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APPENDICES

4. Identification, Evaluation and Selection of Water Management Strategies Based on Needs

This chapter describes the analysis required within 31 TAC 357.7 (a) (4-7) regarding the identification of water user groups with needs and identification, evaluation and selection of appropriate water management strategies for the Region H water planning area. Water management strategies have been defined for each of the identified future water shortages within Region H as required by the regional water planning process. Included within this report are:

- Review of the projected water shortages.
- Description of the potentially available water management strategies.
- Definition of the recommended management strategies.
- Allocation of selected strategies to specific Wholesale Water Providers (WWPs) and Water User Groups (WUGs).

In addition to the above, this report contains a description of socioeconomic impacts of not meeting the identified needs.

4.1 Identification of Needs

In Chapter 2, water demands were identified for all WUGs. In Chapter 3, water supplies available to Region H were identified and allocated to WUGs and WWPs based on current usage and contracts. By matching the supplies and the demands, projected surpluses and shortages were determined. Table 4A-1 in Appendix 4A lists all WUGs within Region H and their respective surplus or shortage. Projected shortages are referred to as needs.

Total water demands in Region H were 2,087,409 acre-feet per year in the year 2000, and are projected to increase to 3,412,457 acre-feet per year in year 2060. The projected 2050 demand is 3,173,614 acre-feet per year, which is approximately equal to the 2050 demand projected in the 2001 Region H Water Plan of 3,188,793 acre-feet per year. As discussed in Chapter 2, the demand projections for municipal and steam-electric power have increased, while those for manufacturing and irrigation have decreased. Total water supplies available to the region were estimated at 3,469,037 acre-feet per year in the year 2000. The estimates of available groundwater supplies included both developed (existing wells) and undeveloped supplies. Available supplies decline to 3,270,675 acre-feet per year in the year 2060 due to reservoir sedimentation and groundwater pumping limits enacted by the Harris-Galveston Coastal Subsidence District and the Fort Bend Subsidence District. This is approximately 200,000 acre-feet lower than the supply availability estimated in the 2001 Region H Water Plan. The decrease in supply is mainly due to the reduced availability reflected for the Carrizo-Wilcox aquifer, based on the estimate adopted by the Mid-East Texas Groundwater Conservation District.

The sum of the projected shortages in Table 4A-1 is 288,560 acre-feet per year in the year 2010, increasing to 1,069,469 acre-feet per year in the year 2060. The 2006 RWP year 2060 shortage is greater than the projected shortage of 790,000 acre-feet per year addressed in the

2001 Region H Plan. However, the increased shortage between the 2001 and 2006 RWPs is consistent with the projected growth rate in the 2001 RWP.

As in the 2001 plan, counties in the northern portion of the region have sufficient supplies to meet demands. Specifically, Austin, Leon, Madison, Polk, Trinity and Walker Counties have no projected shortages, predominantly due to the availability of groundwater. Additionally, the only projected shortages in Liberty and San Jacinto Counties are in irrigation, where some water rights for irrigation are not reliable during drought of record conditions.

Water shortages are projected for 250 WUGs in Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, San Jacinto and Waller Counties (see Table 4-1). The projected shortages are predominantly in Fort Bend, Harris and Montgomery Counties, where the majority of the WUGs are located and the current groundwater supply (from the Gulf Coast aquifer) will be exceeded by demands in the next 20 years. The greatest shortage increases from the 2001 plan are seen in Brazoria County, where manufacturing demand projections are significantly higher than in the 2001 plan (379,000 acre-feet per year in 2060, compared to 344,000 acre-feet per year in 2050 in the 2001 plan). Also, the Fort Bend Subsidence District regulatory plan has accelerated the need to bring surface water into that county. The demand projection for steam electric power also dramatically increased from the 2001 plan, which eliminated the surplus previously shown in that category.

Despite the increase in Brazoria County, the overall demand projection for manufacturing declined by approximately 5% from the previous planning cycle. Also, the projection for overall irrigation demands declined by approximately 10%.

Wholesale water providers (WWP) supplies and contracts were reviewed to determine their respective surplus or shortage during the planning period. These results are shown in Table 4A-2A in Appendix 4A. As discussed in the next section, one of the first water management strategies considered was the increase of existing water supply contracts from WWP sources to meet projected customer demands. This resulted in the full use of some WWP supplies, as shown in Table 4A-2B.

Table 4-1: Projected Shortages by County and Category

Brazoria	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
MUN	-9,280	-10,716	-14,006	-17,417	-21,888	-26,984
IRR	-32,511	-24,158	-23,298	-23,231	-25,045	-26,696
MFR	-47,629	-69,994	-91,937	-114,463	-134,894	-159,815
MIN	-393	-568	-805	-1,049	-1,337	-1,622
TOTAL	-89,813	-105,436	-130,046	-156,160	-183,164	-215,117
Chambers						
MUN	-1,526	-1,844	-2,145	-2,414	-2,703	-3,014
IRR	-27,053	-27,277	-27,411	-27,534	-27,652	-27,753
MFR	-8,264	-9,230	-10,252	-11,284	-12,240	-13,445
MIN	-5,708	-8,517	-10,378	-12,209	-14,026	-15,659
TOTAL	-42,551	-46,868	-50,186	-53,441	-56,621	-59,871
Fort Bend						
MUN	-20,713	-36,027	-63,093	-88,107	-121,713	-161,061
MFR	-1,362	-2,685	-4,298	-4,515	-4,659	-4,240
MIN	-43	-278	-786	-811	-834	-854
TOTAL	-22,118	-38,990	-68,177	-93,433	-127,206	-166,155
Galveston						
MUN	-3,940	-4,708	-5,126	-5,206	-5,294	-5,399
IRR	-10,143	-9,809	-9,264	-9,261	-9,277	-9,304
MIN	-31	-44	-50	-57	-63	-69
TOTAL	-14,114	-14,561	-14,440	-14,524	-14,634	-14,772
Harris						
MUN	-26,951	-120,973	-190,009	-228,382	-269,287	-312,724
MFR	-32,477	-42,126	-50,358	-57,634	-63,078	-60,346
MIN	-271	-423	-518	-613	-709	-794
PWR	0	-8,218	-12,038	-16,695	-22,371	-29,564
TOTAL	-59,699	-171,740	-252,923	-303,324	-355,445	-403,428
Liberty						
IRR	-14,346	-14,543	-15,827	-17,264	-18,972	-21,032
Montgomery						
MUN	-10,909	-33,316	-53,880	-76,064	-106,014	-141,307
MFR	-343	-884	-1,291	-1,672	-2,056	-2,442
MIN	-80	-193	-261	-315	-368	-413
PWR	0	0	0	-1,815	-4,140	-6,885
TOTAL	-11,332	-34,393	-55,432	-79,866	-112,578	-151,047
San Jacinto						
IRR	-492	-492	-492	-492	-492	-492
Waller						
MUN	-52	-101	-121	-120	-276	-1,026
IRR	0	0	0	0	-192	-1,133
MFR	0	0	0	0	-1	-6
TOTAL	-52	-101	-121	-120	-469	-2,165
Region H Total						
MUN	-73,371	-207,685	-328,380	-417,710	-527,175	-651,515
IRR	-84,545	-76,279	-76,292	-77,782	-81,630	-86,410
MFR	-90,075	-124,919	-158,136	-189,568	-216,928	-240,294
MIN	-6,526	-10,023	-12,798	-15,054	-17,337	-19,411
PWR	0	-8,218	-12,038	-18,510	-26,511	-36,449
TOTAL	-254,517	-427,124	-587,644	-718,624	-869,581	-1,034,079

Note: Shortages reflect use of currently developed and future available groundwater.

4.2 Potential Water Management Strategies

Potentially feasible water management strategies were identified in three ways. First, strategies recommended in the 2001 Region H Water Plan for either implementation or additional study were considered potentially feasible. Next, new strategies were solicited during the scope development period for the 2006 Water Plan. Finally, sponsoring agencies that conducted independent strategy studies could bring their reports to the planning group and request they be considered in the plan. As examples, the Brazos Saltwater Barrier was strategy developed during the scoping period, and the two municipal wastewater reclamation strategies were brought to the RHWPG during the planning cycle.

In the 2001 Regional Water Plan, thirteen water management strategies (WMS) were recommended to meet future demands. Of these, two have been implemented: the voluntary redistribution of BRA supplies through contract adjustments and the purchase of Trinity River supplies from CLCND by the SJRA. In Amendment 1 to the 2001 Plan, indirect reuse of wastewater by SJRA was recommended and that permit has since been issued by the TCEQ. The remaining eleven strategies were reassessed during the current round of planning. Two additional strategies were considered, an interbasin transfer of existing supplies from east Texas (i.e., the Lower Neches Valley Authority and the Sabine River Authority) and a saltwater barrier to protect water quality in the lower Brazos River. During the planning period, Governor Perry started a seawater desalination initiative through the TWDB. One of the sites considered is within Region H and specifically located in Freeport. Finally, the 2001 Regional Water Plan was amended to add additional strategies being pursued by Wholesale Water Providers in the region. All of the management strategies discussed above were considered as potential management strategies in this plan.

