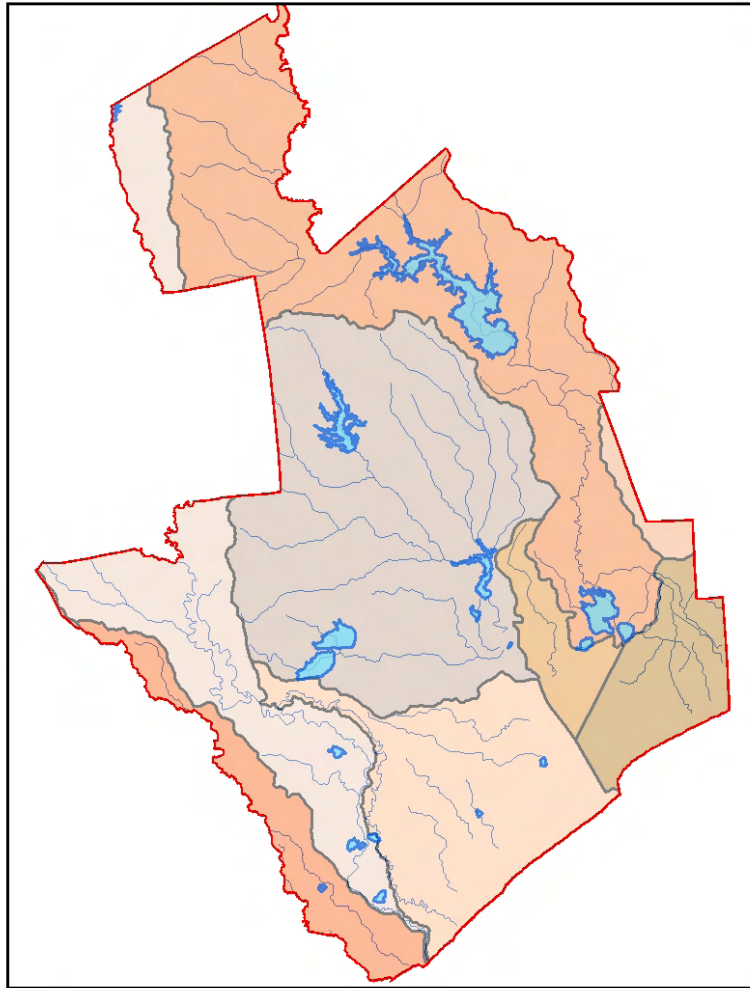


Region H Water Planning Group



Draft Environmental Flows Analysis

AECOM

January 2009
Job No. 60025663

Region H Water Planning Group

Draft Environmental Flows Analysis

for

Region H Water Planning Group

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Contents

Executive Summary	ES-1
ES.1 Bay and Estuary Inflows.....	ES-1
ES.2 Instream Flows.....	ES-2
Section 1 – Introduction.....	1-1
1.1 The Role of WRAP in Modeling Environmental Impacts	1-1
1.2 Purpose of Current Study.....	1-2
1.3 Water Management Strategies in 2006 Region H Regional Water Plan	1-2
Section 2 – Development of Water Availability Models for Evaluating Management Strategies	2-1
2.1 Scenario A: Naturalized Flow.....	2-1
2.2 Scenario B: Existing Diversions With Full Return Flows.....	2-1
2.3 Scenario C: Full Authorized Diversions With Full Return Flows	2-2
2.4 Scenario D: Future 2060 Conditions With Existing Permits and Full Return Flows	2-2
2.4.1 D ₁ : Municipal Conservation.....	2-3
2.4.2 D ₂ : Irrigation Conservation.....	2-3
2.4.3 D ₃ : Freeport Seawater Desalination.....	2-3
2.4.4 D ₄ : Expanded Use of Groundwater.....	2-3
2.4.5 D ₅ : Expand/Increase Current Contracts.....	2-3
2.4.6 D ₆ : New Contracts From Existing Supply	2-4
2.4.7 D ₇ : BRA System Operations Permit.....	2-4
2.4.8 D ₈ : Allens Creek Reservoir	2-4
2.4.9 D ₉ : Little River Off-Channel Reservoir	2-4
2.4.10 D ₁₀ : Non-Municipal Contractual Transfers	2-4
2.4.11 D ₁₁ : Wastewater Reuse for Industry	2-4
2.4.12 D ₁₂ : TRA to Houston Contract.....	2-5
2.4.13 D ₁₃ : TRA to SJRA Contract.....	2-5
2.4.14 D ₁₄ : Houston to GCWA Transfer.....	2-5
2.4.15 D ₁₅ : Houston Indirect Wastewater Reuse	2-5
2.4.16 D ₁₆ : NHCRWA Indirect Wastewater Reuse	2-6
2.4.17 D ₁₇ : Lake Houston Additional Yield.....	2-6
2.5 Scenario E: Future 2060 Conditions With Return Flows and All Recommended WMS	2-6
2.6 Scenario F: Full Authorized Diversions With No Return Flows.....	2-6
Section 3 – Evaluation of Bay and Estuary Inflows and Target Attainment.....	3-1
3.1 B&E Flow Results	3-1

3.1.1	B&E Inflow Targets and Attainment Frequency	3-1
3.1.2	Location of B&E Inflows.....	3-6
3.2	Evaluation of Alternatives for Meeting GBFIG Targets	3-7
3.2.1	Concept and Target Conditions.....	3-7
3.2.2	Methodology	3-8
3.3	Impacts to Future Water Supply	3-12
3.3.1	Water Right Yield.....	3-12
3.3.2	Reservoir Levels.....	3-13
Section 4 – Evaluation of Instream Flow Requirements for Future Water Management Strategies.....		4-1
4.1	Identification of Critical Segments	4-1
4.2	Lyons Flows and Field Evaluations	4-2
Section 5 – Discussion		5-1
5.1	Bay and Estuary Inflows	5-1
5.1.1	Changes in Volume, Timing, and Location of B&E Inflows	5-1
5.1.2	Upper Basin Return Flows.....	5-2
5.1.3	Frequency of Target Attainment	5-4
5.1.4	Considerations.....	5-4
5.2	Instream Flows	5-7
5.2.1	Critical Segments.....	5-7
5.2.2	Field Observations.....	5-8
Section 6 – Conclusions.....		6-1
Section 7 – References.....		7-1

List of Tables

- Table 1-1. WMS Supply Volume for Selected Strategies
- Table 3-1. Monthly Galveston Bay Inflow Targets
- Table 3-2. Frequency of Target Attainment
- Table 3-3. FTA for D₀, D₁₂, and E Models
- Table 3-4. Frequency of Max H Target Attainment
- Table 3-5. Frequency of Min Q-Sal Target Attainment
- Table 3-6. Minimum Annual Diversions for Max H and Min Q-Sal Reservoir Operation
- Table 4-1. Impacts of WMS Implementation on Critical Stream Segments
- Table 4-2. Lyons and Observed Flows for Field Study Points
- Table 5-1. Minimum Annual Diversions With and Without Upper Basin Return Flow

List of Figures

- Figure 3-1. WRAP Model Median Monthly Bay and Estuary Inflows
- Figure 3-2. Seasonal Frequency of Target Attainment

Figure 3-3. Monthly Frequency of Target Attainment

Figure 3-4. B&E Contributions of the San Jacinto and Trinity Basins

Figure 3-5. Available Reservoir Water and Demands

Figure 3-6. Monthly Target Shortages for Max H

Figure 3-7. Frequency and Volume of Reservoir Releases for Max H Attainment

Figure 3-8. Monthly Target Shortages for Min Q-Sal

Figure 3-9. Frequency and Volume of Reservoir Releases for Min Q-Sal Attainment

Figure 3-10. Lake Houston Storage Volume for Revised Reservoir Operation

Figure 3-11. Lake Livingston Storage Volume for Revised Reservoir Operation

Figure 5-1. Comparison of Trinity Basin B&E Discharge With and Without Region C Return Flows

Figure 5-2. Distribution of Monthly B&E Inflows for Max H Revised Operation Model

Figure 5-3. Distribution of Monthly B&E Inflows for Min Q-Sal Revised Operation Model

List of Exhibits

Exhibit 1 – Basins with Study Control Points

Exhibit 2 – Critical Segments and Survey Points

List of Appendices

Appendix A – WRAP Overview

Appendix B – Median Flows for Selected Control Points for Models A Through F

Appendix C – 10th Percentile Flows for Critical Segments Analysis

Appendix D – Field Study Survey Point Summary

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Acronyms and Abbreviations

B&E	Bay and Estuary
BRA	Brazos River Authority
CFS	Channel Flow Status
COH	City of Houston
CWA	Coastal Water Authority
FTA	frequency of target attainment
GBFIG	Galveston Bay Freshwater Inflows Group
GCWA	Gulf Coast Water Authority
GIS	geographic information systems
IBT	interbasin transfer
LROCR	Little River Off-Channel Reservoir
MGD	millions of gallons per day
NHCRWA	North Harris County Regional Water Authority
RWP	Regional Water Plan
SJRA	San Jacinto River Authority
TCEQ	Texas Commission on Environmental Quality
TRA	Trinity River Authority
TWDB	Texas Water Development Board
USGS	United States Geological Survey
WAM	Water Availability Model
WMS	water management strategy
WRAP	Water Rights Analysis Package
WUG	water user group
WWTP	wastewater treatment plant

Model Descriptions

A	Naturalized Flow
B	Existing Diversions with Full Return Flows
C	Full Authorized Diversions with Full Return Flows
D ₀	Future 2060 Conditions with Existing Permits and Full Return Flows
D ₃	D ₀ + Freeport Seawater Desalination
D ₄	D ₀ + Expanded Use of Groundwater
D ₇	D ₀ + BRA System Operations Permit
D ₈	D ₀ + Allens Creek Reservoir
D ₉	D ₀ + Little River Off-Channel Reservoir
D ₁₁	D ₀ + Wastewater Reuse for Industry
D ₁₂	D ₀ + TRA to Houston Contract
D ₁₃	D ₀ + TRA to SJRA Contract
D ₁₄	D ₀ + Houston to GCWA Transfer
D ₁₅	D ₀ + Houston Indirect Wastewater Reuse
D ₁₆	D ₀ + NHCRWA Indirect Wastewater Reuse
D ₁₇	D ₀ + Lake Houston Additional Yield
E	Future 2060 Conditions with Return Flows and All Recommended WMS
F	TCEQ Run 3 (Full Authorized Diversions with No Return Flows)

WRAP Cards

Identifier	Card Type	Function
CI	Constant Inflows and/or Outflows	A set of 12 monthly values of inflow (or outflow) applied at a specified location each year of the simulation
CP	Control Point Information	Establishes system connectivity and identifies methods for obtaining evaporation, precipitation, and drainage area
FY	Firm Yield and Yield Reliability	Activates yield-reliability analysis for a specified water right and generates an output table
RF	Monthly Multipliers for Return Flows	A set of 12 monthly multipliers used to distribute return flows from water right diversions
SV/SA	Storage Volume vs. Storage Area Table	Paired records establishing a storage volume vs. surface area relationship for a specified reservoir
TS	Target Series	Optional card associated with a water right diversion allowing the diversion target to be set through a number of methods
UC	Usage Coefficients	A set of 12 monthly multipliers used to distribute an annual water right diversion for the monthly time step
WR	Water Right	Establishes the location of a diversion with options for diversion amount, return flows, and other functions
WS	Reservoir Storage and/or Hydropower Data	Associates a water right diversion with storage in a specified reservoir as well as additional options

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Executive Summary

The importance of environmental flows to the health of Galveston Bay has been considered by the Region H Water Planning Group throughout the regional water planning process. The Region H Regional Water Planning Group adopted Bay & Estuary (B&E) target flow recommendations developed by the Galveston Bay Freshwater Inflows Group (GBFIG) in both the 2001 and 2006 Region H Regional Water Plans. Most recently in the 2006 Region H Regional Water Plan (RWP) the impacts of implementing water management strategies (WMS) were determined for the year 2060 condition. This analysis demonstrated a decrease in freshwater inflows to Galveston Bay as current levels of water use are increased to full authorized diversion. However, models of the projected future conditions demonstrated that freshwater inflow targets were met at levels approaching or exceeding the recommendations of GBFIG for scenarios which included expected return flows. However, the 2006 study stopped short of identifying resulting impacts to Bay and Estuary (B&E) inflows from individual WMS.

Additionally, no analysis was completed in the 2006 study which examined impacts to environmental flows at specific stream segments. Instream flows were further assessed in a study by the Texas Water Development Board that was included in the 2007 State Water Plan (SWP) with participation by the Region H Planning Group. However, again no analysis was completed during this study which related individual WMS to impacts on environmental flows.

In order to address these issues, the Region H Planning Group authorized a study to evaluate a variety of flow conditions for the year 2060 and examine the impacts of individual WMS. The Water Rights Analysis Package (WRAP) was executed for five baseline conditions which did not include Region H strategies, plus 12 sets of strategy models that were intended to isolate the impacts of individual Region H WMS. Strategy models were developed from a base model representing Full Authorized Diversion conditions with expected return flows and no term permits. Additionally, a study was undertaken to assess methodologies for increasing the frequency at which B&E inflows targets were attained and assess the impacts such an approach would have upon existing and future water supplies.

ES.1 Bay and Estuary Inflows

A comparison of the B&E inflows produced by each of the study models indicated specific trends in flows with variations in volume of flow, the seasonal timing of flows, and the geographic location that these flows occurred in the bay. The addition of WMS in both the upper basin (Region C) and Region H were found to have an overall improvement on the frequency of attainment of Max H, Min Q, and Min Q-Sal targets for Galveston Bay. Typically, any failure to meet the predetermined goals at the appropriate desired frequency occurred during the spring for Max H and Min Q-Sal. For Min Q, reduced levels of attainment were typically observed in the summer months. On a monthly basis, the future condition model, with all strategies implemented, did not achieve Max H, Min Q, and Min Q-Sal target flows for many of the months throughout the year. Monthly attainment was considered to be achieved if that month met its flow target for a number of years equal to or greater than the required frequency when compared to the entire period of simulation.

On an individual basis, WMS strategies were found to have minimal impacts on B&E inflows and did not result in a significant variation in attainment level until implemented in unison. The WMS with greatest individual impact, the transfer of water from the Trinity River Authority (TRA) to the City of Houston, was found to increase the rate of target attainment by 0 to 10 percent on a monthly basis over the base model due to the reintroduction of diverted water to the San Jacinto and San Jacinto-Brazos basins. However, the overall change in B&E inflow from this strategy on an annualized basis was minimal. Additionally, some of the impact of the TRA to Houston transfer is an artifact of the

original Full Authorized Diversion models, which already included the water for the IBT leaving the Trinity Basin but did not reflect it entering the San Jacinto Basin. Thus, incorporation of the flow into the San Jacinto Basin in the strategy models created slightly increased B&E inflows. In general, the greatest impact from WMS were identified in the comparison of the base models with and without upstream strategies, indicating that return flows from Region C have a critical role in maintaining freshwater inflows to Galveston Bay.

A review of monthly target attainment data indicated that the majority of shortages (i.e., difference between simulated flows and inflow target flows) were of a relatively small magnitude. A methodology was developed to make up the smallest of these shortages through releases of water from reservoir storage in order to meet the desired attainment level for Max H and Min Q-Sal for months with attainment levels less than the GBFIG recommendation. Reservoir storage was used to meet these shortages because it was recognized that the magnitude of the shortages were in excess of available unappropriated flows within the basins. Any attempt to address shortages solely through streamflow depletion would require additional pass-through flows from upstream senior rights, circumventing the priority system for existing water rights. The resulting methodology was found to meet the desired frequency of target attainment for Max H and Min Q-Sal without impact to the future firm yield of existing or future water rights. However, impacts were identified in the resulting reservoir levels for both Max H and Min Q-Sal. Reductions in median reservoir levels between the adjusted Max H model and the base condition model were found to be 8 percent and 17 percent for Lake Houston and Lake Livingston, respectively. For the adjusted Min Q-Sal model, the median levels of Lake Houston and Lake Livingston were found to be reduced by 11 and 24 percent, respectively. This reduction in storage represents a loss in protection against potential future droughts that are in excess of the drought of record (DOR) tested in this study. Furthermore, the inability of the reservoirs to reach a full condition after releasing water to meet inflow targets poses an issue to future water supply, even under the assumed DOR conditions, because reductions in reservoir storage may tend to continue to occur over an extended period of record.

Finally, it was also considered that this traditional approach to B&E flow targets does not fully consider the importance of the distribution of inflow target flows throughout the entire year, but instead treats the monthly targets as discrete goals. Simulated inflows from the revised Max H and Min Q-Sal models was plotted to demonstrate the distribution of flows resulting from the revised operational strategies. It was found that, although the monthly targets were met at the prescribed level of attainment when prescribed reservoir releases were made, the overall inflow distribution did not correspond to the recommended Max H and Min Q-Sal target distributions.

ES.2 Instream Flows

The same models used for evaluating B&E inflows were used to compare changes in instream flows resulting from WMS. Tenth-percentile flows were compared for conditions with and without each WMS and the results were compared to determine which locations were most impacted by each strategy. Four locations in the San Jacinto and two locations in the Brazos River Basins were found to be most impacted by the implementation of WMS. Changes in 10th percentile flows were generally found to be less than 10 percent. The exceptions to this are two points identified in the San Jacinto River basin that resulted in substantial increases in flow due to water imports from the Trinity River basin (WRAP Identifier SPSP) and the expanded use of groundwater (WRAP Identifier 1004). WRAP identifier SPSP experienced an increase in 10th percentile flows by more than 189 percent due to the transfer of water from the TRA to Houston strategy. This same point was expected to experience an increase in 10th percentile flows of 278 percent as a result of implementing all recommended WMS.

A field study was also performed to evaluate stream health during low flow conditions. Seven segments were identified for investigation based on their accessibility and proximity to United States Geological Survey (USGS) stream gages in order to obtain accurate stream measurements. Sites were evaluated primarily for Channel Flow Status (CFS). Observed flow rates were found to range

between 2 to 91 percent of the Lyons flow for each segment and the observed CFS was generally found to be between low to moderate for each segment. However, streams generally appeared to be in fair to good condition with healthy vegetation and observed presence of aquatic wildlife.

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Section 1 – Introduction

1.1 The Role of WRAP in Modeling Environmental Impacts

The Water Rights Analysis Package (WRAP [Wurbs 2007]) was developed as a tool for modeling water rights allocations and river and reservoir operations on a monthly time-step. In addition to this basic objective, the nature of the application allows for the modeling of various environmental conditions, especially the determination of instream flows and bay and estuary (B&E) flows as a result of operations within the basin. This process is made simpler by the constant maintenance of Water Availability Models (WAMs) for each basin in the State of Texas by the Texas Commission on Environmental Quality (TCEQ). These WAMs can then be modified as necessary and executed by WRAP to determine impacts from various changes. Please see *Appendix A* for an overview of the WRAP components discussed in this report. Currently, TCEQ maintains two versions of the WAMs for permitting purposes: 1) a full-diversion model with no return flows, known as the WAM Run 3, and 2) a current conditions model based on historical water use, known as the WAM Run 8. The period of record for both models contains the critical drought period for each basin.

A recent study by the Texas Water Development Board (TWDB) in the production of the 2007 State Water Plan (SWP) Appendix 6.2 – Streamflow Assessments (TWDB 2007) examined environmental flows as a result of water management strategies (WMS) recommended in the 16 individual Regional Water Plans (RWPs). The TWDB used the TCEQ Run 8 as a basis for evaluating future strategies. Diversions in each basin were increased according to the volume of use anticipated in the RWPs while code was also added to account for new strategies that were not yet permitted in the current WAMs. Median and 10th percentile instream flows were then compared between the unmodified Run 8 models and the future conditions models.

In Region H, the WAM has been used to characterize inflows to Galveston Bay for various conditions. In the 2006 Region H RWP Chapter 4, Section 5 (Region H Water Planning Group 2005), the consultant team modeled five flow conditions in the Neches-Trinity, Trinity, Trinity-San Jacinto, San Jacinto, and San Jacinto-Brazos Basins:

- Naturalized Flow
- Current Conditions (TCEQ Run 8)
- Full Permit With Return Flows
- Full Permit Without Return Flows (TCEQ Run 3)
- Full Permit With Return Flows and Strategies for Regions C and H

Changes in annual inflow were determined and a comparison was made between various percentiles of modeled inflows and the freshwater inflow targets for Galveston Bay as described by Max H, Min Q, and Min Q-Sal. The results of this study indicated that:

- The TCEQ WAM runs reveal a decrease in the freshwater inflows to Galveston Bay as existing water rights are used to their Full Authorized Diversion amounts.
- The Full Authorized Diversion scenario with no return flows results in a significant reduction in inflows to Galveston Bay, such that inflows are consistently lower than freshwater inflow targets.
- Sedimentation in reservoirs in the Trinity and San Jacinto Basins has a minimal impact on freshwater inflows.

- The Current Conditions, Full Authorized Diversions With Return Flows and Full Authorized Diversions plus Management Strategies represent models of increasing demand and return flows in Region H. These models show the portion of inflows to Galveston Bay from the San Jacinto Basin will increase while the portion from the Trinity Basin will decrease.
- Region C Management Strategies produce a net increase in flows to Galveston Bay as a result of large amounts of imported water producing return flows in the upper Trinity Basin.
- The incorporation of Management Strategies results in inflow patterns most similar to the Current Conditions.
- When aggregating the monthly statistics, freshwater inflow targets are met at levels approaching or exceeding the Galveston Bay Freshwater Inflows Group (GBFIG) frequency goals for all but the no return flow scenario.
- The individual monthly statistics for freshwater inflows reveal selected months which are not met at the target frequency, while in other months the target frequency is exceeded.

The 2006 study indicated several trends in B&E inflows. However, no effort was made at this point to determine the impact of individual strategies. As this study was completed during the course of the Regional Water Planning process, final strategies for upstream reaches of the Trinity Basin were not available for incorporation into the model as they were for the TWDB environmental flows study. Furthermore, this limited analysis did not approach the question of how to address potential impacts from future WMS.

1.2 Purpose of Current Study

This study is intended to serve as a continuation of the 2006 Region H study by investigating the impacts of individual WMS on B&E inflows and to evaluate the feasibility of meeting existing B&E targets through operational strategies in the contributing basins. This methodology includes the development of various future conditions models to represent each management strategy and provide comparison to determine the magnitude of strategy impacts. Models will also be created to meet existing B&E targets using operational techniques while utilizing current and future WMS.

Additionally, this study is intended to determine impacts to instream flows in each basin. This analysis has not been performed as part of the Region H planning process up to this point. This includes a review of instream flows at certain critical points as well as field observations to provide data on habitat quality along with observed flow regimes.

1.3 Water Management Strategies in 2006 Region H Regional Water Plan

The 2006 Region H RWP examined 32 WMS. Strategies were evaluated based on a number of parameters, including yield, cost, location, water quality, various environmental impacts, and several other factors. Of these, 23 were recommended by the RWP as recommended WMS. This study selected 17 of the recommended WMS as potential candidates for modeling. The WMS selected for study are summarized below. For additional details, see Chapter 4 of the 2006 Region H RWP. Estimated Year 2060 yields for the strategies are shown in *Table 1-1*.

Table 1-1. WMS Supply Volume for Selected Strategies

No.	Strategy	Volume ¹ (ac-ft)
1	Municipal Conservation	101,000
2	Irrigation Conservation	77,900
3	Freeport Desalination	28,000
4	Expanded Groundwater	91,000
5	Expand/Increase Contracts	68,300
6	New Contracts	293,400
7	BRA System Operations	163,700
8	Allens Creek Reservoir	97,400
9	Little River Off-Channel Reservoir	32,100
10	Non-Municipal Contractual Transfers	21,000
11	Wastewater Reuse for Industry	67,200
12	Trinity River Authority (TRA) to Houston Contract	150,000
13	TRA to San Jacinto River Authority (SJRA) Contract	50,000
14	Houston to GCWA Contract	56,000
15	Houston Indirect Reuse	52,500
16	North Harris County Regional Water Authority (NHCRWA) Indirect Reuse	31,400
17	Lake Houston Additional Yield	² 1,000

¹. Rounded to nearest 100 ac-ft.

². Modeled at full unallocated volume of 32,500 ac-ft.

