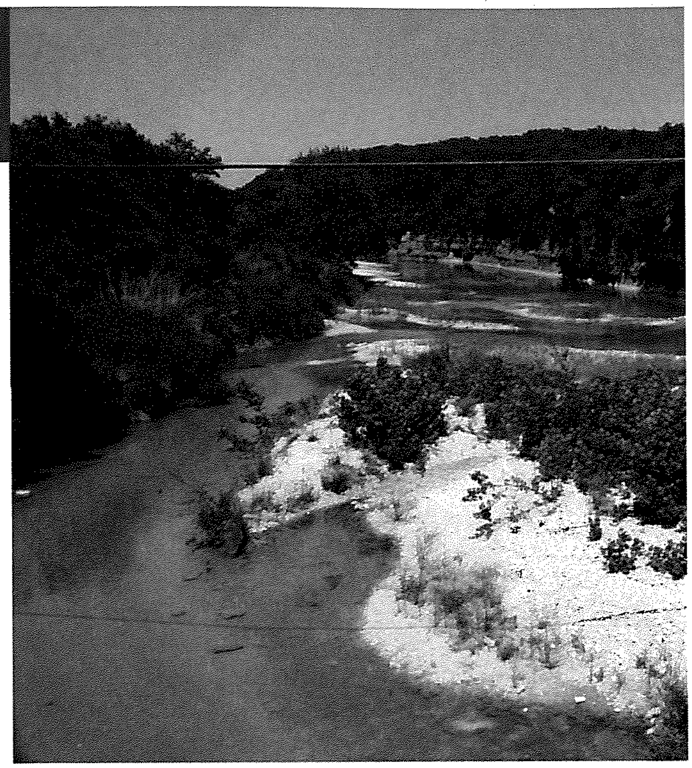
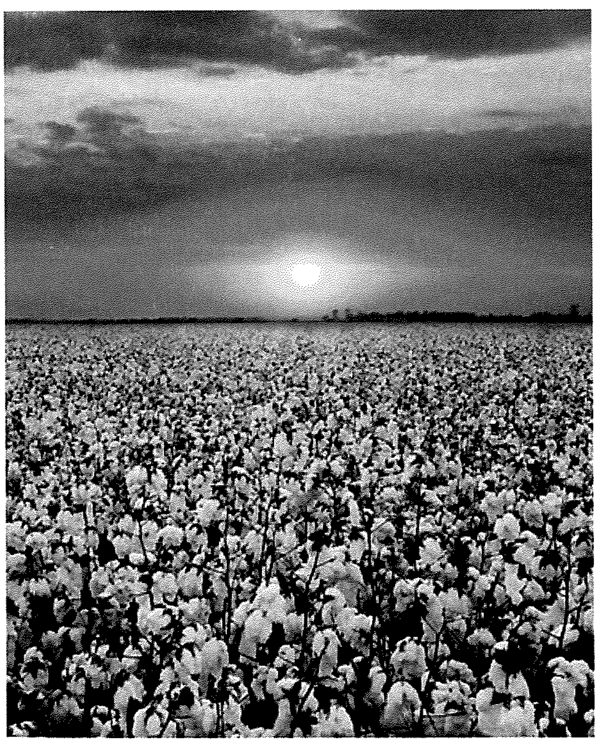
PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD.





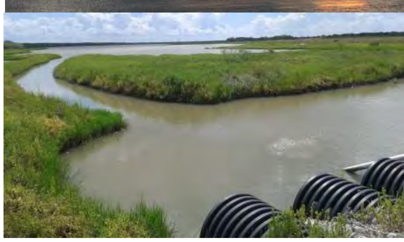
Nueces BBASC Work Plan Study No. 3

Nueces Watershed Pre- and Post-Development Nutrient Budgets

Texas Water Development Board

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC)

August 2015



Nueces BBASC Work Plan Study No. 1

Re-Examination of the 2001 Agreed Order Monthly Targets and Safe Yield Versus Current Demand Evaluations

Texas Water Development Board

August 2015

HDR

Nueces BBASC Work Plan Study No. 1

Re-Examination of the 2001 Agreed Order Monthly Targets and Safe Yield Versus Current Demand Evaluations

Prepared for:

Texas Water Development Board

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC)

PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD.

Prepared by:
HDR
TBPE Firm No. F-754
TBPG Firm No. 50226
August 2015

STATE OF TEXAS
ADAM CORY SHOCKLEY
94761
LICENSED
PROFESSIONAL ENGINEER

Adam Cory Shockley
8-24-15

Adam Cory Shockley, P.E.

This Page Intentionally Left Blank

Contents

1 Introduction ... 3

2 Corpus Christi Water Supply Model Description ... 5

3 Scenario Development and Interaction with Stakeholders ... 6

4 Re-evaluation of the Agreed Order Monthly Targets ... 7

4.1 Data Compilation ... 7

4.2 Data Analysis ... 8

4.3 Data Evaluation ... 14

5 Comparison of Safe Yield versus Current Demand ... 22

6 Conclusions / Recommendations ... 29

7 References ... 31

List of Figures

Figure 1-1. Location of the Study Area ... 4

Figure 2-1. CCWSM Main Input Screen ... 6

Figure 4-1. July Precipitation Totals near Calallen for 1895 - 2014 ... 9

Figure 4-2. July Precipitation Totals and 10-year Moving Average near Calallen 1895 - 2014 ... 9

Figure 4-3. July Precipitation Totals and 10-year Moving Average near Calallen for 1895 – 2014 with Long-Term, Short-Term and Recent Trend Lines ... 10

Figure 4-4. Comparison of Monthly Percentage of Annual Precipitation near Calallen ... 12

Figure 4-5. Comparison of Monthly Percentage of Annual Stream flow Nueces near Tilden ... 13

Figure 4-6. Comparison of Monthly Percentage of Annual Naturalized Flow for Nueces near Mathis ... 13

Figure 4-7. Storage Trace for Baseline and Uniform Scenarios during 1990s Drought ... 18

Figure 4-8. Storage Frequency Trace for Baseline and Uniform (Dashed Lines = Trigger Levels) ... 18

Figure 4-9. Monthly Bay Inflow Frequency for Baseline and Uniform ... 19

Figure 4-10. Storage Trace for Baseline and MJJ during 1990s Drought ... 19

Figure 4-11. Storage Frequency Trace for Baseline and MJJ (Dashed Lines = Trigger Levels) ... 20

Figure 4-12. Monthly Bay Inflow Frequency for Baseline and MJJ ... 20

Figure 4-13. Storage Trace for Baseline and AMJJAD during 1990s Drought ... 21

Figure 4-14. Storage Frequency Trace for Baseline and AMJJAD (Dashed Lines = Trigger Levels) ... 21

Figure 4-15. Monthly Bay Inflow Frequency for Baseline and AMJJAD ... 22

Figure 5-1. Storage Trace for Safe Yield and Current Demand scenarios ... 24

Figure 5-2. Storage Trace for Safe Yield and Current Demand Scenarios during 1990s Drought ... 24

Figure 5-3. Monthly Storage Frequency for the CCR/LCC System for the Safe Yield and Current Demand Scenarios (Dashed Lines = Trigger Levels) ... 25

Figure 5-4. Storage Zone Frequency for Safe Yield (SY) and Current Demand (CD) Scenarios ... 26

Figure 5-5. Frequency Plot of Monthly Bay Inflow ... 27

Figure 5-6. Frequency Plot of Monthly Bay Inflow (Zoomed Scale) ... 28

List of Tables

Table 4-1. Comparison of Recent (R) and Short-Term (ST) Hydrology with the Long-Term.................. 11
Table 4-2. Monthly Targets (acft) for *Baseline* Safe Yield Scenario.. 15
Table 4-3. Monthly Targets (acft) for *Uniform* Safe Yield Scenario... 15
Table 4-4. Monthly Targets (acft) for *MJJ* Safe Yield Scenario 16
Table 4-5. Monthly Targets (acft) for *AMJJAD* Safe Yield Scenario.. 16
Table 4-6. Modeling Results for Selected Scenarios 17
Table 5-1. Storage Zone Frequency for Safe Yield and Current Demand Scenarios 25
Table 5-2. Target Attainment Frequency for Safe Yield and Current Demand Scenarios 27
Table 5-3. Long-Term Annual Average Freshwater Inflows and Harvest 29

List of Appendices

Appendix A. 2001 TCEQ Agreed Order

Appendix B. Presentations to NEAC

Appendix C. Hydrologic Data Plots

Appendix D. Scope of Work for the Study

Appendix E. Comments from TWDB on Draft Final Report

Appendix F. Response to Comments on Draft Final Report

1 Introduction

The City of Corpus Christi (CoCC or City) operates the Choke Canyon Reservoir / Lake Corpus Christi / Lake Texana System (CCR/LCC System) as its primary water supply for a population of over 500,000 (in the area), 300,000 of which reside in Corpus Christi. In the operation of this system, the City is subject to the terms and conditions of the 2001 Texas Commission on Environmental Quality (TCEQ) Agreed Order (Agreed Order; attached as Appendix A) that defines the monthly freshwater inflow targets for Nueces Bay which, in turn, govern the passage of inflows through the reservoir system. The monthly targets in the Agreed Order are generally based on the MaxH (Maximum Harvest) and MinQ (Minimum Flow) solutions obtained from the TWDB's TxEMP Model for the Nueces Estuary.[1,2] These solutions are based, in part, on functional relationships relating bimonthly freshwater inflows to reported commercial harvests of seven selected species (recognizing that other factors such as temperature, fuel cost, economics, harvest pressure, gulf stock, etc. may affect harvest also). Studies of recent hydrologic trends, driven by more frequent and severe drought cycles, indicate that the timing of freshwater inflows may no longer correspond to the timing of these events as defined in the Agreed Order.

The Nueces Basin and Bay Area Stakeholder Committee (Nueces BBASC) recommended a study be performed to re-examine the monthly pass-through targets that are part of the Agreed Order. As described in Section 4.1 of the Nueces Basin and Bay Expert Science Team report (Nueces BBEST 2011), it is believed that there has been a seasonal shift in inflows to Nueces Bay and the CCR/LCC System that serves as the CoCC primary water supply. The Nueces BBASC report (Nueces BBASC, August 2012), in Section 2.3, suggests that opportunities to better manage limited freshwater inflows may be identified by reviewing new data that were not available during development of the 1995 Agreed Order, which is the pre-cursor to the 2001 Agreed Order, for current pass-through operations of the reservoir system. This research was recommended to see what modifications to the Agreed Order might be considered for ecological purposes and to quantify the associated impact of any such modifications on the reliable water supply of the City and its customers.

Another question to be answered by this study involves a comparison of the City's current demand with that of the safe yield demand used for regional planning purposes, as well as CCR/LCC System operations and associated differences in freshwater inflows (FWI) to Nueces Bay. The concern is that, as the City's demands increase into the full safe yield demand (which is greater than the current demand), freshwater inflows to the Nueces Bay could be further reduced. As part of this study, simulations of the current demand and the safe yield demand were completed in order to compare current and future freshwater inflow magnitudes and frequencies of occurrence in Nueces Bay. Safe yield for purposes of this analysis is defined as the annual water supply demand that can be placed on the CCR/LCC System which results in a minimum system storage of approximately 125,000 acft during the worst month in a repeat of the critical drought.

The two main goals of the study are:

- Determine if a "shift" has occurred in CCR/LCC System inflows and what impact this "shift," if used to modify monthly targets in the Agreed Order, might have on safe yield and FWI to Nueces Bay (Scope of Work Task 1).

---

[1] TWDB, TPWD, & TNRCC, "Texas Bays and Estuaries Program, Determination of Freshwater Inflow Needs," September 1998.

[2] TPWD & TWDB, "Freshwater Inflow Recommendation for the Nueces Estuary," September 2002.

- Compare FWI to Nueces Bay resulting from a safe yield demand of 192,000[3] acft/yr to a current demand of 130,000 acft/yr on the CCR/LCC System.

This report describes the analyses performed to achieve the goals and contains a brief summary of the potential impacts of modifying the Agreed Order on reservoir system yield. The report also briefly discusses the future implications for the study area, Figure 1-1, with recommendations for additional investigation.

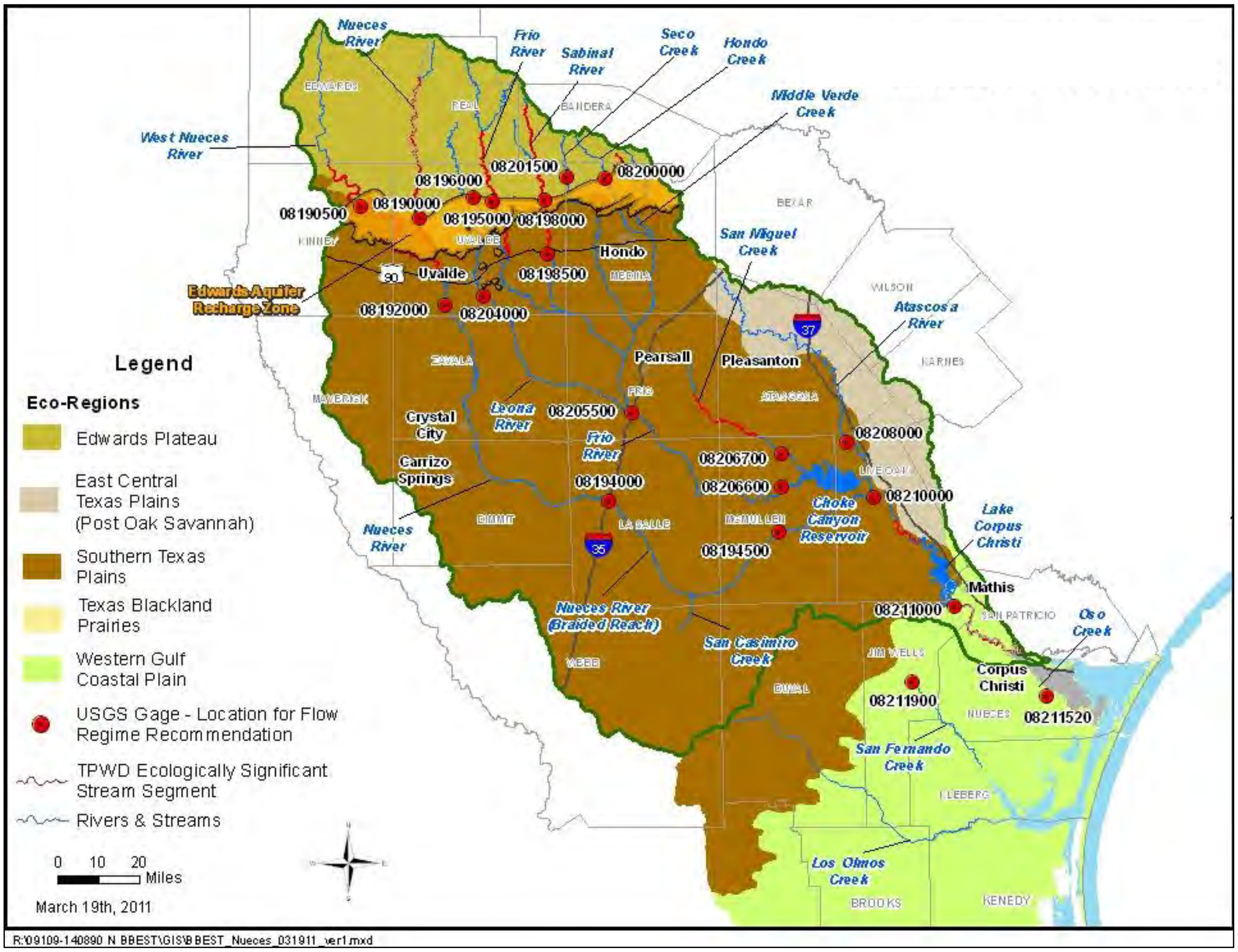


Figure 1-1. Location of the Study Area

[3] Note that the scope of work referenced a safe yield of 205,000 acft/yr. This value was from the 2011 Region N plan and associated modeling assumptions. For this analysis, the safe yield was updated to be consistent with the safe yield reported in the 2016 Region N Initially Prepared Plan, 192,000 acft/yr.

2 Corpus Christi Water Supply Model Description

The Corpus Christi Water Supply Model (CCWSM) is a multi-basin water supply model that includes operations of Choke Canyon Reservoir (CCR), Lake Corpus Christi (LCC; including reservoir “pass-throughs” for Nueces Bay), Lake Texana, and potential future water supplies from the Lower Colorado River (i.e. Garwood water). For the 2006 Coastal Bend Regional Water Plan (2006 Plan), the CCWSM was updated (HDR 2006) to include hydrology for the drought of the 1990s, which extended the simulation period of the model from 1934 to 2003. The CCWSM is a planning / operational model that uses historical hydrologic data (natural inflows and evaporation) to simulate reservoir operations on a monthly time-step under various demands / environmental flow scenarios.

The model was originally developed as a tool to evaluate the effects of reservoir operation and environmental flow policies on system yield and FWI. Computations in the model simulate evaporation losses in the reservoirs, as well as channel losses in the rivers associated with water delivery from CCR to LCC, and from LCC to the City’s water supply intake near the Calallen Diversion Dam. In addition, to account for sediment deposition in the reservoirs, the model includes elevation-area-capacity relationships representative of different decades including 2010, 2020, 2060, and 2070. The history of CCWSM development and applications is summarized in a series of HDR project reports dating back to 1991 (HDR, et al., May 1991, November 1991, 1993, January 1999, and 2006).

The CCWSM is a water accounting model and as such does not try to replicate existing data in the model output, in other words it does not require calibration. The CCWSM utilizes known input data (inflows, evaporation) under a set of hypothetical operating scenarios (water rights usage, environmental pass-throughs, etc.) to evaluate the impacts of user-specified scenarios on reservoir levels, water supply reliability, and bay inflow. The CCWSM focuses on major water rights, reservoir operations, and alternative management scenarios in the lower Nueces River Basin while the TCEQ water availability model (HDR October 1999) simulates all water rights throughout the Nueces River Basin.

Figure 2-1 displays a screen shot for the main input screen of the CCWSM. The CCWSM was the primary tool for performance of this study. The model was used to evaluate the effects of changes in demands and monthly bay inflow targets on safe yield and frequency and magnitude of bay inflows.

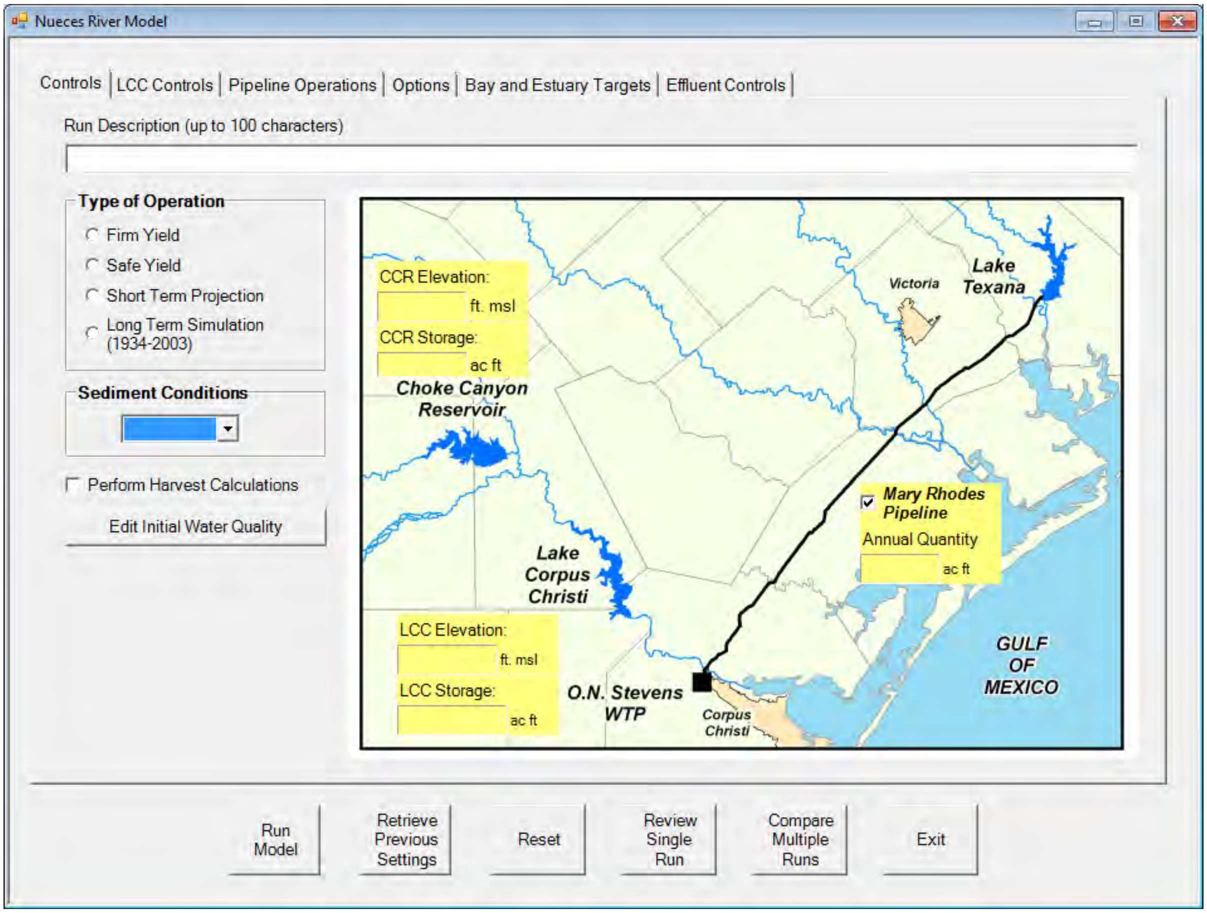


Figure 2-1. CCWSM Main Input Screen

3 Scenario Development and Interaction with Stakeholders

Study objectives and results were presented at meetings in the Corpus Christi area. The first stakeholder meeting occurred on June 16, 2014, as part of the Nueces Estuary Advisory Council (NEAC) meeting in Corpus Christi. This meeting focused on presenting the scope of the study and its goals. Input was solicited and received from stakeholders regarding their expectations of desired outcomes. Presentation materials used at this meeting are included in Appendix B.

Three subsequent meetings were attended to present preliminary results to the NEAC. The first of these meetings coincided with a regularly scheduled NEAC meeting and occurred on October 20, 2014, and included attendees from TCEQ, Coastal Bend Bays and Estuaries Program (CBBEP), Nueces River Authority (NRA), Sherwin Alumina, Texas Water Development Board (TWDB), Port of Corpus Christi Authority (Port), Center for Coastal Studies (CCS), Harte Research Institute (HRI), City of Corpus Christi (CoCC), Texas Parks and Wildlife Department (TPWD), and the South Texas Water Authority (STWA), among others. Presentation materials from this meeting are included in Appendix B. This meeting focused on explaining the preliminary results from Task 2 analysis comparing current system demands with safe yield demand and the associated differences in FWI.

A second results meeting occurred on February 23, 2015, at a regularly scheduled NEAC meeting in Corpus Christi. The meeting included attendees from CBBEP, NRA, TWDB, TCEQ, Port, CCS, HRI, CoCC, Naismith Engineering (NE), RPS Group, and STWA, among others. Presentation materials from this meeting are included in Appendix B. This meeting focused on explaining the preliminary results of Task 1 analysis including monthly flow and precipitation patterns, inflow trends, and evaluation criteria utilized for modeling exercises.

The third meeting occurred on June 22, 2015, at a regularly scheduled NEAC meeting in Corpus Christi. The meeting included attendees from CBBEP, NRA, TWDB, TCEQ, Port, CCS, HRI, CoCC, NE, RPS Group, and STWA, among others. Presentation materials from this meeting are included in Appendix B. This meeting focused on presenting the modeling analysis completed for Task 1 and the preliminary conclusions and recommendations of the study.

4 Re-evaluation of the Agreed Order Monthly Targets

As mentioned previously and referenced in the Nueces BBASC and BBEST reports, there are data that suggest a potential shift in the monthly inflow patterns that have been recently occurring in the Nueces Bay and Estuary and the CCR/LCC System. Task 1 of the Nueces BBASC Study No. 1 consists of compiling reference data (including stream flow, precipitation, and model naturalized flow), determining whether the data suggest a different monthly pattern, and evaluating how an alternative monthly pattern might affect safe yield of the system and resulting bay inflows.

HDR compiled available data for both long-term and recent periods for the Nueces watershed. Sources of data included the U.S. Geological Survey (USGS), National Climate Data Center (NCDC), Nueces River Authority (NRA), and other public entities. The current period of record of the CCWSM is 1934 – 2003. This data focused on the long-term (1934 – 2014), the short-term (1986 – 2014; since Choke Canyon Reservoir initially filled), and the recent (2004 – 2014; since the end of data contained in the CCWSM) time frames in order to identify any changes in seasonal hydrology. Geographically diverse sets of data were evaluated to try and identify variability within the Nueces watershed, but all data showed similar trends regardless of location in the basin. Relative magnitudes of flow and precipitation generally increase closer to the coast, but the trends within the data appear similar regardless of location.

4.1 Data Compilation

HDR obtained long-term monthly precipitation data[4] for four sites in the study area including:

- Nueces River near Tilden,
- Frio River near Derby,
- Lake Corpus Christi, and
- Calallen Dam.

These data include monthly values starting in 1895. Even though a portion of these data is outside the study period (1934 – 2014), it is interesting to note that the minimum annual precipitation at all four sites occurred in 1917 and ranged from 6.34 inches at Tilden to 10.11 inches at Calallen. These data were evaluated for trends by comparing statistics representative of the long-term, short-term, and recent periods.

Naturalized inflows were obtained from the CCWSM for three control point locations:

[4] http://prism.oregonstate.edu/

- CP01 – Nueces River at Tilden,
- CP02 – Frio River near Derby, and
- CP05 - Nueces River near Mathis.

These data are available for the period of record of the CCWSM (1934 – 2003). Naturalized flow is stream flow data that has been adjusted to remove any anthropogenic effects (diversions, discharges, reservoirs, etc.). In other words, this is the stream flow that would have occurred at these sites if human development of the resource had not occurred. Naturalized flow is the base hydrological parameter that the CCWSM utilizes when simulating various operational and management scenarios. Similar to precipitation, naturalized flow data were evaluated for trends by comparing statistics representative of the long-term and short-term periods. Recent trends are not available since the data have not been updated past 2003.

Available stream flow data from the USGS was obtained for four different sites covering a variety of timeframes, including:

- USGS 08210400 Lagarto Creek near George West, TX (1972 – 2014);
- USGS 08194500 Nueces River near Tilden, TX (1942 – 2014);
- USGS 08205500 Frio River near Derby, Texas (1915 – 2014); and
- USGS 08189700 Aransas River near Skidmore, TX (1964 – 2014).

Similar to precipitation and naturalized flow, gaged stream flow data were evaluated for trends by comparing statistics representative of the long-term, short-term, and recent periods.

4.2 Data Analysis

Hydrologic data were organized and statistical analyses were performed. For example, the precipitation data were summarized by month and plotted as time series for each station as shown in Figure 4.1. The 10-yr moving average was calculated for this data and added to the plot, as shown in Figure 4-2. Arithmetic means were then added to the plot for the three time periods being evaluated in this study. In Figure 4-3, the red line represents the long-term average; the green line represents the short-term average; and the purple line the recent average. Similar analyses were performed for each month at each location. These monthly analyses were also performed for naturalized flow and stream flow data.

The purpose of this analysis was to identify months in which the short-term and recent averages were different than the long-term average. As an example, in Figure 4-3, the recent July precipitation average (purple line) is about 4.5 inches, while the long-term and short-term averages are 2.5 – 3 inches. This difference indicates a potential shift in the data. Generally, if a potential shift was identified in one site for a variable, then that shift would be apparent at the other sites for the same variable. The short-term and recent averages were compared to the long-term averages for each variable (precipitation, naturalized flow, and stream flow) for each month at the selected locations. The entire period of record available for each variable was included in determining the long-term average. The comparison of the short-term and recent data for apparent shifts was made against the long-term average as well as looking at the 10-year moving averages of the same data.

As mentioned previously, arithmetic means were compared to identify potential shifts. A parallel analysis was also performed using medians for all data sets since mean data can be skewed by extreme outlier events (i.e. significant rainfall during a tropical event). The results using medians were similar to the results using means. While the long-term monthly median and mean values are not appreciably different in most instances, the short-term and recent values show more variability. This is likely due to the short lengths of time considered (11-29 years) for these periods. Therefore, since the results for means and medians are similar, only the results for the means are presented in this report. Tests of statistical significance were applied to confirm or reject the visual indications.

The Kolmogorov-Smirnov (K-S) test[5] was utilized to assess whether the apparent trends identified by looking at the statistics in the monthly hydrology are significant when the recent and short-term time periods are compared with the long-term time period. The K-S test is a general test of the equivalence of two distribution functions, and is based on the comparison of two empirical distribution functions. For this work, the empirical distribution functions are associated with the monthly values of precipitation, gaged stream flow, and naturalized flow (QNAT) for two different time periods under consideration. The null hypothesis that two different distributions are the same is rejected at the α level (e.g. 15%) when there is a confidence level of [1-α]. 15% was used as the threshold of statistical significance for this study.

Appendix C contains selected plots of the data compiled and analyzed as part of this study. This appendix also contains the numerical values from the K-S tests.

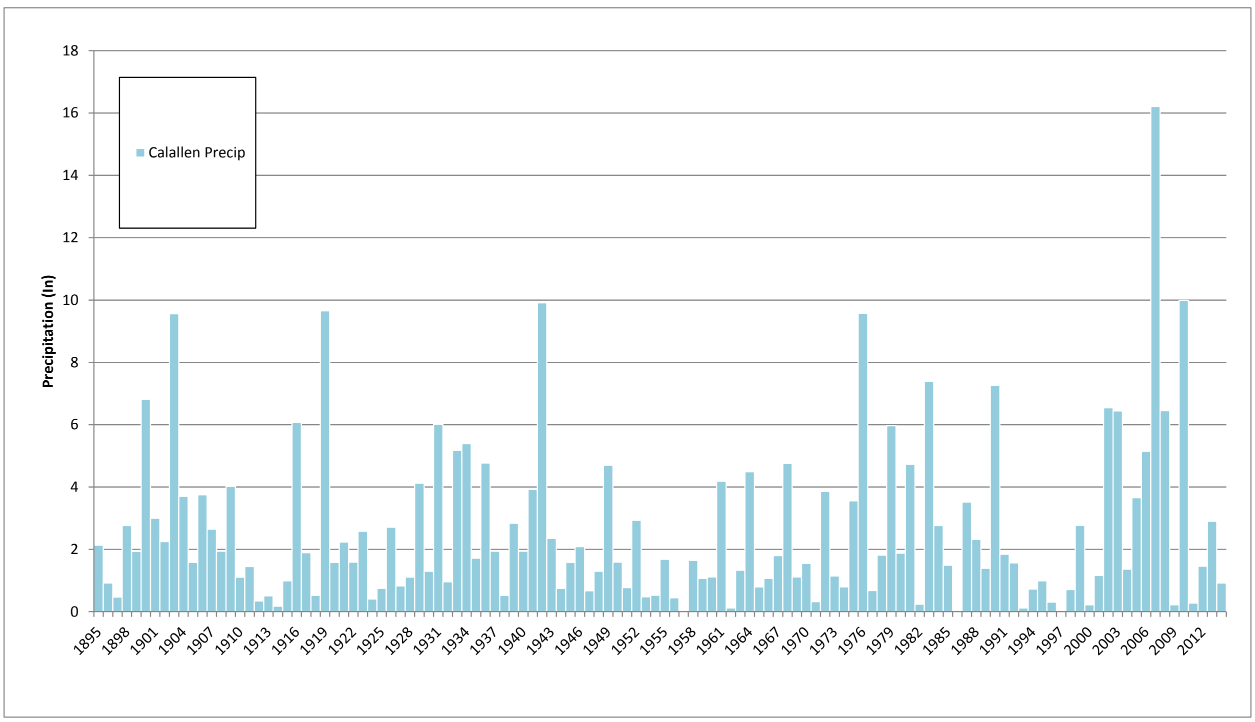


Figure 4 1. July Precipitation Totals near Calallen for 1895 - 2014

[5] http://www.itl.nist.gov/div898/handbook/eda/section3/eda35g.htm

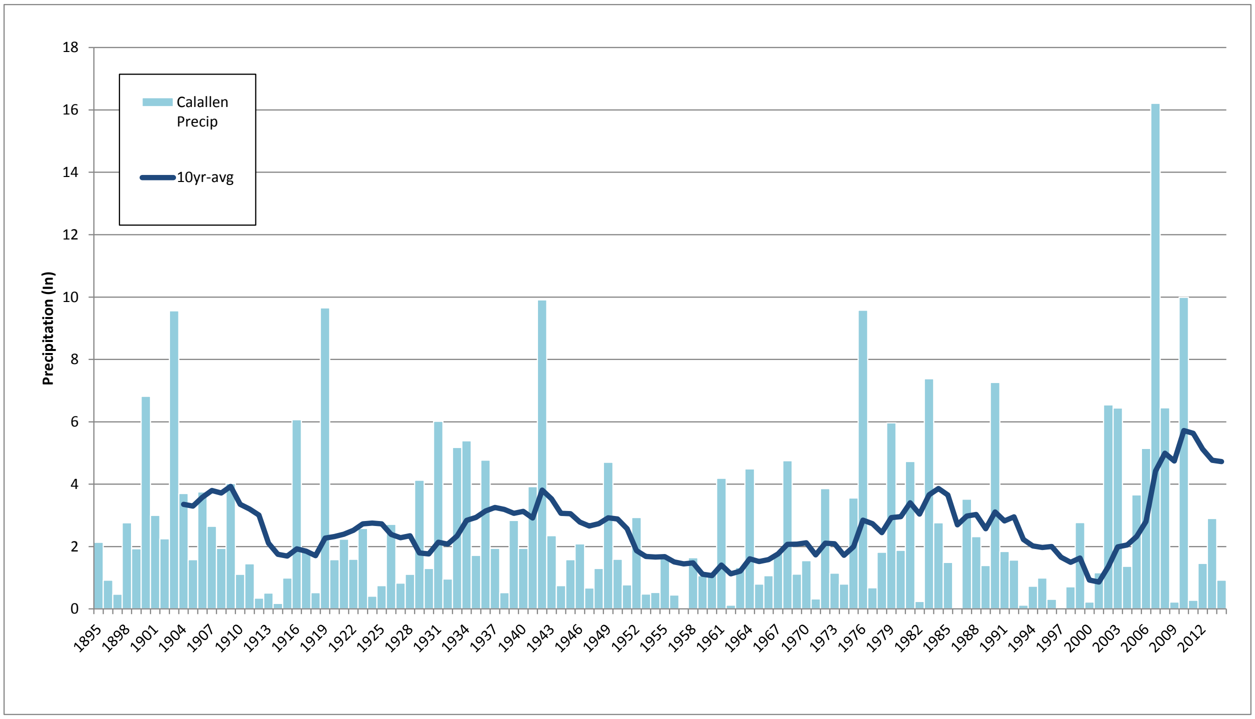


Figure 4-2. July Precipitation Totals and 10-year Moving Average near Calallen 1895 - 2014

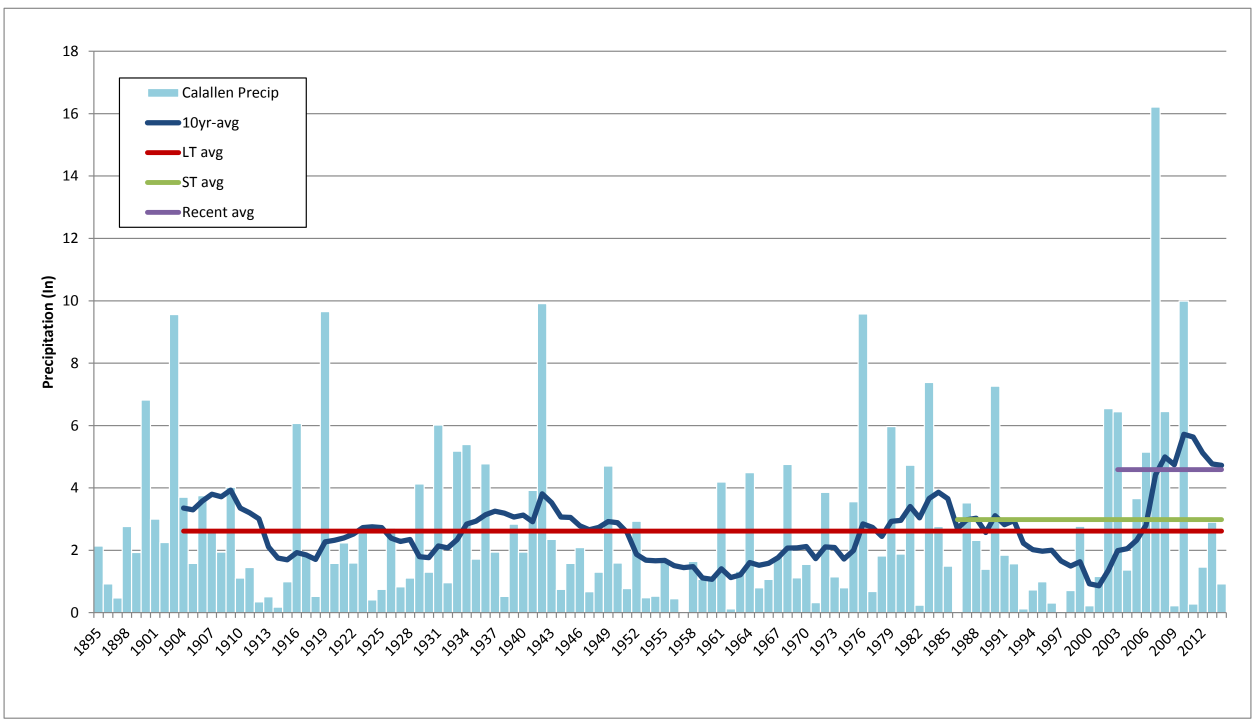


Figure 4-3. July Precipitation Totals and 10-year Moving Average near Calallen for 1895 – 2014 with Long-Term, Short-Term and Recent Trend Lines

Statistical significance was determined and used to verify potential shifts for each variable for the different time frames. Results are summarized in Table 4-1 and suggest that April, May, June, August, and December may be associated with a hydrological shift to drier conditions. Overall trends (drier, wetter, or no change) were determined by aggregating the results for precipitation, stream flow, and naturalized flow and making a determination based on engineering judgment. For example, a comparison of the means for the hydrologic variables for July indicates a potential hydrological shift to wetter conditions. In other words, all of the variables showed wetter shifts when looking at the means for July. However, after testing for statistical significance, only precipitation for the recent period and QNAT for the short-term period showed any actual significance. The resulting determination when looking at all the variables after a statistically significance test was no change compared to the long-term.

Based on these results, five of the months (April, May, June, August, and December) are shown to be trending drier than the long-term average. The other months are shown to have no significant trend either drier or wetter. Even though there have been record setting wet events in July during the recent and short-term periods, means associated with these periods are not significantly different from the long-term means. One interesting note is that most of the data that showed a wetter July also showed a return to drier than normal conditions over the last couple of years evaluated. This would seem to indicate, although more years of data will be needed to confirm, that the recent wetter Julys are part of a natural hydrological cycle and not a seasonal shift.

Table 4-1. Comparison of Recent (R) and Short-Term (ST) Hydrology with the Long-Term

Variable	Jan-ST	Jan-R	Feb-ST	Feb-R	Mar-ST	Mar-R	Apr-ST	Apr-R	May-ST	May-R	Jun-ST	Jun-R
Precipitation	↔	↑	↔	↔	↑	↔	↔	↓	↓	↓	↔	↔
Streamflow	↔	↓	↔	↔	↓	↓	↓	↔	↓	↔	↓	↓
QNAT	↔		↑		↑		↔		↔		↓	
Trend	No Change		No Change		No Change		Drier		Drier		Drier	

Variable	Jul-ST	Jul-R	Aug-ST	Aug-R	Sep-ST	Sep-R	Oct-ST	Oct-R	Nov-ST	Nov-R	Dec-ST	Dec-R
Precipitation	↔	↑	↓	↓	↓	↑	↓	↓	↔	↔	↔	↓
Streamflow	↔	↔	↓	↔	↔	↓	↔	↑	↔	↓	↓	↓
QNAT	↑		↔		↔		↓		↔		↔	
Trend	No Change		Drier		No Change		No Change		No Change		Drier	

Additional analyses were completed to look at the monthly contribution percentage to the annual totals for the same hydrologic parameters of precipitation, stream flow and naturalized flow. These results provide a slightly different perspective than the above analysis. These results are indicative of a potential shift in monthly contribution, but do not address the question of volume which the previously described analysis does.

Figure 4-4 compares the monthly contribution of precipitation near Calallen for the three time periods referenced in the study. This figure indicates that the months of July and September have been contributing more to the annual totals for the recent time period than has historically occurred for the long and short-term periods, while June and August have shown to be lower contributors.

Figure 4-5 which provides the same information for stream flow on the Nueces River near Tilden shows somewhat similar results. The lower June and higher July shifts are present in this data; however, the

August and September trends are not there with an October showing to be a bigger contributor for the recent period.

Figure 4-6 is the same information for naturalized flow at the Nueces near Mathis location, but as mentioned previously these data are only available for the long and short-term periods. These data generally align similar for most months but show some slight variation to lower contribution in May, June, September and October with higher November and December.

This methodology attempts to directly address whether the relative monthly percentages of annual inflow have changed in recent years. For precipitation and stream flow there is an indication that the data suggest a lower contribution for June and more of a contribution in July. This is similar to the findings of those shown in Table 4-1. When combined with the results from Table 4-1 the data suggest that recent periods have been drier with a slight shift away from June inflows to more potential inflows in July.

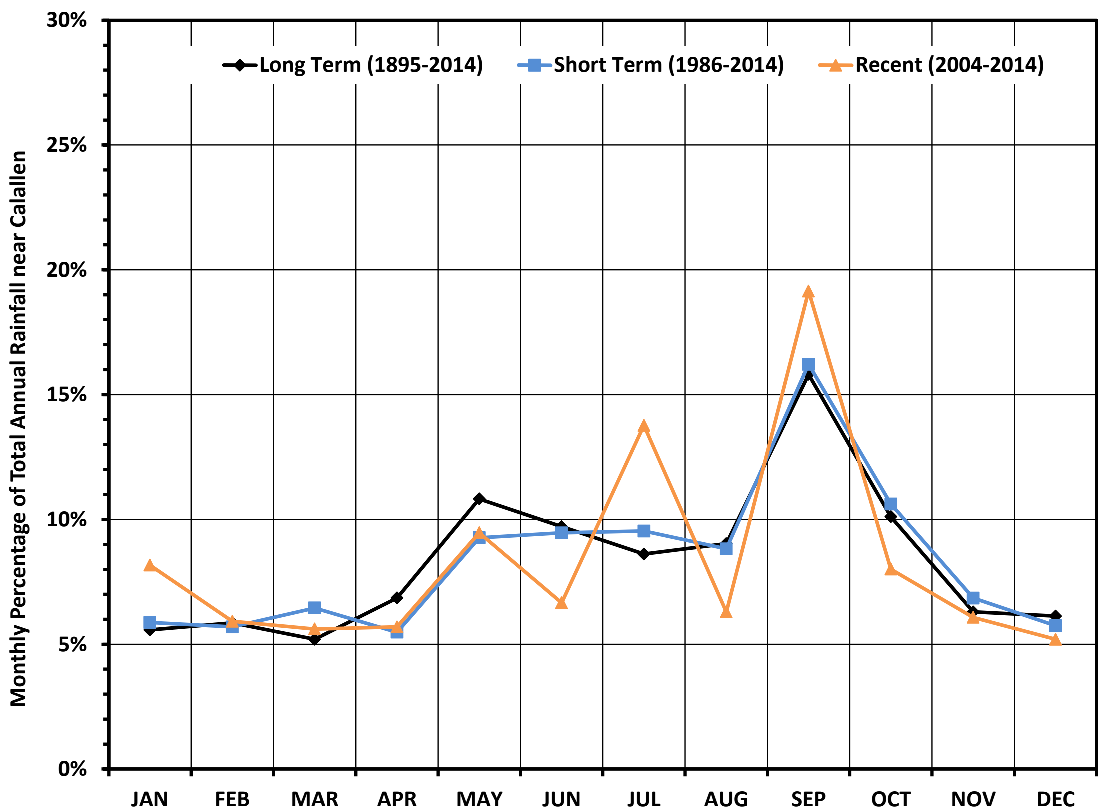


Figure 4-4. Comparison of Monthly Percentage of Annual Precipitation near Calallen

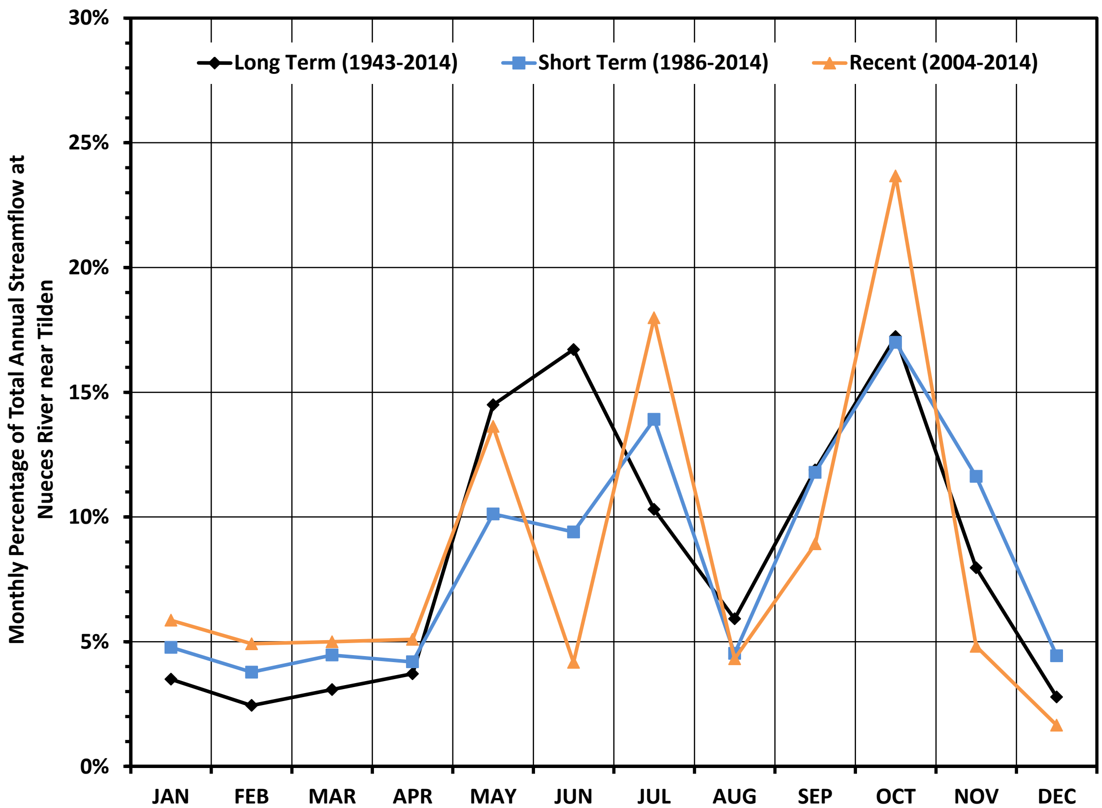


Figure 4-5. Comparison of Monthly Percentage of Annual Stream flow Nueces near Tilden

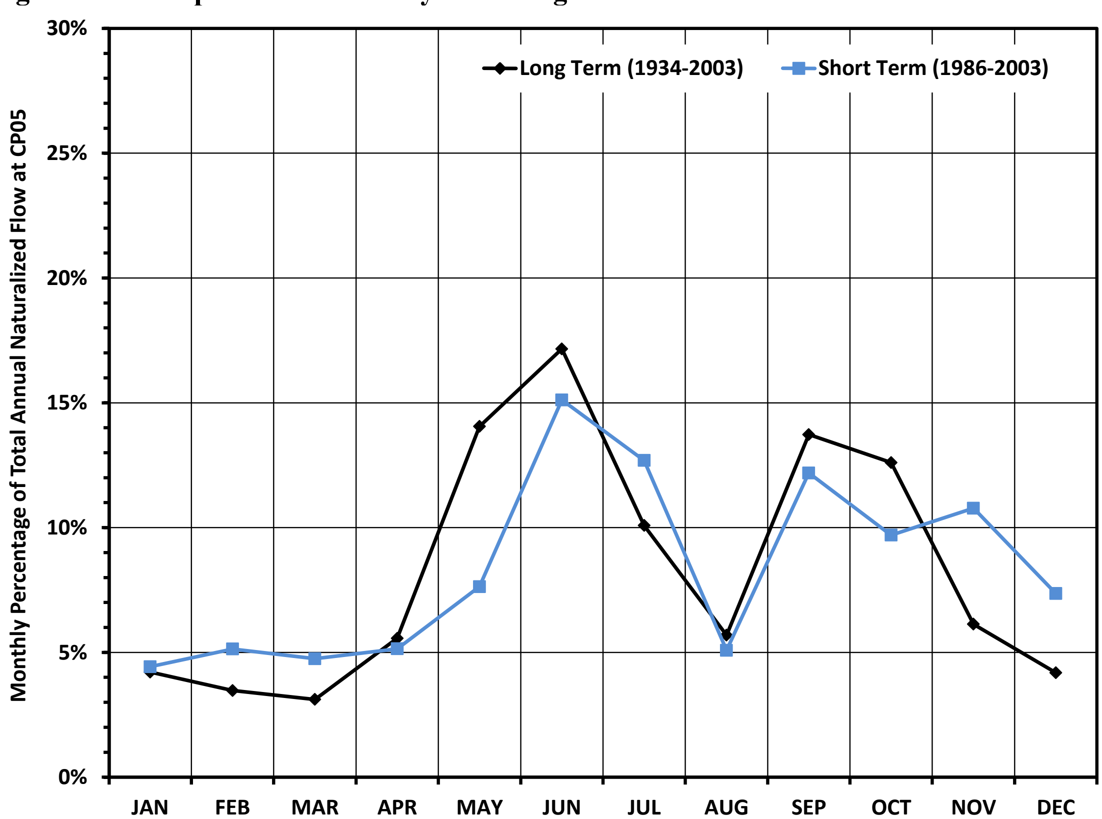


Figure 4-6. Comparison of Monthly Percentage of Annual Naturalized Flow for Nueces near Mathis

4.3 Data Evaluation

One of the goals of this study is to determine if different monthly pass-through targets associated with a seasonal shift in hydrology are a feasible alternative to the existing targets in the Agreed Order. A series of integrated water availability modeling analyses were conducted with the CCWSM to assess the relative implications of different alternative water management scenarios. These analyses are useful for consideration of the balance between water supply and environmental flow needs in the development of strategies involving the reservoir system, Nueces Bay inflows, and Rincon Bayou Pipeline operations.

Even thought the first part of this evaluation did not show statistically significant shifts that could be incorporated into a new set of recommended monthly pass-through targets, the findings of the analyses did influence the alternative scenarios discussed in the following text. Shifts in hydrology that indicate drier climatic conditions do not necessarily correlate to lowering targets. While targets can be lowered in one month to allow for a raise in another, lowering a target for a month that is trending drier will likely not have a large impact on either safe yield or FWI. This is because the targets are just that, targets and can only be met with inflows to the reservoir system and downstream runoff. If a month is trending drier, lowering the targets is not going to result in any significant change in FWI unless targets are drastically lowered, such that what inflow does occur can be kept in the reservoir for water supply. However, one key characteristic of drought in the Nueces River Basin is a severe lack of inflows. No inflows equates to no pass-throughs regardless of target amounts.

Three alternative reservoir operating scenarios (*Uniform*, *May-June-July (MJJ)*, and *April-May-June-July-August-December* (*AMJJAD)*) were developed and modeled as part of this study. These scenarios are all generally based on the same set of operating assumptions with only the volume and timing of the inflow targets in the Agreed Order being modified between simulations. While the baseline scenario utilizes monthly targets and trigger levels described in the 2001 Agreed Order, the other three scenarios presented in this section utilize monthly inflow targets that result in different bay inflow regimes. These scenarios were informed by the results of the trend analyses described in Section 4.2. Note that for all scenarios, the annual totals of the inflow targets remained the same, the zone definitions were not changed, and the zone 3 and 4 triggers and targets were not altered.

Table 4-2 summarizes the monthly inflow targets by zone for the 2001 Agreed Order, the baseline scenario for this study. Zone 1 is defined as system storage down to 70%. Zone 2 is defined as system storage between 70% and 40%, while zone 3 is 40%-30%. There are no pass through targets when the reservoir system drops below 30% of conservation capacity.

Table 4-2. Monthly Targets (acft) for *Baseline* Safe Yield Scenario

	Month	Target		Month	Target		Month	Target
Zone 1	*Jan*	2,500	Zone 2	*Jan*	2,500	Zone 3	*Jan*	1,200
	Feb	2,500		*Feb*	2,500		*Feb*	1,200
	Mar	3,500		*Mar*	3,500		*Mar*	1,200
	Apr	3,500		*Apr*	3,500		*Apr*	1,200
	May	25,500		*May*	23,500		*May*	1,200
	Jun	25,500		*Jun*	23,000		*Jun*	1,200
	Jul	6,500		*Jul*	4,500		*Jul*	1,200
	Aug	6,500		*Aug*	5,000		*Aug*	1,200
	Sept	28,500		*Sept*	11,500		*Sept*	1,200
	Oct	20,000		*Oct*	9,000		*Oct*	1,200
	Nov	9,000		*Nov*	4,000		*Nov*	1,200
	Dec	4,500		*Dec*	4,500		*Dec*	1,200
	TOTAL	138,000		*TOTAL*	97,000		*TOTAL*	14,400

Table 4-3 shows the same information for the Uniform scenario. In this scenario, the monthly target volumes are spread uniformly through the traditionally "wetter" months of April through Nov. Changes were applied to both the zone 1 and zone 2 values.

