0
Jul-56	8	3,034	8	3,026	0	4,409	8	4,401	0
Aug-56	6	3,006	6	3,000	0	4,370	6	4,364	0
Sep-56	5	2,886	5	2,881	0	4,197	5	2,163	2,029
Oct-56	484	2,874	484	2,390	0	4,177	484	0	3,693
Nov-56	4,485	2,621	2,621	0	0	3,812	3,812	0	0
Dec-56	4,579	2,678	2,678	0	0	3,900	3,900	0	0
Total	32,111	33,102	19,014	14,088	0	48,139	27,417	15,000	5,722

Table 1b: 2020 and 2070 Supply and Demand – Worst Year Supplies from Daily Analysis
 Values in Acre-Feet

Month	CA 4415 Available Supplies from Daily Analysis	2020 Conditions				2070 Conditions			
		Beaumont Demand	CA4415 Supplies Used to Meet Demand	Supplies from Other Sources	Shortage	Beaumont Demand	CA4415 Supplies Used to Meet Demand	Supplies from Other Sources	Shortage
Jan-56	3,901	2,723	2,723	0	0	3,962	3,901	61	0
Feb-56	4,164	2,419	2,419	0	0	3,518	3,518	0	0
Mar-56	3,765	2,623	2,623	0	0	3,816	3,765	51	0
Apr-56	3,701	2,579	2,579	0	0	3,749	3,701	48	0
May-56	3,955	2,842	2,842	0	0	4,131	3,955	176	0
Jun-56	775	2,817	775	2,042	0	4,098	775	3,323	0
Jul-56	0	3,034	0	3,034	0	4,409	0	4,409	0
Aug-56	0	3,006	0	3,006	0	4,370	0	4,370	0
Sep-56	0	2,886	0	2,886	0	4,197	0	2,562	1,635
Oct-56	0	2,874	0	2,874	0	4,177	0	0	4,177
Nov-56	116	2,621	116	1,158	1,347	3,812	116	0	3,696
Dec-56	1,857	2,678	1,857	0	821	3,900	1,857	0	2,043
Total	22,234	33,102	15,934	15,000	2,168	48,139	21,588	15,000	11,551

- The remainder of this memorandum describes the calculations in more detail. Attachment 1 contains the actual daily calculations of available supply.

Water Rights

- Table 2 is a summary of the Beaumont (CA 06-4415) and LNVA water rights (CA 06-4411). These two water rights are the primary run-of-the-river diversions from the lower Neches River. LNVA rights are for diversions from both the Neches River and Pine Island Bayou. A canal connects the main stem of the Neches River to the LNVA diversion point on Pine Island Bayou. The LNVA right contains a complex set of maximum diversion rates for the various priorities which vary by location which are discussed in the section on the daily analysis. The LNVA rights also include authorization for Steinhagen and Rayburn Reservoirs, which are not included in Table 2.

Table 2: Beaumont and LNVA Water Rights

Number	Owner	Priority Date	Diversion Amount	Type of Use
CA 06-4415	City of Beaumont	5-Apr-15	6,570	Municipal
		8-Jan-25	49,897	Municipal and Industrial
		<i>Total</i>	<i>56,467</i>	
CA 06-4411	LNVA	12-Aug-13	107,108	Municipal, Industrial, Irrigation, Mining
		8-Nov-13	219,252	
		31-Dec-24	55,516	
		<i>Total</i>	<i>326,360</i>	

Available Supplies Using WAM

- Figure 2 shows the annual diversions from the Neches River under the Beaumont water right from the Neches WAM plus the 15,000 acre-feet per year available from other sources (LNVA contract and groundwater). The Beaumont 2020 and 2070 annual demands are included for reference. The Beaumont diversion of 56,567 acre-feet per year is approximately 89% reliable.
- Figures 3a and 3b are annual summaries comparing 2020 and 2070 Beaumont demands to available supplies, using the monthly availability from the WAM. For this analysis, each month in the WAM simulation is compared to the projected Beaumont demand for that month. If there is not enough water available from the Neches River, then the 15,000 acre-feet per year

from alternative sources is used if available. Once this supply is used up there is a shortage. In 2020 the three sources are sufficient to meet all Beaumont demands. In 2070, there are shortages in 1966, 1967 and 1971. The maximum shortage of 5,722 acre-feet is in 1956.