4.2.1 Studies by the RHWPG

Potential water management strategies were defined based on the above determination of needs. Strategies were updated and configured to address the specific types and nature of identified shortages. As in the 2001 RWP, the strategies were analyzed at the wholesale provider or county level. A number of potential strategies were defined for Montgomery County due to the projected growth in the county. The following potential management strategies were identified:

- Municipal Water Conservation
- Irrigation Conservation
- Industrial Conservation
- Non-Municipal Contractual Transfers
- Allens Creek Reservoir
- Bedias Reservoir
- Bedias Reservoir to Lake Conroe Transfer
- Little River Reservoir
- Wastewater Reclamation for Industry
- City of Houston/Trinity River Authority Contract Agreement

- Luce Bayou Interbasin Conveyance
- Houston To Gulf Coast Water Authority Transfer
- Brazos Saltwater Barrier
- Brazos River Authority System Operations Permit
- Houston Indirect Wastewater Reuse
- NHCRWA Indirect Wastewater Reuse
- New permits in the San Jacinto Basin (Lake Houston yield, San Jacinto run-of-river, and four bayous)
- Redesignation of Existing Water Rights
- San Jacinto River Authority/ Trinity River Authority Contract Agreement
- Expanded use of Groundwater
- Sabine Basin to Region H Interbasin Transfer
- Municipal Irrigation Reuse

For each of these management strategies a detailed technical memorandum is provided in Appendix 4B. Not all of the strategies evaluated are based on developing additional water. Several strategies consist of water transfer facilities only (e.g., Luce Bayou or Bedias Transfer). Expanded use of groundwater addresses the requirements to fully develop existing groundwater supplies. Other strategies only involve the contractual exchange of water supplies between various water suppliers (e.g., the TRA / City of Houston water transfers). These strategies recognize the need to transfer supply from areas of excess to the specific areas of need.

No groundwater transport strategies were investigated since there is projected to be full utilization of the regulated or sustainable yield of all of the aquifers within the counties of highest water demand. The 2001 plan identified Leon and Madison Counties as having surplus groundwater supplies, but did not recommend development and transport of that supply. Since then, the Bluebonnet, Lone Star and Mid-East Texas Groundwater Conservation Districts were formed, and each has published a Groundwater Management Plan. The Region H Water Planning Group has elected to not consider strategies that move groundwater out of its county of origin.

The technical memorandum reviewing 19 potential surface water reservoir projects was updated and included in Appendix 4B. Separate, more detailed technical memoranda are included for the three projects recommended in the 2001 Regional Water Plan (Allens Creek reservoir, Bedias Reservoir and Little River Reservoir).

Assessment of each of the potential management strategies conducted as a part of this study included an evaluation of cost, environmental impacts, impacts on other water resources, and additional factors as applicable. Discussions of necessary implementation activities associated with various strategies are also included in the technical memoranda. In order to assess the strategies on a comparable cost basis, a detailed set of unit costs was developed and applied to each alternative. A description of the costing methodology is contained within Appendix 4C.

4.2.2 Studies by Others

Several of the water management strategies considered by the RHWPG were studied in detail by other agencies. The Freeport Seawater Desalination Project, Brazos River Authority System Operations Permit, and the Little River Off-Channel Reservoir were studied in greater detail by others and incorporated into the current plan as potential management strategies. The technical memoranda included in Appendix 4B contain summaries and/or extracts from the source reports.

Governor Perry directed the TWDB in 2002 to develop a seawater desalination demonstration project. The TWDB selected three potential sites, in the Lower Rio Grande Valley – Brownsville, Corpus Christi and Freeport, this last being within Region H. The Freeport study recommends a 10-mgd demonstration facility be constructed, with the potential for future expansions up to 50-mgd.

The Brazos River Authority submitted a water right application in 2004 for additional yield gained through System Operations. The technical study in support of the application determined that additional firm yield could be realized from the BRA system when their reservoirs are operated as a system instead of as separate sources. The additional yield comes from a combination of reservoir capacity not recognized in the existing permits, efficiencies realized when operated as a system, and the ability to use unreliable river flows, when available, to meet demands and thus increase the amount of stored water for drought periods.

Finally, the Brazos G Water Planning Group studied several new reservoirs in the middle and upper Brazos River Basin, and has modeled these sites using the Watershed Availability Model. The Little River Reservoir was selected as a management strategy by Region H in the 2001 plan. The Little River Off-Channel Reservoir (Beaver Creek Site) was considered by the RHWPG in this round of planning. Excerpts from the Brazos G report are contained in the technical memoranda for Little River Off-Channel Reservoir.

4.2.3 Need for Interbasin Transfers

As can be seen by reviewing the current water supplies and potential water management strategies, Region H is highly dependent upon the interbasin transfer of water. Water is currently imported from Lake Livingston and the Trinity River to meet demands in Harris County, and from the Brazos River to meet demands in Galveston County. Future strategies recommend fully utilizing existing supplies in all basins, which will require transferring additional water from the Trinity Basin to the San Jacinto basin for Harris and Montgomery Counties. Most important of these in the near term is the Luce Bayou Transfer, which will move available water from the Trinity River into Lake Houston where it can be utilized.

Under current law, amending a water right to allow the interbasin transfer of supply makes the water right junior to all other rights in the source basin. Because reliability is partially based on the seniority of a water right, this provision in the water code makes new interbasin transfers difficult to accomplish. However, water transferred from a river basin to the adjoining coastal basin is not considered an interbasin transfer. Therefore, transfers from the Brazos River to Galveston County or from the Trinity River to eastern Harris County are not at risk. However, a significant portion of the growth and demands to be met are in the San Jacinto basin. Some of the water identified to meet this demand is already permitted for

interbasin transfer. These supplies include the TRA portion of Lake Livingston, the City of Houston Trinity River permits and the SJRA Devers Canal permit. Other water rights must be amended to allow this transfer, such as the CLCND supply recently purchased by the SJRA.

4.2.4 Drought Management

The Regional Water Planning Guidelines require that drought management strategies be considered for each identified need. If drought management is not selected as a strategy, the reason must be documented. Drought management strategies may include water demand management.

The supply and demand values used for this plan are based on estimated drought of record conditions. Under non-drought conditions, the region will have an overall surplus of supply, that surplus does not coexist with the growing demand areas. The majority of available supply is in Lake Livingston, which is in the Trinity Basin. The majority of the growth is occurring in Brazoria, Fort Bend, Harris and Montgomery Counties, which are in the Brazos and San Jacinto Basins. To meet the demands where they occur, supply from the Trinity must be transferred into the San Jacinto Basin. Once that infrastructure is constructed, it is not "drought-susceptible", because the permitted yield of the underlying water rights does not exceed the drought yield. Similarly, surface supplies are replacing groundwater due to subsidence regulations, and that supply is also firm yield.

Within the Brazos Basin, there is a significant difference between the permitted and drought yield of the DOW manufacturing water right (almost 60,000 acre-foot/year, or 30% of the permitted yield). Other lower basin water rights also see drought affects, although none so severe. The TCEQ requires that supplies used to meet municipal demands be firm (drought-of-record) yields, so none of this non-reliable supply may be assigned to meet future growth. It is generally more costly to transfer existing supply from the Trinity Basin than to develop new supply in-basin; therefore, the new in-basin projects with firm yields were recommended in the plan as being superior to inter-basin transfers.

The shortages identified in the plan are based on future demands (based on projected growth) exceeding the drought yield of existing supplies. The strategies recommended to meet these shortages also reflect estimated drought yields. Because Region H was able to address all projected shortages through conservation, allocation of existing supplies and development of new supplies, no unmet demands remain to be addressed through drought management strategies.

This does not preclude some WUG's from electing to use drought management in lieu of a recommended strategy. The best example of this is for irrigation. Region H recommends irrigation conservation as a management strategy in those counties with projected irrigation shortages. However, portions of those irrigation demands are met today through the use of water rights which are not fully reliable, backed up by one-year contracts for reliable supply as needed. Irrigators holding interruptible water rights may choose not to implement conservation (at an annual cost), but instead choose to reduce their irrigated acreage during a drought year (for a discrete cost), or enter into long-term contracts for reliable surface water from a wholesale supplier (which will be available in our eastern counties). That is an

individual economic decision and the Region H plan leaves them the flexibility to exercise that option.

Region H has sufficient supply available from existing sources and recommended strategies to meet near-term and long-term needs under projected drought of record conditions. In the counties with greatest projected demands, the groundwater use from the Gulf Coast aquifer is limited through Subsidence District regulations and not by aquifer productivity. While over-drafting of the aquifer is not the recommended drought response, it remains as a short-term safety net while new surface supplies are developed.

Finally, municipalities and water providers throughout the region have published drought contingency plans. In general, these plans are designed to address short-term periods of limited water availability through public notice and outdoor water use restrictions. While these methods are effective over a limited period of time, they are unlikely to overcome the drought of record, which lasted five years. Only the development of reliable supplies to meet projected growth will protect the region from the economic impacts of a prolonged drought.

4.3 Strategy Evaluation and Selection

In evaluating the potential water management strategies, the Region H Water Planning Group made three assumptions. First, water user groups would continue to develop groundwater until it was fully utilized. This is based upon the observed pattern of development in the region, where the Gulf Coast aquifer is available in all of the southern counties. Second, those WUGs currently receiving water from Wholesale Water Providers would be able to increase their contract amounts until the WWP supplies were fully allocated.

Finally, the RHWPG assumed that every municipal WUG with a projected shortage would utilize conservation before seeking out or increasing a WWP contract. Based on these assumptions, the projected shortage in 2060 is reduced from 1,069,500 acre-feet to 941,700 acre-feet (see Table 4-2).