Table 4-3. Monthly Targets (acft) for *Uniform* Safe Yield Scenario

	Month	Target		Month	Target		Month	Target
Zone 1	*Jan*	1,500	Zone 2	*Jan*	1,250	Zone 3	*Jan*	1,200
	Feb	1,500		*Feb*	1,250		*Feb*	1,200
	Mar	1,500		*Mar*	1,250		*Mar*	1,200
	Apr	16,500		*Apr*	11,500		*Apr*	1,200
	May	16,500		*May*	11,500		*May*	1,200
	Jun	16,500		*Jun*	11,500		*Jun*	1,200
	Jul	16,500		*Jul*	11,500		*Jul*	1,200
	Aug	16,500		*Aug*	11,500		*Aug*	1,200
	Sept	16,500		*Sept*	11,500		*Sept*	1,200
	Oct	16,500		*Oct*	11,500		*Oct*	1,200
	Nov	16,500		*Nov*	11,500		*Nov*	1,200
	Dec	1,500		*Dec*	1,250		*Dec*	1,200
	TOTAL	138,000		*TOTAL*	97,000		*TOTAL*	14,400

Table 4-4 shows the monthly target information for the MJJ scenario, which stands for May, June, and July. The focus of this scenario is to move some of the higher May and June targets to July to attempt to capture any effects of the recent inconclusive trend showing July to be wetter than the long-term average. Changes were applied to both the zone 1 and zone 2 values.

Table 4-4. Monthly Targets (acft) for *MJJ* Safe Yield Scenario

	Month	Target		Month	Target		Month	Target
Zone 1	Jan	2,500	Zone 2	Jan	2,500	Zone 3	Jan	1,200
	Feb	2,500		Feb	2,500		Feb	1,200
	Mar	3,500		Mar	3,500		Mar	1,200
	Apr	3,500		Apr	3,500		Apr	1,200
	May	13,750		May	12,750		May	1,200
	Jun	13,750		Jun	12,500		Jun	1,200
	Jul	30,000		Jul	25,750		Jul	1,200
	Aug	6,500		Aug	5,000		Aug	1,200
	Sept	28,500		Sept	11,500		Sept	1,200
	Oct	20,000		Oct	9,000		Oct	1,200
	Nov	9,000		Nov	4,000		Nov	1,200
	Dec	4,500		Dec	4,500		Dec	1,200
	TOTAL	138,000		TOTAL	97,000		TOTAL	14,400

Table 4-5 shows the monthly target information for the AMJJAD scenario, which stands for April, May, June, July, August, and December. The focus of this scenario is to attempt to capture any effects of the recent trends showing some of these months to be drier while others are wetter than the long-term averages. Changes were applied to both the zone 1 and zone 2 values.

Table 4-5. Monthly Targets (acft) for *AMJJAD* Safe Yield Scenario

	Month	Target		Month	Target		Month	Target
Zone 1	Jan	2,500	Zone 2	Jan	2,500	Zone 3	Jan	1,200
	Feb	2,500		Feb	2,500		Feb	1,200
	Mar	3,500		Mar	3,500		Mar	1,200
	Apr	3,325		Apr	3,325		Apr	1,200
	May	22,950		May	21,150		May	1,200
	Jun	22,950		Jun	20,700		Jun	1,200
	Jul	12,875		Jul	10,275		Jul	1,200
	Aug	5,850		Aug	4,500		Aug	1,200
	Sept	28,500		Sept	11,500		Sept	1,200
	Oct	20,000		Oct	9,000		Oct	1,200
	Nov	9,000		Nov	4,000		Nov	1,200
	Dec	4,050		Dec	4,050		Dec	1,200
	TOTAL	138,000		TOTAL	97,000		TOTAL	14,400

Table 4-6 summarizes safe yields and annual Nueces Bay inflow statistics associated with the four scenarios as generated by simulation in the CCWSM. QBAY1 is the CCWSM output variable that relates to Nueces Bay inflow. As shown in the table, all the changes associated with evaluating these different scenarios are small for both safe yield and FWI. Generally, increases in safe yield result in reductions in the average and median annual Nueces Bay inflows.

Table 4-6. Modeling Results for Selected Scenarios

		Annual QBAY (acft/yr)		
Scenario	**Safe Yield (acft/yr)**	**Average**	**Median**	**Minimum**
Baseline	191,839	390,467	164,530	6,515
Uniform	195,145	387,520	164,930	6,515
MJJ	196,092	386,565	159,005	6,515
AMJJAD	192,525	389,814	166,319	6,515

Figures 4-7 through 4-15 below present system storage for the 1990s drought, storage frequency plots for the entire period of record, and monthly frequency of Nueces Bay inflow for each of the three evaluated scenarios compared to the baseline scenario. System storage is the combined storages of LCC and CCR; Lake Texana storage is not included in this system storage calculation. The plots illustrate the relatively minor changes that result from modifying the pass-through targets. Once again this illustrates how the system is driven by inflows and diversions, not the pass-through targets. The option to evaluate these results using the TWDB TxBLEND model was given in the scope of work. However, since the results were similar to the baseline run, this additional task was deemed to have little value for the study. However, small differences seen in the monthly bay inflows, depending on the time of year and weather conditions, could impact salinity in the Bay. The TxBLEND model may not capture the fine scale salinity changes that could make an impact on this ecosystem. Perhaps future studies could focus on fine scale salinity changes in the bay associated with smaller changes in monthly inflows.

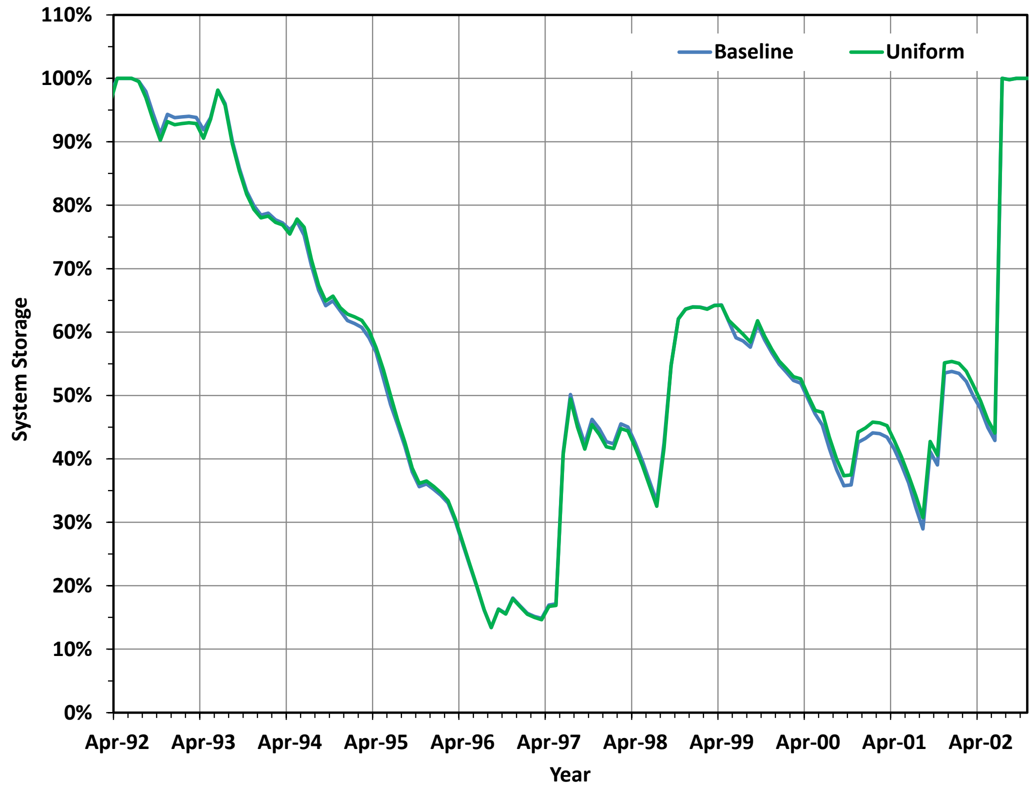


Figure 4-7. Storage Trace for Baseline and Uniform during 1990s Drought

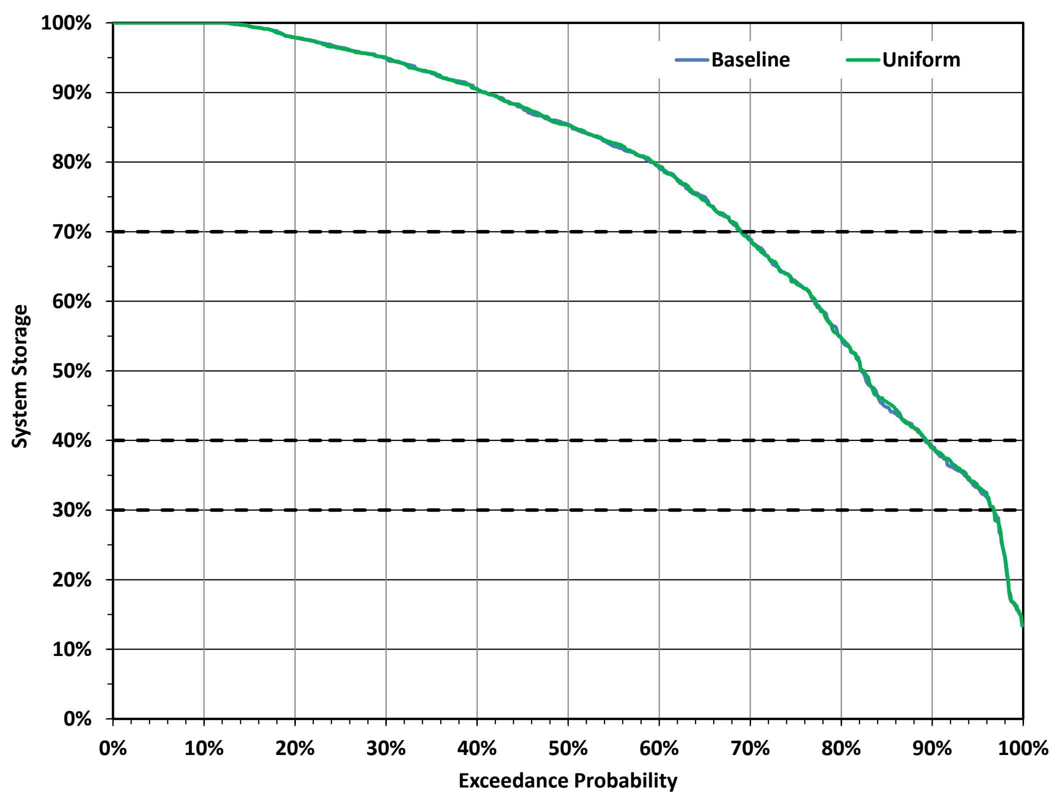


Figure 4-8. Storage Frequency for Baseline and Uniform (Dashed Lines = Trigger Levels)

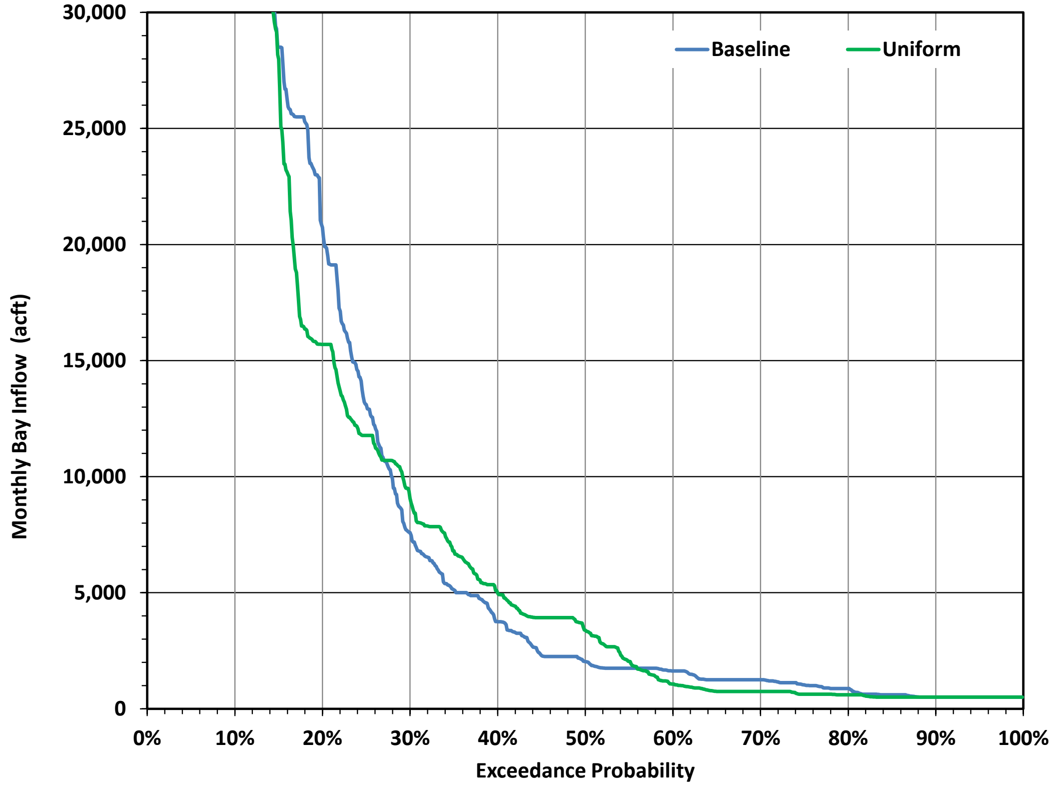


Figure 4-9. Monthly Bay Inflow Frequency for Baseline and Uniform

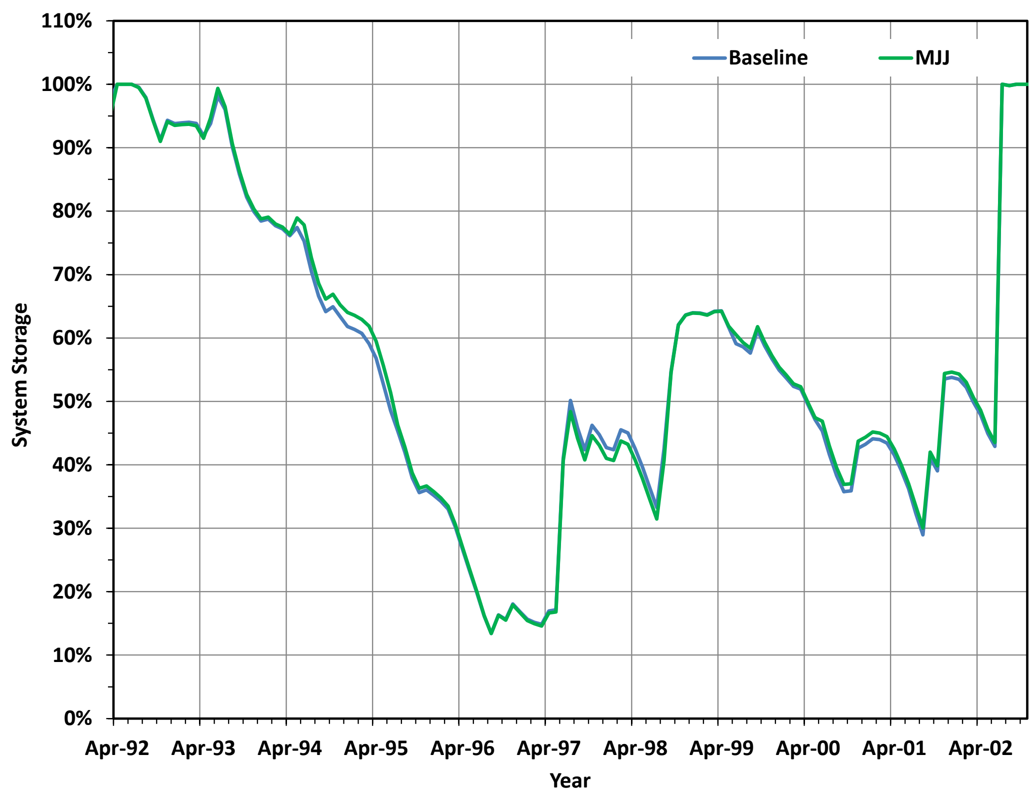


Figure 4-10. Storage Trace for Baseline and MJJ during 1990s Drought

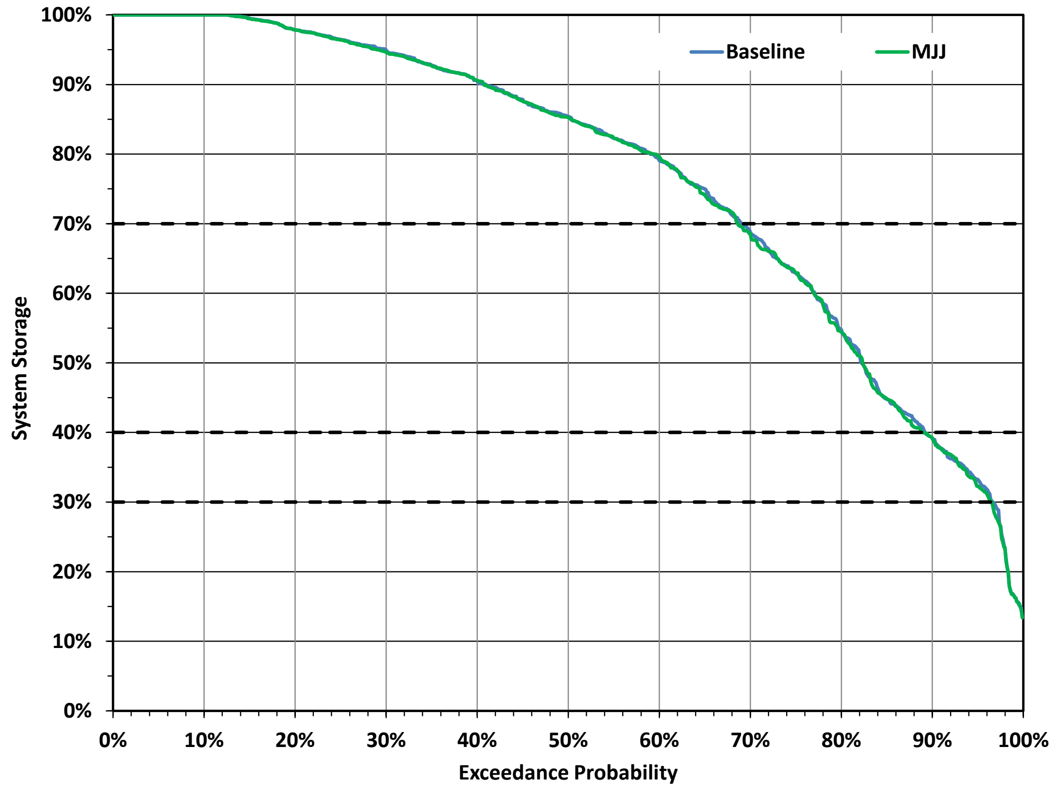


Figure 4-11. Storage Frequency Trace for Baseline and MJJ (Dashed Lines = Trigger Levels)

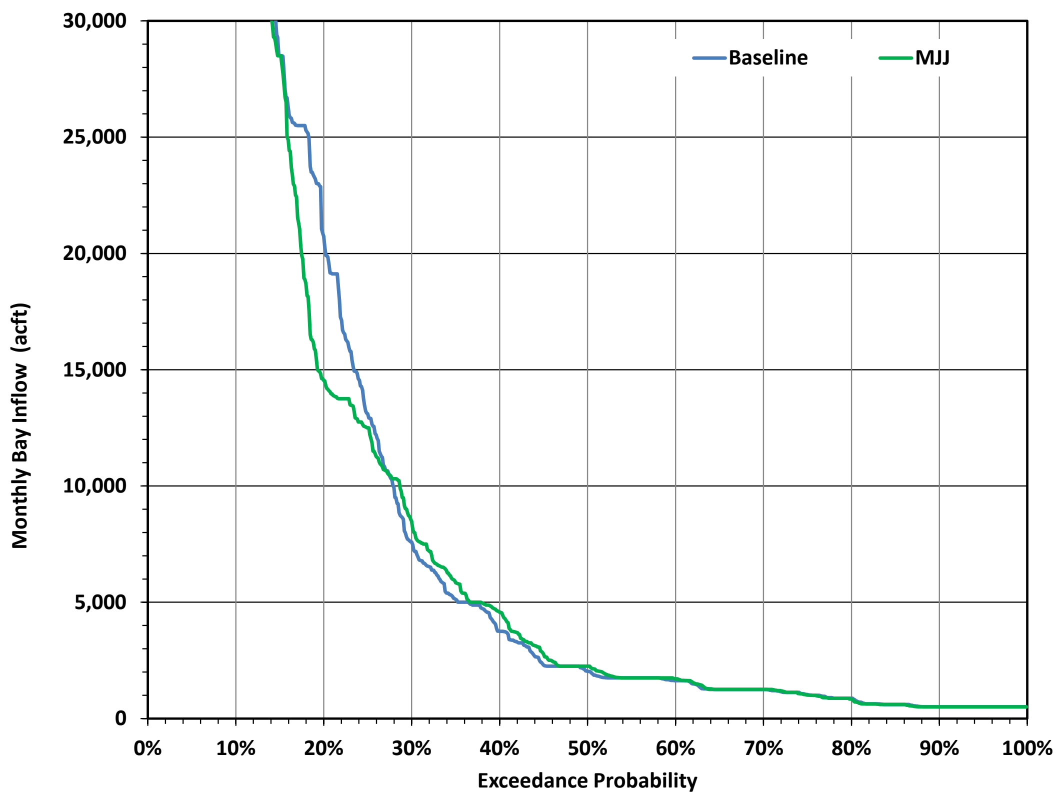


Figure 4-12. Monthly Bay Inflow Frequency for Baseline and MJJ

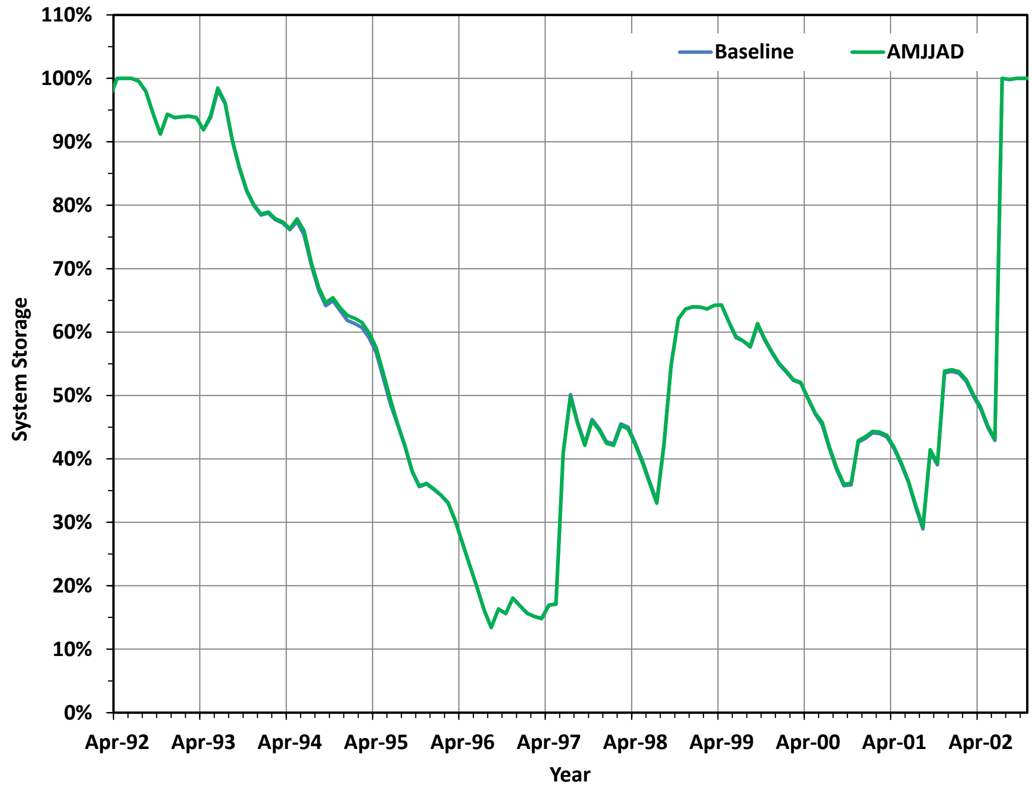


Figure 4-13. Storage Trace for Baseline and AMJJAD during 1990s Drought

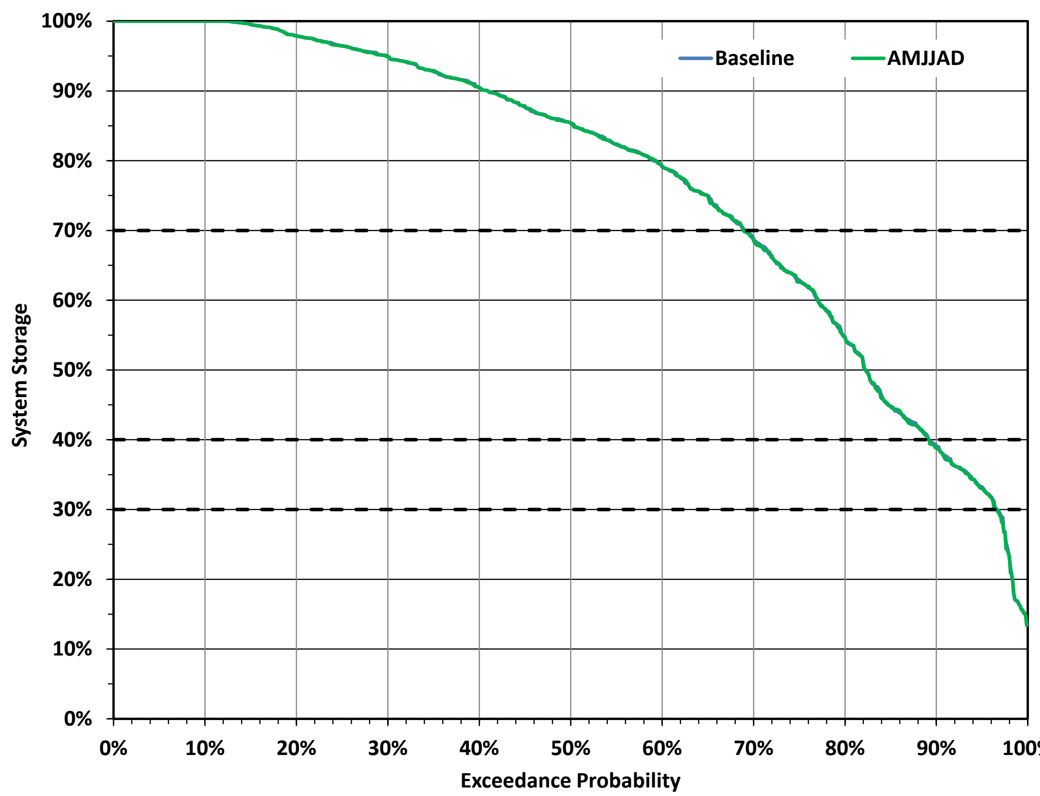


Figure 4-14 Storage Frequency Trace for Baseline and AMJJAD (Dashed Lines = Trigger Levels)

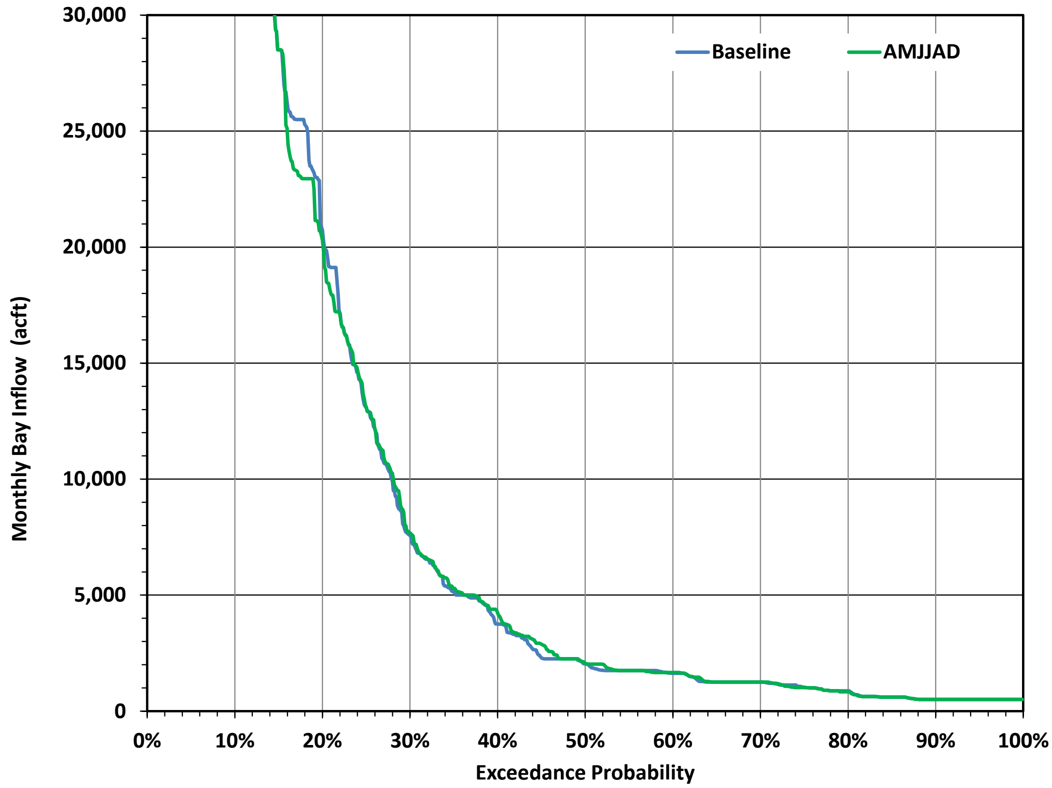


Figure 4-15. Monthly Bay Inflow Frequency for Baseline and AMJJAD

5 Comparison of Safe Yield versus Current Demand

One question that arose during the meetings of the Nueces BBASC was if the current drought (2010-2013) is resulting in such limited inflows to Nueces Bay, how much lower might these inflows have been if the system were under a full safe yield demand. The objective of Task 2 of this study is to provide quantitative analysis to illustrate the differences in FWI under two different demand scenarios. The results provide some general information that can be applied to the current drought even though this drought is not contained in the CCWSM.

The CCWSM was utilized to simulate the City water supply system under two different demand scenarios. The first scenario is the baseline (i.e. safe yield) with a demand of about 192,000 acft/yr, which leaves a minimum reserve storage of about 125,000 acft in the reservoir system during the drought of record. This is approximately the 2020 estimated safe yield of the CCR/LCC System without the use of Mary Rhodes Phase 2 Pipeline used in the 2016 Coastal Bend Region Initially Prepared Plan. The second scenario is the current demand scenario with a demand of 130,000 acft/yr on the water supply system. These scenarios were simulated subject to the following modeling assumptions.

- 2001 Agreed Order monthly targets and pattern
- Lake Texana deliveries via the Mary Rhodes pipeline
  - 41,840 acft/yr firm contract
  - 12,000 acft/yr interruptible contract when Lake Texana is above 43 ft-msl
- Municipal and industrial return flow to Nueces Bay

  - o 5.35 MGD (about 499 acft/mo) which counts towards meeting any monthly inflow target
- 2020 estimated storage conditions in all reservoirs

Safe yield supply is the amount of water that can be withdrawn from a reservoir such that a specific volume remains in reservoir storage during the critical month of the drought of record. For regional planning purposes, the surface water availabilities for the City of Corpus Christi and their customers are currently based on safe yield analyses and assume a reserve of 125,000 acft (i.e., 14 percent of LCC/CCR System conservation storage) remaining in storage.

The results of these simulations are summarized in the following figures and tables and focus on combined reservoir storage, freshwater inflows to Nueces Bay, and mass balance of the system. Figure 5-1 shows the combined storage trace of the reservoirs represented as percent of system conservation storage. The blue line represents the safe yield scenario and the green line represents the current demand scenario.

As expected, the blue line is lower during much of the simulation period as a result of the higher water supply demand on the system. This difference is most notable during periods of drought when reservoir system storage drops below 70% of capacity for extended periods of time. Figure 5-2 shows the same information, but focuses on the drought of record contained in the CCWSM which occurred in the 1990s. This graph shows that, as the drought progresses, the difference in storage increases because of the higher demand under the safe yield scenario. Figure 5-3 is the same information as Figure 5-1, but presented as a frequency plot. This plot shows the exceedance probability for system storage under the two demand scenarios. Dashed lines on this graph represent the triggers that separate the zones specified in the Agreed Order. This information is also presented in Table 5-1 for three time periods: 1986-2003, representing the period after CCR filled; 1934-1985, representing the period before CCR filled; and 1934-2003, representing the entire simulation period of the model. Figure 5-4 is the same information, but presented graphically comparing the two demands by time period showing the percent of time in each storage zone. Three things stand out from looking at these figures and this table. One is that the higher demand from the safe yield scenario results in system storage dropping into the lower zones whereas the current demand does not. Two is that the current period from 1986-2003 is drier than the entire period, as shown by the overall lower attainment frequencies. Three is that the pre-CCR period is wetter than the entire period of record shown by the overall higher attainment frequencies.

These plots show how the different demands relate to lake level, but this is not the entire picture that must be considered when looking at FWI to the bay. Higher system storage equals higher zone and higher targets, but without inflow these higher targets do not result in additional inflow to the bay.

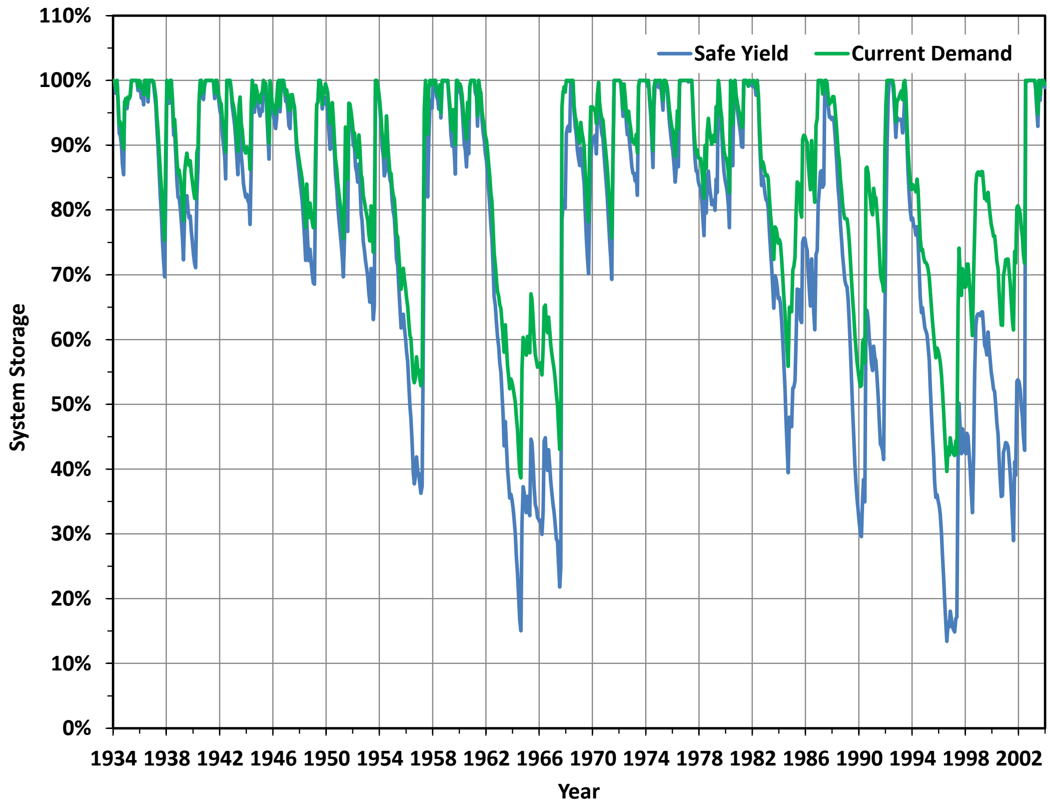


Figure 5-1. Storage Trace for Safe Yield and Current Demand scenarios

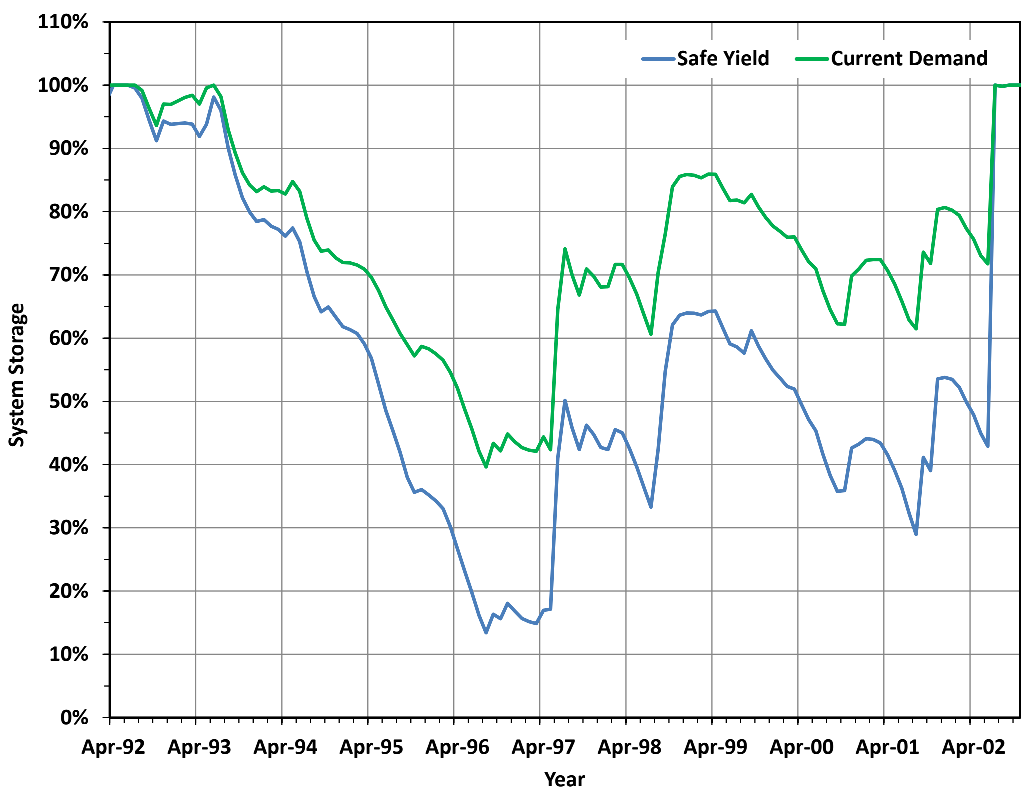


Figure 5-2. Storage Trace for Safe Yield and Current Demand Scenarios during 1990s Drought

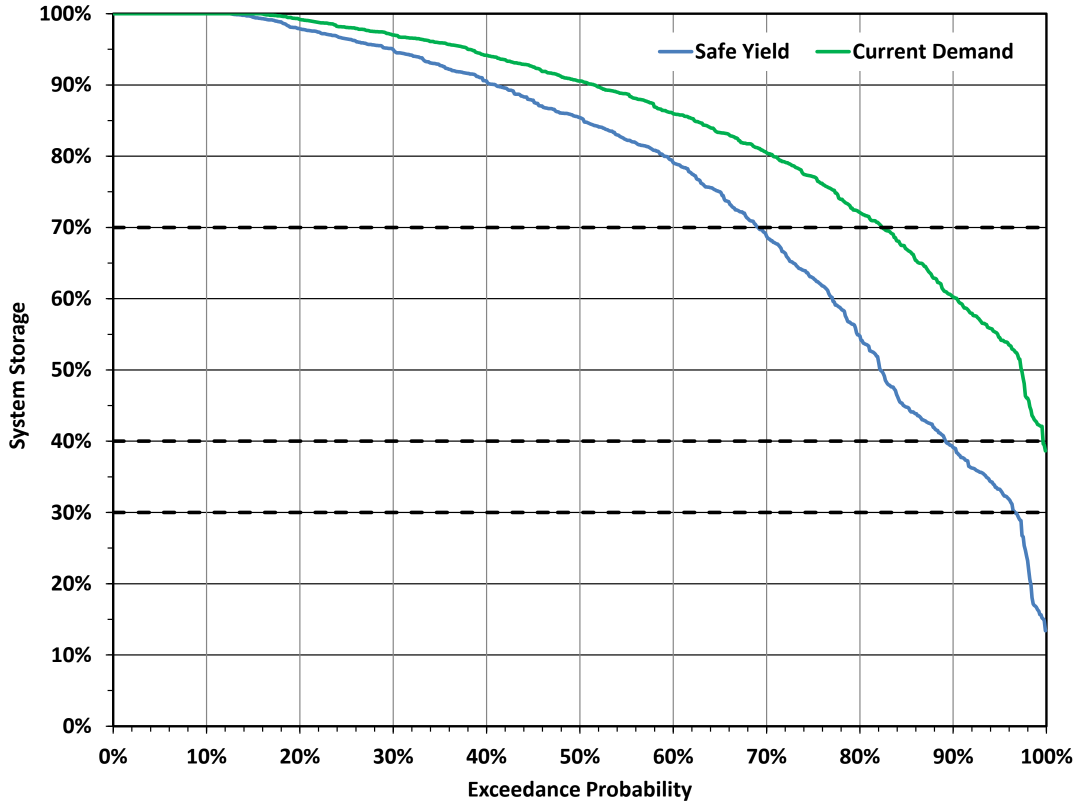


Figure 5-3. Monthly Storage Frequency for the CCR/LCC System for the Safe Yield and Current Demand Scenarios (Dashed Lines = Trigger Levels)

Table 5-1. Storage Zone Frequency for Safe Yield and Current Demand Scenarios

Scenario	Time Period	Storage Zone 1	Storage Zone 2	Storage Zone 3	Storage Zone 4
Safe Yield	1986-2003	36.6%	44.4%	11.6%	7.4%
Current Demand		72.2%	27.3%	0.5%	0.0%
Safe Yield	1934-1985	80.4%	11.7%	5.9%	1.9%
Current Demand		86.1%	13.6%	0.3%	0.0%
Safe Yield	1934-2003	69.2%	20.1%	7.4%	3.3%
Current Demand		82.5%	17.1%	0.4%	0.0%

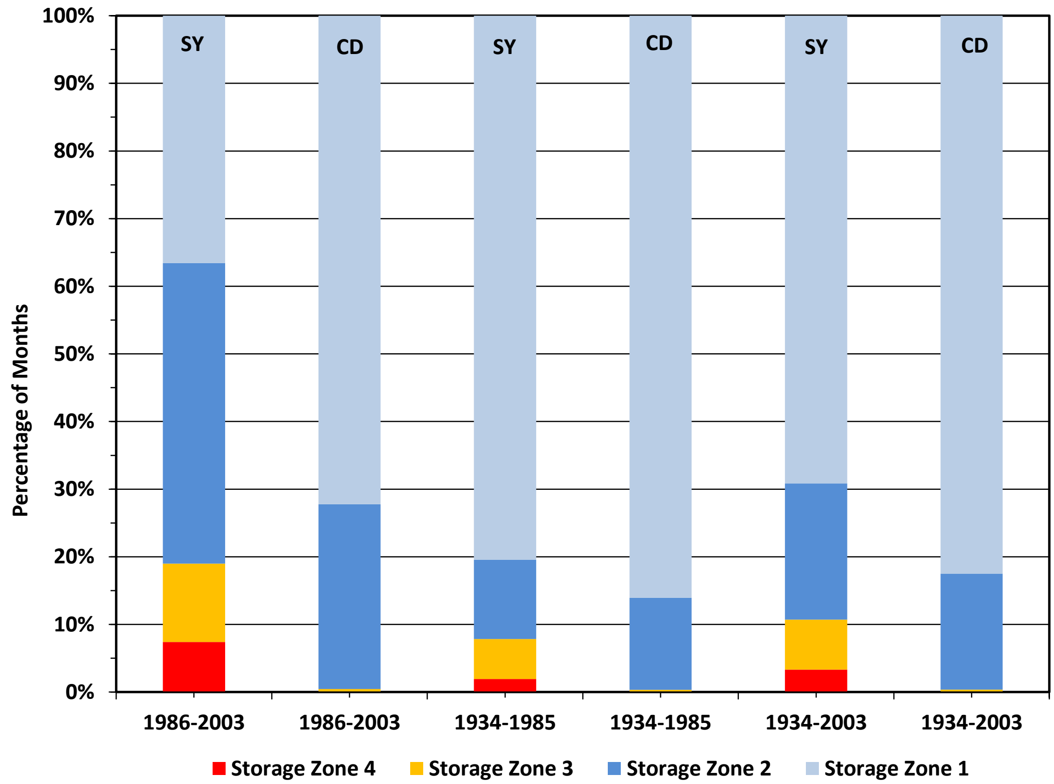


Figure 5-4. Storage Zone Frequency for Safe Yield (SY) and Current Demand (CD) Scenarios

The other metric evaluated in the comparison of current demand versus safe yield demand is the volume and frequency of inflow to Nueces Bay. Figure 5-5 is a frequency plot of the monthly bay inflows from the model output for the two scenarios. At this scale, the figure illustrates a system that is driven by short periods of high flows and long periods of low flows with another small period of moderate flows that provide opportunity to manage the system.

Table 5-2 lists target attainment frequency as a percent of time (months) and as a percent of target volume (annual target) for the three time periods for both scenarios. Monthly targets are met between 23% and 30% of the time for all time periods and scenarios. The table shows that the maximum annual target volume (138,000 acft/yr) is met between 33% and 62% of the time for all time periods and scenarios. The higher attainment frequencies in the table show that the 1934-1985 period was wetter than the 1986-2003 period. Note that this is due to the natural variation of the hydrologic cycle and not the construction of CCR, as CCR is included in the model runs as if it were constructed in 1934. As shown in the table, the monthly percent of time attainment frequencies are slightly higher for the safe yield scenario during the 1986 – 2003 time frame. Although counterintuitive at first, this is a result of the target levels dropping into lower zones more quickly during the dry times. In other words, during dry times, the safe yield scenario is more likely to meet targets because they are lower than the current demand scenario. This indicates that, even though system storage was higher and carried with it higher targets, the lack of inflows during dry periods resulted in only slight percentage differences in FWI to the bay.

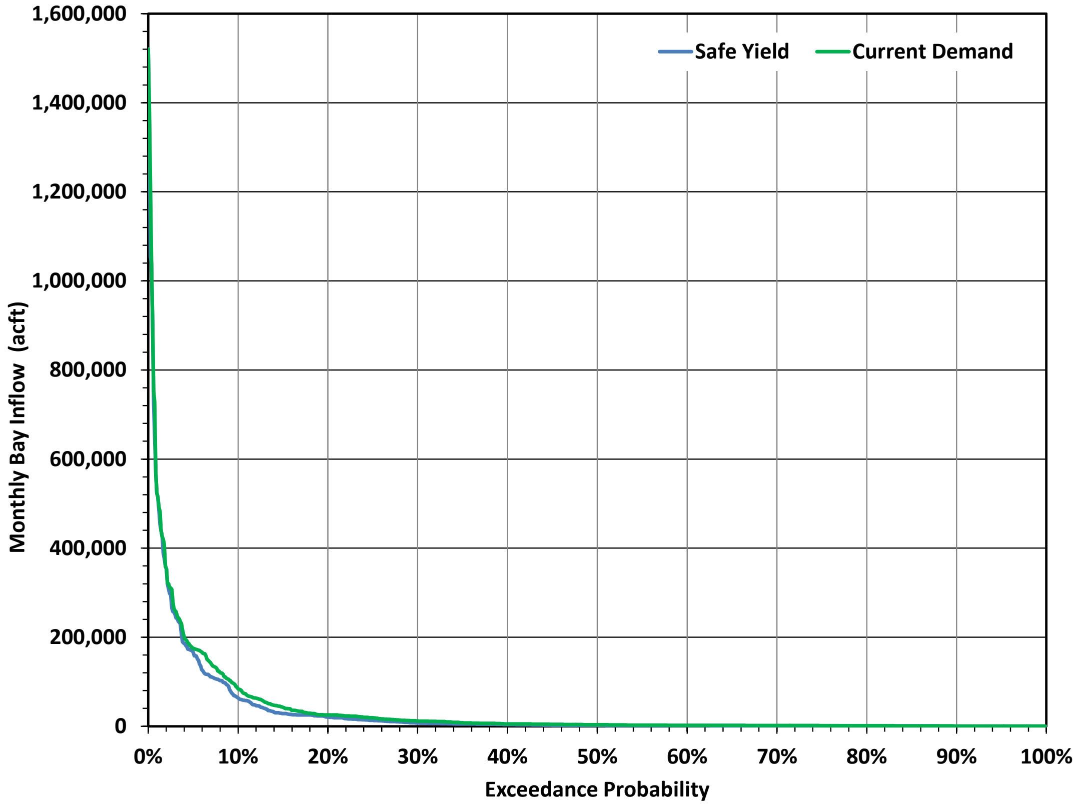


Figure 5-5. Frequency Plot of Monthly Bay Inflow

Table 5-2. Target Attainment Frequency for Safe Yield and Current Demand Scenarios

Scenario	Time Period	Target Attainment (% of months)	Target Attainment (% of Max Annual Target Volume - 138,000 acft)
Safe Yield	1986-2003	26.4%	33.3%
Current Demand		23.6%	33.3%
Safe Yield	1934-1985	27.6%	61.5%
Current Demand		32.2%	71.2%
Safe Yield	1934-2003	27.3%	54.3%
Current Demand		30.0%	61.4%

Figure 5-6 is the same information as Figure 5-5, but on an exaggerated scale covering the typical magnitude of the highest volume monthly targets. This graph illustrates the difference between the two scenarios when not dominated by high volume spill events. This figure shows that for both scenarios, about 60% of the time the simulated FWI is less than 5,000 acft/month. The differences between the two scenarios are driven by the lower demand leading to higher targets due to the higher lake levels resulting from lower overall demand. Through the steeper part of the curve, down to about 5,000 acft/month, there is about a 6% difference where the current demand would result in higher flows in about 6%, or less, of the months. Below 5,000 acft/mo are key months where the Rincon pipeline can be used to deliver smaller volumes of freshwater to the Rincon Bayou to maximize effectiveness of the freshwater releases.

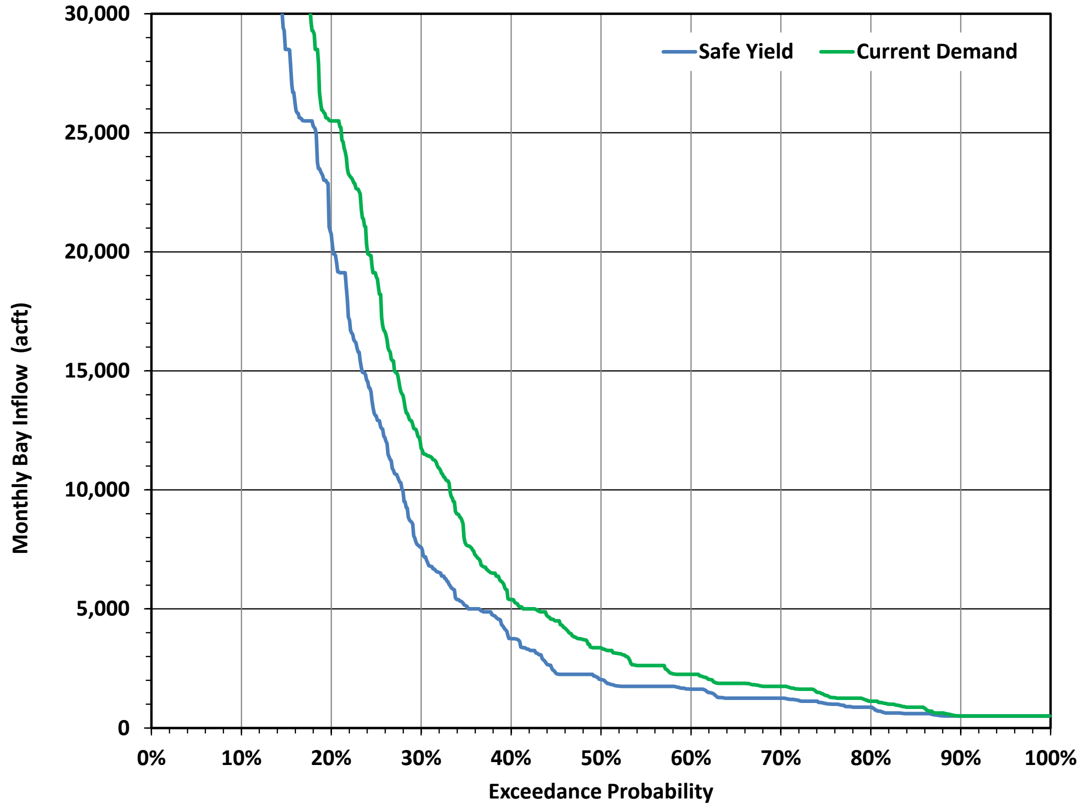


Figure 5-6. Frequency Plot of Monthly Bay Inflow (Zoomed Scale)

The CCWSM has the ability to calculate annual harvest for seven key species using the TWDB Nueces Harvest Equations[6] and simulated freshwater inflows subject to a selected demand or operational scenario. Such calculations are particularly relevant as the monthly targets in the Agreed Order are based, in part, on these harvest equations. Annual harvest calculations were performed for seven species using time series of simulated inflows for the two demand scenarios. Table 5-3 summarizes long-term average annual freshwater inflow and harvest for each of these species for the two demand scenarios and includes the adjusted coefficient of determination for each species harvest equation as an indication of predictive power.

[6] TWDB, "Values and Constraints for the TXEMP Model Used in the Freshwater Inflow Analysis of the Nueces Estuary," Technical Memorandum (Appendix in Freshwater Inflow Recommendation for the Nueces Estuary), August 2001.