Figure 2: Annual Available Supply from Beaumont Sources Based on Neches WAM

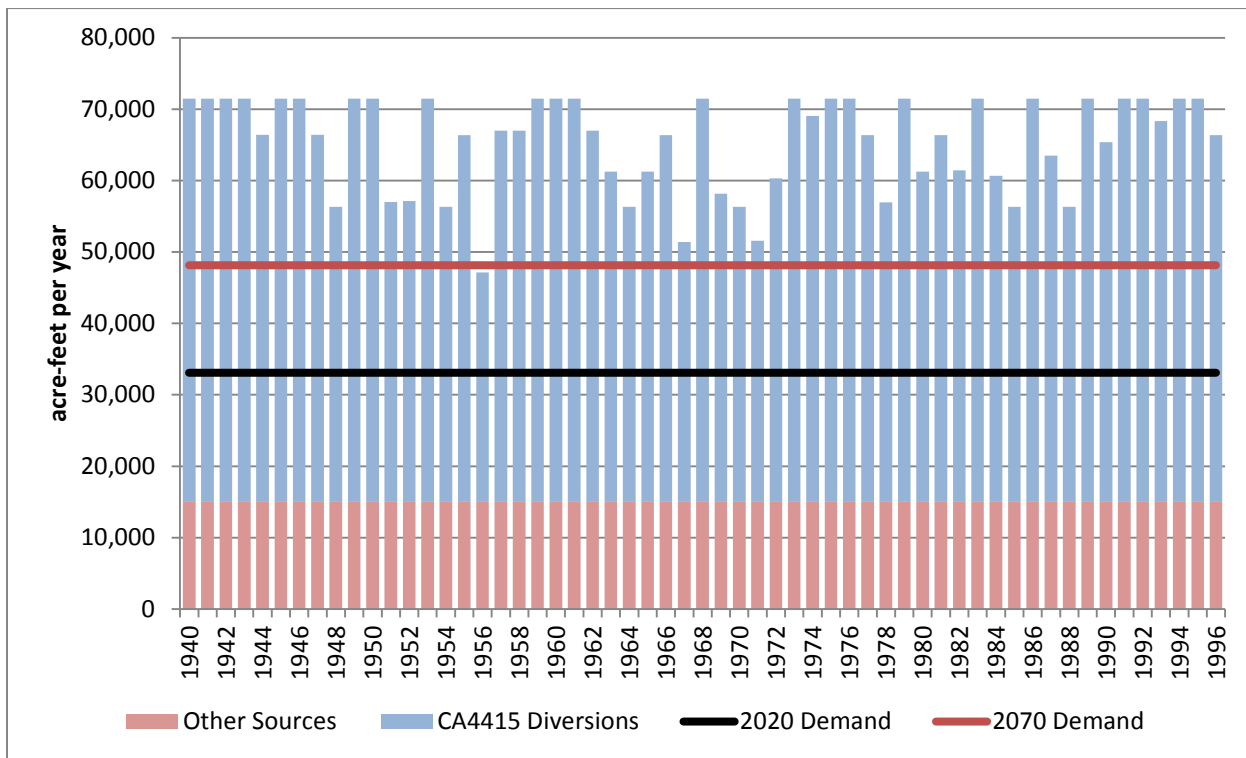


Figure 3a: Annual Source of Supply Based on Monthly Analysis using WAM – 2020 Conditions

