EVALUATION OF ALTERNATIVE INSTREAM AND BAY & ESTUARY FLOW CRITERIA FOR RUN-OF-THE-RIVER DIVERSIONS

TECHNICAL MEMORANDUM

TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA

Texas Water Development Board
Texas Parks & Wildlife Department
Texas Natural Resource Conservation Commission
San Antonio River Authority
San Antonio Water System
Edwards Underground Water District
Guadalupe-Blanco River Authority
Lower Colorado River Authority
Bexar Metropolitan Water District
Nueces River Authority

HDR Engineering, Inc.
June, 1995

Trans-Texas Water Program
West Central Study Area

Technical Memorandum

Evaluation of Alternative Instream and Bay & Estuary Flow Criteria for Run-of-the-River Diversions

HDR Engineering, Inc.
June 13, 1995

Introduction

This memorandum presents various concepts for a second generation of environmental flow criteria for the Guadalupe - San Antonio River Basin to be used in the Trans-Texas Water Program. In Phase 1 of the Trans-Texas Water Program, preliminary environmental criteria as outlined in a document entitled "Trans-Texas Water Program Environmental Assessment" were used to determine water potentially available for most of the supply alternatives. Criteria for Instream Flows, Freshwater Inflows to Bays and Estuaries, and New Reservoirs were used to determine when surplus flows could be obtained by run-of-the-river diversions and when inflows to proposed reservoirs could be impounded. The results of the Phase 1 analyses for proposed reservoir projects generally showed that sufficient firm yield remained after honoring the criteria to consider the reservoir projects potentially viable with respect to firm yield. However, the results of the Phase 1 studies for most run-of-the-river diversion projects indicated that very little water, if any, would be available during drought, leading to the conclusion that run-of-the-river diversion projects are essentially infeasible with respect to firm yield under the existing preliminary Trans-Texas Environmental Criteria.

A review of the Trans-Texas Environmental Criteria shows that one very significant difference between the criteria for reservoirs and for run-of-the-river diversions is the inclusion of drought contingency provisions. For reservoir projects, a drought contingency provision allows reduction in desired reservoir inflow passage targets once storage falls below a selected threshold capacity (i.e., 40%, 60%, or 80% of full capacity). When this condition occurs, desired reservoir inflow passage targets are reduced from mean monthly flows (April, May, June, August, September, and October) or median monthly flows (January, February, March, July, November, and December) to the median daily streamflow observed during the historical drought of record. There is no similar explicit drought contingency provision for run-of-the-river diversions. Under the existing criteria, new run-of-the-river diversions would not be allowed at any time when inflow to the affected estuary system would be less than the monthly mean inflow in May, June, September, and October or the monthly median inflow in other months. Furthermore, under the existing criteria, new run-of-the-river diversions would not be allowed at any time when instream flows at the point of diversion would be less than 60% of the monthly median natural flow in March through September or 40% of the monthly median natural flow in the remaining months.

Several meetings involving representatives of the Texas Water Development Board (TWDB), Texas Parks and Wildlife Department (TPWD), and Texas Natural Resource Conservation Commission (TNRCC) were held to discuss potential alternative Trans-Texas Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries which would include drought contingency provisions applicable to run-of-the-river diversions. It was decided by the agencies that triggers for implementation of drought contingency provisions would be based on moving averages of streamflow and that two alternative drought contingency provisions would be evaluated using three locations in the Guadalupe - San Antonio River Basin as test cases. The two alternative drought contingency provisions evaluated are: 1) Abatement of existing Trans-Texas Environmental Criteria for Freshwater Inflows to Bays & Estuaries to that for Instream Flows; and 2) Abatement of existing Trans-Texas Environmental Criteria for both Instream Flows and Freshwater Inflows to Bays & Estuaries to some lesser monthly minimum amounts (targets) selected by the sponsors.

Major components of this evaluation of alternative environmental criteria included: 1) Preliminary statistical analyses to identify monthly flow-frequency relationships and drought contingency targets and triggers over a range of streamflow moving average durations; 2) Enhancement of the Guadalupe - San Antonio River Basin Model (GSA Model) to track streamflow moving averages and incorporate normal and drought monthly flow targets; 3) Performance of water availability analyses to assess potential effects on water supply alternatives; and 4) Presentation of modified streamflow statistics which reflect the effects of diversion of water available under alternative environmental criteria. Each of these components is addressed in the following sections of this memorandum. Evaluation of potential biological effects of implementation of environmental criteria is not within the scope of this study.

Preliminary Statistical Analyses

Preliminary statistical analyses of natural monthly streamflows for the 1934-89 historical period were conducted for three selected locations including: 1) Saltwater Barrier near Tivoli; 2) Guadalupe River at Cuero (USGS #1758); and 3) San Antonio River at Goliad (USGS #1885). A summary of natural monthly streamflows for each of these locations is available on a Data Disk to be provided upon request (See Appendix C for a complete listing of Data Disk contents). These natural streamflows were derived by adjustment of streamflow records to account for historical diversions, return flows, and reservoir operations and are identical to those used in Phase 1 of the Trans-Texas Water Program. In the Guadalupe - San Antonio River Basin, natural streamflows are based on historical pumpage and springflow from the Edwards Aquifer.

At each location, streamflow-frequency relationships for each month and for moving averages of variable duration ending in each month were developed by ranking monthly values. Figures A1, A2, and A3 in Appendix A present natural streamflow-frequency relationships for the three selected locations showing curves representative of all months and of typically high and low streamflow months. Figures B1 through B10 in Appendix B present moving average streamflow-frequency relationships for durations of two, three, four, and six months for the three selected locations showing curves representative of all ending months and of typically high and low average ending months.

After preliminary review of the figures in Appendices A and B and discussions among the sponsors, a streamflow moving average of 4-month (approx. 120 day) duration was adopted as the triggering mechanism for implementation of drought contingency provisions. Furthermore, the tenth percentile streamflow (10-year low flow) for each month was selected by the sponsors as the instream flow target when drought contingency provisions are implemented. Hence, when the moving average of streamflows for the previous four months falls below the 35th, 25th, or 15th percentile value for a given location, new diversions at that location during the current month will be limited by a drought instream flow target approximately equal to the tenth percentile flow for the current month. Applicable natural streamflow statistics, flow criteria, and drought contingency triggers for the three selected locations are summarized in Table 1.

River Basin Modelling

The GSA Model was originally developed in the Guadalupe - San Antonio River Basin Recharge Enhancement Study (Edwards Underground Water District, 1993) and was subsequently refined in Phase 1 of the Trans-Texas Water Program for the West Central Study Area. The GSA Model employs a monthly time step proceeding with flow calculations in an upstream to downstream order simulating recharge, water rights diversions, return flows, channel losses, and reservoir operations. The model may be used to estimate additional quantities of water potentially available for diversion from a specified location subject to specified monthly minimum streamflows at each control point (streamflow gage) and track the effects of such additional diversions on downstream flows.

Modifications to the GSA Model were necessary to input and use: 1) Drought (in addition to normal) monthly streamflow targets; 2) Monthly percentile drought contingency triggers; and 3) Variable moving average durations. Program code was added to facilitate monthly updating of moving averages of modified streamflows, compare these averages to drought contingency triggers, and determine appropriate flow criteria for the following month at all control points. Although drought conditions throughout the river basin were originally to be determined by moving averages of streamflow at the Saltwater Barrier near Tivoli, program logic was included at the sponsors' request to independently determine drought conditions at each control point. Use of percentile flow criteria unique to each month maintains seasonal streamflow fluctuation patterns even in drought. Figure 1 presents the monthly water availability computation logic employed by the modified version of the GSA Model used in this study.

The following general assumptions remained fixed for all applications of the GSA Model described herein:

1) Spring flows resulting from a fixed Edwards Aquifer pumpage rate of 400,000 acre-feet per year (acft/yr) with existing recharge structures.
2) Hydropower water rights subordinated to 365 cubic feet per second (cfs) at Lake Dunlap. Central Power & Light 300 cfs once-through cooling right on the Guadalupe River near Victoria fully subordinated.
3) Uncommitted firm yield of Canyon Lake (6,532 acft/yr) diverted near New Braunfels. Committed firm yield assigned to 38,438 acft/yr.
4) Return flows set at rates observed in 1988.

ENVIRONMENTAL CRITERIA SUMMARY **TABLE 1**

SALTWATER BARRIER NEAR TIVOLI

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN NATURAL STREAMFLOW (ACFT) [1]	149,744	154,610	138,182	174,203	260,311	252,135	149,876	86,279	177,444	172,249	141,939	135,487	1,992,459
MEDIAN NATURAL STREAMFLOW (ACFT) [1]	119,235	111,426	118,399	108,476	162,334	138,734	86,267	71,697	83,865	90,673	92,774	103,130	1,287,010
EXISTING B&E INFLOW CRITERIA (ACFT) [2]	119,235	111,426	118,329	108,476	260,311	252,135	86,267	71,697	177,444	172,249	92,774	103,130	1,673,473
EXISTING INSTREAM FLOW CRITERIA (ACFT) [2]	47,694	44,570	71,039	65,086	97,400	83,240	51,760	43,018	50,319	36,269	37,110	41,252	668,757
DROUGHT CONTINGENCY CRITERIA (ACFT) [3]	42,577	39,430	40,824	34,812	44,588	27,283	20,456	18,626	19,064	30,278	29,237	31,199	378,374
DROUGHT CONTINGENCY TRIGGER (ACFT) [4]													
35% TRIGGER	90,730	91,517	90,068	95,847	99,389	105,816	105,848	90,891	83,788	73,522	73,130	75,687	1,076,233
25% TRIGGER	68,170	69,616	72,740	78,607	76,264	81,387	78,656	75,562	73,545	60,509	61,322	62,768	859,146
15% TRIGGER	45,914	46,970	53,293	56,922	58,320	59,692	40,500	46,746	51,638	39,426	42,082	39,892	581,395

GUADALUPE RIVER AT CUERO

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN NATURAL STREAMFLOW (ACFT) [1]	91,602	94,516	91,215	113,754	171,418	160,670	99,449	54,487	96,871	98,738	91,065	85,325	1,249,110
MEDIAN NATURAL STREAMFLOW (ACFT) [1]	72,668	69,880	69,004	72,576	102,101	85,090	53,442	43,191	57,371	59,263	55,694	58,247	798,527
EXISTING INSTREAM FLOW CRITERIA (ACFT) [2]	29,067	27,952	41,402	43,546	61,261	51,054	32,065	25,915	34,423	23,705	22,278	23,299	415,967
DROUGHT CONTINGENCY CRITERIA (ACFT) [3]	26,492	27,952	32,672	27,003	29,439	22,160	16,493	10,243	11,427	13,910	20,483	23,299	261,573
DROUGHT CONTINGENCY TRIGGER (ACFT) [4]													
35% TRIGGER	54,266	50,654	49,764	60,071	67,117	73,479	71,936	63,726	53,248	50,174	45,833	45,934	686,202
25% TRIGGER	40,532	39,254	44,430	48,300	49,840	51,172	52,709	47,643	45,571	34,244	37,694	36,513	527,902
15% TRIGGER	27,222	34,406	33,283	35,047	35,102	36,784	30,114	34,897	31,396	23,366	21,076	23,089	365,782

SAN ANTONIO RIVER AT GOLIAD

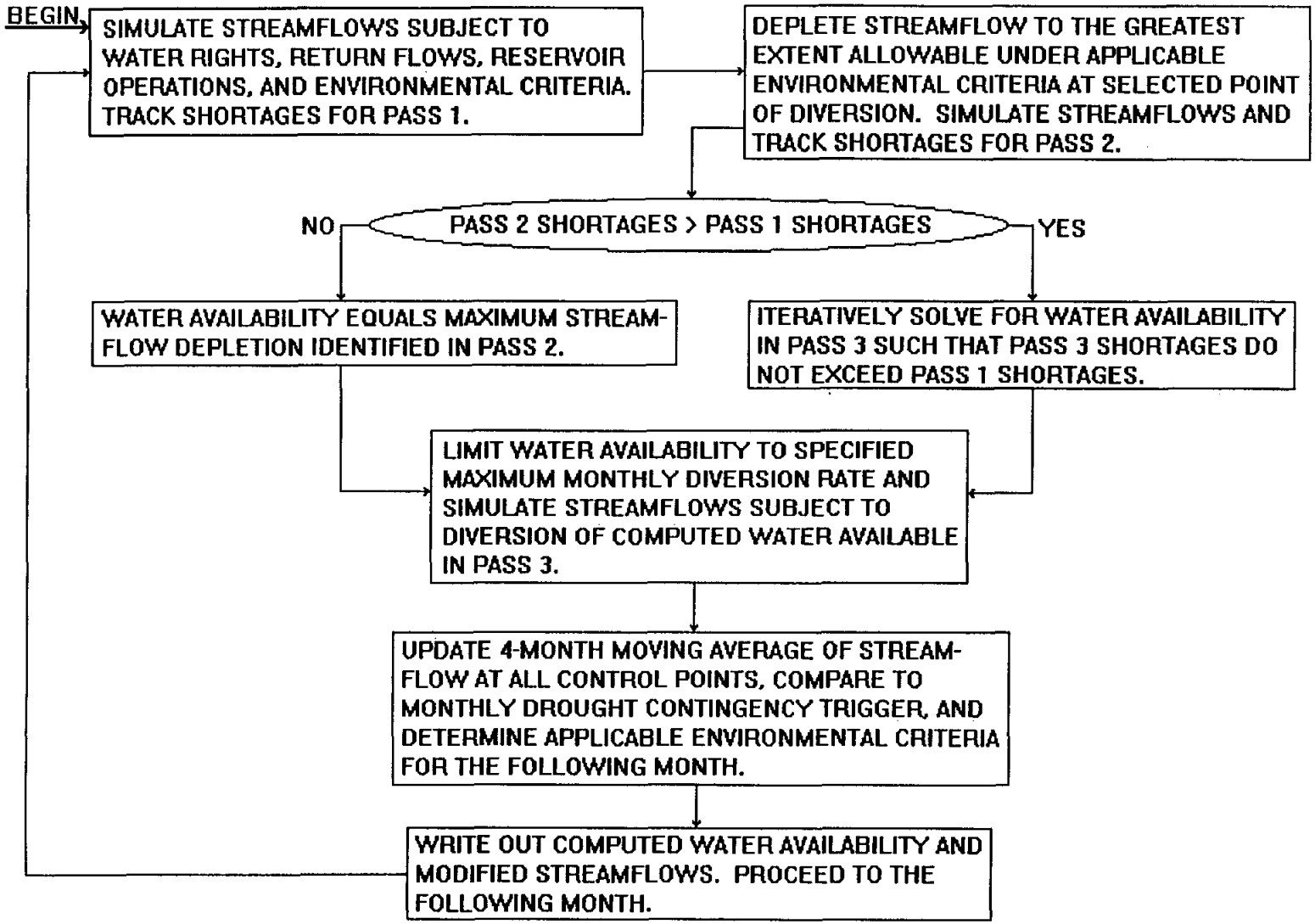
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN NATURAL STREAMFLOW (ACFT) [1]	31,676	30,847	26,132	40,890	63,752	71,977	36,968	24,419	59,764	47,657	33,312	27,941	495,335
MEDIAN NATURAL STREAMFLOW (ACFT) [1]	21,068	20,989	23,775	25,816	34,364	35,980	17,766	17,282	24,389	21,926	20,505	20,974	284,834
EXISTING INSTREAM FLOW CRITERIA (ACFT) [2]	8,427	8,396	14,265	15,490	20,618	21,588	10,660	10,369	14,633	8,770	8,202	8,318	149,736
DROUGHT CONTINGENCY CRITERIA (ACFT) [3]	6,231	6,552	7,580	7,743	9,768	4,704	3,463	2,618	5,445	6,178	6,573	7,095	73,950
DROUGHT CONTINGENCY TRIGGER (ACFT) [4]													
35% TRIGGER	18,419	17,758	16,564	18,526	19,473	22,228	27,290	22,286	20,095	18,542	18,712	21,268	241,161
25% TRIGGER	13,299	14,313	13,850	13,503	15,292	17,643	16,493	18,085	16,222	15,126	14,807	15,490	184,123
15% TRIGGER	9,042	7,798	8,666	9,655	11,814	12,056	8,718	11,041	11,856	8,827	8,168	9,979	117,620