4.3.1 Evaluation of Water Management Strategies

The potential water management strategies were compared using a screening table (See Table 4A-3 in Appendix 4A), with the required environmental assessments summarized in Table 4A-4. The comparison table summarized project yield, capital and unit water costs, impacts on wetlands habitats and B&E flows, and impacts on landform. Evaluation criteria included cost, yield, location, water quality, environmental land and habitats, local preference, institutional constraints or risk of non-implementation, impacts on environmental flows and impacts on other water management strategies. In each of the evaluation categories, the strategy was rated positively (+1), neutral (0) or negatively (-1), using evaluation criteria summarized in Table 4-3, below. As would be expected, water conservation and full use of existing supplies rated the highest of the potential strategies. Direct wastewater reuse for industry also rated highly. Although direct reuse is more costly that using existing supply, it is less expensive than developing a new freshwater source, and with fewer environmental impacts. Seawater desalination ranked below direct reuse due to the higher cost of the supply, but it too carried few environmental impacts. Equal in rank with desalination were the inter-basin transfer of existing Lake Livingston supply, increased yield realized from Lake Houston, the BRA System operations permit and the construction of a saltwater barrier

on the lower Brazos River. All of these strategies would impact flows in the source basins. Next ranked were the indirect reuse strategies for Houston and North Harris County Regional Water Authority, and the transfer of supply from Houston to GCWA. All of the above strategies were rated positively in the cost-benefit-impact analysis. Certain strategies (i.e., the inter-basin transfer of supply from east Texas and all of the potential reservoir sites) were rated negatively due to the significant habitat and flows impacts these projects entail.

Table 4-2: Initial and Net Shortages by County

	2010	2020	2030	2040	2050	2060
Brazoria County						
Initial Shortage*	-89,813	-105,436	-130,046	-156,160	-183,164	-215,117
Municipal Conservation	1,321	2,290	2,713	2,976	3,274	3,600
Contract Expansions (1)	2,350	3,220	4,715	4,835	4,835	4,835
Net Shortage**	-87,719	-102,277	-125,098	-149,903	-175,921	-206,703
Chambers County						
Initial Shortage*	-71,405	-75,994	-79,498	-82,954	-86,366	-89,888
Municipal Conservation	114	137	158	174	196	216
Net Shortage**	-71,291	-75,857	-79,340	-82,780	-86,170	-89,672
Fort Bend County						
Initial Shortage*	-22,118	-38,990	-68,177	-93,433	-127,206	-166,155
Municipal Conservation	2,792	3,998	6,749	8,357	10,418	12,869
Contract Expansions (2)	0	1,178	1,178	1,178	1,178	1,178
Net Shortage**	-19,326	-34,518	-60,609	-83,898	-115,610	-152,108
Galveston County						
Initial Shortage*	-14,114	-14,561	-14,440	-14,524	-14,634	-14,772
Municipal Conservation	548	604	636	643	649	657
Net Shortage**	-13,566	-13,957	-13,804	-13,881	-13,985	-14,115
Harris County						
Initial Shortage*	-59,699	-171,740	-252,923	-302,492	-355,445	-403,428
Municipal Conservation	5,100	18,153	21,179	23,845	26,468	29,296
Contract Expansions (3)	10,334	62,198	62,268	62,313	62,313	62,322
Net Shortage**	-47,592	-93,664	-171,016	-218,193	-267,168	-311,813
Liberty County						
Irrigation Shortage*	-19,535	-19,774	-21,089	-22,558	-24,303	-26,405
Montgomery County						
Initial Shortage*	-11,332	-34,393	-55,432	-79,866	-112,578	-151,047
Municipal Conservation	4,285	5,695	6,971	8,312	10,112	12,230
Net Shortage**	-7,047	-28,698	-48,461	-71,554	-102,466	-138,817
San Jacinto County						
Irrigation Shortage*	-492	-492	-492	-492	-492	-492
Waller County						
Initial Shortage*	-52	-101	-121	-120	-469	-2,165
Municipal Conservation	10	10	10	10	167	602
Net Shortage**	-42	-91	-111	-110	-302	-1,589
Region H Totals						
Initial Shortages	-288,560	-461,481	-622,218	-752,599	-904,657	-1,069,469
Net Shortages	-266,610	-369,328	-520,020	-643,369	-786,417	-941,714

* Shortage values reflect the sum of all WUG shortages without offsets for other WUG surpluses.

** Net Shortage value is not the mathematical difference because conservation and expansions do not align exactly with WUG shortages.

(1) Contract expansions by Brazosport Water Authority

(2) Contract expansion by City of Houston for WHCRWA

(3) Contract expansions by Cities of Houston and Pasadena, and Baytown Area Water Authority

The effects of strategies in combination were considered through the use of the TCEQ Water Availability Model, described in Section 4.5 and Appendix 4D. For this modeling scenario, the recommended water management strategies from the 2001 Regional Water Plans were incorporated into the model. As described in detail in Section 4.5, the cumulative affect of the current State Water Plan on Galveston Bay was a slight increase in freshwater inflows over current conditions, with a shift of inflows west from Trinity Bay into Upper Galveston Bay. A portion of that study was directed at determining the affects of the WMS in combination on lake levels. This is discussed in greater detail in Chapter 5, but is generally discussed below. The lake level study compared current use, full use of water rights with current return flow percentages, full use of water rights with full reuse (no return flows) and future strategies in combination with current return flow percentages unless reuse was specified. The comparison underscored the volume of return flows within the Trinity and San Jacinto basins, and the potential impacts full reuse would have on water availability.

Table 4-3: WMS Rating Criteria

	Rating Criteria		
Category	**-1**	**0**	**1**
Cost	<$100/ac-ft	<$200/ac-ft	>$200/ac-ft
Yield	Size is too small or too large for need	Size is flexible or meets needs	Size can be adjusted to optimum
Location	IBT required, long distance or outside Region H.	No IBT required. Conveyance required.	No IBT required. Relatively near demand.
Water Quality	Quality of supply is reduced.	No known water quality issues.	Existing water quality problems are reduced.
Environmental Land & Habitat	Significant environmental issues and opposition.	Environmental impacts can be mitigated. Limited concerns.	Limited or no known impacts.
Local Preference	No local support. Significant opposition.	Some local support. Limited opposition.	Widespread local support. Multi-use benefits likely.
Institutional Constraints / Risk of Implementability	Permits opposed. Significant property required.	Permits expected with minimal problems. Property available.	Permits issued. Facilities or land owned. Water available.
Impacts on Environmental Flows	Reduces instream or B&E flows.	No impact.	Increases instream or B&E flows.
Impacts on Other Management Strategies	Negative impact.	No impact.	Positive impact.

4.3.2 Water Conservation

The RHWPG advocates water conservation for all water users in the Region, noting that "the least expensive water you can get is the water you already have." Some conservation will be realized through low-flow water fixture laws (embedded in the demand estimates), and from new energy-efficient clothes washers, but more savings can be achieved. Every water user group and provider is encouraged to establish an aggressive water conservation goal. The Water Conservation Implementation Task Force established by the 78th Texas Legislature recommended a goal of reducing demand by 1% each year to achieve an average demand of 140-gpcd. Because the median municipal water demand in this region is 135-gpcd, because

conservation programs are voluntary, and because they require an investment of time and resources to implement, this plan only reflects water conservation as a water management strategy for water user groups with projected shortages and those that specifically asked to reflect their program in the plan tables. These savings are conservatively estimated at 5.5 to 7 percent of total demand, based on current best management practices that are producing results.

4.3.3 Selection of Water Management Strategies

To facilitate the strategy selection process, water needs and potential strategies were grouped and evaluated on a county-by-county basis (see Table 4A-5). Efforts were then made to select the best-rated strategies to meet the needs in those counties. In Chambers, Liberty, San Jacinto and Waller Counties, that was possible because a combination of water conservation and existing supply was sufficient to meet the projected shortages. Several larger strategies, (BRA System Operations, Freeport Desalination, Allens Creek Reservoir and Little River Off-Channel Reservoir) were required to meet the needs of Fort Bend and Brazoria Counties. In Harris County, direct and indirect reuse along with TRA supply purchased from Lake Livingston was sufficient to meet projected demands. In Montgomery County, the ability to transfer Trinity Basin supply via Luce Bayou and Lake Houston facilitated the full use of existing supplies. Once the slate of strategies was selected, the starting decades were adjusted to match the projected demands. A summary is provided in Table 4-4, below, and shown in detail in Table 4A-6.

Two projects from the 2001 Region H Water Plan were replaced under this selection process. Little River (on-channel) Reservoir was replaced with a combination of BRA System Operations and the Little River Off-Channel Reservoir. The System Operations strategy requires no infrastructure other than diversion pump stations, and the off-channel version of Little River Reservoir avoids bottomlands areas. These two strategies have less potential impact on wetlands and aquatic habitats than the original reservoir strategy. Second, Bedias Reservoir and the associated interbasin transfer were replaced with a shared interbasin transfer from the Trinity Basin to Lake Houston.

Several of the recommended strategies produce no yield. The Luce Bayou Transfer is a conveyance project that would be used in conjunction with Expanding Current Contracts, New Contracts from Existing Supply, TRA to Houston Contract, and TRA to SJRA Contract. The Brazos Saltwater Barrier would protect current water right holders in the lower Brazos from saltwater migration during periods of low flows and increased future diversions (i.e., full utilization of authorized diversions). Redesignation of existing water rights to add use types does not increase the yield of that right, but allows the water provider to serve new water users as they change within a given service area.