1. **Municipal Conservation:** This WMS relies on demand reduction to allow existing supplies to meet demands for longer periods of time. This can also potentially delay the need to develop new municipal supplies. Potential conservation methods include water system audits, conservation pricing, plumbing fixture retrofits, landscape irrigation conservation, and incentives for purchasing water-efficient appliances, as well as a number of other methods.
2. **Irrigation Conservation:** The Irrigation Conservation strategy is similar in intent to the municipal conservation WMS. Potential conservation methods include irrigation scheduling, leveling and contour farming, ditch lining, and drip line installation, as well as other methods.
3. **Freeport Desalination:** The Freeport Desalination WMS involves the construction of a 10 MGD desalination facility in Freeport, Texas on the site of the Dow chemical plant. The proposed strategy includes the ability to upgrade to 100 MGD by 2060. Water desalinated by the plant would be piped upstream for municipal use in demand centers in Fort Bend and Brazoria Counties.
4. **Expanded Use of Groundwater:** This WMS relies on sustainable expansion of existing groundwater supplies, with limits on increases to correspond with groundwater reduction plans and conservation district rules. Increases are within the limits of sustainable yield and subject to groundwater conservation district and subsidence district rules.
5. **Expand/Increase Current Contracts:** This WMS includes allocation of currently permitted water supplies for use by current contract participants. This includes the extension of current

contracts with terms ending before the year 2060, as well as the increase of current contracts to meet future demands.

6. **New Contracts from Existing Supply:** New contracts would be created from existing supply sources.
7. **BRA System Operations Permit:** The Brazos River Authority (BRA) System Operations WMS aims to increase the yield of BRA reservoirs by coordinating operation of reservoirs as a system and the permitting of a portion of the return flows in the Brazos River basin. This would allow for additional yield without the need for construction of new infrastructure.
8. **Allens Creek Reservoir:** The Allens Creek Reservoir WMS is a proposed off-channel reservoir in Austin County. The reservoir would hold peak flows diverted from the Brazos River, with diversions to the reservoir indexed to streamflow. Water from the reservoir would be used to supply municipal, industrial, and irrigation needs in several counties.
9. **Little-River Off-Channel Reservoir:** This WMS would be an off-channel reservoir in Milam County intended to divert and store excess flows for producing firm capacity. The WMS was originally assessed by the Brazos G region but has been investigated by Region H.
10. **Non-Municipal Contractual Transfers:** The Non-Municipal Contractual Transfer WMS involves transferring surplus water supply to neighboring counties and basins with projected shortages. These transfers would make use of existing conveyances where possible.
11. **Wastewater Reuse for Industry:** Water for this WMS would come from treated effluent from three City of Houston (COH) Waste Water Treatment Plants (WWTPs). After treatment, water would be piped to industrial users along the south side of the Houston Ship Channel corridor.
12. **TRA to Houston Contract:** This is a surface water agreement between the COH and TRA to allow COH to acquire a portion of uncommitted TRA water supplies from the Lake Livingston-Wallisville Saltwater Barrier system.
13. **TRA to SJRA Contract:** This strategy proposes the transfer of some SJRA supply in the Trinity River and some TRA supply in Lake Livingston to Montgomery County via Lake Houston. Water may be transferred through the proposed Luce Bayou conveyance.
14. **Houston to Gulf Coast Water Authority (GCWA) Transfer:** The Houston to GCWA WMS involves the transfer of water from the Coastal Water Authority (CWA) system to GCWA's Texas City Reservoir by way of the CWA Bayport facility. Shortages would be met in Galveston County and possibly Fort Bend County.
15. **Houston Indirect Wastewater Reuse:** Water for this WMS would be reclaimed from effluent from 35 City of Houston WWTPs in seven small basins. Water would receive additional treatment and be transferred by bed and banks permits to diversion locations for municipal and industrial users.
16. **NHCRWA Indirect Wastewater Reuse:** The NHCRWA Indirect Reuse strategy includes reclamation of water from up to 163 WWTPs in the NHCRWA service area discharging to tributaries of the San Jacinto River and Lake Houston. Water would be transferred via bed and banks permits to diversion locations to serve industrial reuse and municipal and commercial irrigation reuse.
17. **Lake Houston Additional Yield:** Based on WRAP modeling for the last RWP, additional unappropriated volume was identified in Lake Houston. This strategy reflects the permitting of this storage.

Section 2 – Development of Water Availability Models for Evaluating Management Strategies

Several model conditions were devised and executed for the Neches-Trinity, Trinity, Trinity-San Jacinto, San Jacinto, and San Jacinto-Brazos Basins to determine the impacts of WMS on inflows to Galveston Bay. Each model represented a particular condition that could be compared to other simulations to determine incremental impacts from individual strategies. The resulting B&E inflows were compared on a basis of frequency to identify any impacts from future strategies that would further hinder the rate of compliance with meeting inflow targets beyond current conditions.

A process was then developed for adjusting reservoir operations to increase B&E inflows during months when future strategies caused a net decrease in frequency for meeting inflow targets. Reservoir spills from Lake Houston in the San Jacinto River Basin and Lake Livingston in the Trinity River Basin were recommended in order to create a condition of zero net impact on inflows to Galveston Bay. A review of water right reliability following this exercise indicated no impact to the reliability of rights resulting from this change to reservoir operations.

A series of four models were originally developed as baseline conditions ranging from Naturalized Flows to a Future 2060 Condition with Existing Permits and Full Return Flows model. This future conditions model, which included upstream strategies in the upper basins, was then modified with the proposed Region H strategies described above. Once the individual strategies had been modeled, a comprehensive model including all of the Region H strategies was developed to represent an expected Future 2060 Condition. Finally, an additional model run of the TCEQ Run 3 (Full Diversion Without Return Flows) was requested by the Region H Planning Group for purposes of comparison with the other models.

2.1 Scenario A: Naturalized Flow

Naturalized flows for all study basins were determined using the TCEQ current conditions (Run 8) WRAP models without modifications. The most recent versions available from the TCEQ website were used for all basins except the Trinity, for which an unreleased updated version was provided by TCEQ. Naturalized flows were retrieved from the model output file using a 2NAT record in the TABLES program.

2.2 Scenario B: Existing Diversions With Full Return Flows

Existing diversions with return flows were analyzed using the same models as those from Scenario A. Regulated flows for this and all subsequent scenarios were retrieved from model output using a 2REG record in the TABLES program.

2.3 Scenario C: Full Authorized Diversions With Full Return Flows

This scenario was based on TCEQ Full Authorized Diversion (Run 3) models. As with Scenarios A and B, the most recent versions available from the TCEQ website were used for all basins except the Trinity, for which an unreleased updated version was provided by TCEQ. Because the Run 3 model includes almost no return flows, Constant Inflow (CI) and Return Flow (RF) cards for each basin were imported from the Run 8 model if present in the Run 8. CI cards imported from Run 8 reflect flows from a current conditions diversion level. However, since the majority of CI cards represent groundwater inputs to the system, no adjustment was required. The exception was the San Jacinto Basin, which includes considerable surface water inflows. For the San Jacinto model, CI cards were scaled up to represent Full Authorized Diversion conditions.

In order to create a Full Authorized Diversions With Return Flows model, a program was developed to extract Run 8 return flows and insert them into the Run 3 model. The program scanned the Run 8 and Run 3 models and, for each model, developed a table of several parameters included on the WR cards. These included the control point, use, priority number, return flow parameters (Run 8 only), and water right identifier. The two tables were then compared and, for diversions with matching parameters, the Run 8 return flow data was copied into the corresponding Run 3 diversion. Non-matching records, or records for which no change was necessary, were not altered.

2.4 Scenario D: Future 2060 Conditions With Existing Permits and Full Return Flows

The Strategy C models discussed in the preceding section were used to develop the series of models corresponding to the various strategies, referred to as the D_0 models. Year 2060 SV/SA records (if available) giving surface area and volume relationships for reservoirs replaced the existing Year 2000 SV/SA records to account for the loss of reservoir storage volume from the effects of sedimentation over time. For the Neches Trinity, Trinity-San Jacinto, and San Jacinto models, no other changes required consideration. Two of the basins, the Trinity and the Brazos/San Jacinto-Brazos, required modification due to the presence of WMS in portions of the basins located in areas outside of Region H.

For the Trinity model, upstream strategies from Region C were included. Sections of code related to these strategies were copied from a file representing Region C's WMS for the TWDB Streamflow Assessment Study found in the 2007 SWP. This file was provided by TWDB. In addition to altering the Strategy D DAT file, changes were also made to the DIS file due to the addition of several control points. For the Brazos/San Jacinto-Brazos model, changes were made based on Region G's 2001 WMS (Brazos G Regional Water Planning Group 2001) as modeled in the same TWDB study. As with the Trinity model, changes for Strategy D were made to both the DAT and DIS files. The resultant models, identified as D_0 models, represent Year 2060 conditions with Full Authorized Diversions and expected return flows, upstream WMS, and no term water rights. However, the D_0 model contained no Region H strategies.

The D_0 models were used as base models for the individual WMS scenarios described in detail below. Changes made for each scenario were specific to the nature of the WMS. Because the regional water planning database (DB07) gives volumes associated with specific WMS for each WUG impacted, it was necessary to associate relevant WUGs with model control points for a number of the strategies examined. As control points in the model are generally not explicitly identified with a WUG, the process of associating WUGs and control points was performed manually. Stream segments and control points for each basin, along with WUG boundaries and WWTP locations, were examined in a GIS environment. The process was fairly straightforward for the majority of WUGs representing communities and cities. Generally, the community's WWTP outfall was located near a return flow

control point within or downstream of the WUG boundary, leading to selection of that control point. For distributed WUGs, such as County-Other, the process of matching WUGs and control points was more complex. Control points were associated with these distributed WUGs in what was determined to be the most reasonable location for the county and basin. If possible, the control points selected were located at an outfall near the major demand centers in the area. If no significant demand centers were identified nearby, the point at the downstream corner of the county-basin was selected.

2.4.1 D₁: Municipal Conservation

Because the D₀ model includes Full Authorized Diversion, this conservation strategy was not modeled, as it does not alter diversion amounts under the Full Authorized Diversion condition. Any water conserved under one use would still be used in another capacity by another WUG.

2.4.2 D₂: Irrigation Conservation

Similar to the D₁ strategy, use of a Full Authorized Diversion base model precluded modeling of the irrigation conservation scenario.

2.4.3 D₃: Freeport Seawater Desalination

This strategy model was developed from the Brazos/San Jacinto-Brazos D₀ model. The effects of added desalination supply were approximated by new return flows at points of use associated with the strategy. The added return flows were modeled with three CI cards at two locations representing the WUGs for Brazos Manufacturing, Brazos County-Other, and San Jacinto-Brazos County-Other. Because detailed information on monthly supply volumes was not available for the strategy, the monthly distributions of WMS volume for the WUGs were based on existing information in the model. The UC cards, which give monthly percentages of annual water right diversions, were grouped together by water use and averaged to yield a monthly pattern for each use type in the basin. The annual WMS volumes associated with the three strategy WUGs were multiplied by these usage pattern to create monthly strategy volumes. These monthly strategy volumes were further scaled by a return flow percentage to convert them to return flow volumes. Assumed return flow factors were 60 percent return flow for municipal use, 40 percent for mining, industrial, and livestock uses, and 0 percent for irrigation. These factors were selected based on prior experience as well as information from existing WAM models. Irrigation return flows were set to 0 percent to maintain consistency with existing Current Conditions return flow factors. Monthly strategy return flows were then converted to CI card format and added to the model.

2.4.4 D₄: Expanded Use of Groundwater

The WMS associated with expanded use of groundwater supplies was modeled in all of the study basins. Because additional groundwater will be utilized near the point of production before entering the stream network, effects of expanded groundwater use were approximated as new return flows. Return flows were modeled with 214 CI cards, one for each point-of-use WUG. As with Scenario D₃, annual WMS volumes were converted into monthly return flows. A similar procedure to that used in the Brazos/San Jacinto-Brazos Basin was used to develop monthly average usage coefficients for each use basin and use type. Assumed return flow factors were 60 percent return flow for municipal use, 40 percent for mining, industrial, and livestock uses, and 0 percent for irrigation.

2.4.5 D₅: Expand/Increase Current Contracts

This strategy was not modeled as the WRAP program allocates water for water right diversions, not contracts. Additionally, since the base model includes Full Authorized Diversions, water that would be transferred has already been accounted for under an existing diversion.

2.4.6 D₆: New Contracts From Existing Supply

This strategy was not modeled for similar reasons as Scenario D₅.

2.4.7 D₇: BRA System Operations Permit

The Brazos System Operations permit was incorporated into the Brazos/San Jacinto-Brazos D₀ model from the TWDB Region G WMS model, with the portion of the permit dealing with Region H reservoirs removed. To simulate the full system operations permit, sections of the code that had been commented out for Region H were reactivated. This reactivated a diversion for the Region H WMS. The diversion amount was updated to reflect the volume given in the most recent Regional Water Planning Group (RWPG) database. Twenty-eight CI cards were added to reflect return flows at the WUG level from this diversion. These cards were generated by multiplying the WMS volume for each WUG by a monthly distribution (same pattern as the UC card for the diversion) and a return flow factor. CI cards were also added to the San Jacinto and Trinity models to represent an interbasin transfer (IBT) from the Brazos Basin. The CI cards for the IBTs were determined in a similar manner to the return flows.

2.4.8 D₈: Allens Creek Reservoir

The Allens Creek Reservoir code was already included in the Brazos/San Jacinto-Brazos D₀ model but commented out. In order to simulate Allens Creek Reservoir, these sections of the model were reinstated. This reactivated instream flow requirements and the WMS diversion for Allens Creek. The diversion amount was altered to reflect the latest value from the RWPG database. The SV/SA card for Allens Creek Reservoir was also uncommented. CI cards were used to represent return flows at the WUG level as well as the IBT of water to the San Jacinto-Brazos Basin. These were calculated in a manner similar to Scenario D₇. Brazos System Operations associated with Allens Creek Reservoir were not reactivated. The IBT from the Brazos Basin to the San Jacinto Basin was also modeled in the San Jacinto model with CI cards at the WUG level.

2.4.9 D₉: Little River Off-Channel Reservoir

The Little River Off-Channel Reservoir (LROCR) was included in the TWDB upstream strategy Brazos/San Jacinto-Brazos model and was incorporated in the D₀ model in a commented-out form. The sections of code associated with LROCR were uncommented to simulate this strategy and the associated diversion. CI cards were added to reflect WUG level return flows from the diversion as well as the IBT to the San Jacinto-Brazos Basin. This strategy also required a section of the DIS file for the Brazos/San Jacinto-Brazos model to be uncommented.

2.4.10 D₁₀: Non-Municipal Contractual Transfers

This strategy was not modeled for similar reasons as Scenarios D₅ and D₆.

2.4.11 D₁₁: Wastewater Reuse for Industry

Wastewater reuse for industry was modeled through the alteration and addition of CI cards in the San Jacinto Basin. Two CI cards representing the three source WWTPs were reduced by the WMS amount. The specific reduction for each plant was assumed proportional to total plant output. Return flows from the strategy were assumed to occur along the Houston Ship Channel. Existing CI cards for industrial return flows in the target area were identified and converted to monthly percentages. The WMS volume was assumed to be distributed evenly among these 26 locations; the volume was scaled using a return flow factor of 0.4 for industrial use and was converted into 26 new CI cards with

monthly distributions matching those of the existing cards. These new CI cards, representing return flows from industrial users, were added to the model after existing CI cards. Because WRAP automatically sums monthly values for multiple CI cards at the same control point, the pre-existing CI cards for flows along the Ship Channel were not removed or replaced.

2.4.12 D₁₂: TRA to Houston Contract

The Trinity Basin is the source of WMS water for this scenario. However, since the Trinity model already reflects the WMS water leaving the basin, no additional changes were necessary in the source basin. For the receiving basins, changes were made to the San Jacinto and Brazos/San Jacinto-Brazos models. A total of 75 CI cards were added in the San Jacinto and Brazos/San Jacinto-Brazos models to reflect return flows from points of use. The monthly patterns of the CI cards were based on the average CI card pattern (percentage of total annual flow for each month) for the corresponding basin and usage type. CI cards assume 60 percent return flow for municipal use, 40 percent for mining, industrial, and livestock uses, and 0 percent for irrigation.

2.4.13 D₁₃: TRA to SJRA Contract

No change was made to the Trinity model under this strategy as the Trinity model already reflects the WMS water leaving the basin. CI cards were added for the southern part of Montgomery County near Conroe, Texas to reflect return flows from points of use. The monthly patterns of the CI cards were based on the average CI card pattern (percentage of total annual flow for each month) for the corresponding basin and usage type. CI cards assume 60 percent return flow for municipal use, 40 percent for mining, industrial, and livestock uses, and 0 percent for irrigation.

2.4.14 D₁₄: Houston to GCWA Transfer

No change was made to the Trinity model under this strategy as the Trinity model already reflects the WMS water leaving the basin. Five total CI cards were added in the Brazos, San Jacinto-Brazos, and San Jacinto Basins to reflect return flows from this WMS. The monthly patterns of the CI cards were based on the average CI card pattern (percentage of total annual flow for each month) for the corresponding basin and usage type. CI cards assume 60 percent return flow for municipal use, 40 percent for mining, industrial, and livestock uses, and 0 percent for irrigation.

2.4.15 D₁₅: Houston Indirect Wastewater Reuse

As noted previously, this scenario involves reclaiming effluent from WWTPs in seven sub-basins in the San Jacinto model for municipal and industrial uses. Locations of specific CI cards for the WWTPs used by the WMS were determined from the Water Availability Modeling for the San Jacinto Basin report (Espey, Padden 2000). The CI cards were sorted by sub-basin and summed. The monthly flow volumes were then divided by the annual total of the CI cards, yielding seven sets of monthly percentages, each representing one sub-basin. These were then converted into UC cards and added to the model to give monthly diversion distributions for the WMS in each relevant sub-basin. Diversions associated with the strategy were represented by eight WR cards (including an IBT to the San Jacinto-Brazos Basin from Sims Bayou) with annual diversion targets proportional to the WWTP flow in each sub-basin. Based on the implementation decade given in DB07, the priority dates for all eight water rights were set to 1/1/2050, junior to all other water rights in the model. Return flows from diversions were assumed to be returned the same month to the next downstream control point, with a return flow factor of 40 percent to represent industrial use. The only exception is the IBT from Sims Bayou to the San Jacinto-Brazos Basin, for which return flows are prevented from returning to the San Jacinto model using an OUT statement. For the Brazos/San Jacinto-Brazos model, the IBT to the San Jacinto-Brazos Basin was modeled using two CI cards representing the Harris Manufacturing and Harris Steam Electric WUGs.

2.4.16 D₁₆: NHCRWA Indirect Wastewater Reuse

While this WMS utilizes outflow from a large number of WWTPs, specific information about volumes and monthly patterns of flow from individual plants was not available. For this reason, Scenario D₁₆ relied on a generalized approach to model indirect wastewater reuse. Allocation of flow volumes involved GIS analysis of WWTP locations. Potential source WWTPs were examined in ArcMap and overlaid with data layers for stream segments, sub-basin boundaries, and the NHCRWA boundaries. WWTP locations were identified primarily in the Greens Bayou Basin or the White Oak Bayou Basin. Available WWTP flow for each category for the WMS was assumed proportional to the number of WWTPs in that category. Of the 31,400 acre-feet identified for the WMS, 4,816 acre-feet was allocated to the Greens Bayou Basin, 6,357 acre-feet to the White Oak Bayou Basin, and the remaining 20,227 acre-feet to the NHCRWA boundary. The WMS was modeled with three new water right diversion WR cards, with diversion locations at the most downstream location of each boundary and annual diversion targets as given above. The assigned priority date of 1/1/2050, which was based off of information in DB07, is the most junior in the model. Water from the D₁₆ strategy is intended for combined industrial reuse and municipal and industrial irrigation; however, the relative volumes for each of these uses are unknown. For this reason, the more conservative return flow factor of 0 percent for irrigation was applied to all three WR cards.

2.4.17 D₁₇: Lake Houston Additional Yield

For the scenario utilizing additional unappropriated flow from Lake Houston, the WMS was represented as a new water right. A WR card with an annual diversion total of 32,500 acre-feet from Lake Houston was added to the model. Monthly diversion distribution was based on the existing municipal usage UC card in the model. The water right was given a priority date of 01/01/2010, as DB07 lists the WMS as potentially active by 2010. Return flows were assumed to be returned the same month as the diversion, with a return flow factor of 60 percent due to the municipal usage type. A WS card at Lake Houston associated with the right was added, with the storage volume for the right located at the top of the conservation pool.

2.5 Scenario E: Future 2060 Conditions With Return Flows and All Recommended WMS

Scenario E incorporated all modeled D strategies for each basin. This was accomplished by inserting code for each of the individual strategies into the model. For several of the basins, multiple strategies relied on representing return flows at the WUG level as CI cards. In these cases, D strategy CI cards did not replace existing cards, but rather were added to the end of the existing list of constant inflows.

2.6 Scenario F: Full Authorized Diversions With No Return Flows

Full Authorized Diversions with no return flows were determined from an unmodified copy of the TCEQ Full Authorized Diversion (Run 3) WRAP models. Models were executed normally and regulated flows were retrieved from model output using a 2REG record in the TABLES program.

Section 3 – Evaluation of Bay and Estuary Inflows and Target Attainment

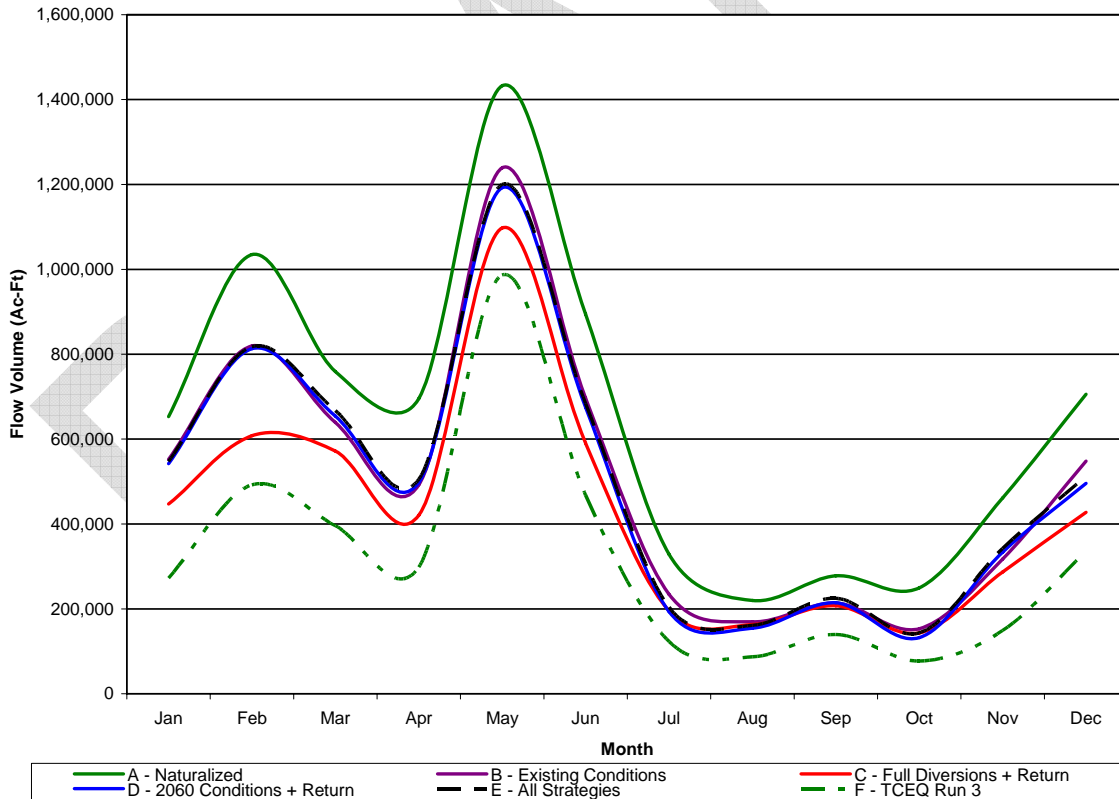
3.1 B&E Flow Results

The TABLES program was used to output regulated flows for relevant control points for all (A-F) scenarios. Resultant regulated flows are given in *Appendix B*. The impacts of recommended WMS were then determined through an analysis of both instream flows and B&E inflows. These two processes are discussed in greater detail below.

3.1.1 B&E Inflow Targets and Attainment Frequency

WRAP strategy model output was used to determine effects of WMS implementation on B&E flows into Galveston Bay for the Year 2060 condition. Monthly median B&E flows were determined for A, B, C, D₀, E, and F. As noted earlier, the strategy models represent a Full Authorized Diversion scenario with the inclusion of expected return flows and strategies from upstream regions. A comparison of monthly medians is given in *Figure 3-1* below.