Table 5-3. Long-Term Annual Average Freshwater Inflows and Harvest

			Average Harvest by Species							
Scenario	Demand (acft/yr)	Average Annual Freshwater Inflow to Nueces Estuary (acft)	White Shrimp Harvest (KLBS)	Brown Shrimp Harvest (KLBS)	Blue Crab Harvest (KLBS)	Southern Flounder Harvest (KLBS)	Black Drum Harvest* (KLBS)	Red Drum Harvest (KLBS)	Spotted Trout Harvest (KLBS)	Total Harvest* (KLBS)
Current Demand	130,000	567,849	775	939	241	48	172	58	77	2,138
Safe Yield	192,000	546,812	809	951	236	46	182	51	70	2,163
Percent Differences	47.7%	-3.7%	4.4%	1.3%	-2.1%	-4.2%	5.8%	-12.1%	-9.1%	1.2%
Adjusted coefficient of determination for Species Harvest Equations (Adj. R^2)			0.55	0.58	0.28	0.45	0.76	0.82	0.93	0.62

* Results for Black Drum were considered inconclusive and were excluded from the total harvest calculation. There are three years in the simulation where the harvest equations did not solve due to bounding conditions for the current demand scenario. If those three years are excluded from both scenarios, the average annual black drum harvest is 2.7% greater for the safe yield scenario.

Observations upon review of Table 5-3 include the following:

- Moving from current demand to full safe yield operations would increase firm water supply by 47 percent while decreasing long-term average annual freshwater inflow by 3.7 percent.
- Adjusted coefficients of determination for the species harvest equations range from 0.28 (Blue crab) to 0.91 (Spotted seatrout) indicating that the equations based on freshwater inflow explain between 28 percent and 91 percent of the variation in annual species harvest.[7] The average of the adjusted coefficients of determination is 0.62.
- Moving from current demand to full safe yield operations might be expected to result in increases in long-term average annual harvest of White shrimp (+4.4%) and Brown shrimp (+1.3%) and decreases in long-term average annual harvest of Blue crab (-2.1%), Spotted seatrout (-9.1%), and Red drum (-12.1%). Results for Black drum (although calculated as an increase of +5.8%) are considered inconclusive.
- In terms of thousands of pounds of long-term average annual harvest (excluding Black drum), moving from current demand to full safe yield operations might be expected to result in an increase on the order of 25 klbs (1,000 pounds) or 1.2 percent.

6 Conclusions / Recommendations

This report describes the analyses performed to achieve the goals of the study which are:

- Determine if a "shift" has occurred in CCR/LCC System inflows and what impact this "shift," if used to modify monthly targets in the Agreed Order, might have on safe yield and FWI to Nueces Bay (Task 1).
- Compare FWI to Nueces Bay resulting from a safe yield demand of 192,000 acft/yr to a current demand of 130,000 acft/yr on the CCR/LCC System (Task 2).

[7] Ibid. TWDB, August 2001.

For Task 1, hydrologic data was compiled and analyzed to identify any changes in monthly patterns potentially indicating that a shift, or redistribution, of Agreed Order monthly targets for bay inflow might be appropriate. Conclusions of these statistical and modeling analyses are summarized as follows.

- Some of the data provided an indication of wetter Julys for the recent period. However, the visual trends in the data were not statistically significant to indicate a wetter July shift. In fact, no months exhibited wetter short-term or recent period averages that are statistically significant. The observed change could be due to natural variation in the hydrologic variables (i.e. random chance).
- The months of April, May, June, August, and December did show short-term and recent reductions in precipitation and flow indicating drier conditions than the long-term average.
- Overall, the short-term period (1986-2014) showed to be generally drier than the long-term average.
- Short-term and recent drier conditions do not suggest lowering of the Agreed Order targets since the target can only be met by passing inflows. If it is truly dry then there are generally limited inflows to pass.
- The data do show a potential difference in monthly contribution for some of the months when looking at precipitation and stream flow. The data presented indicate less contribution in June and more in July when looking at precipitation and stream flow, which appears to be a shift from historical patterns. The data also suggest less contribution in August with more in the fall, but these are not a shift as much as they appear to be a strengthening of an existing pattern.
- Three alternative monthly pass-through target scenarios were evaluated to determine the potential effects of modifying the Agreed Order monthly targets on safe yield and FWI.
- Changes associated with evaluating these different scenarios are small for both safe yield and FWI. Generally, increases in safe yield result in reductions in average and median annual Nueces Bay inflows. Each scenario including modification of monthly Agreed Order pass-through targets resulted in increased safe yield and decreased FWI.
- While the analysis does not suggest a need to change the Agreed Order targets to accommodate a shift in the in the monthly occurrence of inflows, there is potential for modifying the Agreed Order targets with potential benefits to safe yield and limited impact to freshwater inflows to Nueces Bay.

For Task 2, the CCWSM was used to simulate operations and FWI under current and safe yield demands and the model output was evaluated in terms of system storage levels and FWI to Nueces Bay. These analyses resulted in the following conclusions.

- Higher (safe yield) system demands result in lower system storage levels and more time spent in zones with lower pass-through targets as defined by the Agreed Order.
    - However, the lower (current) demand scenario does not result in significantly higher attainment frequencies (months and volume) of FWI during the driest times. Since the Nueces system seems to be driven by extreme wet and dry times, the higher pass-through targets (resulting from lower demand and higher lake levels) are not met because the Nueces watershed does not generate much inflow during dry times.

- Freshwater inflows to Nueces Bay could be reduced as water use from the CCR/LCC System approaches safe yield. Such reductions in FWI, however, are not necessarily indicative of equivalent percentage reductions in average annual fisheries harvest. As described in Section 5, moving from current demand to full safe yield operations would increase firm water supply by 47 percent while decreasing long-term average annual freshwater inflow by 3.7 percent and potentially increasing overall pounds of commercial harvest of key species.
- In addition, this comparison of different demand scenarios reflects neither the potential increases in effluent entering the estuarine system with increases in demand nor the incremental ecological benefits of freshwater diversions to the Nueces delta through the Rincon pipeline and the Rincon diversion canal.

Following is a list of recommendations for additional study specifically focused on Agreed Order pass-through targets, system operations, and FWI to the bay.

- Additional studies looking at adaptive management opportunities should be performed prior to any potential updates to the Agreed Order. The pass-through targets in the Agreed Order are static in that there is no flexibility to pass-through May or June target deficits when significant inflows occur in July. What this study has shown is that the targets can be adjusted with potential benefit to safe yield and limited impact to FWI. Additional investigation might examine how the Agreed Order could be adapted to provide needed relief during short-duration drought episodes. Operations of the Rincon Bayou pipeline, which brings freshwater into the delta, illustrates how adaptive management can provide significant benefit with modest quantities of water.
- As shown in the hydrologic data compiled for this study, the period of 2004 – 2014 contains a wide variety of both wet and dry events. None of these events are included in the period of record hydrology for the CCWSM. The CCWSM should be updated to include this data to better evaluate system operations during these extreme events. This would also allow for the trend analysis to be completed for the QNAT beyond 2003.

A copy of the original scope of work is contained in Appendix D. A copy of the TWDB comments received on the Final Draft Report is contained in Appendix E. The responses to the comments are contained in Appendix F.

7 References

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

HDR, *Water Availability in the Nueces River Basin*, Texas Natural Resource Conservation Commission, October 1999.

HDR, *Water Supply Update for City of Corpus Christi Service Area*, City of Corpus Christi, January 1999.

HDR and Geraghty & Miller, Inc., *Nueces River Basin Regional Water Supply Planning Study*, Nueces River Authority, City of Corpus Christi, Edwards Underground Water District, South Texas Water Authority, Texas Water Development Board, May 1991.

HDR, Naismith Engineers, Inc., Shiner, Moseley, & Associates, Inc., and University of Texas Marine Science Institute, *Nueces Estuary Regional Wastewater Planning Study, Phase I*, City of Corpus Christi, Port of Corpus Christi Authority, Corpus Christi Board of Trade, South Texas Water Authority, Texas Water Development Board, November 1991.

HDR, Naismith Engineers, Inc., and University of Texas Marine Science Institute, *Nueces Estuary Regional Wastewater Planning Study, Phase II*, City of Corpus Christi, Port of Corpus Christi Authority, Corpus Christi Board of Trade, South Texas Water Authority, Texas Water Development Board, June 1993.

Texas Commission on Environmental Quality (TCEQ), Agreed Order Establishing Operational Procedures Pertaining to Special Condition B, Certificate of Adjudication No. 21-3214, Held by City of Corpus Christi, et al., April 28, 1995.

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team (Nueces BBEST), *Environmental Flows Recommendations Report: Final Submission to the Environmental Flows Advisory Group, Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholders Committee, and Texas Commission on Environmental Quality*, October 2011.

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholders Committee (Nueces BBASC), *Environmental Flow Standards and Strategies Recommendations Report: Final Submission to the Environmental Flows Advisory Group and Texas Commission on Environmental Quality*, August 2012.

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholders Committee (Nueces BBASC), *Work Plan for Adaptive Management: Submission to the Environmental Flows Advisory Group and Texas Commission on Environmental Quality*, November 2012.

APPENDIX A – 2001 TCEQ Agreed Order

This Page Intentionally Left Blank

FILE

TEXAS NATURAL RESOURCE CONSERVATION COMMISSION

WATER

APR 0 5 2001

ADMINISTRATION

SCANNED DATE May 2001 BOX # 16 F3

AN AGREED ORDER Amending the operational procedures and continuing an Advisory Council pertaining to Special Condition 5.B., Certificate of Adjudication No. 21-3214; Docket No. 2001-0230-WR

On April 4, 2001, came to be considered before the Texas Natural Resource Conservation Commission ("Commission") the Motion by the City of Corpus Christi and Nueces River Authority for the adoption of an amendment to the Agreed Order issued April 28, 1995, establishing operating procedures pertaining to Special Condition 5.B., Certificate of Adjudication No. 21-3214, held by the City of Corpus Christi, the Nueces River Authority, and the City of Three Rivers" (the two cities and river authority shall be referred to herein as "Certificate Holders"). The Certificate Holders and the Executive Director of the Texas Natural Resource Conservation Commission have agreed to the provisions of this Agreed Order.

The City of Corpus Christi (managing entity) requests that Section 2 of this Agreed Order be amended to add further detail to the provisions regarding the use of water for bays and estuaries and to make changes in the required passage of inflows for the bays and estuaries automatic at 40 percent and 30 percent of total reservoir system capacity upon institution of mandatory outdoor watering restrictions. Additionally, Certificate Holders request the most recent bathymetric surveys be used for determining reservoir system storage capacity. The Certificate Holders request details be added regarding provisions for two projects to enhance/augment the amount of freshwater going into the receiving estuary and timelines for those projects.

After considering the proposals and the presentations of the parties, the Commission finds that it has authority to establish operational procedures under Special Condition 5.B. of Certificate of Adjudication No. 21-3214, and that operational procedures previously established should be amended. The Commission finds that, because of the need to continue to monitor the ecological environment and health of related living marine resources of the estuaries to assess the effectiveness of freshwater inflows provided by requirements contained in this Agreed Order relating to releases and spills from Choke Canyon Reservoir and Lake Corpus Christi (collectively referred to as the Reservoir System), as well as return flows, and to evaluate potential impacts which may occur to the reservoirs as well as to the availability of water to meet the needs of the Certificate Holders and their customers which may result from those operational procedures, the existing advisory council should be maintained to consider such additional information and related issues and to formulate recommendations for the Commission's review.

The Commission additionally finds that based on the preliminary application of the Texas Water Development Board's Mathematical Programming Optimization Model, (GRG-2), 138,000 acre-feet of fresh water is necessary to achieve maximum harvest in the Nueces Estuary; and, therefore, when water is impounded in the Lake Corpus Christi-Choke Canyon Reservoir System to the extent greater than 70 percent of the system's storage capacity, the delivery of 138,000 acre-feet of water to Nueces Bay and/or the Nueces Delta, by a combination of releases and spills, together with diversions and return flows noted below, should be accomplished; and that during periods when the reservoir system contains less than 70 percent storage capacity, reductions in releases and spills, along with diversions and return flows, are appropriate in that a satisfactory level of marine harvest will be sustained and the ecological health of the receiving estuaries will be maintained.

The Commission finds that return flows, other than to Nueces Bay and/or the Nueces Delta, that are delivered to Corpus Christi Bay and other receiving estuaries are currently in the assumed mount of 54,000 acre-feet per annum (per calendar year), and that they shall be credited at this amount until such time as it is shown that actual return flows to Corpus Christi Bay and other receiving estuaries exceed 54,000 acre-feet per annum.

The Commission finds that by contractual relationships, the City of Corpus Christi is the managing entity for operating the Reservoir System.

The Commission finds that the Motion by the City of Corpus Christi and Nueces River Authority to Amend this Agreed Order is reasonable and should be granted. Benefits of the proposed diversion project and operating changes will include increased water supply, increased reservoir storage levels, increased positive flow events for Rincon Bayou and the upper Nueces Delta, increased sources of nitrogen for the upper delta, and lower salinity levels in the upper delta.

When the Commission uses the word "release" in this Order, release means spills, inflow passage, intentional releases, and return flows; provided, however, under this Order no release from storage is required to meet conditions of this Order.

By consenting to the issuance of this Agreed Order, no party admits or denies any claim, nor waives with respect to any subsequent proceeding any interpretation or argument which may be contrary to the provisions of this Agreed Order.

NOW, THEREFORE, BE IT ORDERED BY THE TEXAS NATURAL RESOURCE CONSERVATION COMMISSION THAT:

1. a. The City of Corpus Christi, as operator of the Choke Canyon/Lake Corpus Christi reservoirs (the "Reservoir System"), shall provide not less than 151,000 acre-feet of water per annum (per calendar year) for the estuaries by a combination of releases and spills from the Reservoir System at Lake Corpus Christi Dam and return flows to Nueces and Corpus Christi Bays and other receiving estuaries (including such credits as may be appropriate for diversion of river flows and/or return flows to the Nueces Delta and/or Nueces Bay), as computed and to the extent provided for herein.

   b. When water impounded in the Reservoir System is greater than or equal to 70 percent of storage capacity, a target amount of 138,000 acre-feet is to be delivered to Nueces Bay and/or the Nueces Delta by a combination of releases and spills from

Delta. Inflow passage from the Reservoir System for the purpose of compliance with the monthly targeted amounts prescribed in subparagraphs 1.b. and 1.c. shall in no case exceed the estimated inflow to Lake Corpus Christi as if there were no impoundment of inflows at Choke Canyon Reservoir. The estimated inflow to Lake Corpus Christi as if there were no impoundment of inflows at Choke Canyon Reservoir shall be computed as the sum of the flows measured at the U.S. Geological Survey (USGS) STREAMFLOW GAGING STATIONS ON THE Nueces River near Three Rivers (USGS No. 08210000), Frio River at Tilden, Texas (USGS No. 08206600), and San Miguel Creek near Tilden, Texas (USGS No. 08206700) less computed releases and spills from Choke Canyon Reservoir.

e. The passage of inflow necessary to meet the monthly targeted allocations may be distributed over the calendar month in a manner to be determined by the City. Relief from the above requirements shall be available under subparagraphs (1) or (2) below and Section 2.(b) and 3.(c) at the option of the City of Corpus Christi. However, passage of inflow may only be reduced under one of those subparagraphs below, for any given month.

(1) Inflows to Nueces Bay and/or the Nueces Delta in excess of the required monthly targeted amount may be credited for up to fifty (50) percent of the targeted requirement for the following month, based on the amount received.

(2) When the mean salinity in Upper Nueces Bay (Lat. 27°51'02", Long. 97°28'52") for a 10-day period, ending at any time during the calendar month for which the reduction of the passage of inflow is sought, is below the SUB*, pass through of inflow from the reservoir system for that same calendar month may be reduced as follows:

(a) For any month other than May, June, September and October, if 5 parts per thousand (ppt) below the SUB for the month, a reduction of 25% of the current month's targeted Nueces Bay inflow;

(b) If 10 ppt below the SUB for the month, a reduction of 50 % of the current month's targeted Nueces Bay inflow except that credit under this provision is limited to 25 % during the months of May, June, September and October;

* "SUB" means "salinity upper bounds" as set forth more specifically in Section 3.b.

(c) If 15 ppt below the SUB for that month, a reduction of 75% of the current month's targeted Nueces Bay inflow.

f. The City of Corpus Christi shall submit monthly reports to the Commission containing daily inflow amounts provided to the Nueces Estuary in accordance with this Agreed Order through releases, spills, return flows and other freshwater inflows.

2. a. Certificate holders are to provide in any future contracts or any amendments, modifications or changes to existing contracts the condition that all wholesale customers and any subsequent wholesale customers shall develop and have in effect a water conservation and drought management plan consistent with Commission rule. The City of Corpus Christi shall solicit from its customers and report to the Commission annually the result of conservation under the City's plan, the customers' plans, and the feasibility of implementing conservation plans and programs for all users of water from the reservoir system. This report shall be submitted with the Certificate Holder's annual water use report as provided by 31 T.A.C. §295.202.

b. The Certificate Holders may reduce targeted Nueces Bay inflows during times of prolonged drought in accordance with this subparagraph 2.

(1) When the combined storage in the Choke Canyon/Lake Corpus Christi reservoir system (Reservoir System Storage) falls below 50% of the total system storage capacity, the City of Corpus Christi shall issue public notice advising and informing the water users of the region of voluntary conservation measures that are requested immediately and required drought management measures to be taken should the Reservoir System Storage fall to under 40% and/or 30% of total system storage capacity. To the extent of its legal authority, the City of Corpus Christi shall require its wholesale customers to issue public notice advising and informing the water users of the region of voluntary conservation measures that are requested immediately and required drought management measures to be taken should the Reservoir System Storage fall to under 40% and/or 30% of total system storage capacity.

(2) In any month when Reservoir System Storage is less than 40%, but equal to or greater than 30% of total system storage capacity, the City of Corpus Christi shall implement time of day outdoor watering restrictions and shall reduce targeted inflows to Nueces Bay to 1,200 acre-feet per month (1,200 acre-feet per month represents the quantity of water that is the median inflow into Lake Corpus Christi during the drought of record). Time of day outdoor watering restrictions prohibit lawn watering between the hours of 10:00 o'clock a.m. and 6:00 o'clock p.m. and are subject to additional conditions as described in the City of Corpus Christi's approved "Water Conservation and Drought Contingency Plan ("Plan")." To the extent of its legal authority, the City of Corpus Christi shall require its wholesale customers to implement time of day outdoor watering restrictions similar to those of the City.

(3) In any month when Reservoir System Storage is less than 30% of total system storage capacity, the City of Corpus Christi shall implement a lawn watering schedule in addition to time of day outdoor watering restrictions (see subparagraph 2.b.(2)) and shall suspend the passage of inflow from the Reservoir System for targeted inflows to Nueces Bay. However, return flows directed into Nueces Bay and/or the Nueces Delta shall continue. The lawn watering schedule shall allow customers to water lawns no oftener than every five days, subject to the time of day restrictions described in subparagraph 2.b.(2) and any additional conditions as described in the City's Plan.

(4) Certificate Holders' may implement whole or partial suspension of the passage of inflow through the reservoir as described above when the City implements, and requires its customers to implement, water conservation and drought management measures at diminished Reservoir System levels, as set forth in subparagraphs b.(2) and b.(3).

c. For purposes of this Agreed Order, Reservoir System storage capacity shall be determined by the most recently completed bathymetric survey of each reservoir. As of 2001, completed bathymetric surveys of each reservoir reports conservation storage capacities of 695,271 acre-feet (below 220.5 feet mean sea level) for Choke Canyon Reservoir (Volumetric Survey of Choke Canyon Reservoir, TWDB September 23, 1993) and 241,241 acre-feet (below 94 feet mean sea level) for Lake Corpus Christi (Regional Water Supply Planning Study-Phase I Nueces River Basin, HDR, December, 1990).

d. Percentage of the Reservoir System capacity shall be determined on a daily basis and shall govern, in part, the inflow to be passed through the reservoir during the remaining days of the month.

e. Within the first ten days of each month, the City of Corpus Christi shall submit to the Commission a monthly report containing the daily capacity of the Reservoir System in percentages and mean sea levels as recorded for the previous month as well as reservoir surface areas and estimated inflows to Lake Corpus Christi assuming no impoundment of inflows at Choke Canyon Reservoir. The report shall indicate which gages or measuring devices were used to determine Reservoir System capacity and estimate inflows to Lake Corpus Christi.

f. Concurrent with implementing subparagraphs 2.b.(1) through 2.b.(3), the City shall proceed to:

1. Acquire land rights to properties necessary to re-open the Nueces River Overflow Channel and make the Nueces River Overflow Channel and Rincon Bayou Overflow Channel permanent features of the Rincon Bayou Diversion;

2. Construct and operate a conveyance facility to deliver up to 3,000 acre-feet per month of required Reservoir System "pass-throughs" directly from the Calallen Pool into the Upper Rincon Bayou by use of one or two of the five authorized points of diversion under Certificate of Adjudication No. 2464, being the existing San Patricio Municipal Water District point of diversion and/or a point on the North bank of the Calallen Pool located at Latitude 27.8823°N, Longitude 97.6254°W, also bearing S 27° 24' W, 4,739 feet from the southwest corner of the J.H.W. Ottman Survey, Abstract No. 212, San Patricio County, Texas, where the water will be pumped at the maximum rate of 45,000 gpm; and

3. Implement an on-going monitoring and assessment program designed to facilitate an "adaptive management" program for freshwater inflows into the Nueces Estuary.

4. Construction necessary to implement subparagraph 2.f.1. shall be accomplished by December 31, 2001 and work necessary to accomplish subparagraph 2.f.2. shall be accomplished by December 31, 2002.

5. In the event the City fails to timely complete the work set forth in subparagraphs 2.f.1. and 2.f.2., this amendment shall automatically terminate and the provisions of the Agreed Order of April 28, 1995 shall be reinstated and become operative despite this amendment, unless the Executive Director grants a modification after considering the recommendations of the Nueces Estuary Advisory Council.

g. The Executive Director is delegated authority to make modifications to subparagraph 2.f., after considering the recommendations of the Nueces Estuary Advisory Council. However, changes may be made through this process only with the City's consent if the changes result in increased costs to the City.

If the Executive Director makes modifications to subparagraph 2.f. as authorized in this paragraph, any affected person may file with the chief clerk a motion for reconsideration of the Executive Director's action no later than 23 days after the date the Executive Director mails notice of the modification to the City. This motion shall be considered under the provisions of 30 Texas Administrative Code § 50.39(d) and (e).

h. The City shall obtain all necessary permits from the Commission before beginning these projects. The deadlines set out above include time necessary to apply for, process and, if necessary, complete hearings on these permits.

3. a. The City of Corpus Christi, with the assistance and/or participation of federal, state and local entities, shall maintain a monitoring program to assess the effect of this

operating plan on Nueces Bay. The cornerstone of this program is the development of a salinity monitoring program. The program shall include at least two monitoring stations, one in upper Nueces Bay (Lat. 27°51'02", Long. 97°28'52") and one in mid Nueces Bay (Lat. 27°51'25", Long. 97°25'28") with the capability of providing continuous salinity and/or conductivity data, temperature, pH, and dissolved oxygen levels. Additional stations may be established at the recommendation of the Advisory Council (continued by paragraph 4 of this Agreed Order) to assess inflow effects throughout the estuarine system, but the City shall not be obligated to establish such additional stations except to the extent authorized by its City Council.

b. The City of Corpus Christi or its designated representatives shall monitor salinity levels in Upper and Mid-Nueces Bay. The lower (SLB) and upper (SUB) salinity bounds (in parts per thousand-ppt) developed for application of the Texas Estuarine Mathematical Programming Model and considered appropriate for use herein, are as follows:

	SLB	SUB		SLB	SUB
January	5	30	July	2	25
February	5	30	August	2	25
March	5	30	September	5	20
April	5	30	October	5	30
May	1	20	November	5	30
June	1	20	December	5	30

c. When the average salinity for the third week (the third week includes the seven days from the 15th through 21st) of any month is at or below the subsequent month's established SLB for upper Nueces Bay (Lat. 27°51'02", Long. 97°28'52"), no releases from the Reservoir System to satisfy targeted Nueces Bay inflow mounts shall be required for that subsequent month.

d. All data collected as a result of the monitoring program required by paragraph 3 of this Agreed Order shall be submitted monthly to the Commission within the first ten days of the immediately following month. The Nueces Estuary Advisory Council shall study the feasibility of developing a method of granting credits for inflows which exceed the required amounts to replace the credits that are set out in subparagraph 1.c.(l) and make recommendations to the Commission for possible implementation. That method shall have as its goal the maintenance of the proper ecological environment and health of related living marine resources and the provision of maximum reasonable credits towards monthly inflow requirements.

4. a. To assist the Commission in monitoring implementation of this Order and making recommendations to the Commission relating to any changes to this Agreed Order and the establishment of future operating procedures, the Nueces Estuary Advisory

Council shall be continued. Its members shall include, but are not limited to a qualified representative chosen by each of the following entities or groups: the Executive Director of the Texas Natural Resource Conservation Commission, whose representative shall serve as chair;the Texas Water Development Board; the Texas Parks and Wildlife Department; the Texas Department of Health; the General Land Office; the holders of Certificate of Adjudication No. 21-3214 (the Cities of Corpus Christi and Three Rivers and the Nueces River Authority; the University of Texas Marine Science Institute; Texas A&M University - Corpus Christi; Save Lake Corpus Christi; Corpus Christi Chamber of Commerce; the City of Mathis; Coastal Bend Bays and Estuaries Program, Inc.; a commercial bay fishing group; a conservation group (e.g. the Sierra Club and the Coastal Bend Bays Foundation); wholesale water suppliers who are customers of the Certificate Holders (e.g., the South Texas Water Authority and the San Patricio Municipal Water District); the Port of Corpus Christi Authority; and a representative of industry. The representatives should have experience and knowledge relating to current or future water use and management or environmental and economic needs of the Coastal Bend area.

b. No modification shall be made to this Order without the unanimous consent of the Certificate Holders, except to the extent provided by law.

c. Matters to be studied by the Nueces Estuary Advisory Council and upon which the Executive Director shall certify recommendations to the Commission shall include, but are not limited to:

(1) the effectiveness of the inflow requirements contained in this Agreed Order on Nueces Estuary and any recommended changes;

(2) the effect of the releases from the Reservoir System upon the aquatic and wildlife habitat and other beneficial and recreational uses of Choke Canyon Reservoir and Lake Corpus Christi;

(3) the development and implementation of a short and long-term regional water management plan for the Coastal Bend Area;

(4) the salinity level to be applied in Paragraphs 1.e. and 3.c., at which targeted inflows in the subsequent month may be suspended;

(5) the feasibility of discharges at locations where the increased biological productivity justifies an inflow credit computed by multiplying the amount of discharge by a number greater than one; and development of a methodology for granting credits for inflows which exceed the required amount to replace the credits that are set out in subparagraph 1.e. That methodology shall have as its goal the maintenance of the proper ecological

environment and health of related living marine resources and the provision of maximum reasonable credits towards monthly inflow requirements; and,

(6) any other matter pertinent to the conditions contained in this Agreed Order.

5. This Agreed Order shall remain in effect until amended or superseded by the Commission.

Issued date: APR 05 2001

TEXAS NATURAL RESOURCE
CONSERVATION COMMISSION

Robert J. Huston, Chairman

APPENDIX B – Briefing presentations at NEAC meetings during the course of the study

This Page Intentionally Left Blank

NUECES BBASC STUDY #1

RE-EXAMINATION OF THE 2001 AGREED ORDER MONTHLY TARGETS AND SAFE YIELD VERSUS CURRENT DEMAND EVALUATIONS

NEAC – JUNE 16, 2014
CORY SHOCKLEY

DISCUSSION

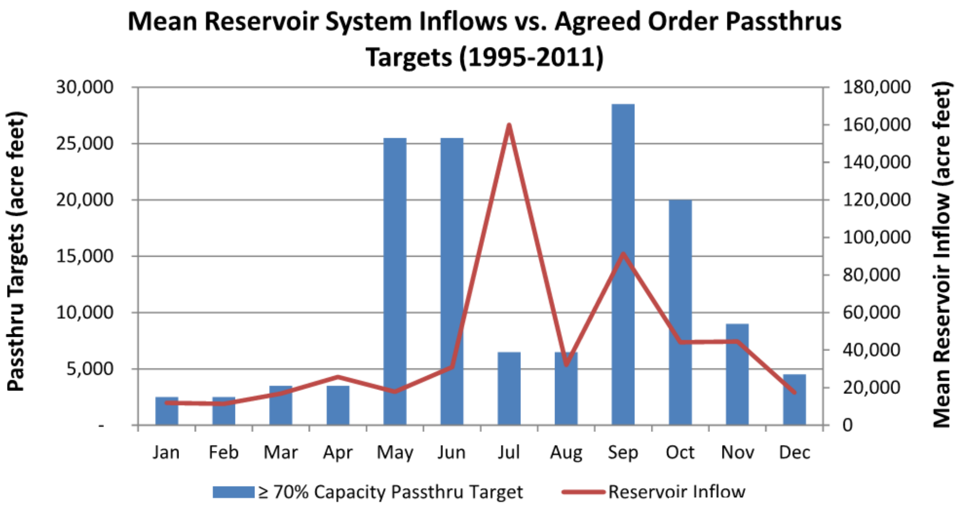
Background

Scope of Work

Schedule

BACKGROUND

- Nueces BBASC work plan
- Nueces BBEST
  - Seasonal shift in inflows
    - BBEST Report Sec. 4.1
    - Nueces Bay
    - Choke Canyon Reservoir / Lake Corpus Christi System
  - Nueces BBASC Report (Sec. 2.3)
    - Opportunities to better manage FWI… since the 1995 development of the Agreed Order
  - Corpus Christi Water Supply Model (CCWSM)



	Targets	2,500	2,500	3,500	3,500	25,500	25,500	6,500	6,500	28,500	20,000	9,000	4,500
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		1,149	733	433	197	154	6	50	23	273	414	175	251
		1,219	772	471	454	205	64	150	100	397	1,069	262	666
		1,533	873	984	599	258	167	317	141	1,747	1,348	376	939
25%		2,330	1,023	1,772	1,104	462	304	535	232	3,007	2,713	480	1,086
		2,969	2,143	2,083	1,450	1,839	588	814	851	5,892	3,089	2,257	1,717
		4,436	3,434	2,449	2,895	2,236	1,063	1,610	1,805	9,322	5,404	3,040	1,743
		4,490	3,781	4,942	4,062	2,922	1,102	4,991	3,058	12,969	5,813	4,935	2,442
		9,120	4,945	6,020	5,132	4,744	1,995	6,499	4,062	14,722	6,609	6,458	2,532
50%		10,650	7,523	6,877	8,969	5,118	8,720	12,352	4,407	25,016	6,622	14,148	4,657
		11,761	9,135	7,345	10,814	9,741	12,861	16,450	5,835	46,356	7,529	23,315	4,751
		12,062	11,407	8,208	17,556	11,009	13,086	31,883	7,858	49,157	12,610	24,021	10,967
		12,973	11,805	13,787	22,951	12,361	15,500	34,043	9,109	63,766	15,053	39,244	13,685
		13,874	14,252	19,067	24,940	15,558	27,023	131,662	12,967	69,331	17,447	60,179	15,297
75%		16,087	22,090	32,556	26,670	16,101	30,184	141,306	46,656	78,089	24,977	72,664	24,128
		29,170	28,200	35,188	28,802	41,458	77,285	249,346	80,345	79,484	129,887	85,091	58,002
		30,487	32,949	65,052	108,180	71,502	157,810	750,255	107,436	161,588	231,260	169,218	74,930
		37,649	37,374	78,979	171,606	108,092	177,394	1,337,481	260,321	932,297	280,307	253,185	77,334
	Total	201,959	192,439	286,213	436,381	303,760	525,152	2,719,744	545,206	1,553,413	752,151	759,048	295,127

BACKGROUND FROM BBASC WORK PLAN

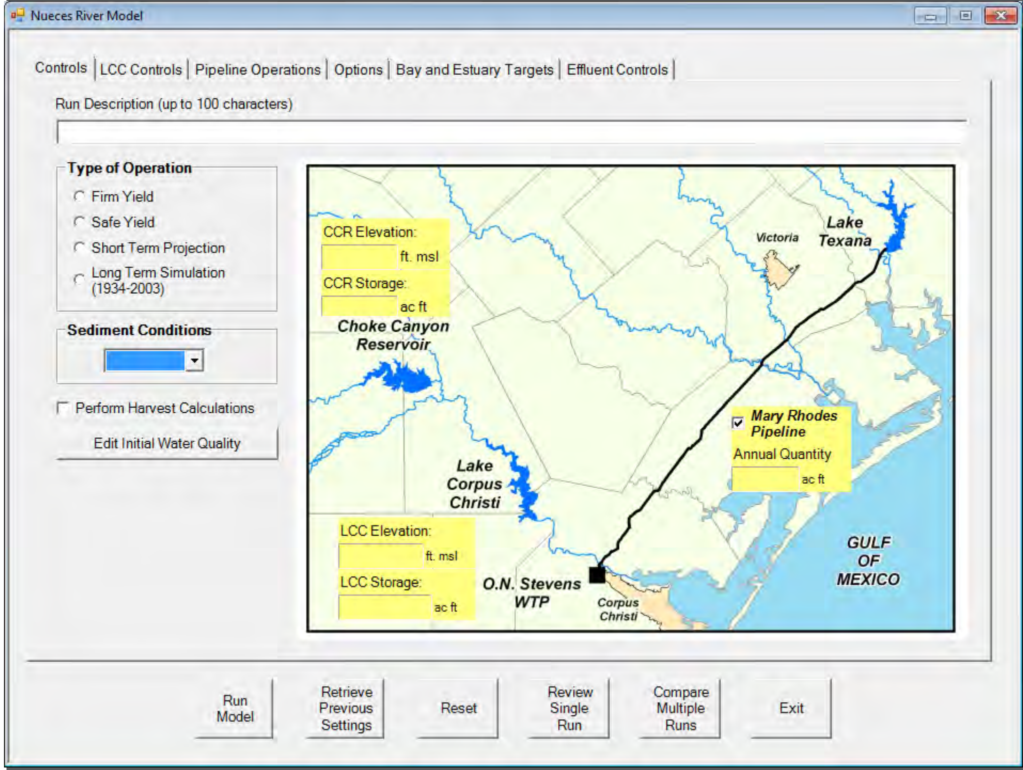
GOALS

- Determine if a “shift” has occurred in the inflows to the Bay and CCR/LCC System and what impact this “shift” may have on Safe Yield and FWI to the Bay.

- Compare the results from a Safe Yield Demand of 205,000 acft/yr to a current demand of 133,000 acft/yr on FWI to the Bay.

SOW

- Task 1 – Compile, Analyze and Evaluate
  - Compile Hydrologic Data
    - Long-term (1934 – 2014)
    - Short-term (1986 – 2014)
    - Recent (2004 – 2014)
  - Analyze Data to Identify Seasonal Shift
    - Compared to 2001 Agreed Order
    - Monthly Inflow Targets
  - Evaluate New Pattern
    - CCWSM Simulations
    - Same Volumes – Different Distribution
    - Results
      - » Yields & FWI to Bay
  - TXBLEND
    - Coordinate with TWDB if requested



SOW

- Task 2 – Compare Safe Yield and Current Demand
  - Safe Yield
    - 205,000 acft/yr
      - 125,000 acft storage reserve (~14%)
      - Regional Planning modeling assumptions
  - Current Demand
    - 133,000 acft/yr
  - Compare
    - FWI to Bay / Reservoir Levels
- Task 3 – Meetings and Report
  - Kickoff Meeting (Today)
  - Up to 2 more meetings to present results
  - Draft and Final Report

SCHEDULE

- Waiting on Contract / NTP
- Anticipate 20 weeks to complete analysis
- Draft report after analysis
- Final report due August 2015


RINCON BAYOU
CBBEP Nueces Delta Preserve

HDR

NUECES BBASC STUDY #1

RE-EXAMINATION OF THE 2001 AGREED ORDER MONTHLY TARGETS AND SAFE YIELD VERSUS CURRENT DEMAND EVALUATIONS

NEAC – OCTOBER 20, 2014
CORY SHOCKLEY

DISCUSSION

Background

Status

Results

Schedule

BACKGROUND

- Nueces BBASC work plan
- Nueces BBEST
  - Seasonal shift in inflows
    - BBEST Report Sec. 4.1
    - Nueces Bay
    - Choke Canyon Reservoir / Lake Corpus Christi System
  - Nueces BBASC Report (Sec. 2.3)
    - Opportunities to better manage FWI… since the 1995 development of the Agreed Order
  - Corpus Christi Water Supply Model (CCWSM)

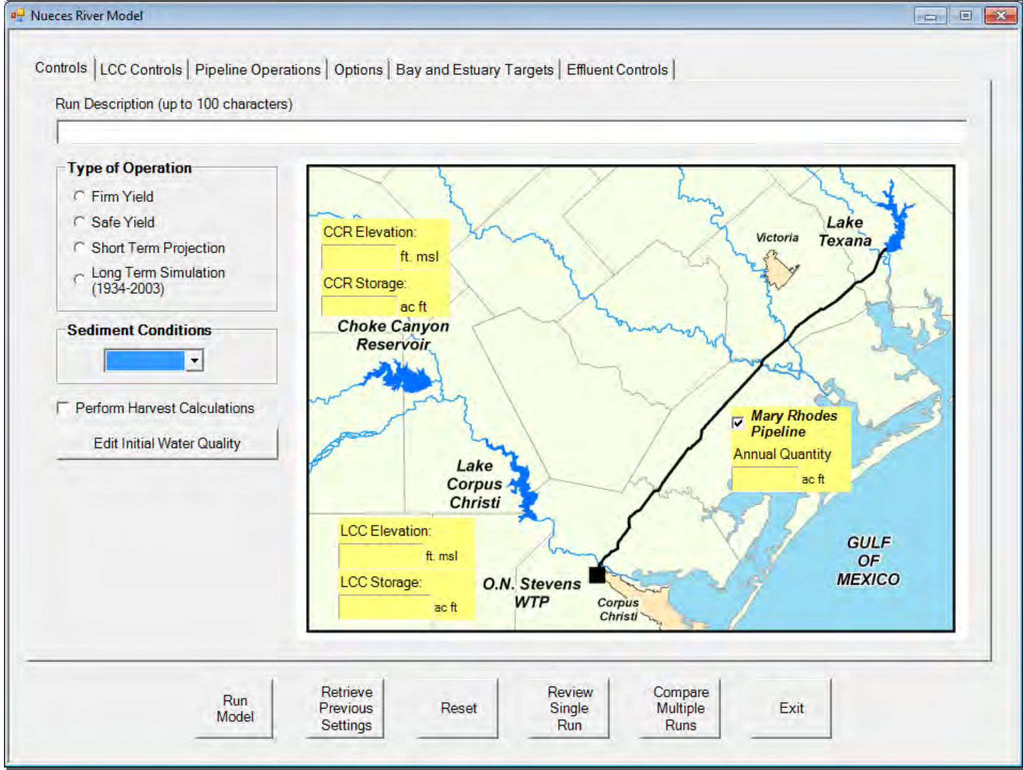
GOALS

- Determine if a “shift” has occurred in the inflows to the Bay and CCR/LCC System and what impact this “shift” may have on Safe Yield and FWI to the Bay.

- Compare the results from a Safe Yield Demand of 205,000 acft/yr to a current demand of 133,000 acft/yr on FWI to the Bay.

TASK 1 – SEASONAL SHIFT

- Compile, Analyze and Evaluate
  - Compilation is Ongoing
    - Compile Hydrologic Data
      - » Inflows. Precipitation
      - » Long-term (1934 – 2014)
      - » Short-term (1986 – 2014)
      - » Recent (2004 – 2014)
  - Next Step - Analyze Data
    - Is there a shift?
    - Compared to 2001 Agreed Order
    - Monthly Inflow Targets
  - Last Step - Evaluate New Pattern
    - CCWSM Simulations
    - Same Volumes – Different Distribution
    - Yields & FWI to Bay
    - TXBLEND (if requested)

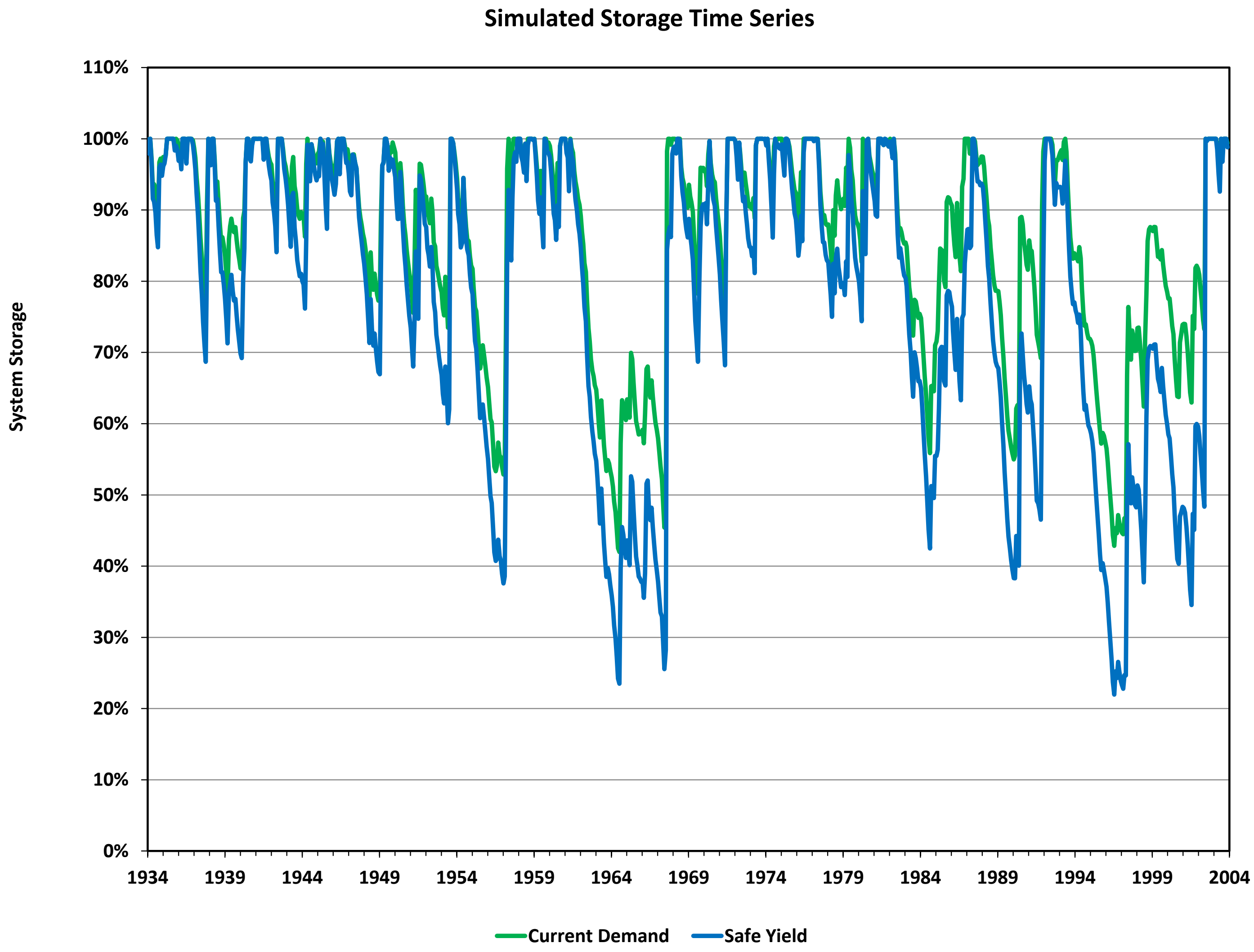


TASK 2 – RESULTS

- Compare Safe Yield and Current Demand
  - Safe Yield
    - 205,000 acft/yr
      - 125,000 acft storage reserve (~14%)
      - Regional Planning modeling assumptions
  - Current Demand
    - 133,000 acft/yr
  - Results
    - Lake Level Comparison
    - FWI Comparison
    - Attainment Frequency
    - Mass Balance

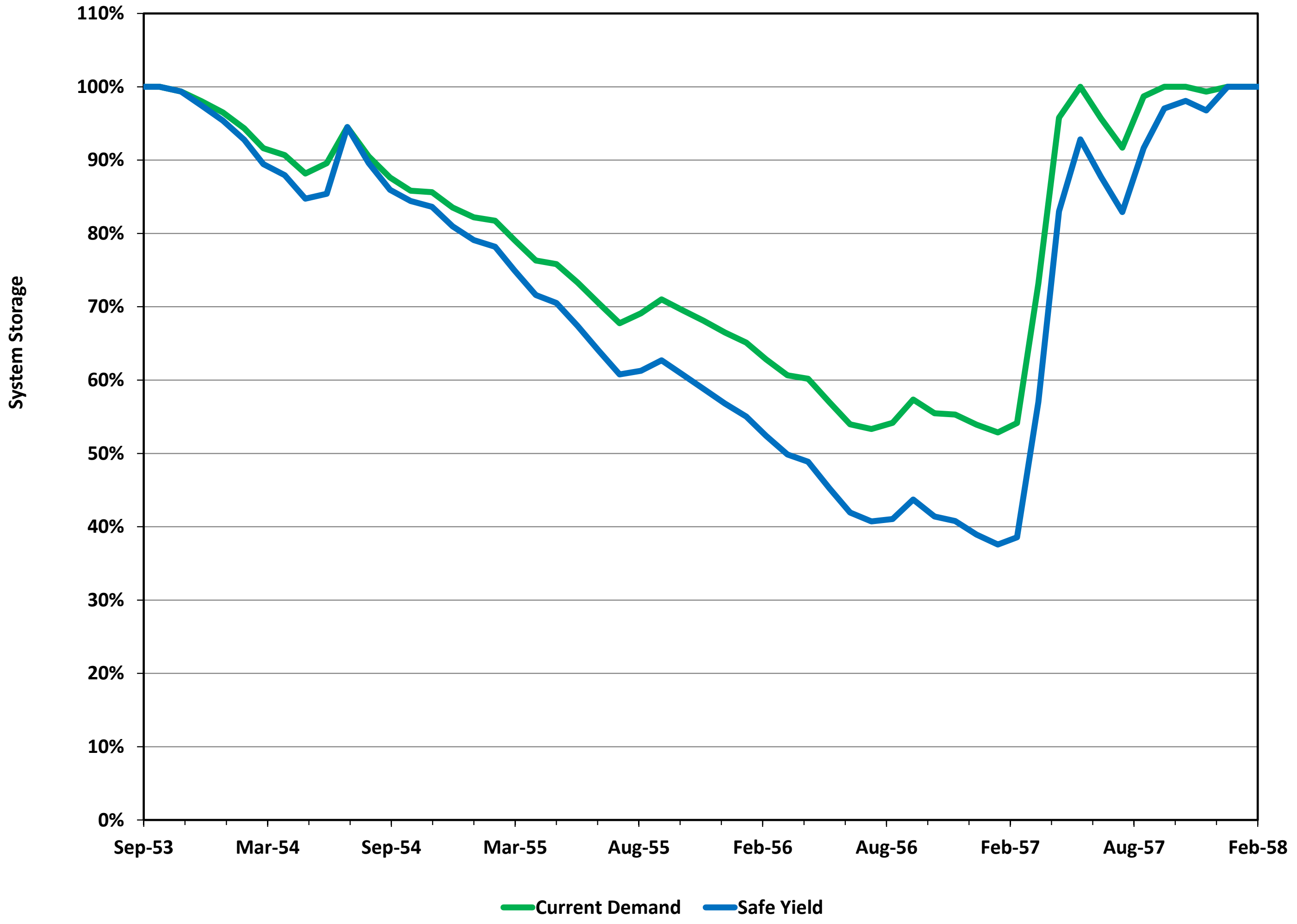
LAKE LEVEL COMPARISONS

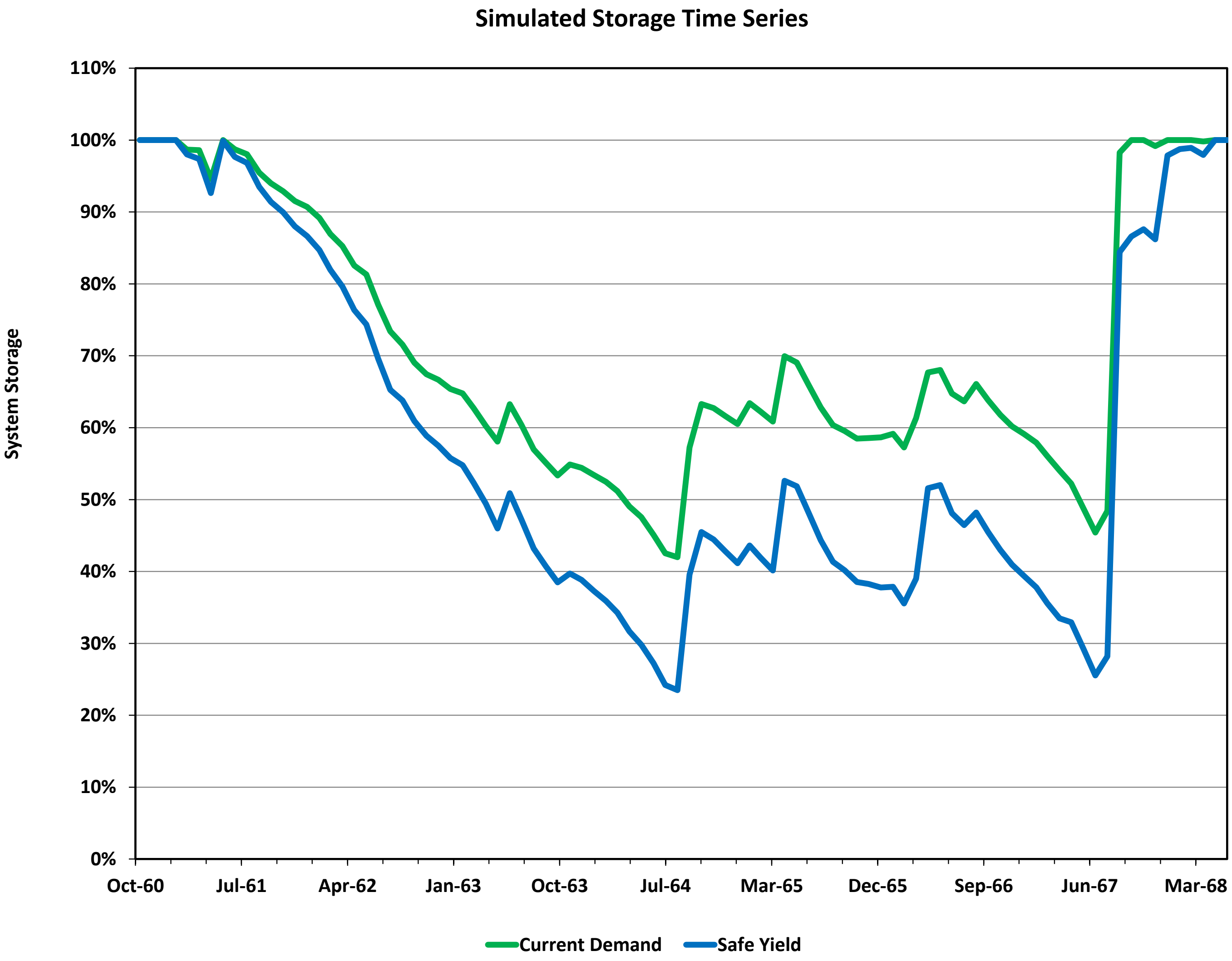
- Time Series Lake Level
- Lake Level Frequency
- Zone Attainment Frequencies