Table 4-4: Recommended Water Management Strategies

WMS	Yield (ac-ft/yr)	Capital Cost	Starting Decade
Municipal Conservation*	101,200	0	2000
Irrigation Conservation	77,900	$ 573,000	2010
Industrial Conservation	TBD	TBD	2000
Expanded Use of Groundwater**	91,497	at WUG level	2010
Expand/Increase Current Contracts	68,300	at WUG level	2010
New Contracts from Existing Supply	215,400	see Luce Bayou	2010
Luce Bayou IBT Conveyance	N/A	$ 239,000,000	2020
BRA System Operations Permit	120,000	$4,500,000	2010
Allens Creek Reservoir	99,700	$ 170,040,000	2030
Little River Off-Channel Reservoir	32,100	$ 96,512,000	2050
Non-Municipal Contractual Transfers	21,000	at WUG level	2010
Wastewater Reuse for Industry	67,200	$ 234,158,000	2020
TRA to Houston Contract	150,000	see Luce Bayou	2030
TRA to SJRA Contract	50,000	see Luce Bayou	2030
Houston to GCWA Transfer****	42,000	$ 102,382,000	2010
Houston Indirect Wastewater Reuse***	98,000	TBD	2050
NHCRWA Indirect Wastewater Reuse***	31,400	TBD	2060
Lake Houston Additional Yield	13,500	$ 0	2010
Freeport Seawater Desalination	33,600	$ 255,699,000	2020
Brazos Saltwater Barrier	N/A	$ 30,300,000	2030
Redesignation of Existing Water Rights	N/A	N/A	2010
New San Jacinto River Water Rights	0	$ 0	2010
New Harris County Bayous Water Rights	0	$ 9,013,000	2010

* Includes COH voluntary conservation.
** Future development of groundwater shown as available to each WUG
***Indirect reuse recommended at 20% of potential yield
****Two tier plan that includes 14,000 ac-ft/yr in 2010 option or up to 42,000 ac-ft/yr in 2050.

Two of the recommended water rights applications produce no firm yield, specifically the Houston/SJRA joint permit application for interruptible supply from the San Jacinto River and the City of Houston permit application for interruptible supply from four bayous within the city limits. They are included to allow the applicants to develop operational plans for conjunctive use of these local supplies with firm supplies transferred from the Trinity River. While these permits would reduce flows into Upper Galveston Bay, the affects would be mitigated by wastewater return flows back into the source streams. The offset Trinity River supplies would remain in-basin and flow into Trinity Bay, where the historic freshwater inflow demand is the greatest.

There were no water quality concerns with any of the recommended WMS. That is, conventional water treatment would provide supply acceptable for the typical WUG needs, unless the strategy itself recommended a specific water quality improvement. These strategies included direct reuse of wastewater and seawater desalination, both of which required filtration and reverse osmosis treatment, and the Brazos saltwater barrier, which protects the quality of existing supply at current diversion points.

4.3.4 Alternate Water Management Strategies

Although all of the recommended WMS are feasible, it is not a certainty that all will be implemented, and those that are implemented may be of a different capacity or on a different schedule than that reflected in this plan. Several alternative WMS are available to Region H, either through increasing the capacity of recommended strategies or by replacing current strategies with feasible strategies recommended in the 2001 plan. Alternative strategies are potentially feasible strategies that will receive first consideration if additional supply is needed. These alternate strategies are summarized in Table 4-5 and described below.

Table 4-5: Alternate WMS Available to Region H

Strategy	WUG(s)	County	Basin	Yield ac-ft/yr	Could Replace
COH Indirect Reuse (50%)	all	101	10	245,100	TRA to COH Transfer
NHCRWA Indirect Reuse (50%)	all	101	10	78,500	Luce Bayou Transfer
Freeport Desal (Full Use)	all	020, 079	12	28,000	BRA System Operations
COH transfer to Fort Bend	MUN	079	10, 11	30,000	COH to GCWA transfer
COH transfer to GCWA	MUN, MFR	084	11	8,000	Little River Off-Channel Reservoir
GCWA transfer to Fort Bend	MUN	079	11, 12	8,000	Little River Off-Channel Reservoir
Bedias Reservoir and Transfer	all	170	10	90,700	TRA to SJRA Transfer
Little River Reservoir	all	020, 079	11, 12, 13	129,000	BRA System Operations
Contractual realignment of future sources between WUGs	All	079, 101, 170	9, 10, 11, 12	None	None

Indirect wastewater reuse by the City of Houston has a potential yield of 490,200 acre-feet per year (in addition to direct reuse of up to 90,700 acre-feet per year for industry). The RHWPG recommended allocating only 20% of that potential yield as a management strategy, based on the shortage after other WMS were applied to Harris County. This strategy could be increased to 50% of the potential available yield if the Luce Bayou transfer is delayed, or the TRA to Houston contract strategy is reduced in size.

Indirect wastewater reuse by the North Harris County Regional Water Authority has a potential yield of up to 157,000 acre-feet per year (in 2060). The RHWPG recommended allocating only 20% of that potential yield as a management strategy, based on the shortage after other WMS were applied to Harris County. This strategy could be increased to 50% of the potential available yield if the Luce Bayou transfer is delayed, or the TRA to Houston contract strategy is reduced in size. Because the majority of the discharges contributing to this permit are in the Lake Houston watershed, the additional yield could be realized at the Northeast Water Purification Plant which supplies the NHCRWA.

The Seawater Desalination Demonstration Plant in Freeport is initially sized at 10-mgd, and 25-mgd in the later decades. It could be expanded to 50-mgd if growth in mid-Brazoria County continues at its current rate, which will reduce the unit cost of water for the strategy.

A water transfer from Houston to the Gulf Coast Water Authority is recommended as a means of meeting demands in Galveston County. The recommended project is oversized for

Galveston County, which would allow the GCWA to reallocate a portion of its Brazos River supply to customers in Fort Bend County. An alternative to this strategy is for the City of Houston to provide water directly to customers in Fort Bend County, particularly since Houston's city limits extend into Fort Bend. Conversely, the GCWA transfer strategy could also be increased in size to bring more water into Galveston County from the east, and allow the GCWA to further increase sales of Brazos water in Fort Bend County.

Two reservoir projects from the 2001 Region H plan were not recommended in the 2006 plan, because other WMS with similar yields were available as substitutions. If the Luce Bayou conveyance from the Trinity River to Lake Houston becomes unfeasible, or if the supply to be transferred is reallocated elsewhere, an alternate transfer strategy would be Bedias Reservoir and the transfer into Lake Conroe. In the Brazos Basin, if the BRA system operations permit is not approved, or allocated elsewhere in the basin, the Little River main-stem reservoir is the only available alternative of similar yield. The development of the Little River Off-Channel Reservoir would remove the main-stem site from consideration, because they capture the same flows. Both of the reservoir alternatives require significant advance planning and permitting, and cannot be implemented as quickly as the other strategies.

Finally, this plan allocates future supply from WWPs to WUGs based on existing contracts and service areas. Many of these WWPs own multiple sources of supply, some of which are located within other WUG service areas. It would be more efficient for those WUGs to receive supply from the nearest source, either through a new contract with the owning WWP, or a transfer of supply between WWPs. This is likely to occur in Montgomery County, where the City of Houston supply in Lake Conroe is closer to the demand centers than the SJRA supply available in the lower San Jacinto Basin. The contractual exchange of either customers or supplies between these WWPs would reduce the infrastructure required to bring new supply into Montgomery County. In Fort Bend County, both the BRA and the City of Houston are capable of providing supply from Allens Creek Reservoir. The WHCRWA is listed in the plan as receiving supply from the east via the City of Houston. However, the WHCRWA extends into Fort Bend County, and could receive a portion of their future supply from this Brazos Basin supply. The BRA and the City would then reallocate their remaining available supplies between the remaining WUGs. Until contracts are actually entered into for all future supplies, the WWP-WUG associations will fluctuate, particularly in areas where service areas meet or overlap.

4.3.5 Future Water Management Strategies

As in the 2001 plan, some of the strategies considered were not recommended for inclusion in this plan, but should be reconsidered in future plans as the population and water demands of Region H increase in future decades. These future strategies include both new and existing water sources.

The transfer of water from East Texas remains a potential source of water for Region H. Toledo Bend and Sam Rayburn reservoirs have significant amounts of water available, and the cost and impacts of transferring this supply may compare favorably against the cost and impacts of developing the next future supply.

Additional desalination facilities should be considered in the subsequent regional plans. The pilot project at Freeport will provide the region with facilities and operational cost and

impact data (as well as 10-mgd of high-quality water). The western rim of Galveston Bay offers several attractive facility locations, including the P.H. Robinson power plant near Kemah and the industrial complex in Texas City.

4.4 Strategy Allocation

Water management strategies were allocated on a county by county basis. The Conservation strategies and Expanded Use of Groundwater were allocated directly to WUGs prior to the selection of new supply strategies, as shown in Table 4-2. New supply strategies were associated with the sponsoring WWP as discussed in the technical memoranda, then allocated by county, and finally down to individual WUGs. The details of these allocations are shown on Table 4A-6: Recommended WUG Water Management Strategies, and Table 4A-7: Recommended Water Management Strategies by WWP, both in Appendix 4A.

The City of Houston, which exists as both a WUG and a WWP, is not projected to experience a shortage within the planning period. However, the City of Houston has an aggressive water conservation program, and asked that it be reflected in the plan as a WMS. For consistency with the other large municipal WUGs (population 10,000 or greater), conservation savings were projected at 7% of total water demand and entered as a WMS.