Figure 3-1. WRAP Model Median Monthly Bay and Estuary Inflows



As shown in *Figure 3-1*, median flows for the D₀ and E models are lower than the naturalized flows but higher than the TCEQ Run 3 (full diversions with limited return flows) model. This is partially due to the inclusion of expected return flows (see the C model curve) and partially due to the inclusion of WMS. Median flows for the E model were also found to be slightly lower than current conditions for the majority of the year, but exceed current conditions by 2.6 to 7.8 percent for March, April, September, and November. B&E flows for the E model were also evaluated with reference to B&E inflow targets recommended by the TWDB. There are three sets of targets designed for maintaining fisheries. These are:

- Max H – The annual inflows required for maximum B&E fisheries harvest as recommended by TWDB/Texas Parks and Wildlife Department (TPWD)
- Min Q – The minimum annual inflow required to maintain the B&E fisheries harvest as recommended by TWDB/TPWD
- Min Q-Sal – The minimum acceptable annual inflow required to maintain the salinity needed for B&E fisheries production as recommended by TWDB/TPWD

Monthly values for all three annual targets for the Galveston Bay system are given in *Table 3-1* below. In general, Max H represents a target condition for ultimate production while Min Q-Sal represents a base condition that must be maintained on a more reliable basis.

Table 3-1. Monthly Galveston Bay Inflow Targets

Month	Max H	Min Q	Min Q-Sal
1	150,500	150,500	150,490
2	155,200	216,700	216,700
3	652,800	363,900	363,900
4	632,500	352,600	267,270
5	1,273,700	679,700	309,970
6	839,700	448,100	413,560
7	211,500	232,700	211,500
8	140,000	154,000	140,000
9	103,000	330,200	102,960
10	78,600	251,900	78,600
11	351,500	351,500	164,390
12	626,800	626,800	93,870
TOTAL	5,215,800	4,158,600	2,513,210

It is not feasible to meet all three of these goals 100 percent of the time while still meeting water demands within these regions. Rather, recommendations proposed by the GBFIG are used in this study to a desired annual frequency for which these targets should be met. Region H formally adopted GBFIG-proposed frequencies of attainment during the 2001 cycle of Regional Water Planning. GBFIG proposed a 50 percent frequency of attainment for Max H, 60 percent for Min Q, and 75 percent for Min Q-Sal. Prior study of freshwater inflows for Galveston Bay (Espey Consultants 2008) demonstrates that consideration should be given to the quantity, quality, seasonality, and location of inflows. However, the GBFIG recommendations do not explicitly address a desired frequency for the seasonality (i.e., monthly distribution) of freshwater inflows. For this study, the recommended annual frequency was used as a placeholder for the evaluation of seasonal

variations (i.e., monthly distribution). The frequency of meeting target flows (frequency of target attainment [FTA]) on an annual basis is given in *Table 3-2*.

Table 3-2. Frequency of Target Attainment

Scenario	Max H (%)	Min Q (%)	Min Q-Sal (%)
GBFIG Recommendation	50	60	75
A - Naturalized	68	67	83
B – Current Conditions	63	58	79
C – Full Diversion	59	53	75
D – 2060 Conditions	60	56	74
E – All Strategies	62	59	77
F – TCEQ Run 3	43	43	56

As shown in the table, the E model meets the recommended GBFIG annual B&E targets at the desired frequency for both the Max H and Min Q-Sal flow. The frequency of attainment for Min Q for the E model is 59 percent, just one percent less than the recommended 60 percent proposed by GBFIG. In general, with the exception of the naturalized flow model and the TCEQ Run 3 model, all of the scenarios examined either achieved or nearly achieved the desired annual frequency of attainment for Max H and Min Q-Sal. The Min Q recommended target frequencies were not achieved under any scenario other than naturalized flow. Note that individual years missing annual targets typically were below the targets by a small amount; however, for purposes of determining annual frequency of attainment, a shortage of even one acre-foot per year counts as failure to meet that year's target.

FTA can also be viewed from a seasonal and monthly perspective, as shown in *Figures 3-2* and *3-3*. For the purpose of this study, three seasons were developed based on the observed flow regime. The spring season was assumed to consist of the months from March through June, while summer was represented as July through October, and the winter season represented as November through February.

Figure 3-2. Seasonal Frequency of Target Attainment

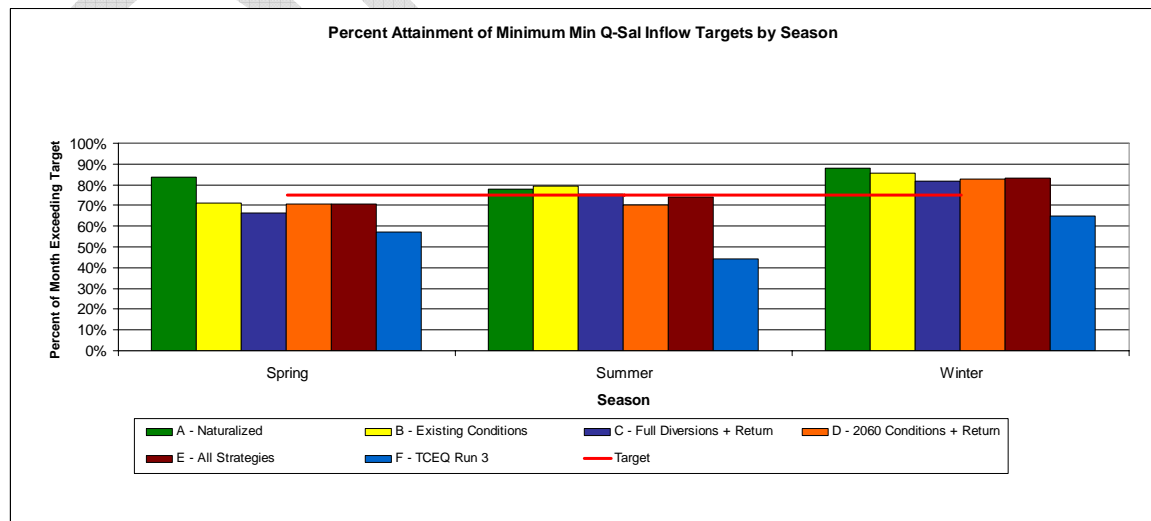
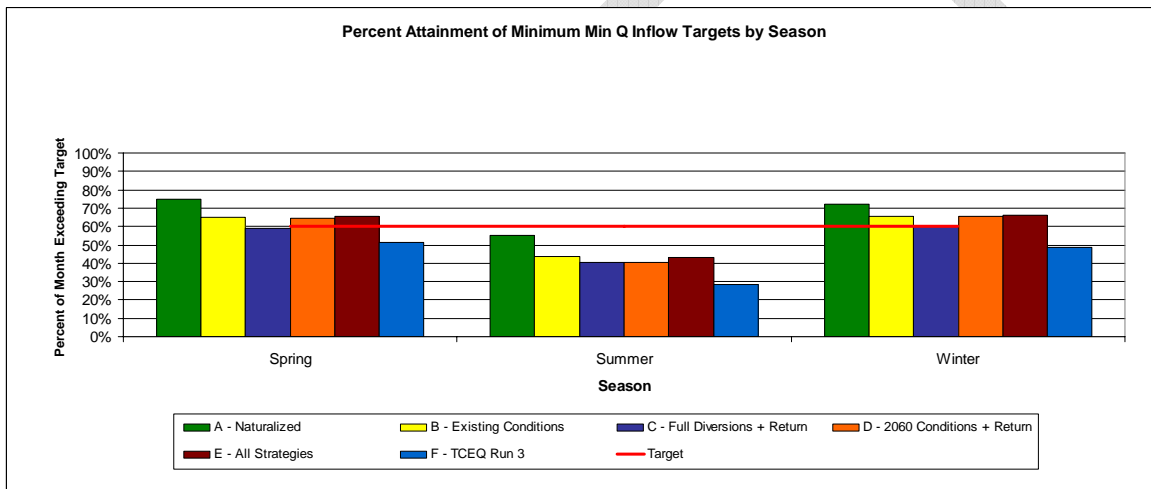
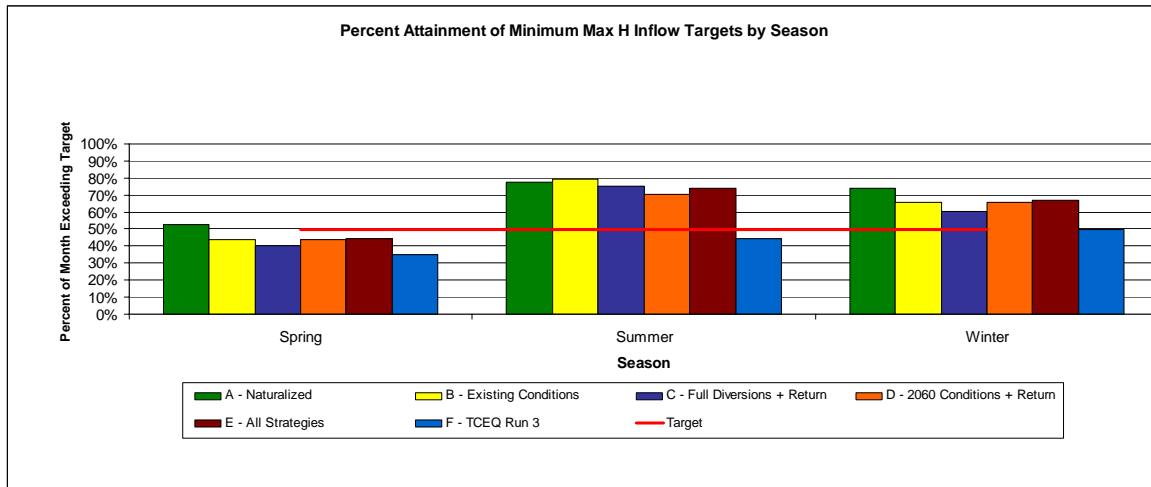
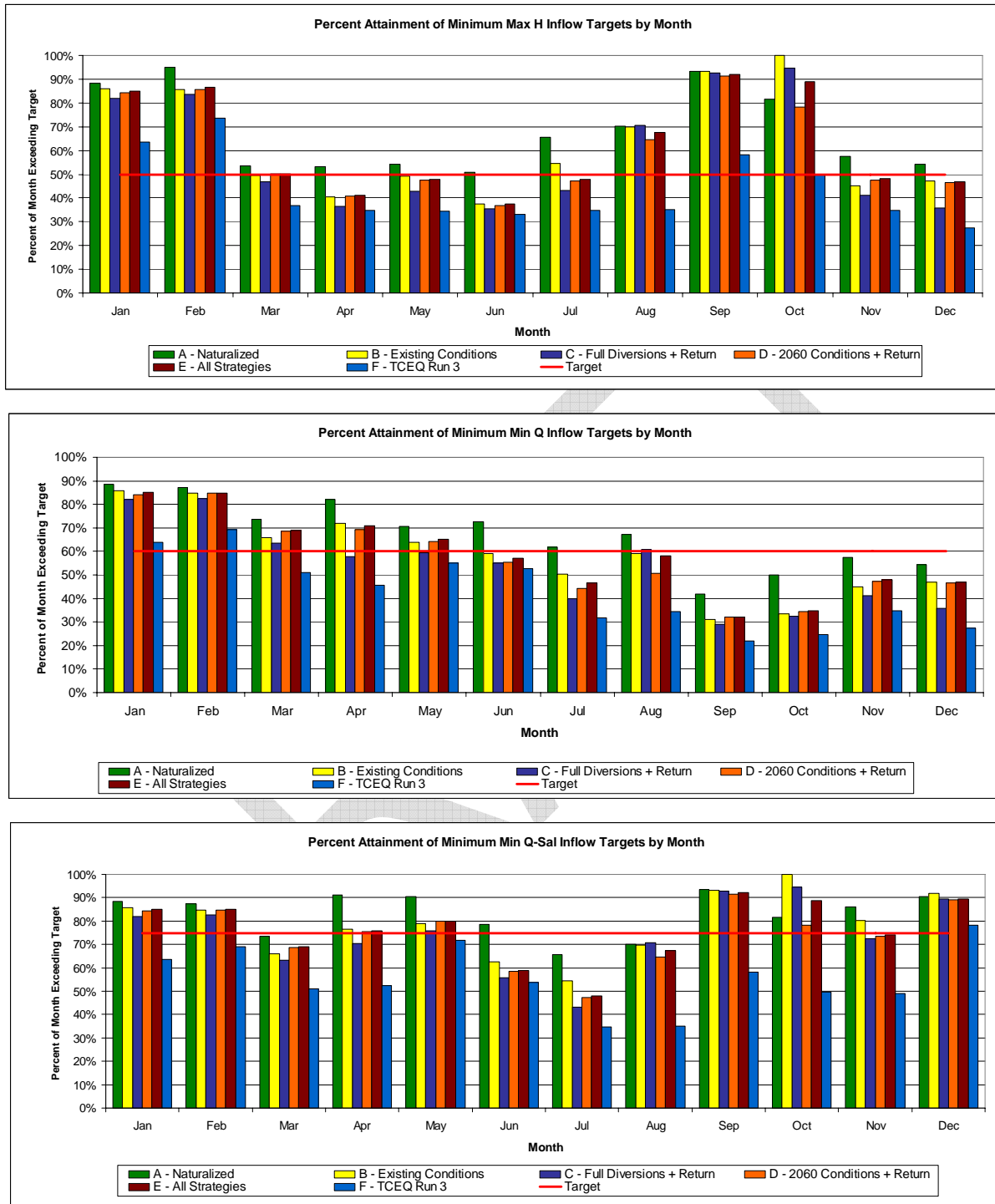


Figure 3-3. Monthly Frequency of Target Attainment



In addition to the E model, all strategies were modeled separately to determine their individual impacts. The impacts of each strategy contributed only minor variation in frequency of B&E target attainment to the base model; the majority of months showed no change, with the few months altered typically varying from the base model by ± 2 percent frequency or less. The exception was the TRA to Houston Contract (D₁₂) model with a volume of 153,000 ac-ft/year, which was up to 10 percentage

points higher in meeting frequency goals than the base model on a monthly basis. However, some of the modeled impact of the TRA to Houston strategy is an artifact of the original Full Authorized Diversion models used to develop the base models for this study. In these original models, the full volume of the interbasin transfer was already shown leaving the Trinity basin; however, the importation of water into the San Jacinto Basin from the IBT was not shown. In reality, the IBT would be expected to alter the location of B&E inflows but should not cause an increase in volume. FTA for the D₁₂ model in comparison the D₀ and E models is given in *Table 3-3*.

Table 3-3. FTA for D₀, D₁₂, and E Models

Month	Max H			Min Q			Min Q-Sal		
	¹ D ₀ (%)	² ΔD ₁₂ (%)	ΔE (%)	D ₀ (%)	ΔD ₁₂ (%)	ΔE (%)	D ₀ (%)	ΔD ₁₂ (%)	ΔE (%)
1	84	2	1	84	2	1	84	2	1
2	86	2	1	85	0	0	85	0	0
3	50	0	0	69	0	0	69	0	0
4	41	0	0	69	1	2	75	0	0
5	48	0	0	64	1	1	80	0	0
6	37	0	0	56	2	2	58	0	0
7	47	0	1	44	0	2	47	0	1
8	65	2	3	51	6	8	65	2	3
9	91	1	1	32	0	0	91	1	1
10	78	10	11	35	0	0	78	10	11
11	47	1	1	47	1	1	73	0	1
12	47	0	0	47	0	0	89	1	1

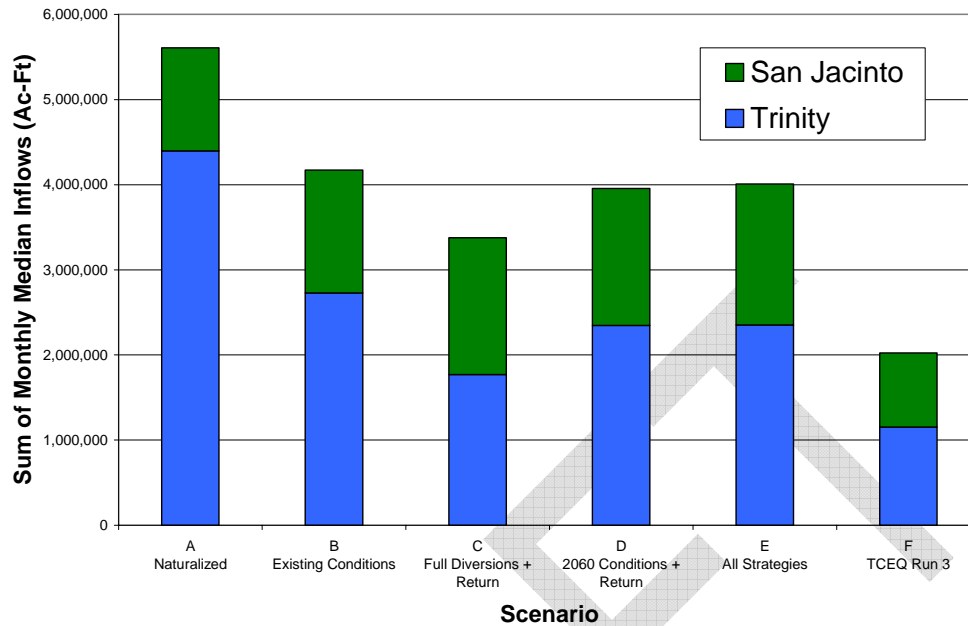
¹ D₀ represents the FTA for the base model.

² ΔD₁₂ and ΔE values indicate increase in frequency of attainment values from the D₀ model.

3.1.2 Location of B&E Inflows

Implementation of WMS will impact not only the FTA but also the proportion of inflow supplied by each basin. This is especially important given that several strategies proposed involve IBTs of water in the Trinity and San Jacinto Basins. Inflows for the San Jacinto and Trinity Basins for several model runs are shown in *Figure 3-4*. Note that the remaining basins are smaller contributors to overall B&E flow and vary by a smaller amount than the two basins shown. This is largely due to the presence of IBTs for the Trinity and San Jacinto Basins.

Figure 3-4. B&E Contributions of the San Jacinto and Trinity Basins



As shown in the figure, for naturalized conditions as well as the current conditions model, B&E inflows are dominated by the Trinity Basin. The proportion of flow provided by the Trinity is lower for the remaining models, including the C model (Full Authorized Diversions + expected return flow). However, the implementation of upstream WMS shown for the D₀ model causes an increase in the relative contributions of the Trinity as compared to the C model. The proportion is slightly lower for the E model, demonstrating that the Region H strategies slightly increase the proportion of water coming from the San Jacinto Basin. This is largely due to the IBT of water into the San Jacinto system.

3.2 Evaluation of Alternatives for Meeting GBFIG Targets

3.2.1 Concept and Target Conditions

As part of the scope of services for the environmental flows investigation, alternatives were considered to allow the WMS (E) models to meet B&E flow targets at the desired frequency for Year 2060 conditions. This task is not intended to determine flow needs for the bay, nor to develop an applied operational solution for achieving desired B&E flows. Rather, the task is intended simply to use the goals already proposed by TWDB and Region H to evaluate how these goals may be achieved and what impacts to future water supply may result. The models used in this process functioned by modifying reservoir operations to reduce B&E target flow shortages. The goal of the modeling process was to assess if a methodology could be developed to achieve a desired target B&E inflow frequency while also maintaining current and future water supplies (that is, without reducing firm yields). Two sets of modified WMS models were developed, one for Max H and another for Min Q-Sal. Models are based on a Year 2060 full diversion scenario with expected return flows and all modeled WMS strategies (E model base).

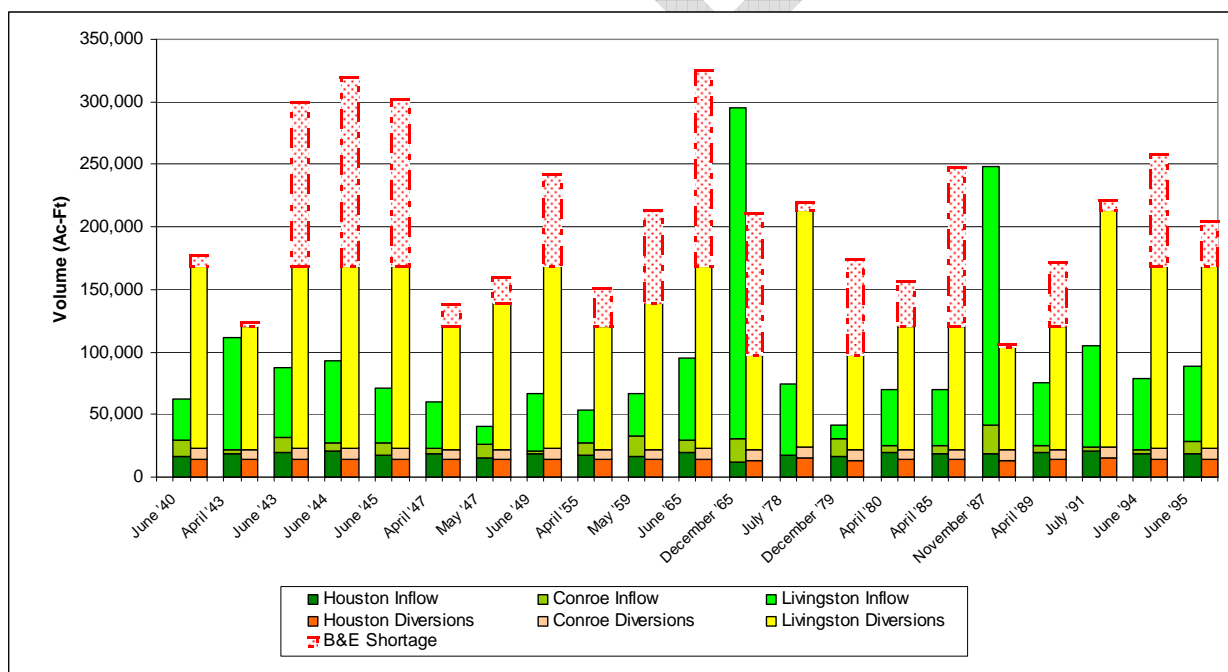
Max H was chosen as a target condition since Max H target flows are achieved at the desired frequency (50 percent of monthly records for each month) under naturalized conditions. Monthly Min Q and Min Q-Sal targets are not achieved at the desired frequency even for naturalized conditions.

The Max H targets represent the proposed peak of total annual fisheries harvest for Galveston Bay bound by the lowest decile and median monthly values and salinity viability limits as output by TWDB methodology. Min Q-Sal was also investigated because it represents a proposed minimum acceptable inflow required to maintain the salinity needed for B&E fisheries productivity rather than the higher flow targets.

3.2.2 Methodology

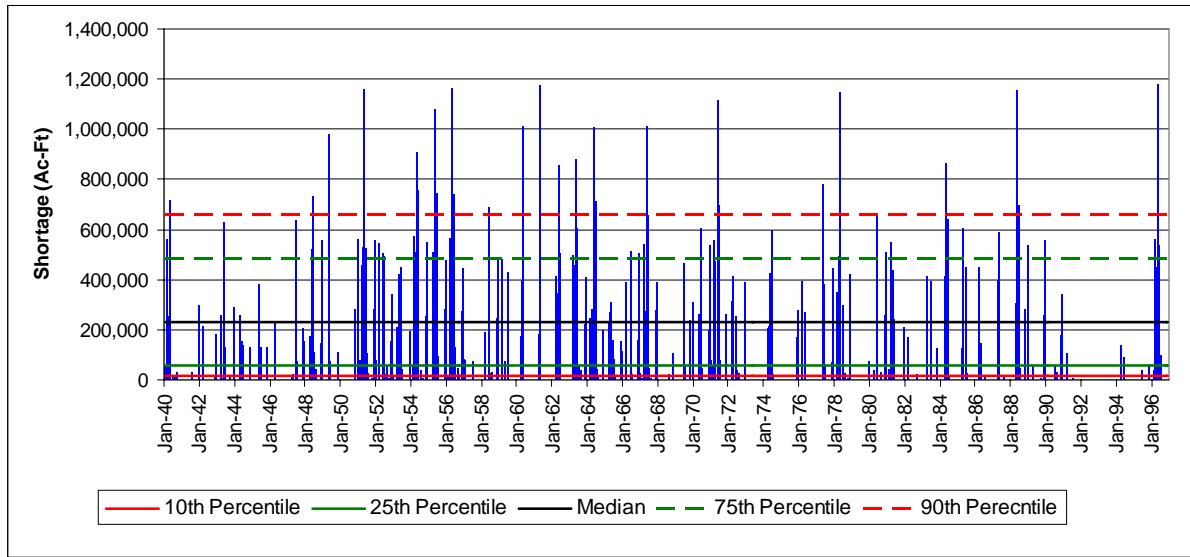
It was assumed that B&E inflow targets are achieved by any flow that equals or exceeds the target flow; thus, flow cannot be too high for the target, but can be too low. FTA is increased by increasing the number of months meeting the volume target, but not by uniformly increasing volumes. The most efficient way to achieve this is to target the months with the smallest shortages and increase the B&E flows for those months to target levels. The primary concern in selecting a specific approach to increasing flows is avoiding superseding the existing priority system; that is, interfering with existing and future water rights and strategies. Setting an instream flow requirement at the basin outlet or similar approaches using pass-through flows from streamflow would likely impact existing rights. Pass-through flows from reservoirs are also likely to create conflicts with existing rights. As shown in *Figure 3-5*, the amount of water available for reservoir pass-through is also sometimes inadequate to meet existing and future demands, indicating that this could not be used without impacting firm yield.