[1] Monthly means and median based on estimated natural streamflows for the 1934-89 historical period. Natural streamflows are derived by adjustment of gaged streamflows to account for historical diversions, return flows, and reservoir operations. Natural streamflows used in the West and South Central Study Areas for the Trans-Texas Water Program are based on historical pumpage and springflow from the Edwards Aquifer.

[2] Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries derived in accordance with document entitled: "Trans-Texas Water Program Environmental Assessment."

[3] Drought Instream Flow target approximately equal to the 10th percentile flow (10-year low flow) for each month as selected by sponsors.

[4] Streamflow moving average of 4-month (approx. 120 day) duration selected by sponsors as the triggering mechanism for implementation of drought contingency provisions governing water potentially available for diversion. When the moving average of streamflows for the previous four months falls below the 35th, 25th, or 15th percentile value for a given location, new diversions at that location during the current month will be limited by drought Instream Flow targets.



GUADALUPE- SAN ANTONIO RIVER BASIN MODEL
MONTHLY WATER AVAILABILITY COMPUTATION LOGIC

NOTE: SHORTAGES COMPUTED WHEN THERE IS INSUFFICIENT STREAMFLOW TO SATISFY WATER RIGHTS AND/OR ENVIRONMENTAL CRITERIA AND WHEN RESERVOIR CONTENTS ARE LESS THAN SPECIFIED CONSERVATION STORAGE.

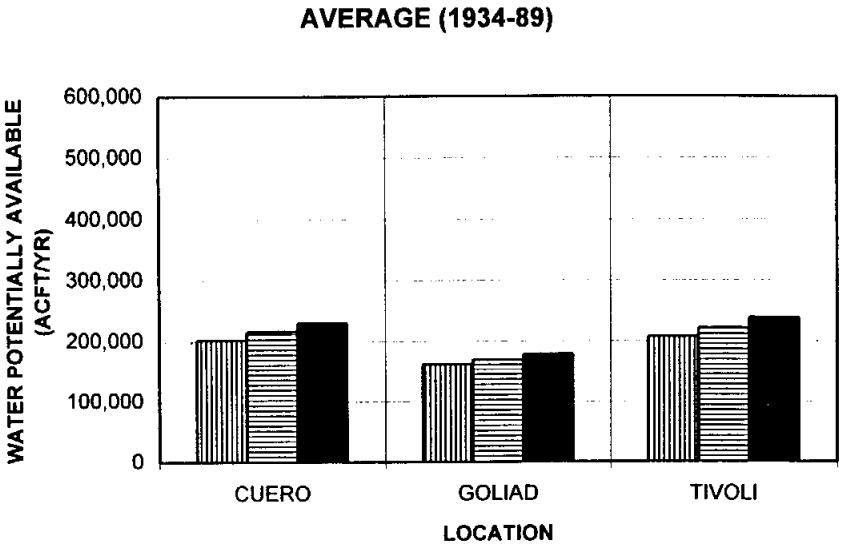
TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. 1

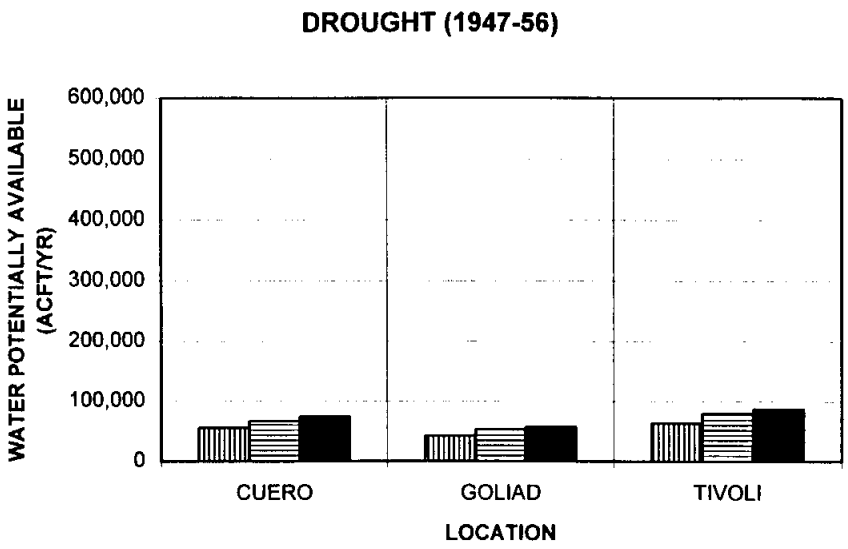
5) All consumptive water rights exercised at their full authorized amounts with the exception of those associated with Applewhite Reservoir which are excluded and those associated with Coleto Creek Reservoir, Braunig Lake, and Calaveras Lake which are exercised as needed to maintain full reservoir pools.
6) Draft agreement between San Antonio Water System, San Antonio River Authority, and City Public Service used to set instream flow requirements for the San Antonio River at Elmendorf and, occasionally, limit make-up diversions for Braunig and Calaveras Lakes.
7) Water availability estimates limited to a maximum diversion rate of 60,000 acft/month (approx. 1,000 cfs).

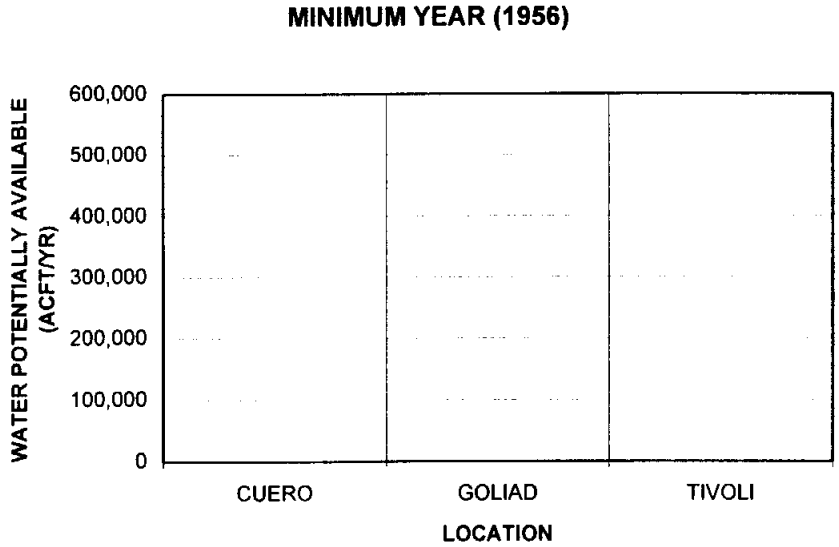
Water Availability Analyses

Water availability was calculated for the Saltwater Barrier near Tivoli, Guadalupe River at Cuero, and San Antonio River at Goliad for alternative environmental criteria under which existing Trans-Texas requirements for Freshwater Inflows to Bays & Estuaries were abated to existing Trans-Texas requirements for Instream Flows subject to drought contingency triggers at the 35th, 25th, and 15th percentiles of 4-month moving averages of natural streamflow. As shown in Figure 2, long-term (1934-89) average water availability under this alternative criteria ranged from 207,773 to 238,668 acft/yr at Tivoli, from 202,189 to 230,516 acft/yr at Cuero, and from 161,919 to 178,628 acft/yr at Goliad depending on assumed drought contingency trigger. Drought (1947-56) average water availability under this alternative criteria ranged from 62,991 to 86,802 acft/yr at Tivoli, from 55,553 to 74,673 acft/yr at Cuero, and from 42,694 to 57,549 acft/yr at Goliad. In the driest years, however, no water would be available for diversion under this alternative environmental criteria.

Water availability was also calculated for alternative environmental criteria under which existing Trans-Texas requirements for both Instream Flow and Freshwater Inflows to Bays & Estuaries were abated to the monthly tenth percentile natural streamflow subject to drought contingency triggers at the 35th, 25th, and 15th percentiles of 4-month moving averages of natural streamflow. As shown in Figure 3, long-term (1934-89) average water availability under this alternative criteria ranged from 217,894 to 265,225 acft/yr at Tivoli, from 207,866 to 249,664 acft/yr at Cuero, and from 164,671 to 190,818 acft/yr at Goliad depending on assumed drought contingency trigger. Drought (1947-56) average water availability under this alternative criteria ranged from 81,152 to 117,629 acft/yr at Tivoli, from 66,957 to 99,262 acft/yr at Cuero, and from 47,021 to 72,736 acft/yr at Goliad. Long-term average availability increased by between 1 and 11 percent and drought average availability increased by between 10 and 35 percent under this alternative criteria as compared to that described in the previous paragraph under which no drought relief from Trans-Texas Instream Flow requirements could be obtained. In the driest years, however, no water would be available for diversion under this alternative environmental criteria.





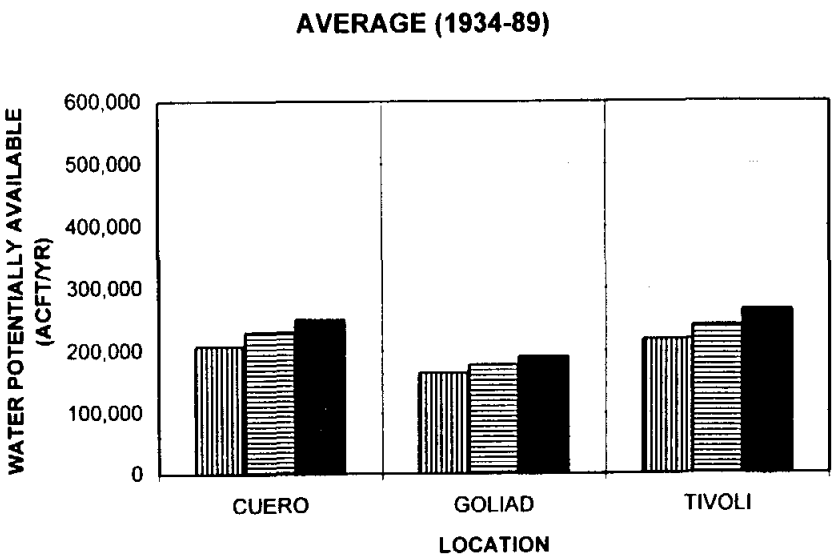


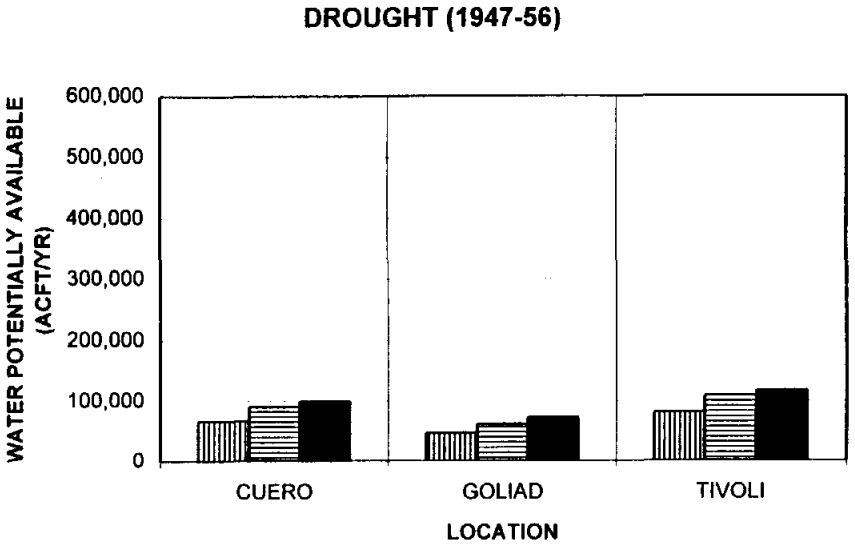
15% DROUGHT CONTINGENCY TRIGGER
25% DROUGHT CONTINGENCY TRIGGER
35% DROUGHT CONTINGENCY TRIGGER