Due to the large number of municipalities and water utilities within Region H, the RHWPG did not attempt to create an absolute linkage between every WUG and the wholesale water providers. Instead, this plan reflects a "Water Available for Purchase" concept, with sufficient supply available in each county to meet, and most cases exceed, projected demands. Selection of a provider is an individual WUG option, and in some locations, there may be three or more providers with available supply. In constructing Table 4A-6, new supplies are shown as coming from the existing water owner (if from a surplus) or from a project sponsor (if from a new supply). Intermediate WWPs (those which purchase supply from the water rights holders and then treat and resell the water) are not reflected in the new supply strategies, but will certainly serve as the closest wholesaler for WUGs in certain areas. Similarly, by the time some future strategies are implemented, there will be new wholesale water providers available, due to the growth of current retailers.

One additional factor affecting strategy allocation which is anticipated but not reflected in the plan is the formation of new regional water authorities. Region H currently has two regional water authorities, and the formation of a third in Fort Bend County is being considered during the current (2005) Legislative Session. These authorities are being formed in response to Subsidence District rules, which limit the amount of water demand that can be met from groundwater in Harris, Galveston and Fort Bend Counties. The Authorities manage the transition from groundwater to surface water for their member cities and utilities. By managing at a collective level, they are able to (1) address those WUGs with the most immediate needs earliest, (2) over-serve some members with surface water in order to allow others to remain on groundwater (because groundwater usage can be aggregated at the Authority level), and (3) enter into water supply contracts and construct required infrastructure at lower unit costs due to economies of scale. An additional advantage of forming Regional Water Authorities is that the RWA management team understands the long-term water supply needs of their area, and does not focus solely on the near-term. Both

the North Harris County RWA and the West Harris County RWA have actively participated in the Region H planning process.

Infrastructure costs were estimated for all of the potential and selected WMS, using the cost estimating methods detailed in Appendix 4C. See the respective technical memoranda in Appendix 4B for the costs associated with each management strategy. In addition, infrastructure costs were estimated for treatment and conveyance to each municipal WUG receiving water from a WMS, to include the cost for additional wells if needed to fully develop available groundwater. In Fort Bend and Montgomery Counties, a significant increase in surface water use is projected to meet future demands. In those counties, regional treatment and distribution facilities were sized to provide a basis for cost estimating, but are not considered the only facility alignment considered consistent with this plan. Variations from these groupings are normal and expected to occur.

In Fort Bend County, new surface water supply will come from the Brazos River. It was assumed that there would be three service areas. One would serve the northern portion of the county (above the Brazos River), one would serve the portion of Subsidence Area A west of the Brazos River (including Richmond and Rosenberg), and the third would serve the eastern edge of the County (including Sugarland and Missouri City). A diagram of these areas, the proposed pump stations, treatment plants and distribution systems are shown on Figure 4C-1 in Appendix C.

In Montgomery County, new surface water supply will come from Lake Conroe, the San Jacinto River at Lake Houston, and the Trinity River via the Luce Bayou transfer into Lake Houston. It was assumed that there would be two service areas. One would serve the northern portion of the county (above Highway 105, including all of Conroe), one would serve the southern portion of the County (including the Woodlands). A diagram of these areas, the proposed pump stations, treatment plants and distribution systems are shown on Figure 4C-2 in Appendix C.

The cost estimates for these regional facilities are provided in Table 4C-1 in Appendix 4C. The individual WUG infrastructure costs required to connect into the regional systems were estimated, and are detailed in Table 4C-2. In that table, each WUG is allocated a pro rata share of the regional facility cost in addition to their internal infrastructure cost.

Water savings associated with the new federal energy regulations which start in year 2007 can be seen in technical memorandum for Municipal Conservation in Appendix 4B-1. The water savings realized as a result of the new energy standards is estimated to range from 3,847 to 21,811 acre-feet for the 2010 and 2060 decades, respectively. Table 4A-1A shows the shortages for WUGs. The savings for the clothes washer conversion is calculated for each WUG, shown included in the shortages shown in Table 4A-1B and the supply reduction shown in Table 4A-10.

4.5 Impacts of the 2001 State Water Plan on Galveston Bay Inflows

As part of the 2002 State Water Plan, Region H and Region C identified new management strategies totaling over 2 million acre-feet per year. While the relationship between Region H and Galveston Bay is readily apparent, Region C also impacts Galveston Bay due to its location in the upper extents of the Trinity River Basin. Thus the management strategies from both regions have the potential to impact inflows to Galveston Bay.

The inflows to Galveston Bay are primarily from the Trinity and San Jacinto Rivers. The Neches-Trinity, Trinity-San Jacinto and San Jacinto-Brazos Coastal Basins also contribute inflows to the bay. For purposes of characterizing the location of inflows, the following 5 sub-bay designations will be used: East, Trinity, Upper Galveston, Lower Galveston and West Bays. Table 4-6 summarizes the basins contributing inflows to the various sub-bays. Figure 4D-1 in Appendix 4D shows the sub-bays of Galveston Bay, and Figure 4D-2 shows the basins contributing to Galveston Bay

Table 4-6: Basins and Sub-bays in the Galveston Bay System

Basin	Drainage Area[1]	Sub-bay
Trinity	17,945 sq mi	Trinity Bay
San Jacinto	3,978 sq mi	Upper Galveston Bay
Neches – Trinity[2]	368 sq mi	East Bay & Trinity Bay
Trinity - San Jacinto	250 sq mi	Upper Galveston Bay
San Jacinto-Brazos[3]	610 sq mi	Upper Galveston Bay, Lower Galveston Bay & West Bay
Total	23,151 sq mi	

1. Drainage areas from TCEQ WAMs.
2. The drainage area for the Neches-Trinity Basin does not include areas draining to the Intracoastal Waterway or Sabine Lake.
3. The drainage area for the San Jacinto-Brazos Basin does not include areas draining directly into the Gulf of Mexico.

Several models were run in order to represent a varied set of conditions. Naturalized flows represent the condition in the absence of any human impacts such as reservoirs, diversions or return flows. Naturalized flows are then used in all models as the base hydrology condition from which streamflow depletions for diversions and to fill reservoirs are made and to which return flows are added. Three models which were developed as part of the TCEQ WAMs have been analyzed, Runs 1 and 3 which simulated full authorized diversions with and without return flows, and Run 8 which simulated current conditions including a year 2000 reservoir area-capacity condition. As part of this project, Runs 1 and 3 were also simulated for year 2000 reservoir conditions. Finally, Run 1 was simulated with year 2060 area-capacity conditions. To this model, the proposed management strategies from Region C and Region H were added. Table 4-7 summarizes the various parameters in the individual models.

As part of the TCEQ WAM process, separate models were created for each river and coastal basin. Thus the total inflows into Galveston Bay are made up by aggregating the flows into various parts of the bay from the individual models.

The model results are presented in percentile tables, representing the amount of flow that occurs with various frequencies, for example, the 25th percentile of flow represents a flow value that is not met 25 percent of the time, and is exceeded 75 percent of the time. Similarly the 90th percentile represents an upper end flow value that is only exceeded 10 percent of the time.

The 2001 Regional Plan included the Galveston Bay Freshwater Inflows Group recommended inflows to Galveston Bay. The current plan also includes these inflow targets. This table, shown in Chapter 3.3.6.1, presents the historical frequency and recommended frequency of meeting the freshwater inflow targets, Max-H, Min-Q, and Min-Q Sal.

Table 4-7: Galveston Bay Inflow Model Scenarios

Scenario	Diversions	Return Flows	Reservoir Condition	Other
Naturalized Flows	None	None	N/A	
TCEQ Run1	Full Authorized	Yes	Original ACE	
TCEQ Run3	Full Authorized	No	Original ACE	
TCEQ Run8	Full Authorized	Yes	Year 2000 ACE	Represents "Current Conditions"
Year 2000 Run1	Full Authorized	Yes	Year 2000 ACE	
Year 2000 Run3	Full Authorized	No	Year 2000 ACE	
Year 2060 Run1	Full Authorized	Yes	Year 2060 ACE	
Year 2060 with Reg. C Strategies	Full Authorized	Yes	Year 2060 ACE	Includes Region C Mgmt Strategies
Year 2060 with Reg. C & H Strategies	Full Authorized	Yes	Year 2060 ACE	Includes Region C & H Mgmt Strategies

The specific results reported include monthly percentile tables, including the percentile ranking of the freshwater inflow targets for the total inflows to Galveston Bay. Similar tables are provided for the Trinity and San Jacinto Basins, with the freshwater inflow targets based on the historical, prorated, value from those basins (54 percent from the Trinity and 28 percent from the San Jacinto Basin). Additional *annual* percentile tables have been developed by basin and by sub-bay. These tables reveal the relative contribution of inflows from the various areas.

All model results are included in Appendix 4D. A brief summary of the various scenarios is presented in the following subsections.

4.5.1 Galveston Bay Inflow Estimates from Existing TCEQ WAM

The results show a reduction in inflows from the naturalized condition to current conditions (Run 8), full authorized diversions with return flows (Run 1), and full authorized diversions with no return flows (Run 3). (See Figure 4.1 in Section 4.6.5.) A comparison of the results from models with return flows (Run 8 and Run 1), shows that as diversions increase, more inflows enter Galveston Bay as return flows through the San Jacinto Basin and Upper Galveston Bay. (See Figure 4.2 in Section 4.6.5.) Comparing the percentile tables for Run 1

and Run 3 highlights the reduced ability to meet freshwater inflow targets in models with no return flows, particularly the theoretical inflow target from the Trinity River Basin.