Figure 3-5. Available Reservoir Water and Demands



The only remaining option, and the one least likely to interfere directly with the priority system, is the discrete release of water from reservoir storage. From a reservoir operations standpoint, this is equivalent to managing releases when shortages for a particular month are less than some specified level. Such an operating scenario in which reservoir releases would be made to address only the smallest B&E target flow shortages would minimize the volume of reservoir releases needed to meet frequency goals and in turn decreases the possibility of reducing the firm yield of existing and future water rights. The range of Max H shortages is shown in *Figure 3-6*.

Figure 3-6. Monthly Target Shortages for Max H



While there are a large number of months with shortages and a median shortage value of 230,000 acre-feet, only a limited number of the smallest shortages must be corrected to achieve the desired frequency goals (50 percent for Max H and 75 percent for Min Q-Sal).

For the Max H condition, frequency of attainment of monthly B&E targets for the E model, described earlier, was compared to the target frequency of attainment. For months with frequencies less than 50 percent, the frequency shortage was defined as the difference between 50 percent and the simulated frequency of attainment. Months with shortages below the targets were identified and ranked in size. Months with the smallest shortages were selected for adjustment by pulling adequate supply out of reservoir storage to meet the Max H target. In WRAP, this was achieved by establishing “dummy” water rights at the basin outlets of the Trinity and San Jacinto Basins. These rights called for reservoir releases (from Lake Houston in the San Jacinto Basin and Lake Livingston in the Trinity Basin) only during the months of smallest shortages identified as described above, with the release amount set slightly larger than the monthly shortage. The outlet rights were not allowed to divert via streamflow depletions and were not allowed to refill reservoir storage after meeting diversion targets. Monthly targets for the dummy water rights were set manually using Target Series (TS) cards associated with the “dummy” water right in each basin. Targets were divided between the two basins based on a ratio of unadjusted monthly reservoir volume. This averaged approximately six percent for Lake Houston and 94 percent for Lake Livingston. The process of determining the number of smallest months and setting reservoir releases was repeated iteratively until the desired 50 percent frequency of attainment was met. The target months selected for modification are illustrated in *Figure 3-7*. Monthly information on frequency of attainment, target reservoir release volumes, and the modified months are given in *Table 3-4*.

Figure 3-7. Frequency and Volume of Reservoir Releases for Max H Attainment

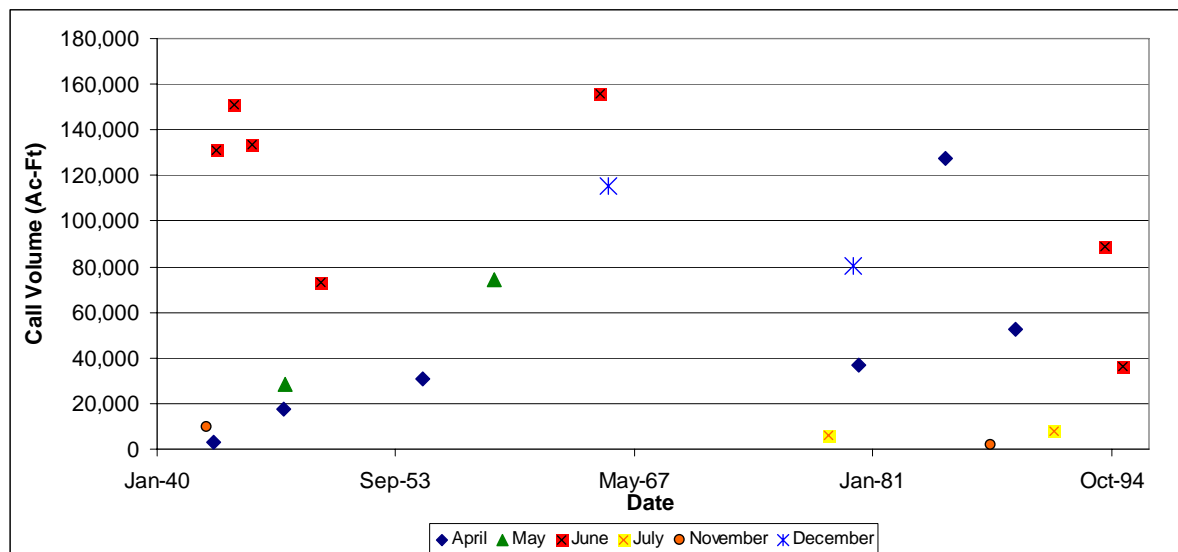


Table 3-4. Frequency of Max H Target Attainment

Month	E Model Frequency (%)	Maximum Target Volume (ac-ft)	Target Percentile of Shortage (%)	Revised Frequency (%)	Months Adjusted
January	85.0			85.0	
February	86.5			86.5	
March	50.3			50.3	
April	41.0	127,500	15.1	50.1	6
May	47.8	74,200	3.4	50.1	2
June	37.3	156,100	20.0	50.1	8
July	47.9	7,900	3.4	50.1	2
August	67.5			67.5	
September	92.1			92.1	
October	88.8			88.8	
November	48.1	9,400	3.4	50.1	1
December	46.8	115,400	3.5	50.1	2

The Maximum Target Volume column gives the monthly upper limit of shortages to be corrected through reservoir releases; shortages greater than these amounts would not result in a reservoir release for that month. A similar process was carried out for the Min Q-Sal targets, with the goal for frequency of attainment set to 75 percent. Pre-revision monthly target attainment for Min Q-Sal is

shown in *Figure 3-8*. Reservoir release calls are shown in *Figure 3-9*, with frequency information in *Table 3-5*.

Figure 3-8. Monthly Target Shortages for Min Q-Sal

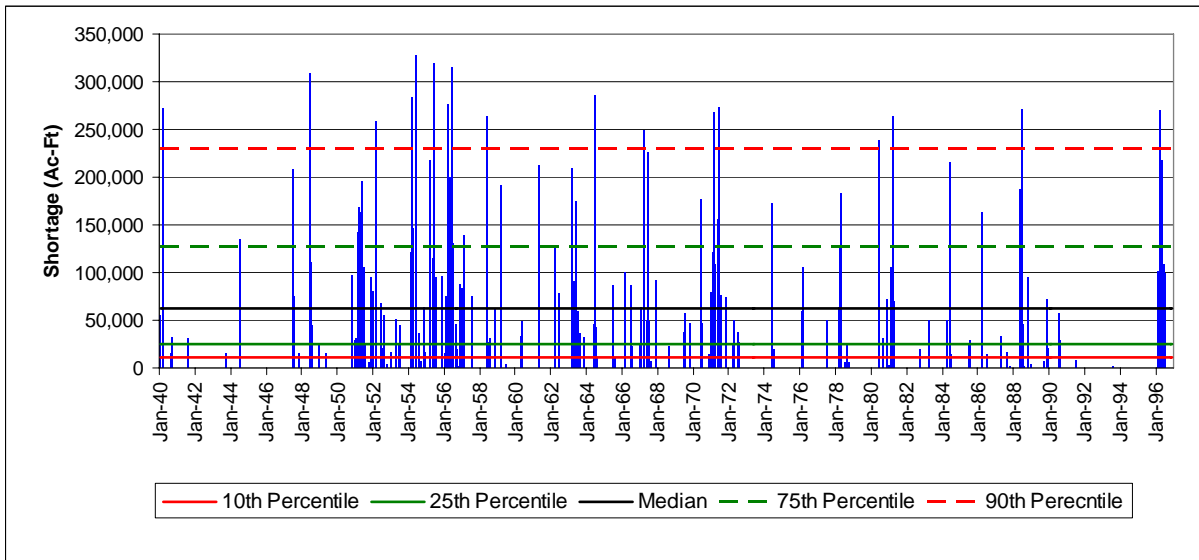


Figure 3-9. Frequency and Volume of Reservoir Releases for Min Q-Sal Attainment

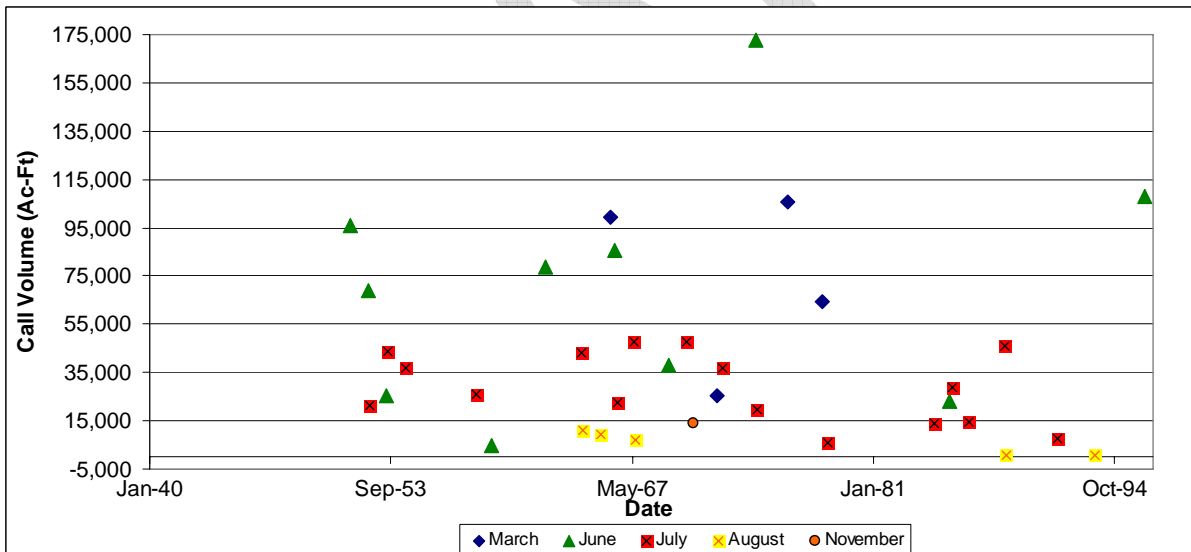


Table 3-5. Frequency of Min Q-Sal Target Attainment

Month	E Model Frequency (%)	Maximum Target Volume (ac-ft)	Target Percentile of Shortage (%)	Revised Frequency (%)	Months Adjusted
January	85.0			85.0	
February	84.9			84.9	
March	68.9	105,500	17.6	75.1	4
April	75.7			75.7	
May	80.0			80.0	
June	58.8	172,600	39.2	75.1	10
July	47.9	48,100	51.8	75.1	16
August	67.5	11,200	22.2	75.1	5
September	92.1			92.1	
October	88.8			88.8	
November	74.0	14,200	1.5	75.1	1
December	89.6			89.6	

3.3 Impacts to Future Water Supply

The impacts to future water supply as a result of the methodology used to address B&E target flow shortages can be demonstrated as a function of future firm yield and future reservoir storage. The release of stored water from Lake Houston and Lake Livingston will result in a reduction of water supply available for diversion for both of these reservoirs as well as potential upstream supply reductions. Supply impacts can be quantified as a reduction in future firm yield and/or a reduction in future reservoir storage. The following report sections address these supply impacts.

3.3.1 Water Right Yield

Firm yields were also calculated for the E model and revised models for selected water rights to determine the impact of managing for FTA on existing rights and future strategies. The firm yield analysis differed from that used in the previous RWP in that the B&E models include return flows, unlike the 2006 RWP. A similar scenario was used in the last RWP for Lake Livingston; however, other project yields in the 2006 RWP were determined without return flows included. For this study, firm yields were approximated as the minimum annual diversion from model results rather than using a Firm Yield (FY) card in the WRAP model. The key rights targeted included supplies identified in the 2006 RWP as well as potentially impacted WMS. Results from the revised models were compared to the E model to determine any change in minimum annual diversion. The results, shown in *Table 3-6* below, demonstrate that in spite of the significant effects on reservoir levels, the altered reservoir operations used to meet FTA goals do not alter the firm yields of the Trinity or San Jacinto Basins. This is because the reservoirs do not empty at any time during the study and monthly diversions continue to be met from a combination of reservoir inflow and stored water.

Table 3-6. Minimum Annual Diversions for Max H and Min Q-Sal Reservoir Operation

Basin	Description	Permit (ac-ft)	Model Minimum Annual Diversion (ac-ft)		
			E	Revised Max H	Revised Min Q-Sal
San Jacinto	Lake Houston	168,000	168,000	168,000	168,000
San Jacinto	Lake Conroe	100,000	82,266	82,266	82,266
Trinity	COH Livingston	940,800	940,800	940,800	940,800
Trinity	*SJRA/Devers ROR	58,500	58,285	58,285	58,285
Trinity	*COH/Dayton	38,000	34,084	34,084	34,084
Trinity	CLCND - Lake Anahuac	39,613	9,317	9,317	9,317
Trinity	*CLCND Fixed Right - CWA	73,334	73,334	73,334	73,334
Trinity	*SJRA - CLCND Fixed Right - CWA	30,000	30,000	30,000	30,000
Trinity	Livingston - TRA	403,200	403,200	403,200	403,200

**Established through fixed right agreements.

The above results, indicating no impact to firm yield supply due to reservoir releases, is a result primarily of the inclusion of expected return flows in the E model. The import of water coupled with the inclusion of expected return flows in the E model creates significant volumes of water in the lower Trinity and San Jacinto basins made available for firm yield diversions and B&E flow releases. These return flows, however, are not currently permitted for use in the lower basins and it is noted that without the inclusion of these return flows, the impact to future firm yield for the supplies listed in *Table 3-6* would be significantly more pronounced.

3.3.2 Reservoir Levels

Impacts to reservoir volumes in the revised E model for Max H and Min Q-Sal targets are shown in *Figures 3-10* and *3-11*. For Lake Houston, managing releases to meet the Max H and Min Q-Sal frequency goals resulted in extended periods of reduced reservoir volume. Lake Houston does not completely refill after 1942 for Max H and 1951 for Min Q-Sal. While Lake Houston averages 98 percent of full for the unaltered E model during the period of record, the revised Max H and Min Q-Sal models average 90 and 87 percent, respectively. The effects of revised reservoir operations are greater for Lake Livingston, which averaged 95 percent of full volume for the E model, 81 percent for Max H revisions, and 78 percent for Min Q-Sal revisions. As with Lake Houston, Lake Livingston did not refill after 1943 for Max H and 1951 for Min Q-Sal.

Figure 3-10. Lake Houston Storage Volume for Revised Reservoir Operation

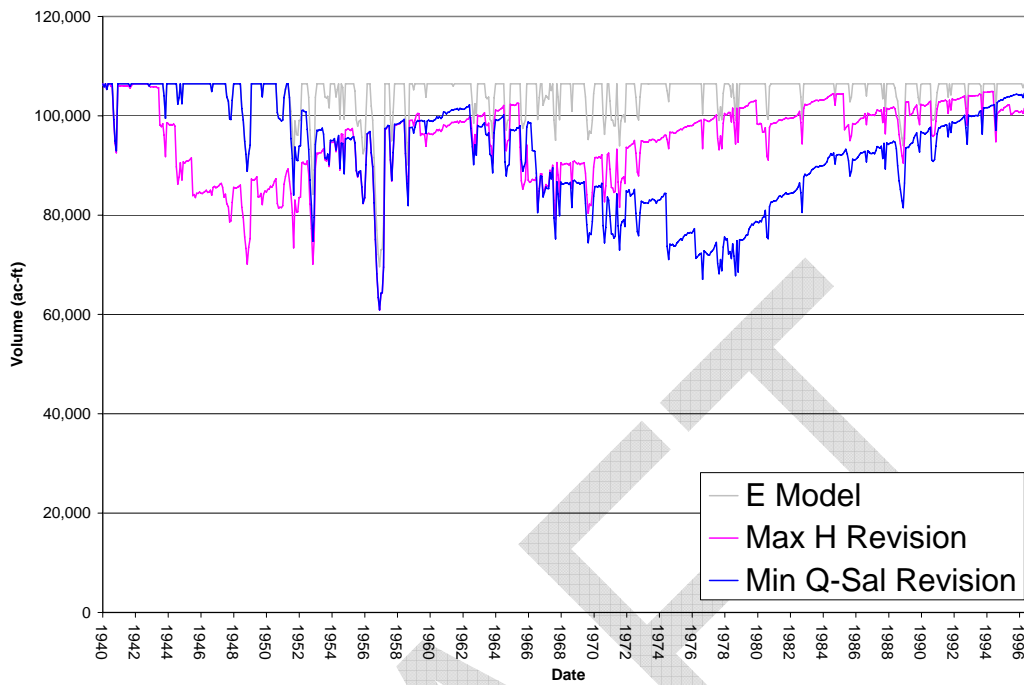
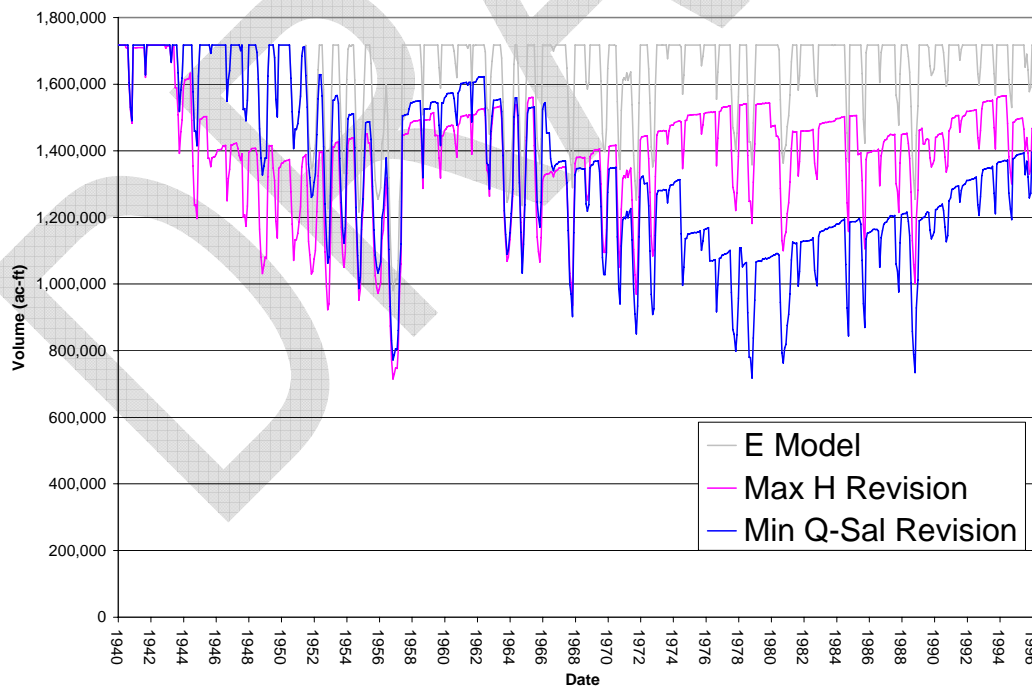


Figure 3-11. Lake Livingston Storage Volume for Revised Reservoir Operation



Section 4 – Evaluation of Instream Flow Requirements for Future Water Management Strategies

4.1 Identification of Critical Segments

A list of 26 segments with the potential to be impacted by Region H WMS was developed from a compilation of segments studied in the TWDB Streamflow Assessment found in the 2002 SWP. Regulated flows at the 26 segments were determined for the base (D_0) models as well as for all WMS models, including the composite E model. Based on monthly results for the model simulation period, 10th percentile flows were calculated to investigate low flow conditions. For each WMS, 10th percentile flows at each of the 26 segments were compared to the D_0 models. For each WMS, the stream segment with the greatest (absolute) percentage difference from the base model was considered to be the most critical segment for that strategy (see *Exhibit 2*). For the 13 strategy models, six segments were identified in the Brazos and San Jacinto Basins as being particularly influenced by Region H WMS. Lyons flows, generally considered to represent a general low-flow condition adequate to maintain sound ecologic function, were calculated for the segments for comparison purposes. Please note that Lyons flows were developed from WAM Run 8. A summary of highly impacted segments is presented in *Table 4-1*. An expanded summary of instream flow critical segments, along with graphical representation of strategy impacts on a monthly basis, are provided in *Appendix C*.

Table 4-1. Impacts of WMS Implementation on Critical Stream Segments

WRAP Identifier	Basin	Strategy	10th Percentile Flows			Lyons Flow (ac-ft)
			D_0 (ac-ft)	Strategy (ac-ft)	Change (%)	
532801	Brazos	Freeport Desalination	41,101	40,776	-0.8	68,751
		BRA System Ops		39,246	-4.5	
		Allens Creek		40,027	-2.6	
BRR170	Brazos	Little River	55,925	55,028	-1.6	78,697
		Houston to GCWA		55,324	-1.1	
SPSP	San Jacinto	TRA to Houston	1,461	4,223	189.1	1,607
		TRA to SJRA		2,736	87.3	
		All Strategies		5,522	278.0	
1004	San Jacinto	Expanded GW	2,082	2,937	41.1	2,444
A5191P	San Jacinto	Indust. WW Reuse	59,845	56,482	-5.6	39,041
		Houston Indir. Reuse		56,863	-5.0	
		NHCRWA Indir. Reuse		59,039	-1.3	
SRGB	San Jacinto	Lake Houston Yield	65,550	66,973	2.2	43,805

With the exception of the Freeport Desalination and the Houston to GCWA transfer strategies, WMS from increased inputs such as increased groundwater, IBTs, or additional permitted reservoir yield resulted in positive impacts to 10th percentile flows. These positive impacts tended to occur year

round, but were greatest during the summer months with some indicating large increases in flow through early fall. The remaining strategies, which resulted in an overall negative impact (i.e., reduced flows) at the critical segments, fell into two distinct groups. The three wastewater reuse strategies (Houston, NHCRWA, and industrial), along with the Freeport Desalination strategy, caused fairly uniform reductions to 10th percentile flows throughout the year, with little or no reasonable variability. For the Freeport Desalination WMS, the critical segment is located upstream of the WMS inputs locations. This suggests that these increases are firming up downstream rights using increased constant inputs, resulting in reduced pass-through flows in upstream segments. The remaining reduction-causing WMS were the three reservoir strategies (BRA System Operations, Allens Creek, and Little River) and the Houston to GCWA transfer. Unlike the reuse WMS, flow reductions were not uniformly distributed and tended to intensify during the spring and summer seasons.

The greatest positive impact for any critical segment was a result of the TRA to Houston Transfer, which created an overall increase in 10th percentile flow of 189 percent. The greatest reduction was -5.6 percent for industrial wastewater reuse. For the model representing full implementation of all strategies (E), the change at the critical segment was a positive increase of 278 percent.

As shown in *Table 4-1*, strategy flows in the San Jacinto Basin exceeded Lyons flow levels, while the Brazos Basin strategy flows were well below calculated Lyons flows; one should note that for the critical segments in the Brazos Basin, 10th percentile flows for D_0 were already lower than Lyons flows. The observation that a number of strategy flows in the San Jacinto Basin exceeded the Lyons flows, even when strategy impacts reduced flow, suggest that categorization of a segment as critical is not a clear indication of its ecological condition.

4.2 Lyons Flows and Field Evaluations

The identification of critical segments described above was paired with a field study to enhance understanding and applicability of flow conditions at the identified segments. While points were labeled as critical, identification as being most impacted does not in of itself reveal whether low-flow or reduced-flow conditions represent an ecologically degraded state. For this reason, the second stage of the instream flow study involved calculating Lyons flows for relevant segments combined with field evaluation of instream flow conditions. Results were then used to examine possible environmental repercussions of WMS. Lyons flows were calculated based on regulated flow rates for the Current Conditions (Run 8) model; values were calculated as 60 percent of median flows for March through September and 40 percent of median flows for October through February.

Field examination of stream segments provided a visual assessment of ecological conditions of the segments. This was combined with quantitative measurement of stage and flow from the United States Geological Survey (USGS) gauges, which enabled qualitative analysis of stream condition to be related to calculated Lyons flows. Seven stream segments were identified in the Brazos, San Jacinto, San Jacinto-Trinity, and Trinity Basins from the TWDB Streamflow Assessment for inclusion in the field study. Selected segments were chosen based on accessibility, availability of streamflow measurement (proximity to reliable USGS gauges), and reliable flow output from WRAP. Sites were examined during a low-flow period in late July 2008 so that recorded flows would be representative of low flow conditions. Segments were primarily evaluated for Channel Flow Status (CFS) based on TCEQ Surface Water Quality Monitoring (SWQM) procedures (TCEQ 2003). Flow status was defined as high if less than five percent of channel substrate was exposed; moderate if five to 25 percent was exposed; and low if greater than 25 percent was exposed. Observations were also made of any potential wetlands or riparian corridor in observable range of the survey point. A description of each survey point along with site photographs and observed and Lyons flow are located in *Appendix D*. A summary of Lyons and observed flows is presented in *Table 4-2* below.