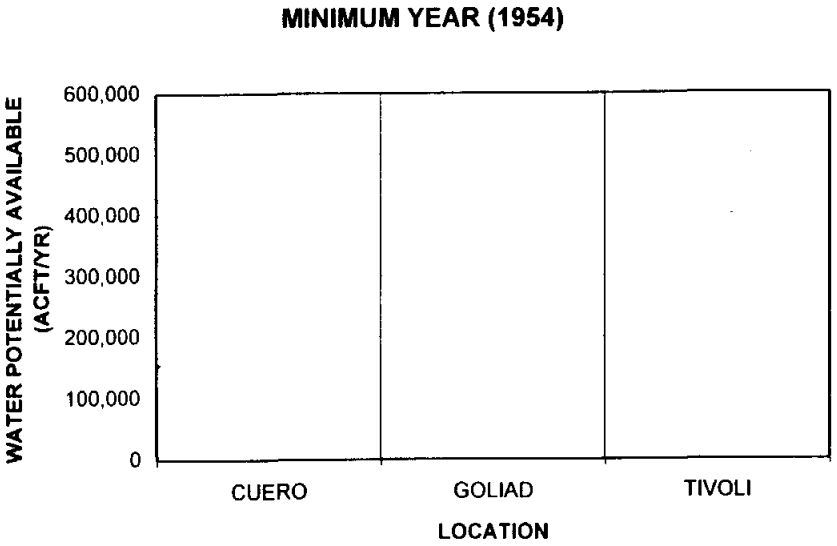
ASSUMPTIONS: DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

WATER AVAILABILITY SUMMARY WITH B&E DROUGHT CONTINGENCY ENVIRONMENTAL CRITERIA

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. 2







15% DROUGHT CONTINGENCY TRIGGER
25% DROUGHT CONTINGENCY TRIGGER
35% DROUGHT CONTINGENCY TRIGGER

ASSUMPTIONS: DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

WATER AVAILABILITY SUMMARY
WITH INSTREAM AND B&E DROUGHT CONTINGENCY ENVIRONMENTAL CRITERIA

TRANS-TEXAS WATER PROGRAM **WEST CENTRAL STUDY AREA** **INSTREAM AND BAY & ESTUARY FLOW CRITERIA**	**6/95** **FIG. 3**

Table 2 provides a statistical summary of water availability at each of the three selected locations subject to the full spectrum of environmental criteria considered in this study. Tables showing estimated monthly water availability for the entire 1934-89 simulation period are available on a Data Disk to be provided upon request (See Appendix C for a complete list of Data Disk contents). Note that these estimates of water potentially available at selected locations are mutually exclusive and cannot be added.

It is important to consider the maximum (35th percentile drought contingency trigger) estimates of water potentially available under each of the two alternative flow criteria scenarios described in the preceding paragraphs in the context of water potentially available under existing preliminary Trans-Texas Environmental Criteria and with no environmental criteria. In the latter case, water availability would be limited only by downstream water rights and maximum monthly diversion rate. As shown in Figures 4 and 5 and Table 2, water availability under alternative criteria with drought contingency provisions would exceed that under existing criteria by between 18 and 40 percent on the long-term average and by factors between 2.0 and 3.4 during drought, depending on the specified point of diversion. Considering the total volume of water potentially available with no environmental criteria applied, between 44 and 57 percent could be captured on the average under the alternative criteria. During drought, these percentages would fall to between 27 and 40 percent. In the driest years, water would only be available for diversion if no environmental criteria were applied and availability were limited only by downstream water rights.

Table 2 also shows that the percentage of months in which some water would be available under alternative criteria exceeds that under the existing Trans-Texas Environmental Criteria by between 15 and 65 percent depending on specified drought contingency provisions and point of diversion. Under the alternative criteria, the maximum number of consecutive months in which no water would be available ranges between 21 and 25 months depending on specified drought contingency provisions and point of diversion. While this represents a significant improvement in water availability over the existing Trans-Texas Environmental Criteria, the possibility of two full years without opportunity for run-of-the-river diversion will likely necessitate the construction of very large off-channel storage reservoirs to ensure continuous water supply during severe drought. Appendix D presents examples illustrating potential off-channel storage requirements necessary to develop firm yield under the range of environmental criteria evaluated in this study.

In order to increase the volume and frequency of water availability in the driest years and still provide water for environmental needs, it will be necessary to further modify the drought contingency provisions. One means of making more water available during severe drought conditions could include replacement of the tenth percentile streamflow (10-year low flow) monthly target with some lesser percentile streamflow target such as the 20-, 25-, or 50-year low flow. In some months, the tenth percentile streamflow may not be representative of severe drought conditions as it actually exceeds the normal (non-drought) instream flow requirement under the existing Trans-Texas Environmental Criteria. A second option could include establishment of an additional percentile streamflow target less than the tenth percentile to be used only in severe drought conditions. For example, as drought severity increases and the moving average of streamflow for the preceding four months falls below a specified secondary drought contingency trigger percentile, streamflow targets for the next month might be reduced to a second percentile streamflow target such as the 25- or 50-year low flow.

WATER AVAILABILITY SUMMARY WITH ENVIRONMENTAL CRITERIA [1] **TABLE 2**

DIVERSION FROM SALTWATER BARRIER NEAR TIVOLI, TEXAS ENVIRONMENTAL CRITERIA	AVERAGE [2] (ACFT/YR)	DROUGHT [2] (ACFT/YR)	MINIMUM [2] (ACFT/YR)	MONTHS AVAILABLE [3] (%)	MAXIMUM CONSECUTIVE MONTHS UNAVAILABLE [4]
NO ENVIRONMENTAL CRITERIA [5]	542,921	318,802	54,671	93	7
INSTREAM AND B&E DROUGHT CONTINGENCY [6]					
35% TRIGGER	265,225	117,629	0	51	21
25% TRIGGER	239,819	108,234	0	46	21
15% TRIGGER	217,894	81,152	0	41	21
B&E DROUGHT CONTINGENCY [7]					
35% TRIGGER	238,668	86,802	0	43	24
25% TRIGGER	221,074	79,873	0	41	25
15% TRIGGER	207,773	62,991	0	37	25
EXISTING ENVIRONMENTAL CRITERIA [8]	189,280	34,671	0	32	50

DIVERSION FROM GUADALUPE RIVER AT CUERO, TEXAS ENVIRONMENTAL CRITERIA	AVERAGE [2] (ACFT/YR)	DROUGHT [2] (ACFT/YR)	MINIMUM [2] (ACFT/YR)	MONTHS AVAILABLE [3] (%)	MAXIMUM CONSECUTIVE MONTHS UNAVAILABLE [4]
NO ENVIRONMENTAL CRITERIA [5]	509,139	272,613	40,065	93	7
INSTREAM AND B&E DROUGHT CONTINGENCY [6]					
35% TRIGGER	249,664	99,262	0	53	24
25% TRIGGER	229,670	89,941	0	47	24
15% TRIGGER	207,866	66,957	0	40	24
B&E DROUGHT CONTINGENCY [7]					
35% TRIGGER	230,516	74,673	0	45	24
25% TRIGGER	216,693	66,662	0	41	24
15% TRIGGER	202,189	55,553	0	37	24
EXISTING ENVIRONMENTAL CRITERIA [8]	189,118	34,399	0	32	50

DIVERSION FROM SAN ANTONIO RIVER AT GOLIAD, TEXAS ENVIRONMENTAL CRITERIA	AVERAGE [2] (ACFT/YR)	DROUGHT [2] (ACFT/YR)	MINIMUM [2] (ACFT/YR)	MONTHS AVAILABLE [3] (%)	MAXIMUM CONSECUTIVE MONTHS UNAVAILABLE [4]
NO ENVIRONMENTAL CRITERIA [5]	335,303	180,835	45,782	93	7
INSTREAM AND B&E DROUGHT CONTINGENCY [6]					
35% TRIGGER	190,818	72,736	0	53	21
25% TRIGGER	177,222	61,682	0	47	21
15% TRIGGER	164,671	47,021	0	41	21
B&E DROUGHT CONTINGENCY [7]					
35% TRIGGER	178,628	57,549	0	46	24
25% TRIGGER	169,351	52,922	0	42	24
15% TRIGGER	161,919	42,694	0	38	25
EXISTING ENVIRONMENTAL CRITERIA [8]	151,397	28,376	0	32	50

[1] Water availability computed on a monthly timestep subject to the following assumptions: a) Full water rights utilization; b) Hydropower subordinated to 365 cfs at Lake Dunlap; c) Return flows observed in 1988; d) Edwards Aquifer pumpage of 400,000 acft/yr; and e) Maximum monthly diversion of 60,000 acft.

[2] Average based on 1934-89 simulation period. Drought based on 1947-56 simulation period. Minimum year variable by simulation.

[3] Percentage of months during 1934-89 simulation period in which some quantity of water would be available for diversion under applicable environmental criteria.

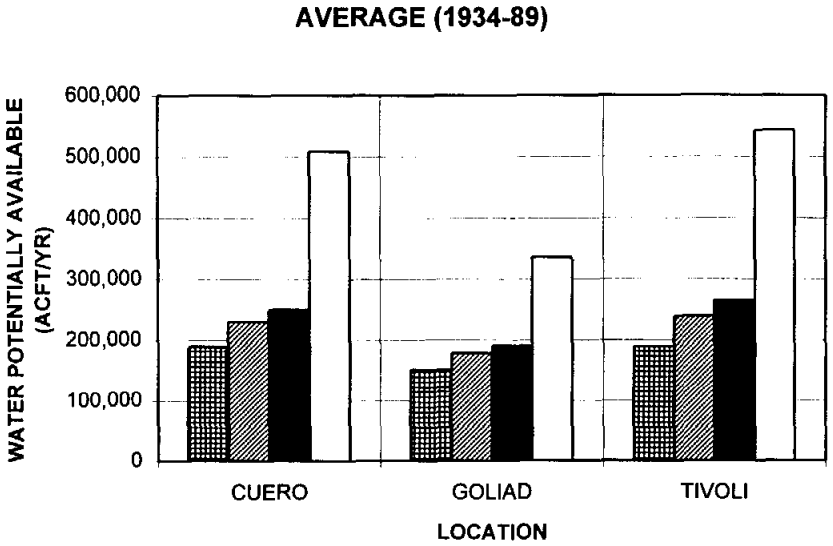
[4] Maximum consecutive number of months during 1934-89 simulation period during which no water would be available for diversion under applicable environmental criteria.

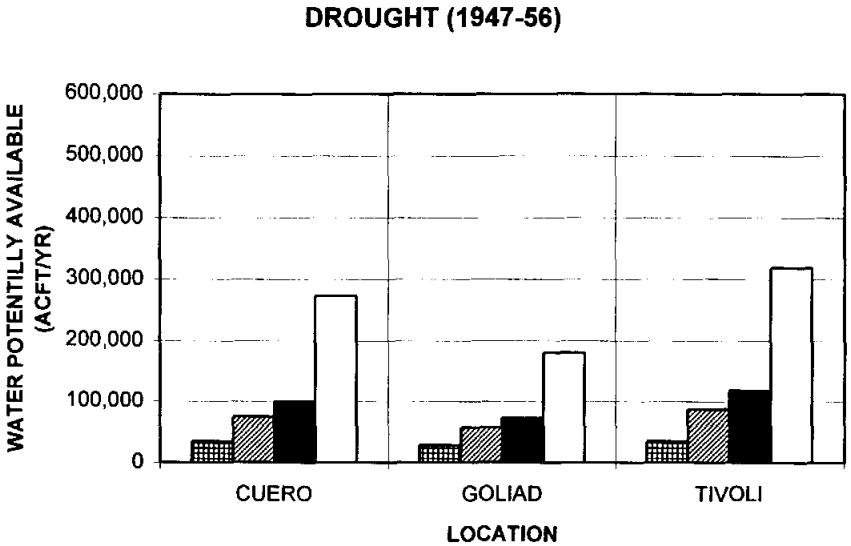
[5] Theoretical maximum water availability subject only to senior water rights.

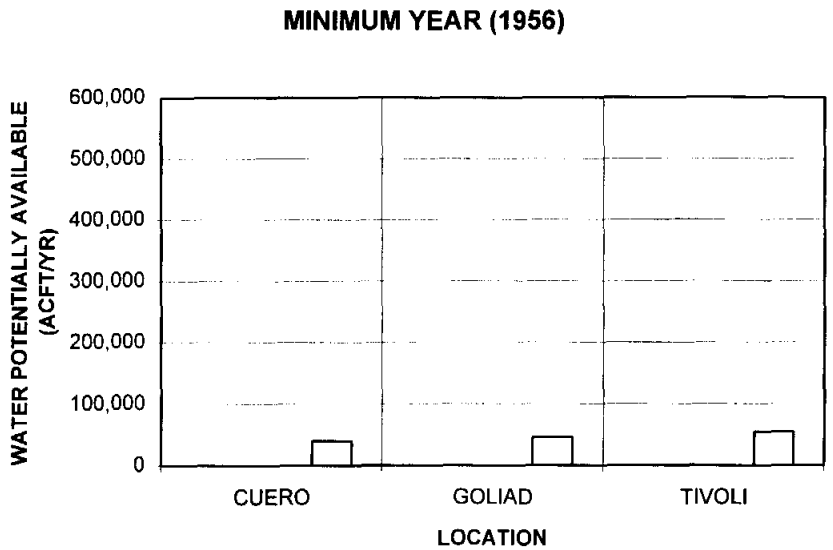
[6] Water availability with drought contingency provisions for both Instream Flows and Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

[7] Water availability with drought contingency provisions for Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

[8] Water availability under existing Trans-Texas Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries which have no drought contingency provisions.