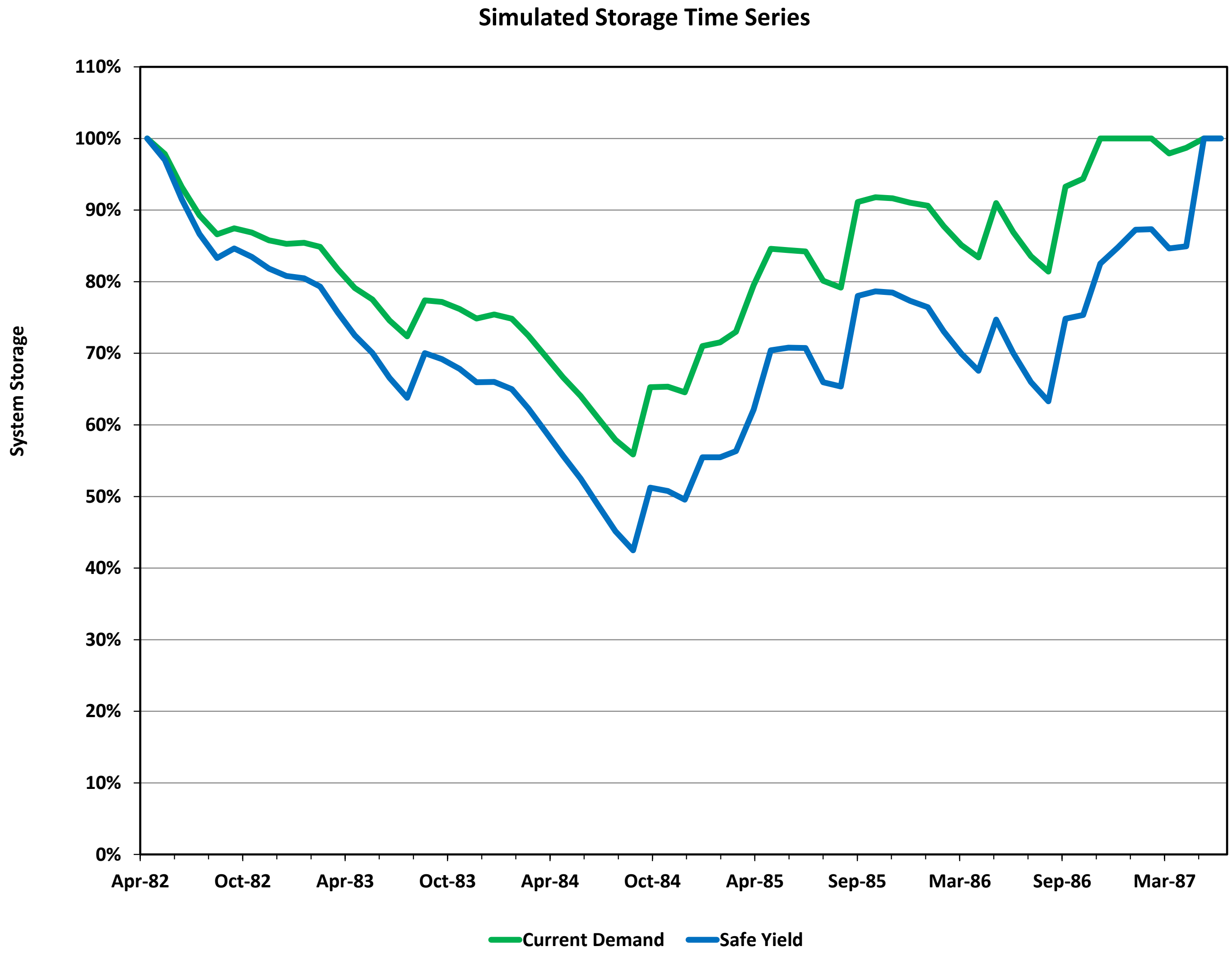


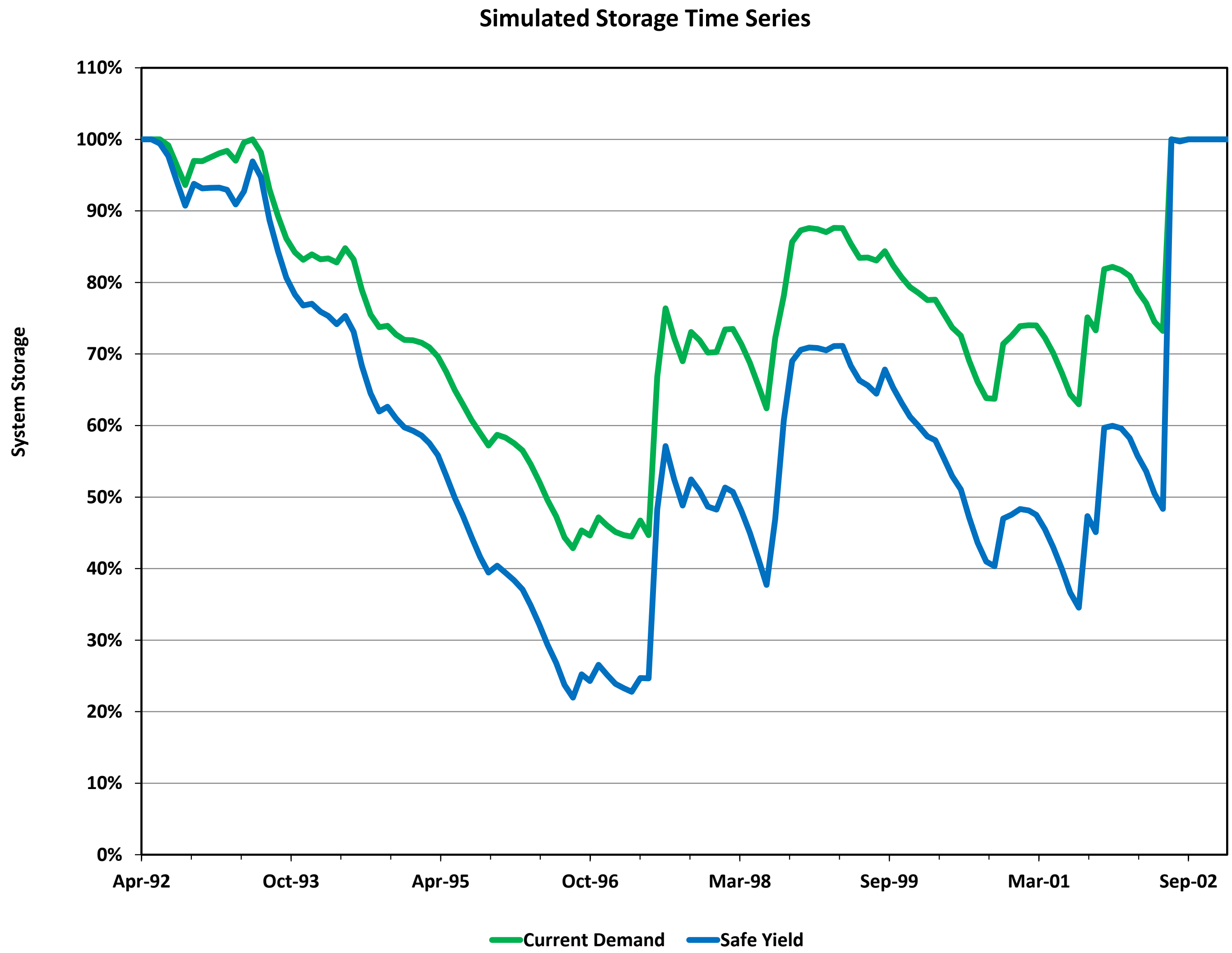
Simulated Storage Time Series
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
System Storage
1934
1939
1944
1949
1954
1959
1964
1969
1974
1979
1984
1989
1994
1999
2004
Current Demand
Safe Yield

Simulated Storage Time Series

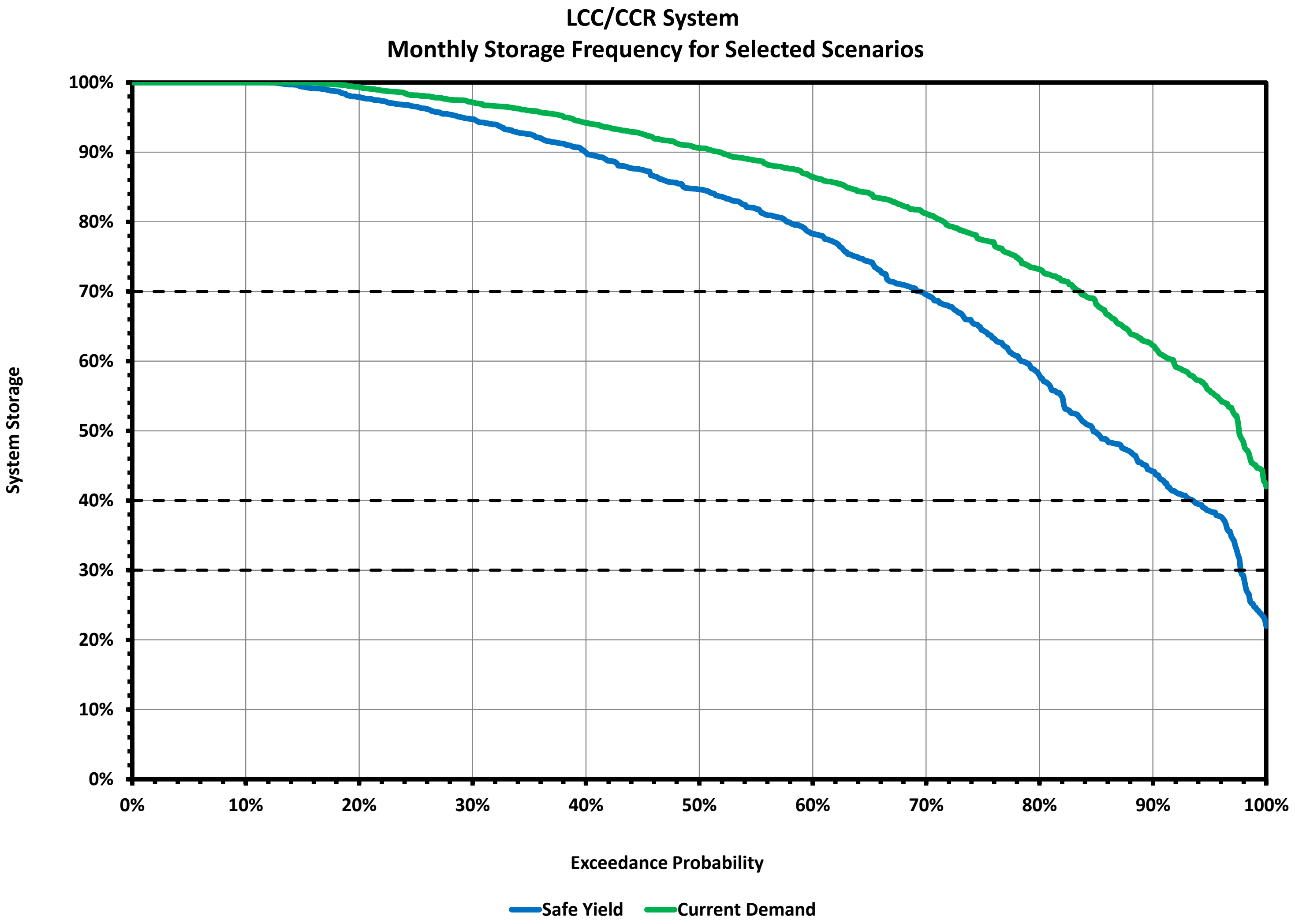



Simulated Storage Time Series
System Storage
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oct-60
Jul-61
Apr-62
Jan-63
Oct-63
Jul-64
Mar-65
Dec-65
Sep-66
Jun-67
Mar-68
Current Demand
Safe Yield


Simulated Storage Time Series
System Storage
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Apr-82
Oct-82
Apr-83
Oct-83
Apr-84
Oct-84
Apr-85
Sep-85
Mar-86
Sep-86
Mar-87
Current Demand
Safe Yield

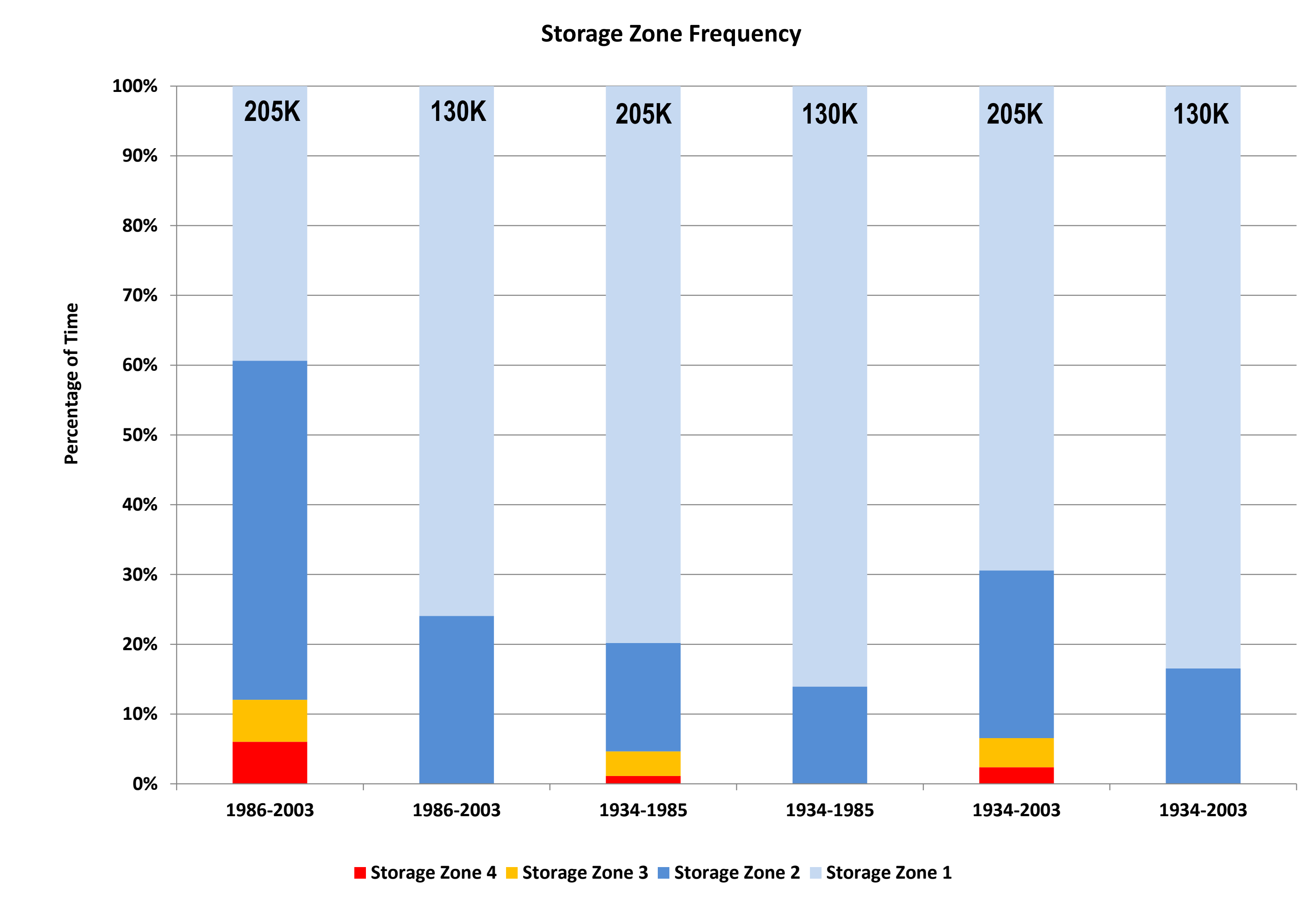


Simulated Storage Time Series
System Storage
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Apr-92
Oct-93
Apr-95
Oct-96
Mar-98
Sep-99
Mar-01
Sep-02
Current Demand
Safe Yield



LCC/CCR System
Monthly Storage Frequency for Selected Scenarios
System Storage
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Exceedance Probability
Safe Yield
Current Demand

Scenario	Time Period	Storage Zone 1	Storage Zone 2	Storage Zone 3	Storage Zone 4
Safe Yield	1986-2003	39.4%	48.6%	6.0%	6.0%
Current Demand		75.9%	24.1%	0.0%	0.0%
Safe Yield	1934-1985	79.8%	15.5%	3.5%	1.1%
Current Demand		86.1%	13.9%	0.0%	0.0%
Safe Yield	1934-2003	69.4%	24.0%	4.2%	2.4%
Current Demand		83.5%	16.5%	0.0%	0.0%

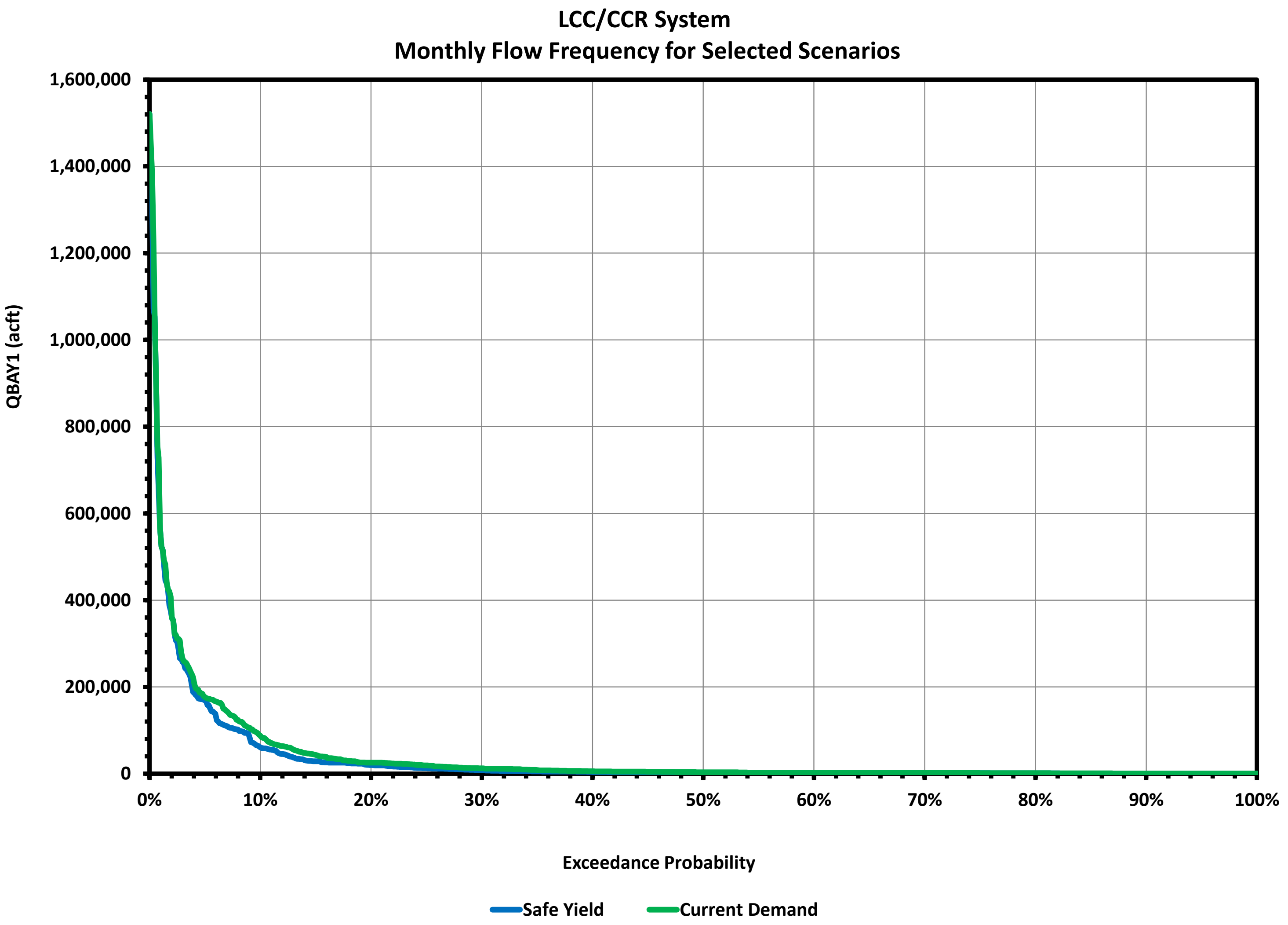


Storage Zone Frequency
Percentage of Time
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
205K
130K
205K
130K
205K
130K
1986-2003
1986-2003
1934-1985
1934-1985
1934-2003
1934-2003
Storage Zone 4
Storage Zone 3
Storage Zone 2
Storage Zone 1

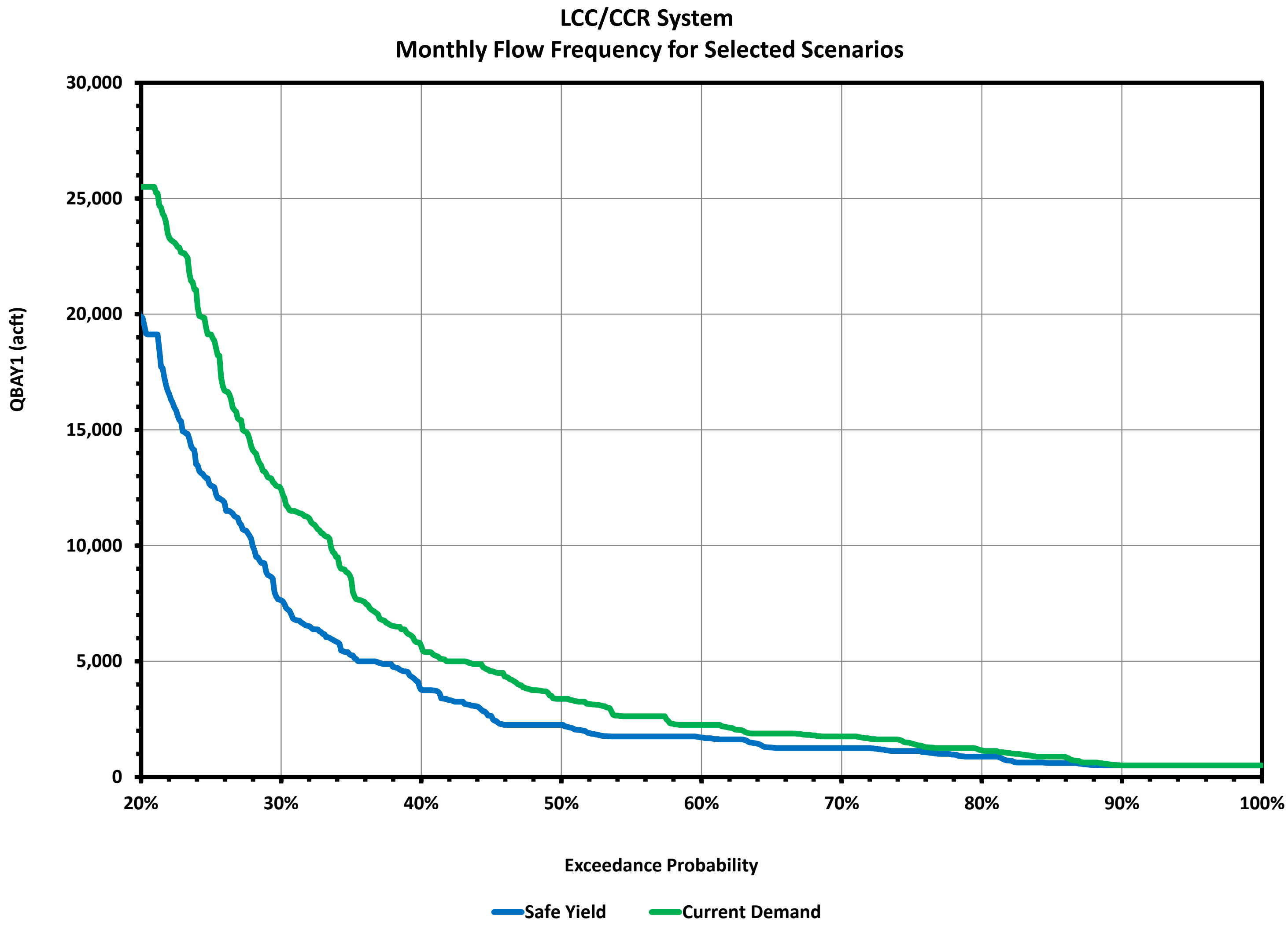
FRESH WATER INFLOW COMPARISONS

- Frequency plots
- Differences
  - From demands
  - From time periods
- Mass Balance Comparisons
  - Demand
  - Evaporation
  - FWI – Pass-throughs
  - Spills

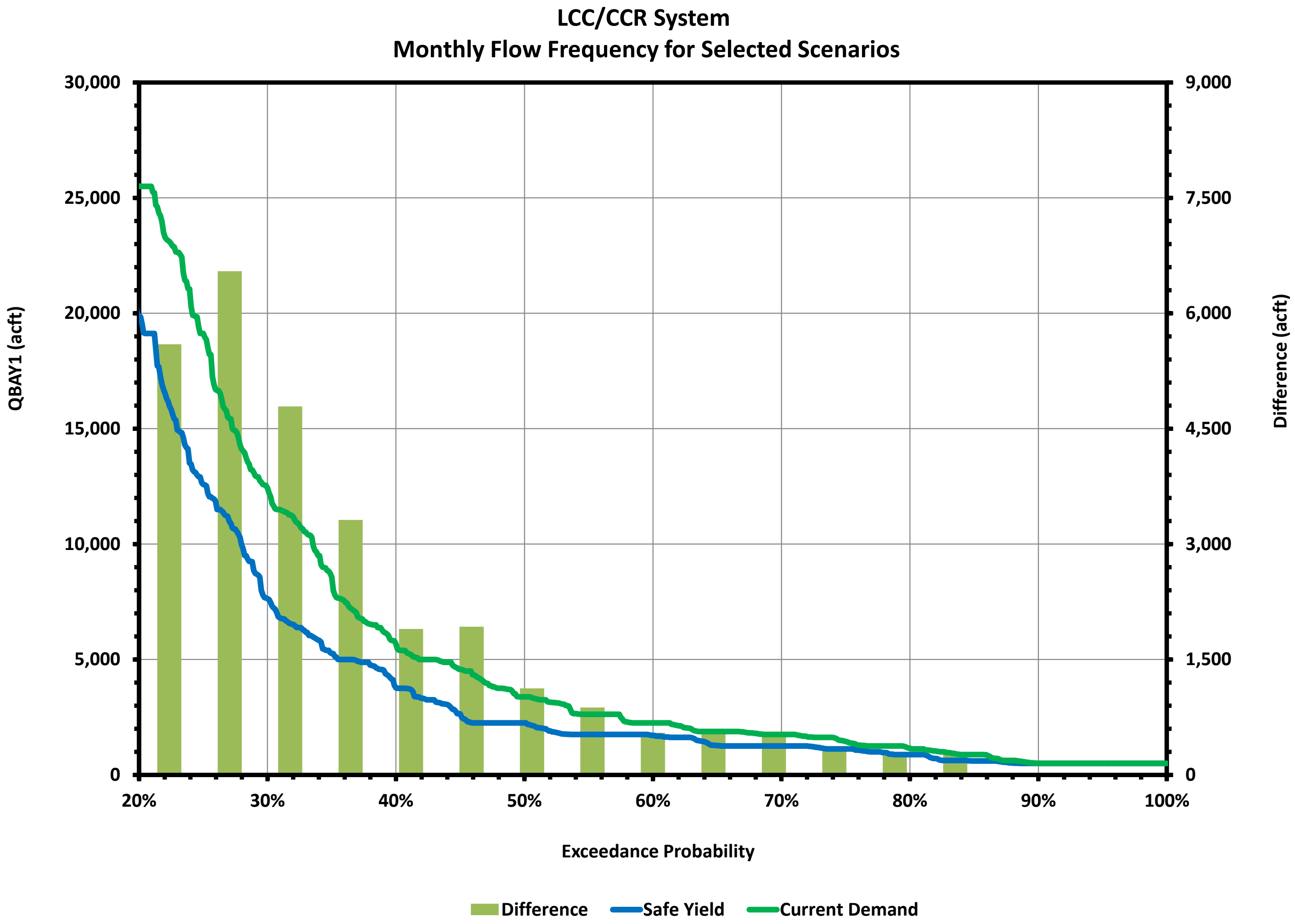
Scenario	Time Period	Target Attainment (% of time)	Target Attainment (% of target volume)
Safe Yield	1986-2003	25.9%	81.5%
Current Demand		25.5%	80.0%
Safe Yield	1934-1985	28.5%	148.2%
Current Demand		34.8%	156.3%
Safe Yield	1934-2003	27.9%	132.8%
Current Demand		32.4%	136.7%



LCC/CCR System
Monthly Flow Frequency for Selected Scenarios
QBAY1 (acft)
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Exceedance Probability
Safe Yield
Current Demand

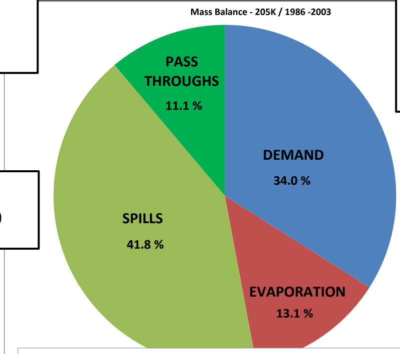

LCC/CCR System
Monthly Flow Frequency for Selected Scenarios
QBAY1 (acft)
30,000
25,000
20,000
15,000
10,000
5,000
0
20%
30%
40%
50%
60%
70%
80%
90%
100%
Exceedance Probability
Safe Yield
Current Demand

Exceedance Probability	Monthly QBAY1 (acft)		
	Safe Yield	**Current Demand**	***Difference***
0%	1520556	1520556	0
5%	168921	176569	7648
10%	60660	87791	27131
15%	28504	43150	14646
20%	19903	25500	5597
25%	12579	19125	6546
30%	7634	12423	4789
35%	5256	8569	3313
40%	3762	5658	1896
45%	2642	4568	1926
50%	2250	3375	1125
55%	1750	2625	875
60%	1704	2250	546
65%	1276	1875	599
70%	1250	1750	500
75%	1125	1443	318
80%	875	1154	279
85%	600	875	275
90%	499	500	1
95%	499	499	0
100%	499	499	0

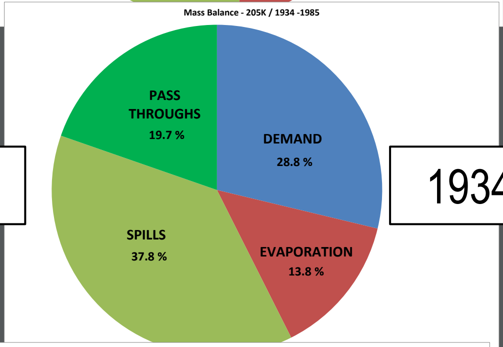

LCC/CCR System
Monthly Flow Frequency for Selected Scenarios
QBAY1 (acft)
Difference (acft)
30,000
25,000
20,000
15,000
10,000
5,000
0
9,000
7,500
6,000
4,500
3,000
1,500
0
20%
30%
40%
50%
60%
70%
80%
90%
100%
Exceedance Probability
Difference
Safe Yield
Current Demand

Safe Yield

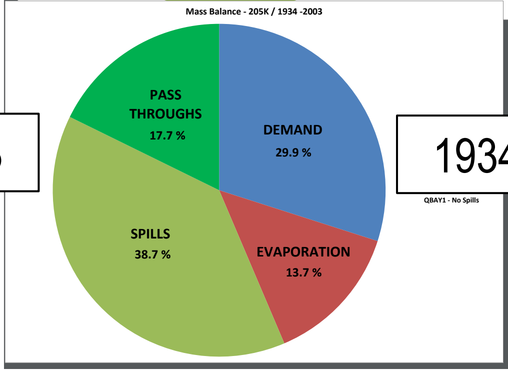
1986-2003



1934-1985



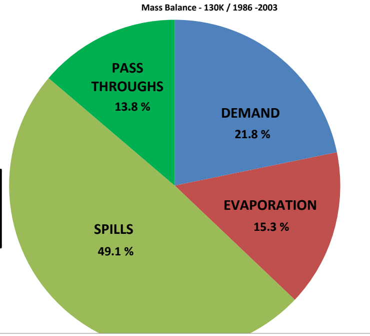
1934-2003



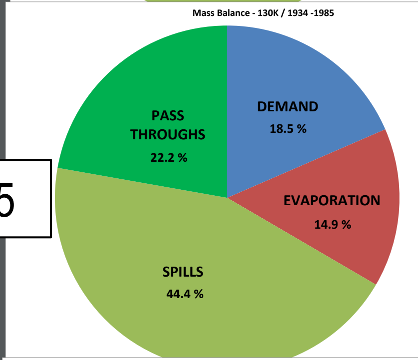
Current Demand

Demand

1986-2003

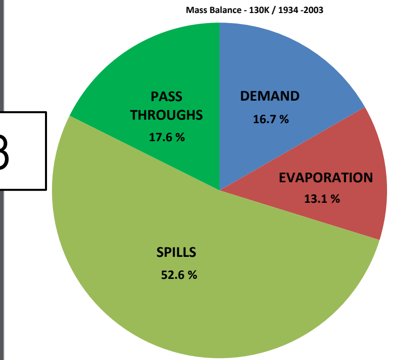


1934-1985



1934-2003

QBAY1 - No Spills



TASK 2 – FINDINGS

- Lower demand = higher lake levels = more opportunity for larger pass-throughs
- Drought times are dominated by lake of inflows

TASK 3 – MEETINGS AND REPORT

- Task 3 – Meetings and Report
  - Kickoff Meeting (June 2014)
  - Results Meeting #1 (Today)
  - 2^{nd} Results Meeting (2015)
  - Draft and Final Report (2015)

SCHEDULE

- Complete Analysis by March 2015
- Present Results Spring 2015
- Draft report after analysis
- Final report due August 2015


RINCON BAYOU
CBBEP Nueces Delta Preserve

NUECES BBASC STUDY #1

RE-EXAMINATION OF THE 2001 AGREED ORDER MONTHLY TARGETS AND SAFE YIELD VERSUS CURRENT DEMAND EVALUATIONS

NEAC – FEBRUARY 23, 2015
CORY SHOCKLEY

DISCUSSION

01 Background

02 Status

03 Results

04 Schedule

BACKGROUND

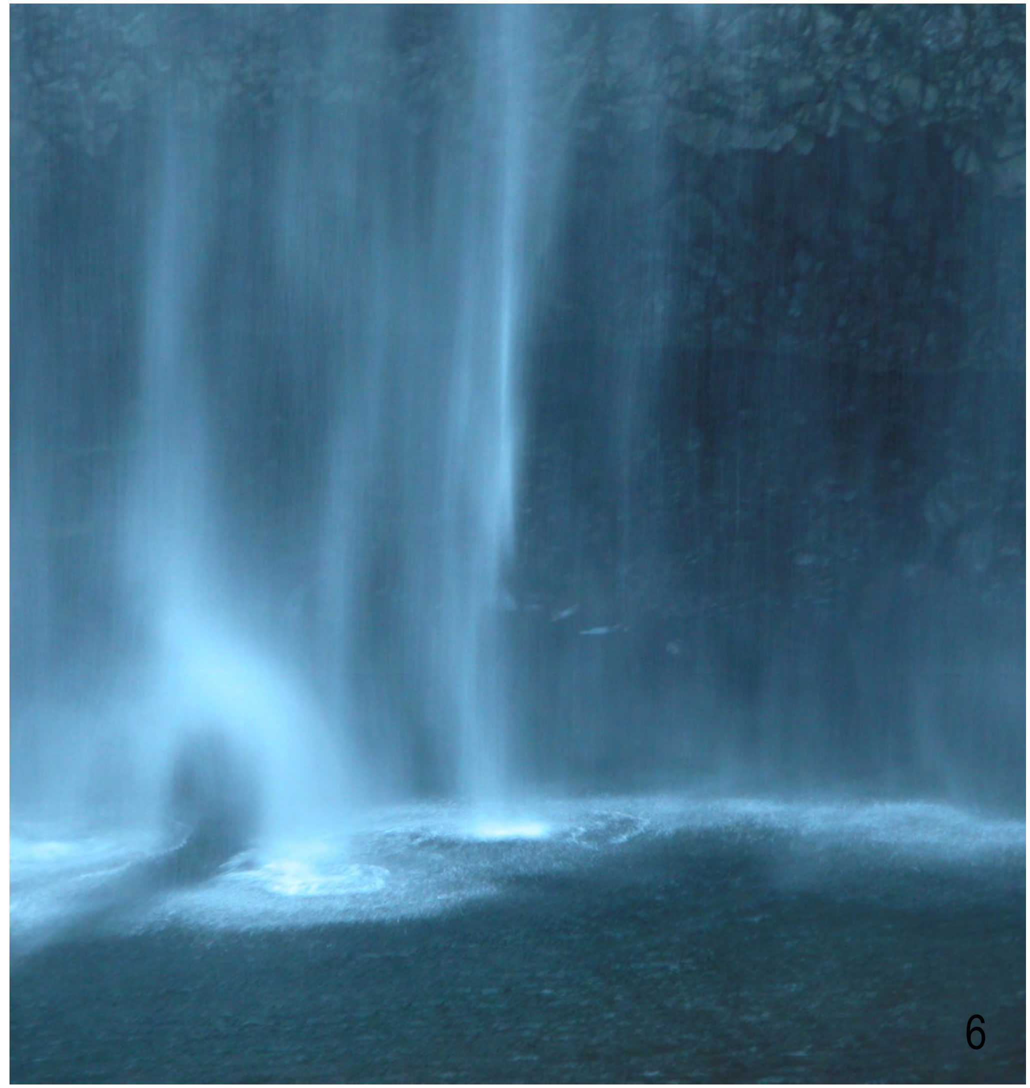
- Nueces BBASC work plan
- TWDB Nueces BBASC Study #1
  - Nueces BBASC Report (Sec. 2.3)
    - Opportunities to better manage fresh water inflows (FWI)… since the 1995 development of the Agreed Order
  - Nueces BBEST
    - Seasonal shift in inflows
      - Similar to BBEST Report Sec. 4.1
      - Inflows into Nueces Bay
      - Operations of Choke Canyon Reservoir / Lake Corpus Christi System

GOALS

- Determine if a "shift" has occurred in the inflows to the Bay and CCR/LCC System and what impact this "shift" may have on Safe Yield and FWI to the Bay.
- Compare the results from a Safe Yield Demand of 205,000 acft/yr to a current demand of 133,000 acft/yr on FWI to the Bay.

TASK 1 – SEASONAL SHIFT

- Task ongoing
- Compile, Analyze and Evaluate
  - Compile Hydrologic Data
    - Streamflows, Inflows & Precipitation
    - Long-term (1934 – 2014)
    - Short-term (1986 – 2014)
    - Recent (2004 – 2014)
  - Analyze Data
    - Is there a shift?
    - Compared to 2001 Agreed Order
  - Evaluate New Pattern
    - CCWSM Simulations
    - Same Volumes – Different Distribution
    - Yields & FWI to Bay
    - TXBLEND (if requested)



SEASONAL SHIFT - METHODOLOGY

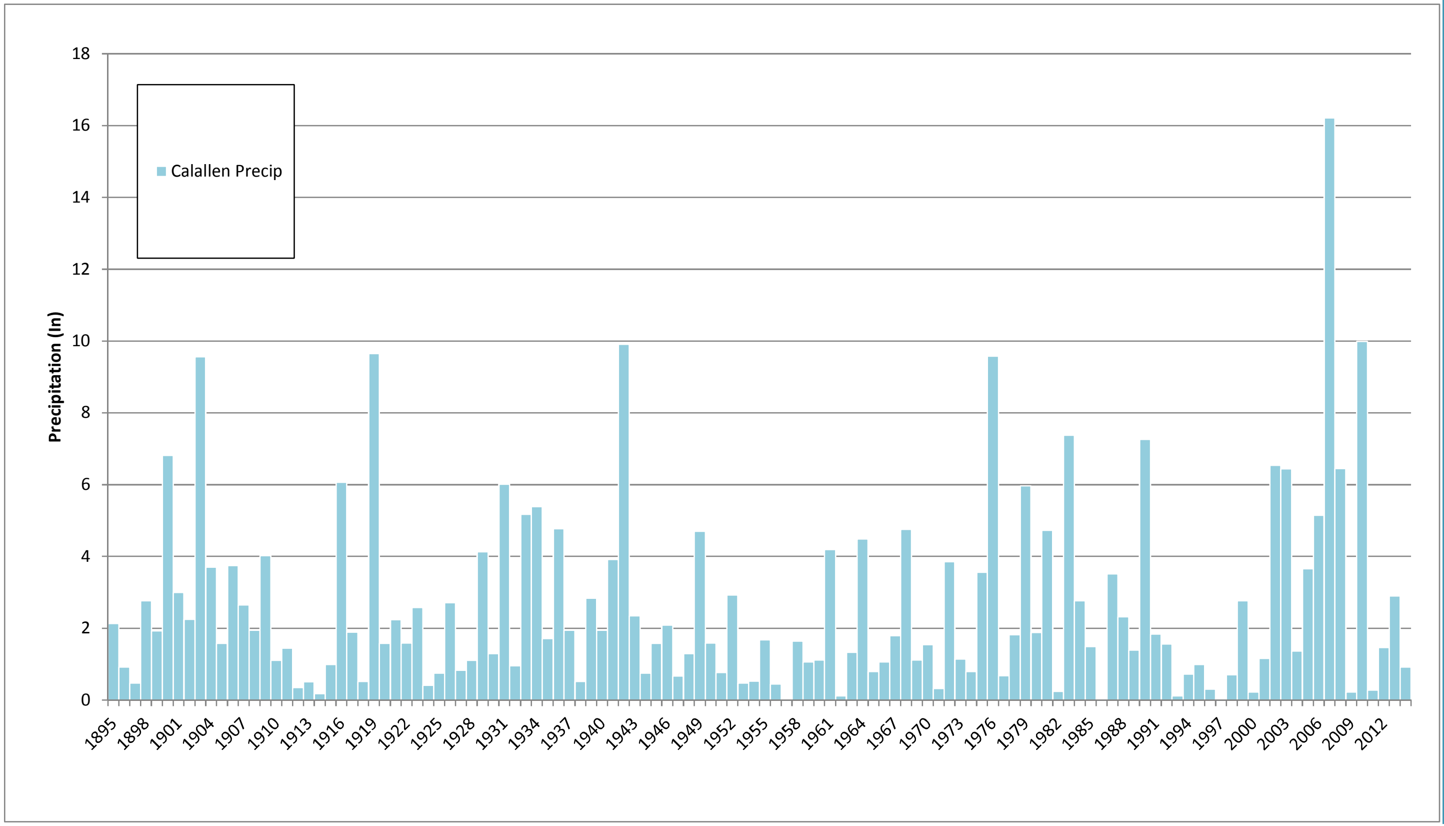
- Historical hydrology
  - Precipitation
    - Multiple sites – similar trends
    - 1895 - 2014
  - Natural Inflows
    - Three sites from NUBAY model
    - 1934 - 2003
  - Gaged Streamflow
    - Multiple sites
    - Range of dates

SEASONAL SHIFT - QUESTIONS

- Is the monthly pattern of occurrence different now compared to what is in the Agreed Order?
- Are there distinctive trends that indicate that inflows may occur in different months than those high target months in the Agreed Order?
- Statistical Analysis
  - Compare monthly values
  - 3 time periods
    - Long Term – 1934 – 2014
    - Short term – 1986 – 2014
    - Recent – 2004 - 2014

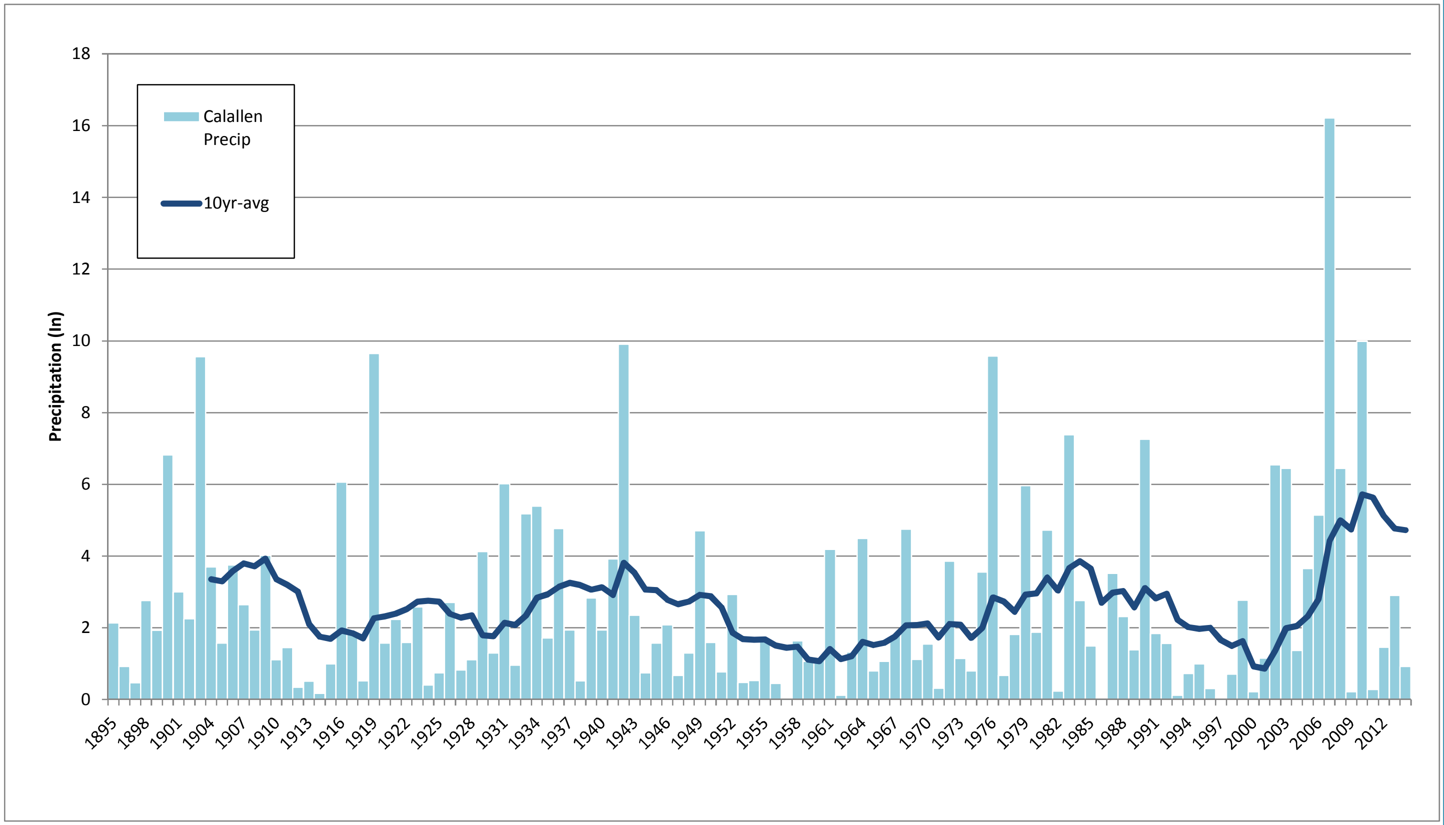
PRECIPITATION

- July Precip Totals
- 1895 - 2014



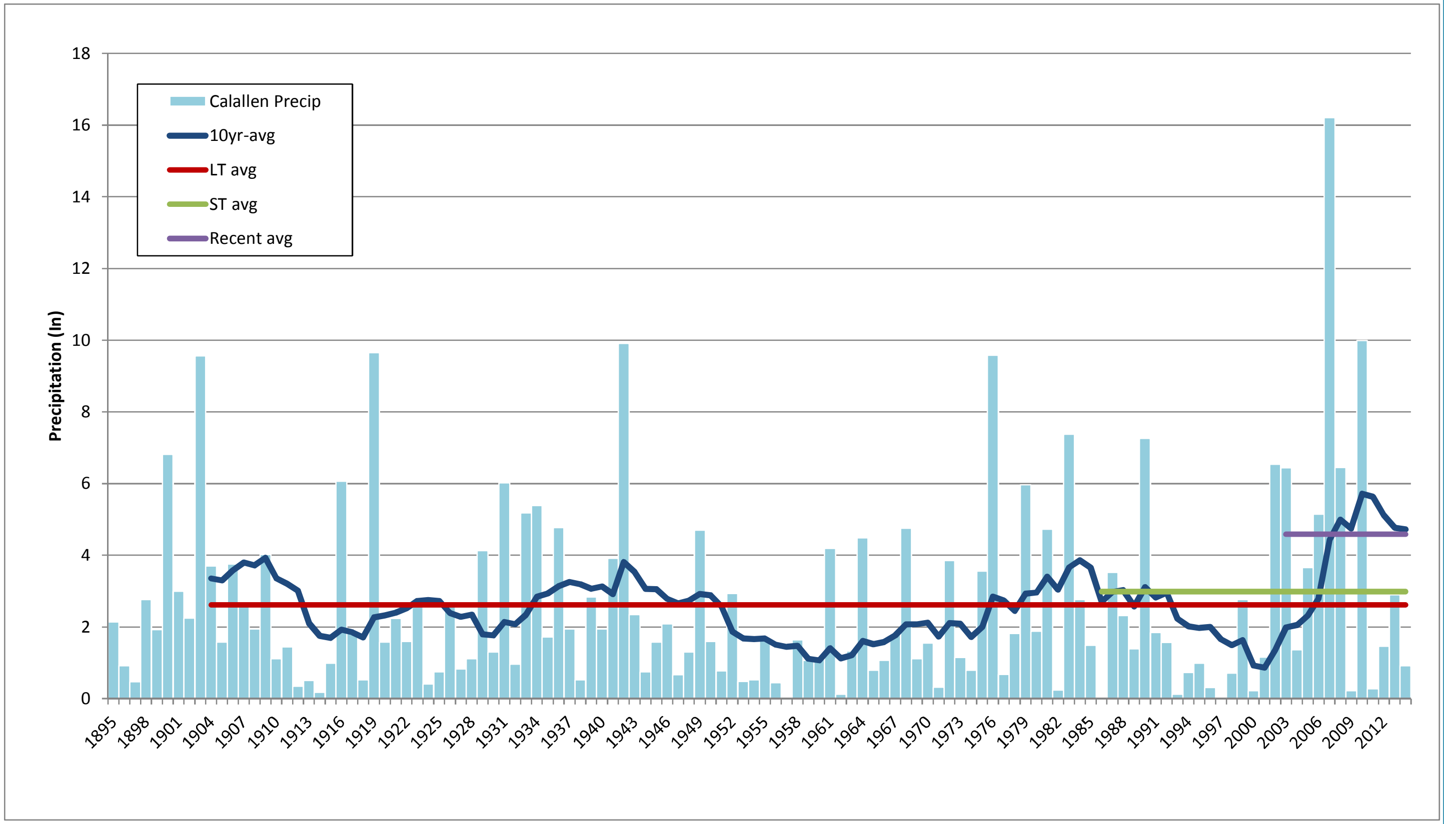
PRECIPITATION

- July Precip Totals
- 1895 – 2014
- 10-yr moving average



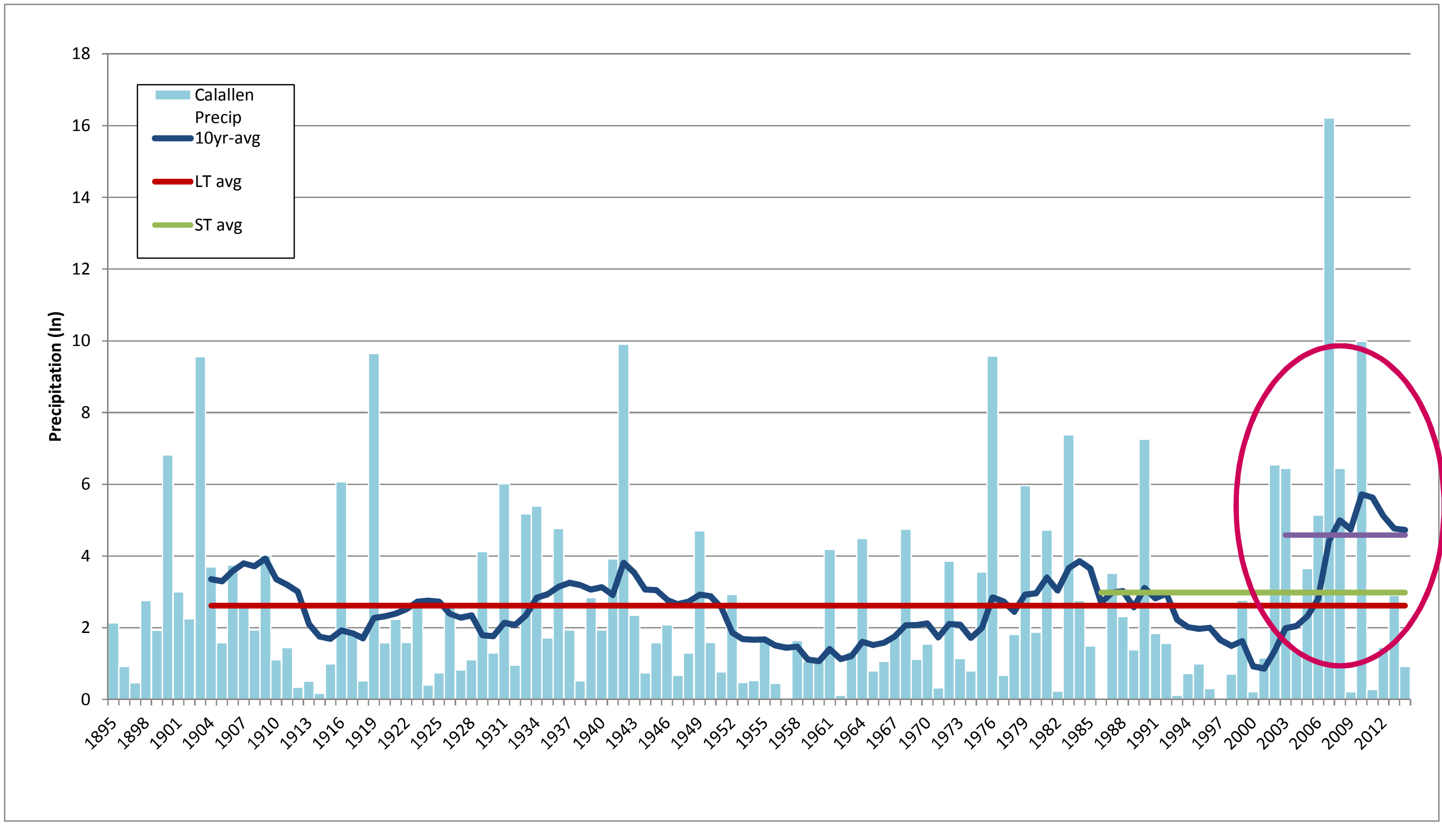
PRECIPITATION

- July Precip Totals
  - o 1895 – 2014
- 10-yr moving average
  - o Trends
- Averages
  - o Long-Term
  - o Short-Term
  - o Recent

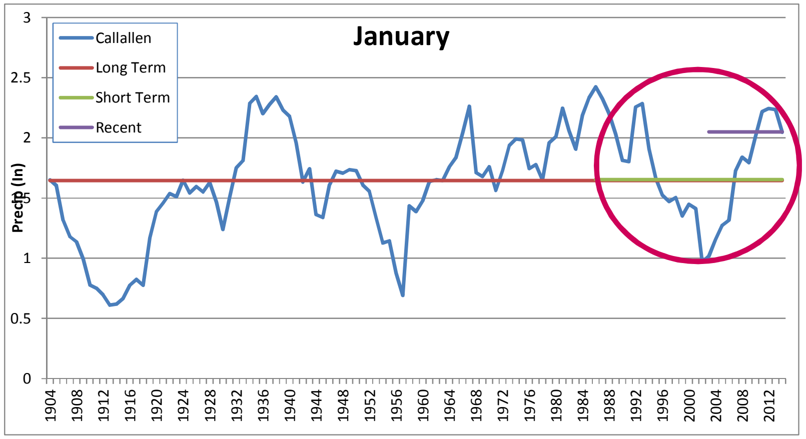


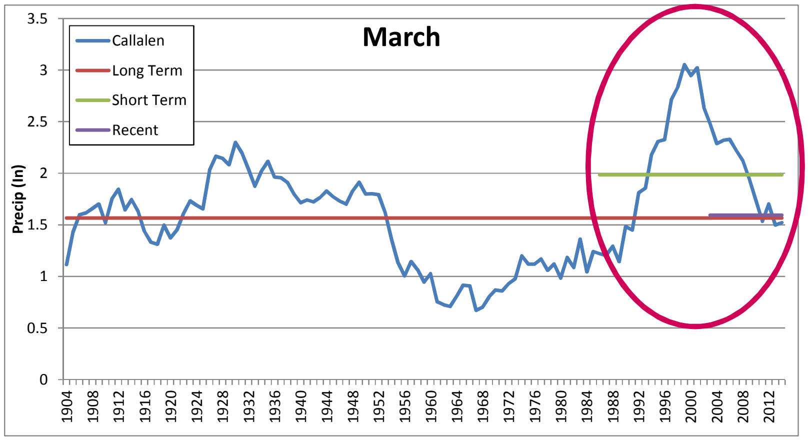
PRECIPITATION

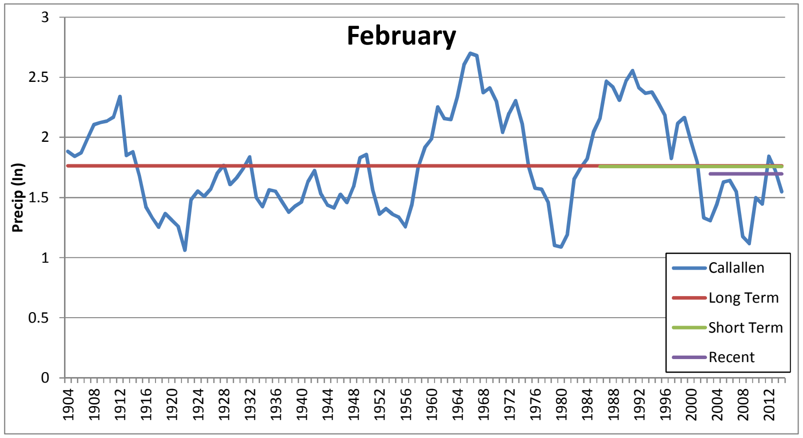
- July Precip Totals
  - o 1895 – 2014
- 10-yr moving average
  - o Trends
- Averages
  - o Long-Term
  - o Short-Term
  - o Recent