Table 4-2. Lyons and Observed Flows for Field Study Points

WRAP ID	Location	Lyons Flow (cfs)	¹ Obs. Flow (cfs)	² CFS	Potential Wetlands? (Y/N)	Potential Riparian Corridor? (Y/N)
8TRRO	Trinity River near Romayor	1,098	1,000	M	N	Y
802	Trinity River at Liberty	1,217	<10,000	M	N	Y
9CBCR	Cedar Bayou near Crosby	4	0.6	L	N	N
A3979A	Luce Bayou near Huffman	12	0.2	L	Y	Y
1004	W Fork San Jacinto near Porter	40	23	M	Y	Y
1009	Cypress Creek near Westfield	40	30	H	N	N
532801	Brazos River near Rosharon	1,118	208	L	N	N

¹For segment 802, an exact gauge reading was not available during the observation period. However, flow was estimated to be below the Lyons flow.

²L = Low, M = Moderate, H = High

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Section 5 – Discussion

5.1 Bay and Estuary Inflows

5.1.1 Changes in Volume, Timing, and Location of B&E Inflows

The overall impact of strategy implementation is shown in *Figure 3-1, Section 3.1.1*. The figure demonstrates that the strategy model (E), while slightly lower than current conditions (B) for several months of the year, is well above B&E flows for the TCEQ Full Authorized Diversion (F) model. As noted earlier, this is partially due to the inclusion of WMS and partially due to the inclusion of expected return flows (see the C model curve). Although the dynamics of the model make explicitly tracking water from its source (return flow vs. WMS) difficult, some idea of the relative importance of the two can be gathered from comparing C, D₀, and E model monthly medians to those from the F model. Using this approximation, on a monthly basis between 36 and 100 percent of the increase in flow above the F model is attributable to return flows; in fact, for two months the C model median flow exceeds the E model, demonstrating that for some months WMS implementation causes a reduction in B&E discharge. This is not, however, an indication that WMS have a negative impact on B&E flows.

Based on the comparison of C and E models, WMS create an increase in B&E discharge over return flows for all months except August and October, with monthly increases as high as 209,800 ac-ft. This includes WMS for both Region H and upper basin WMS. Comparing the D₀ and E models to the C model, the majority of increase in monthly medians over the C model is observed in the D₀ model, with the E model tending to be only slightly higher than the D₀ model. This suggests that the upstream Region C WMS tend to have a greater impact on B&E flows than the proposed Region H WMS examined in this study. There were several exceptions, with greater Region H impacts for July, August, and October. For all three of these months, the models indicated a decrease in monthly median flow caused by upper basin WMS that was wholly or partially negated by Region H WMS. Overall, Region H WMS increased monthly median flows by 5,000 to 17,100 acre-feet. This small volume relative to total B&E inflow, in addition to the generally much greater contributions of Region C WMS, suggests that the impacts of Region H WMS on total B&E flows will be minimal.

Strategy D₁₂, the TRA to Houston transfer, was identified earlier as the WMS with the greatest individual impact. By strategy volume, this was the second largest strategy at 152,700 acre-feet per year, with only the Brazos System Operations WMS (163,700 acre-feet per year) being larger. Please note that this does not include contractual transfers which could not be modeled. The BRA System Operations strategy created minor increases in monthly median B&E flow for most of the year, but created a reduced discharge for November and December. Strategy D₁₂ created increased median monthly B&E discharge year round, with changes varying from approximately 4,600 to 14,200 acre-feet.

As shown in *Figure 3-2*, for both Max H and Min Q-Sal, failure to meet B&E targets at the recommended frequency occurs primarily during the spring for all models except naturalized flow. For Min Q, failure to meet targets with sufficient frequency occurred primarily during the summer. The TCEQ Run 3 model failed to meet targets at recommended frequency for all seasons for all three targets. Please note that for the Min Q target, B&E flows do not meet the target with adequate frequency for the summer season under any flow condition, including naturalized flow. On a monthly basis (*Figure 3-3*), the E model failed to meet attainment frequency goals for Max H for six months (April – July, November, December), Min Q for seven months (June – December), and Min Q-Sal for five months (March, June – August, November). For all but one of these months, the desired FTA was also not reached by the current conditions model. For Min Q and Min Q-Sal, naturalized flows failed to meet targets with adequate frequency for several months. For Min Q, the naturalized

condition was below target attainment for September through December. For Min Q-Sal, naturalized flows failed to meet frequency goals for March, July, and August.

The function of the Galveston B&E system is influenced by a number of factors. The seasonal variability of WMS effects is highlighted by the results discussed in the preceding paragraphs. Beyond volume and timing of flows, one should also consider the relative proportion of inflows contributed by each basin. While the TWDB flow targets treat the B&E system as a single unit, in reality the B&E system is not perfectly homogeneous across all locations. Local ecological dynamics may vary from one basin outlet to another and among the various parts of the estuary system. As noted earlier, the Trinity Basin dominates inflows into the B&E system, followed by the San Jacinto Basin, with the other rivers making relatively minor contributions. Viewed over the entire period of record, movement from a naturalized condition (A model) to current conditions (B model) shows a substantial shift toward the San Jacinto Basin, while the Future 2060 Conditions with strategies (E model) has similar proportions to current conditions. Viewing the proportions of flow on the basis of monthly medians reveals a more substantial impact. While the proportion of flow for the Trinity Basin in the B model is reduced by 11 percent or less from naturalized conditions for December through June, the remainder of the year shows a reduction in median proportion of 25 to 49 percent. The proportion of flow from the Trinity Basin during this half of the year is further decreased in the E model, with median flows for July through October reflecting little or no contribution from the Trinity Basin.

The extended period of low median monthly contributions from the Trinity Basin reflected under non-naturalized conditions, especially for the E model, bears consideration due to the potential for excessive local salinity and ecological damage. However, two factors suggest that inflow location change caused by strategy implementation would not be inherently responsible for damage to the B&E system. The first factor is that the majority of the change in flow location is present in the current conditions model, which represents the existing, healthy condition of the B&Es. The second factor is that the further shift away from the Trinity Basin and the resultant four month period of near-nonexistent flows are not a function of strategy implementation, but rather an artifact of a Full Authorized Diversion condition. Examination of median monthly flows (*Appendix B*) for the C (Full Authorized Diversions with Return Flow), D₀ (C Model + Upstream WMS), and F (TCEQ Full Authorized Diversion) models shows that all three have extremely low B&E discharge in the Trinity Basin during the period of concern. While the C model has higher flows in the Trinity Basin than the F model during the period of concern, the strategy models (D₀ through E) have lower flows, implying that strategy implementation does result in some flow reduction. However, the fact that the D₀ and E models have identical median discharges during this period suggests that additional shift of water away from the Trinity Basin could be largely a result of upstream strategies.

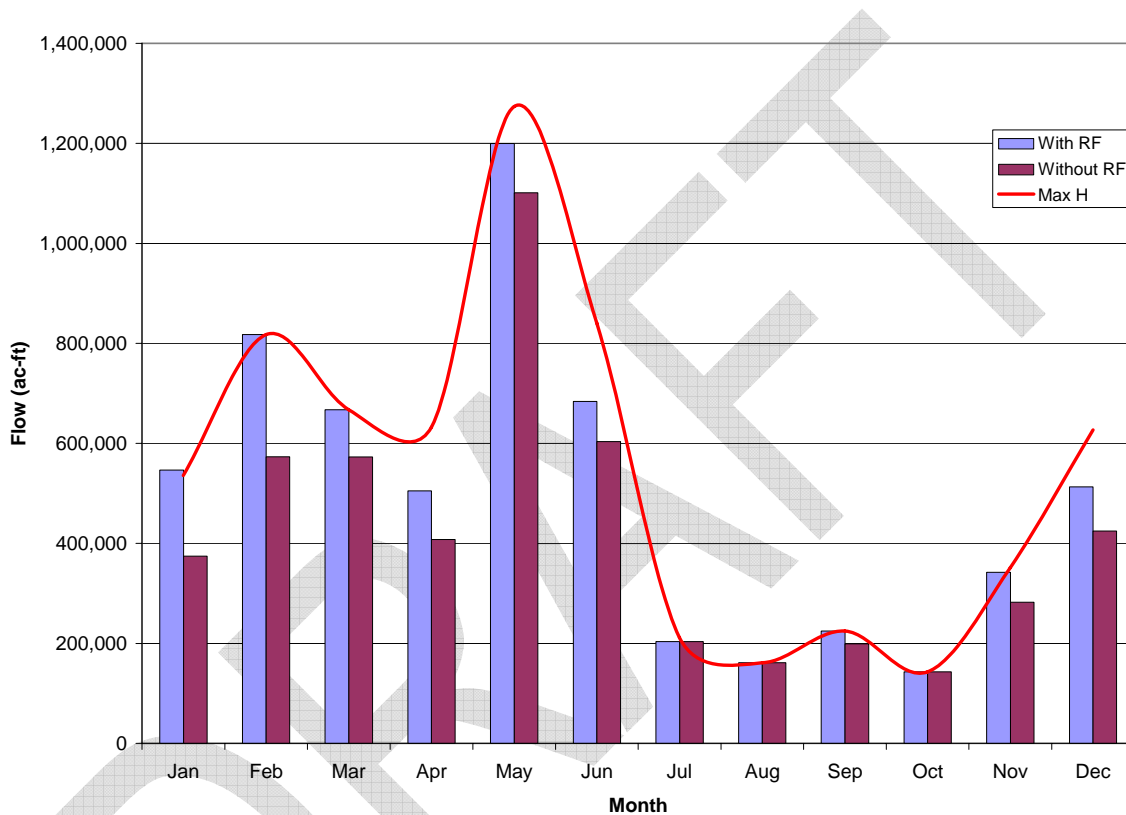
5.1.2 Upper Basin Return Flows

Upper basin return flows are an important consideration in this study due to their inclusion in the base model and, in particular, the substantial contributions made by Region C return flows to Region H in the Trinity Basin model. Water imports into the upper Trinity River Basin account for additional return flows that may potentially be an important source for both lower basin water rights and B&E inflows. This is made even more important due to the Trinity being a source basin for several major IBTs to the San Jacinto supplying the major demand centers in Region H. The importance of return flows to the WMS models presented in this study is highlighted by a comparison of the C and F model results. For every month of the full period of simulation, the addition of return flows in the C model resulted in increased B&E flow over the F model, with a minimum monthly increase of 27,897 acre-feet and a median increase of 80,878 acre-feet.

In addition to the primary models carried out for the study, an additional secondary model was developed to determine the effects of removing upper basin return flows from the Trinity model for expected Year 2060 conditions. Using the unmodified E model as a base, non-Region H constant inflow cards were removed from the model code, along with any identified Region C return flows not

explicitly associated with modeling reservoir operations. The revised model was executed and examined on the basis of B&E discharge and minimum annual diversion (as a proxy for firm yield) for key supply rights. As shown in *Figure 5-1*, removal of upstream return flows resulted in substantial reductions of median flow for the first half of the year, with relatively smaller changes for the rest of the year. Over the entire period of record, this is equivalent to a 20 percent reduction in B&E discharge from the Trinity Basin.

Figure 5-1. Comparison of Trinity Basin B&E Discharge With and Without Region C Return Flows



As seen in *Table 5-1*, of the seven major supply rights examined, six experienced a reduction in firm yield due to removal of upper basin return flows. These reductions in firm yield ranged from 34 to 54 percent, with the year of minimum annual diversion occurring primarily in 1956 during the drought of record. As such, any future Region C WMS which reduces return flows to Region H will have the potential to substantially alter B&E flow regimes as well as the firm yield of water rights in the Trinity and San Jacinto Basins.

Table 5-1. Minimum Annual Diversions With and Without Upper Basin Return Flow

Basin	Description	Permit	E Model		E Model without RF	
			MAD (ac-ft)	Min. Date	MAD (ac-ft)	Min. Date
Trinity	COH Livingston	940,800	940,800	NA	536,303	1956
Trinity	*SJRA/Devers ROR	58,500	58,285	1950	33,718	1956
Trinity	*COH/Dayton	38,000	34,084	1956	15,846	1956
Trinity	CLCND - Lake Anahuac	39,613	9,317	1956	9,317	1956
Trinity	*CLCND Fixed Right - CWA	73,334	73,334	NA	43,207	1956
Trinity	*SJRA - CLCND Fixed Right - CWA	30,000	30,000	NA	17,322	1963
Trinity	Livingston - TRA	403,200	403,200	NA	264,408	1956

5.1.3 Frequency of Target Attainment

The evaluation of alternatives for meeting TWDB targets at GBFIG-recommended frequency was successful for both Max H and Min Q-Sal conditions; the desired FTA was met for both conditions while maintaining minimum annual diversions for current and future water supplies. The annual yields for major supply rights were not impacted, primarily due to significant upper basin return flows in the Trinity Basin as discussed in *Section 5.1.2*. Although targets were met without reducing firm yield, a loss of modeled reservoir storage did result for both Lake Houston and Lake Livingston. For Max H, the median level for Lake Houston was reduced by eight percent (8,741 ac-ft) and for Lake Livingston by 17 percent (284,603 ac-ft). The storage loss was larger for the Min Q-Sal condition, with the median storage level reduced by 11 percent (12,069 ac-ft) in Lake Houston and 24 percent (404,816 ac-ft) in Lake Livingston. The greater loss of storage for Min Q-Sal may seem counterintuitive, given that the monthly targets are less than or equal to the Max H targets (48 percent of Max H on an annual basis); however, the FTA for Min Q-Sal is greater (75 percent vs. 50 percent) than that for Max H. Because the methodology used in this study attempts to modify frequency and therefore minimizes the volume required to meet FTA, it appears that the loss of storage may be unavoidable unless the desired FTA differed from the current GBFIG recommendation.

Results of the alternative analysis are focused on and are applicable only to expected Year 2060 conditions. Due to the staging of scenarios and return flows over time, the most critical scenario for FTA or reservoir response may occur at an intermediate decade or decades. The Region H planning scope for the 2011 RWP has elements to address pre-2060 decades during the second biennium of the plan.

5.1.4 Considerations

There are a number of concerns related to the presented evaluation of alternatives for meeting FTA. Foremost, the approach used to meet FTA is a “hard-wired” approach that couldn’t be realistically replicated as a reservoir operating rule. The operating rule applied in the model equates to, “If monthly flow Y is less than monthly minimum X, release (X - Y) of additional water from the reservoir.” However, actual application of this rule would require foreknowledge of total flow for the upcoming month. Additionally, reservoirs are operated at timescales much smaller than a monthly basis. Even if future shortages could be known on a monthly basis, there would be no clear way to translate this into daily operational rules; trying to apply FTA on a daily basis would also be unreasonable.

Another predictive issue is related to reservoir operation and the maintenance of firm water supplies for both anticipated and unexpected conditions. If drought exceeds the known drought of record, simulated in this study, reservoir storage may be critical for maintaining firm yield. Although drops in reservoir level in this exercise never impacted yield, the maintenance of a reduced reservoir level reduces a water supply's protection against unforeseen drought conditions. Furthermore, it is noteworthy to observe that the reservoir levels at the end of the revised reservoir operation simulations never reach a full level. In both the model and actual operation, the reservoirs of concern are not refilled at a set priority through a water right or agreement but rather are limited to impounding unappropriated flows available at the reservoir location. Even if one assumes that the period of record is representative of future conditions to come, successive cycles of the period of record would result in continually dwindling reservoir levels and, ultimately, a loss of firm yield.

Another concern with the approach taken is the validity of assuming that annual GBFIG targets are applicable on a seasonal or monthly basis. Sub-annual time scales are clearly of importance; it is mathematically possible to meet an annual flow target while flows for one or more months could be low enough to be ecologically inadequate. Whether FTA is more critical for some seasons or months than others has not yet been established. The application of the annual GBFIG FTA to monthly targets was made due to a lack of a more reasonable alternative and should be studied further.

Finally, while the purpose of this study is not to evaluate B&E needs or develop new flow targets or FTA, the underlying assumption that B&E flow needs are met if the desired FTA is achieved must be considered critically. One potential concern is that this approach does not consider a bracket of flows, but only if the flow equals or exceeds the desired B&E flow. This does not account for the possibility that, in some circumstances, excessive flows may also result in less than optimum conditions. It is important to remember that the State's Max H, Min Q, and Min Q-Sal flow regimes are not made up of individual flow targets but rather represent optimal harvest when all 12 months in a year are at or near the monthly target. However, Espey Consultants (2008) has noted that the pattern of flows defined by Max H does not occur historically; in order to meet the 50% frequency on Max H, the monthly Max H targets would have to be bracketed by $\pm 1,045$ percent. Monthly flow patterns for the Max H and Min Q-Sal models are given in *Figures 5-2* and *5-3*. As seen in the figures, the revised model median for Max H and 25th percentile for Min Q-Sal (corresponding to 50 and 75 percent FTA) are at or above the target values for all months of the year. While this means that the FTA requirement has been met using the definitions and assumptions for this study, the difference in distribution between the targets and revised models indicate flow conditions that do not meet optimum goals as provided by TWDB targets. Additionally, it is important to recognize that these are percentile distributions; even if the median or 25th percentile curve perfectly matched the targets, this does not guarantee that every month of a particular year was at or near target as required to meet TWDB's definition of optimal performance.

Figure 5-2. Distribution of Monthly B&E Inflows for Max H Revised Operation Model

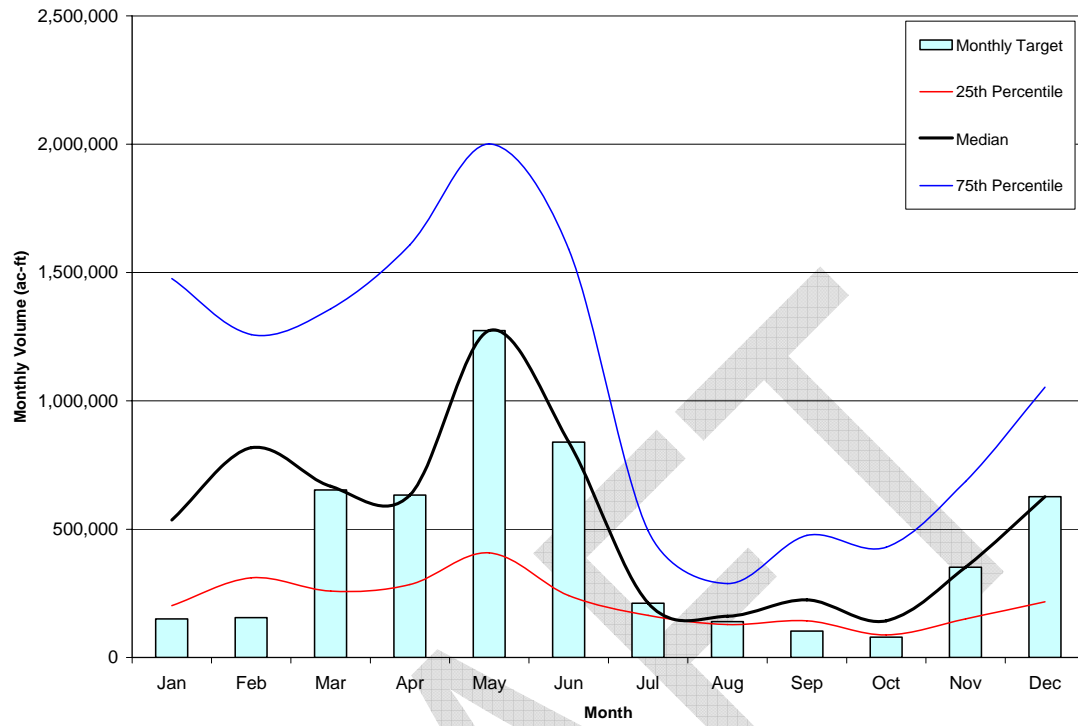
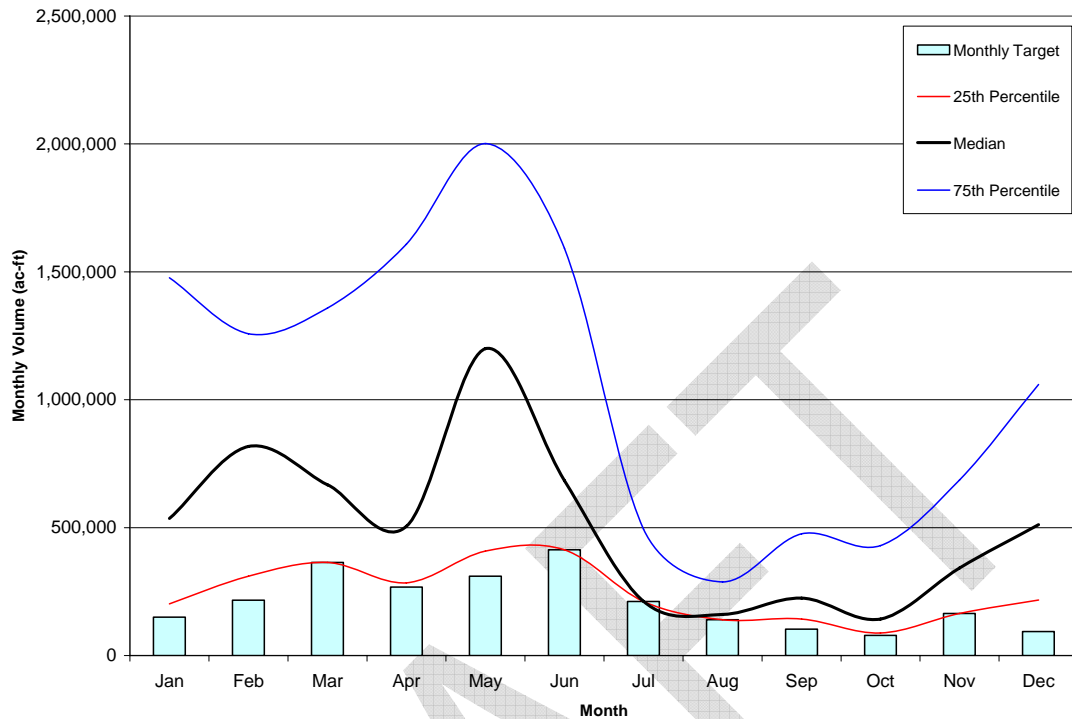


Figure 5-3. Distribution of Monthly B&E Inflows for Min Q-Sal Revised Operation Model



5.2 Instream Flows

5.2.1 Critical Segments

As shown in *Table 4-1* in the preceding section, the critical (most impacted) segments for the various strategy models occurred at six locations in the San Jacinto Basin and lower portion of the Brazos Basin. The critical changes in the San Jacinto Basin are predominantly increases due to increased supply (IBTs, increased groundwater inputs, Lake Houston yield) to the San Jacinto Basin and decreases created by reuse strategies. While one would expect the large IBT projects to substantially impact the source (Trinity Basin) basin, this is not the case due to the large IBTs being included in the TCEQ Full Authorized Diversion (F) model, which was used to build the base model (D₀) for Region H WMS implementation.

The positive increases in flow due to IBTs occurred year round but were greatest for the summer period. Due to the approximately uniform distribution of additional supply from IBT strategies in the source basin, this is not due to the monthly input distribution. Rather, for the base (D₀) model, median and 10th percentile flows in the San Jacinto Basin tend to be lower during the summer and early winter months, especially at the critical segments. Since flows at these points tend to be low during the summer, the proportional change caused by the uniform input is greater than for higher-flow periods. The reduction in flow at some segments in the San Jacinto due to reuse may seem counterintuitive since additional demands are being met without the development of new water sources. However, the reuse strategies result in either a reduction of return flows to streams or the withdrawal of return flows at some point as part of a bed and banks permit conveyance. The same is true of other points impacted by these strategies (see *Appendix C*).

Critical stream segments in the Brazos Basin were impacted mainly by reservoir projects, as well as the Houston to GCWA transfer and Freeport Desalination. All critical segments in the Brazos Basin

showed decreased 10th percentile flows to WMS due to diminished pass-through flows from upstream rights, even for the increased supplies created by Freeport Desalination and the Houston to GCWA transfer. The change in 10th percentile flow at critical segments in the Brazos Basin, though consistently negative, was minor on an annual basis, with decreases of 4.6 percent or less annually. Changes were also generally small for monthly 10th percentile values, with the exception of a 28 percent reduction in May for the Allens Creek WMS. For these two strategies, the critical segments are located upstream of the locations of increased input. This suggests that, unlike the increased supply strategies in the San Jacinto Basin, these increases are firming up downstream rights using increased constant inputs, resulting in reduced pass-through flows in upstream segments. The BRA System Operations and Allens Creek strategies showed the greatest percent reduction in flow during the winter and spring months, due to “scalping” of higher seasonal flows. The Little River Off-Channel Reservoir exhibited its largest change in August. This is a function of the peaked monthly usage distribution pattern associated in the model with the Little River Off-Channel diversion, which reaches its highest levels in July and August and is substantially lower for the remainder of the year.