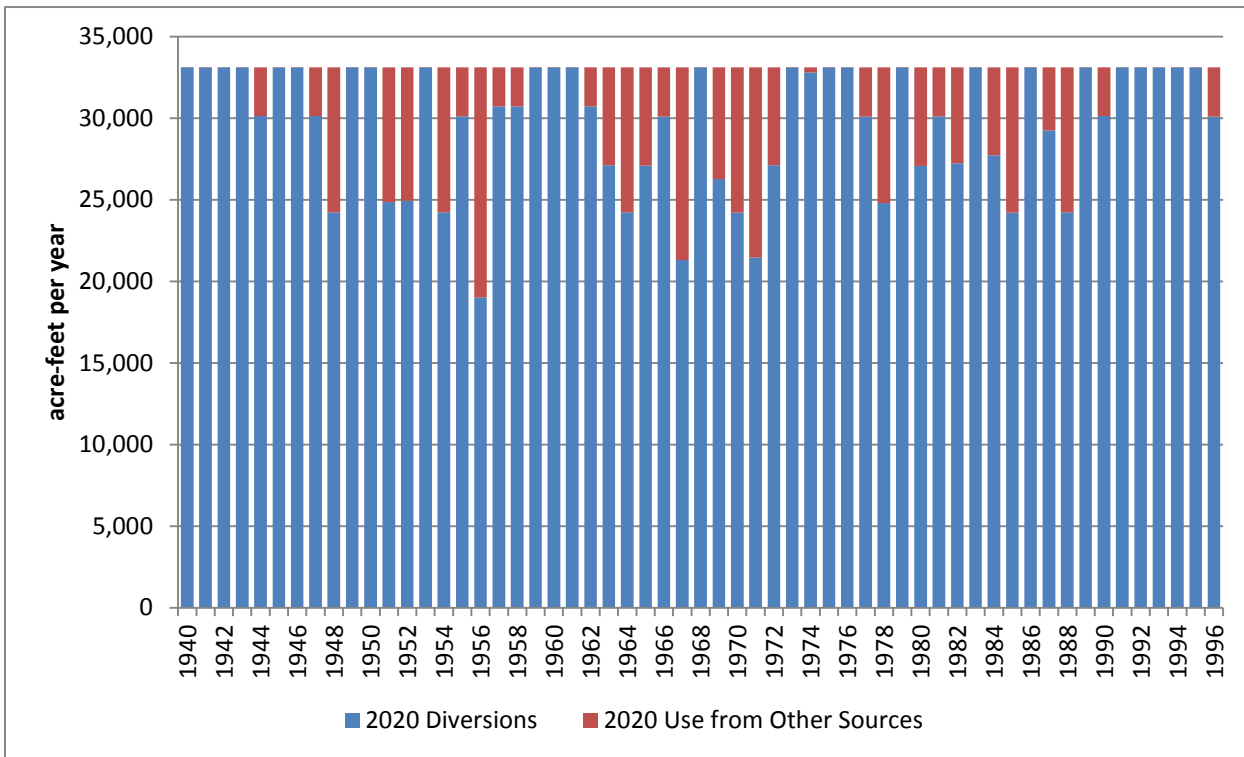
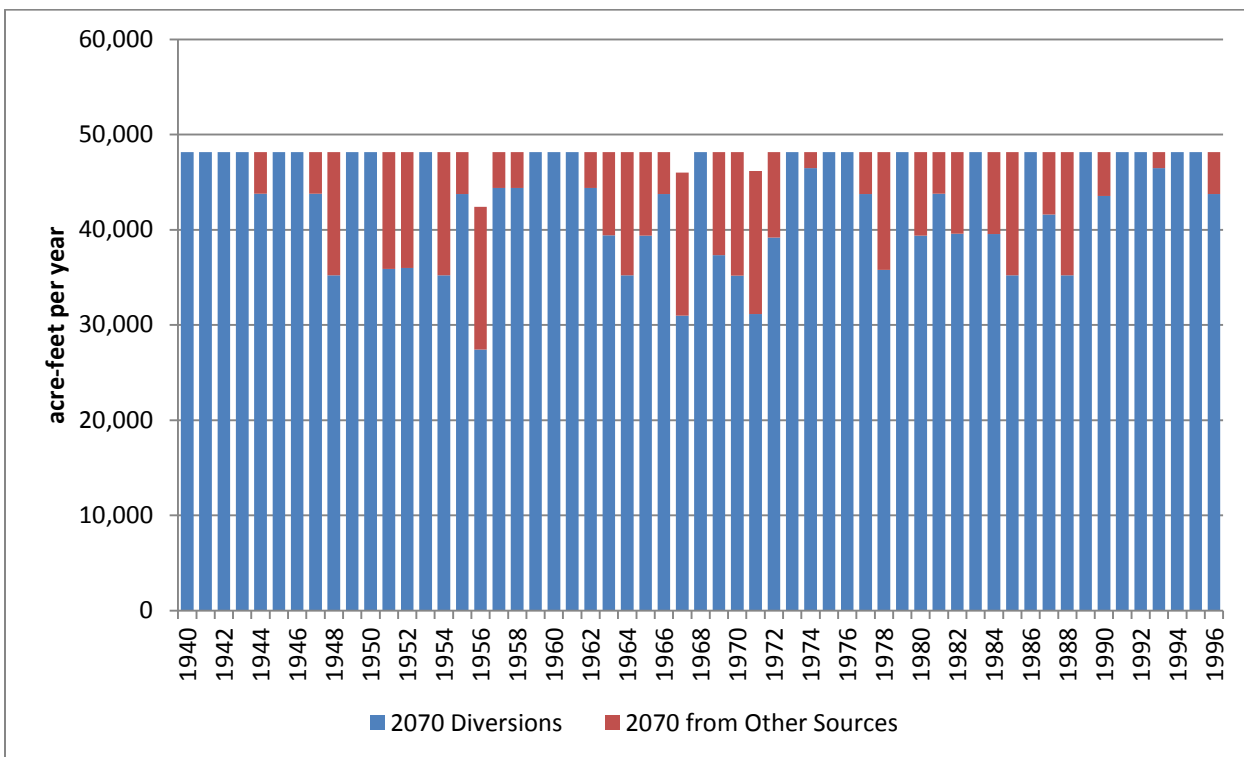