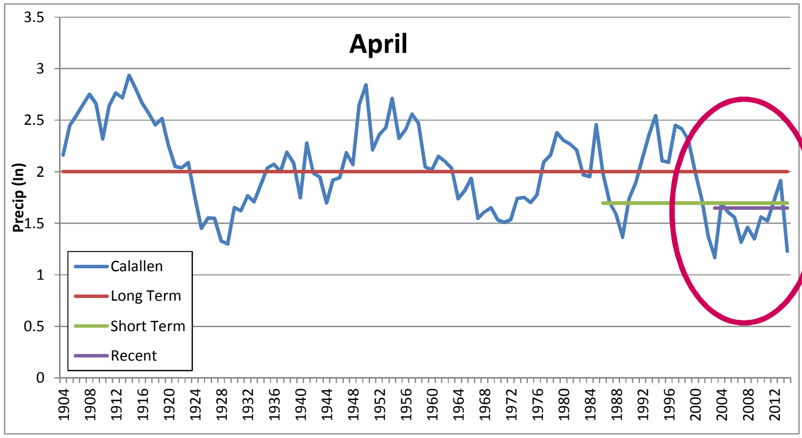


MONTHLY PRECIPITATION COMPARISONS

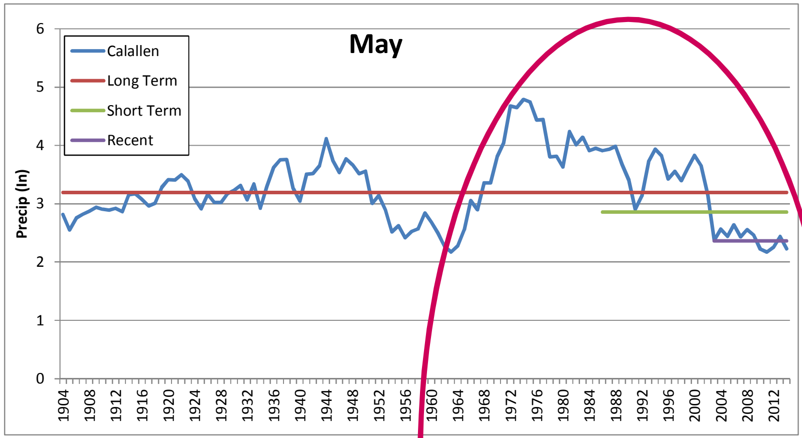


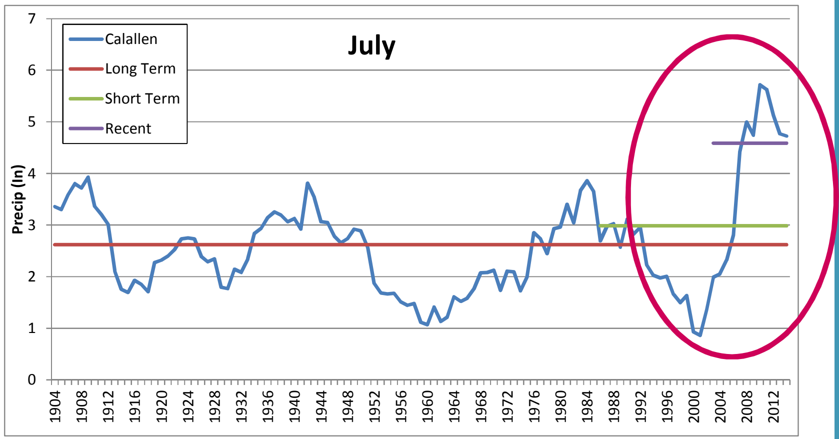


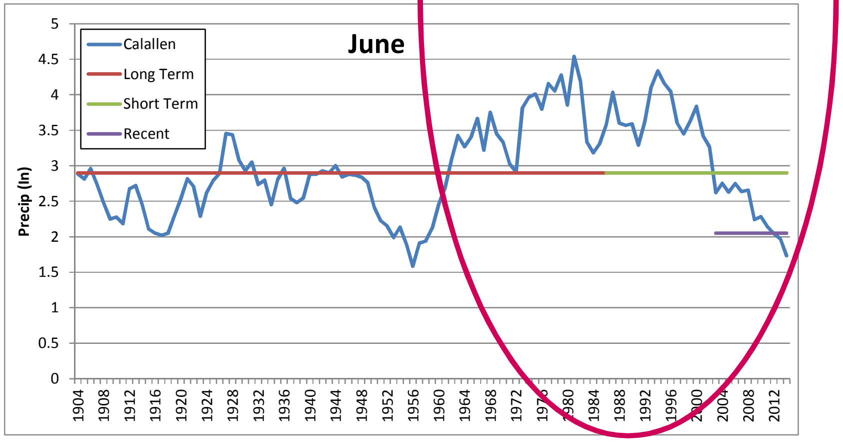


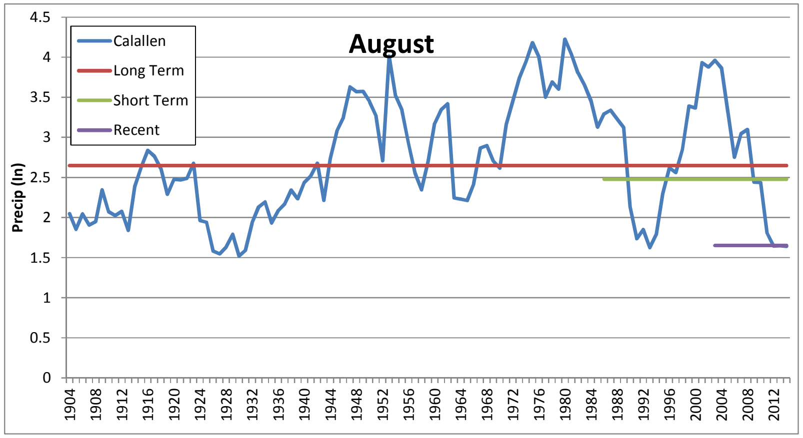


MONTHLY PRECIPITATION COMPARISONS

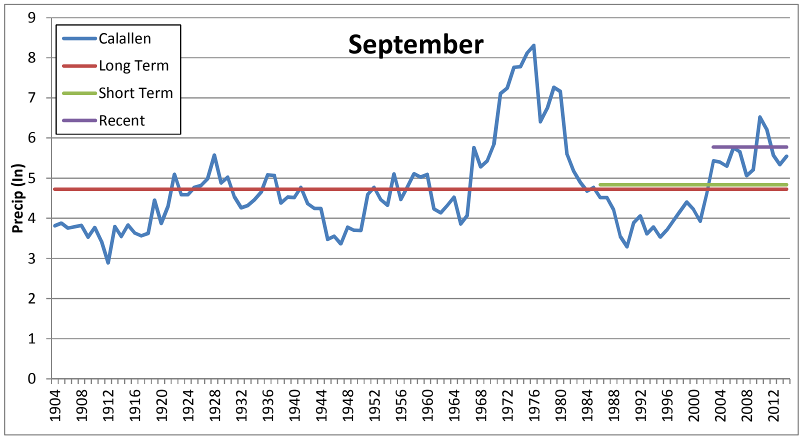


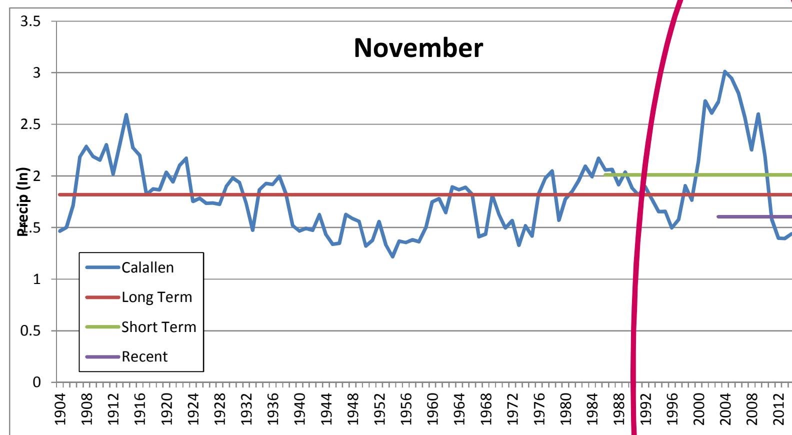


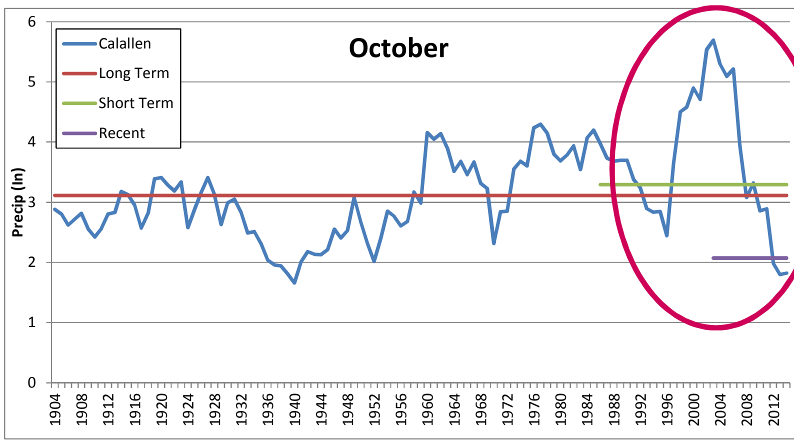


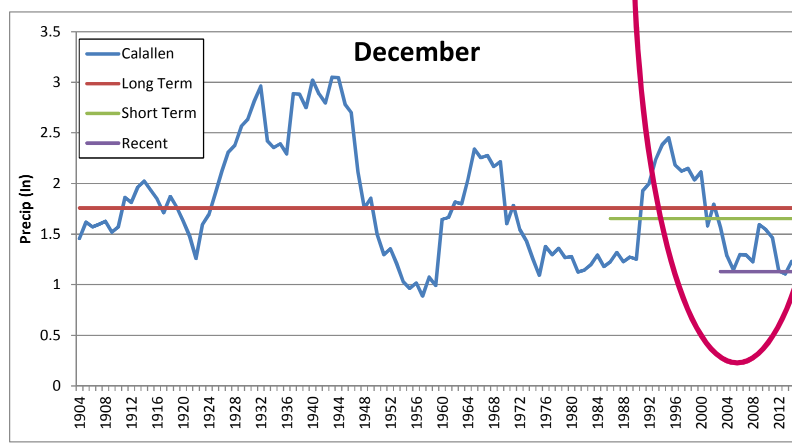


MONTHLY PRECIPITATION COMPARISONS



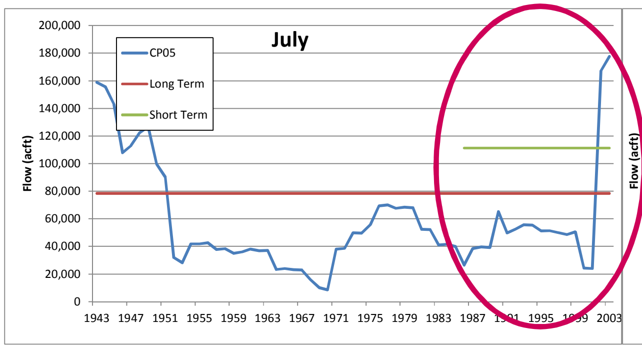


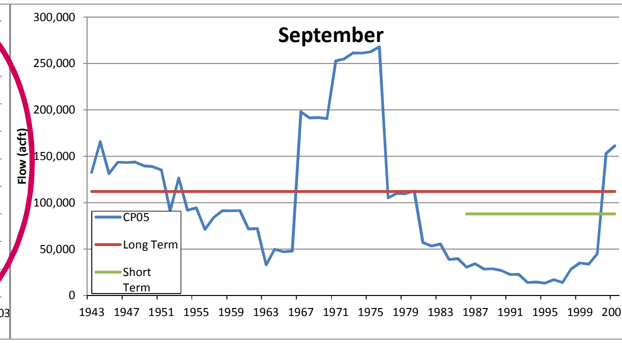


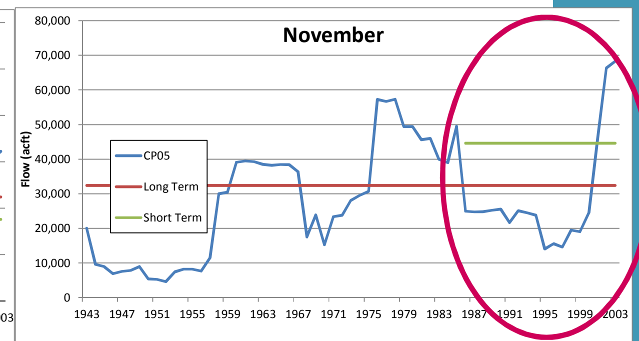


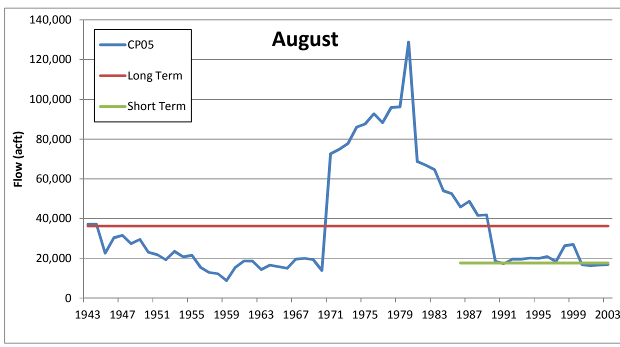
NATURALIZED FLOW

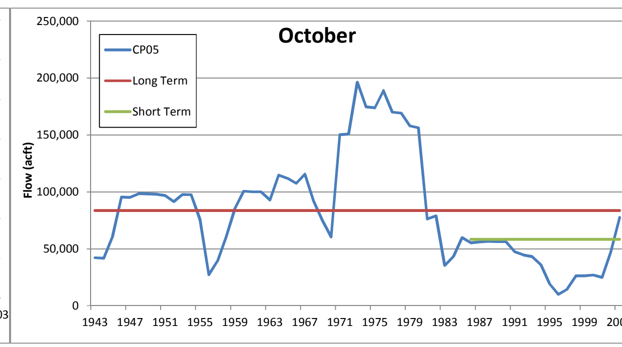
NATURALIZED FLOW

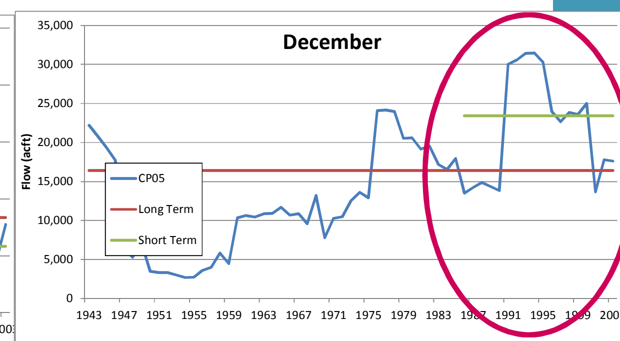




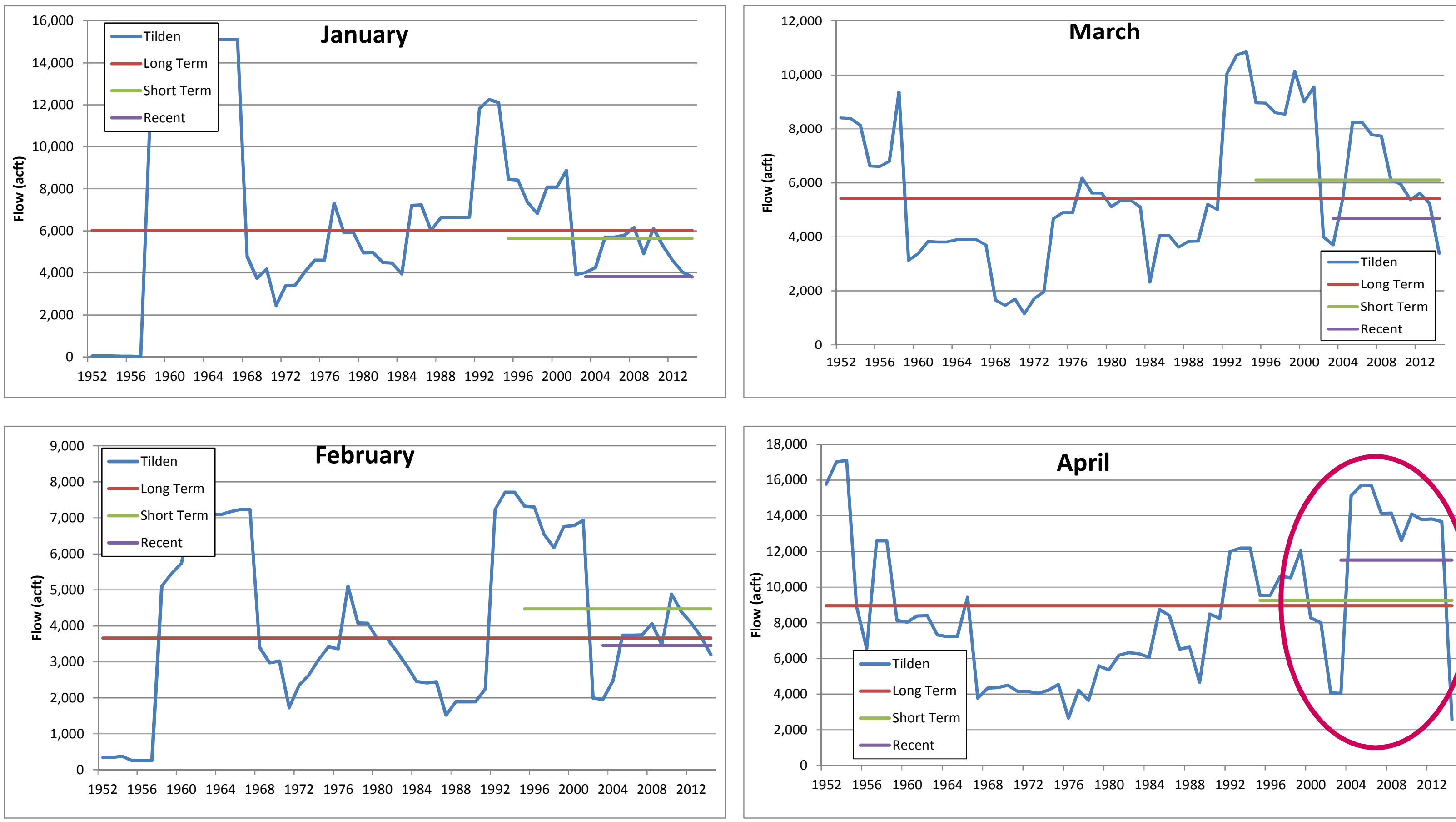




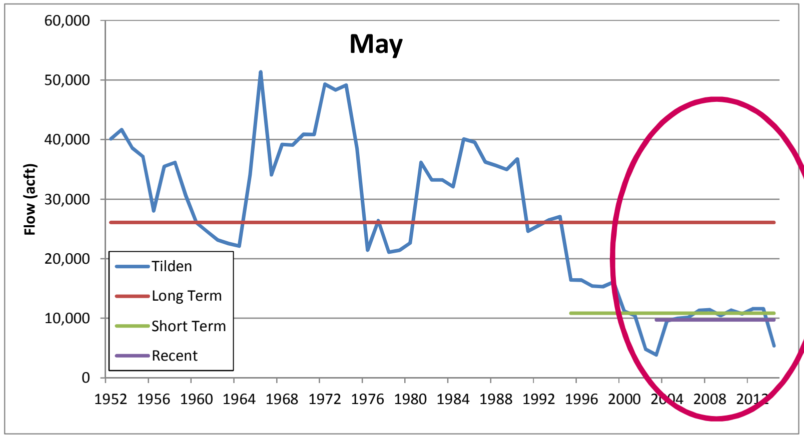


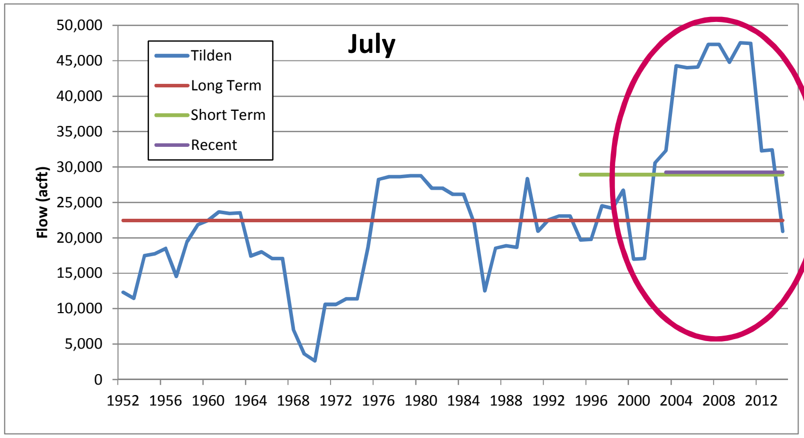


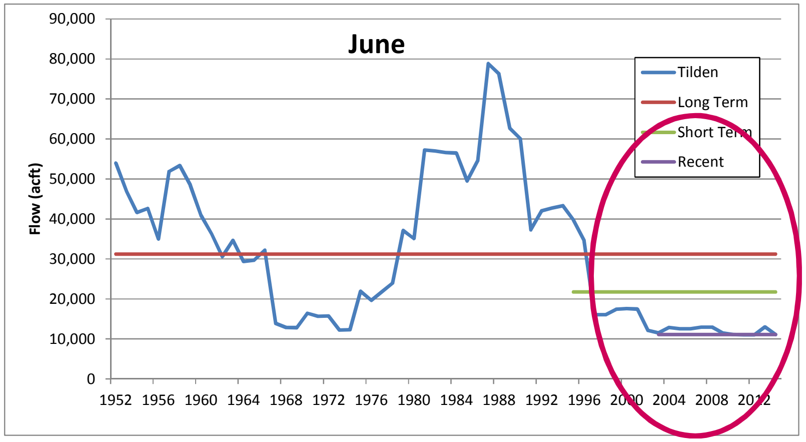
STREAMFLOW – MONTHLY COMPARISONS

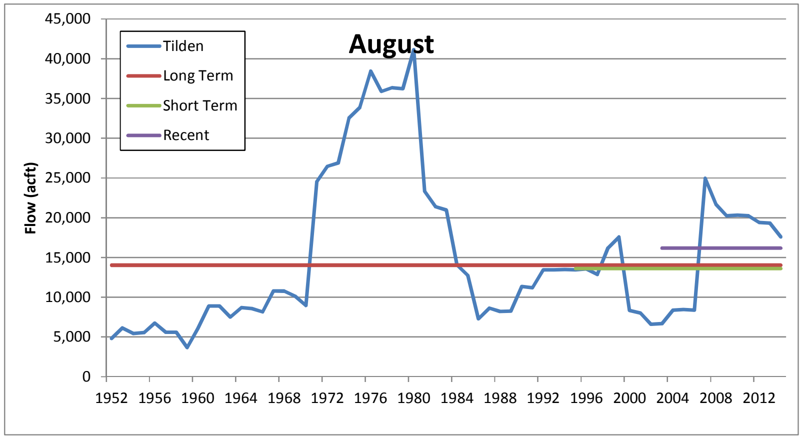


STREAMFLOW – MONTHLY COMPARISONS

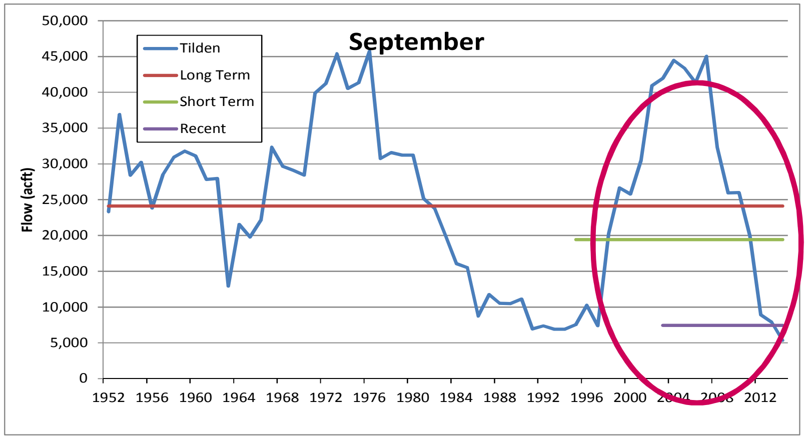


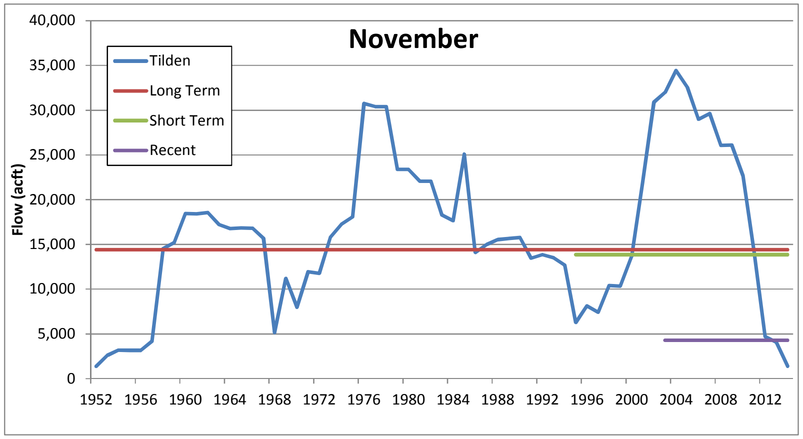


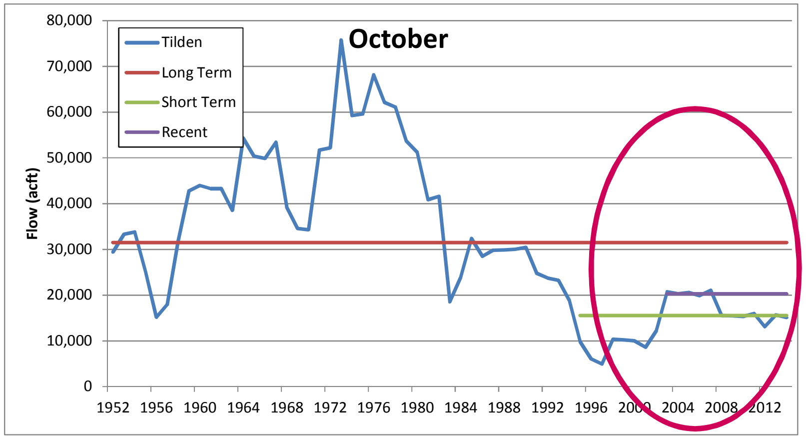


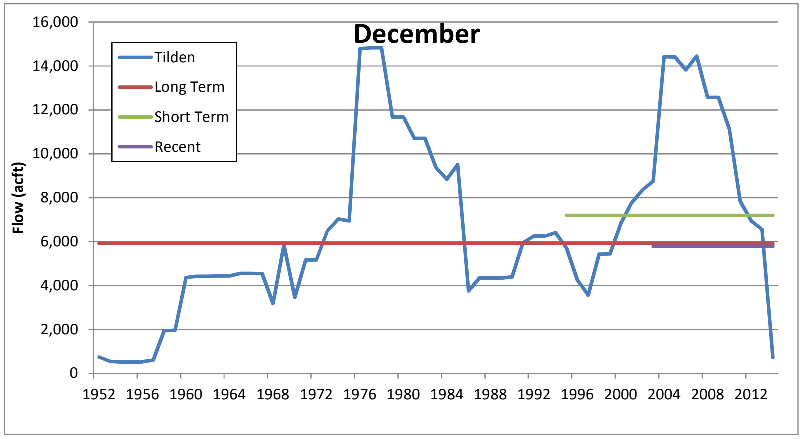


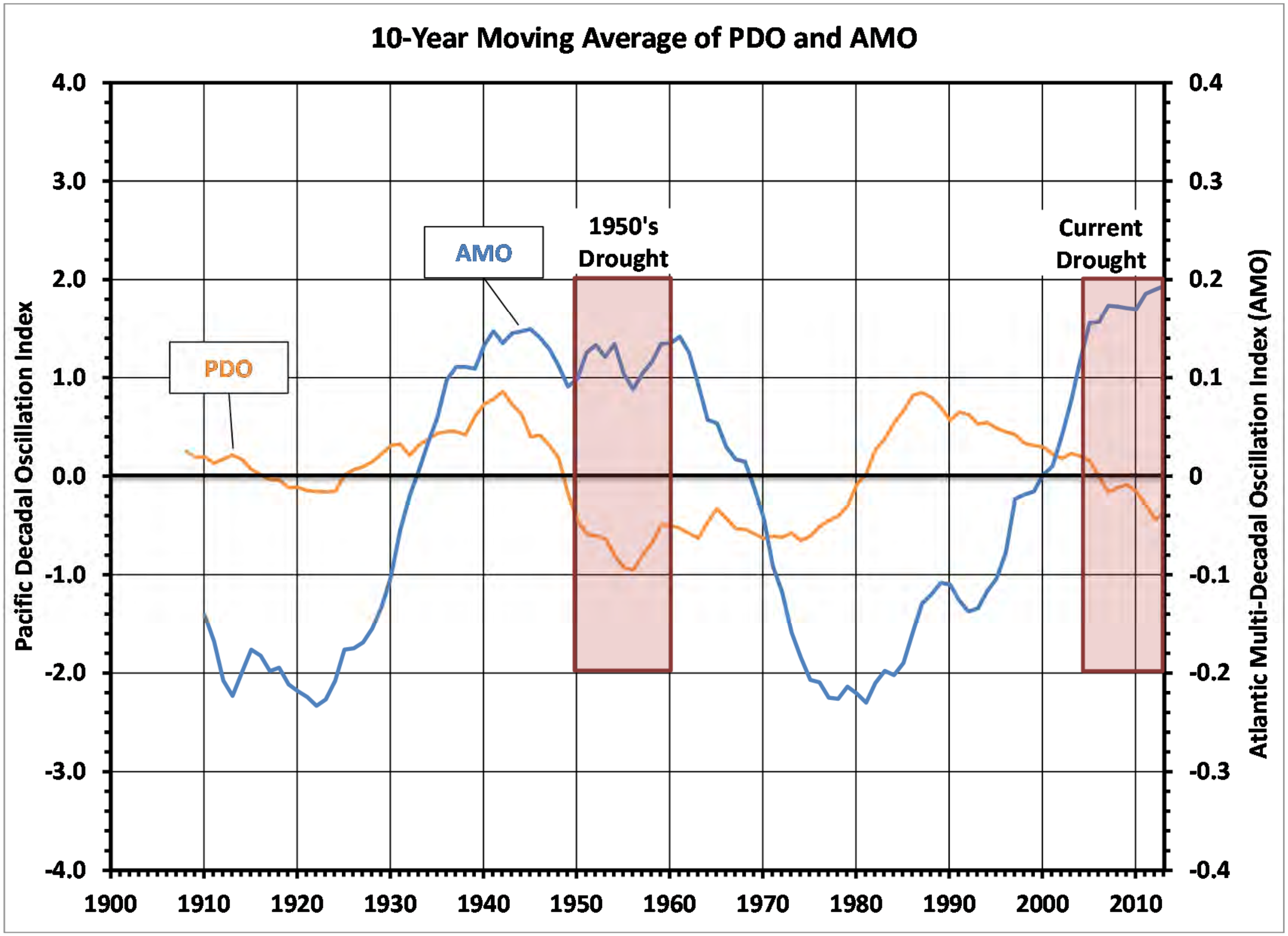
STREAMFLOW – MONTHLY COMPARISONS










10-Year Moving Average of PDO and AMO
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Pacific Decadal Oscillation Index
Atlantic Multi-Decadal Oscillation Index (AMO)
AMO
PDO
1950's Drought
Current Drought

CONCLUSIONS

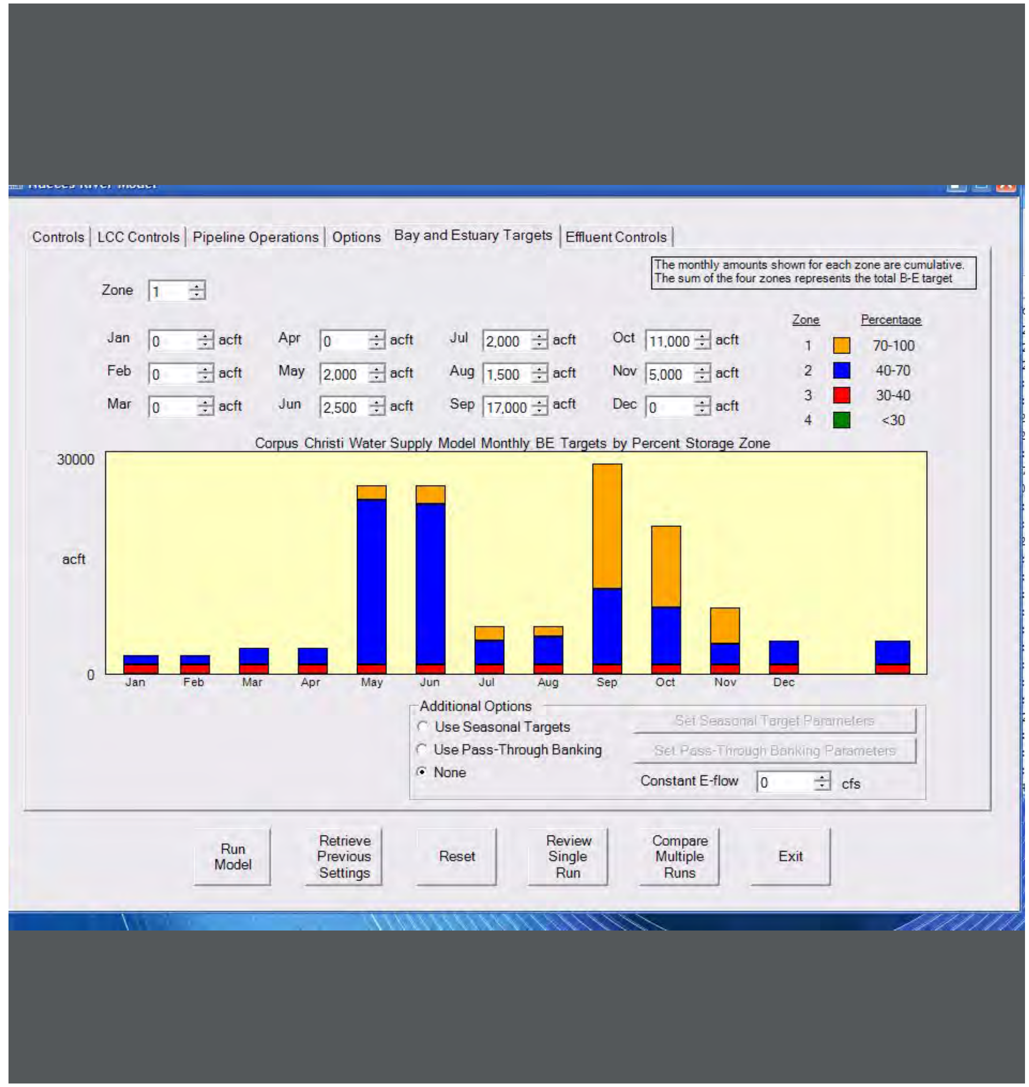
	Jan-ST	Jan-R	Feb-ST	Feb-R	Mar-ST	Mar-R	Apr-ST	Apr-R	May-ST	May-R	Jun-ST	Jun-R	Jul-ST	Jul-R	Aug-ST	Aug-R	Sep-ST	Sep-R	Oct-ST	Oct-R	Nov-ST	Nov-R	Dec-ST	Dec-R
Precipitation	↔	↑	↔	↔	↑	↔	↓	↓	↓	↓	↔	↓	↑	↑	↔	↓	↔	↑	↔	↓	↑	↓	↔	↓
Streamflow	↔	↓	↑	↔	↑	↓	↔	↑	↓	↓	↓	↓	↑	↑	↔	↔	↓	↓	↓	↓	↔	↓	↑	↔
QNAT	↓		↑		↑		↓		↓		↓		↑		↓		↓		↓		↑		↑	
Trend	No Change		No Change		No Change		Drier		Drier		Drier		Wetter		No Change		Drier		Drier		No Change		No Change	

- Six months show no significant trend
  - 4 of these show some minor dry trend in the recent average
- Five months show a drier trend
  - May, June, & Oct being the most significant
- One month shows a wetter trend
  - July is trending wetter in all categories
- The months in the Agreed Order with the highest targets all show drier trends
  - May, June, Sep, Oct

SEASONAL SHIFT - NEXT STEPS

- If the trend is drier then there is no need to adjust the targets down
- Evaluate impact of the wetter July trend
- CCWSM Simulations
  - Shift target to July
    - Keep overall annual target volume the same
      - Reduce from May / June
    - Impact to Bay FWI
    - Impact to Safe Yield

Discussion

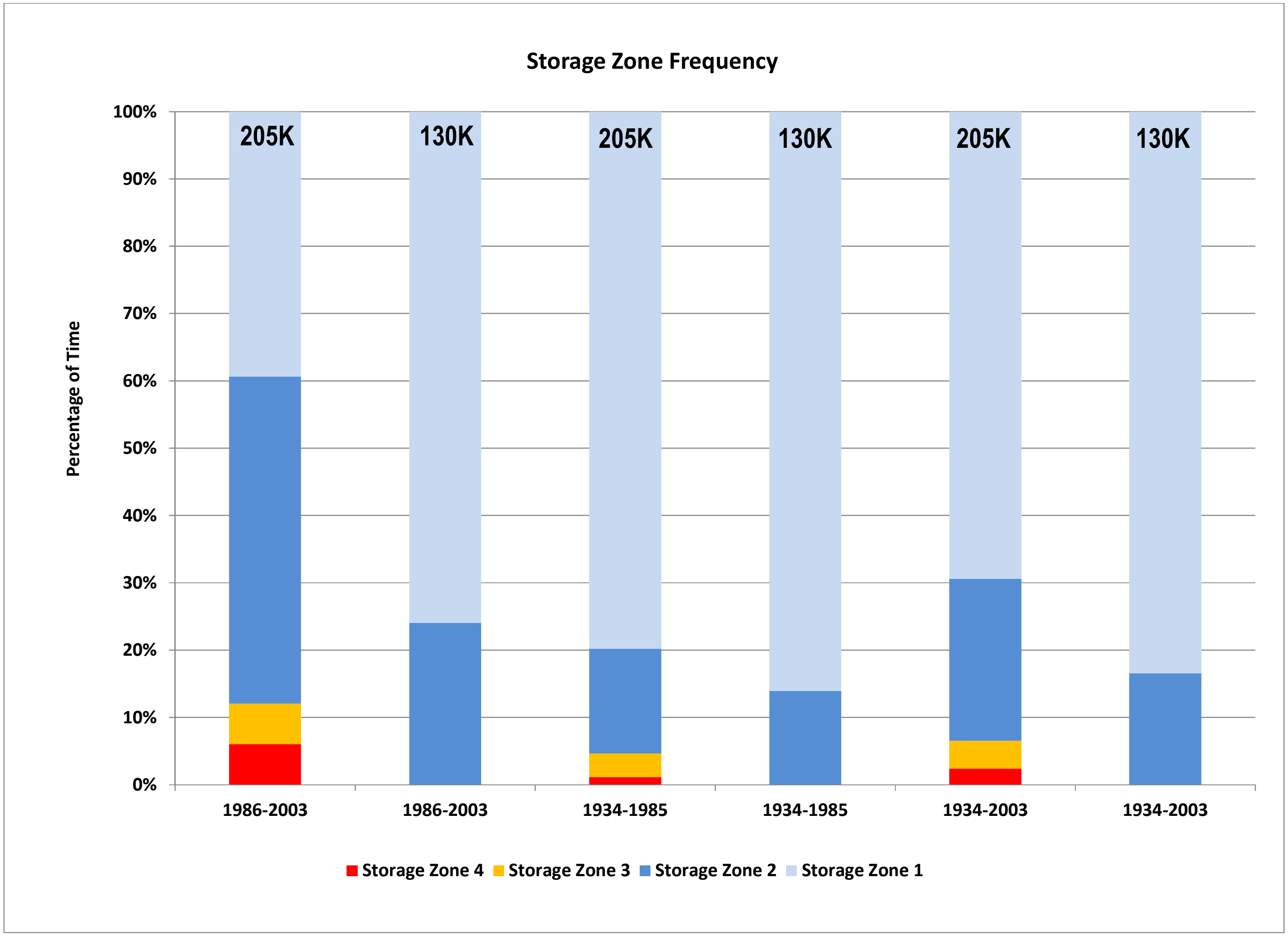


TASK 2 – YIELD COMPARISON

- Task Complete
- Compare Safe Yield and Current Demand
  - Safe Yield
    - 205,000 acft/yr
      - 125,000 acft storage reserve (~14%)
      - Regional Planning modeling assumptions
  - Current Demand
    - 133,000 acft/yr
  - Results
    - Lake Level Comparison
    - FWI Comparison
    - Attainment Frequency
    - Mass Balance

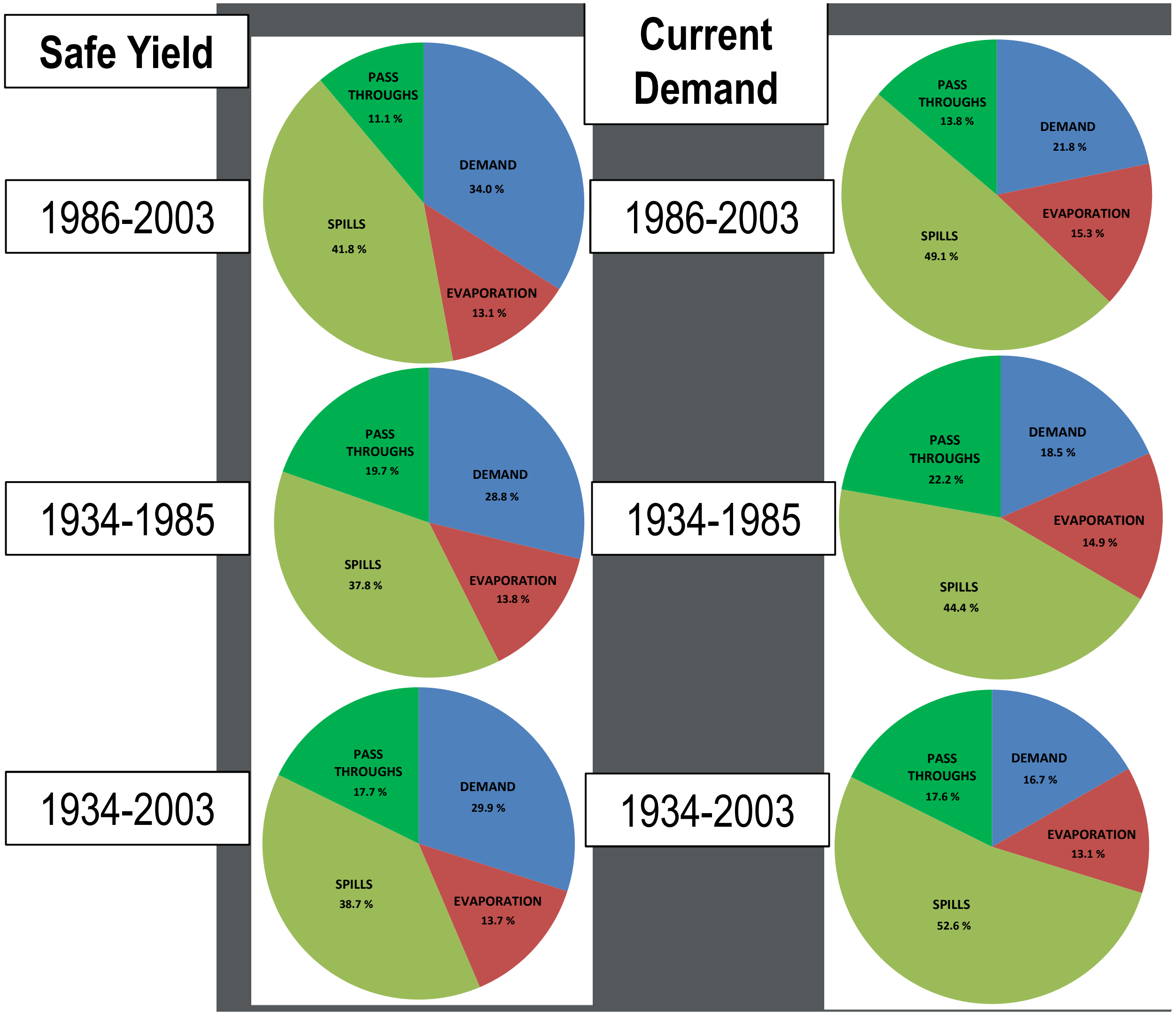
RESULTS

- Two different demands
- Three time periods
- Variable attainment frequencies



MASS BALANCE

- Spills are significant
- Long-term
  - Evaporation 0.6% Difference
  - Pass-Throughs 0.1% difference
  - Demand and Spills are the rest
- Short-term
  - Evaporation 2.2% Difference
  - Pass-Throughs 2.7% Difference



TASK 2 – FINDINGS

- Lower demand = higher lake levels = more opportunity for larger pass-throughs
  - On the long-term average: differences small
- Drought times are dominated by lack of inflows
  - During droughts the differences are increased but still small

TASK 3 – MEETINGS AND REPORT

- Task 3 – Meetings and Report
  - Kickoff Meeting (June 2014)
  - Results Meeting #1 (Oct 2014)
  - Results Meeting #2 (Feb 2015)
  - Draft and Final Report (Summer 2015)

SCHEDULE

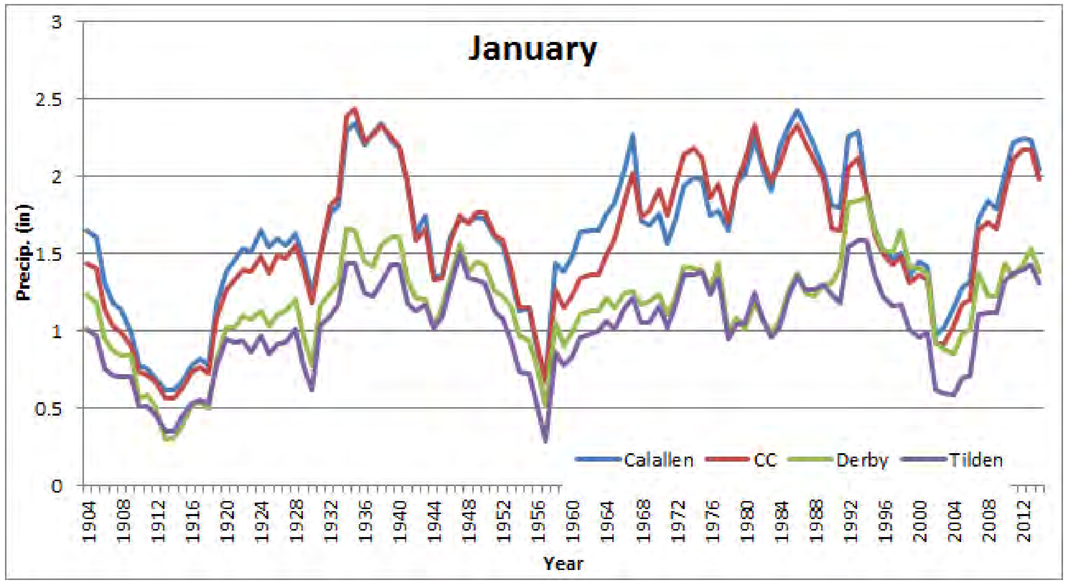
- Complete Analysis in March 2015
- Draft report June 2015
- Final report due August 2015