4.5.2 Galveston Bay Inflow Estimates from WAM updated with Year 2000 Area-Capacities

Year 2000 reservoir conditions were simulated to quantify the impact of current levels of sedimentation on freshwater inflows, as well as to allow a comparison of the current diversion amounts to the authorized diversions amounts, with a common reservoir condition. Thus TCEQ WAM Runs 1 & 3 were modified and rerun using year 2000 reservoir area-capacity relationships. The results show a very slight increase in inflows to Galveston Bay as compared to the TCEQ WAM Runs 1 and 3, due to a reduced ability of reservoirs to capture streamflows. This increase is insignificant however, relative to the impact of different diversion and return flow parameters. The trend of reducing levels of inflows from the naturalized to the current, full authorized diversions with return flows and full authorized diversions with no return flows conditions still dominates the results.

4.5.3 Galveston Bay Inflow Estimates from WAM updated with Year 2060 Area-Capacities

Year 2060 area-capacity relationships were developed in order to allow evaluation of the impacts of existing water rights and future management strategies at the end of the planning horizon. The only basins with major on channel reservoirs (capacity greater than 5000 ac-ft) were the Trinity and San Jacinto. As a part of the TCEQ WAM project, year 2000 area-capacity relationships for the current conditions run had been developed. The sedimentation rates were based on historical reservoir surveys and projected sediment loading. The same methodology was used to develop year 2060 area-capacity relationships. As in the year 2000 models, future sedimentation will reduce reservoir storage capacities, and thus their ability to capture inflows is also reduced. A year 2060 Run 1 (full authorized diversions with return flows) was developed to quantify that impact. Comparison to the TCEQ Run 1 and Year 2000 Run 1 shows that reservoirs would tend to spill more frequently, creating a slightly higher level of inflows to Galveston Bay.

4.5.4 Incorporation of Region C and Region H Strategies in the Models

In order to evaluate water management strategies, many of which involve reuse or the transfer of supplies from one area to another, the base model must include expected return flows. Thus the Region C and H management strategies were added to the Year 2060 Run 1 as described in the previous section.

Both Region C and Region H have management strategies outside of the two river and three coastal basins which drain into Galveston Bay. The models developed for quantification of the impacts of the management strategies only include those basins which drain into Galveston Bay. Several reservoir strategies that are located outside of these basins will supply users in the basins. These strategies are thus modeled to the extent that they produce return flows in the basins draining into Galveston Bay.

4.5.4.1 Region C Management Strategies

Table 4-8 summarizes the Region C Water Management Strategies that impact the Trinity River Basin. Out of basin strategies have a combined yield of 830,900 acre-feet per year. The return flows associated with these strategies have been simulated as constant inflow (CI) cards at the wastewater treatment plants where other return flows from the same suppliers are discharged. In-basin management strategies total 120,000 ac-ft/yr. The water rights associated with these strategies were included in the TCEQ WAM models, and thus no changes were necessary. The yield associated with reuse strategies totals 301,172 ac-ft/yr. Most reuse strategies are simulated by reducing the return flows associated with imports and in-basin water. The majority of the reuse strategies produce return flows, thus the strategies are typically simulated to represent the net reduction in return flows. The TRWD Trinity River Reuse is simulated as a new diversion. Appendix 4D provides further details on how each individual strategy was modeled.

Table 4-8: Region C 2001 Management Strategies Impacting the Trinity River Basin

Management Strategy	Yield (ac-ft/yr)	Source Basin	Supplier
Increased use of Lake Texoma	10,000	Red	NTMWD
Oklahoma Transfer (Lake Hugo)	62,000	Oklahoma	NTMWD/TRWD
Lower Bois d'Arc Creek Lake	98,000	Red	NTMWD
Marvin Nichols Lake	431,300	Sulphur	Dallas/NTMWD/TRWD
Lake Fork Connection	120,000	Sabine	Dallas
Lake Palestine Connection	109,600	Neches	Dallas
Extend Elm Fork permit	10,000	Trinity	Dallas
Cedar Creek / Richland-Chambers Pipeline	110,000	Trinity	TRWD
Lake Texoma Reuse	35,872	N/A	NTMWD
Dallas Indirect Reuse	68,300	N/A	Dallas
TRWD Trinity River Reuse	115,500	N/A	TRWD
Las Colinas Reuse	7,000	N/A	TRA
Joe Pool Reuse	28,000	N/A	TRA
Mountain Creek Reuse	3,000	N/A	TRA
Ellis County Reuse	20,000	N/A	TRA
Denton County Reuse	5,000	N/A	TRA
Tarrant County Reuse	2,500	N/A	TRA
Grapevine Lake Reuse	16,000	N/A	TRA

4.5.4.2 Region H Management Strategies

Table 4-9 summarizes the Region H management strategies. Advanced municipal and irrigation conservation totaling 74,144 ac-ft/yr, is not explicitly modeled, but reduces the demand and thus the need for additional management strategies. New reservoir strategies

supplying Region H total 289,350 ac-ft/yr. The reservoir strategies produce return flows in the Trinity, San Jacinto, and San Jacinto-Brazos Basins. Wastewater reclamation reduces the net amount of return flows from wastewater treatment plants along the Houston Ship Channel, while making that water available as an alternate supply. Within Region H, the BRA reallocation strategy represents 35,000 ac-ft/yr of the total strategy of 75,000 ac-ft/yr. Contractual transfers move water within Region H, or represent the reallocation of a water right from industrial to irrigation. Appendix 4D provides additional detail regarding the manner in which these strategies were modeled.

Table 4-9: Region H 2001 Management Strategies

Management Strategy	Yield (ac-ft/yr)	Source Basin	Supplier/Use Location
Municipal Conservation	30,563	N/A	N/A
Irrigation Conservation	43,581	N/A	N/A
Allens Creek Reservoir	99,650	Brazos	COH in SJ-Braz BRA in Brazos
Little River Reservoir	99,000[1]	Brazos	GCWA in SJ-Braz BRA in Brazos
Bedias Reservoir	90,700	Trinity	SJRA in San Jacinto TRA in Trinity
Wastewater Reclamation	90,700	San Jacinto	COH in San Jacinto
BRA Voluntary Redistribution	35,000[2]	Brazos	GCWA in SJ Braz
Contractual Transfers	28,500	San Jac-Braz	San Jac-Braz
Houston/TRA Contract	200,000	Trinity	COH in San Jacinto
Houston/GCWA Transfer	23,000	Trinity	GCWA in SJ-Braz
SJRA/CLCND Contract	30,000	Trinity	SJRA in San Jacinto

1. Total Yield from Little River Reservoir is 129,000 ac-ft/yr of which 99,000 afy is to Region H.
2. Total Yield from BRA Voluntary Redistribution is 75,000 ac-ft/yr of which 35,000 afy is to Region H.

4.5.4.3 Galveston Bay Inflow Estimates with Region C and Region H Management Strategies

The incorporation of Region C Management Strategies has a significant impact on freshwater inflow into Galveston Bay due to the increased return flows into the Trinity River Basin from import strategies. Region H Management Strategies also produce increased total inflows to Galveston Bay. The most significant impact of Region H strategies is a further shifting of the source of inflows from the Trinity to the San Jacinto Basin, primarily due to the City of Houston/TRA Contractual Transfer. This transfer provides 200,000 ac-ft/yr of additional Lake Livingston supplies to the City of Houston distribution system. Additionally, Region H Management Strategies using Brazos River Basin supplies result in increased return flows in the San Jacinto–Brazos Basin.

4.5.5 Results

Evaluation of the TCEQ model runs reveals the significant impact of varying levels of diversions and return flows on total inflows to Galveston Bay. The Year 2000 scenarios revealed that the impacts of the present levels of sedimentation (which result in a slight increase in inflows) are insignificant relative to the diversion and return flow parameters.

The Year 2060 Run 1, with further sedimentation also produces a slight increase in total inflows. The management strategies, which change the diversion and return flow parameters, again have a significant impact, generally increasing inflows to Galveston Bay.

As the sedimentation impacts are minimal, for graphical comparison purposes, only selected models which have distinctions in their results are shown. For example, the differences in the results for TCEQ Run 1 with the original reservoir area-capacity relationships compared with year 2000 or year 2060 area-capacity relationships are minimal and thus not portrayed. The key models from which distinctions in the results can be seen are:

- Naturalized Flows
- Current Conditions (TCEQ Run 8)
- Full Authorized Diversions with Return Flows (TCEQ Run 1 which is similar to Year 2000 Run 1 and Year 2060 Run 1)
- Full Authorized Diversions with NO Return Flows (TCEQ Run 3 which is similar to Year 2000 Run 3)
- Full Authorized Diversions with Region C Strategies and Return Flows (Yr 2060 Reg C)
- Full Authorized Diversions with Region C & H Strategies and Return Flows (Yr 2060 Reg C & H)

4.5.5.1 Annual Inflows

Figure 4-1 shows the total annual inflows to Galveston Bay for the selected models. The Naturalized Flows provide the highest level of inflows, due the absence of any consumptive use from the watershed. The Current Conditions brings a reduction in flow, however the pattern of flow is dominated by hydrologic conditions, such that the Naturalized Flows are essentially shifted down, with the difference between Naturalized Flows and Current Conditions representing the current level of net consumptive use in the watershed. The full authorized diversions with return flows furthers the downward shift in total inflows as there is more net consumptive use. Full authorized diversions with no return flows produces the lowest level of inflows of the models simulated. This scenario is a "worst case" and assumes that all currently permitted diversions are consumed and reused to the extent that there are no net return flows. The addition of management strategies from the Region C plan increases the inflows to Galveston Bay due to the return flows from out-of-basin supplies. The Region H management strategies bring a further, albeit alight, increase in total inflows to Galveston Bay. Due to the closeness of the results for total inflows between the Region C and the Region C & H models, only the Region C & H model results are shown. The distinction between these models is shown in other figures where the variation is significant.