5.2.2 Field Observations

As noted in the results earlier, field observations of flow and environmental condition were made at seven locations during a period of low flow conditions of approximately Lyons flow levels. Because natural variations in flow precluded examining all of the stream segments simultaneously at exact flow rates, observed flows were somewhat lower than the Lyons value. USGS flow values, where available, varied widely in relation to the target condition for field observation, ranging from 2 to 91 percent of Lyons flow. Based on CFS indicators, the observed flow status was primarily low to moderate. By the definition of Lyons flows, the observed flow conditions at all visited segments would represent an ecologically distressed condition. However, classification of several segments as moderate flow status, along with observations of channel condition and vegetation, did not indicate significant ecological degradation (see *Appendix D* for photographs and summary). While some observed locations did show indications of mild bank erosion, streams generally appeared in fair to good condition, with healthy vegetation and observed presence of aquatic wildlife.

Additionally, it is important to note that observations were taken as closely as possible to easily accessible USGS gauging stations to get accurate flow results. These stations are typically located at bridges and stream crossings which have generally been channelized or altered to some degree and may not perfectly represent more natural segments immediately upstream or downstream.

Visual observations of more natural segments suggested that even at the low flow rates, stream health was not seriously impaired. Additionally, viable wetlands and riparian corridors were observed in the immediate vicinity of some of the survey points. This conflict between the definition of Lyons flow and observed indicators of stream health call into question the applicability of Lyons flow as a stream health indicator in this area. As such, more study would be required to determine whether the Lyons flows are representative of an ecologically sound condition for Region H stream segments. This question may be addressed more clearly by the Texas Instream Flows Program.

Section 6 – Conclusions

This study was intended to evaluate the impacts of individual management strategies on environmental flows including both B&E inflows and instream flows in channels. Furthermore, an evaluation of impacts to existing and future water supplies was performed for two scenarios aimed at increasing the frequency of attaining B&E inflow targets. The following observations were made through the course of the study:

B&E Inflow Volume, Location, and Target Attainment

- In general, the inclusion of strategies upstream of and within Region H generally leads to a net increase in B&E inflows due to the import of new water to the basin.
- Impacts of individual Region H WMS are relatively minor with the exception of the TRA to Houston transfer, which resulted in an increase in FTA of up to 10 percent for one month.
- Shortages in meeting Max H and Min Q-Sal targets occur generally in the spring. Shortages for Min Q generally occur during the summer months.
- B&E flows generally transition from originating in the Trinity River Basin to the San Jacinto River Basin as time passes and additional water is diverted to meet demands in the latter basin.
- Removal of return flows from Region C were found to result in a 20 percent reduction in B&E discharges from the Trinity River which represents a substantial impact to the total volume of B&E flows. Reductions in firm yield for six of seven key water rights were also caused by this elimination of upstream return flows.

Revised Models for Increasing FTA

- A methodology using the release of stored water was identified as the most effective means of increasing FTA while minimizing impacts to firm yield. Two separate models were developed to increase the occurrence of meeting monthly Max H and Min Q-Sal targets at the desired level.
- Although no reductions in firm yield were identified during the period of record, reductions in reservoir storage point to a reduced level of reliability in reservoir supply during unforeseen drought conditions and successive occurrences of the observed period of record.
- The developed methodology approaches recommended targets as “minimum criteria” to be met, rather than a pattern of flows for an optimal level of estuary production. Additional steps would be required to address target attainment from this perspective.

Instream Flows

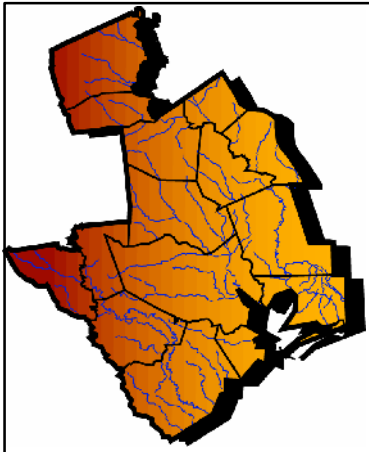
- The predominant changes to instream flows are increases in flow due to new water sources such as IBTs and groundwater.
- Reservoir and operations projects in the Brazos River Basin resulted in reductions in stream flow.
- Field observations were made at a time when stream levels were at a rate near that of the calculated Lyons flows for each segment. Despite this flow condition, there were no indications of impaired stream health at the observed locations.

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Section 7 – References

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EXHIBITS



Region H Water Planning Group

Exhibit 1: Basins with Study Control Points

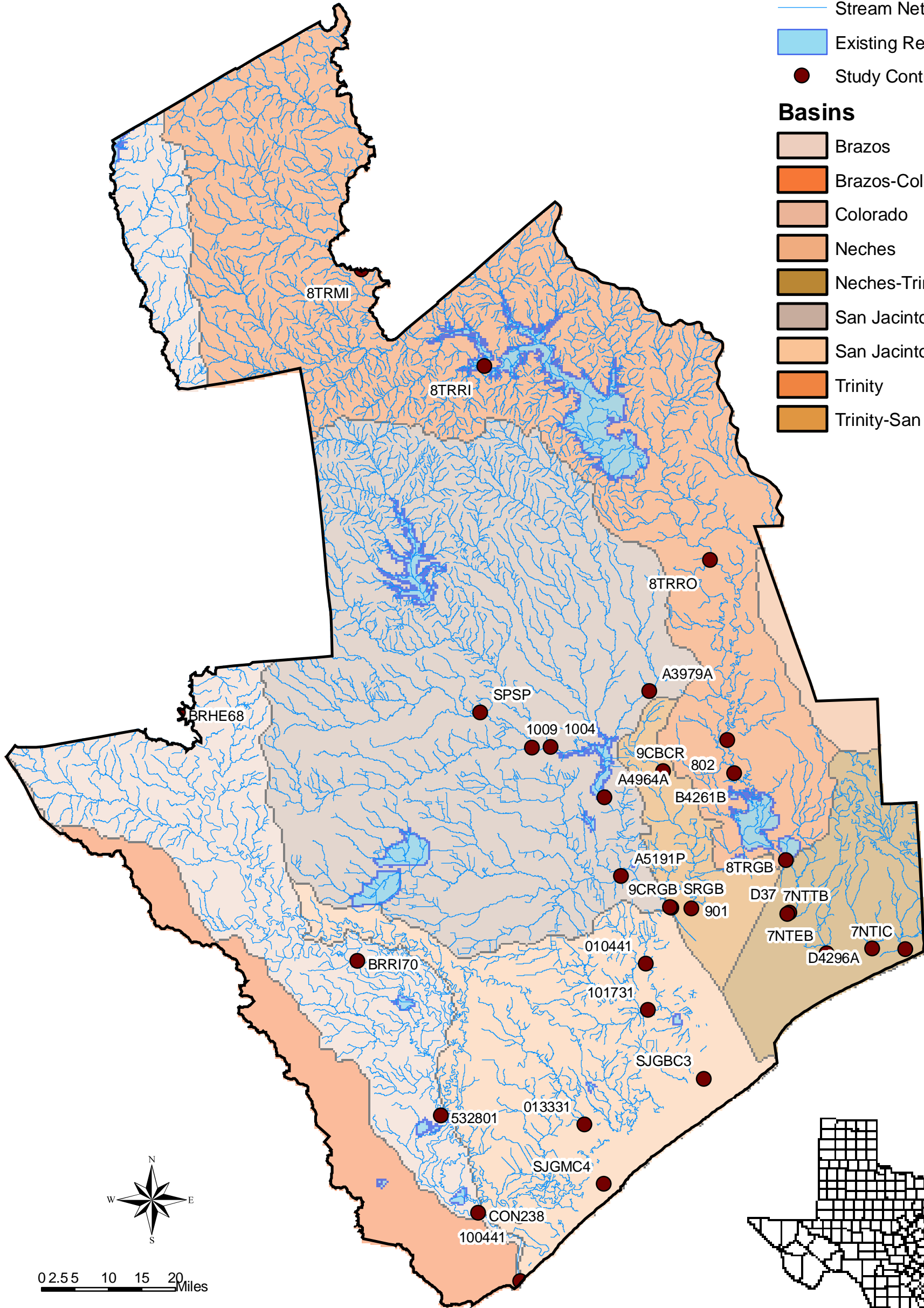
DRAFT

Legend

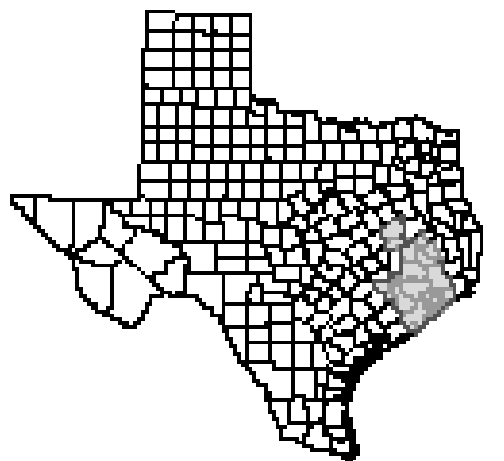
- Stream Network
- Existing Reservoirs
- Study Control Points

Basins

- Brazos
- Brazos-Colorado
- Colorado
- Neches
- Neches-Trinity
- San Jacinto
- San Jacinto-Brazos
- Trinity
- Trinity-San Jacinto



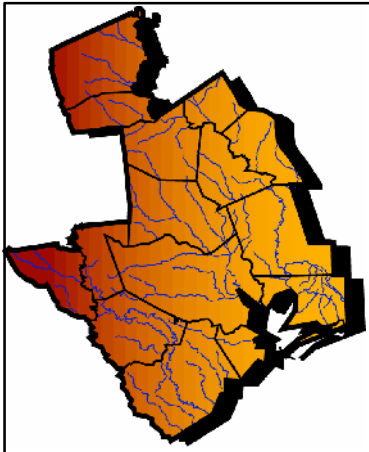
0 2.55 10 15 20 Miles



KBR

JOINT VENTURE

TCB | AECOM



Region H Water Planning Group

Exhibit 2: Critical Segments and Survey Points

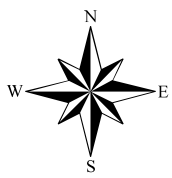
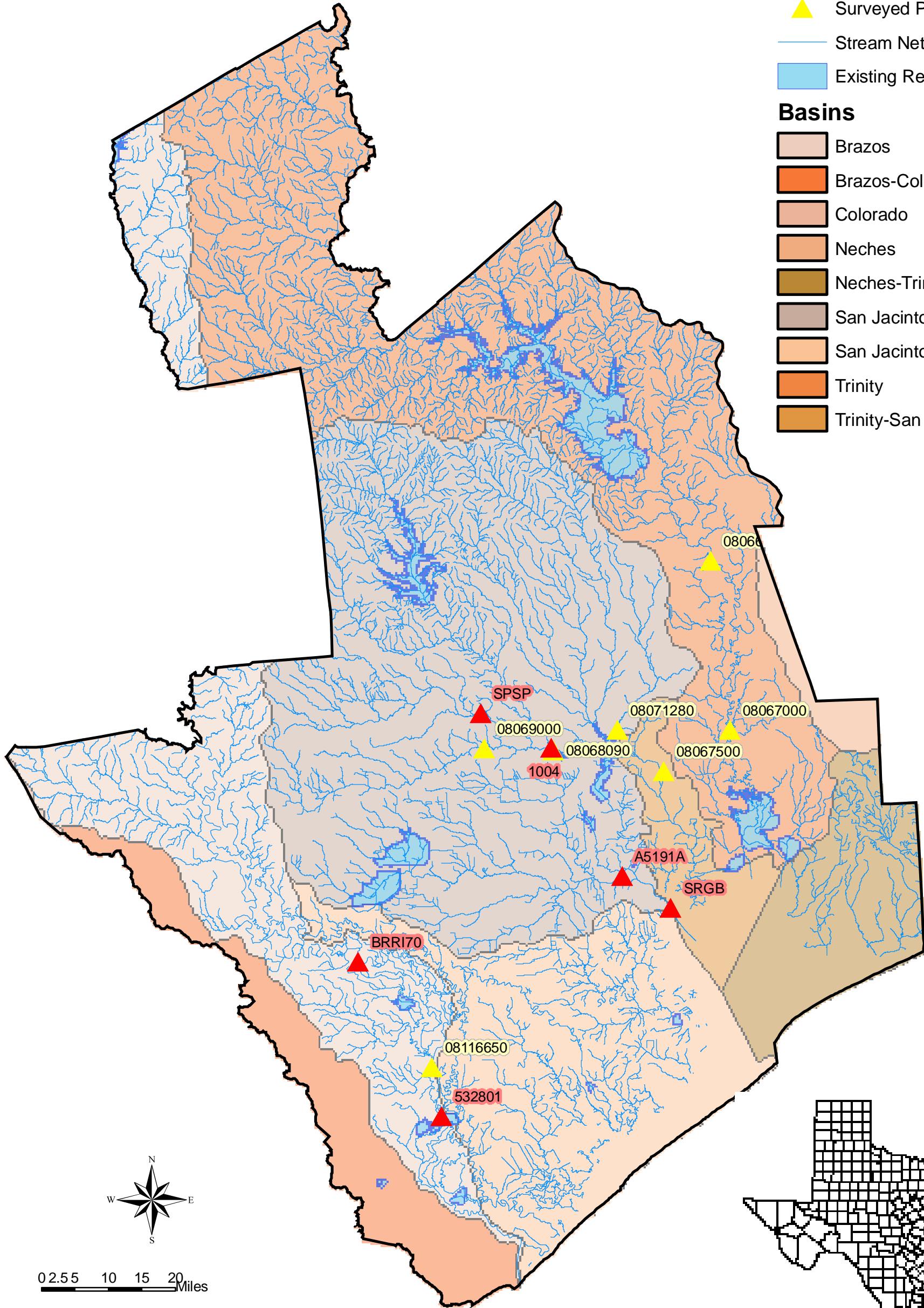
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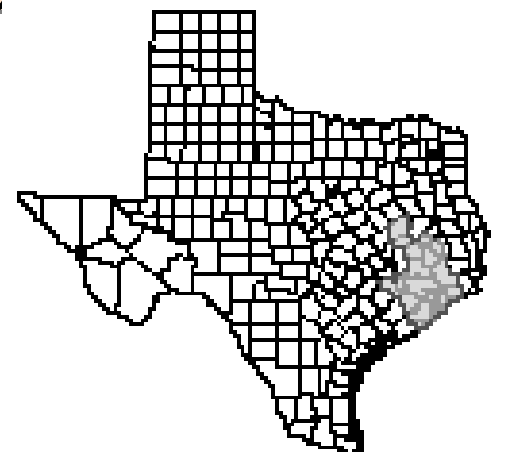
- Critical Segments
- Surveyed Points
- Stream Network
- Existing Reservoirs

Basins

- Brazos
- Brazos-Colorado
- Colorado
- Neches
- Neches-Trinity
- San Jacinto
- San Jacinto-Brazos
- Trinity
- Trinity-San Jacinto



0 2.55 10 15 20 Miles



KBR

JOINT VENTURE

TCB | AECOM

APPENDIX A

MEDIAN FLOWS FOR SELECTED CONTROL POINTS FOR MODELS A THROUGH F

CP	Month	A	B	C	D ₀	D ₃	D ₄	D ₇	D ₈	D ₉	D ₁₁	D ₁₂	D ₁₃	D ₁₄	D ₁₅	D ₁₆	D ₁₇	D _{MAX}	D _{MIN}	E	F	
All Flows in Units of Acre-Feet																						
100441	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13331	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101731	1	0	1,357	1,134	3	436	172	3	271	3	3	3	3	3	3	3	3	436	3	873	3	
	2	0	1,394	1,164	2	430	191	2	283	2	2	2	2	2	2	2	2	430	2	900	2	
	3	0	1,516	1,263	0	463	210	0	312	0	0	0	0	0	0	0	0	463	0	991	0	
	4	0	1,649	1,372	0	495	232	0	343	0	0	0	0	0	0	0	0	495	0	1,083	0	
	5	0	1,709	1,420	0	579	264	0	381	0	0	0	0	0	0	0	0	579	0	1,237	0	
	6	0	1,905	1,581	0	650	294	0	408	0	0	0	0	0	0	0	0	650	0	1,379	0	
	7	0	2,036	1,689	0	738	315	0	442	0	0	0	0	0	0	0	0	738	0	1,531	0	
	8	0	2,292	1,905	0	698	300	0	299	0	0	0	0	0	0	0	0	698	0	1,329	0	
	9	0	2,219	1,851	0	633	251	0	434	0	0	0	0	0	0	0	0	633	0	1,327	0	
	10	0	2,068	1,723	0	563	196	0	395	0	0	0	0	0	0	0	0	563	0	1,165	0	
	11	0	1,892	1,578	2	482	176	2	363	2	2	2	2	2	2	2	2	2	482	2	1,020	2
	12	0	1,605	1,339	3	452	166	3	313	3	3	3	3	3	3	3	3	3	452	3	927	3
10441	1	0	1,852	1,544	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	70	
	2	0	1,903	1,588	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	58	0	
	3	0	2,069	1,727	0	0	275	0	0	0	0	0	0	0	0	0	0	275	0	569	0	
	4	0	2,241	1,873	0	0	133	0	0	0	0	0	0	0	0	0	0	133	0	443	0	
	5	0	2,307	1,932	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96	0	
	6	0	2,551	2,145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	7	0	2,722	2,291	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	283	0	
	8	0	3,079	2,591	0	0	156	0	0	0	0	0	0	0	0	0	0	156	0	426	0	
	9	0	3,018	2,528	0	0	135	0	0	0	0	0	0	0	0	0	0	135	0	489	0	
	10	0	2,819	2,362	0	0	500	0	89	0	0	0	0	0	7	0	0	500	0	831	0	
	11	0	2,579	2,158	0	0	194	0	7	0	0	3	0	0	5	0	0	194	0	501	0	
	12	0	2,193	1,829	1	0	7	1	5	1	1	3	1	1	4	1	1	7	0	221	1	

CP	Month	A	B	C	D ₀	D ₃	D ₄	D ₇	D ₈	D ₉	D ₁₁	D ₁₂	D ₁₃	D ₁₄	D ₁₅	D ₁₆	D ₁₇	D _{MAX}	D _{MIN}	E	F		
All Flows in Units of Acre-Feet																							
9CBCR	1	2,727	2,049	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407	1,407		
	2	3,131	2,685	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	
	3	1,842	1,432	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	
	4	1,850	1,206	681	681	681	681	681	681	681	681	681	681	681	681	681	681	681	681	681	681	681	
	5	2,957	2,027	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	1,358	
	6	1,903	908	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244	244
	7	1,053	393	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
	8	614	200	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43	43
	9	626	336	161	161	161	161	161	161	161	161	161	161	161	161	161	161	161	161	161	161	161	161
	10	644	393	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
	11	1,052	1,026	911	911	911	911	911	911	911	911	911	911	911	911	911	911	911	911	911	911	911	911
	12	2,572	2,111	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021	2,021
901	1	8,476	8,759	6,923	6,923	6,923	6,986	6,923	6,923	6,923	6,923	6,923	6,923	6,923	6,923	6,923	6,923	6,986	6,923	6,986	5,867		
	2	9,734	10,135	9,423	9,423	9,423	9,536	9,423	9,423	9,423	9,423	9,423	9,423	9,423	9,423	9,423	9,423	9,423	9,536	9,423	9,536	8,391	
	3	5,725	6,184	5,570	5,570	5,570	5,639	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,570	5,639	5,570	5,639	4,551	
	4	5,751	5,618	4,829	4,829	4,829	4,896	4,829	4,829	4,829	4,829	4,829	4,829	4,829	4,829	4,829	4,829	4,829	4,896	4,829	4,896	3,823	
	5	9,192	8,576	7,570	7,570	7,570	7,653	7,570	7,570	7,570	7,570	7,570	7,570	7,570	7,570	7,570	7,570	7,570	7,653	7,570	7,653	6,526	
	6	5,916	5,153	4,348	4,348	4,348	4,410	4,348	4,348	4,348	4,348	4,348	4,348	4,348	4,348	4,348	4,348	4,348	4,410	4,348	4,410	3,292	
	7	3,273	2,936	2,705	2,705	2,705	2,832	2,705	2,705	2,705	2,705	2,705	2,705	2,705	2,705	2,705	2,705	2,705	2,832	2,705	2,832	1,674	
	8	1,907	2,220	2,153	2,153	2,153	2,266	2,153	2,153	2,153	2,153	2,153	2,153	2,153	2,153	2,153	2,153	2,153	2,266	2,153	2,266	1,134	
	9	1,945	2,539	2,554	2,554	2,554	2,631	2,554	2,554	2,554	2,554	2,554	2,554	2,554	2,554	2,554	2,554	2,554	2,631	2,554	2,631	1,535	
	10	2,003	2,593	2,277	2,277	2,277	2,348	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,277	2,348	2,277	2,348	1,307	
	11	3,270	4,246	4,262	4,262	4,262	4,327	4,262	4,262	4,262	4,262	4,262	4,262	4,262	4,262	4,262	4,262	4,262	4,327	4,262	4,327	3,243	
	12	7,995	8,953	8,970	8,970	8,970	9,038	8,970	8,970	8,970	8,970	8,970	8,970	8,970	8,970	8,970	8,970	8,970	9,038	8,970	9,038	7,963	
9CBGB	1	10,378	11,223	9,386	9,386	9,386	9,453	9,386	9,386	9,386	9,386	9,386	9,386	9,386	9,386	9,386	9,386	9,386	9,453	9,386	9,453	7,870	
	2	11,918	12,768	12,056	12,056	12,056	12,172	12,056	12,056	12,056	12,056	12,056	12,056	12,056	12,056	12,056	12,056	12,056	12,172	12,056	12,172	10,576	
	3	7,010	8,102	7,459	7,459	7,459	7,520	7,459	7,459	7,459	7,459	7,459	7,459	7,459	7,459	7,459	7,459	7,459	7,520	7,459	7,520	5,996	
	4	7,041	7,347	6,558	6,558	6,558	6,629	6,558	6,558	6,558	6,558	6,558	6,558	6,558	6,558	6,558	6,558	6,558	6,629	6,558	6,629	5,113	
	5	11,254	11,093	10,087	10,087	10,087	10,174	10,087	10,087	10,087	10,087	10,087	10,087	10,087	10,087	10,087	10,087	10,087	10,174	10,087	10,174	8,589	
	6	7,244	6,924	6,119	6,119	6,119	6,207	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,119	6,207	6,119	6,207	4,604	
	7	4,008	4,120	3,889	3,889	3,889	4,020	3,889	3,889	3,889	3,889	3,889	3,889	3,889	3,889	3,889	3,889	3,889	4,020	3,889	4,020	2,408	
	8	2,335	3,091	3,024	3,024	3,024	3,142	3,024	3,024	3,024	3,024	3,024	3,024	3,024	3,024	3,024	3,024	3,024	3,142	3,024	3,142	1,562	
	9	2,381	3,430	3,415	3,415	3,415	3,496	3,415	3,415	3,415	3,415	3,415	3,415	3,415	3,415	3,415	3,415	3,415	3,496	3,415	3,496	1,952	
	10	2,452	3,465	3,149	3,149	3,149	3,223	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,223	3,149	3,223	1,756	
	11	4,004	5,424	5,440	5,440	5,440	5,508	5,440	5,440	5,440	5,440	5,440	5,440	5,440	5,440	5,440	5,440	5,440	5,508	5,440	5,508	3,977	
	12	9,789	11,185	11,202	11,202	11,202	11,273	11,202	11,202	11,202	11,202	11,202	11,202	11,202	11,202	11,202	11,202	11,202	11,273	11,202	11,273	9,757	