Figure 3b: Annual Source of Supply Based on Monthly Analysis using WAM – 2070 Conditions



Daily Analysis

10. The preferred method for calculating availability for Beaumont is based on an analysis performed during the negotiations between LNVA and Beaumont in 2011. These negotiations were overseen by TCEQ. Attachment 1 contains a detailed description of the calculations performed as part of the negotiations. The analysis uses daily historical flows for the years 1956, 1967, 2000, 2010 and 2011. 1956 had the lowest availability for Beaumont and was selected for the basis of water availability for Region I.

ATTACHMENT 1: DESCRIPTION OF DAILY ANALYSIS SPREADSHEET

The daily analysis spreadsheet includes the following worksheets:

Worksheet 1 (Analysis of Available Flow at the Salt Water Barrier) – This worksheet estimates the natural flows for the Neches River at the Salt Water Barrier based on inflow and outflow data from Sam Rayburn and B.A. Steinhagen Reservoirs and USGS streamflow data.

Worksheet 2 (Adjusted LNVA Analysis of Diversions Assigned to Water Rights) – This worksheet assigns diversions to various water rights using a modified version of the analysis performed by LNVA. The analysis preserves LNVA's logic and philosophy for allocating flow and diversions by water right. However, the analysis substitutes Freese and Nichols' calculations for available flow (see Worksheet 1, above); uses actual daily diversions by the City of Beaumont (Worksheet 5) instead of the hypothetical diversion in the original LNVA analysis; and divides Beaumont's diversions between 1915 and 1925 priority.

Worksheet 3 (Corps Data) – presents the raw inflow and outflow data for Sam Rayburn Reservoir and inflow data for B.A. Steinhagen Reservoir, as extracted from the Corps of Engineers' website: <http://www.swf-wc.usace.army.mil/cgi-in/rcshtml.pl?page=Hydrologic>. These data are provided as backup for calculations in Worksheet 1.

Worksheet 4 (USGS Data) – presents gage flow in cubic feet per second, as extracted from the U.S. Geological Survey website: <http://waterdata.usgs.gov/tx/nwis/current/?type=flow>. These data are provided as backup for calculations in Worksheet 1.

Worksheet 5 (Beaumont Diversions) – presents the daily diversions by the City of Beaumont from the Neches River. This data was provided by Karin Warren of the City of Beaumont to Freese and Nichols, Inc. by Beaumont. Worksheet 5 converts the raw data, provided in million gallons per day, to cubic feet per second (cfs) using the factor 1 MGD = 1.55 cfs. These data are presented as backup for calculations in Worksheet 2.

Worksheets 1 and 2 are discussed in greater detail below.

WORKSHEET 1 – ANALYSIS OF AVAILABLE FLOW AT THE SALT WATER BARRIER

This table estimates natural flows above the Salt Water Barrier. The columns in the worksheet are developed as follows:

- (A) Date. This is the date to which the data apply.
- (B) Inflow to Sam Rayburn Reservoir. Obtained from the U.S. Army Corps of Engineers' website. "Adjusted" inflows in cubic feet per second are used for 1 January 2010 through 30 September

2010. Adjusted inflows are not available for dates later than 30 September 2010; calculated inflows from the same data set are used for the period 1 October 2010 through 14 November 2011.