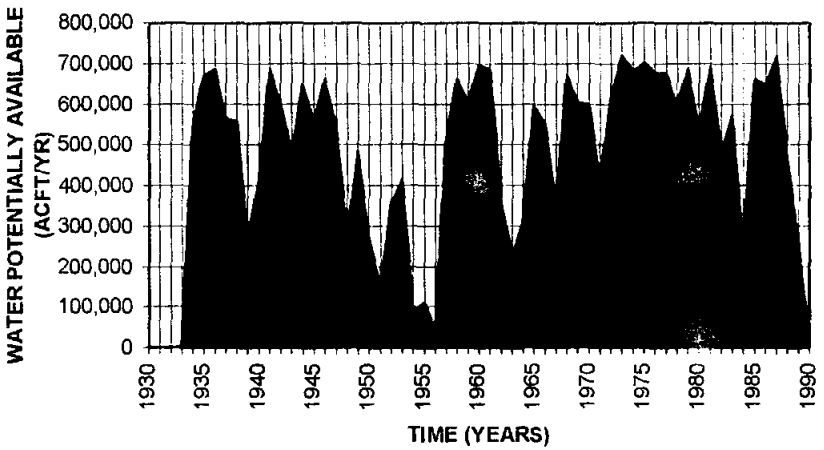
EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

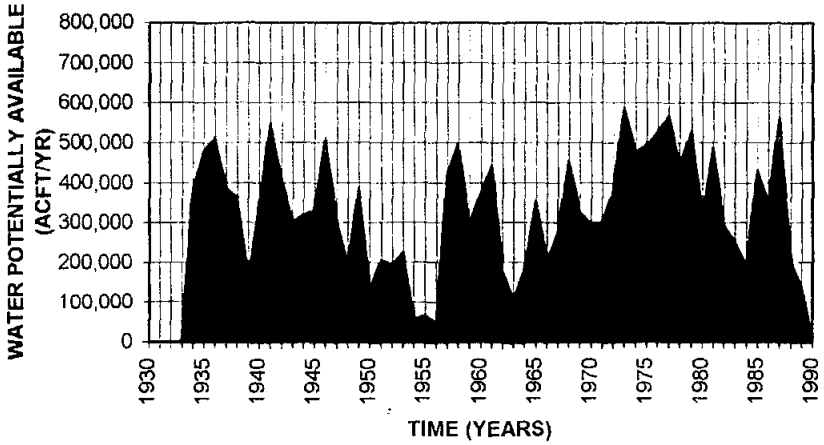
WATER AVAILABILITY SUMMARY
WITH ENVIRONMENTAL CRITERIA
STATISTICAL COMPARISON

TRANS-TEXAS WATER PROGRAM **WEST CENTRAL STUDY AREA** **INSTREAM AND BAY & ESTUARY FLOW CRITERIA**	**6/95** **FIG. 4**

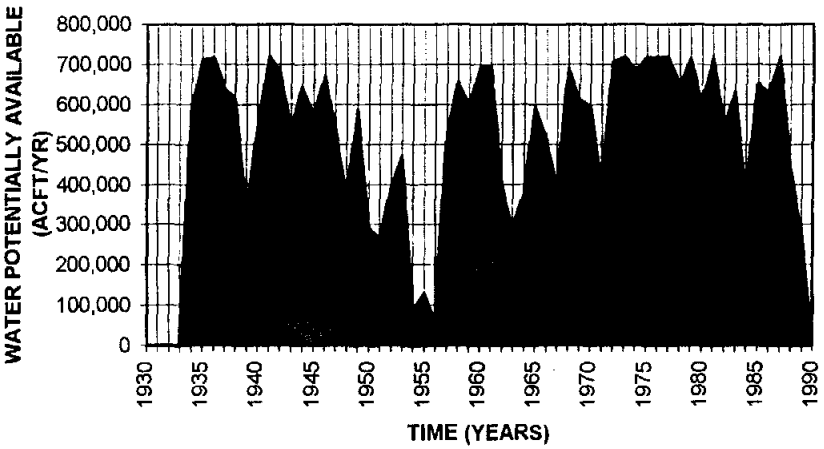
GUADALUPE RIVER AT CUERO



SAN ANTONIO RIVER AT GOLIAD



SALTWATER BARRIER NEAR TIVOLI



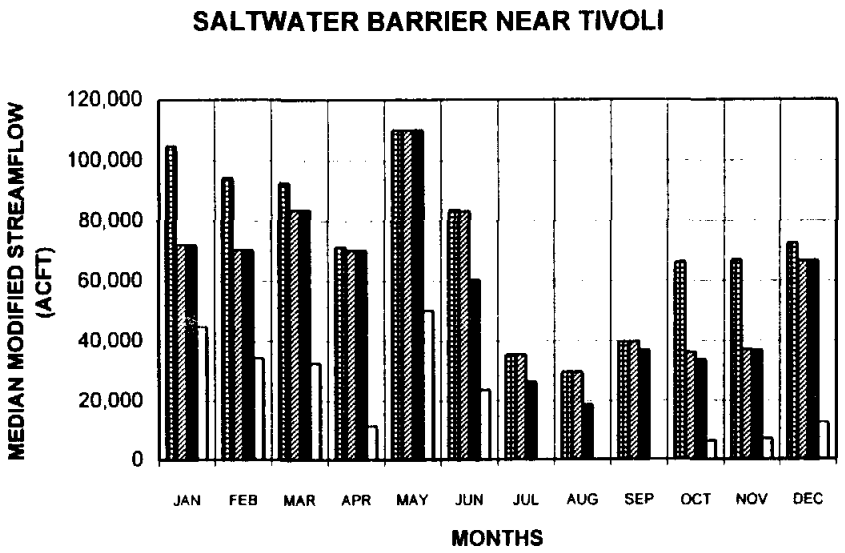
EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

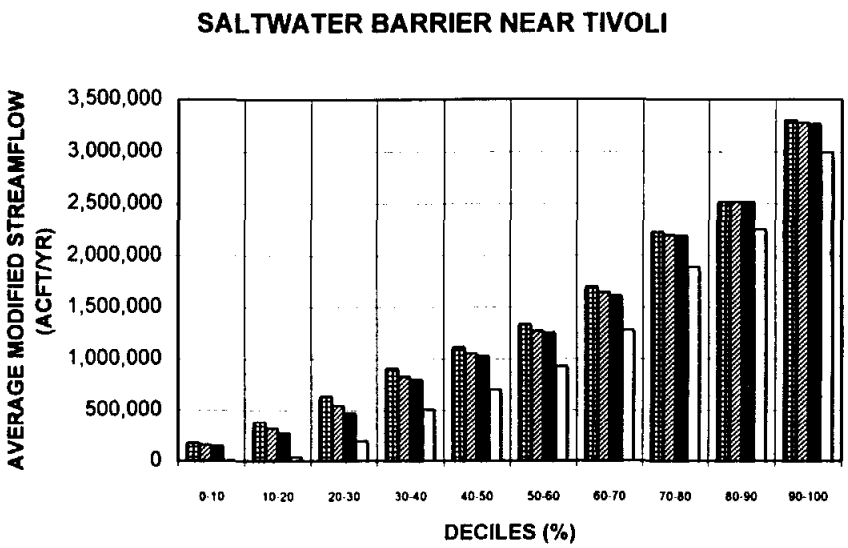
ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MONTH MAXIMUM DIVERSION.

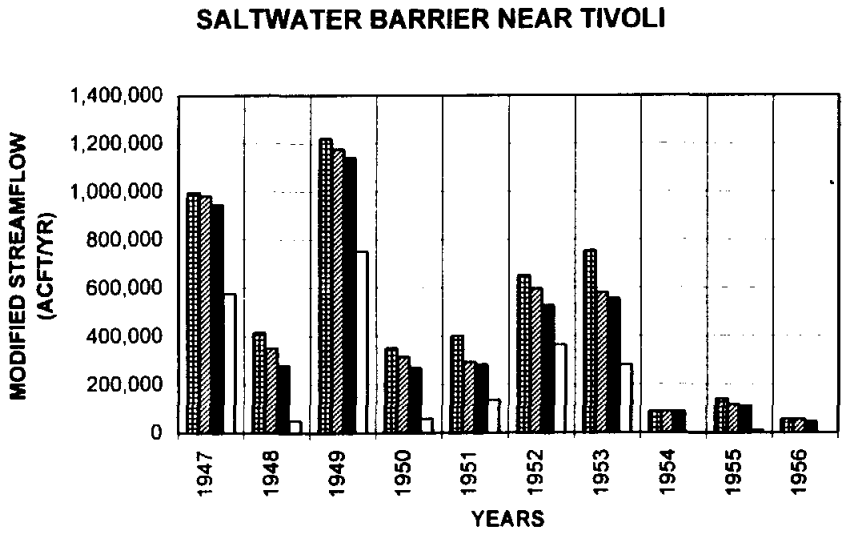
WATER AVAILABILITY SUMMARY
WITH ENVIRONMENTAL CRITERIA
TIME SERIES COMPARISON

TRANS-TEXAS WATER PROGRAM **WEST CENTRAL STUDY AREA** **INSTREAM AND BAY & ESTUARY FLOW CRITERIA**	**6/95** **FIG. 5**

The remaining figures and tables in this memorandum summarize the effects of diversion of water potentially available on streamflows both at the point of diversion and at the Saltwater Barrier. Streamflows which reflect the effects of these potential diversions are generally referred to herein as "modified streamflows." Tables showing monthly modified streamflows at each selected location for the entire 1934-89 simulation period subject to the full spectrum of environmental criteria considered in this study are available on a Data Disk. Also available on the Data Disk are "baseline" modified streamflows which reflect full utilization of existing water rights, but no additional diversions. Figures 6 through 12 present comparisons of monthly medians, annual decile averages, and drought sequences of modified streamflows at the Saltwater Barrier, Guadalupe River at Cuero, and San Antonio River at Goliad. These graphical comparisons are based on modified streamflows associated with the application of existing Trans-Texas Environmental Criteria, alternative criteria with drought contingency provisions, and no environmental criteria. Tables 3 through 7 summarize monthly medians and annual decile averages of modified streamflows subject to the full spectrum of environmental criteria considered in this study. These tables also include comparable statistics for natural streamflows and baseline modified streamflows for reference and perspective. Specific comparisons of changes in modified streamflows under various environmental criteria are not included in this memorandum as the significance of such changes involves biological considerations beyond the scope of this study.







EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

MODIFIED STREAMFLOW SUMMARY
DIVERSION FROM SALTWATER BARRIER NEAR TIVOLI

TRANS-TEXAS WATER PROGRAM	**6/95**
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	**FIG. 6**

MODIFIED STREAMFLOW SUMMARY [1] **TABLE 3**

DIVERSION FROM SALTWATER BARRIER NEAR TIVOLI

MONTHLY MEDIAN AND ANNUAL DECILE COMPARISONS

MONTHLY MEDIAN COMPARISON

ENVIRONMENTAL CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
WITH ADDITIONAL DIVERSIONS													
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	44,759	34,182	32,526	11,323	50,033	23,700	0	0	0	6,145	6,854	12,482	784,992
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]													
35% TRIGGER	71,899	70,251	83,586	70,076	110,033	60,310	26,320	18,626	36,722	33,645	36,863	66,637	1,141,324
25% TRIGGER	91,863	92,857	83,586	71,323	110,033	69,201	26,320	20,745	38,815	38,498	58,608	69,945	1,166,843
15% TRIGGER	102,890	92,857	91,797	71,323	110,033	80,142	30,985	23,792	39,684	59,113	66,618	72,482	1,216,169
B&E DROUGHT CONTINGENCY (ACFT) [4]													
35% TRIGGER	71,899	70,251	83,586	70,076	110,033	83,240	35,343	29,616	39,684	36,269	37,110	66,637	1,176,679
25% TRIGGER	91,863	92,857	83,586	71,323	110,033	83,240	35,343	29,616	39,684	38,498	58,608	69,945	1,176,679
15% TRIGGER	102,890	92,857	91,797	71,323	110,033	83,240	35,343	29,616	39,684	59,113	66,618	72,482	1,222,106
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	104,759	94,182	92,526	71,323	110,033	83,700	35,343	29,616	39,684	66,145	66,854	72,482	1,222,106
WITHOUT ADDITIONAL DIVERSIONS													
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	104,759	94,182	92,526	71,323	110,033	83,700	35,343	29,616	39,684	66,145	66,854	72,482	1,381,073
NATURAL CONDITIONS (ACFT) [7]	116,323	110,345	118,185	104,804	148,297	138,408	82,219	68,759	82,319	89,161	84,639	87,587	1,749,070

ANNUAL DECILE AVERAGE COMPARISON

ENVIRONMENTAL CRITERIA	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
WITH ADDITIONAL DIVERSIONS										
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	3,090	37,941	193,805	508,066	700,864	923,333	1,273,340	1,893,396	2,250,555	2,994,985
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]										
35% TRIGGER	142,022	274,952	470,069	795,051	1,032,175	1,247,839	1,606,647	2,192,343	2,515,579	3,263,771
25% TRIGGER	142,022	274,952	526,719	870,732	1,051,285	1,267,225	1,644,593	2,209,952	2,516,120	3,289,900
15% TRIGGER	144,571	312,123	575,956	897,738	1,078,400	1,307,557	1,655,641	2,219,475	2,516,120	3,302,200
B&E DROUGHT CONTINGENCY (ACFT) [4]										
35% TRIGGER	158,090	316,590	545,274	827,839	1,053,977	1,269,450	1,640,379	2,197,721	2,515,579	3,275,154
25% TRIGGER	158,090	316,590	580,665	885,934	1,067,167	1,277,960	1,663,123	2,214,017	2,516,120	3,295,793
15% TRIGGER	158,090	332,641	604,604	902,324	1,090,266	1,313,013	1,665,368	2,223,540	2,516,120	3,302,200
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	175,232	384,026	634,523	906,318	1,115,896	1,333,738	1,693,616	2,226,080	2,516,120	3,302,200
WITHOUT ADDITIONAL DIVERSIONS										
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	175,232	384,026	661,239	1,042,268	1,278,652	1,557,300	1,915,326	2,539,437	2,912,217	3,714,601
NATURAL CONDITIONS (ACFT) [7]	380,496	675,686	1,004,959	1,387,701	1,645,876	1,950,209	2,314,881	2,919,382	3,381,634	4,119,466

[1] Monthly medians and/or annual decile averages based on the 1934-89 simulation period.