CP	Month	A	B	C	D ₀	D ₃	D ₄	D ₇	D ₈	D ₉	D ₁₁	D ₁₂	D ₁₃	D ₁₄	D ₁₅	D ₁₆	D ₁₇	D _{MAX}	D _{MIN}	E	F		
		All Flows in Units of Acre-Feet																					
B4261B	1	358,240	253,624	149,140	226,705	226,705	227,212	226,706	226,705	226,705	226,705	226,705	226,705	226,705	226,705	226,705	226,705	226,705	227,212	226,705	227,212	51,638	
	2	519,778	357,907	257,878	361,359	361,359	361,988	361,391	361,359	361,359	361,359	361,359	361,359	361,359	361,359	361,359	361,359	361,359	361,988	361,359	362,020	117,030	
	3	470,746	358,879	293,548	348,784	348,784	349,382	348,852	348,784	348,784	348,784	348,784	348,784	348,784	348,784	348,784	348,784	348,784	349,382	348,784	349,450	189,712	
	4	550,295	320,478	257,171	320,971	320,971	321,689	321,012	320,971	320,971	320,971	320,971	320,971	320,971	320,971	320,971	320,971	320,971	321,689	320,971	321,729	208,814	
	5	831,481	655,757	505,788	603,007	603,007	603,817	603,301	603,007	603,007	603,007	603,007	603,007	603,007	603,007	603,007	603,007	603,007	603,817	603,007	604,111	378,906	
	6	482,060	270,134	181,861	245,222	245,222	246,980	245,353	245,222	245,222	245,222	245,222	245,222	245,222	245,222	245,222	245,222	245,222	246,980	245,222	247,111	140,333	
	7	184,826	48,230	18,011	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	15,829	16,210
	8	53,593	25,688	15,754	15,089	15,089	15,088	15,089	15,089	15,089	15,089	15,089	15,089	15,089	15,089	15,089	15,089	15,089	15,089	15,089	15,088	15,088	14,609
	9	98,954	24,470	8,171	7,840	7,840	7,839	7,840	7,840	7,840	7,840	7,840	7,840	7,840	7,840	7,840	7,840	7,840	7,840	7,840	7,839	7,839	7,987
	10	139,507	25,937	3,194	2,900	2,900	2,899	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,900	2,899	2,899	3,461
	11	217,588	83,888	3,106	25,213	25,213	25,874	25,214	25,213	25,213	25,213	25,213	25,213	25,213	25,213	25,213	25,213	25,213	25,874	25,213	25,875	2,774	
	12	355,621	237,642	81,802	180,054	180,054	180,665	180,055	180,054	180,054	180,054	180,054	180,054	180,054	180,054	180,054	180,054	180,054	180,665	180,054	180,666	14,001	
8TRGB	1	365,784	264,884	150,864	229,396	229,396	229,903	229,397	229,396	229,396	229,396	229,396	229,396	229,396	229,396	229,396	229,396	229,396	229,903	229,396	229,904	60,344	
	2	542,859	370,475	257,613	376,859	376,859	377,481	376,859	376,859	376,859	376,859	376,859	376,859	376,859	376,859	376,859	376,859	376,859	377,481	376,859	377,482	119,120	
	3	475,774	361,279	291,853	348,320	348,320	348,918	348,387	348,320	348,320	348,320	348,320	348,320	348,320	348,320	348,320	348,320	348,320	348,918	348,320	348,986	188,424	
	4	561,410	321,921	256,016	319,816	319,816	320,533	319,856	319,816	319,816	319,816	319,816	319,816	319,816	319,816	319,816	319,816	319,816	320,533	319,816	320,574	207,659	
	5	849,466	651,610	500,246	597,465	597,465	598,275	597,759	597,465	597,465	597,465	597,465	597,465	597,465	597,465	597,465	597,465	597,465	598,275	597,465	598,569	383,128	
	6	498,158	305,608	204,411	254,507	254,507	255,467	254,506	254,507	254,507	254,507	254,507	254,507	254,507	254,507	254,507	254,507	254,507	255,467	254,506	255,468	167,848	
	7	191,939	36,241	3,684	1,531	1,531	1,534	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,531	1,534	1,531	1,534	1,286	
	8	58,559	12,444	772	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	375	706
	9	100,791	18,999	903	464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	739
	10	144,262	26,435	2,356	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	440	680
	11	224,396	88,682	9,786	37,705	37,705	37,942	37,705	37,705	37,705	37,705	37,705	37,705	37,705	37,705	37,705	37,705	37,705	37,942	37,705	37,942	7,041	
	12	384,938	269,987	91,709	181,228	181,228	181,839	181,259	181,228	181,228	181,228	181,228	181,228	181,228	181,228	181,228	181,228	181,228	181,839	181,228	181,870	16,162	

CP	Month	A	B	C	D ₀	D ₃	D ₄	D ₇	D ₈	D ₉	D ₁₁	D ₁₂	D ₁₃	D ₁₄	D ₁₅	D ₁₆	D ₁₇	D _{MAX}	D _{MIN}	E	F
All Flows in Units of Acre-Feet																					
7NTIC	1	8,902	8,296	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446	6,446
	2	5,676	5,184	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714	4,714
	3	4,255	3,704	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316	3,316
	4	9,502	7,839	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178	7,178
	5	11,414	8,835	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819	7,819
	6	10,996	7,731	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659	6,659
	7	7,267	5,349	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369	4,369
	8	5,899	4,811	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344	4,344
	9	11,063	10,087	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503	10,503
	10	7,963	6,950	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968	6,968
	11	7,844	7,328	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484	7,484
	12	9,276	8,635	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996	8,996

APPENDIX B

10TH PERCENTILE FLOWS FOR CRITICAL SEGMENTS ANALYSIS

10th Percentile Flows for Examined Control Points (Units of Acre-Feet)																										
Strategy	532801	CON238	BRR170	BRR17D	100441	13331	101731	10441	D37	7NTTB	D4296A	7NTEB	A5191P	SPSP	1009	1004	A3979A	A4964A	SRGB	8TRMI	8TRRI	8TRRO	802	B4261B	9CBCR	901
D ₀	41,101	23,721	55,925	55,925	0	0	0	0	27	139	0	561	59,845	1,461	1,996	2,082	559	0	65,550	86,138	89,543	70,893	74,146	1,737	13	1,350
D ₃	40,776	23,736	55,518	55,518	0	0	434	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D ₄	41,411	23,692	56,073	56,073	0	0	169	0	27	139	0	561	60,069	1,474	2,100	2,937	640	0	66,000	86,197	89,760	70,792	74,143	1,737	13	1,422
D ₇	39,246	23,784	54,684	54,684	0	0	0	0	NA	NA	NA	NA	60,601	1,461	2,004	2,082	559	0	66,330	86,138	89,543	70,893	74,146	1,737	NA	NA
D ₈	40,027	23,390	54,918	54,918	0	0	280	0	NA	NA	NA	NA	61,175	1,461	1,996	2,082	559	0	66,977	NA	NA	NA	NA	NA	NA	NA
D ₉	40,592	23,714	55,028	55,028	0	0	0	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D ₁₁	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	56,482	1,461	1,996	2,082	559	0	62,338	NA	NA	NA	NA	NA	NA	NA
D ₁₂	41,168	23,738	56,140	56,140	0	0	0	0	NA	NA	NA	NA	64,199	4,223	2,082	2,032	558	0	70,502	86,138	89,543	79,476	56,995	1,737	NA	NA
D ₁₃	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	59,845	2,736	1,993	2,662	558	0	66,085	86,138	89,543	77,072	56,995	1,737	NA	NA
D ₁₄	41,219	23,786	55,324	55,324	0	0	0	0	NA	NA	NA	NA	59,920	1,461	1,996	2,082	559	0	65,626	NA	NA	NA	NA	NA	NA	NA
D ₁₅	41,101	23,721	55,925	55,925	0	0	0	0	NA	NA	NA	NA	56,863	1,461	1,996	2,082	559	0	62,568	NA	NA	NA	NA	NA	NA	NA
D ₁₆	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	59,039	1,461	1,992	2,082	559	0	64,871	NA	NA	NA	NA	NA	NA	NA
D ₁₇	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	59,845	1,461	1,996	2,082	559	0	66,973	NA	NA	NA	NA	NA	NA	NA
E	37,835	24,070	136,730	136,730	0	0	896	0	27	139	0	561	59,370	5,522	2,154	3,307	600	0	67,785	86,197	89,761	80,893	56,977	1,737	13	1,422

Absolute Percent Difference in Strategy and D ₀ Flows for Examined Control Points																										
Strategy	532801	CON238	BRR170	BRR17D	100441	13331	101731	10441	D37	7NTTB	D4296A	7NTEB	A5191P	SPSP	1009	1004	A3979A	A4964A	SRGB	8TRMI	8TRRI	8TRRO	802	B4261B	9CBCR	901
D ₀	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
D ₃	0.79	0.07	0.73	0.73	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D ₄	0.75	0.12	0.26	0.26	NA	NA	NA	NA	0.00	0.00	NA	0.00	0.37	0.89	5.26	41.09	14.44	NA	0.69	0.07	0.24	0.14	0.00	0.01	0.00	5.33
D ₇	4.51	0.27	2.22	2.22	NA	NA	NA	NA	NA	NA	NA	NA	1.26	0.04	0.41	0.00	0.00	NA	1.19	0.00	0.00	0.00	0.00	0.00	NA	NA
D ₈	2.61	1.39	1.80	1.80	NA	NA	NA	NA	NA	NA	NA	NA	2.22	0.00	0.00	0.00	0.00	NA	2.18	NA	NA	NA	NA	NA	NA	NA
D ₉	1.24	0.03	1.60	1.60	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
D ₁₁	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5.62	0.00	0.00	0.00	0.00	NA	4.90	NA	NA	NA	NA	NA	NA	NA
D ₁₂	0.16	0.08	0.39	0.39	NA	NA	NA	NA	NA	NA	NA	NA	7.28	189.08	4.35	2.37	0.15	NA	7.55	0.00	0.00	12.11	23.13	0.00	NA	NA
D ₁₃	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	87.31	0.12	27.86	0.15	NA	0.82	0.00	0.00	8.72	23.13	0.00	NA	NA
D ₁₄	0.29	0.28	1.07	1.07	NA	NA	NA	NA	NA	NA	NA	NA	0.13	0.00	0.00	0.00	0.00	NA	0.12	NA	NA	NA	NA	NA	NA	NA
D ₁₅	0.00	0.00	0.00	0.00	NA	NA	NA	NA	NA	NA	NA	NA	4.98	0.00	0.00	0.00	0.00	NA	4.55	NA	NA	NA	NA	NA	NA	NA
D ₁₆	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.35	0.00	0.17	0.00	0.00	NA	1.04	NA	NA	NA	NA	NA	NA	NA
D ₁₇	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.00	0.04	0.00	0.00	0.00	NA	2.17	NA	NA	NA	NA	NA	NA	NA
E	7.95	1.47	144.49	144.49	NA	NA	NA	NA	0.00	0.00	NA	0.00	0.79	277.99	7.94	58.83	7.27	NA	3.41	0.07	0.24	14.11	23.15	0.01	0.00	5.33

APPENDIX C

FIELD STUDY AND CRITICAL SEGMENT SITE SUMMARY

Critical Segment - CP SPSP

Stream: San Jacinto River Basin

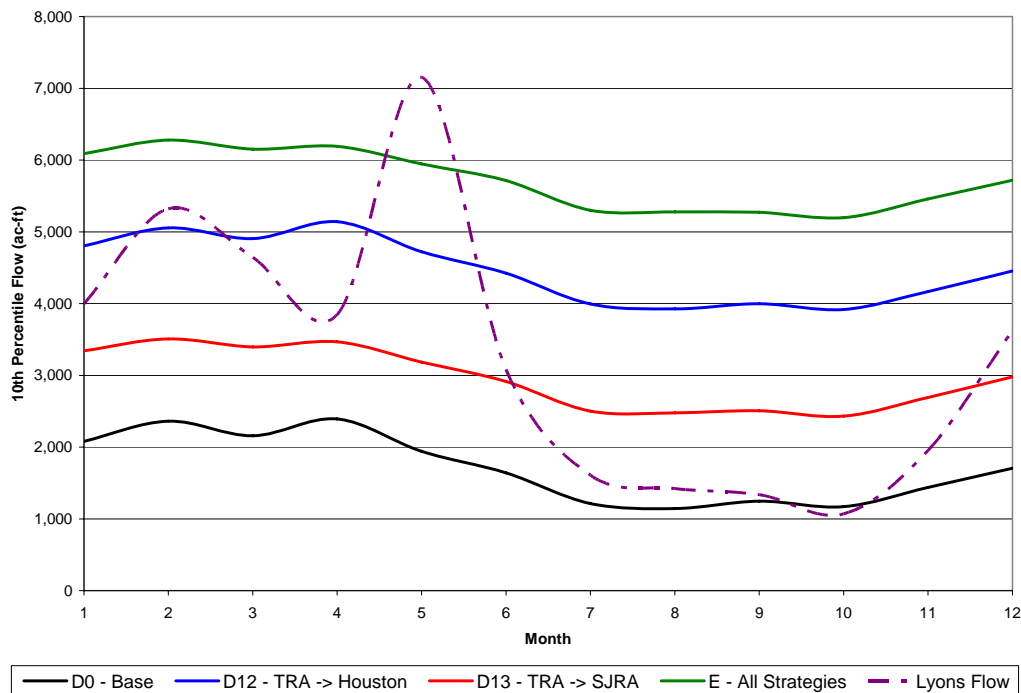
Segment: 1008 on Spring Creek
From the confluence with the West Fork San Jacinto River in Harris/Montgomery County to the most upstream crossing of FM 1736 in Waller County.

Impacted by: Bacteria – impaired water body on 2006 303(d) lists
Depressed Dissolved Oxygen

Characteristics: Freshwater Stream
Water Body size: 69.0 miles

Segment 1008 Use: Aquatic Life Use
General Use
Public Water Supply Use
Recreation Use

10th Percentile Flow for Critical Strategies:



References

2006 Texas 303(d) List; dated June 27, 2007

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_303d.pdf

2006 Texas Water Quality Inventory – Basin Assessment Data by Segment

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_basin10.pdf

Critical Segment - CP 1004

Stream: San Jacinto River Basin

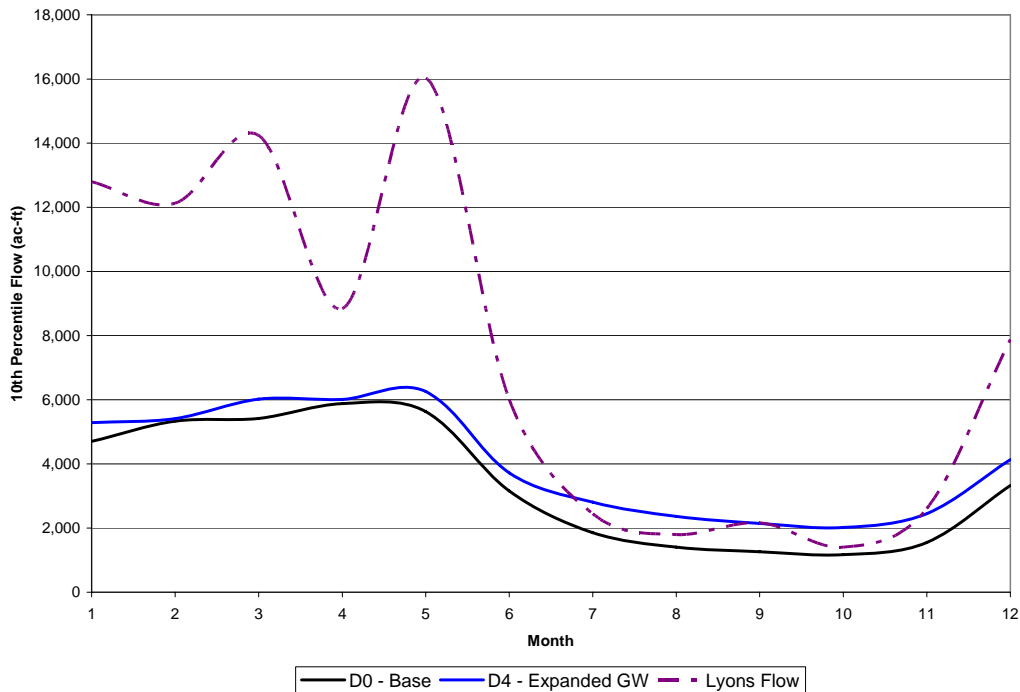
Segment: 1004 West Fork San Jacinto River
From the confluence of Spring Creek in Harris/Montgomery County to Conroe Dam in Montgomery County.

Impacted by: Bacteria – impaired water body on 2006 303(d) lists

Characteristics: Freshwater Stream
Water Body size: 40.0 miles

Segment 1004 Use: Aquatic Life Use
General Use
Public Water Supply Use
Recreation Use

10th Percentile Flow for Critical Strategies:



References

2006 Texas 303(d) List; dated June 27, 2007

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_303d.pdf

2006 Texas Water Quality Inventory – Basin Assessment Data by Segment

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_basin10.pdf

Critical Segment - CP A5191P

Stream: San Jacinto River Basin

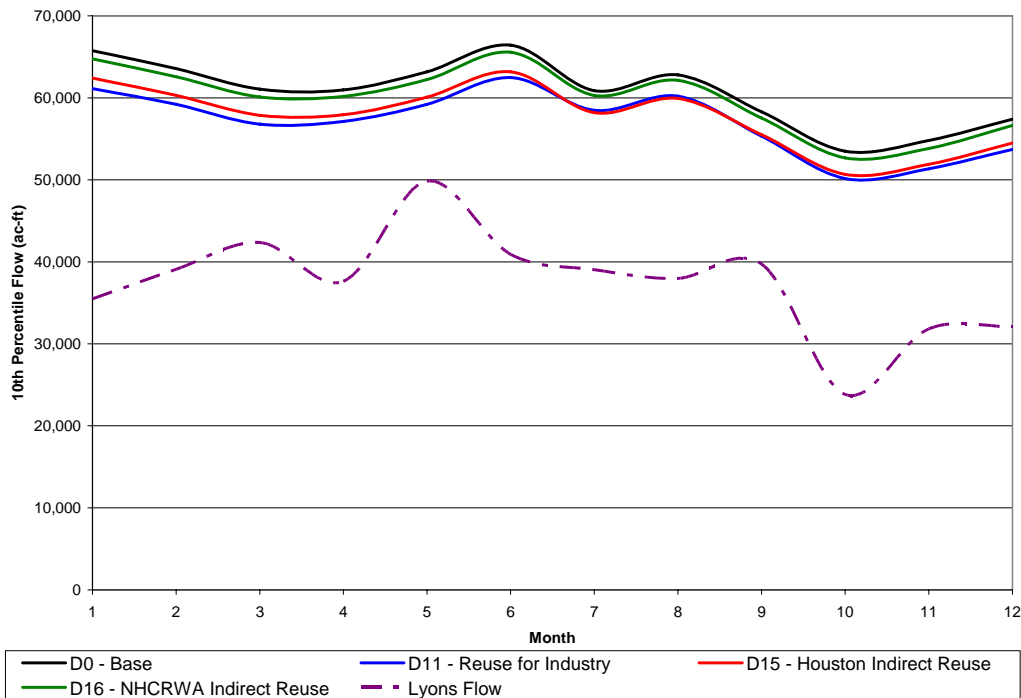
Segment: 1005 Houston Ship Channel/San Jacinto River Tidal
From the confluence of Galveston Bay with Morgan's Point in Harris/Chambers County to a point 100 meters (110 yards) downstream of IH 10 in Harris County.

Impacted by: Bacteria – impaired water body on 2006 303(d) lists

Characteristics: Tidal Stream
Water Body size: 12.0 miles

Segment 1005 Use: Aquatic Life Use
Fish Consumption Use
General Use
Recreation Use

10th Percentile Flow for Critical Strategies:



References

2006 Texas 303(d) List; dated June 27, 2007

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_303d.pdf

2006 Texas Water Quality Inventory – Basin Assessment Data by Segment

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_basin10.pdf

Critical Segment - CP BRR170

Stream: Brazos River Basin

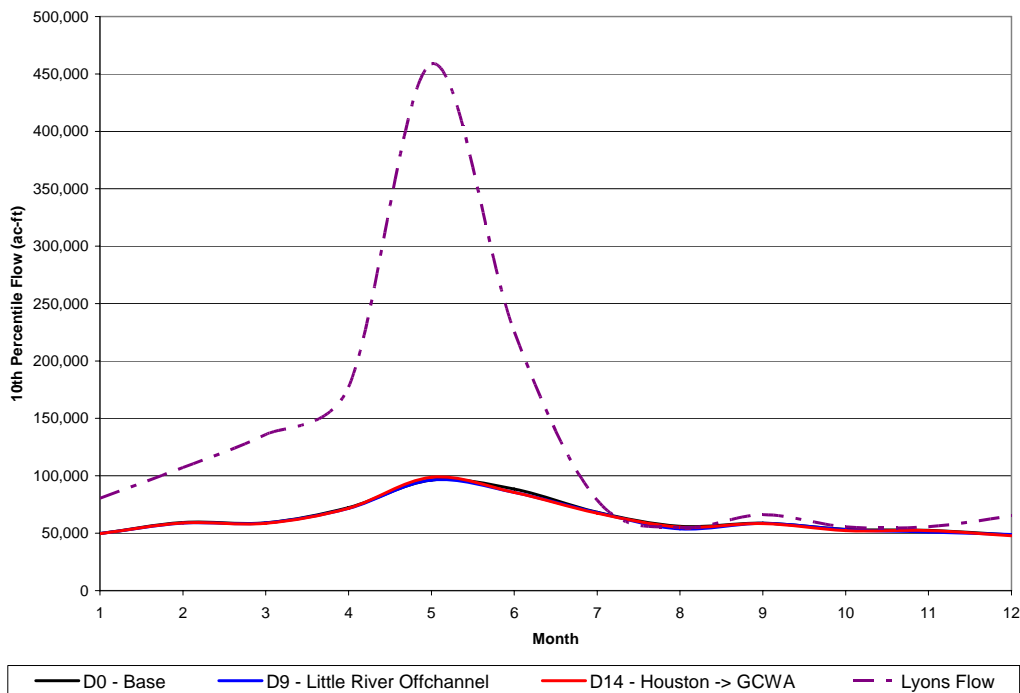
Segment: 1202 Brazos River Below Navasota River
From a point 100 meters (110 yards) upstream of SH 332 in Brazoria County to the confluence of the Navasota River in Grimes County.

Impacted by: Bacteria – impaired water body on 2006 303(d) lists

Characteristics: Freshwater Stream
Water Body size: 199.0 miles

Segment 1202 Use: Aquatic Life Use
Fish Consumption Use
General Use
Public Water Supply Use
Recreation Use

10th Percentile Flow for Critical Strategies:



References

2006 Texas 303(d) List; dated June 27, 2007

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_303d.pdf

2006 Texas Water Quality Inventory – Basin Assessment Data by Segment

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_basin10.pdf

Critical Segment - CP SRGB

Stream: San Jacinto River Basin

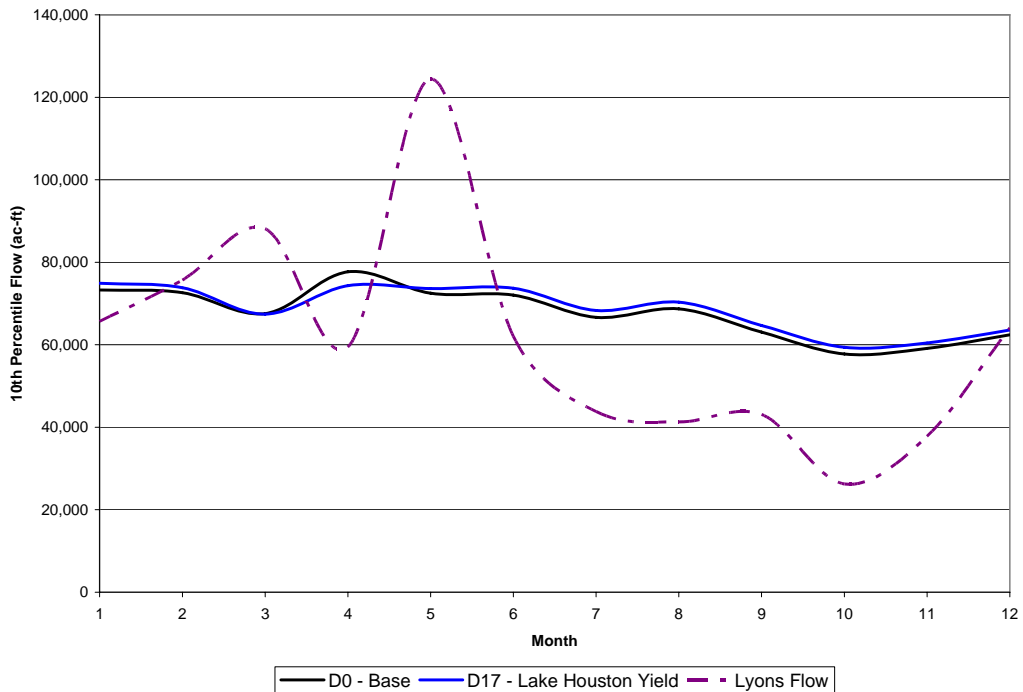
Segment: 1005 Houston Ship Channel/San Jacinto River Tidal
From the confluence of Galveston Bay with Morgan's Point in Harris/Chambers County to a point 100 meters (110 yards) downstream of IH 10 in Harris County.