- (C) Flow at the Rockland USGS Gage. Daily flow in cfs from the U.S. Geological Survey website.
- (D) Estimated Inflow to BA Steinhagen Reservoir (Not Including Releases from Sam Rayburn). This is the estimated inflow to B.A. Steinhagen Reservoir downstream from Sam Rayburn Reservoir and is based on the flow at the Rockland USGS gage multiplied by the drainage area ratio. The drainage area of B.A. Steinhagen Reservoir downstream from Sam Rayburn Reservoir is 4,124 square miles, and the drainage area of the Rockland gage is 3,636 square miles, resulting in a ratio of 1.1342.
- (E) Total Natural Inflow above Dams. Calculated in the spreadsheet as the sum of Column B and Column D. This value, expressed in cfs, represents inflow from the portion of the Neches River watershed above Sam Rayburn Reservoir and B. A. Steinhagen Reservoirs.
- (F) Natural Inflow above Dams with Negatives set to Zero. As noted previously, natural inflow may be zero during dry periods but cannot be negative. Negative numbers in the spreadsheet represent inconsistent data. This column replicates Column G with the difference that any negative value has been reset to zero.
- (G) Flow at Town Bluff Gage. Daily flow in cfs from the U.S. Geological Survey website. Data points after 7/25/2011 are provisional; all prior data are approved. Note that the datum for 10/5/2011 is missing. We have filled in 598 cfs, which is the average of flows for 10/4 and 10/6.
- (H) Flow at Evadale Gage. Daily flow in cfs from the U. S. Geological Survey website. Data points after 7/25/2011 are provisional; all prior data are approved. Note that the datum for 10/5/2011 is missing. We have filled in 635 cfs, which is the average of flows for 10/4 and 10/6.
- (I) Evadale less Town Bluff (Lagged 1.5 days). Calculated in the spreadsheet as Column H minus the average of the Column G value from one and two days prior. This use of previous days' values for Town Bluff flows represents travel time between the two gages. Scenarios of 1, 1.5, 2, 2.5, and 3 days travel time were tested; 1.5 days travel time produced the fewest negative values and appears to be the best fit.
- (J) Corrected Flow from Town Bluff to Evadale. In certain cases, Column I contains negative numbers (highlighted in pink). While flow between the two gages may be zero under some conditions, it should not be negative. We believe these negative numbers are an artifact of varying travel times. Column J represents a manual adjustment to Column I to remove negative inflows by adjusting the inflows of adjacent dates such that no entry is less than zero and the total volume remains unchanged.
- (K) Flow at Village Creek near Kountze Gage. Daily flow in cfs from the U.S. Geological Survey website. Data from 10/4/2010 on are provisional. All prior data are approved. Note that the datum for 10/5/2011 is missing. We have filled in 15 cfs, which is the average of flows for 10/4 and 10/6.

- (M) Flow at Pine Island Bayou near Sour Lake Gage. Daily flow in cfs from the U.S. Geological Survey website. Data from 10/5/2010 on are provisional; all prior data are approved.
- (N) Ungaged Flow. Estimates the ungaged flow between Lake B.A. Steinhagen and the Salt Water Barrier by using a drainage area ratio and flows for the gaged portion of the watershed. The watershed above the Salt Water Barrier (9,789 square miles) minus the portion of the watershed above B.A. Steinhagen Reservoir (7,574 square miles) reflects 2,215 square miles of total watershed below B.A. Steinhagen Reservoir. The gaged portion of this drainage area is the gaged portion of the Pine Island Bayou watershed (336 square miles) plus the gaged portion of the Village Creek watershed (860 square miles) plus the gaged portion of the main stem watershed between the Evadale and Town gages (7,951 square miles minus 7,574 square miles, or 377 square miles). The total gaged portion of the watershed below B.A. Steinhagen is therefore 1,573 square miles (336 + 860 + 377). The ungaged portion of the watershed is 642 square miles (2,215 total – 1,573 gaged). The ratio of 642 square miles (ungaged area) to the gaged portion (1,573 square miles) is 0.41. (The drainage area of each gage is taken from the USGS website.) The spreadsheet accordingly multiplies (Column (H) + Column (K) + Column (L)) by 0.41 to calculate Column N.
- (O) Flow Between BA Steinhagen and Neches at the Salt Water Barrier. Computes the total flow between Lake B.A. Steinhagen and the Salt Water Barrier by adding gaged and ungaged flow and is equal to Column (J) + Column (K) + Column (L) + Column (M).
- (P) Estimated Natural Flow on Neches at Salt Water Barrier (O + F (Lagged 1.5 Days)). Estimates the total natural flow in the Neches River at the Salt Water Barrier by adding the estimated natural flow from the portion of the watershed below B.A. Steinhagen Reservoir (Column O) to estimated natural flow above the dams (Column F) with a 1.5 day lag for the flow values from the upper portion of the watershed (average of Column F values for 1 and 2 days prior).