[2] Resultant streamflows for diversion of theoretical maximum water available subject only to senior water rights.

[3] Resultant streamflows for diversion of water available with drought contingency provisions for both Instream Flows and Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

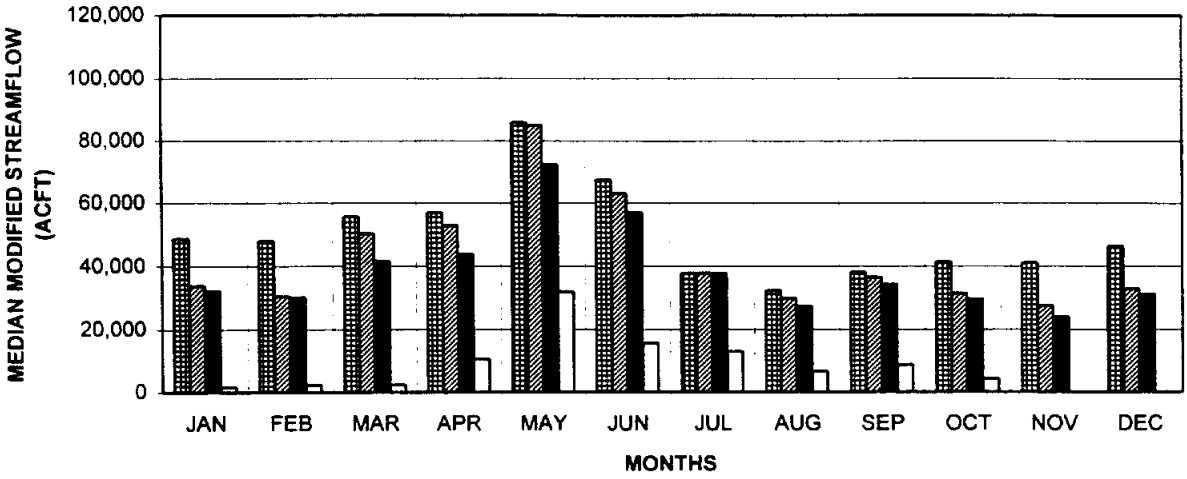
[4] Resultant streamflows for diversion of water available with drought contingency provisions for Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

[5] Resultant streamflows for diversion of water available under existing Trans-Texas Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries which have no drought contingency provisions.

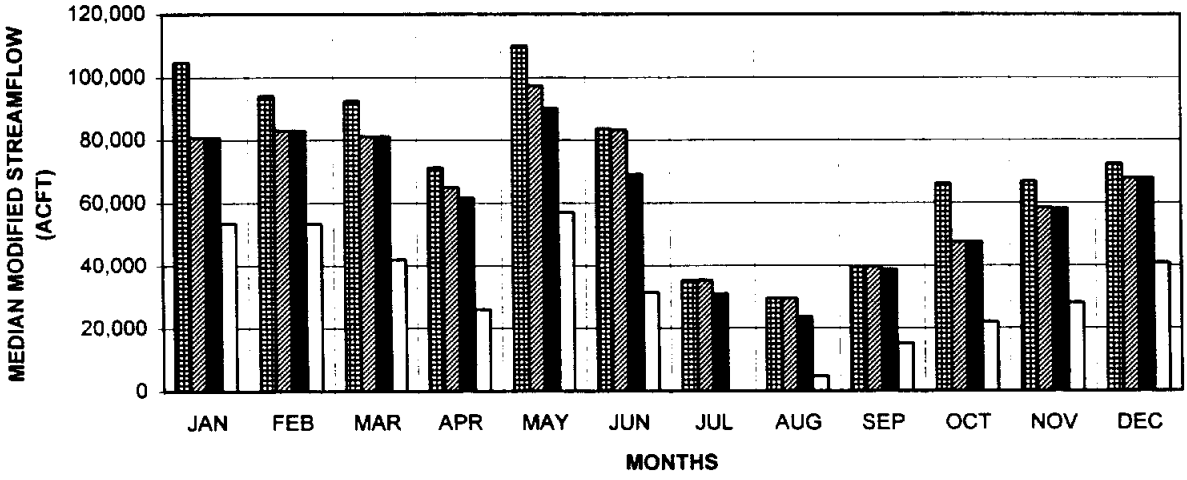
[6] Baseline streamflows (without additional diversion) subject to the following assumptions: a) Full water rights utilization; b) Hydropower subordinated to 365 cfs at Lake Dunlap; c) Return flows observed in 1988; and d) Edwards Aquifer pumpage of 400,000 acft/yr.

[7] Natural streamflows derived by adjustment of gaged streamflows to account for historical diversions, return flows, and reservoir operations. Natural streamflows used in the West and South Central Study Areas for the Trans-Texas Water Program are based on historical pumpage and springflow from the Edwards Aquifer.

GUADALUPE RIVER AT CUERO



SALTWATER BARRIER NEAR TIVOLI



EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

MODIFIED STREAMFLOW SUMMARY
DIVERSION FROM GAUDALUPE RIVER AT CUERO
MONTHLY MEDIAN COMPARISON

TRANS-TEXAS WATER PROGRAM	6/95
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	FIG. 7

MODIFIED STREAMFLOW SUMMARY [1] **TABLE 4**

DIVERSION FROM GUADALUPE RIVER AT CUERO

MONTHLY MEDIAN COMPARISON

POINT OF DIVERSION

ENVIRONMENTAL CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
WITH ADDITIONAL DIVERSIONS													
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	1,616	2,322	2,358	10,710	31,952	15,761	12,963	6,611	8,751	4,215	1	1	413,131
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]													
35% TRIGGER	32,304	30,259	41,859	43,933	72,522	57,098	37,877	27,415	34,423	29,788	24,117	31,161	735,728
25% TRIGGER	40,173	37,720	54,222	47,785	79,679	63,121	37,877	30,744	36,607	34,840	28,174	33,035	759,175
15% TRIGGER	46,833	47,722	55,249	57,075	86,013	63,121	37,991	30,744	38,261	35,224	37,562	43,710	760,666
B&E DROUGHT CONTINGENCY (ACFT) [4]													
35% TRIGGER	33,896	30,568	50,330	52,872	85,013	63,121	37,991	29,998	36,607	31,457	27,639	33,035	749,036
25% TRIGGER	40,173	40,623	55,205	57,075	85,013	64,734	37,991	30,744	36,607	35,224	32,240	35,552	764,486
15% TRIGGER	46,833	47,722	55,249	57,075	86,013	64,734	37,991	30,744	38,261	35,413	37,562	43,710	764,486
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	48,807	48,162	55,778	57,075	86,013	67,516	37,991	32,411	38,261	41,487	41,178	46,361	764,486
WITHOUT ADDITIONAL DIVERSIONS													
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	61,616	60,212	57,710	58,527	91,952	67,516	39,597	32,776	40,384	49,071	46,119	48,708	944,641
NATURAL CONDITIONS (ACFT) [7]	67,397	69,698	68,836	69,234	101,938	77,348	52,485	43,191	47,838	58,436	53,243	57,469	1,049,119

SALTWATER BARRIER

ENVIRONMENTAL CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
WITH ADDITIONAL DIVERSIONS													
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	53,624	53,523	41,957	26,073	57,163	31,428	0	4,745	15,273	22,090	28,170	40,849	880,034
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]													
35% TRIGGER	80,836	83,124	81,250	61,642	90,225	69,200	31,004	23,806	38,815	47,638	58,297	67,836	1,156,839
25% TRIGGER	91,443	84,140	83,586	70,076	110,033	80,142	31,004	25,947	39,099	59,112	58,982	69,945	1,188,165
15% TRIGGER	95,595	92,859	91,797	71,323	110,033	80,812	31,089	29,616	39,687	60,824	64,415	72,482	1,227,952
B&E DROUGHT CONTINGENCY (ACFT) [4]													
35% TRIGGER	80,836	83,124	81,250	65,084	97,398	83,238	35,353	29,616	39,687	47,638	58,608	67,836	1,172,669
25% TRIGGER	91,443	88,296	83,586	70,076	110,033	83,238	35,353	29,616	39,687	59,112	59,643	69,945	1,194,157
15% TRIGGER	95,595	92,859	91,797	71,323	110,033	83,238	35,353	29,616	39,687	60,824	64,415	72,482	1,227,952
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	104,762	94,184	92,527	71,323	110,033	83,701	35,353	29,616	39,687	66,158	66,862	72,482	1,231,969
WITHOUT ADDITIONAL DIVERSIONS													
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	104,759	94,182	92,526	71,323	110,033	83,700	35,343	29,616	39,684	66,145	66,854	72,482	1,381,073
NATURAL CONDITIONS (ACFT) [7]	116,323	110,345	118,185	104,804	148,297	138,408	82,219	68,759	82,319	89,161	84,639	87,587	1,749,070

[1] Monthly medians and/or annual decile averages based on the 1934-89 simulation period.

[2] Resultant streamflows for diversion of theoretical maximum water available subject only to senior water rights.

[3] Resultant streamflows for diversion of water available with drought contingency provisions for both Instream Flows and Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

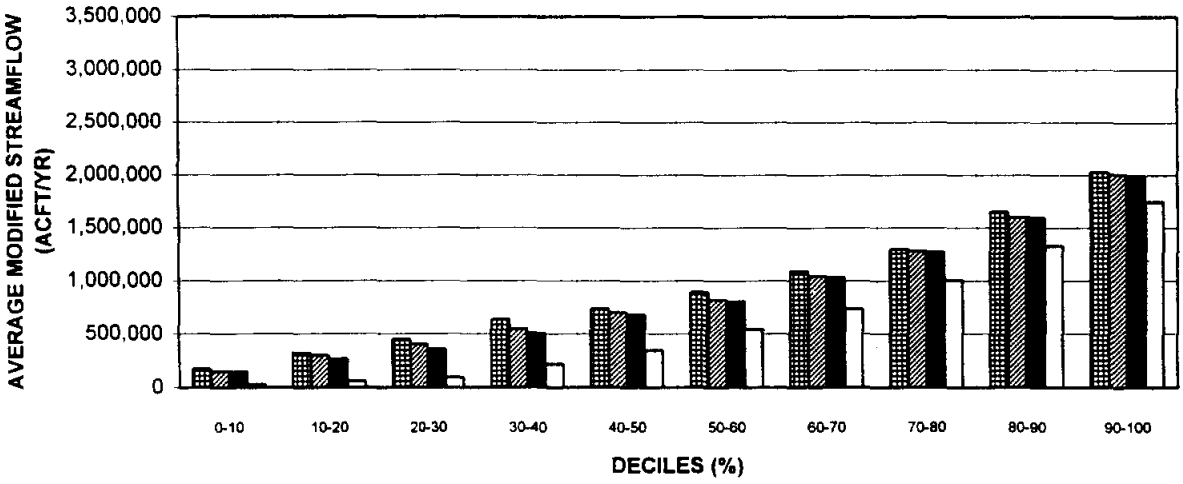
[4] Resultant streamflows for diversion of water available with drought contingency provisions for Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

[5] Resultant streamflows for diversion of water available under existing Trans-Texas Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries which have no drought contingency provisions.

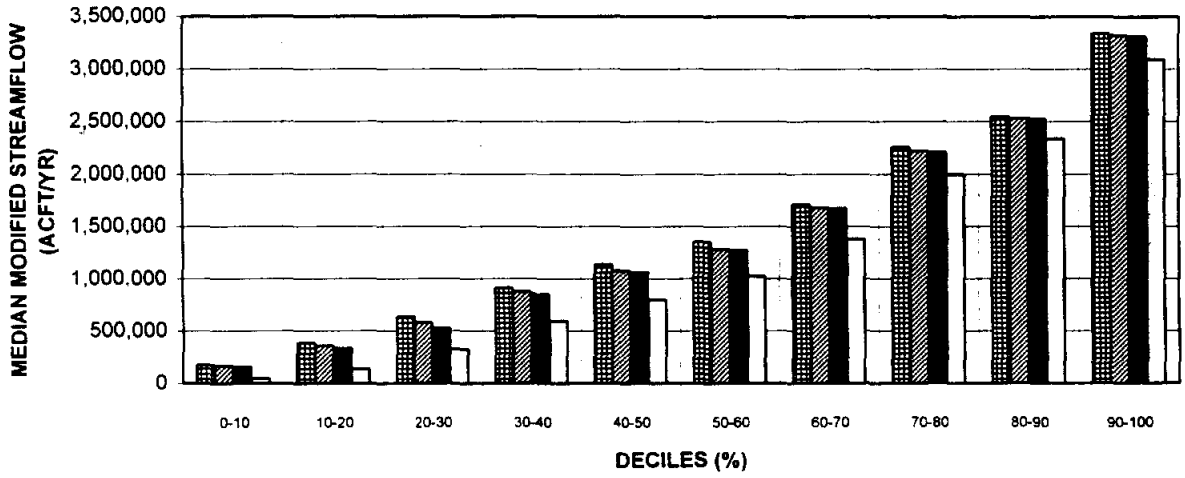
[6] Baseline streamflows (without additional diversion) subject to the following assumptions: a) Full water rights utilization; b) Hydropower subordinated to 365 cfs at Lake Dunlap; c) Return flows observed in 1988; and d) Edwards Aquifer pumpage of 400,000 acft/yr.

[7] Natural streamflows derived by adjustment of gaged streamflows to account for historical diversions, return flows, and reservoir operations. Natural streamflows used in the West and South Central Study Areas for the Trans-Texas Water Program are based on historical pumpage and springflow from the Edwards Aquifer.