4.5.5.2 Inflows By Basin

Figure 4-2 shows the median annual inflows to Galveston Bay from the Trinity and San Jacinto Basins. The trend for the Trinity Basin is similar to the trend for the total inflows to Galveston Bay, with inflows decreasing from Naturalized to Current Conditions to Full Diversions with Return Flows to Full Diversions with No Return Flows. The addition of Region C Management Strategies increases the inflows to a level between Current

Conditions and Run 1. Region H Management Strategies cause a slight reduction in inflows from the Trinity River Basin as additional water is transferred to the San Jacinto Basin.

Figure 4-1: Annual Inflows to Galveston Bay

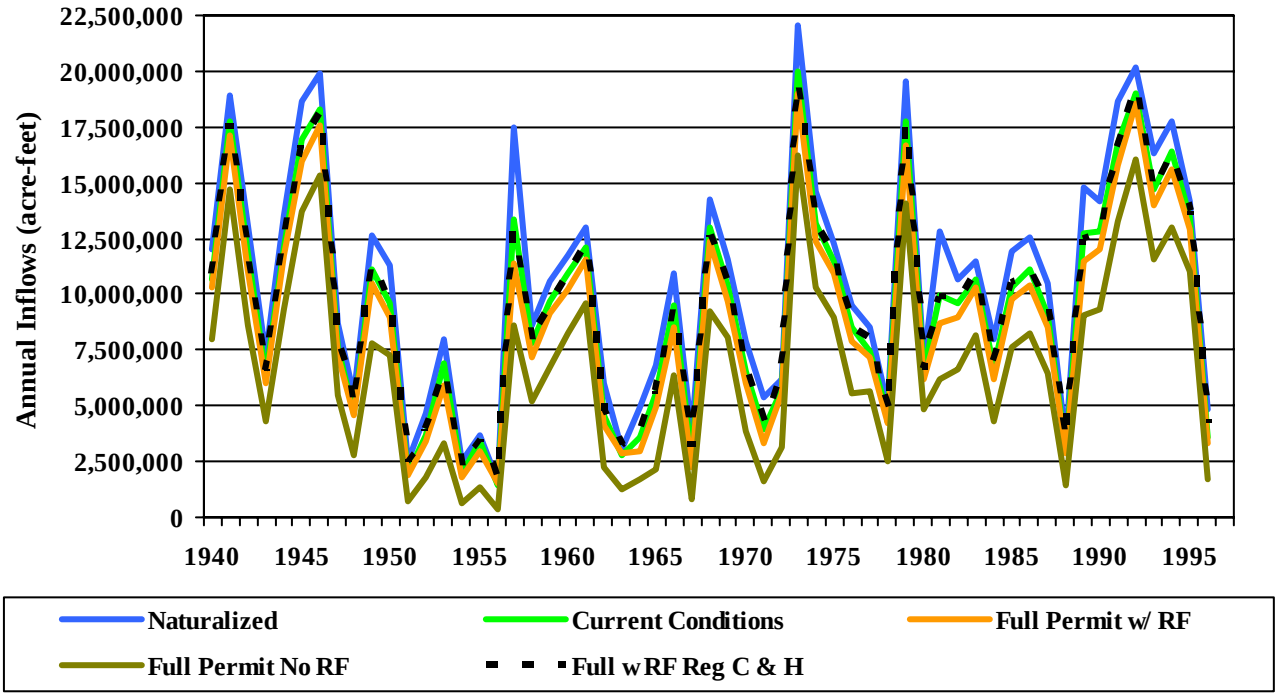
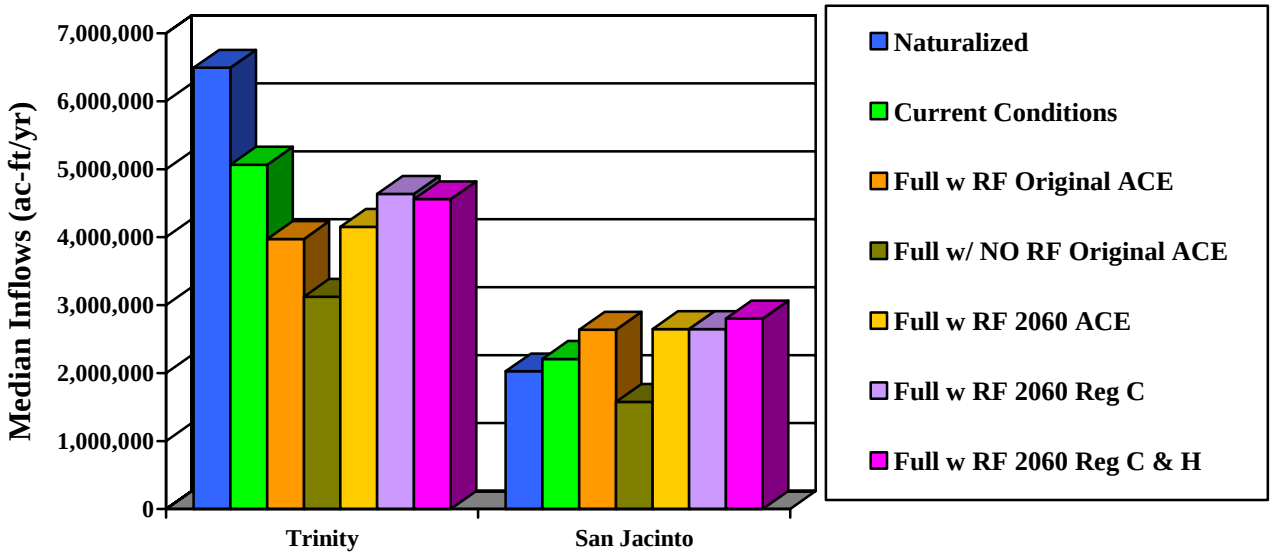


Figure 4-2: Median Inflows by Basin

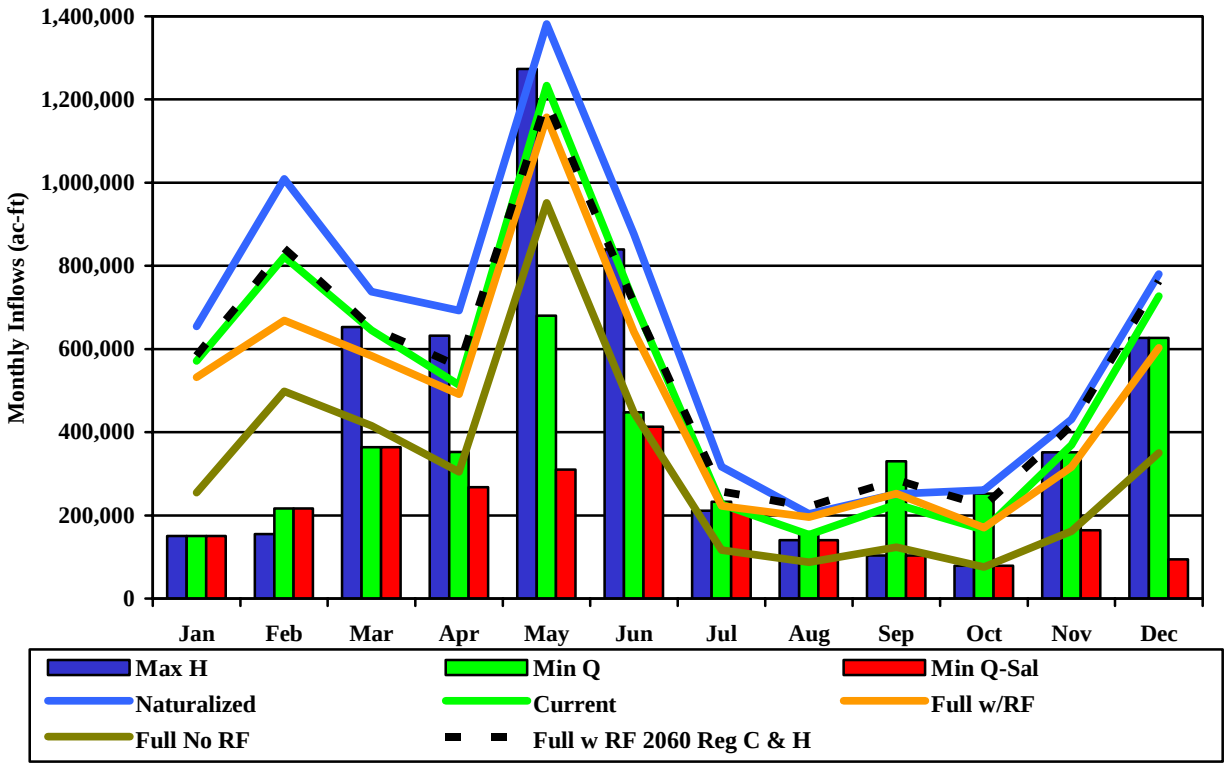


The median inflows to Galveston Bay from the San Jacinto Basin increase from the Naturalized condition due to return flows in the Current Conditions, Full Diversions with Return Flows and Region H Management Strategies. Each of these models represents higher levels of use in the San Jacinto Basin, and thus higher levels of return flows. Due to the significant amount of supplies coming from outside of the basin (primarily from the Trinity), the net impact is increased inflows to Galveston Bay from the San Jacinto Basin. Only Run 3, with no Return Flows yields lesser return flows to Galveston Bay from the San Jacinto Basin than the Naturalized Flows.