WORKSHEET 2 – ADJUSTED LNVA ANALYSIS OF DIVERSIONS ASSIGNED TO WATER RIGHTS

Unless otherwise indicated, the procedures used to divide available flows among water rights and priorities are the same as the procedures followed by the LNVA in its spreadsheet.

- (A) Date. This is the date to which the data apply.
- (B) Estimated Natural Flow in the Neches River at the Salt Water Barrier – from Worksheet 1. Calculated by FNI as described in Worksheet 1. Data from Column Q, Worksheet 1, is copied to Column B, Worksheet 2. The computations are described under Worksheet 1 above. The data are different from the data used by LNVA.
- (C) LNVA Pumpage at Neches First. Actual LNVA pumping at the Neches First Lift Pump Station, as reported by LNVA on a daily basis, in cfs.
- (D) Neches First Year to Date. Cumulative pumping by LNVA at Neches First Pump Station for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying diversions in cfs by 1.98347 (to convert to acre-feet) and adding each day's value to the prior

day's to determine a cumulative running total.

- (E) LNVA Pumpage at Neches BI First. Actual LNVA pumping at the BI First Lift Pump Station, as reported by LNVA on a daily basis, in cfs.
- (F) BI First Year to Date. Cumulative pumping by LNVA at BI First Lift Pump Station for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying diversions in cfs by 1.98347 (to convert to acre-feet) and adding each day's value to the prior day's to determine a cumulative running total.
- (G) 8/12/1913 BI First Run-of-the-River Right (up to 450 cfs). Allocates LNVA's diversion at BI First (in cfs) to the most senior water right for that location, limited by the available flow (Column B), the total diversion at BI First lift (Column E), the maximum allowable diversion rate at this priority, and the maximum annual diversion at this location and priority.
- (H) Year to Date Use of 1913 BI (Ac-Ft). Cumulative pumping by LNVA at BI First Lift Pump Station at the 1913 priority for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying diversions in cfs by 1.98347 (to convert to acre-feet) and adding each day's value to the prior day's to determine a cumulative running total. It is used to assure that diversions at the 1913 priority cease when the maximum annual diversion at that priority is reached.
- (I) 11/8/1913 Neches First Run-of-the-River Right (up to 588 cfs). Allocates LNVA's diversion at Neches First (in cfs) to the most senior water right for that location, limited by the available flow less flow allocated to BI First 1913 (Column B – Column G), the total diversion at Neches First lift (Column C), the maximum allowable diversion rate at this priority, and the maximum annual diversion at this location and priority.
- (J) Year to Date Use of 1913 Neches (Ac-Ft). Cumulative pumping by LNVA at Neches First Lift Pump Station at the 1913 priority for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying diversions in cfs by 1.98347 (to convert to acre-feet) and adding each day's value to the prior day's to determine a cumulative running total. It is used to assure that diversions at the 1913 priority cease when the maximum annual diversion at that priority is reached.
- (K) Beaumont Diversion from Neches (cfs). Actual diversion by the City of Beaumont, expressed in cfs. Data for diversions in mgd were provided by the City of Beaumont by email from Karen Warren to Tom Gooch, FNI, dated 14 November 2011. The original data are included in Worksheet 5 as Column B. This column was on in LNVA's computations.
- (L) 4/15/1915 City of Beaumont Right Diversion. The portion of Beaumont's diversion that can be made with available water at a 1915 priority. It is limited to the lesser of actual diversions; available flow less diversions by LNVA under their 1913 rights (The lesser of Column K and Column B – Column G – Column I); the maximum allowable diversion rate at this priority; and the maximum annual diversion at this priority. In their computations, LNVA used an assumed 50 cfs diversion by LNVA rather than actual diversions (which were always less than 50 cfs) in this column.