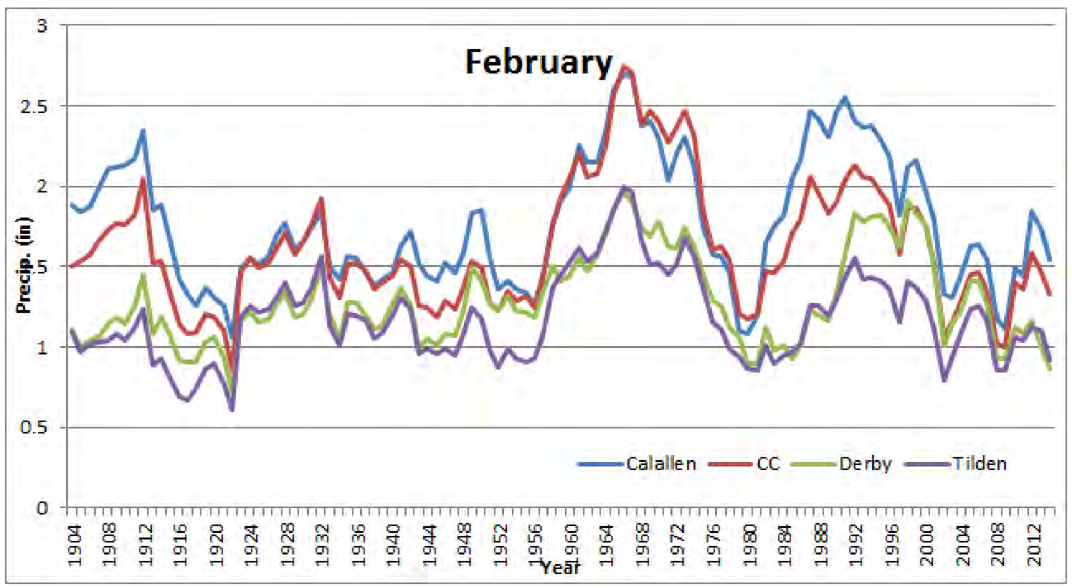

RINCON BAYOU
CBBEP Nueces Delta Preserve

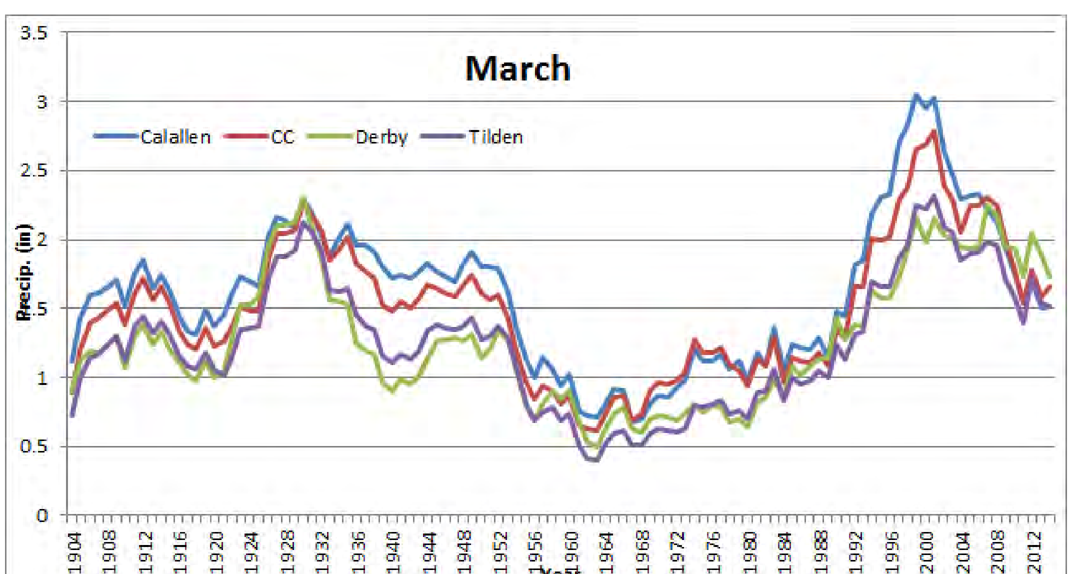
APPENDIX C – Plots of compiled data

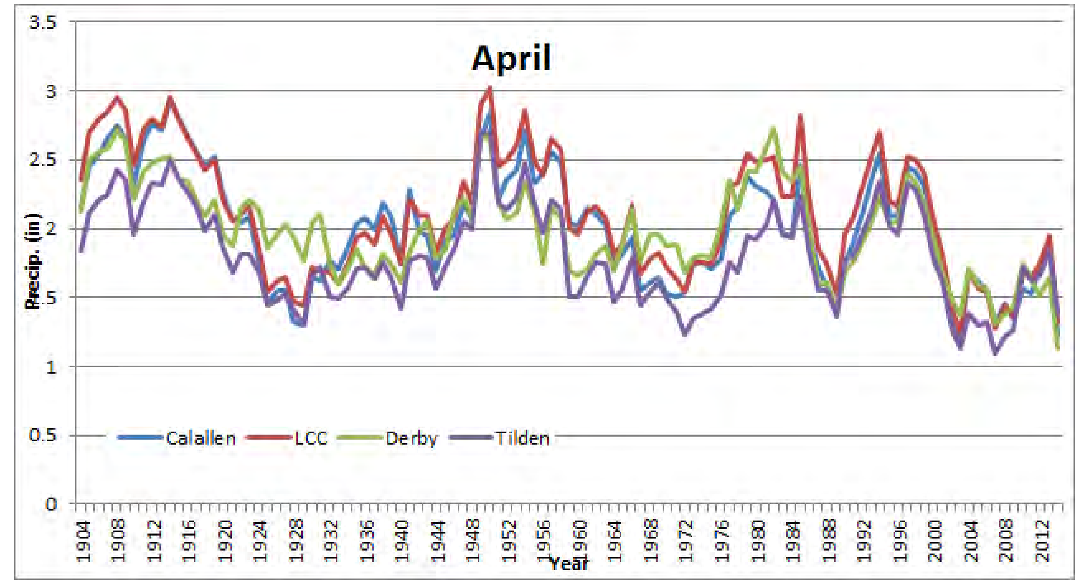
This Page Intentionally Left Blank

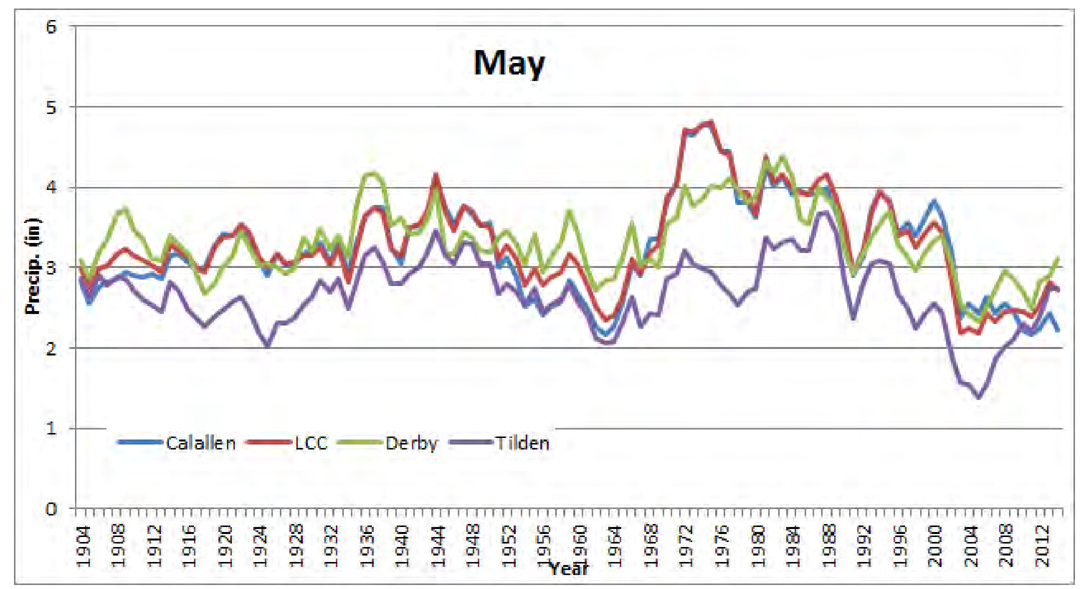
Precipitation - 10 year moving average

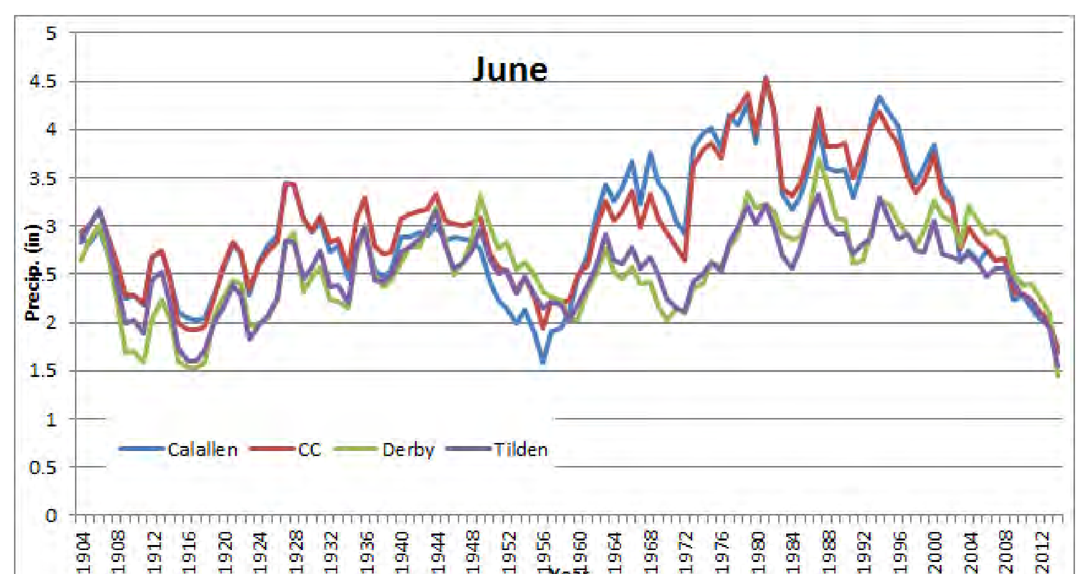




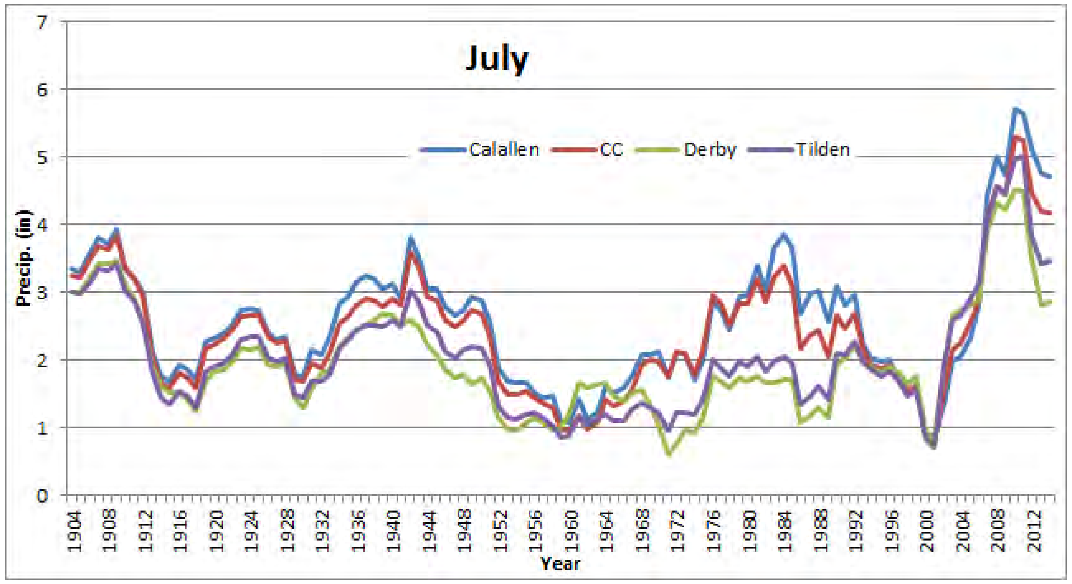


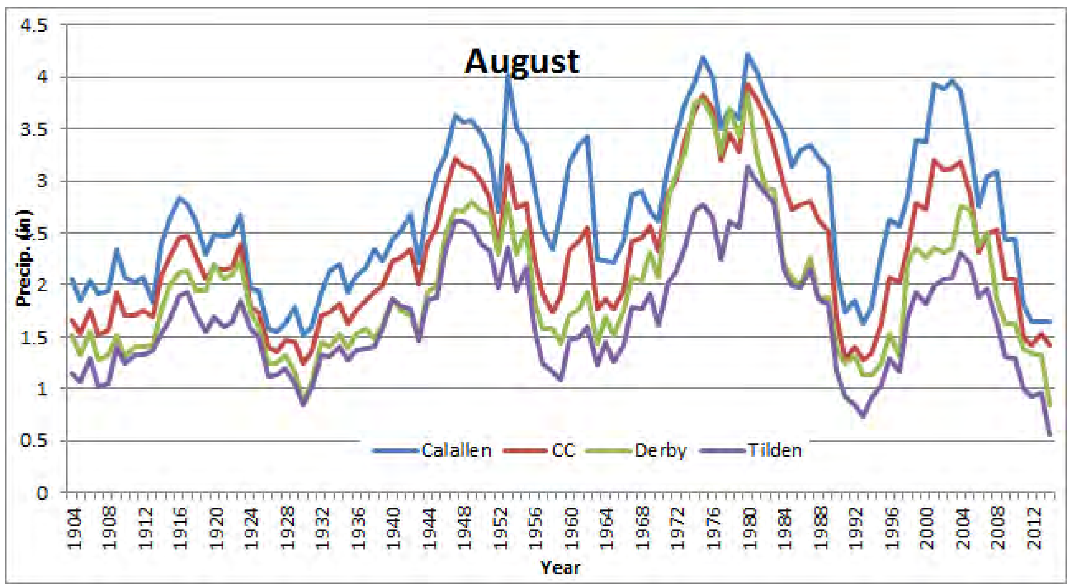


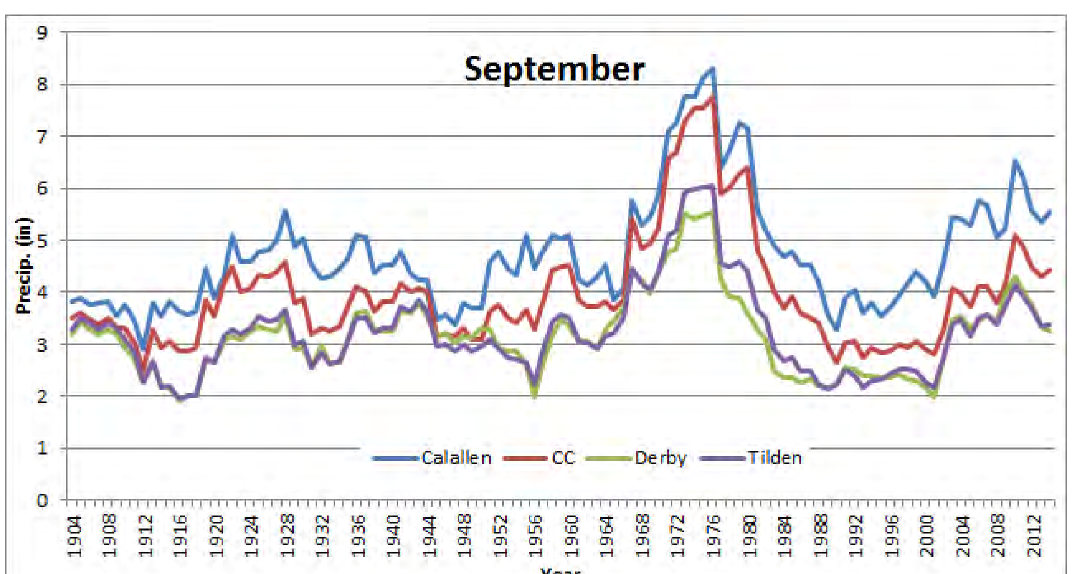


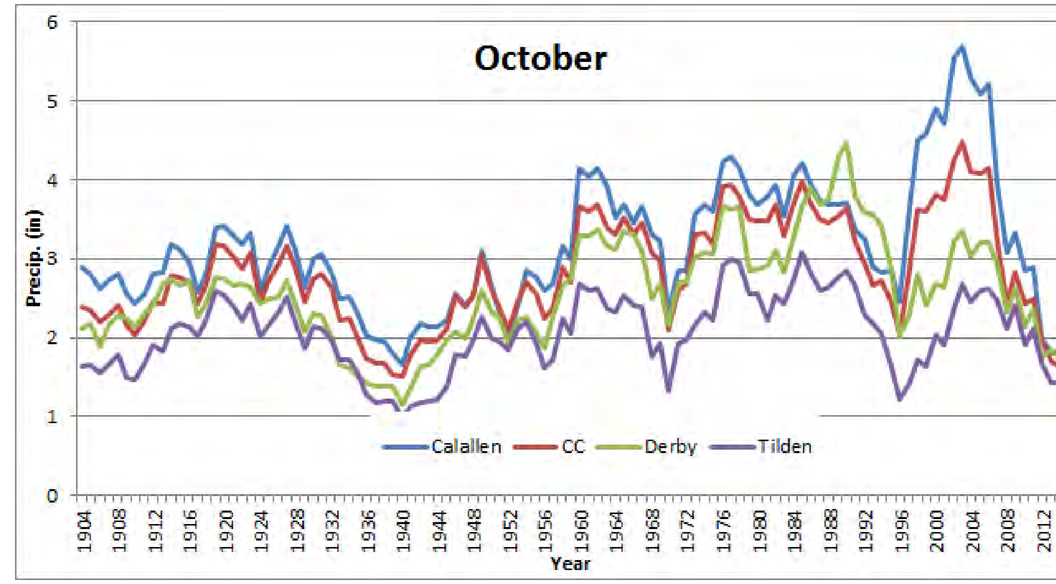


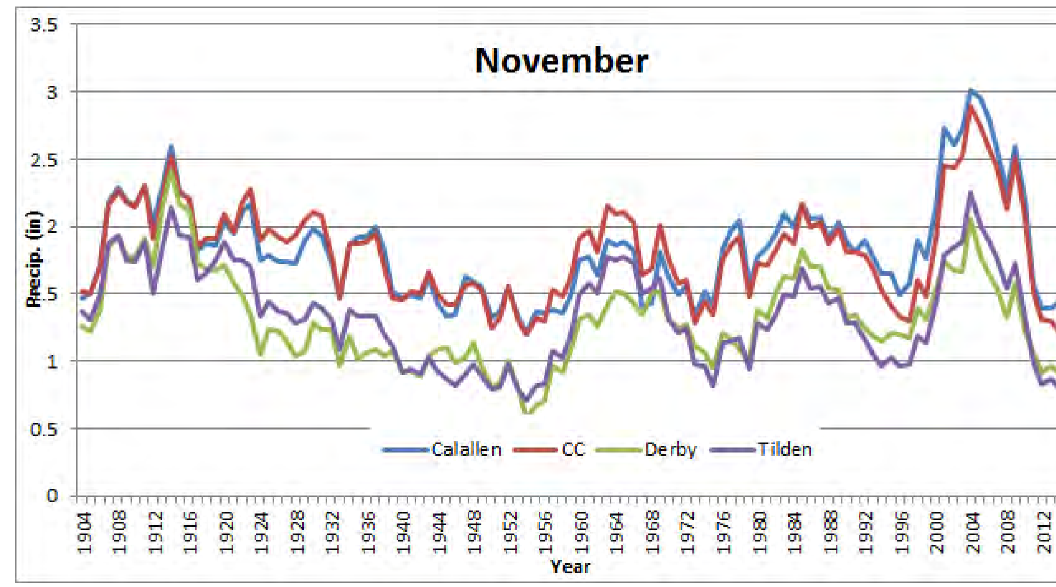
Precipitation - 10 year moving average

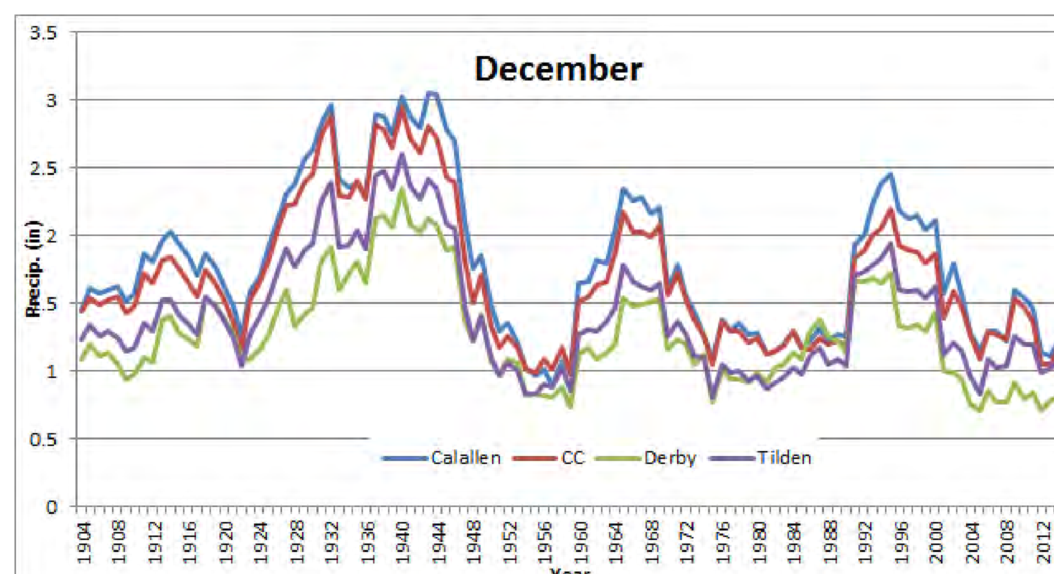




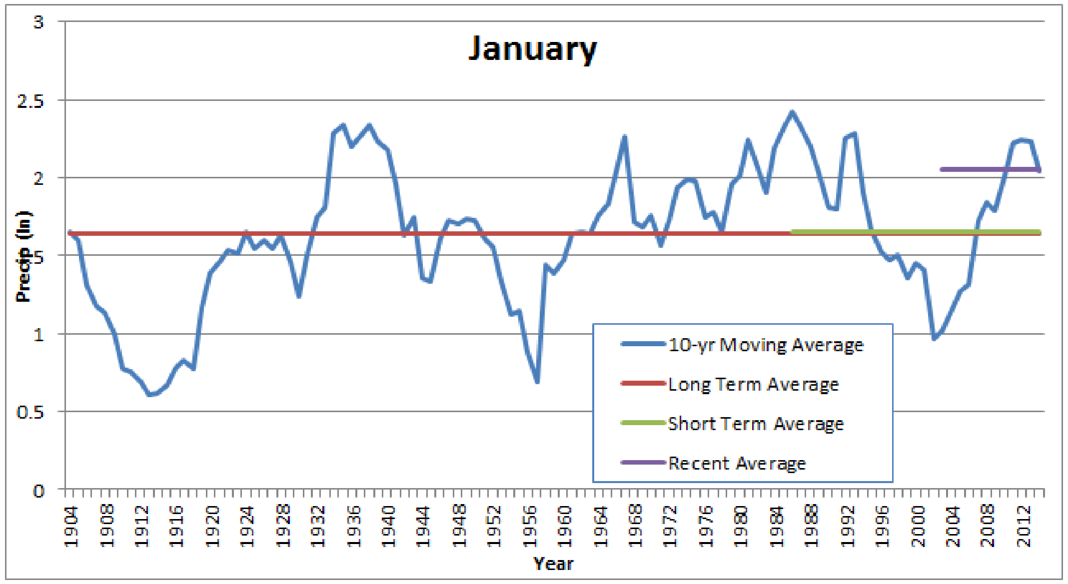


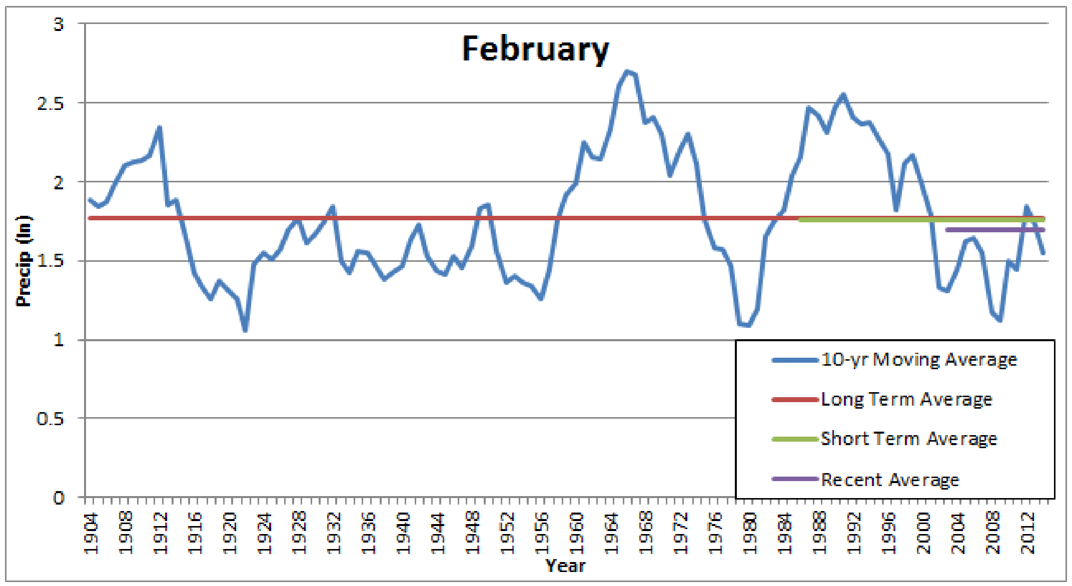


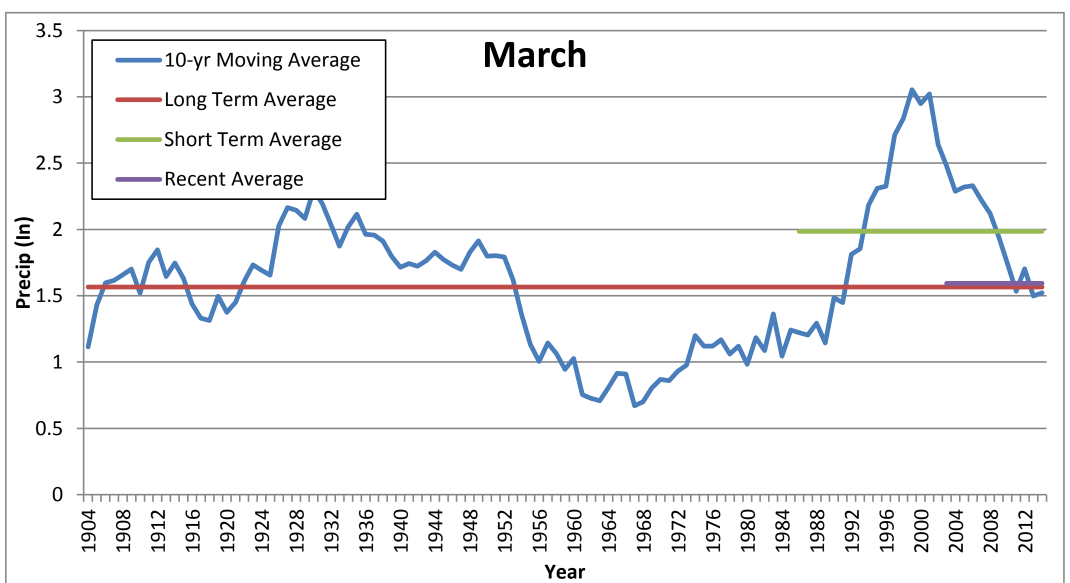


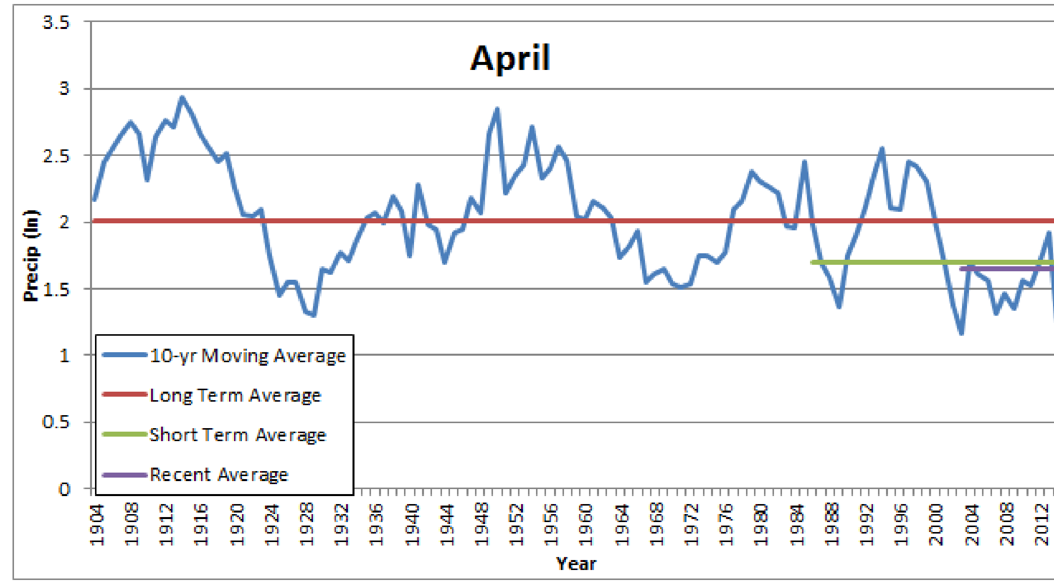


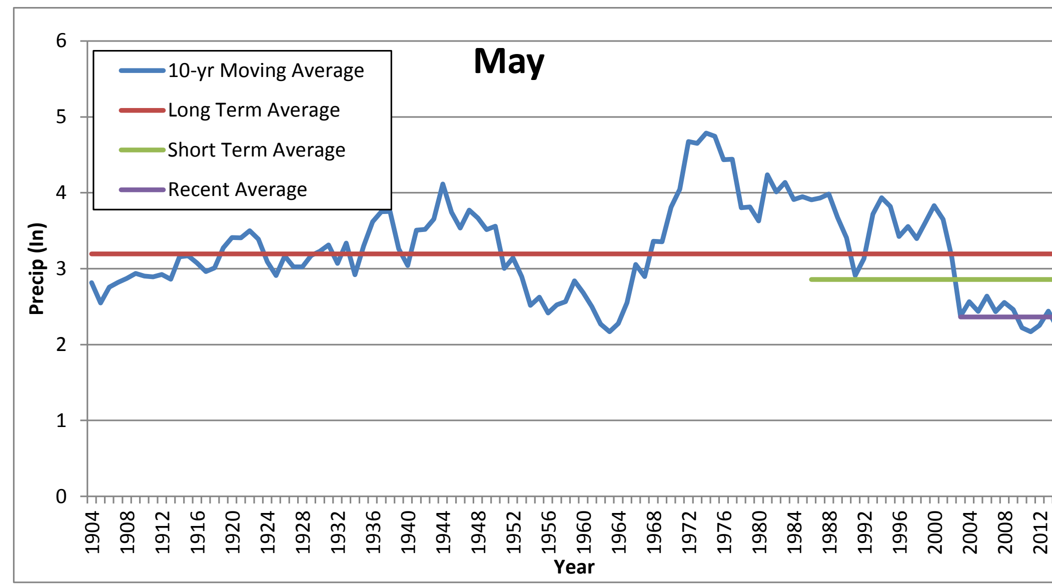
Precipitation – Calallen

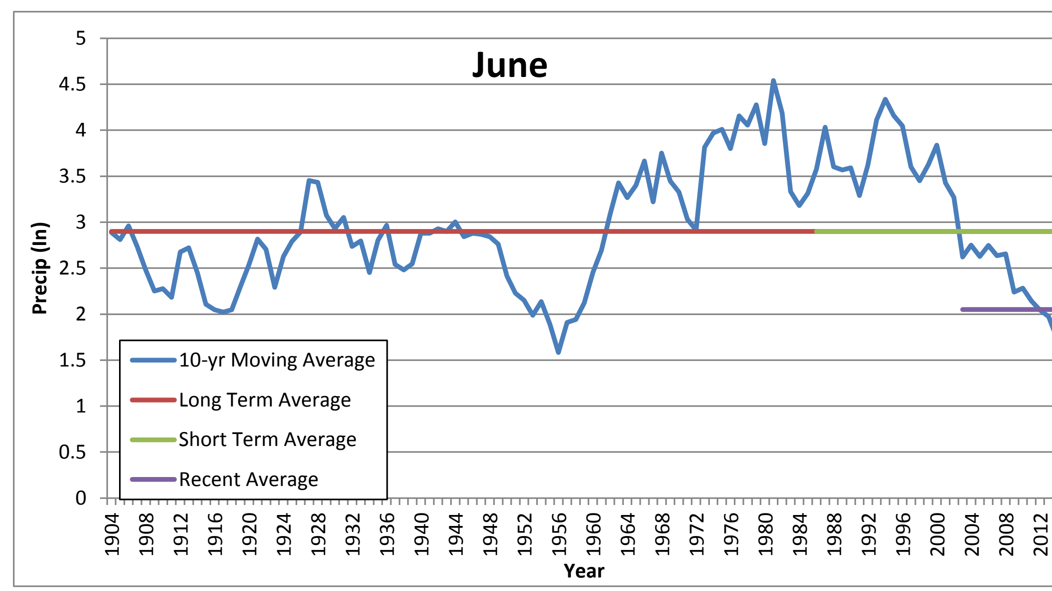




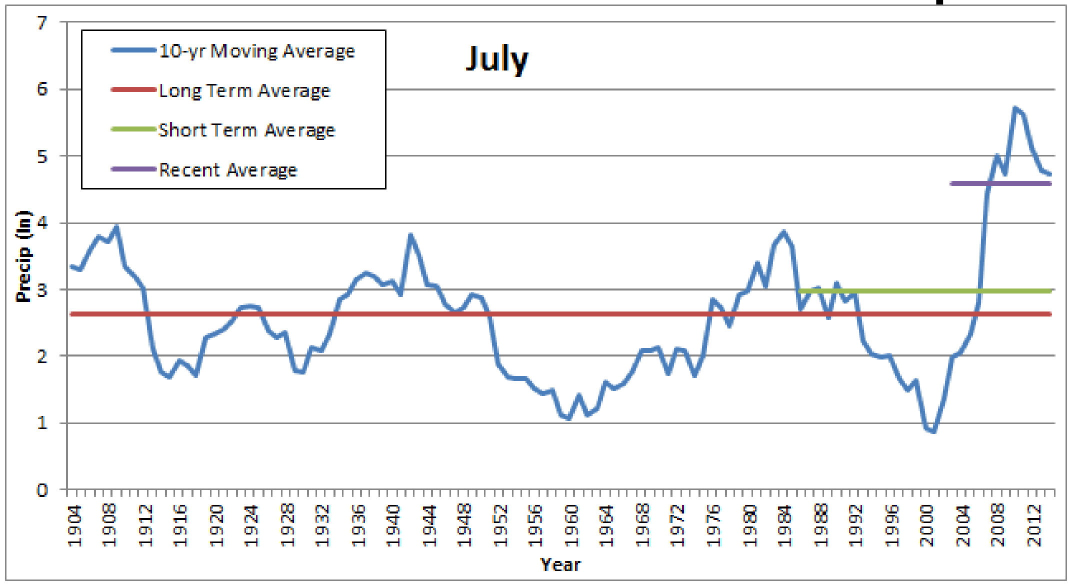


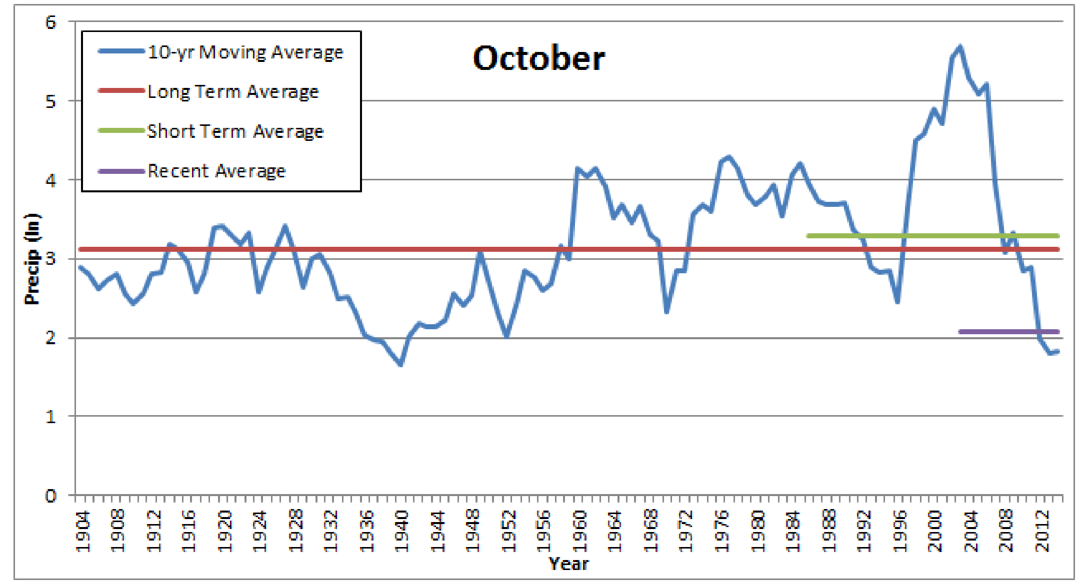


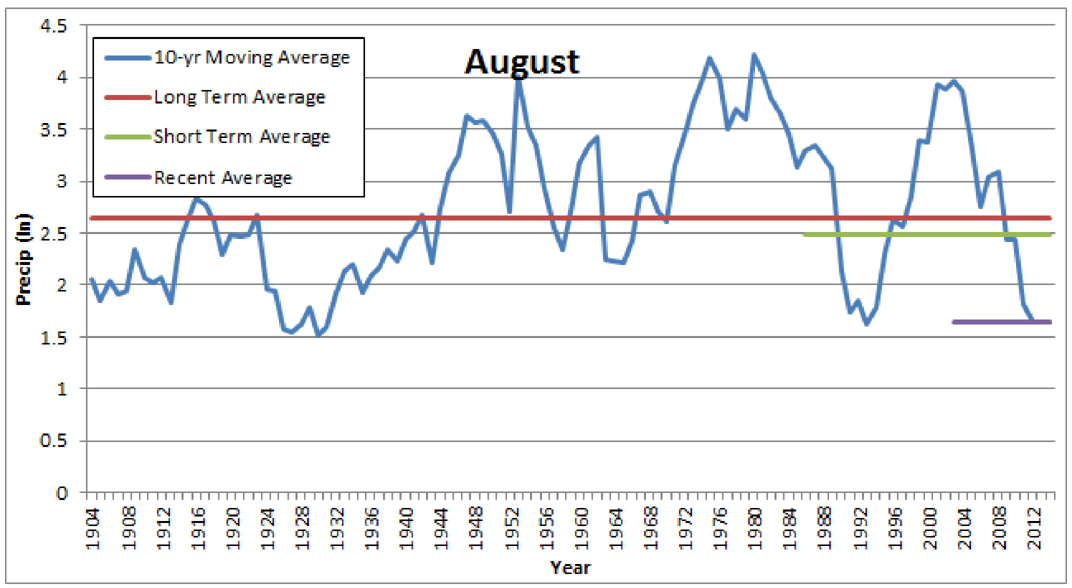


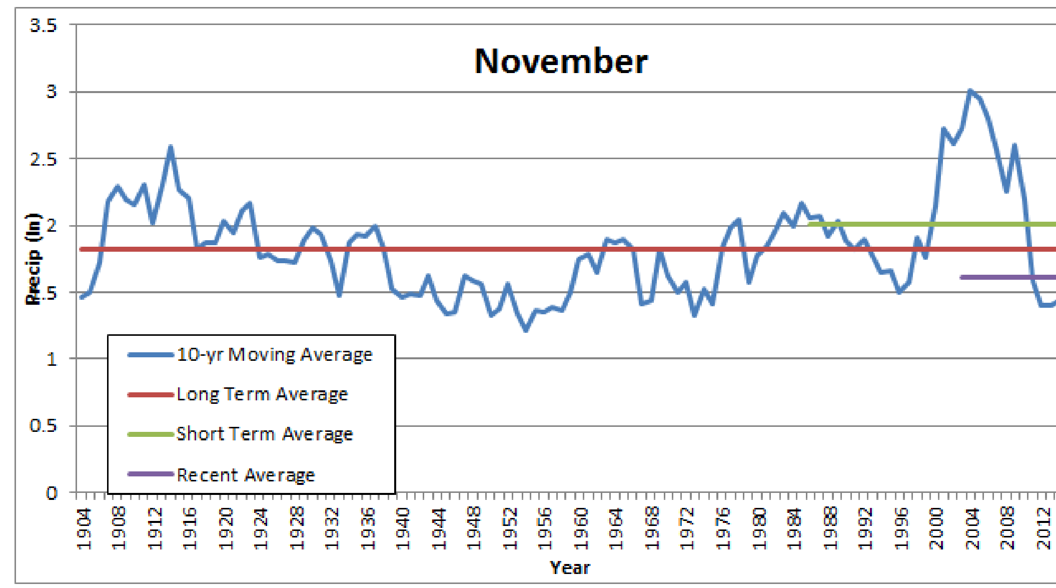


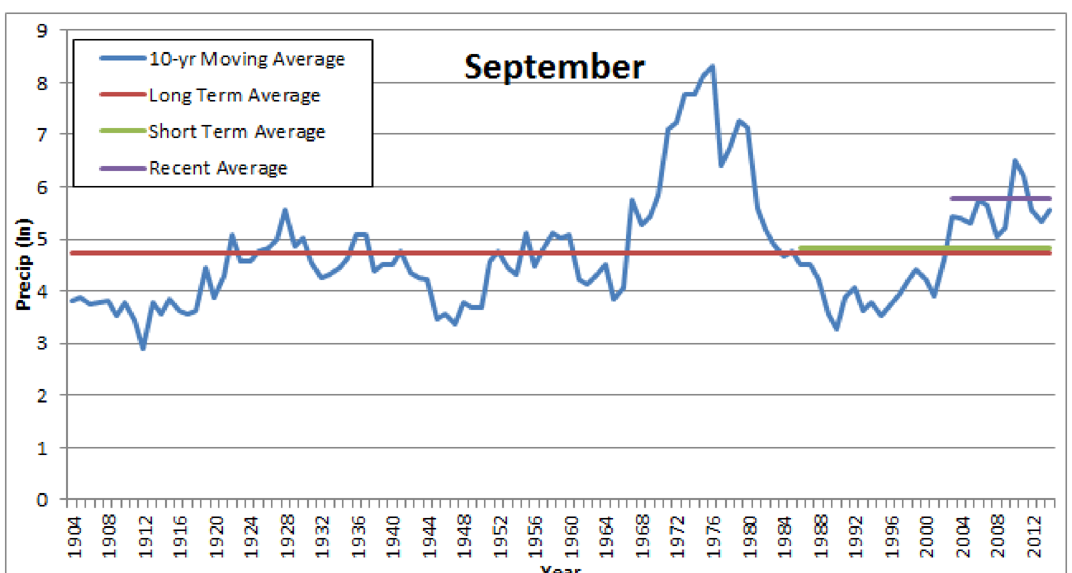
Precipitation – Calallen

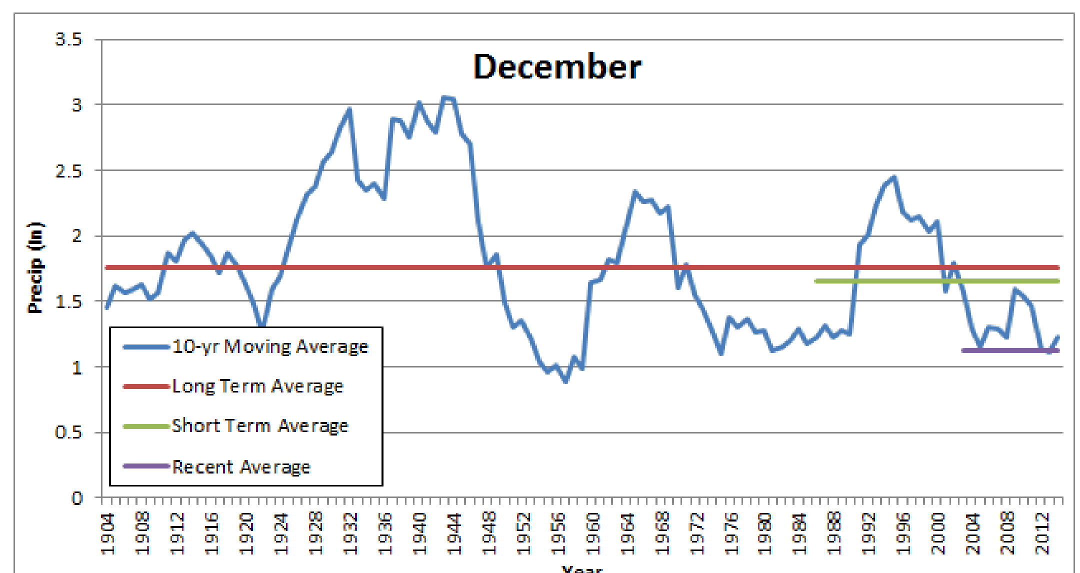




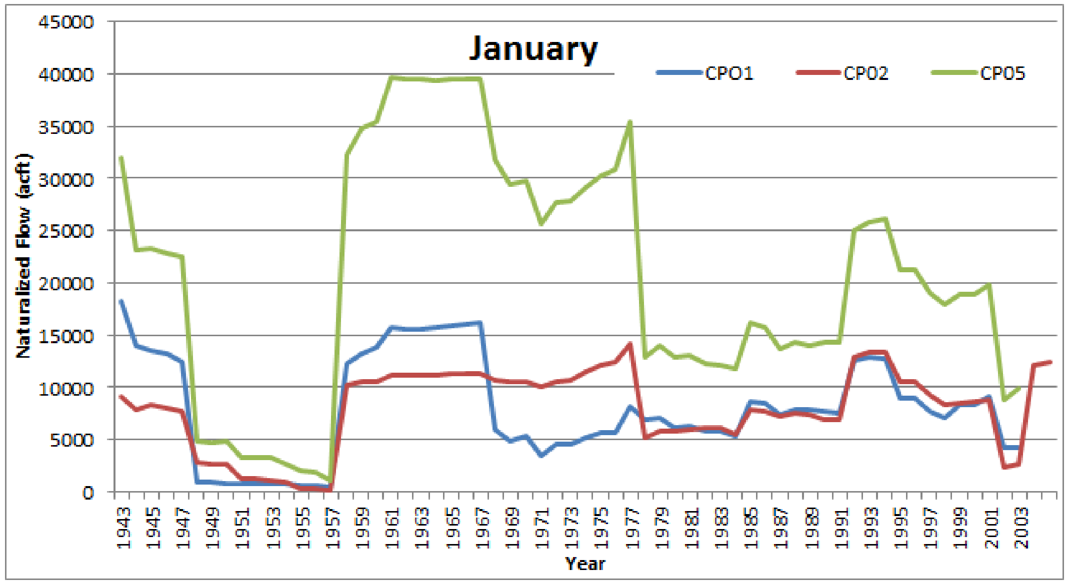


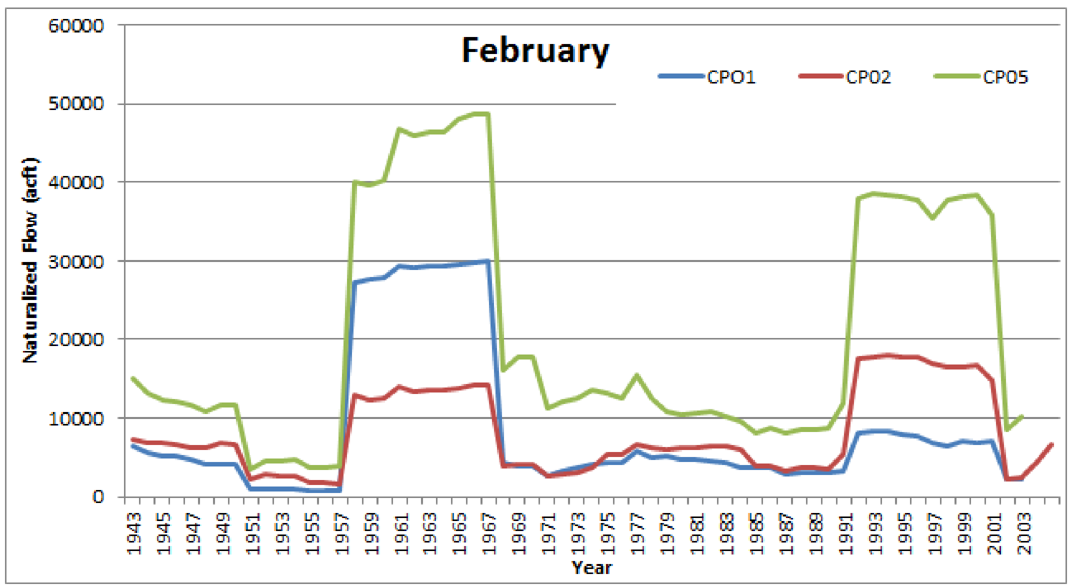


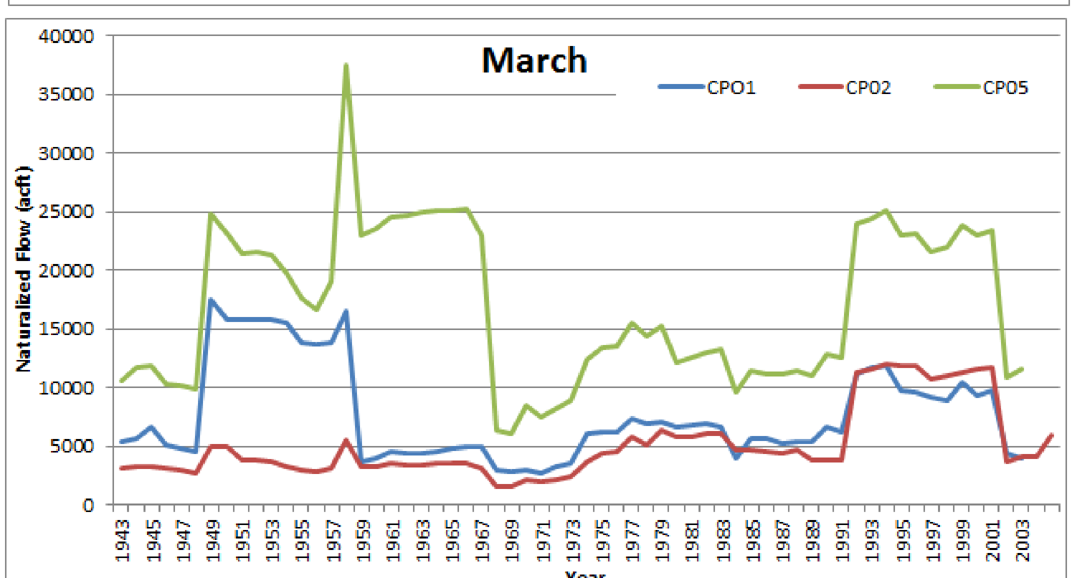


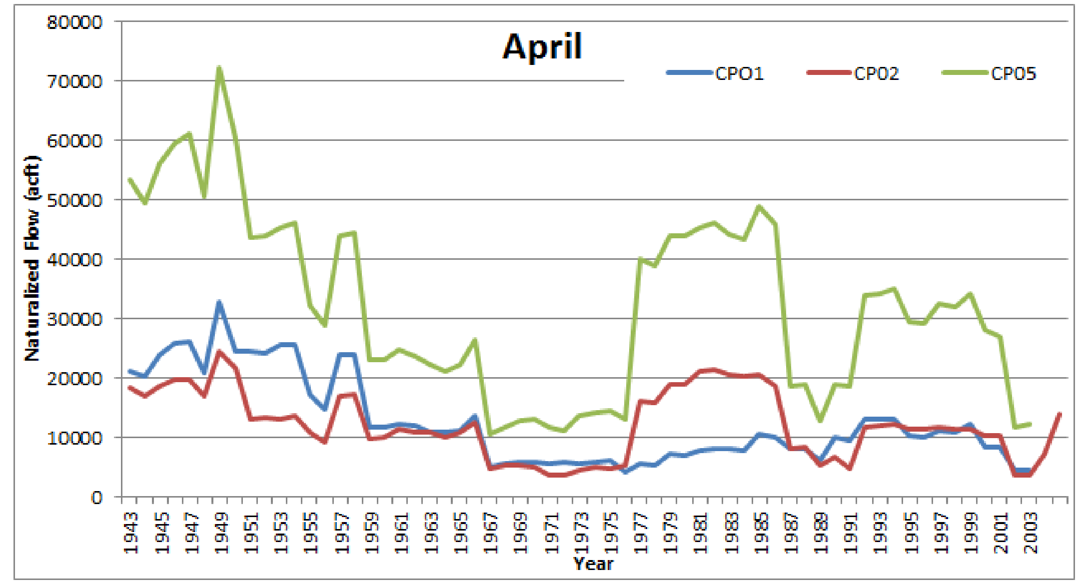


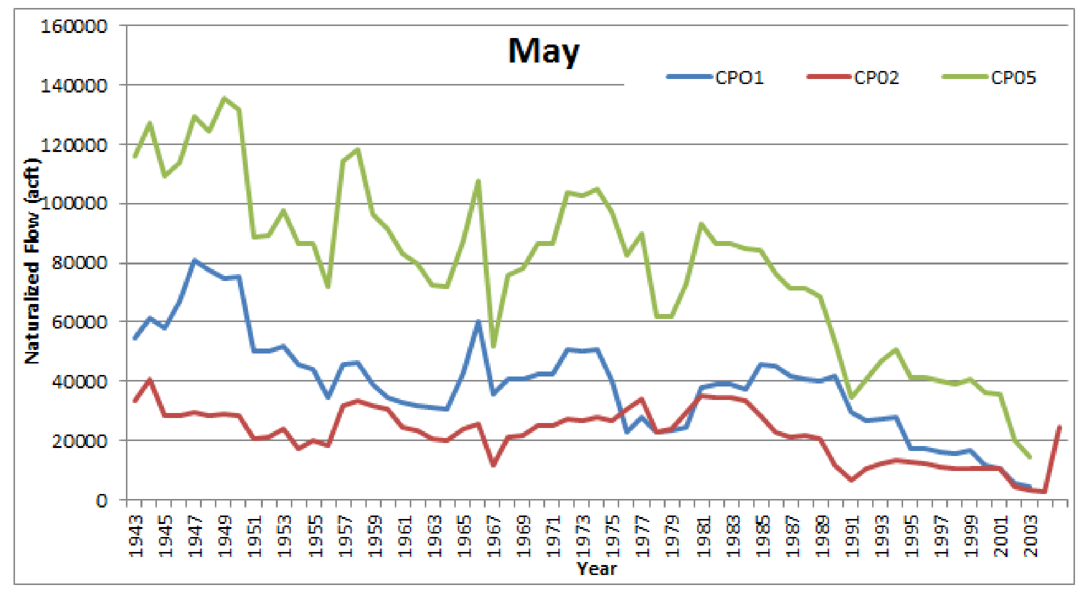
QNAT – 10 year average

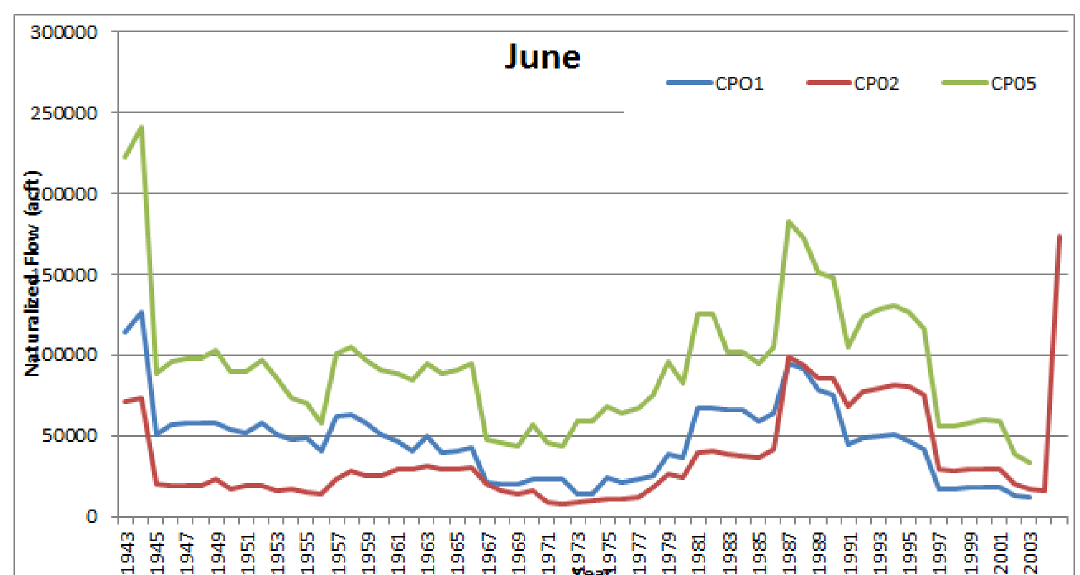




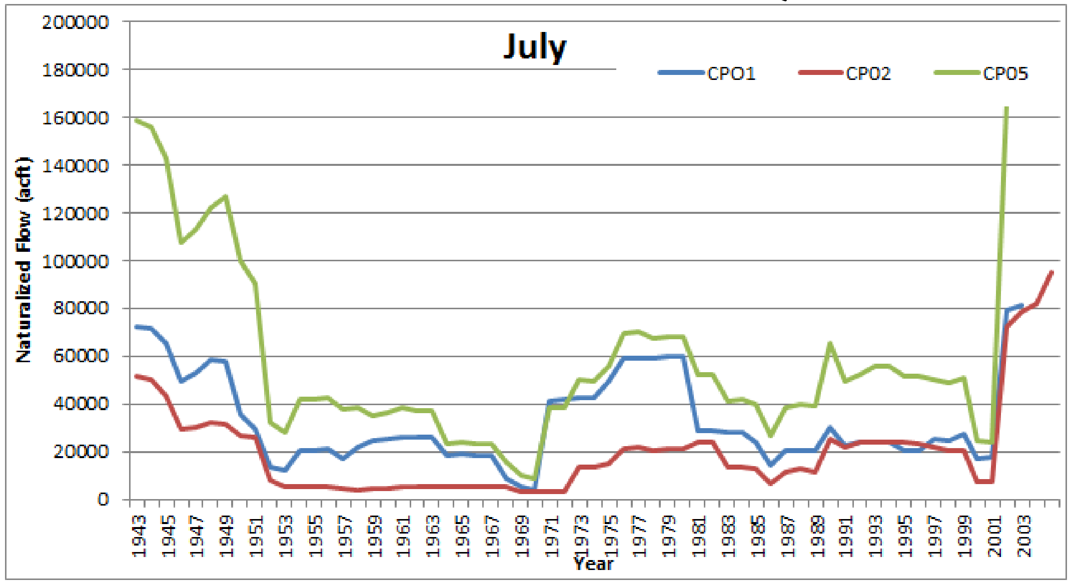


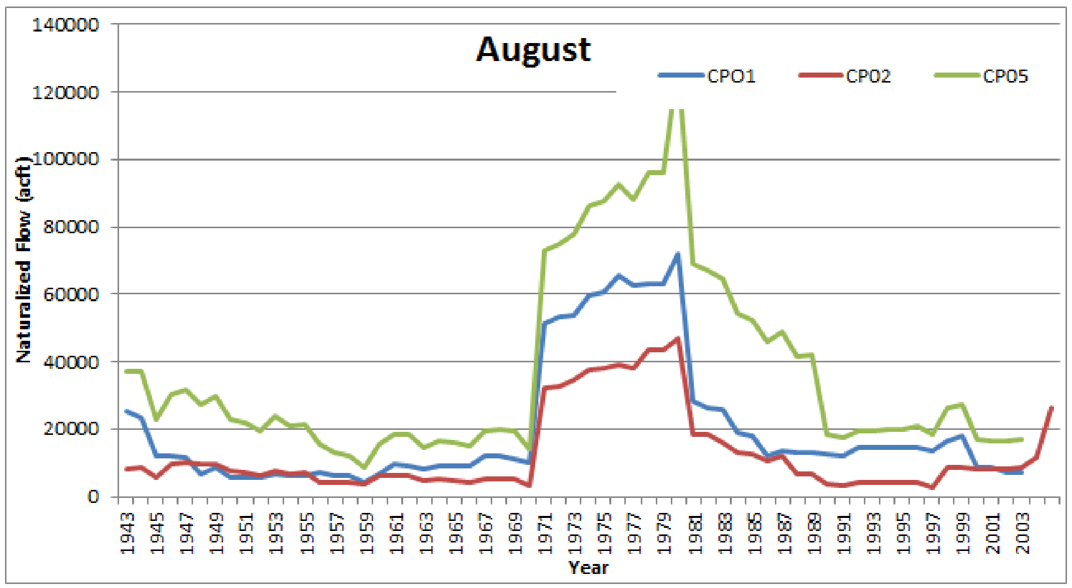


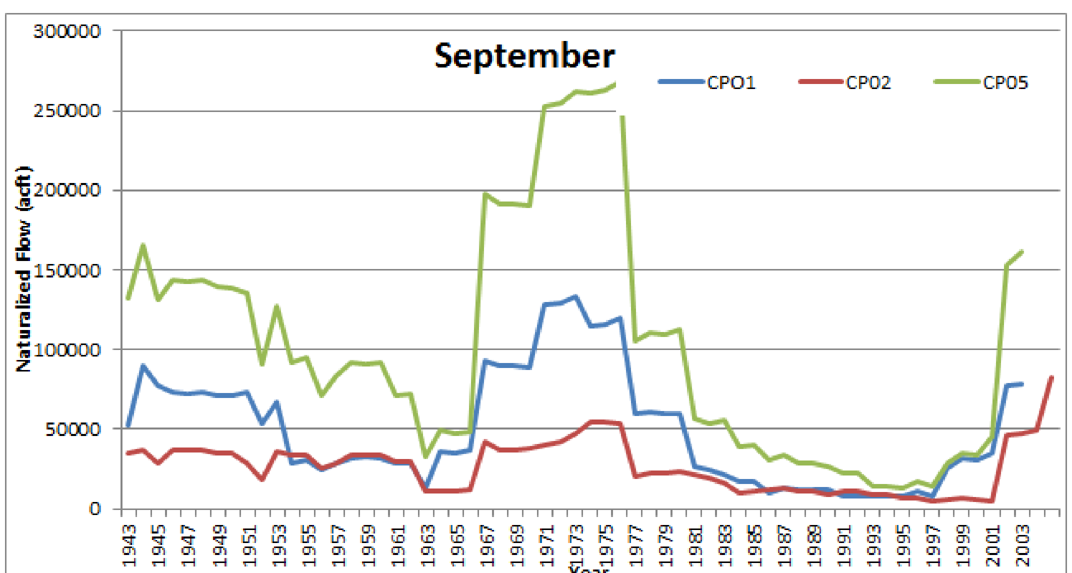


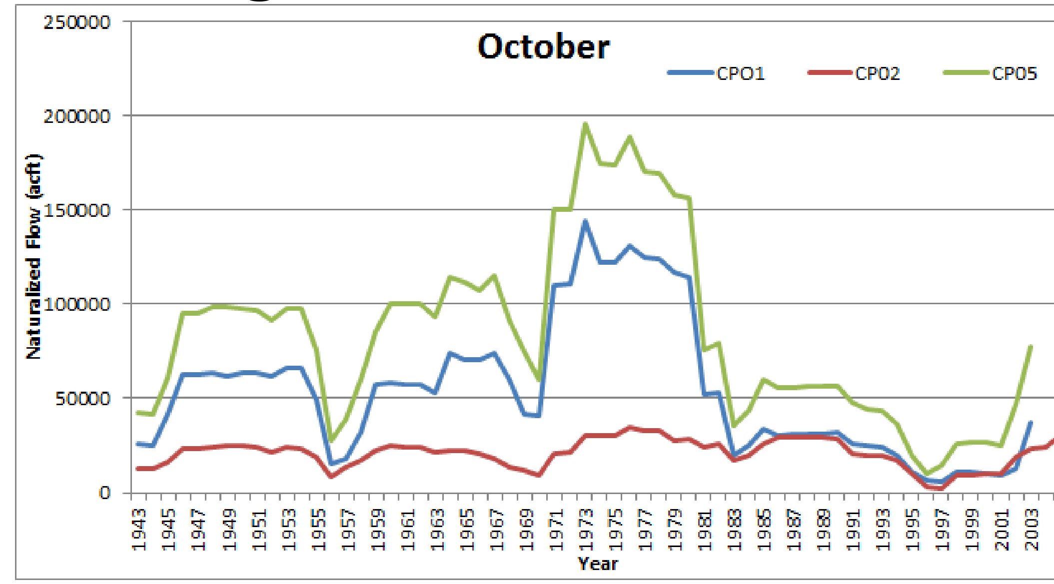


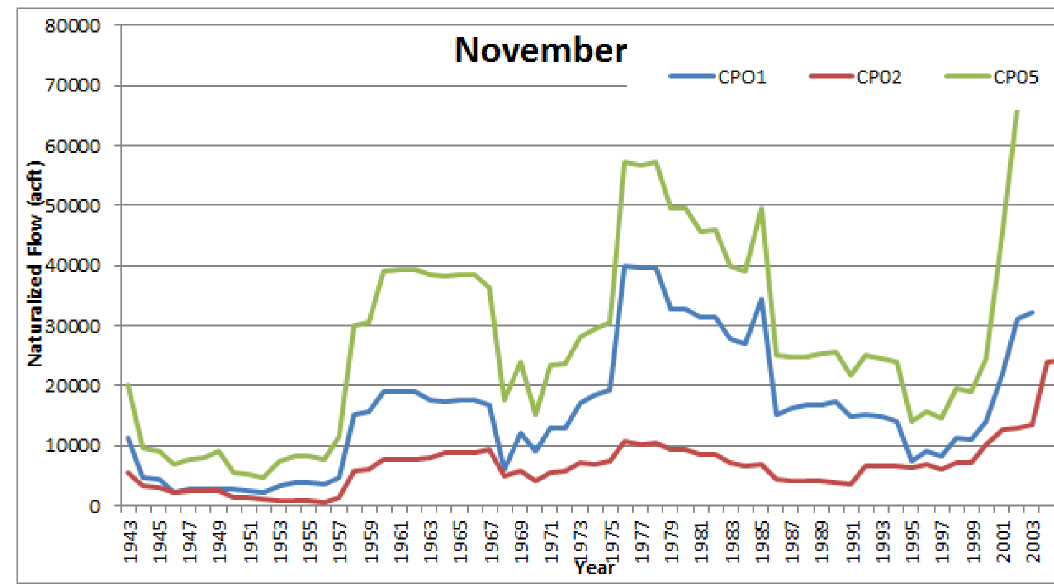
QNAT – 10 year average

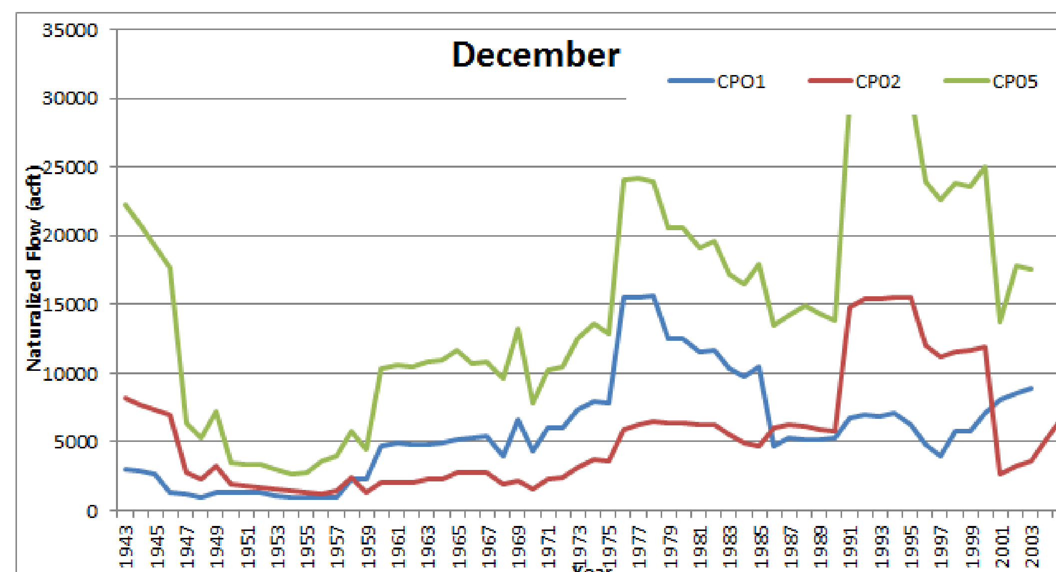




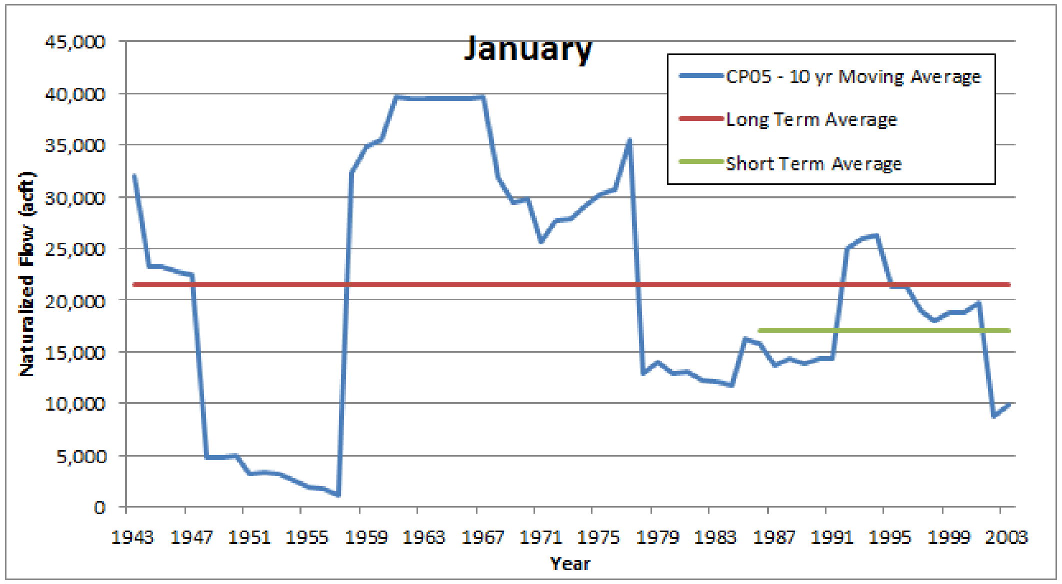


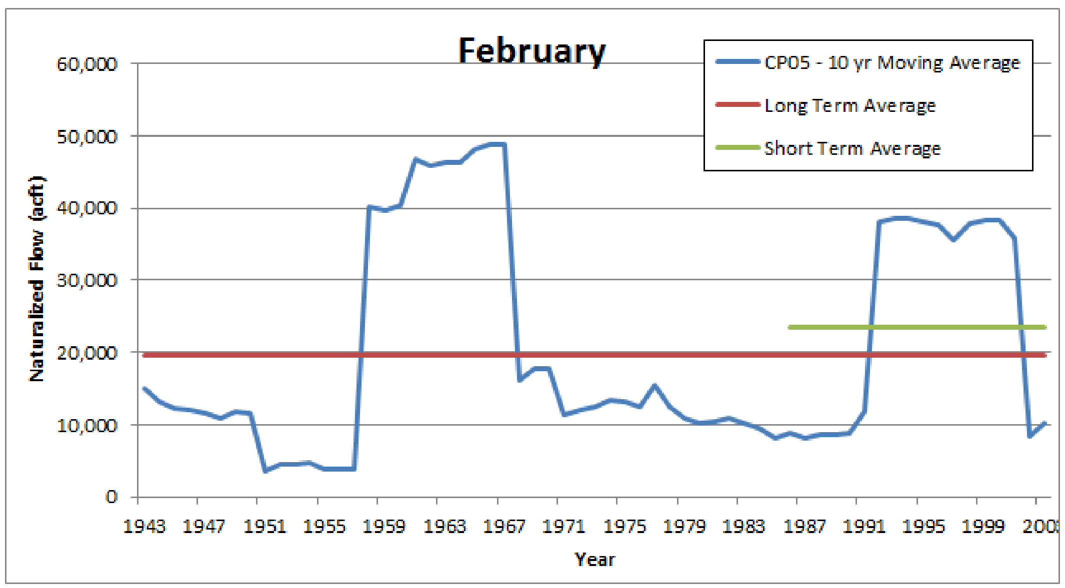


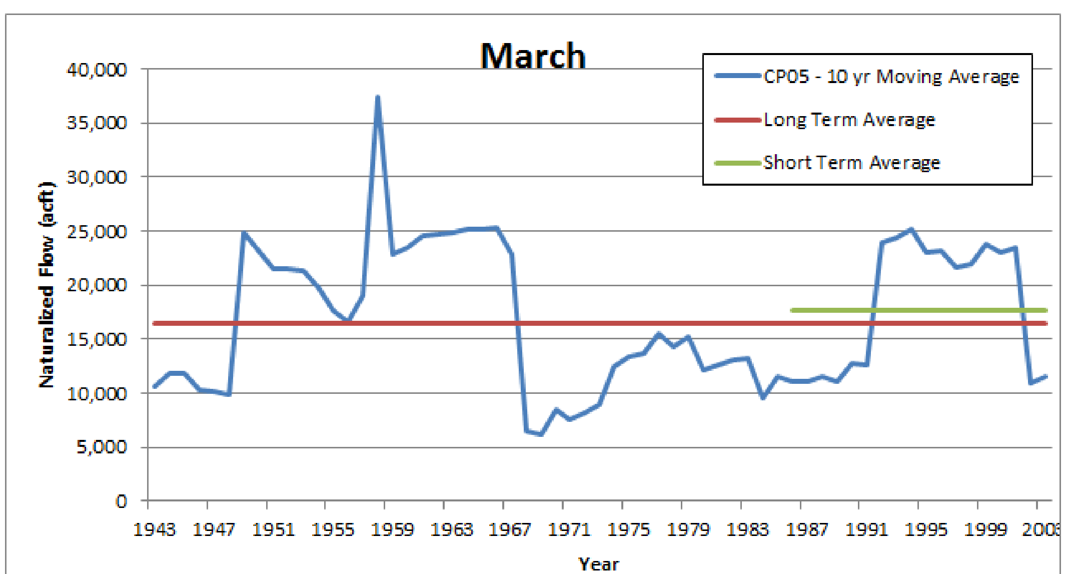


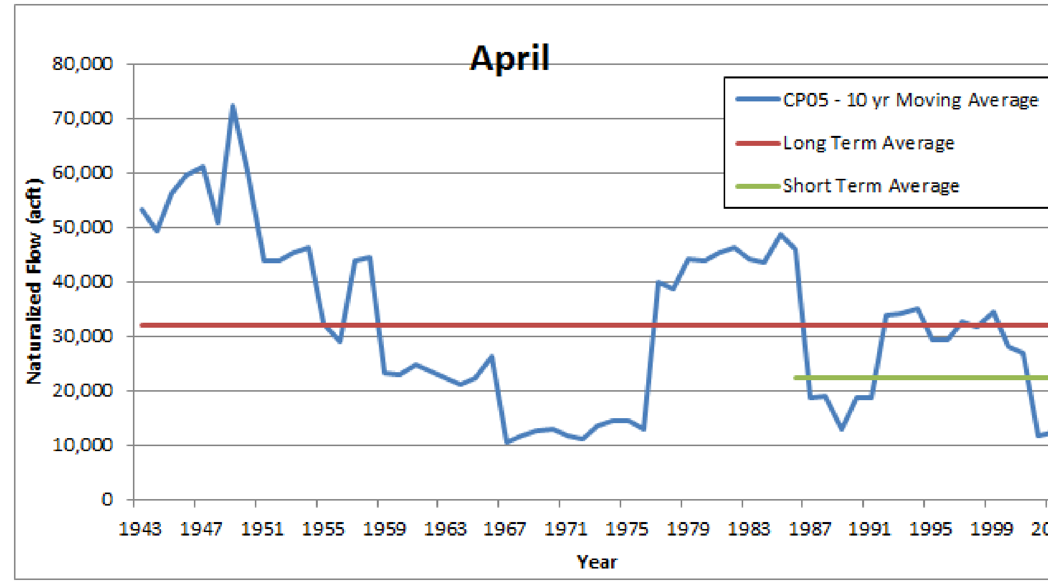


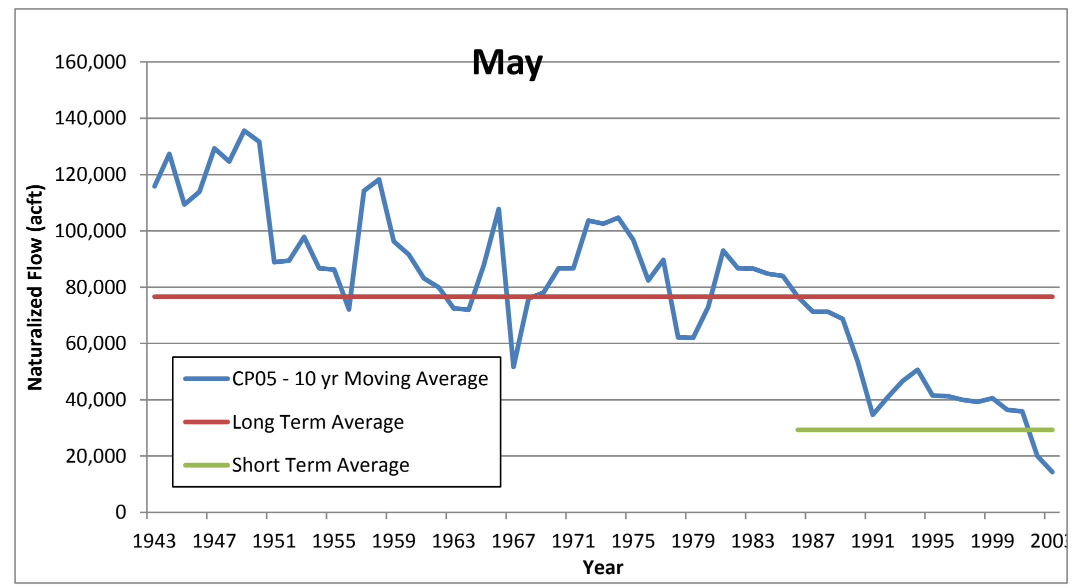
QNAT – CP05 Nueces River at Mathis

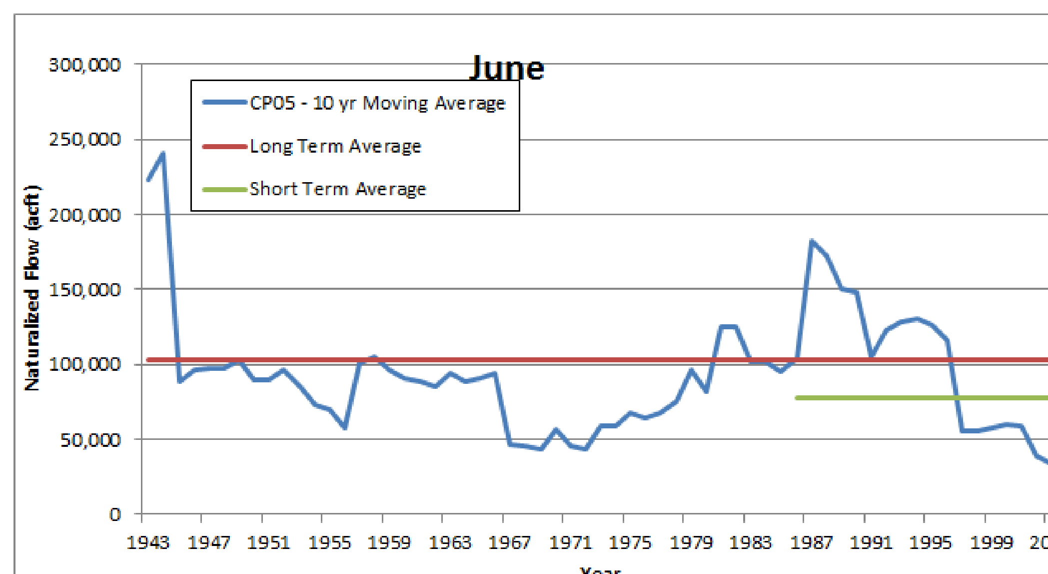




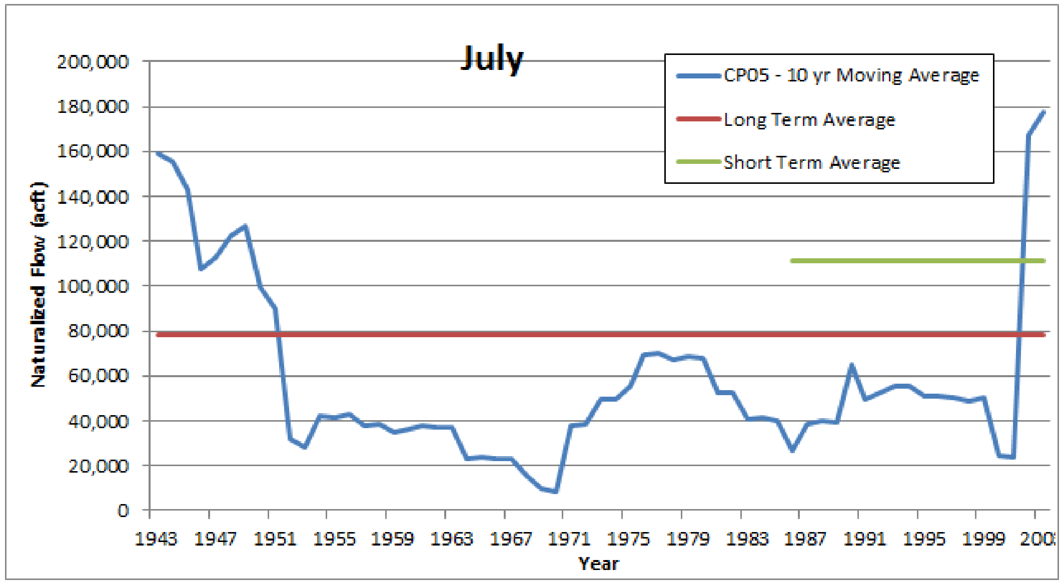


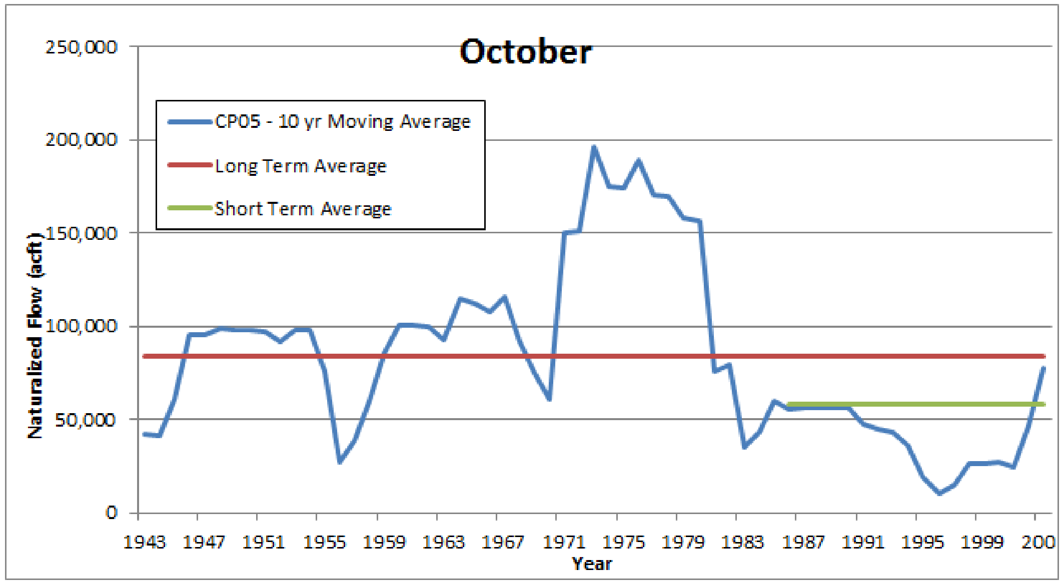


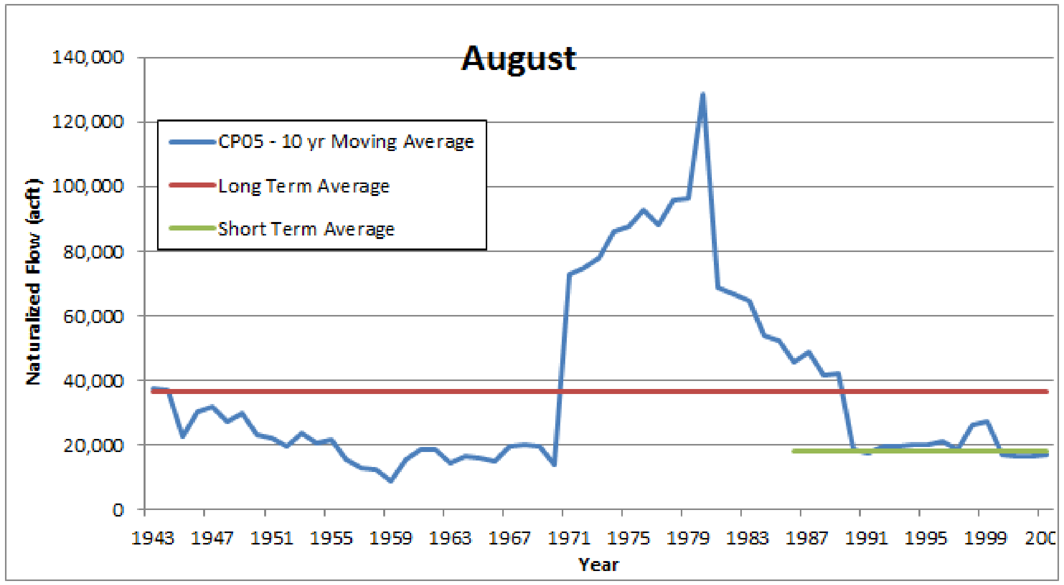


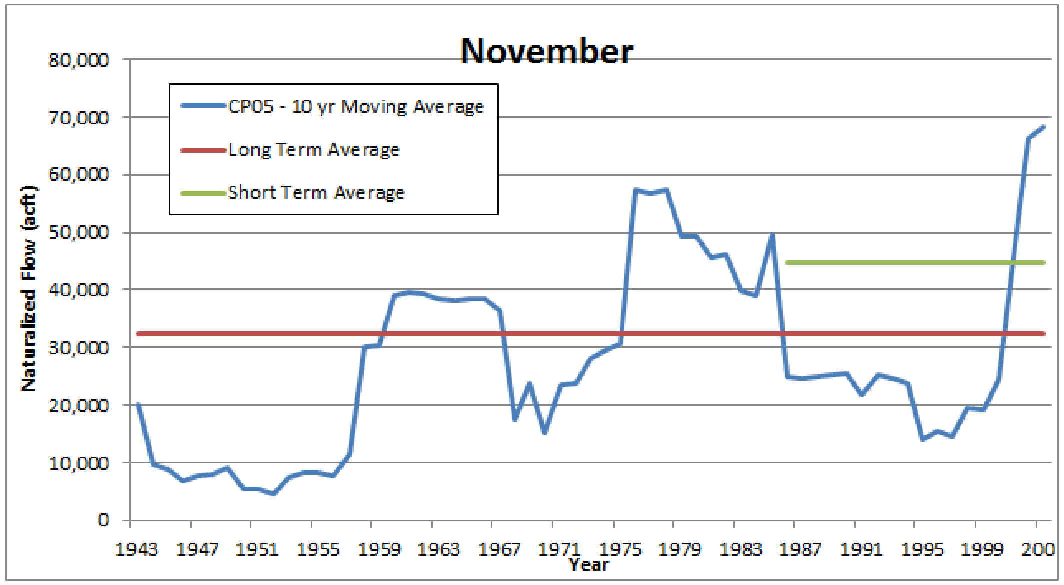


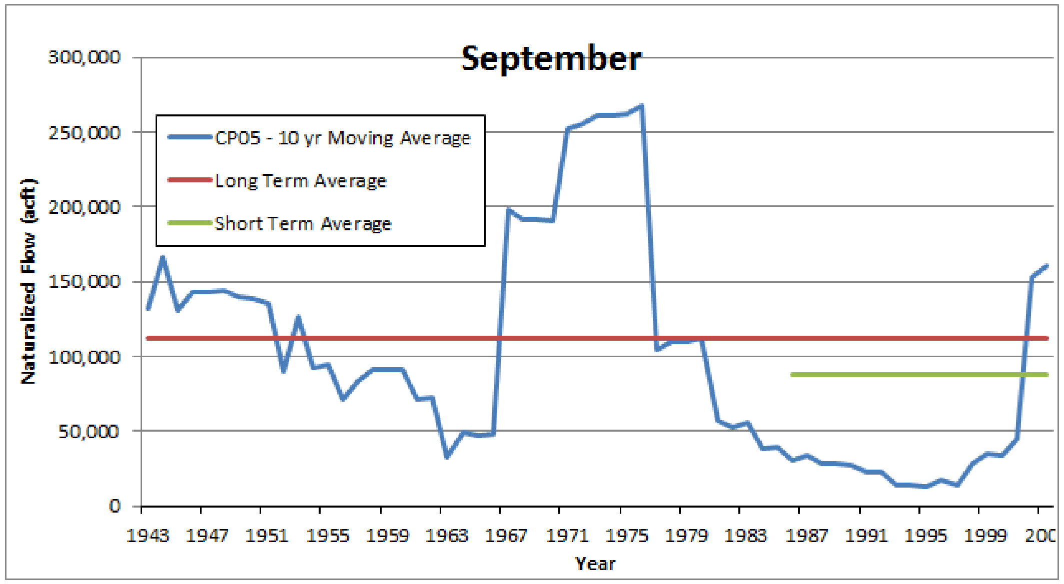
QNAT – CP05 Nueces River at Mathis

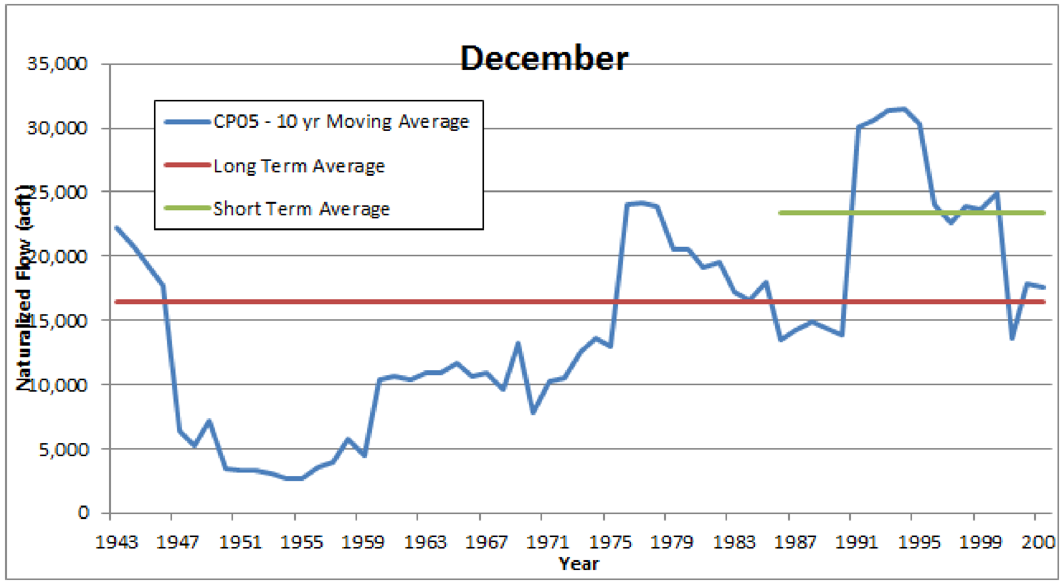




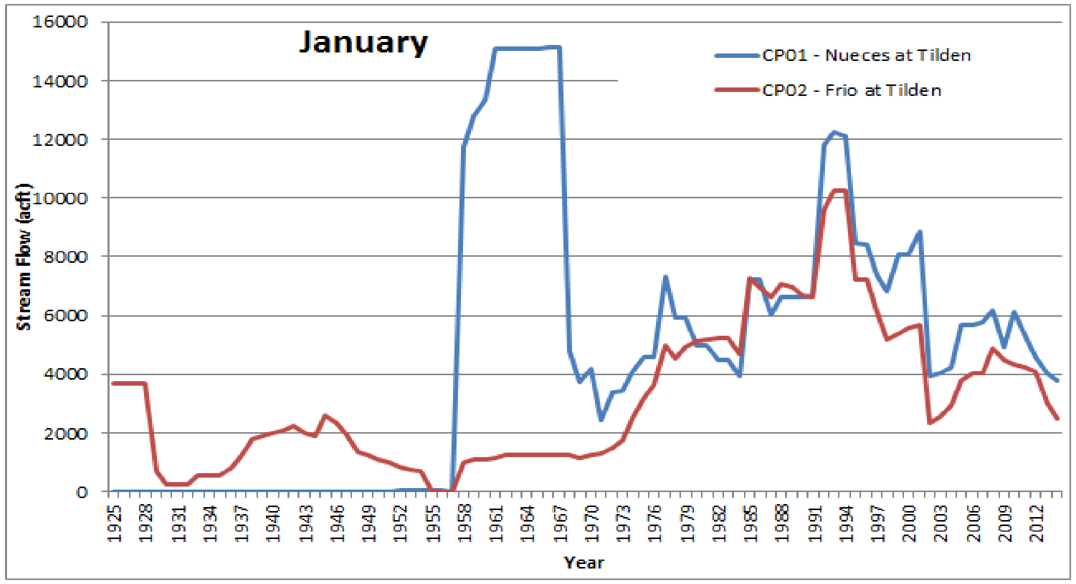


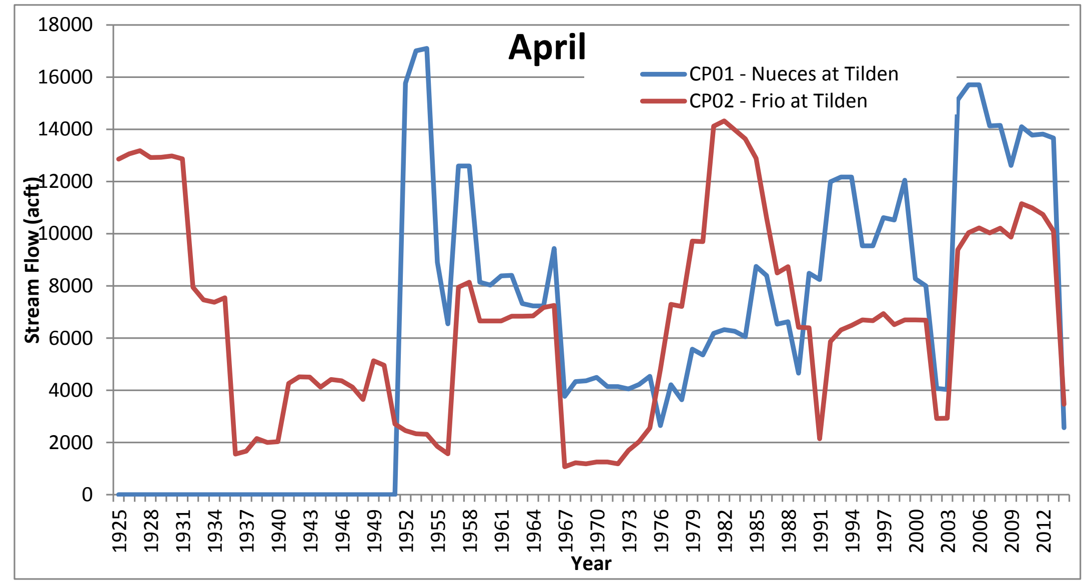


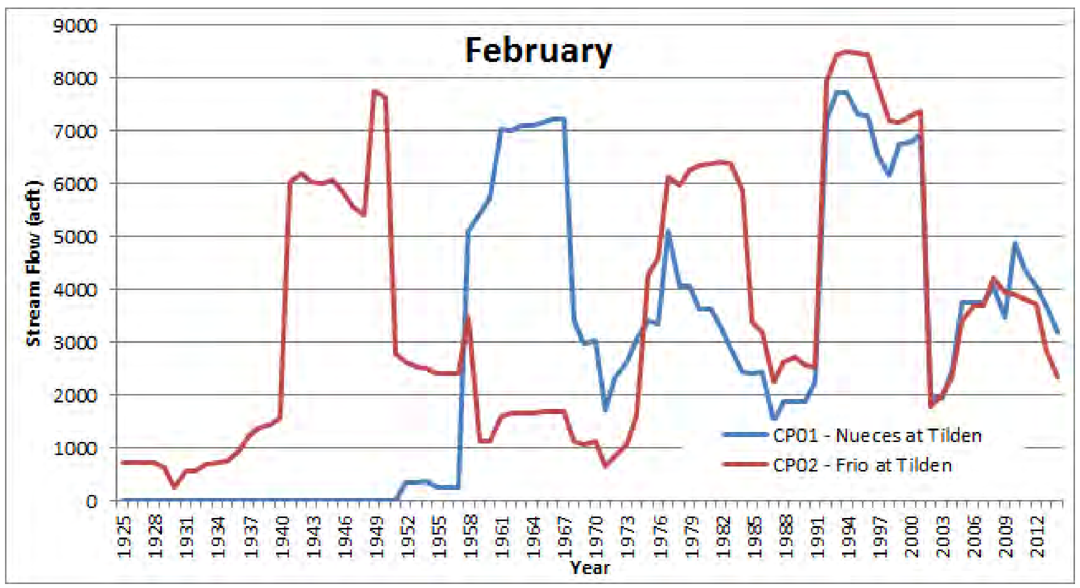


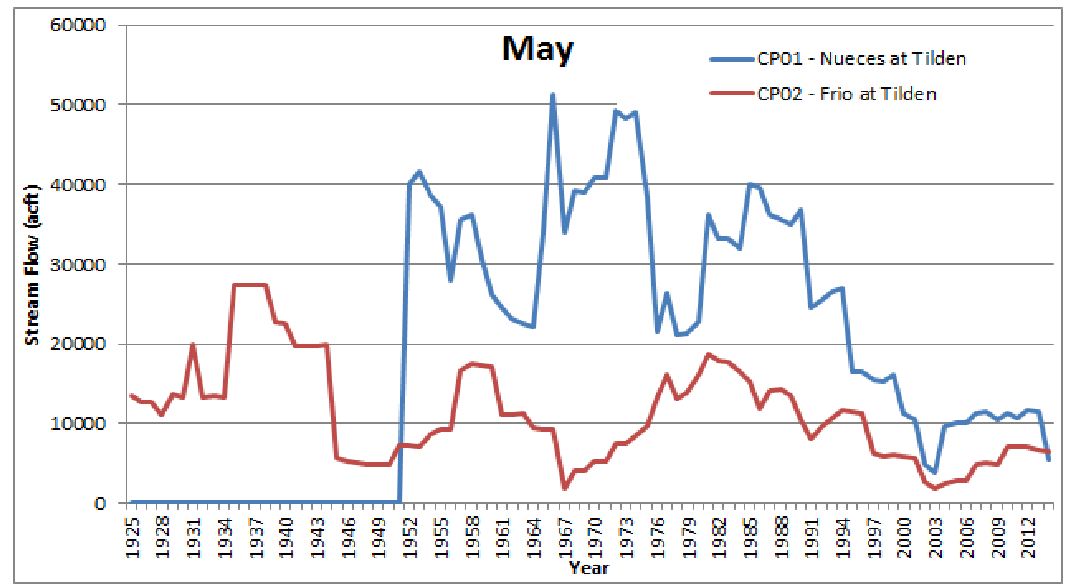


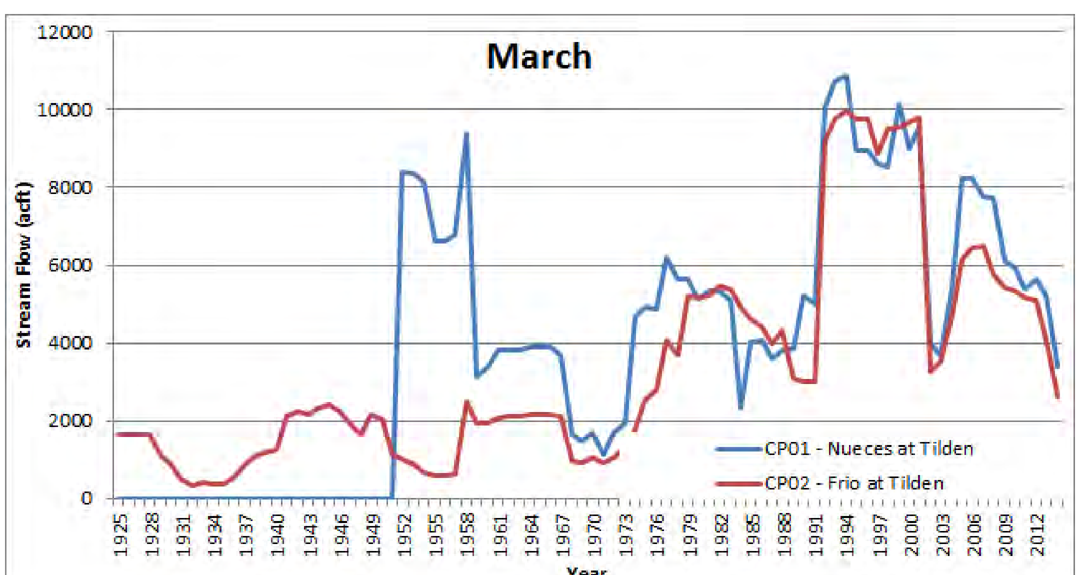
USGS Stream flow – 10 year Average

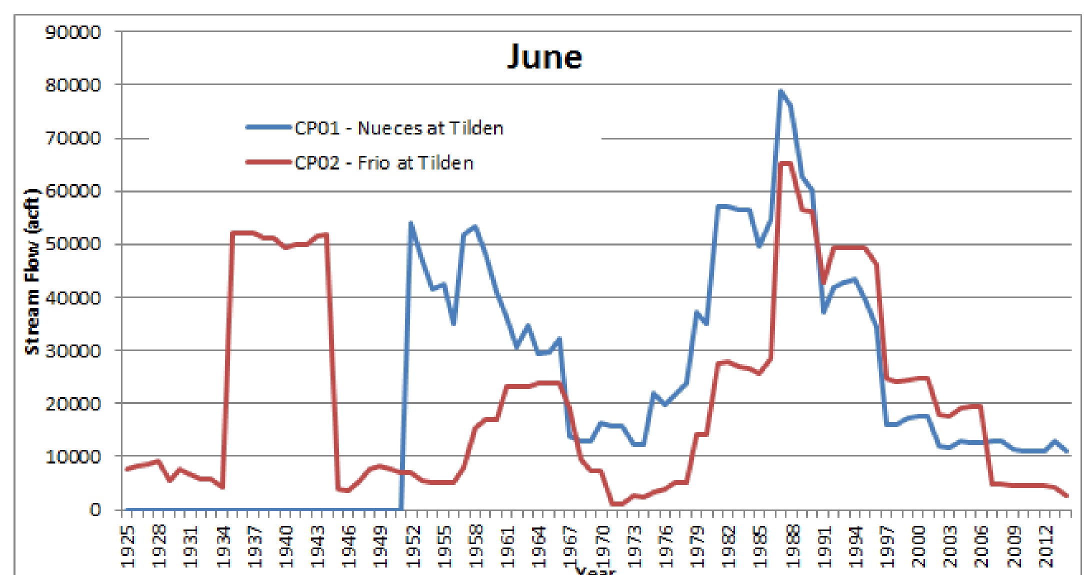




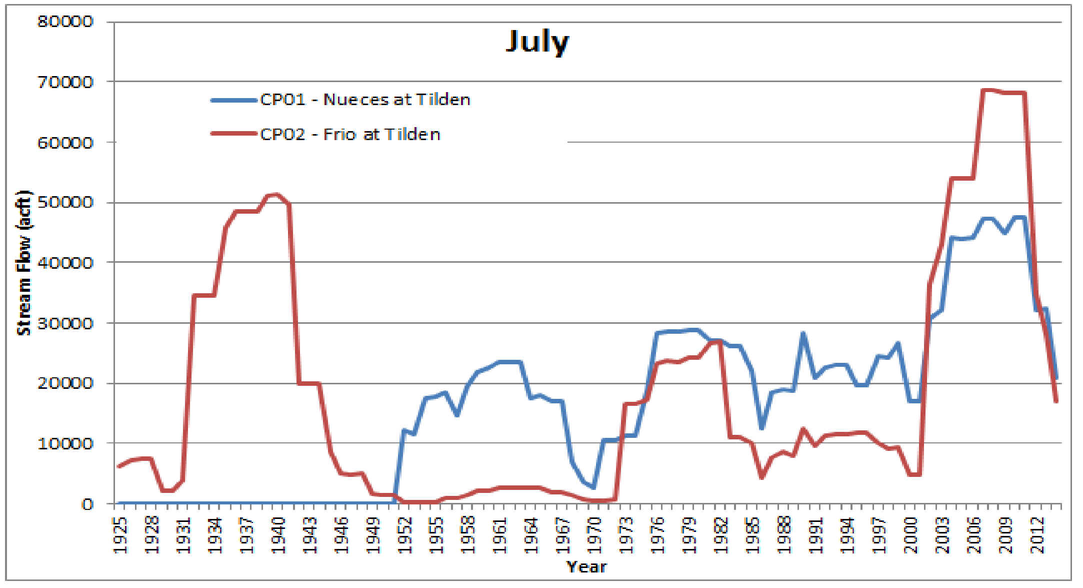


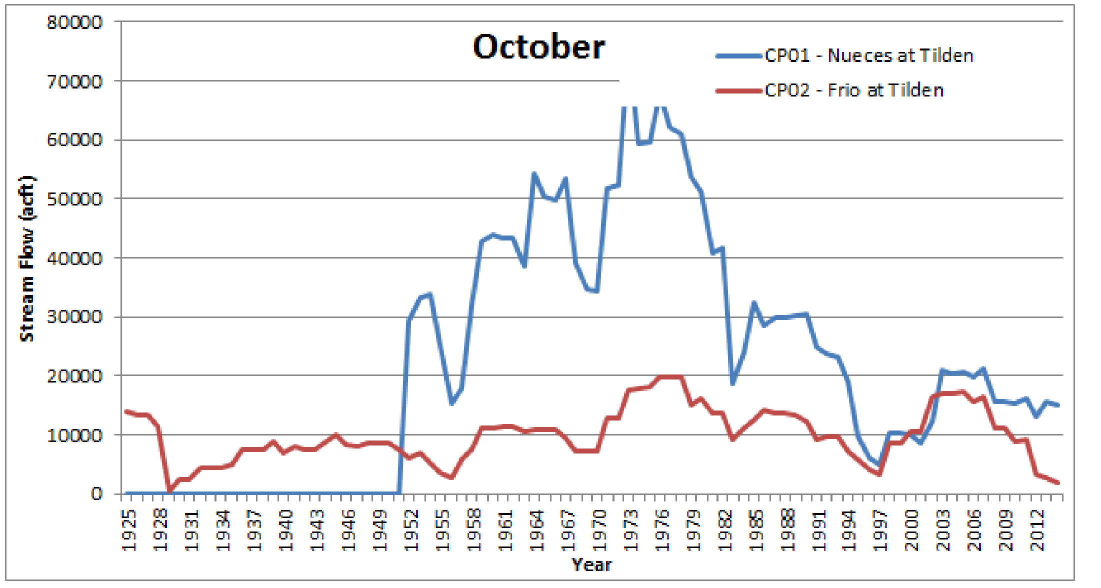


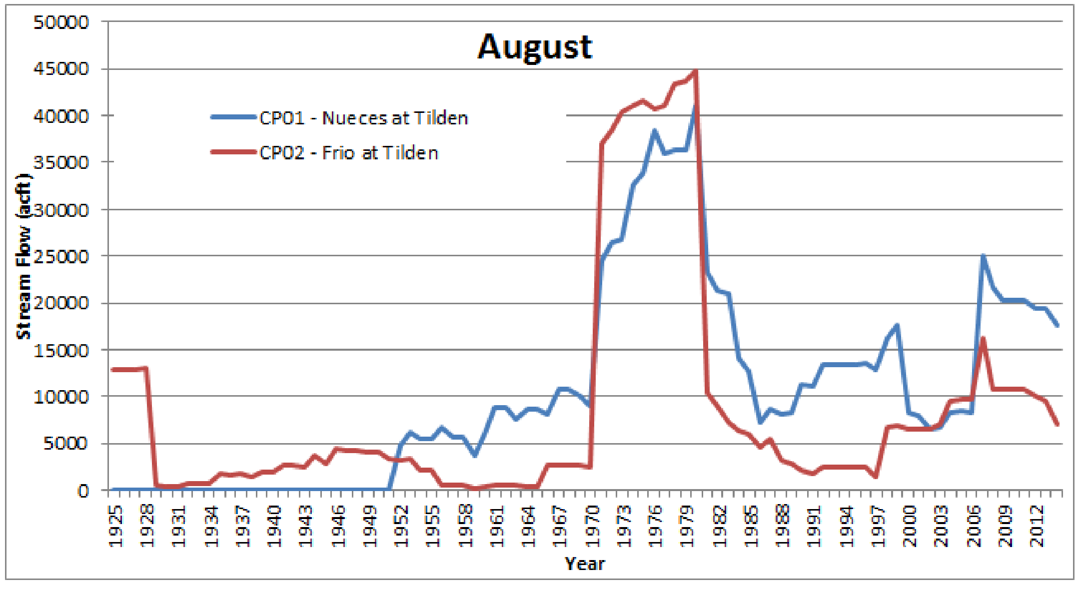


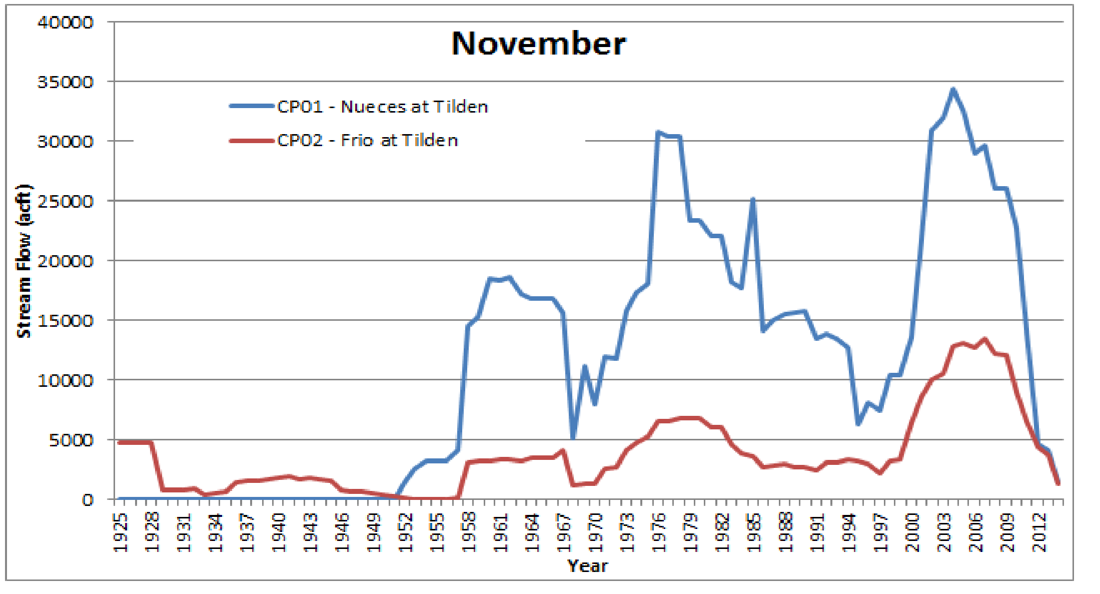


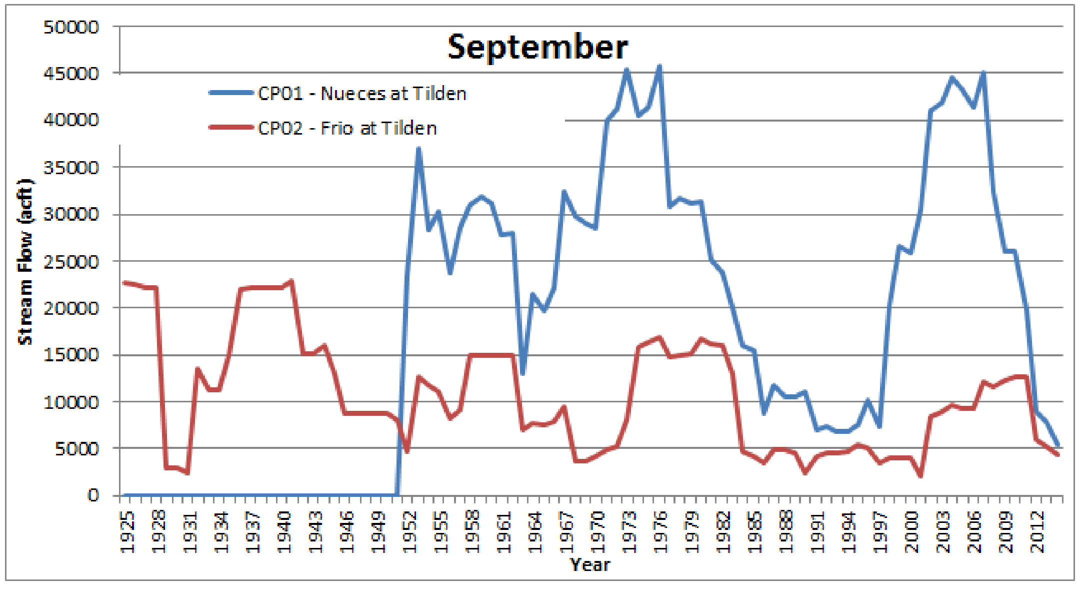
USGS Stream flow – 10 year Average

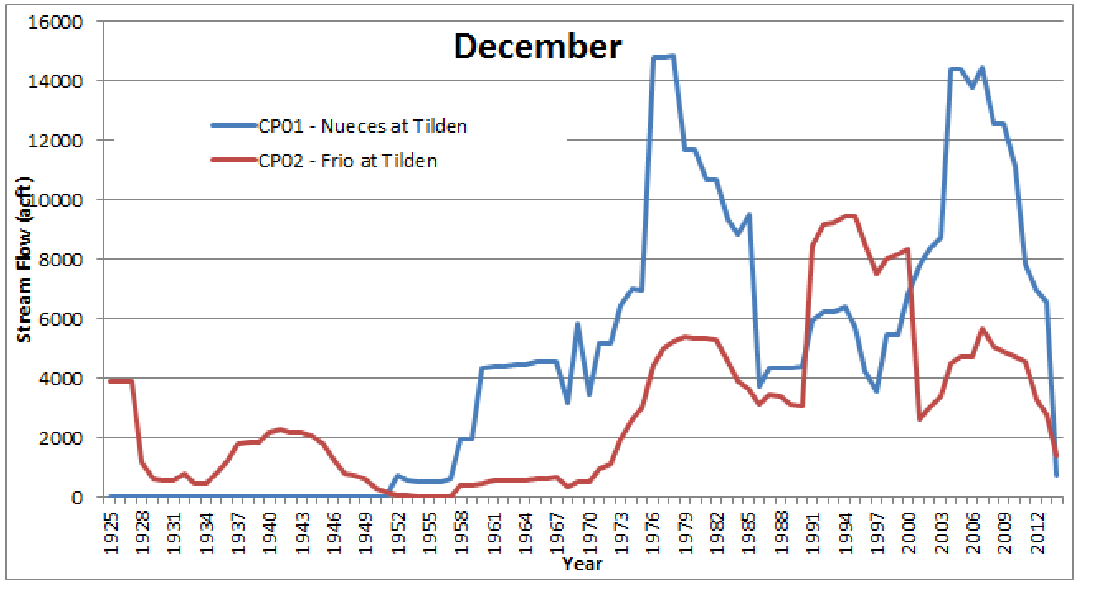




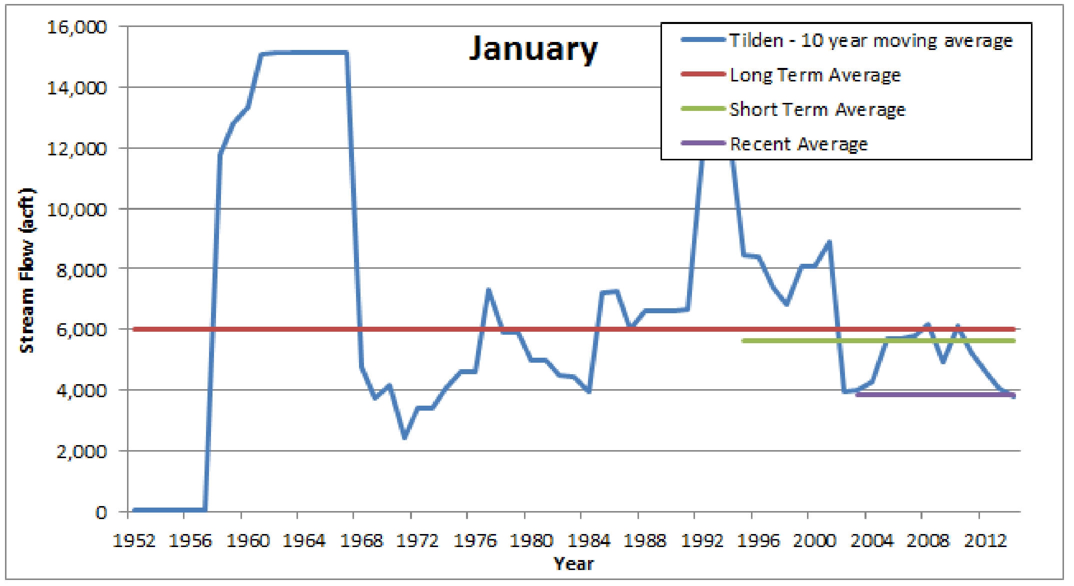


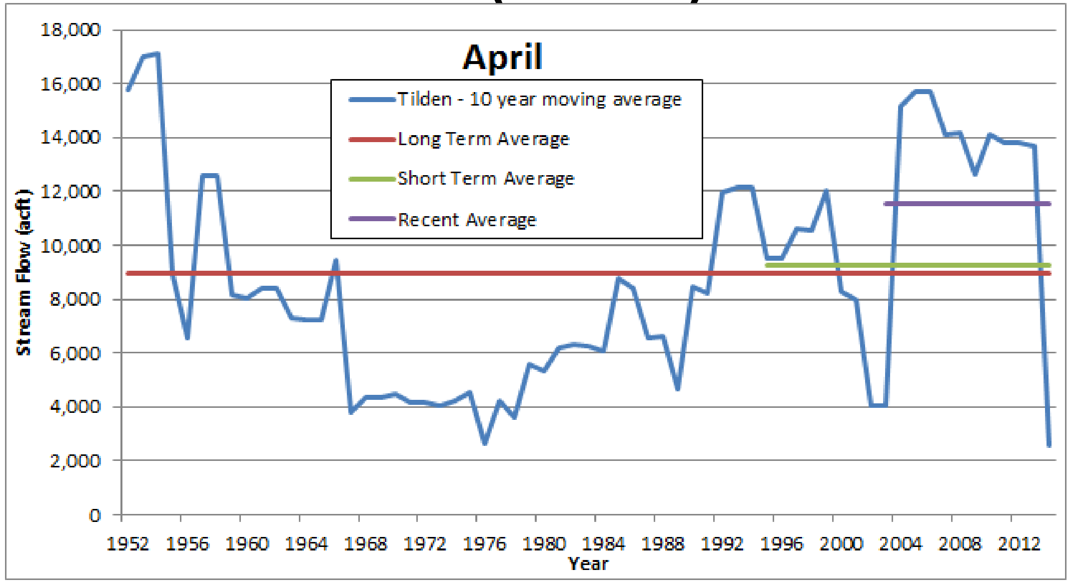


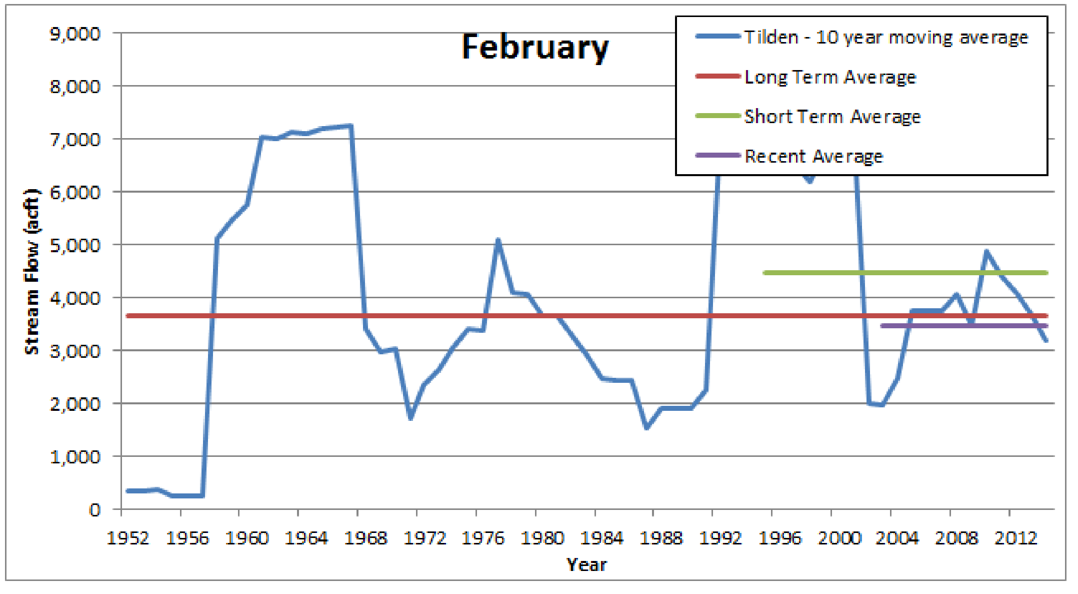


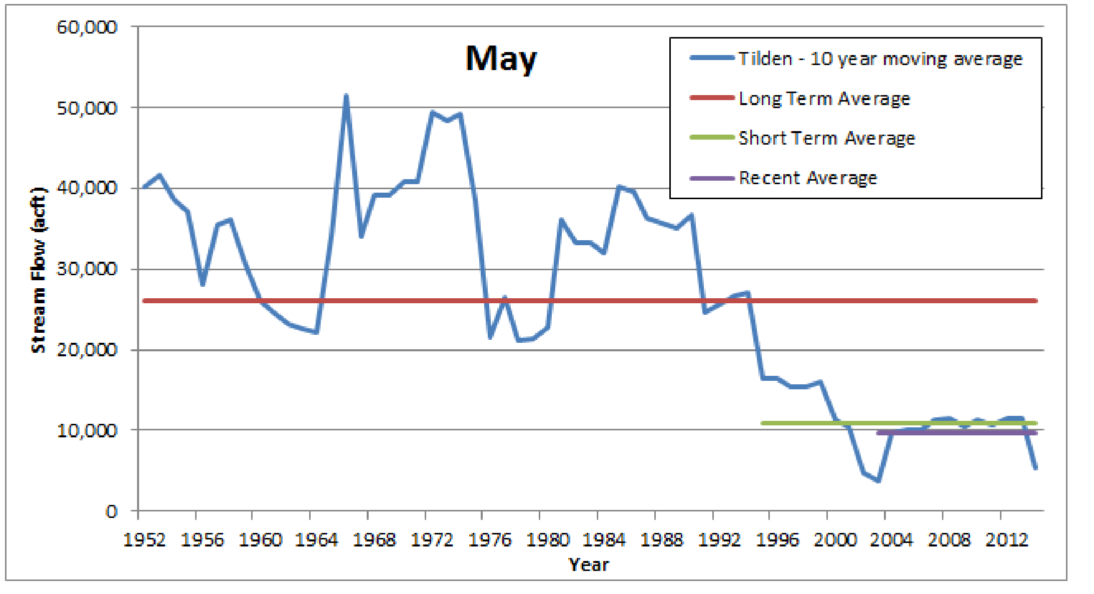


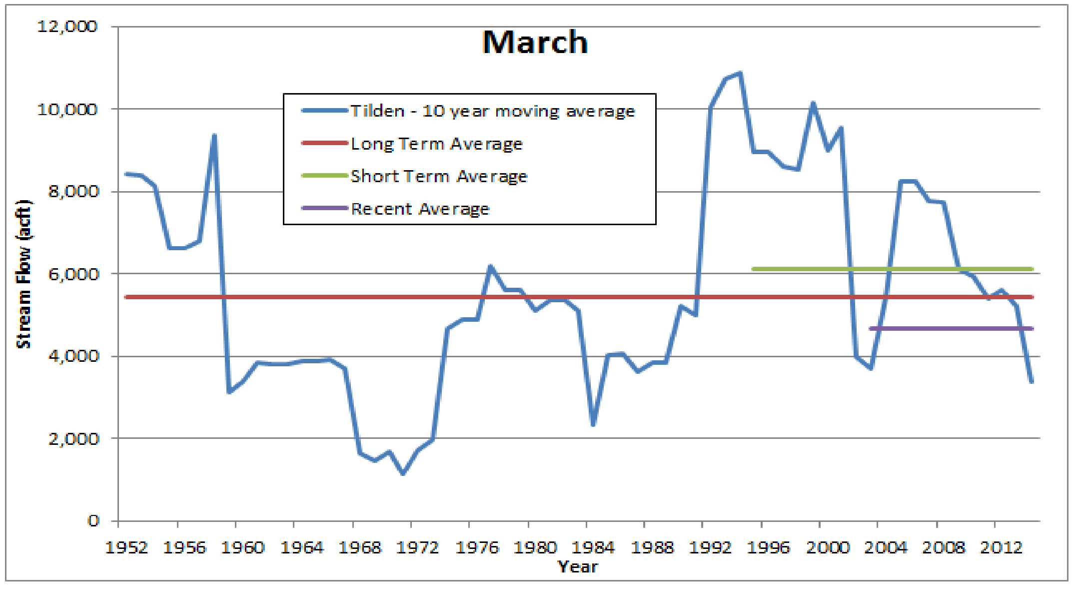
Stream flow – Nueces River near Tilden (CP01)

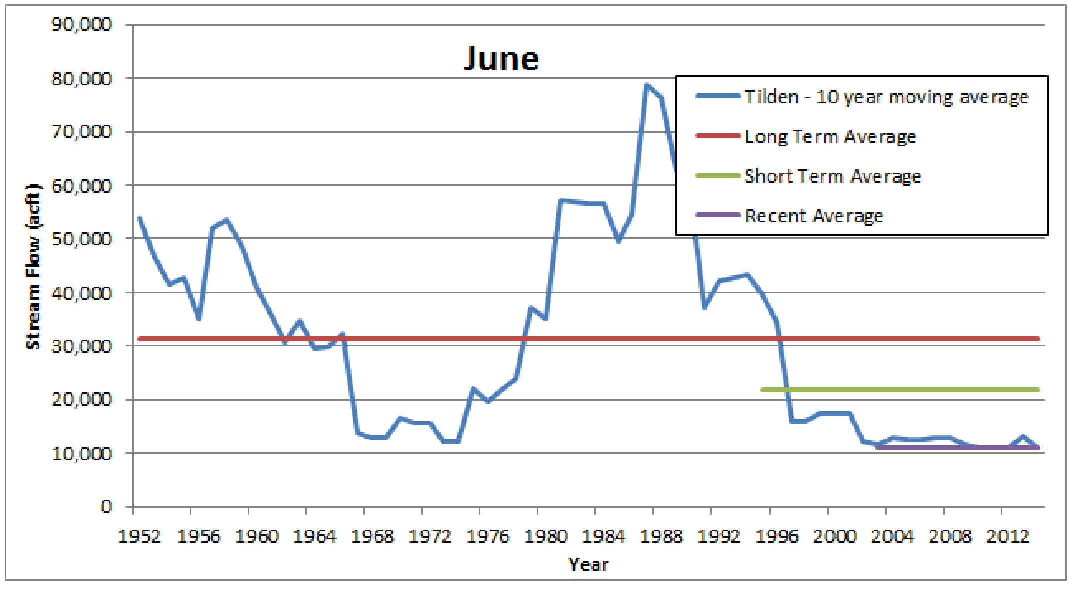




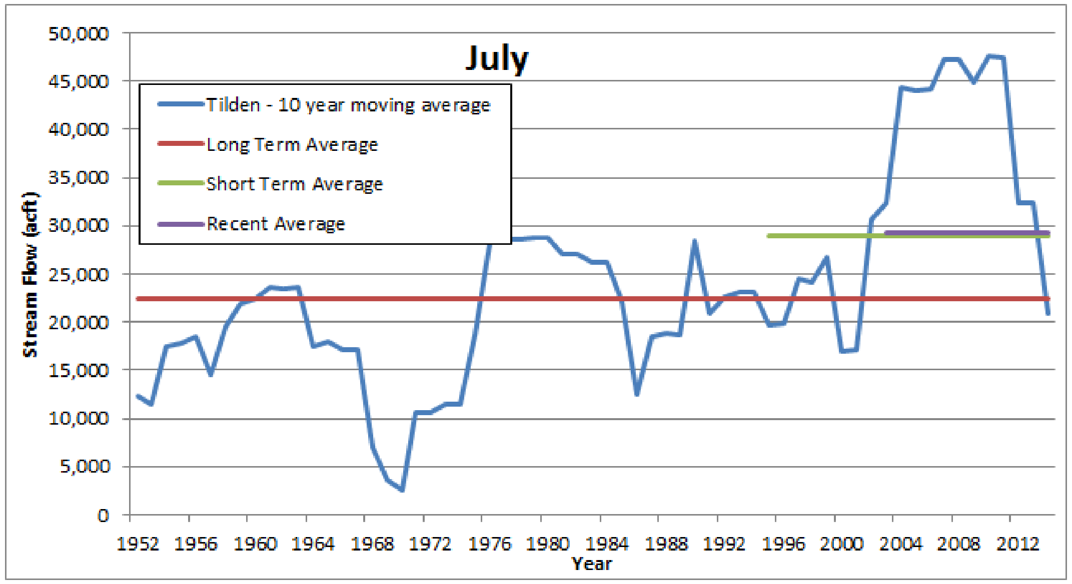


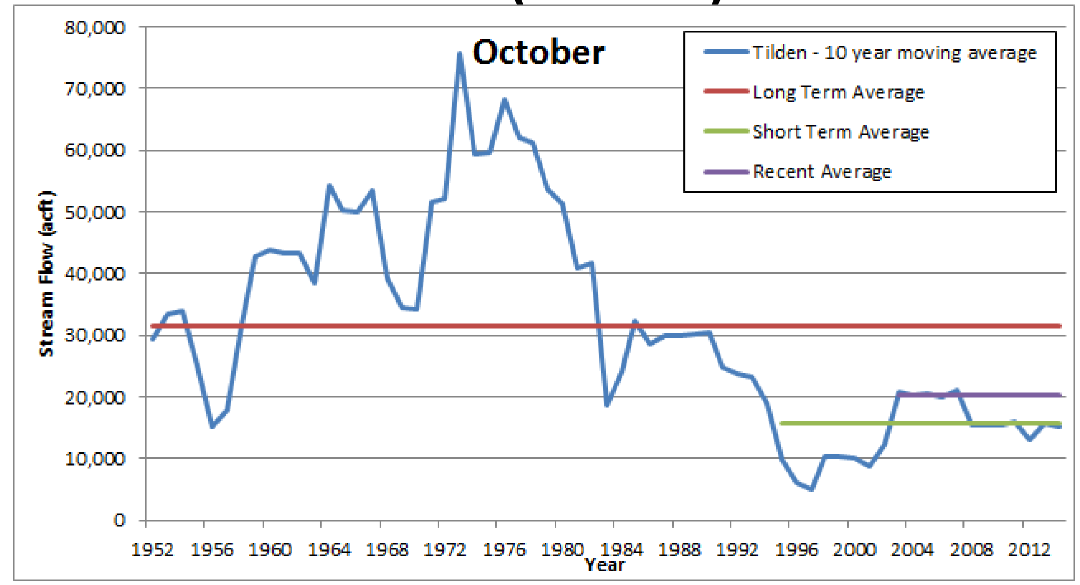


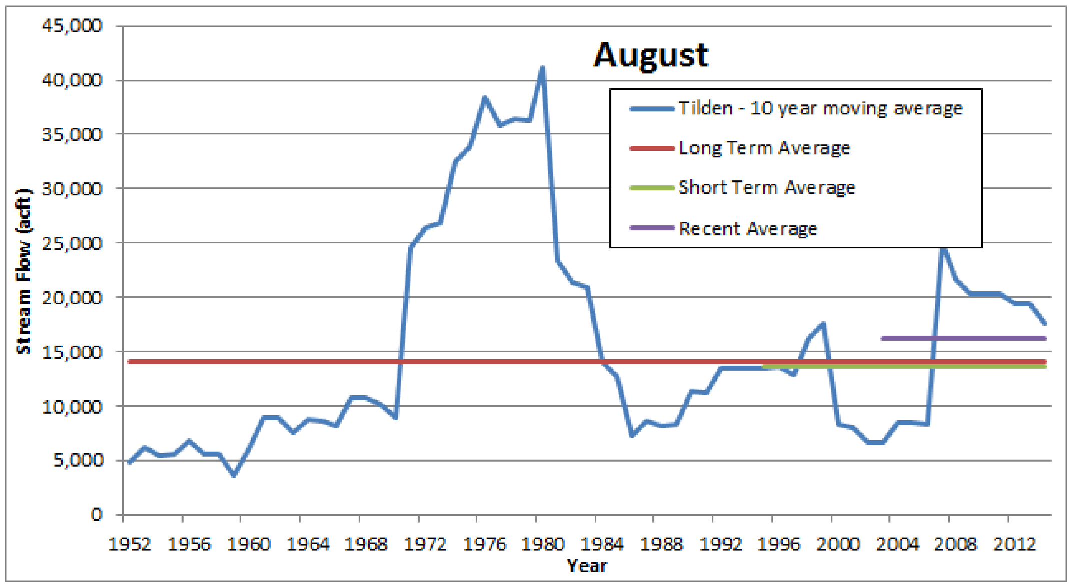


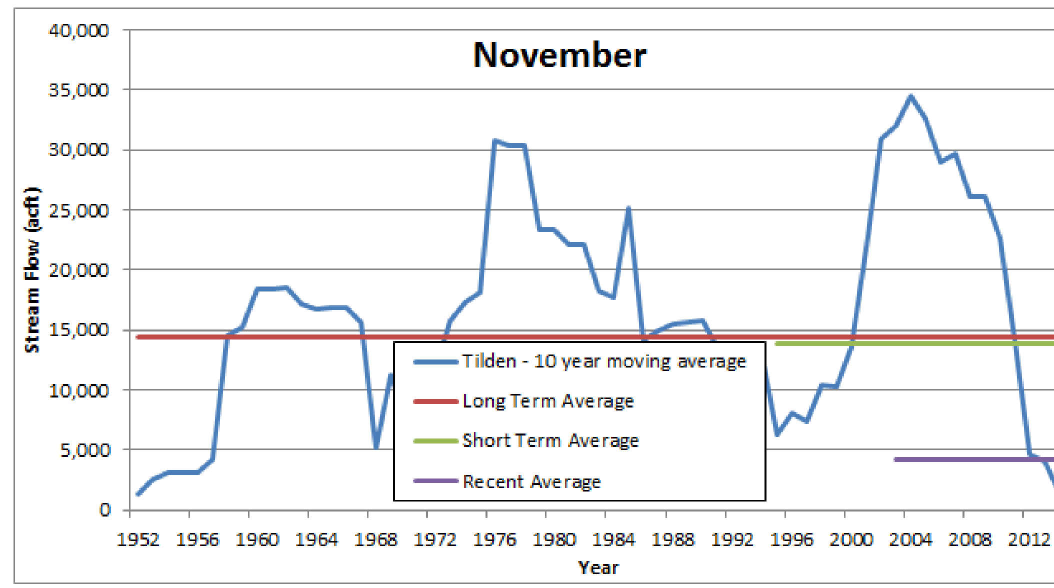


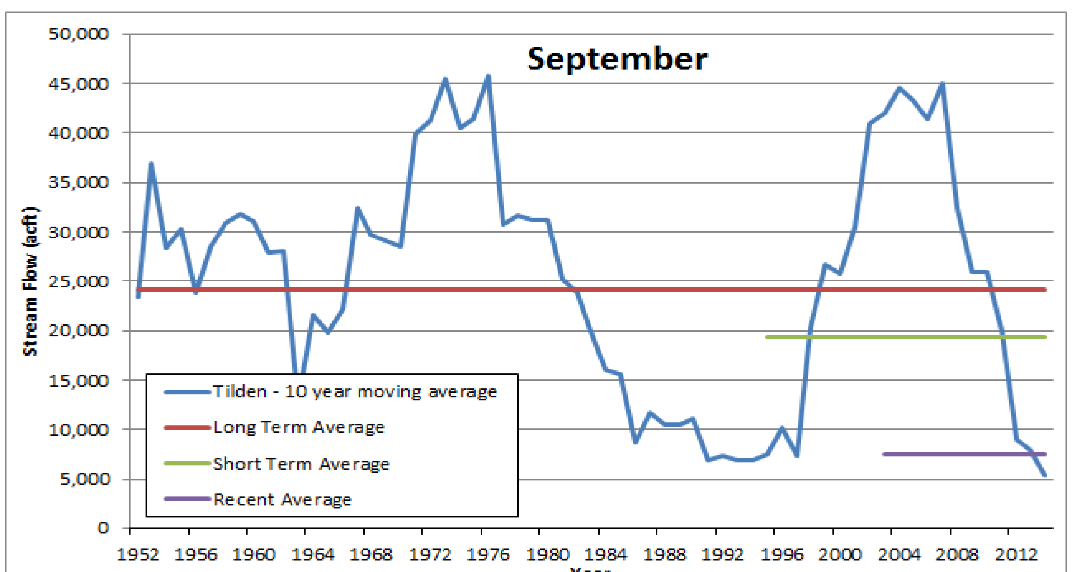
Stream flow – Nueces River near Tilden (CP01)

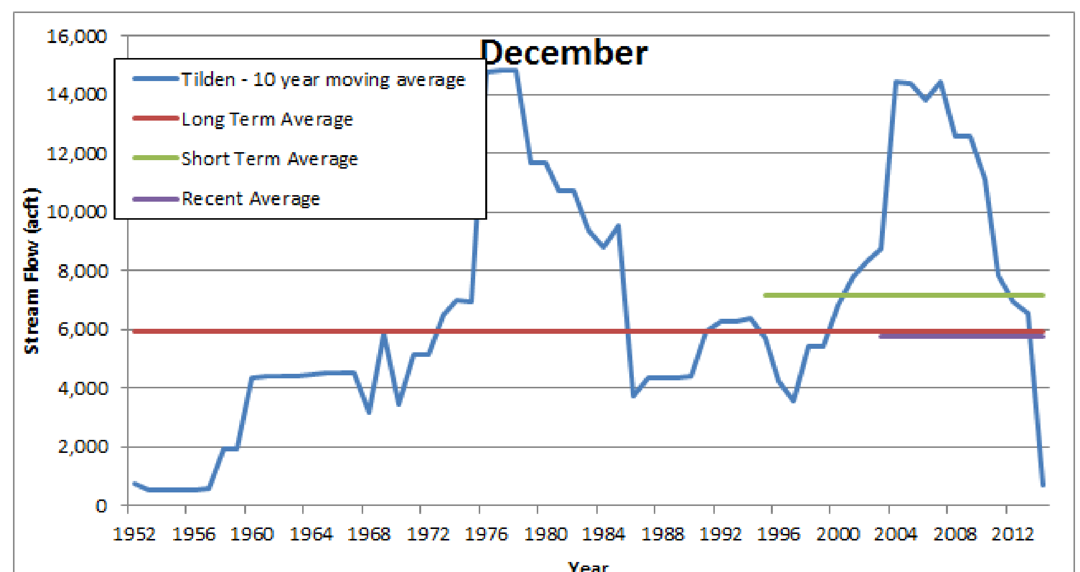












K-S Test P-Values

COMPARISON w/ LONG TERM TREND (K-S p-values; p-values <0.150 = significance)

Parameter	January		February		March		April		May		June		July		August		September		October		November		December	
	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend	ST Trend	Recent Trend
Precipitation	0.988	0.344	0.254	0.048	0.154	0.986	0.256	0.075	0.192	0.151	0.976	0.418	0.367	0.229	0.773	0.070	0.789	0.418	0.869	0.137	0.670	0.874	0.411	0.033
Naturalized Flow	0.005	n/a	0.070	n/a	0.157	n/a	0.445	n/a	0.033	n/a	0.026	n/a	0.734	n/a	0.606	n/a	0.958	n/a	0.431	n/a	0.371	n/a	0.096	n/a
Gage Flow	0.195	0.853	0.688	0.920	0.688	0.587	0.357	0.173	0.024	0.104	0.014	0.017	0.561	0.920	0.442	0.135	0.222	0.023	0.284	0.414	0.586	0.173	0.926	0.173

LEGEND
n/a - category not included because this was not included in the presentation
ST - Short Term
Not significant at the 15% level
##% - signifcant at the 15% level

This Page Intentionally Left Blank

APPENDIX D – Scope of Work for the Nueces BBASC Work Plan Study #1

This Page Intentionally Left Blank

Texas Water Development Board (TWDB)

Nueces River and Corpus Christi and Baffin Bays Basin and Bay Area Stakeholder Committee (Nueces BBASC)

Study No. 1
Re-Examination of the 2001 Agreed Order Monthly Targets and Safe Yield Versus Current Demand Evaluations
Scope of Work

May 28, 2014

HDR will perform the professional engineering services described in this Scope of Work. Services include re-examination of the 2001 Agreed Order Monthly Targets and a comparison of safe yield of the Corpus Christi Water Supply System versus current demand.

Background

The Nueces BBASC is requesting that this project be completed to re-examine the monthly pass-through targets that are part of the 2001 Agreed Order between the City of Corpus Christi (CoCC or City) and the Texas Commission on Environmental Quality (TCEQ). As described in Section 4.1 of the Nueces BBEST Report, it is believed that there has been a seasonal shift in inflows to Nueces Bay and the Choke Canyon Reservoir / Lake Corpus Christi (CCR/LCC) System that serves as the CoCC primary water supply. The Nueces BBASC report, in Section 2.3, suggests that opportunities to better manage limited freshwater inflows may be identified by reviewing new data that were not available during development of the 1995 Agreed Order, which is the basis for current pass-through operations of the reservoir system. Task 1 of this scope of work focuses on examination of recent inflow and precipitation trends to identify potential alternative seasonal freshwater inflow targets and system storage triggers, and then evaluate the impact of these targets on the safe yield of the water supply system.

HDR developed the Corpus Christi Water Supply Model (CCWSM) for the CoCC and other regional interests to simulate operations of the City's water supply system under the Agreed Order. One use of the CCWSM is to determine the yield of the system under a variety of operating scenarios. Currently, the City uses a safe yield of 205,000 acft/yr (including Lake Texana), with a reserve of 125,000 acft in the CCR/LCC System, as its supply number for planning purposes. The estimated current demand on the system is 133,000 acft/yr. There is a concern among the stakeholders in the region that, as the City grows into the full safe yield of the system, inflows to Nueces Bay will be reduced to a degree greater than has been experienced in the current drought thereby stressing ecological conditions in Nueces Bay. In Task 2 of the scope of work, HDR will simulate operations of the water supply system under two demand scenarios (current demand and safe yield) and evaluate differences in freshwater inflows to the Bay.

Organization of Scope of Work

Under this Scope of Work, HDR will perform three major tasks to re-examine the 2001 Agreed Order monthly targets and system storage triggers and compare safe yield of the Corpus Christi Water Supply System to current demand:

Task 1: Compile reference data, including reservoir inflow and precipitation estimates, determine whether the data suggest a different monthly pattern (volume and/or spatial), and evaluate the new pattern characterizing safe yield of the system and resulting bay inflows.

Task 2: Perform modeling analysis for safe yield and current demand scenarios and examine and characterize the resulting output focusing on the volume and frequency of inflow to the bay.

Task 3: Participate in meetings and develop a technical memorandum.

Task 1. Compile Reference Data, Analyze Data for New Pattern, and Evaluate Pattern using the CCWSM

Specific subtasks associated with this task are as follows.

Task 1.1 Compile available inflow and precipitation estimates

HDR will compile available inflow estimates for both long-term and recent drought periods for the Nueces Estuary and the CCR/LCC System. HDR will compile areal precipitation data for the ungaged area below Lake Corpus Christi and the reservoir watersheds. Sources of data include the USGS, NCDC, Nueces River Authority, and other public entities. The current period of record of the CCWSM is 1934 – 2003. It is anticipated that the focus of this analysis will be on the long-term (1934 – present), the short-term (1986 – present; since Choke Canyon Reservoir), and the recent (2004 – 2014) time frame to identify any significant changes in seasonal hydrology.

Task 1.2 Analyze Data for Identification of a Monthly Pattern

The data obtained in task 1.1 will be analyzed to see how well the natural occurrence of inflow and precipitation matches with the pattern established in the Agreed Order. The evaluation will also include attempts to identify a new pattern that may exist as part of a seasonal shift in the natural occurrence of inflows to the bay and reservoir system different than that described in the Agreed Order.

Task 1.3 Evaluate New Pattern using the CCWSM

Any new pattern identified in Task 1.2 will be evaluated in the CCWSM to determine what impacts there may be on the safe yield of the water supply system and any changes in the occurrence and volumes of freshwater entering the bay. HDR anticipates that there will be runs with new monthly patterns where the same annual volume target as the existing Agreed Order is used. New monthly patterns derived from the data analyses (Task 1.2) will be considered. System storage triggers may be varied as well.

Task 1.4 Coordination with TWDB on TxBLEND Analysis

If so requested by NEAC, HDR will prepare output summaries from the baseline scenario and the scenarios identified and evaluated in Task 1.3 for submittal to the TWDB to perform TxBlend simulations. The TWDB will provide a summary of the results and comparison of the different monthly inflow targets sets on the salinity of the Nueces Bay. HDR will include this information in summary presentations and technical memoranda.

Task 2. Perform Evaluation Comparing Safe Yield and Current Demand

Separate from the analyses in Task 1, HDR will compare model results from the safe yield scenario with that of the current demand scenario keying in on the volume and frequency of freshwater inflow events that occur in these two scenarios.

Task 2.1 Perform Scenario Evaluations

HDR will use the CCWSM to simulate the CoCC water supply system under two different demand scenarios. The first scenario will be the safe yield scenario with a demand of approximately 205,000 acft/yr, which leaves a reserve storage of about 125,000 acft in the reservoir system during the drought of record. The second scenario will be a current demand scenario with a demand of 133,000 acft/yr on the water supply system. Following is a list of assumptions that will be common to both scenarios (note: all these will apply to the Task 1 runs, except use of the Agreed Order):