4.5.5.3 Inflows versus GBFIG Freshwater Inflow Targets

Figure 4-3 represents the total monthly median inflows as compared to the freshwater inflow targets. When the targets were developed, they were constrained to fall within the 10th and 50th percentile of historical flows. Thus the median inflows in the Naturalized and Current Conditions, as would be expected, meet or exceed almost all monthly inflow targets. Full authorized diversions with return flows produces a reduced ability to meet the Max H inflow targets in several months, and when return flows are excluded, Max H is only met in months with relatively low targets. The Region C & H management strategies bring the median monthly inflows back to levels comparable with the Current Conditions.

Figure 4-3: Median Monthly Inflows vs. Freshwater Inflow Targets



As explained in Section 4.5, percentile tables are included in Appendix 4D which show the monthly and annual percentile rankings of total inflows to Galveston Bay, as well as inflows from the Trinity and San Jacinto River Basins. These tables also include the freshwater inflow targets, and the frequencies with which the targets are achieved on a monthly basis. Table 4-10 summarizes the overall frequencies of meeting these targets.

Table 4-10: Overall Frequencies of Meeting Monthly Inflow Targets

Inflow Target	Max H	Min Q	Min Q-Sal
Historical Frequency	66%	78%	82%
GBFIG Target Frequency	50%	60%	75%
Naturalized	68%	67%	83%
Current Conditions	64%	59%	79%
Full Diversions with Return Flows	65%	59%	81%
Full Diversions with no Return Flows	43%	42%	55%
Full Diversions w RF And Reg C & H Strategies	71%	67%	87%

The GBFIG target frequencies for Max H, Min Q and Min Q-Sal are 50, 60 and 75 percent. Thus Figure 4-3 above, with the median monthly flows is most suitable for comparison to the Max H target. In order to portray how Min Q is being met on a monthly basis, Figure 4-4 has been developed for the 40th percentile, represent the flow which would be met or exceeded 60 percent of the time.

Figure 4-4 shows that the target frequency is consistently met or exceeded for the first 6 months of the year for all but the no return flow scenario. In the last 4 months of the year, the 40th percentile inflows are at levels less than the targets. Thus while the Min Q target frequency is met on a overall basis for all but the no return flow models, there are individual months where inflows targets are met at a consistently lower basis. The impact of future management strategies is, however, not furthering these shortages. As with many of the other measures, the future management strategies bring the 40th percentile inflows to levels very similar to the Current Conditions scenario.

Figure 4-5 has been developed to show the ability to meet MinQ-Sal as compared to the 25th percentile (the value exceeded 75 percent of the time). For all but the no return flow scenario, the 25th percentile flows exceed the MinQ-Sal target in nine months of the year. While the June values for the Current, Full Authorized and Management Strategy runs is significantly lower than the target, the May values for these runs greatly exceeds the target.

Figure 4-4: 40th Percentile Inflows vs. Freshwater Inflow Targets

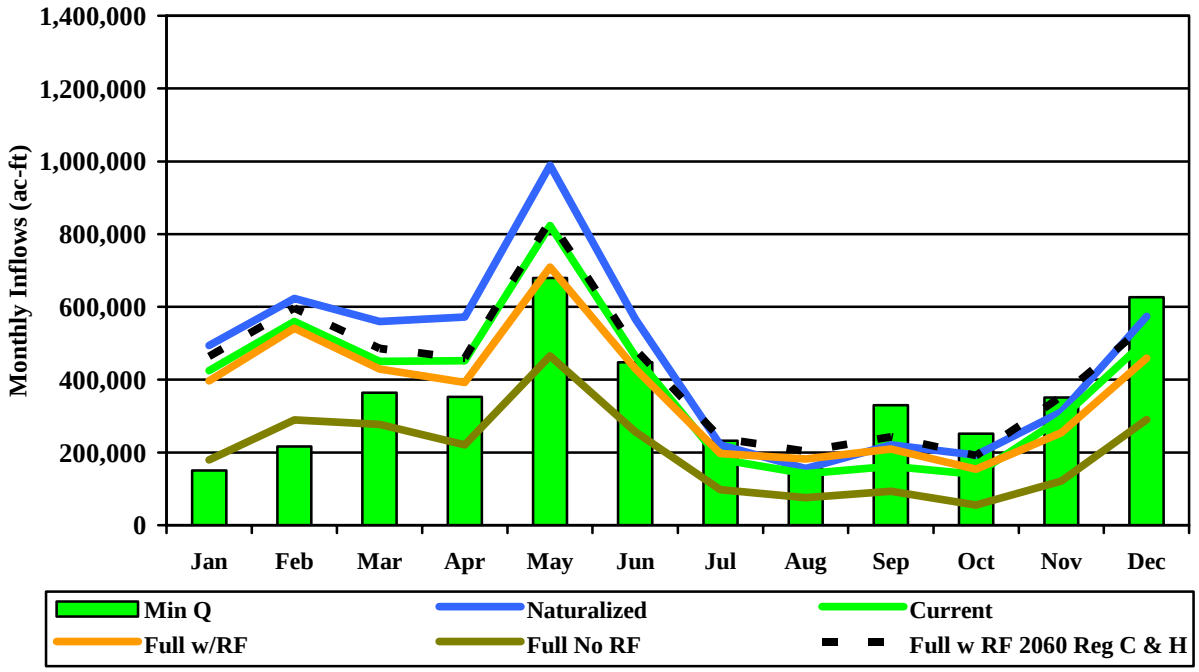
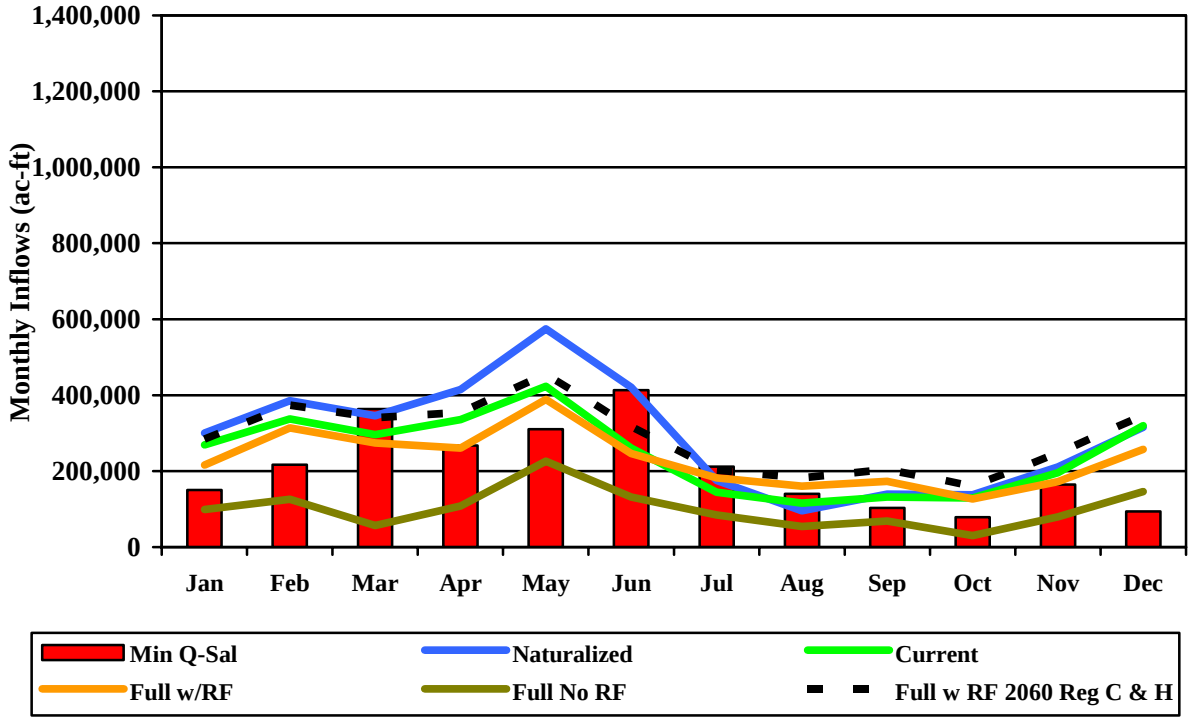


Figure 4-5: 25th Percentile Inflows vs. Freshwater Inflow Targets



4.5.5.4 Summary of Results

- 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 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.

4.6 Socio-Economic Impacts of Not Meeting Demands

Region H could address every projected water need through a combination of conservation, allocation of existing supply and development of new water supplies. However, the regional planning guidelines in 31 TAC 357 require that the social and economic impacts of not meeting demands be estimated and considered. The TWDB Water Use and Projection Section performed the social and economic impacts modeling for Region H. A description of the impact model assumptions and tabulated model results are presented in Appendix 4E, along with a full discussion of the potential social and economic impacts of not meeting demands.