Impacted by: Bacteria – impaired water body on 2006 303(d) lists

Characteristics: Tidal Stream
Water Body size: 12.0 miles

Segment 1005 Use: Aquatic Life Use
Fish Consumption Use
General Use
Recreation Use

10th Percentile Flow for Critical Strategies:



References

2006 Texas 303(d) List; dated June 27, 2007

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_303d.pdf

2006 Texas Water Quality Inventory – Basin Assessment Data by Segment

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_basin10.pdf

Critical Segment - CP 532801

Stream: Brazos River Basin

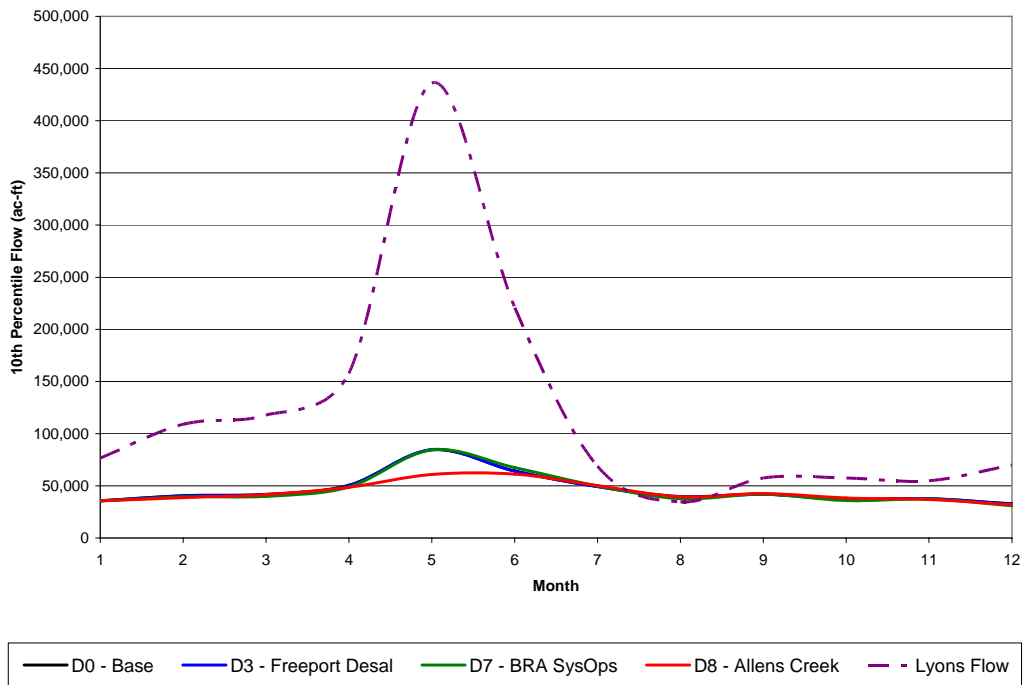
Segment: 1202 Brazos River Below Navasota River
From a point 100 meters (110 yards) upstream of SH 332 in Brazoria County to the confluence of the Navasota River in Grimes County.

Impacted by: Bacteria – impaired water body on 2006 303(d) lists

Characteristics: Freshwater Stream
Water Body size: 199.0 miles

Segment 1202 Use: Aquatic Life Use
Fish Consumption Use
General Use
Public Water Supply Use
Recreation Use

10th Percentile Flow for Critical Strategies:



References

2006 Texas 303(d) List; dated June 27, 2007

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_303d.pdf

2006 Texas Water Quality Inventory – Basin Assessment Data by Segment

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/06twqi/2006_basin10.pdf

Survey Point - USGS Station 0806650 Trinity River at Romayor Bridge

Stream: Trinity River Basin

Segment: 0802 Classified Trinity River Below Lake Livingston
From a point 3.1 km (1.9 miles) downstream of US 90 in Liberty County to
Livingston Dam in Polk/San Jacinto County

Station: USGS 08066500

Characteristics: Freshwater Stream
Water Body Size 84 miles

Segment 1202 Land Use: Cultivated land
Residential housing
Commercial development
Residential uses

References:

TCEQ Surface Water Quality Viewer

<http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/viewer/viewer.html>

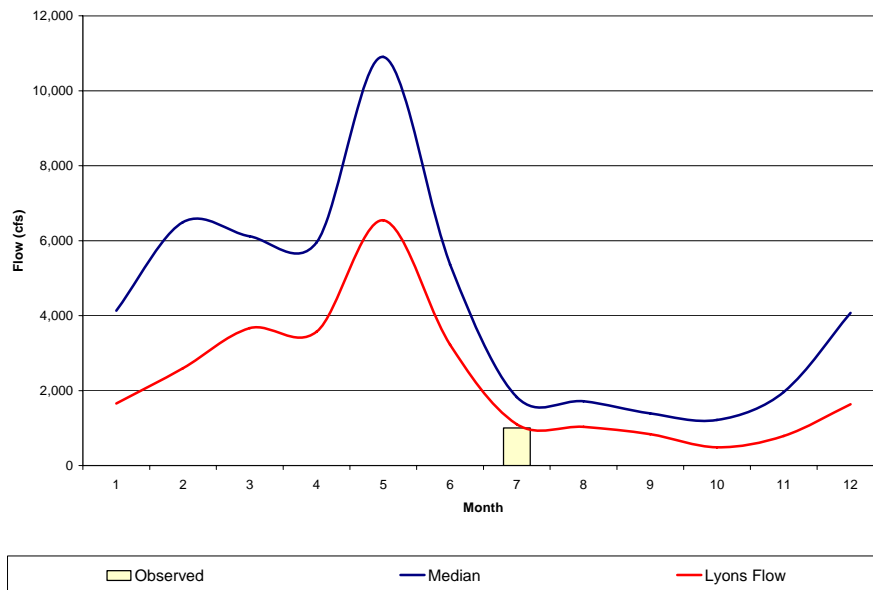
2008 Texas Water Quality Inventory – Basin Assessment Data by Segment (March 19, 2008)

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_basin8.pdf

Ecologically Significant River and Stream Segment – Trinity River (Downstream of Lake Livingston)

http://www.tpwd.state.tx.us/publications/pwdpubs/pwd_rp_t3200_1059c/trinity_river2.phtml

Observed status: At the time of observation (July 21, 2008), the Trinity River appeared to meet the definition of “Moderate” Channel Flow Status. Less than 25 percent of channel substrate was exposed. No potential wetlands and a small potential riparian corridor appeared to be present.



Survey Point - USGS Station 0806650 Trinity River at Romayor Bridge (photos)



Survey Point - USGS Station 08069000 Cypress Creek at IH 45 crossing near Westfield, TX

Stream: Trinity River Basin

Segment: 1009 Cypress Creek

From the confluence with Spring Creek in Harris County to the confluence of Snake Creek and Mound Creek in Waller County

Station: USGS 08069000

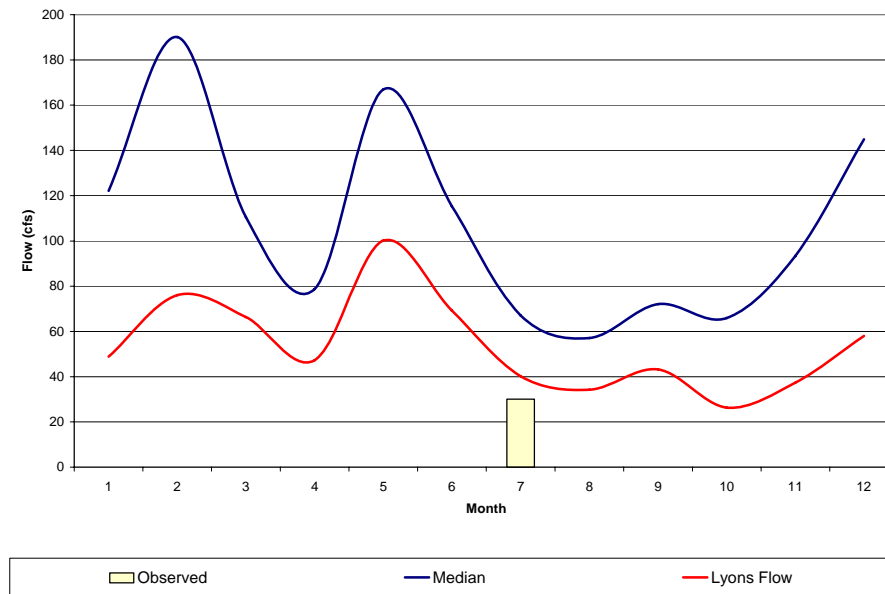
Characteristics: Freshwater Stream
Water Body Size 53 miles

Segment 1009 Land Use: Aquatic life
General use
Public water supply
Residential uses

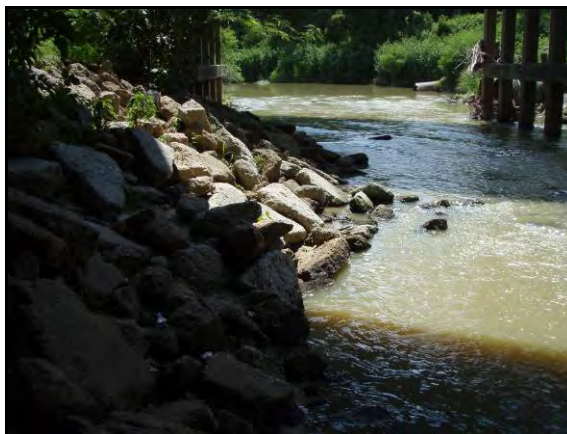
References:

2008 Texas Water Quality Inventory – Basin Assessment Data by Segment (March 19, 2008)
http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_basin10.pdf

Observed status: At the time of observation (July 21, 2008), Cypress Creek appeared to meet the SQWM definition of “High” Channel Flow Status. Less than 5% of the channel substrate was exposed. No potential wetlands or riparian habitats were visible at the location of the USGS monitoring station.



Survey Point - USGS Station 08069000 Cypress Creek at IH 45 crossing near Westfield, TX
(photos)



Survey Point - USGS 08068090 West Fork San Jacinto River above Lake Houston near Porter, TX

Stream: San Jacinto River Basin

Segment: 1004 Classified West Fork San Jacinto River
From the confluence of Spring Creek in Harris/Montgomery County to Conroe Dam in
Montgomery County

Station: USGS 08068090

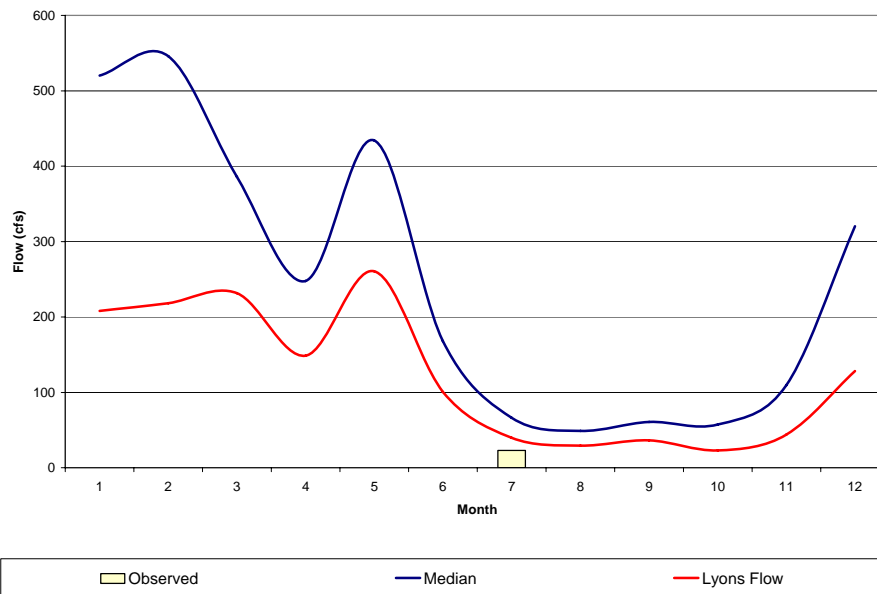
Characteristics: Freshwater Stream
Body Size 40 miles

Segment 1004 Land Use: Aquatic life
General use
Public water supply use
Residential use

References:

2008 Texas Water Quality Inventory – Basin Assessment Data by Segment (March 19, 2008)
http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_basin10.pdf

Observed status: At the time of observation (July 21, 2008), West Fork San Jacinto River appeared to meet the definition of “Moderate” Channel Flow Status. Less than 25 percent of channel substrate was exposed. Small sloughs jutting off the main river channel were present near the USGS monitoring station. These sloughs are potential wetlands. Some potential riparian areas were also present.



USGS 08068090 (photos)



Survey Point - USGS 08071280 Luce Bayou above Lake Houston near Huffman, TX

Stream: San Jacinto River Basin

Segment: 1002B Unclassified Water Body - Luce Bayou
From confluence with Lake Houston (Harris County) to FM 1008 (Liberty Texas)
Luce Bayou above Lake Houston near Huffman Texas

Station: USGS 08071280

Characteristics: Freshwater Stream
Water Body Size 22.3 miles

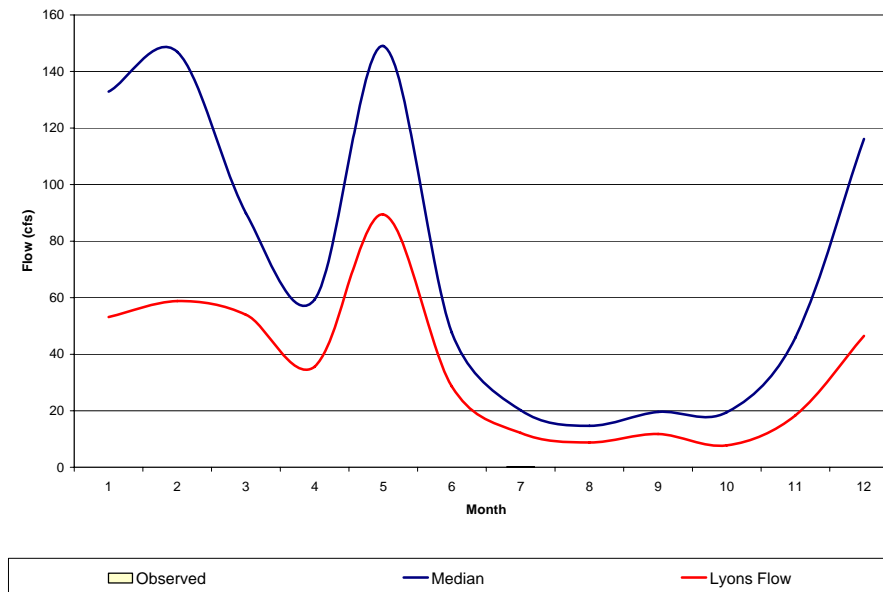
Segment 1002B Land Use: Aquatic life
General use
Residential use

References:

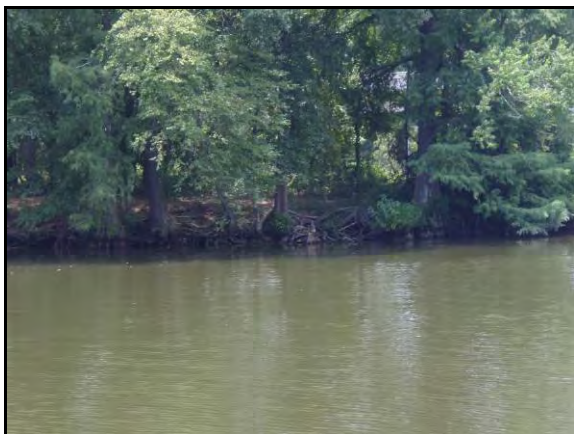
TCEQ Surface Water Quality Viewer
<http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/viewer/viewer.html>

2008 Texas Water Quality Inventory – Basin Assessment Data by Segment (March 19, 2008)
http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_basin10.pdf

Observed status: At the time of observation (July 21, 2008), Luce Bayou appeared to meet the definition of “Moderate” Flow Status. Less than 25 percent of channel substrate was exposed. Some potential fringe wetlands were present. Potential riparian habitats were present north of FM 2100 at the observed location.



Survey Point - USGS 08071280 Luce Bayou above Lake Houston near Huffman, TX (photos)



Survey Point - USGS 08067500 Cedar Bayou near Crosby, TX

Stream: Trinity-San Jacinto Coastal Basin

Segment: 0902 Classified Cedar Bayou Above Tidal
From a point 2.2 km (1.4 miles) upstream of IH 10 in Chambers/Harris County to a point 7.4 km (4.6 miles) upstream of FM 1960 in Liberty County.

Station: USGS 080067500

Characteristics: Freshwater Stream
Water Body Size 25 miles

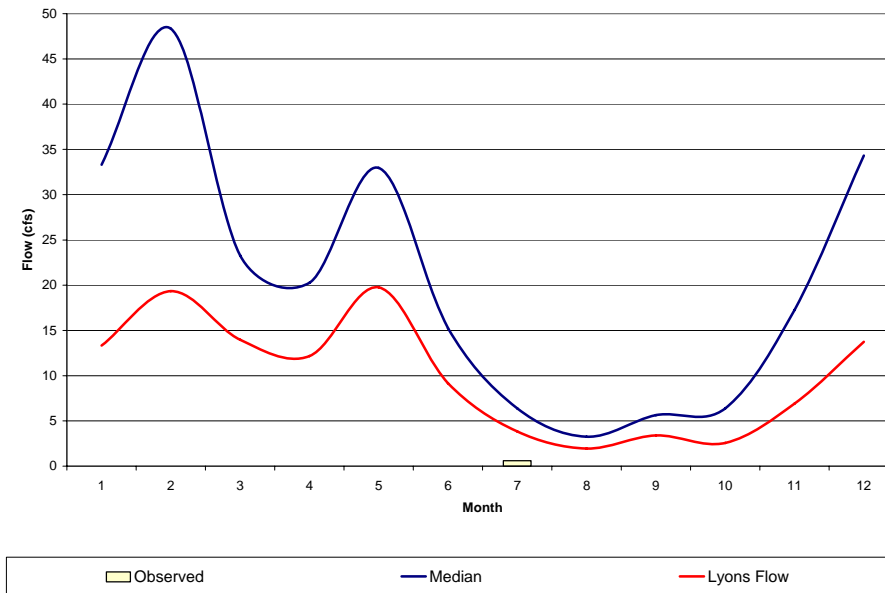
Segment 0902 Land Use: Aquatic life
General use
Public water supply
Residential

References:

TCEQ Surface Water Quality Viewer
<http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/viewer/viewer.html>

2008 Texas Water Quality Inventory – Basin Assessment Data by Segment (March 19, 2008)
http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_basin9.pdf

Observed status: At the time of observation (July 21, 2008), Cedar Bayou appeared to meet the definition of “Low” Channel Flow Status. Water filled 25 – 75 percent of the available channel and riffle substrates were mostly exposed. No potential wetlands or riparian habitats were visible.



Survey Point - USGS 08067500 Cedar Bayou near Crosby, TX (photos)



Survey Point - USGS 08116650 Brazos River near Rosharon, TX

Stream: Brazos River Basin

Segment: 1202 Classified Brazos River Below Navasota River
From a point 100 meters (110 yards) upstream of SH 332 in Brazoria County to the
confluence of the Navasota River in Grimes County

Station: USGS 08116650

Characteristics: Freshwater Stream
Water Body Size 217 miles

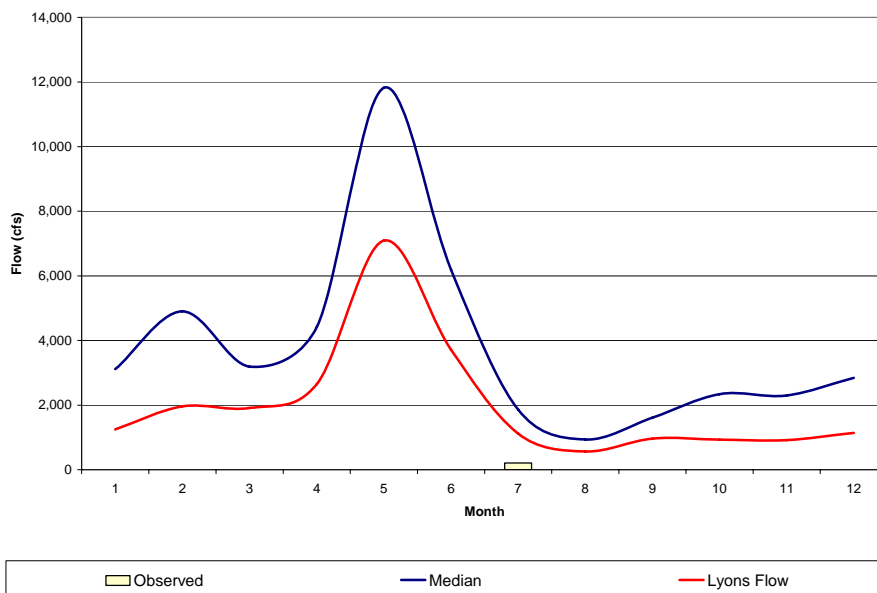
Segment 1202 Land Use: Aquatic life use
Fish consumption
General use
Public water supply
Recreation use

References:

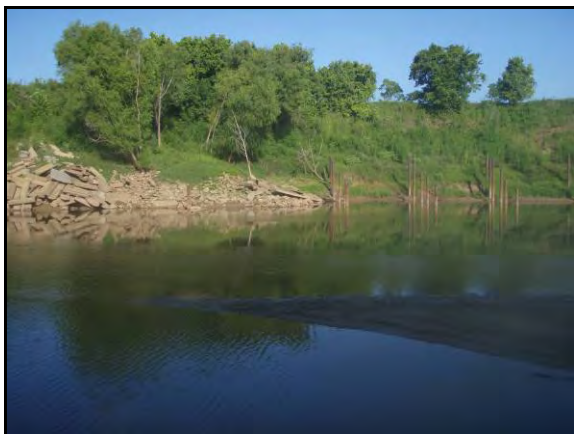
TCEQ Surface Water Quality Viewer
<http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/viewer/viewer.html>

2008 Texas Water Quality Inventory – Basin Assessment Data by Segment (March 19, 2008)
http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_basin12.pdf

Observed status: At the time of observation (July 21, 2008), the Brazos River appeared to meet the definition of “Low” Channel Flow Status. Water filled 25 – 75 percent of the available channel and riffle substrates were exposed. No potential wetlands or riparian habitats were visible.



Survey Point - USGS 08116650 Brazos River near Rosharon, TX (photos)



Survey Point - USGS 08067000 Trinity River at Liberty, TX

Stream: Trinity River Basin

Segment: 0802 Classified Trinity River Below Lake Livingston
From a point 3.1 km (1.9 miles) downstream of US 90 in Liberty County to
Livingston Dam in Polk/San Jacinto County

Station: USGS 080067000

Characteristics: Freshwater Stream
Water Body Size 84 miles

Segment 0802 Land Use: Cultivated land
Residential housing development
Commercial development
Residential uses

References:

TCEQ Surface Water Quality Viewer

<http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/viewer/viewer.html>

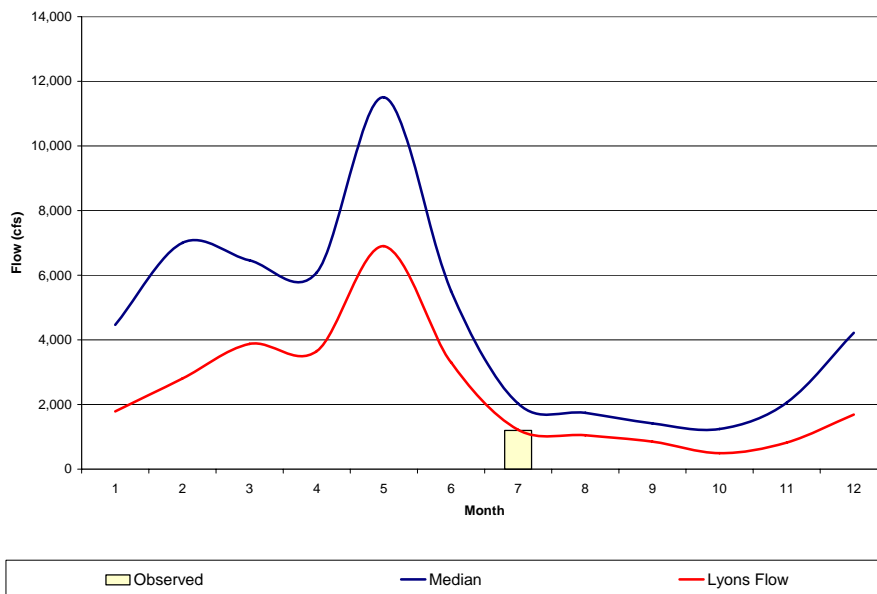
2008 Texas Water Quality Inventory – Basin Assessment Data by Segment (March 19, 2008)

http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_basin8.pdf

Ecologically Significant River and Stream Segment – Trinity River (Downstream of Lake Livingston)

http://www.tpwd.state.tx.us/publications/pwdpubs/pwd_rp_t3200_1059c/trinity_river2.phtml

Observed status: At the time of observation (July 21, 2008), the Trinity River appeared to meet the definition of “Moderate” Channel Flow Status. Less than 25 percent of channel substrate was exposed. No potential wetlands and a small potential riparian corridor appeared to be present.



Survey Point - USGS 08067000 Trinity River at Liberty, TX (photos)