GUADALUPE RIVER AT CUERO



SALTWATER BARRIER NEAR TIVOLI



EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

MODIFIED STREAMFLOW SUMMARY
DIVERSION FROM GUADALUPE RIVER AT CUERO
ANNUAL DECILE AVERAGE COMPARISON

TRANS-TEXAS WATER PROGRAM	**6/95**
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	**FIG. 8**

MODIFIED STREAMFLOW SUMMARY [1] **TABLE 5**

DIVERSION FROM GUADALUPE RIVER AT CUERO

ANNUAL DECILE AVERAGE COMPARISON

POINT OF DIVERSION

ENVIRONMENTAL CRITERIA	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
WITH ADDITIONAL DIVERSIONS										
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	29,813	58,796	93,433	217,126	343,886	544,435	738,883	1,005,868	1,328,435	1,746,127
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]										
35% TRIGGER	147,079	267,935	360,395	509,879	684,542	811,674	1,038,415	1,271,872	1,597,175	1,997,288
25% TRIGGER	147,594	269,450	381,862	562,045	717,824	814,157	1,054,704	1,289,453	1,646,527	2,006,667
15% TRIGGER	150,054	286,856	427,212	614,661	725,615	857,261	1,073,553	1,292,330	1,655,058	2,028,974
B&E DROUGHT CONTINGENCY (ACFT) [4]										
35% TRIGGER	151,198	301,202	403,945	549,153	704,943	824,841	1,047,859	1,282,437	1,601,117	2,008,361
25% TRIGGER	151,198	303,892	414,844	584,721	724,084	824,841	1,060,458	1,293,482	1,646,527	2,013,515
15% TRIGGER	151,198	310,083	435,554	625,392	728,007	861,427	1,077,759	1,293,785	1,655,058	2,028,974
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	173,555	322,100	453,284	638,831	740,402	897,336	1,092,512	1,299,133	1,655,058	2,028,974
WITHOUT ADDITIONAL DIVERSIONS										
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	173,556	329,207	519,676	733,118	877,377	1,105,693	1,346,833	1,632,287	2,013,302	2,445,392
NATURAL CONDITIONS (ACFT) [7]	240,537	417,994	654,683	803,039	1,014,373	1,241,527	1,479,419	1,835,106	2,146,886	2,563,465

SALTWATER BARRIER

ENVIRONMENTAL CRITERIA	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
WITH ADDITIONAL DIVERSIONS										
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	48,151	137,397	324,294	593,504	796,601	1,025,209	1,381,415	1,997,359	2,339,316	3,091,191
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]										
35% TRIGGER	159,199	332,127	526,949	855,839	1,067,589	1,276,605	1,676,289	2,207,902	2,527,872	3,310,989
25% TRIGGER	159,631	336,547	560,086	875,950	1,084,246	1,298,334	1,692,038	2,250,359	2,537,457	3,319,194
15% TRIGGER	160,076	352,635	605,642	907,219	1,115,258	1,330,815	1,695,603	2,253,463	2,544,965	3,338,886
B&E DROUGHT CONTINGENCY (ACFT) [4]										
35% TRIGGER	166,237	357,128	581,094	878,298	1,078,533	1,290,293	1,683,814	2,219,275	2,529,399	3,320,703
25% TRIGGER	166,237	358,159	599,573	891,005	1,092,325	1,303,371	1,699,003	2,250,359	2,538,984	3,325,224
15% TRIGGER	166,237	360,660	623,961	911,989	1,120,290	1,331,791	1,699,274	2,253,463	2,546,492	3,338,886
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	175,258	384,059	638,780	916,910	1,140,679	1,355,103	1,712,382	2,258,095	2,546,492	3,338,886
WITHOUT ADDITIONAL DIVERSIONS										
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	175,232	384,026	661,239	1,042,268	1,278,652	1,557,300	1,915,326	2,539,437	2,912,217	3,714,601
NATURAL CONDITIONS (ACFT) [7]	380,496	675,686	1,004,959	1,387,701	1,645,876	1,950,209	2,314,881	2,919,382	3,381,634	4,119,466

[1] Monthly medians and/or annual decile averages based on the 1934-89 simulation period.

[2] Resultant streamflows for diversion of theoretical maximum water available subject only to senior water rights.

[3] Resultant streamflows for diversion of water available with drought contingency provisions for both Instream Flows and Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

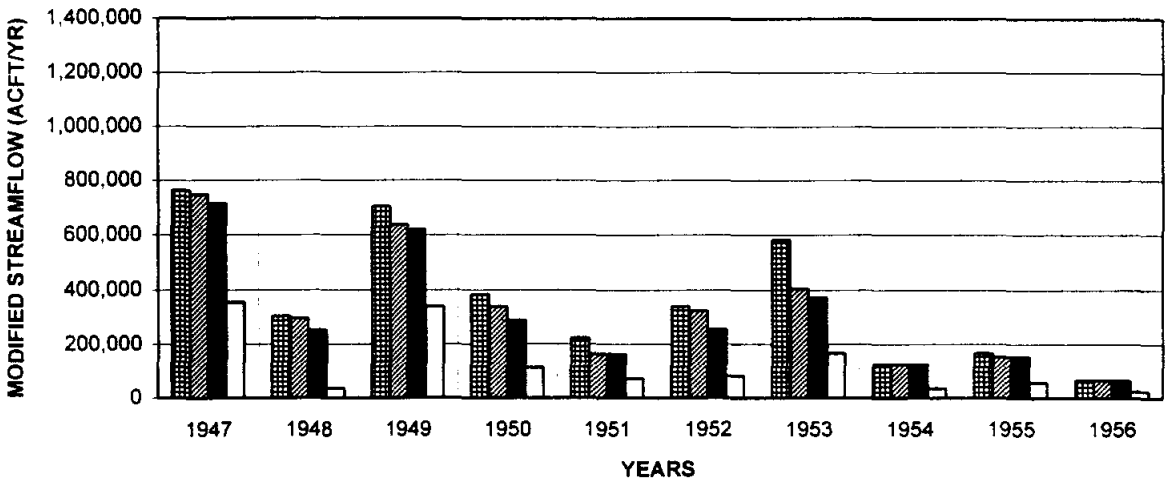
[4] Resultant streamflows for diversion of water available with drought contingency provisions for Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

[5] Resultant streamflows for diversion of water available under existing Trans-Texas Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries which have no drought contingency provisions.

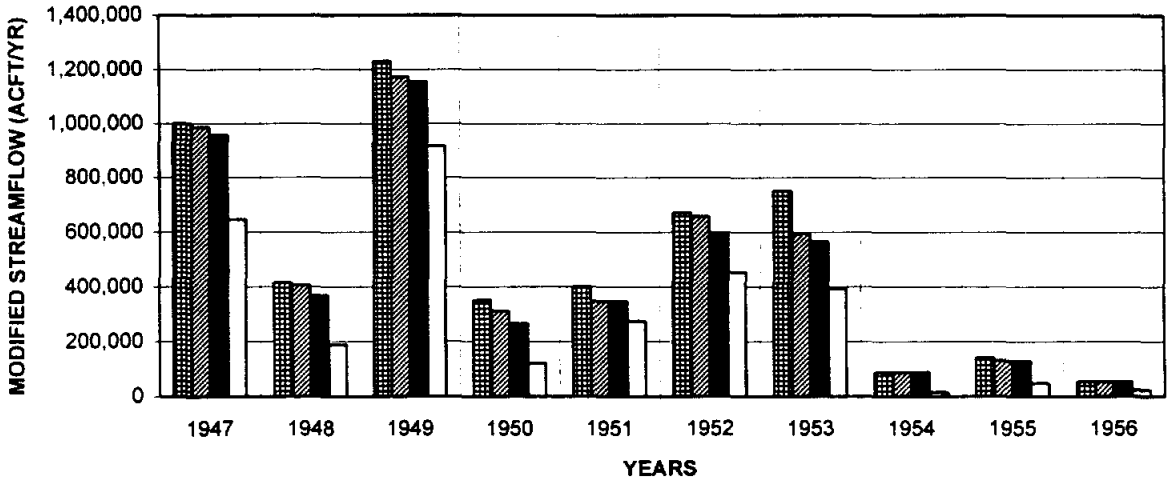
[6] Baseline streamflows (without additional diversion) subject to the following assumptions: a) Full water rights utilization; b) Hydropower subordinated to 365 cfs at Lake Dunlap; c) Return flows observed in 1988; and d) Edwards Aquifer pumpage of 400,000 acft/yr.

[7] Natural streamflows derived by adjustment of gaged streamflows to account for historical diversions, return flows, and reservoir operations. Natural streamflows used in the West and South Central Study Areas for the Trans-Texas Water Program are based on historical pumpage and springflow from the Edwards Aquifer.

GUADALUPE RIVER AT CUERO



SALTWATER BARRIER NEAR TIVOLI



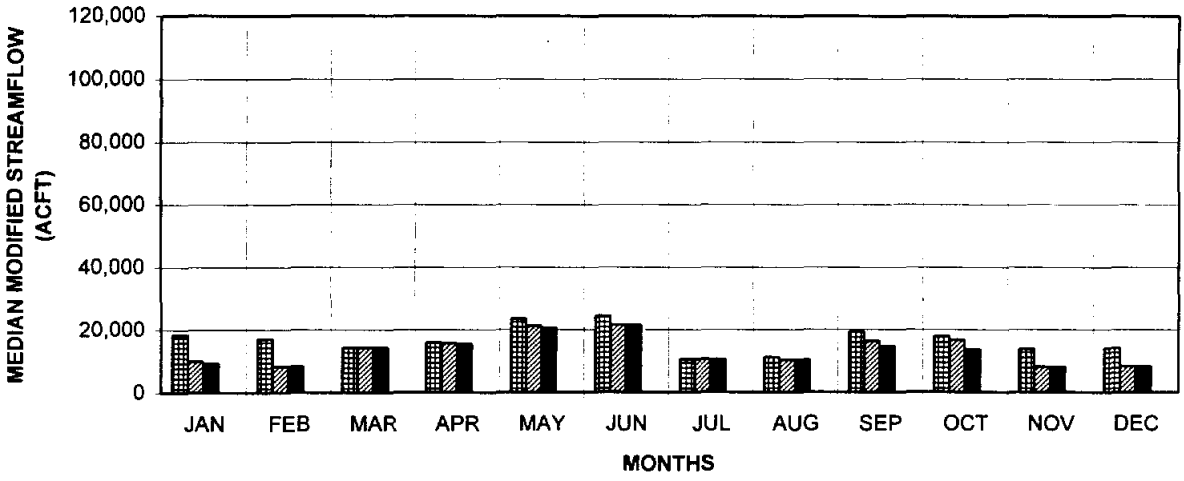
EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

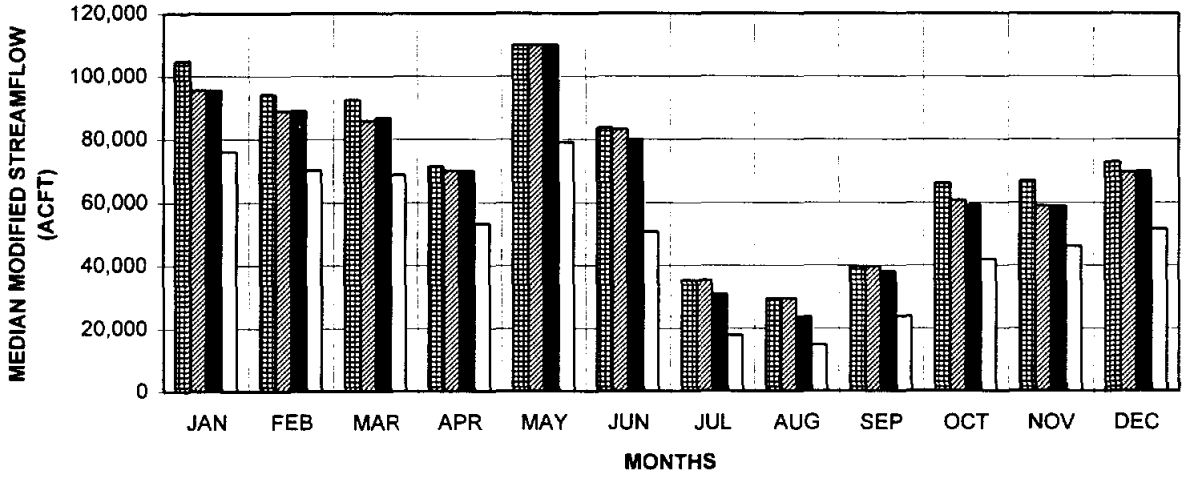
MODIFIED STREAMFLOW SUMMARY
DIVERSION FROM GUADALUPE RIVER AT CUERO
TIME SERIES COMPARISON

TRANS-TEXAS WATER PROGRAM	**6/95**
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	**FIG. 9**

SAN ANTONIO RIVER AT GOLIAD



SALTWATER BARRIER NEAR TIVOLI



EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

MODIFIED STREAMFLOW SUMMARY
DIVERSION FROM SAN ANTONIO RIVER AT GOLIAD
MONTHLY MEDIAN COMPARISON

TRANS-TEXAS WATER PROGRAM	**6/95**
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	**FIG. 10**

MODIFIED STREAMFLOW SUMMARY [1] **TABLE 6**

DIVERSION FROM SAN ANTONIO RIVER AT GOLIAD

MONTHLY MEDIAN COMPARISON

POINT OF DIVERSION

ENVIRONMENTAL CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
WITH ADDITIONAL DIVERSIONS													
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	0	0	0	0	0	0	0	0	0	0	0	0	48,370
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]													
35% TRIGGER	9,362	8,396	14,265	15,490	20,618	21,588	10,660	10,369	14,633	13,737	8,202	8,318	218,118
25% TRIGGER	12,557	10,279	14,265	15,490	20,618	21,588	10,660	10,369	14,694	16,794	8,799	8,318	227,797
15% TRIGGER	15,330	10,957	14,265	15,490	21,944	21,588	10,660	10,509	17,137	16,914	11,033	11,028	255,599
B&E DROUGHT CONTINGENCY (ACFT) [4]													
35% TRIGGER	10,117	8,396	14,265	15,842	21,220	21,588	10,660	10,369	16,466	16,794	8,202	8,318	227,797
25% TRIGGER	12,557	10,331	14,265	15,842	21,220	21,588	10,660	11,235	17,137	17,018	9,801	8,328	227,797
15% TRIGGER	15,330	10,957	14,265	15,983	23,554	21,588	10,660	11,235	18,402	17,095	11,427	11,742	259,320
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	18,582	17,109	14,265	15,983	23,554	24,533	10,660	11,252	19,270	17,939	13,924	14,226	270,295
WITHOUT ADDITIONAL DIVERSIONS													
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	25,294	23,325	23,368	22,620	30,110	29,189	13,236	15,725	20,712	22,904	22,705	23,732	387,702
NATURAL CONDITIONS (ACFT) [7]	19,891	20,754	23,630	25,604	33,746	29,651	16,527	17,263	21,364	21,372	18,330	20,568	417,808