- Approximate 2010 reservoir conditions (2010 elevation – area – capacity relationships),
- Use of the 2001 Agreed Order monthly targets and pattern,
- Full use of the Lake Texana system (41,840 acft/yr firm plus 12,000 acft/yr interruptible),
- Lake Corpus Christi Target Stabilization Level = 74 ft-msl,
- 5.35 MGD municipal & industrial effluent returned to Nueces Bay, and
- 52% return flow factor applied to all CoCC demands with discharges to the Nueces Estuary.

Task 2.2 Compare Results from the Two Scenarios

From the scenarios simulated in Task 2.1, HDR will compare the outputs focusing on the volume and frequency of freshwater inflow events to Nueces Bay. HDR will develop graphs that illustrate the similarities and differences of freshwater inflow events under the two scenarios.

Task 3. Participate in Meetings and Develop Technical Memorandum

Specific subtasks associated with this task are as follows.

Task 3.1 Participate in Project Kickoff Meeting

Participate in a meeting involving TWDB staff, members of the Nueces Estuary Advisory Council (NEAC), a subcommittee of the Nueces BBASC, the City of Corpus Christi, and others to discuss study approach and scope. This meeting is expected to be scheduled within one (1) month of receipt of notice to proceed.

Task 3.2 Present Initial & Final Results

Prepare for and participate in up to two (2) meetings involving TWDB staff, members of the NEAC, the City of Corpus Christi, and others to summarize analyses performed, results obtained, and recommendations for further study. The first of these meetings is expected to be scheduled within two (2) months after the meeting described in Task 3.1. Scheduling of the second meeting is to be determined.

Task 3.3 Prepare a Draft Technical Memorandum and Presentation

Prepare a draft Technical Memorandum and electronic presentation summarizing analyses performed, results obtained, and recommendations for further study. The anticipated schedule is to submit these deliverables to the TWDB for review within five (5) months of receipt of the notice to proceed, but not later than June 30, 2015.

Task 3.4 Prepare and Submit Final Technical Memorandum and Presentation

Prepare and submit a final Technical Memorandum and electronic presentation to the TWDB within one (1) month of receipt of comments on the drafts, but not later than August 31, 2015.

Task 3.5 Deliverables include quarterly progress reports, draft report and final report

Prepare a progress report quarterly and provide to Contract Manager. A draft technical memorandum is due June 30, 2015. A final technical memorandum that incorporates BBASC/TWDB comments is due August 31, 2015.

Project Schedule

The following are estimated time requirements for completion of the project tasks from date of notice to proceed. All work is anticipated to be completed in 2014, but all final documents must be submitted no later than August 31, 2015.

Task	Task Description	Time for Completion (from Notice to Proceed)
1	Compile, Analyze, and Evaluate	NTP + 20 weeks
2	Safe Yield Versus Current Demand Modeling Analysis	NTP + 20 Weeks
3	Meetings and Develop Technical Memorandum	Ongoing (Finalization 8/31/2015)
	Anticipated Total Time to Complete Tasks 1 – 3	~28 weeks

Fee Estimate

The following tables summarize the fee estimated to be required to complete the above scope of work.

TASK BUDGET

TASK	DESCRIPTION	AMOUNT
1	Compile, Analyze, and Evaluate	$17,575
2	Safe Yield Versus Current Demand Modeling Analysis	$8,045
3	Meetings and Develop Technical Memorandum	$19,380
Total		**$45,000**

EXPENSE BUDGET

CATEGORY	AMOUNT
Salaries & Wages[1]	$13,925
Fringe[2]	$6,904
Travel[3]	$886
Other Expenses[4]	$1,189
Subcontractor Services	$0
Overhead[5]	$17,596
Profit (10%)	$4,500
Total	**$45,000**

[1] Salaries and Wages is defined as the cost of salaries of engineers, draftsmen, stenographers, surveymen, clerks, laborers, etc., for time directly chargeable to this contract.
[2] Fringe is defined as the cost of social security contributions, unemployment, excise, and payroll taxes, workers' compensation insurance, retirement benefits, sick leave, vacation, and holiday pay applicable thereto.
[3] Travel is limited to the maximum amounts authorized for state employees by the General Appropriations Act, Tex. Leg. Regular Session, 2011, Article IX, Part 5, as amended or superseded.
[4] Other Expenses is defined to include computational technology, expendable supplies, communications, reproduction, postage, and costs of public meetings directly chargeable to this contract.
[5] Overhead is defined as the costs incurred in maintaining a place of business and performing professional services similar to those specified in this contract.

- Indirect salaries, including that portion of the salary of principals and executives that is allocable to general supervision;
- Indirect salary fringe benefits;
- Accounting and legal services related to normal management and business operations;
- Travel costs incurred in the normal course of overall administration of the business;
- Equipment rental not directly involved in collecting or analyzing contract data;
- Depreciation of furniture, fixtures, equipment, and vehicles;
- Dues, subscriptions, and fees associated with trade, business, technical, and professional organizations;
- Other insurance;
- Building rent and utilities; and
- Repairs and maintenance of furniture, fixtures, and equipment.

This Page Intentionally Left Blank

APPENDIX E – Comments from TWDB / BBASC on Draft Final Report

This Page Intentionally Left Blank

Texas Water Development Board

P.O. Box 13231, 1700 N. Congress Ave.
Austin, TX 78711-3231, www.twdb.texas.gov
Phone (512) 463-7847, Fax (512) 475-2053

August 3, 2015

Mr. Cory Shockley
HDR Engineering, Inc.
4401 West Gate Blvd., Suite 400
Austin, Texas 78745

RE: Research Contract between the Texas Water Development Board (TWDB) and HDR Engineering, Inc. (HDR), TWDB Contract No. 1400011716, Draft Report Comments

Dear Mr. Shockley:

Staff members of the TWDB and external reviewers have completed a review of the draft report prepared under the above-referenced contract. ATTACHMENT I provides the comments resulting from this review. In addition to these comments, please ensure that the cover page of the final report includes the following language:

> *PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD.*

As stated in the TWDB contract, HDR will consider revising the final report in response to comments from the Executive Administrator and other reviewers. In addition, HDR will include a copy of the Executive Administrator's draft report comments in the Final Report.

The TWDB looks forward to receiving one (1) electronic copy of the entire Final Report in Portable Document Format (PDF) and six (6) bound double-sided copies. **Please further note, that in compliance with Texas Administrative Code Chapters 206 and 213 (related to Accessibility and Usability of State Web Sites), the digital copy of the final report must comply with the requirements and standards specified in statute. For more information, visit http://www.sos.state.tx.us/tac/index.shtml.** If you have any questions on accessibility, please contact David Carter with the Contract Administration Division at (512) 936-6079 or David.Carter@twdb.texas.gov

HDR shall also submit one (1) electronic copy of any computer programs or models, and, if applicable, an operations manual developed under the terms of this Contract.

If you have any questions concerning the contract, please contact Dr. Junji Matsumoto, the TWDB's designated Contract Manager for this project at (512) 936-0825.

Sincerely,

Robert E. Mace, Ph.D., P.G.
Deputy Executive Administrator
Water Science and Conservation

Enclosures

c: Junji Matsumoto, Ph.D., TWDB

Re-examination of the 2001 Agreed Order Monthly Targets and Safe Yield Versus Current Demand Evaluations

Adam Cory Shockley, P.E.
Contract #1400011716
TWDB/BBASC Comments to Final Report

REQUIRED CHANGES

General Draft Final Report Comments:

Please add the following statement to the cover page of the final report:

PURSUANT TO SENATE BILL 1 AS APPROVED BY THE 83RD TEXAS LEGISLATURE, THIS STUDY REPORT WAS FUNDED FOR THE PURPOSE OF STUDYING ENVIRONMENTAL FLOW NEEDS FOR TEXAS RIVERS AND ESTUARIES AS PART OF THE ADAPTIVE MANAGEMENT PHASE OF THE SENATE BILL 3 PROCESS FOR ENVIRONMENTAL FLOWS ESTABLISHED BY THE 80TH TEXAS LEGISLATURE. THE VIEWS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE AUTHOR(S) AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE TEXAS WATER DEVELOPMENT BOARD

This study scope of work was focused on re-evaluating the monthly inflow targets of the 2001 Agreed Order. The goal of this effort was to determine if changes in recent hydrologic trends of precipitation and streamflow indicate a need to modify the freshwater inflow targets as defined in the Agreed Order. This study also modeled simulations of current demands and safe yield demands in order to compare current and future freshwater inflow to Nueces Bay. Work tasks described in the study Scope of Work were addressed in the draft final report.

Please check the document for grammar, spelling, and typographical errors such as missing words.

Please ensure that all Table and Figure titles adequately describe their contents and can stand apart from the text.

Please ensure that all acronyms are defined the first time they are used.

Specific Draft Final Report Comments:

1. Section 1, Introduction, page 3, 1st ¶ (also relevant to Section 4): TWDB's TxEMP Model was used to determine the amount of freshwater necessary for maximum harvest of the Bay for the Agreed Order. It is unclear whether this model also was used to determine the amounts for each monthly target. Please provide a citation or more

information about the data used to determine monthly and annual target amounts of water to be released as stated in the Agreed Order.

2. Section 1, Introduction, page 3, 3rd ¶: Please define safe yield the first time it is mentioned in the text.

3. Section 1, Introduction, page 3, 2nd bullet point: A safe yield demand of 202,000 ac-ft/yr is cited in the draft report (also mentioned on page 29, 2nd bullet point) but a safe yield demand of 205,000 ac-ft/yr is cited in the Scope of Work. Please clarify which safe yield demand was used in the analysis.

4. Section 4.1, Data Compilation, page 7: Footnote 1 refers to an erroneous website. Please replace with an active website.

5. Section 4.1, Data Compilation, page 8, 2nd full ¶: The last sentence states that "Like precipitation, naturalized flow data were evaluated for trends by comparing statistics representative of the long-term, short-term, and recent periods." Given that the period of record for naturalized flows extends only to 2003 and the recent period was defined as 2004-2014, please correct the statement or clarify how statistics for the naturalized flows for the recent period were derived.