- (M) Year to Date Use of 1915 Beaumont (Ac-Ft) (Acre-feet). Cumulative pumping by Beaumont at Neches First Lift Pump Station at the 1913 priority for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying cumulative diversions in cfs by 1.98347 (to convert to acre-feet). It is used to assure that diversions at the 1915 priority cease when the maximum annual diversion at that priority is reached.
- (N) 12/31/1924 BI First Right. These are diversions by LNVA at the BI First Lift Pump Station that are allocated to LNVA's 1924 water right. They are limited by the difference between total diversions at BI First Lift (Column E) and diversions allocated to the 1913 priority (Column G), the difference between total available flow (Column B) and flows allocated to prior water rights (Columns G, I, and L), the 30 cfs diversion rate available under this right, and the total annual amount available under this right. There is a slight difference from the LNVA spreadsheet in this column. Rather than limiting diversions to (Column B – Column G – Column I – Column L), LNVA limited diversions to (Column B – Column G – Column I). This difference (correcting what appears to be a minor miscalculation by LNVA) does not significantly affect the results.
- (O) 12/31/1924 Neches First Right. These are diversions by LNVA at the Neches First Lift Pump Station that are allocated LNVA's 1924 water right. They are limited by the difference between total diversions at BI First Lift (Column C) and diversions allocated to the 1913 priority (Column I), the difference between total available flow (Column B) and flows allocated to prior water rights (Columns G, I, L, and N), the 45 cfs diversion rate available under this right, and the total annual amount available under this right.
- (P) Total of 1924 BI and Neches First Lift Year to Date Diversions. Cumulative pumping by LNVA at BI and Neches First Lift Pump Stations at the 1924 priority for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying 1924 priority diversions in cfs at both pump stations by 1.98347 (to convert to acre-feet) and adding each day's value to the prior day's to determine a cumulative running total. It is used to assure that diversions at the 1924 priority cease when the maximum annual diversion at that priority is reached.
- (Q) 1/8/1925 City of Beaumont Right Diversion. The portion of Beaumont's diversion that can be made with available water at a 1925 priority. It is limited to the lesser of actual diversions less diversions at the 1915 priority (Column K – Column L); available flow less diversions by LNVA under their 1913 and 1924 rights and by Beaumont at its 1915 right (Column B – Column G – Column I – Column L – Column N – Column O); and the maximum allowable diversion rate less diversions at the 1915 priority.
- (R) Diversions by Beaumont in Excess of Available Flow. This is equal to Column K – Column L – Column Q. These diversions could be taken from channel storage or, as LNVA points out, could come from LNVA's releases from upstream reservoirs.
- (S) 11/12/1963 Actual Diversions of Water from Storage. The amount of water LNVA diverts from releases of stored water on the day in question. It is equal to LNVA's total diversions (Column C + Column E) less the diversions allocated to run-of-the-river water rights (Column G + Column I + Column N + Column O).
- (T) Total Year to Date Diversions from Storage. Cumulative diversions by LNVA of water released

from reservoir storage for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying diversions of water released from storage (Column S) in cfs by 1.98347 (to convert to acre-feet) and adding each day's value to the prior day's to determine a cumulative running total. It is used to assure that diversions of water released from storage do not exceed the maximum annual amount.

(U) 11/12/1963 – Called Releases of Water from Storage. The amount of water that was released from storage in upstream reservoirs for the day. This was provided by LNVA.

(V) Total Year to Date Diversions from Storage. Cumulative water released from reservoir storage for the year. This value is expressed in acre-feet. It is computed in the spreadsheet by multiplying water released from storage (Column U) in cfs by 1.98347 (to convert to acre-feet) and adding each day's value to the prior day's to determine a cumulative running total. It is used to assure that water released from storage does not exceed the maximum annual amount.