SALTWATER BARRIER

ENVIRONMENTAL CRITERIA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
WITH ADDITIONAL DIVERSIONS													
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	76,015	70,237	68,853	53,384	79,086	50,977	18,015	14,800	23,970	41,946	46,246	51,823	1,078,461
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]													
35% TRIGGER	95,593	89,083	86,873	70,074	110,031	80,140	31,004	23,806	38,029	59,265	58,980	69,943	1,232,830
25% TRIGGER	102,664	92,123	86,057	71,321	110,031	83,699	31,004	23,806	38,813	61,593	64,413	69,943	1,267,534
15% TRIGGER	102,664	92,857	92,117	71,321	110,031	83,699	35,011	24,269	39,097	64,267	66,860	72,480	1,282,920
B&E DROUGHT CONTINGENCY (ACFT) [4]													
35% TRIGGER	95,593	89,083	85,873	70,074	110,031	83,238	35,351	29,614	39,685	60,822	58,980	69,643	1,258,372
25% TRIGGER	102,664	92,857	91,536	71,321	110,031	83,699	35,351	29,614	39,685	61,593	66,860	69,943	1,273,878
15% TRIGGER	102,664	92,857	92,117	71,321	110,031	83,699	35,351	29,614	39,685	64,267	66,860	72,480	1,282,920
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	104,760	94,182	92,525	71,321	110,031	83,699	35,351	29,614	39,685	66,156	66,860	72,840	1,282,920
WITHOUT ADDITIONAL DIVERSIONS													
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	104,759	94,182	92,526	71,323	110,033	83,700	35,343	29,616	39,684	66,145	66,854	72,482	1,381,073
NATURAL CONDITIONS (ACFT) [7]	116,323	110,345	118,185	104,804	148,297	138,408	82,219	68,759	82,319	89,161	84,639	87,587	1,749,070

[1] Monthly medians and/or annual decile averages based on the 1934-89 simulation period.

[2] Resultant streamflows for diversion of theoretical maximum water available subject only to senior water rights.

[3] Resultant streamflows for diversion of water available with drought contingency provisions for both Instream Flows and Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of stream flow.

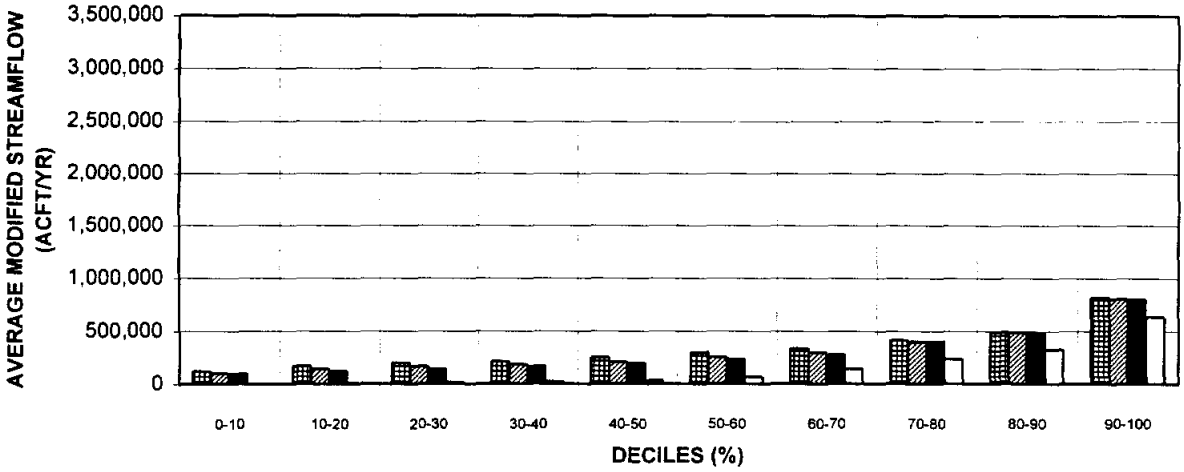
[4] Resultant streamflows for diversion of water available with drought contingency provisions for Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

[5] Resultant streamflows for diversion of water available under existing Trans-Texas Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries which have no drought contingency provisions.

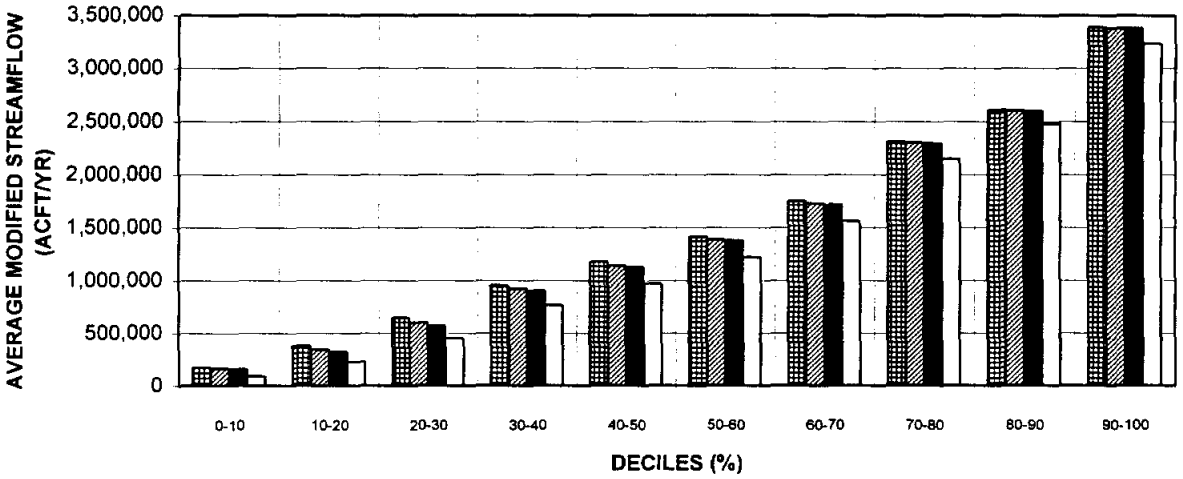
[6] Baseline streamflows (without additional diversion) subject to the following assumptions: a) Full water rights utilization; b) Hydropower subordinated to 365 cfs at Lake Dunlap; c) Return flows observed in 1988; and d) Edwards Aquifer pumpage of 400,000 acft/yr.

[7] Natural streamflows derived by adjustment of gaged streamflows to account for historical diversions, return flows, and reservoir operations. Natural streamflows used in the West and South Central Study Areas for the Trans-Texas Water Program are based on historical pumpage and springflow from the Edwards Aquifer.

SAN ANTONIO RIVER AT GOLIAD



SALTWATER BARRIER NEAR TIVOLI



EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

MODIFIED STREAMFLOW SUMMARY
DIVERSION FROM SAN ANTONIO RIVER AT GOLIAD
ANNUAL DECILE AVERAGE COMPARISON

TRANS-TEXAS WATER PROGRAM	**6/95**
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	**FIG. 11**

MODIFIED STREAMFLOW SUMMARY [1] **TABLE 7**

DIVERSION FROM SAN ANTONIO RIVER AT GOLIAD

ANNUAL DECILE AVERAGE COMPARISON

POINT OF DIVERSION

ENVIRONMENTAL CRITERIA	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
WITH ADDITIONAL DIVERSIONS										
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	0	5,729	15,913	21,962	34,486	66,391	143,662	236,677	323,241	639,727
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]										
35% TRIGGER	96,415	122,583	142,132	168,412	196,961	234,927	280,194	399,603	486,833	803,995
25% TRIGGER	97,110	128,053	152,170	180,438	207,616	263,092	325,421	405,313	492,823	814,720
15% TRIGGER	101,664	144,667	172,666	200,145	238,624	281,800	329,557	414,386	492,823	814,720
B&E DROUGHT CONTINGENCY (ACFT) [4]										
35% TRIGGER	102,721	141,187	166,023	183,763	208,588	256,043	299,173	400,717	486,833	807,912
25% TRIGGER	102,721	142,113	170,389	193,582	214,703	279,424	328,178	405,313	492,823	816,591
15% TRIGGER	104,778	147,705	180,703	205,199	239,244	288,173	329,557	414,386	492,823	816,591
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	120,798	173,998	200,572	212,600	252,711	298,015	337,040	414,386	492,823	819,949
WITHOUT ADDITIONAL DIVERSIONS										
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	123,768	188,657	240,501	308,847	353,138	457,486	505,172	712,764	823,269	1,120,679
NATURAL CONDITIONS (ACFT) [7]	91,762	165,417	221,727	303,880	363,254	467,153	526,165	762,543	870,753	1,139,397

SALTWATER BARRIER

ENVIRONMENTAL CRITERIA	1-10%	10-20%	20-30%	30-40%	40-50%	50-60%	60-70%	70-80%	80-90%	90-100%
WITH ADDITIONAL DIVERSIONS										
NO ENVIRONMENTAL CRITERIA (ACFT) [2]	93,730	230,496	455,382	770,152	973,418	1,224,414	1,564,294	2,149,688	2,480,636	3,233,246
INSTREAM AND B&E DROUGHT CONTINGENCY (ACFT) [3]										
35% TRIGGER	160,735	325,704	572,379	905,115	1,134,233	1,383,811	1,719,763	2,298,643	2,601,497	3,380,234
25% TRIGGER	162,119	332,904	588,510	921,848	1,154,155	1,400,755	1,743,756	2,307,135	2,610,300	3,382,444
15% TRIGGER	163,078	345,361	630,528	950,824	1,167,500	1,406,643	1,745,652	2,307,135	2,610,300	3,388,457
B&E DROUGHT CONTINGENCY (ACFT) [4]										
35% TRIGGER	166,498	346,291	601,605	924,028	1,144,607	1,388,910	1,730,819	2,303,204	2,604,219	3,380,234
25% TRIGGER	166,498	347,322	611,707	938,708	1,159,015	1,402,418	1,746,857	2,308,836	2,610,300	3,382,444
15% TRIGGER	166,498	352,027	635,665	954,548	1,169,260	1,407,316	1,747,056	2,308,836	2,610,300	3,388,457
EXISTING ENVIRONMENTAL CRITERIA (ACFT) [5]	175,250	384,044	647,212	960,153	1,181,278	1,420,555	1,753,963	2,311,870	2,610,300	3,388,457
WITHOUT ADDITIONAL DIVERSIONS										
BASELINE WITH SENIOR WATER RIGHTS (ACFT) [6]	175,232	384,026	661,239	1,042,268	1,278,652	1,557,300	1,915,326	2,539,437	2,912,217	3,714,601
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[1] Monthly medians and/or annual decile averages based on the 1934-89 simulation period.

[2] Resultant streamflows for diversion of theoretical maximum water available subject only to senior water rights.

[3] Resultant streamflows for diversion of water available with drought contingency provisions for both instream Flows and Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

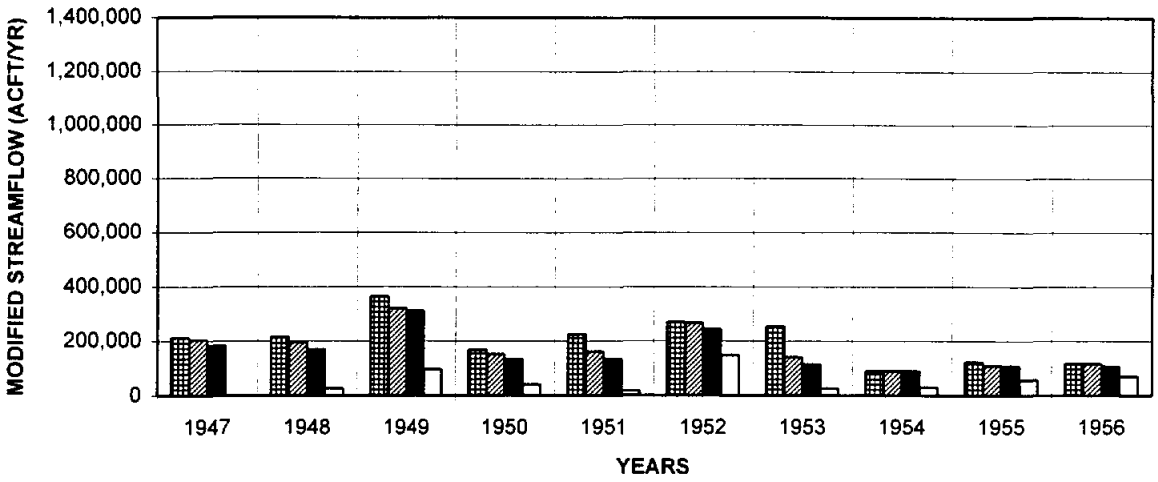
[4] Resultant streamflows for diversion of water available with drought contingency provisions for Freshwater Inflows to Bays & Estuaries subject to three triggers based on 4-month moving averages of streamflow.

[5] Resultant streamflows for diversion of water available under existing Trans-Texas Environmental Criteria for Instream Flows and Freshwater Inflows to Bays & Estuaries which have no drought contingency provisions.