6. Section, 4.2, Data Analysis, pages 11-12: The methodology used to determine the statistical significance of changes, by month, for precipitation, streamflow, and naturalized flow is well explained, and the evaluation of both arithmetic means and median amounts are informative. However, the methodology for the overall determination of trend (i.e. "No Change", "Drier") is not as well described. Please provide more information as to how the trend was determined. Was it an actual statistical determination of trend (i.e., statistical significance of the slope of a regression line through each monthly variable), or some other approach for aggregating the results for precipitation, streamflow, and naturalized flow?

7. Section 4.2, Data Analysis, page 11: Please provide the numerical values from the K-S test to which you refer in the text.

8. Section 4.3, Data Evaluation, page 14: Same comment as above. It is stated that "Even though the first part of this evaluation did not show statistically significant shifts..." however, the significance values are not provided. Please provide the results of the statistical test, either in the report or in an appendix.

9. Section 4.3, Data Evaluation, page 15, 2nd ¶: Please define MJJ and AMJJAD before their acronyms are used.

10. Section 5, Comparison of Safe Yield versus Current Demand, page 22, 1st sentence: Please correct the date range listed in the first sentence and consider adding a citation. Also, please clarify how the analyses of Section 5 (which evaluate past droughts over the modeling period of the CCWSM through 2003) relate to the current drought.

11. Section 5, Comparison of Safe Yield versus Current Demand, page 28: Please add a proper citation for the TWDB Harvest Equations and describe the data used in the Harvest Equations and the CCWSM, or consider eliminating this aspect of the analysis since it was not a required task in the Scope of Work. If included, please provide an expanded discussion on this aspect of the analysis, such as a description of the measure of confidence in the predictive power of the harvest equations to better contextualize the significance of a 1.9% reduction in harvest amounts.

Figures and Tables Comments:

1. Section 4.2, Page 14, Figure 4-6: Please correct the title by removing the word 'precipitation'

2. Appendix A. Please ensure labels and units are added to the axes of all figures.

SUGGESTED CHANGES

Specific Draft Final Report Comments:

1. Section 1, Introduction, page 3, 1st ¶: Consider revising the first sentence to state that the CCR/LCC system provides for water to a population of about 500,000 (in the area), 300,000 of which reside in the City of Corpus Christi.

2. Section 1, Introduction, page 3, 1st ¶: Consider mentioning other factors that affect the potential recreational and commercial harvest estuarine species, such as the magnitude of gulf stock, harvest pressure, economics, etc.

3. Section 1, Introduction, page 3, 1st ¶: Consider re-phrasing, "The monthly targets in the Agreed Order are based on the timing and magnitude of freshwater inflows to Nueces Bay as these are understood to affect the potential harvest of several estuarine species of commercial and/or recreational value" to "The monthly targets in the Agreed Order are based on the timing and magnitude of freshwater inflows to Nueces Bay as these **flows contribute to the variation in amount of** potential harvest of several estuarine species of commercial and/or recreational value."

4. Section 1, Introduction, page 3, 1st paragraph. Consider labeling Appendices in the same order as they appear in the text of the report (e.g. Appendix C is the first Appendix referred to on page 3. Appendix A should be the first Appendix referred to in the text.)

5. Section 3, Scenario Development, page 6, 2nd ¶: Consider changing the Coastal Bend Bays and Estuary Program to the Coastal Bend Bays and **Estuaries** Program.

6. Section 3, Scenario Development page 6: Consider defining acronyms for the Port of Corpus Authority, Center for Coastal Studies, and Naismith Engineering for use in the subsequent paragraphs.

7. Page 7, Section 4, 2nd ¶: Please consider describing the rationale for establishing the long-term period (1934 – 2014) to be inclusive of the short- and near-term periods.

8. Section 4.2 Data Analysis, page 9, 2nd ¶: Consider explaining that arithmetic means can be heavily influenced by extreme outliers, and thus the evaluation of median flows was necessary. As an example, the Nueces Basin has historically experienced significant tropical events that can impact the interpretation of certain statistics.

9. Section 4.2, Data Analysis, page 12, 2nd and 3rd ¶: Consider evaluating the statistical significance of the changes in monthly percent contributions of precipitation, streamflow, and naturalized flow, as was conducted for the time series data.

10. Section 4.3 Data Evaluation, page 17, last ¶: The description of the CCWSM implies that Texana I is included in system storage, but please consider making it explicit that it is included.

11. Section 4.3 Data Evaluation, page 17, last ¶: The selected modeling scenarios show little difference in storage and bay inflows and as such, the TxBLEND model was not evaluated. However, small differences were seen in the monthly bay inflows and depending the time of year and the weather conditions, salinity in the bay could be affected. The TxBLEND model may not capture the fine scale salinity changes that could make an impact on this ecosystem. Consider the idea that future studies could focus on fine scale salinity changes in the bay associated with smaller changes in the monthly inflows. Also, the way in which monthly targets are distributed over the month could be evaluated to determine the effect on salinity in the bay. Salinity modeling may be important for looking at the effects of future increased usage because there will be a greater chance the reservoir levels are in lower zones with less pass-through targets.

12. Section 5, Comparison of Safe Yield versus Current Demand, page 23, 3rd ¶, 3rd sentence: Given the consensus from the scientific community that the recent drought is considered to be the new drought of record, consider re-stating the sentence to refer to the 'drought' that occurred in the 1990's.

13. Section 6, Conclusions, Page 29, 1st bullet point after 2nd ¶: Consider explaining the meaning of statistical significance. For example, the fact that the observed change is not statistically significant means that the likelihood that such a change is due to mere random chance cannot be ruled out.

14. Section 6, Conclusions, page 29, last bullet point after 2nd ¶: While it is true that there is a potential for modifying the Agreed Order targets with minimal impact to the safe yield of the system, consider also that there is a potential for modifying the Agreed Order targets with minimal impact to the amount of freshwater inflows to Nueces Bay. It could

be stated that there is a potential for modifying the targets with potential benefit to safe yield and limited impact to freshwater inflow.

15. Section 6, Conclusions, page 30, 1st and 2nd bullet point: Consider combining the 1st and 2nd bullet point sinee they are related.

16. Section 6, Conclusions, page 30, 3rd bullet point. Consider eliminating this conclusion as it is not relevant to the tasks identified in the Scope of Work. However, if included, please consider revising the statement to ".....are not necessarily indicative of equivalent percentage reductions in average annual fisheries harvest."

17. Section 6, Recommendations, page 30: The author could consider recommending the analysis of existing studies, such as Dr. Paul Montagna's study in the Rincon Bayou on benthic macrofauna in relation to freshwater inflows/pumping events and Dr. Ken Dunton's long-term vegetation surveys in the Nueces Delta, to better understand the biological effects of freshwater inflow releases.

Figures and Tables Comments:

1. Section 4.3 Data Evaluation and Section 5, Comparison of Safe Yield and Current Demand, Figures 4-7 through 5-3: The blue and green colors used in the Figures are very similar and difficult to distinguish when the lines are close together. Please consider changing one of the line styles to dots or dashes, or distinctive colors.

This Page Intentionally Left Blank

APPENDIX F – Response to Comments on Draft Final Report

This Page Intentionally Left Blank

Re-Examination of the 2001 Agreed Order Monthly Targets and Safe Yield Versus Current Demand Evaluations

Adam Cory Shockley, P.E.
Contract # 1400011716
Responses to TWDB/BBASC Comments to Final Report

1 Required Changes

1.1 General Draft Final Report Comments

- HDR added the provided statement to the cover and title pages of the final report.
- Document was checked for grammar, spelling, and typographical errors such as missing words.
- Ensured that all tables and figure titles adequately describe the contents and can stand apart from the text.
- Ensured that all acronyms are defined the first time they are used.

1.2 Specific Draft Final Report Comments

1. Added explanation and references to text.
2. Safe yield is now defined the first time it is mentioned in the text.
3. Clarified that the 192,000 acft/yr was the safe yield demand used in this analysis. The 205,000 acft/yr was from the previous Region N plan and was out of date by the time this analysis was completed.
4. Footnote updated with corrected website URL.
5. Modified text to explain that only short-term and long-term trends can be evaluated for the naturalized flow data.
6. Modified text to explain that the overall shift (trend) was determined by looking at the aggregated results of all the variables.
7. KS test results provided in Appendix C.
8. KS test results provided in Appendix C.
9. Acronyms now described in text.
10. Corrected the date range for the current drought. Also added some explanation on how the analysis using the droughts contained in the CCWSM period of record can relate to the current drought.
11. Added explanation and table to text to further explain the results.

1.3 Figures and Tables Comments

1. Removed 'precipitation' from Figure 4-6
2. Added labels and units to figures in Appendix A.

2 Suggested Changes

2.1 Specific Draft Final Report Comments

1. Changed text to accommodate suggested edit.
2. The sentence is sufficient as written. It is stating how the targets were established not that freshwater inflows are the only factor impacting harvest.
3. Changed text to accommodate suggested edit.
4. Appendices reordered as they appear in text.
5. Changed text to accommodate suggested edit.
6. Defined acronyms for use in subsequent paragraphs.
7. Changed text to accommodate suggested edit.
8. Changed text to accommodate suggested edit.
9. No change. Statistical significance was not determined on the monthly percentage data.
10. Added text to define system storage. Lake Texana is not included as part of the system storage calculation.
11. Added text recommending a consideration for fine scale salinity modeling.
12. Clarified text to state that this is the drought of record in the CCWSM.
13. Changed text to accommodate suggested edit.
14. Added text to clarify bullet.
15. Made the second bullet a sub-bullet to show the dependency between the statements.
16. Added text to clarify bullet.
17. No change.

2.2 Figures and Tables Comments

1. Many of the lines on these graphs are exactly on top of each other and there is no distinction to be made. No change.