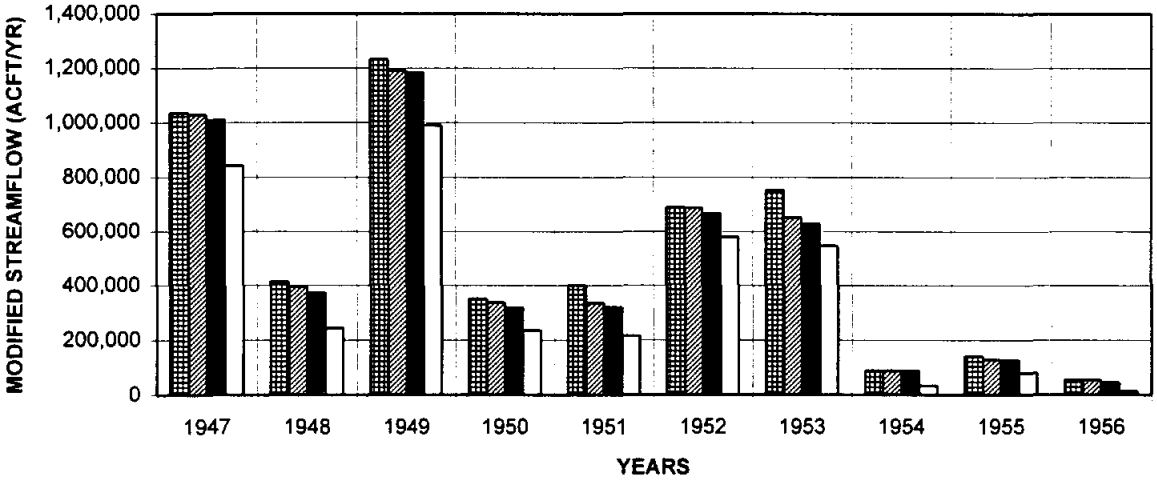
[6] Baseline streamflows (without additional diversion) subject to the following assumptions: a) Full water rights utilization; b) Hydropower subordinated to 365 cfs at Lake Dunlap; c) Return flows observed in 1988; and d) Edwards Aquifer pumpage of 400,000 acft/yr.

[7] Natural streamflows derived by adjustment of gaged streamflows to account for historical diversions, return flows, and reservoir operations. Natural streamflows used in the West and South Central Study Areas for the Trans-Texas Water Program are based on historical pumpage and springflow from the Edwards Aquifer.

SAN ANTONIO RIVER AT GOLIAD



SALTWATER BARRIER NEAR TIVOLI



EXISTING ENVIRONMENTAL CRITERIA
B&E DROUGHT CONTINGENCY
INSTREAM AND B&E DROUGHT CONTINGENCY
NO ENVIRONMENTAL CRITERIA

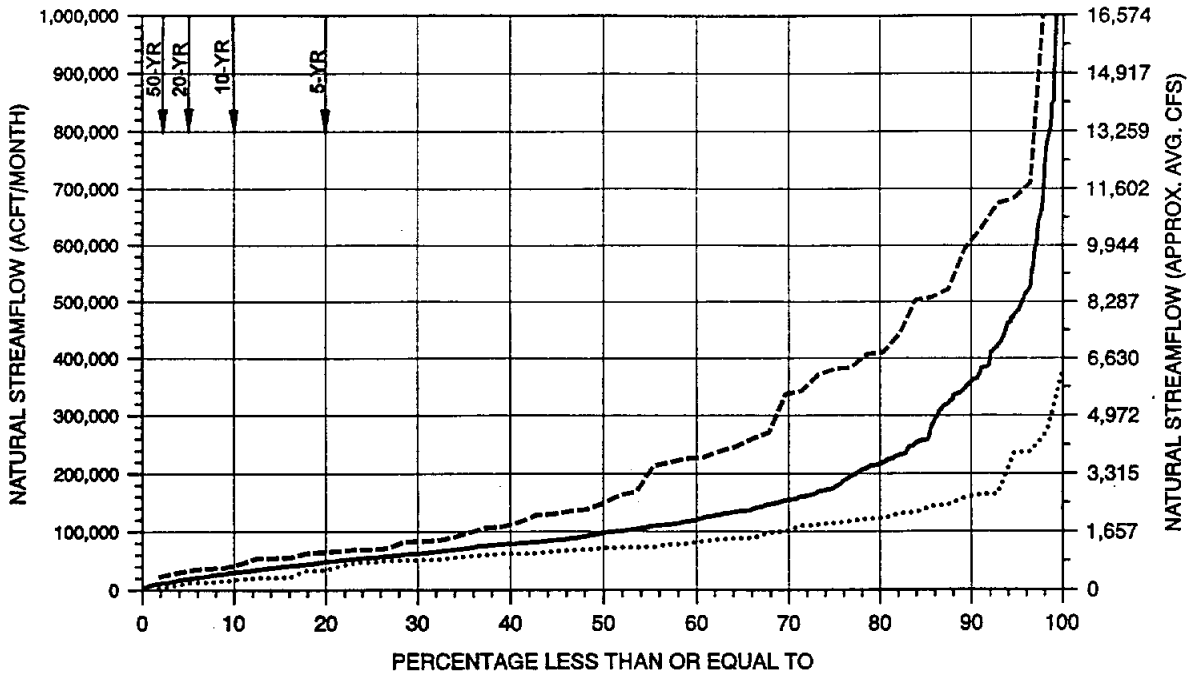
ASSUMPTIONS: 35% TRIGGER FOR DROUGHT CONTINGENCY BASED ON A 4-MONTH MOVING AVERAGE. 60,000 ACFT/MO MAXIMUM DIVERSION.

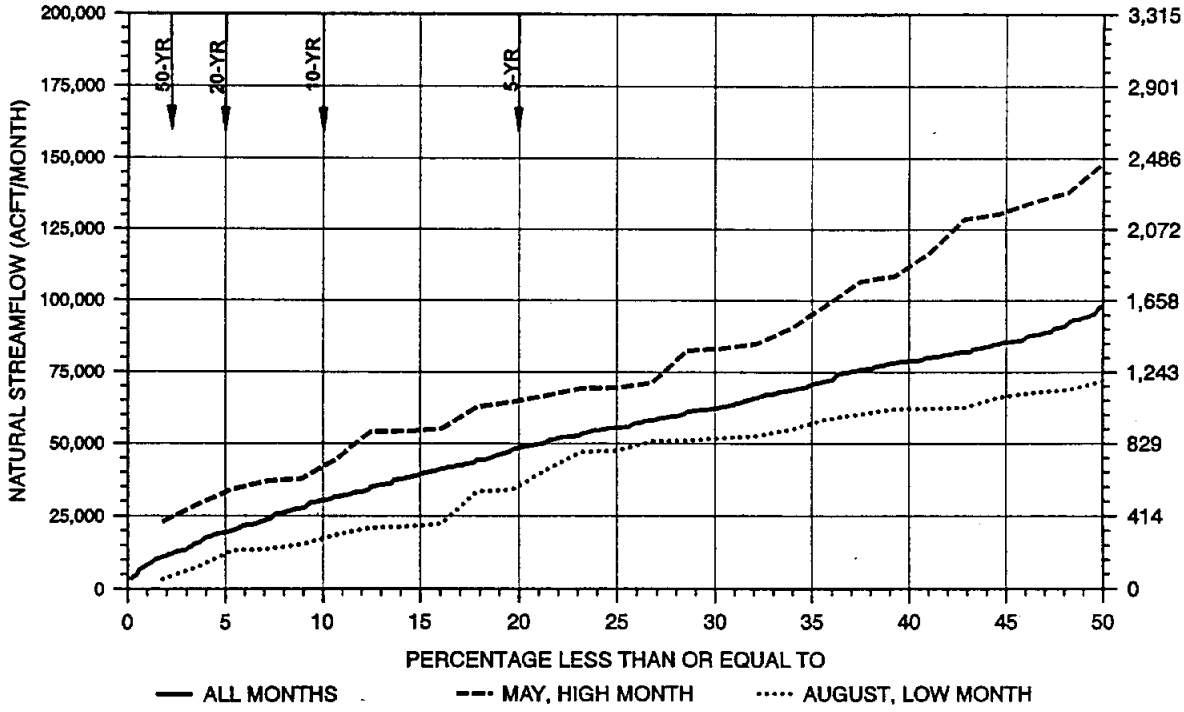
MODIFIED STREAMFLOW SUMMARY
DIVERSION FROM SAN ANTONIO RIVER AT GOLIAD
TIME SERIES COMPARISON

TRANS-TEXAS WATER PROGRAM	**6/95**
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	**FIG. 12**

APPENDIX A

SALTWATER BARRIER NEAR TIVOLI (USGS #1888)
NATURAL STREAMFLOW FREQUENCY





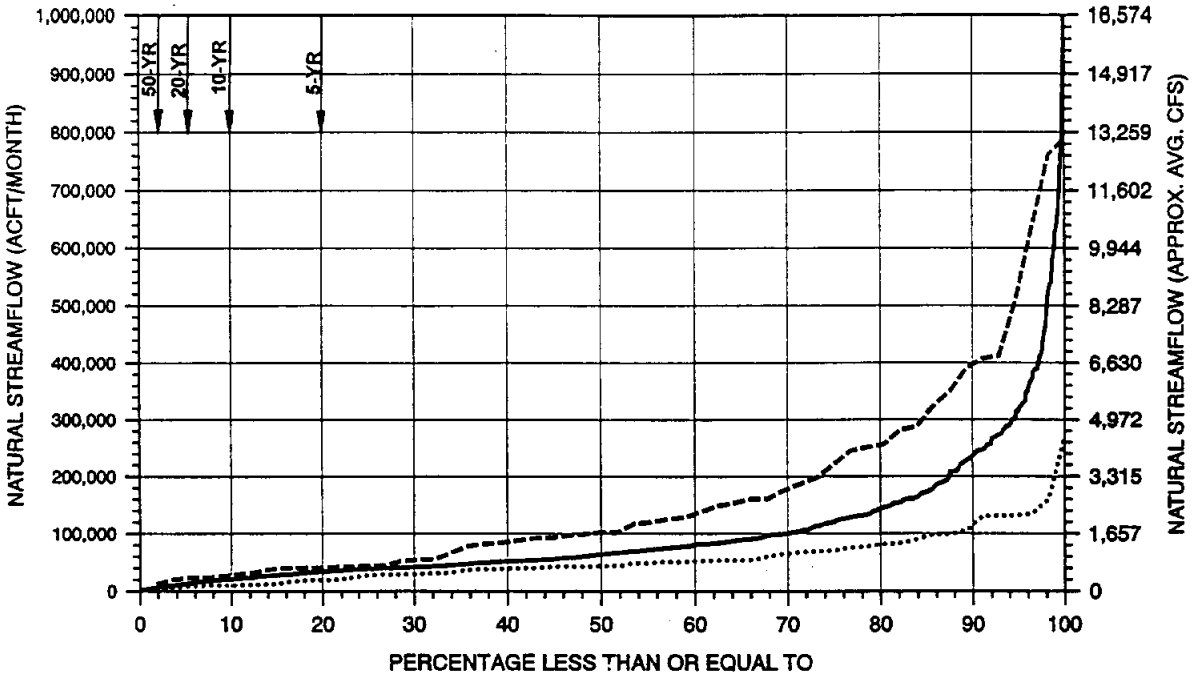
NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW MONTHS ONLY.

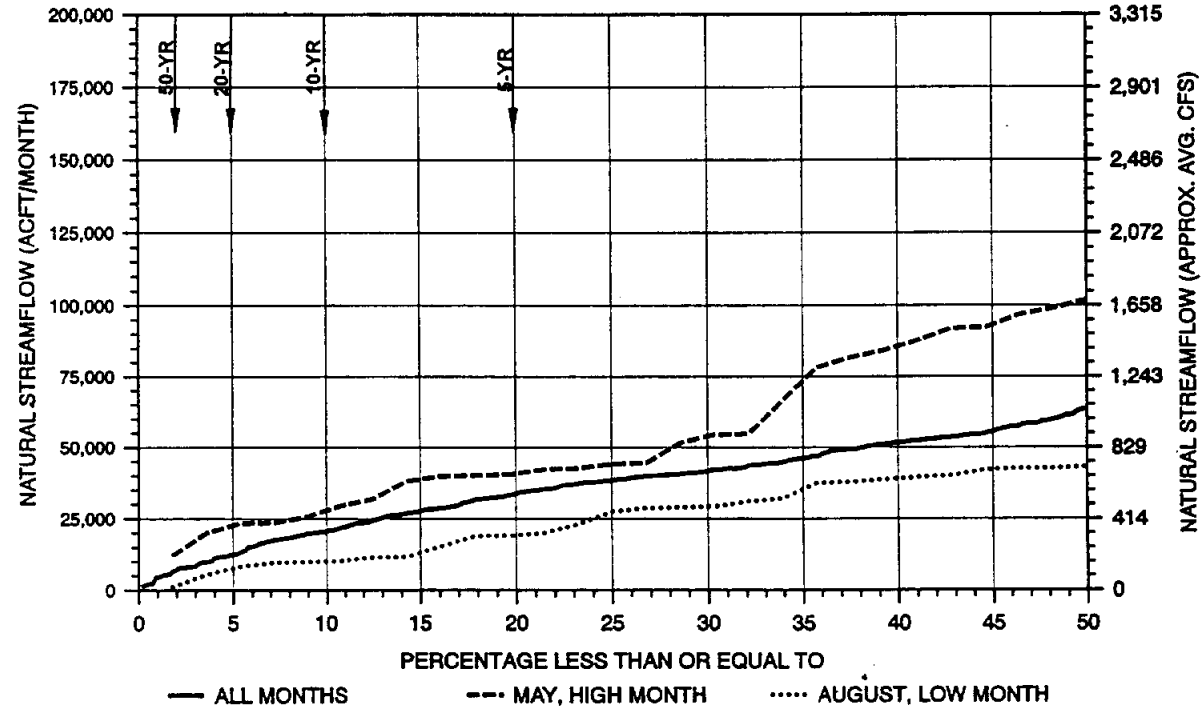
TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA
INSTREAM AND BAY & ESTUARY FLOW CRITERIA

6/95

FIG. A1

GUADALUPE RIVER @ CUERO (USGS #1758)
NATURAL STREAMFLOW FREQUENCY

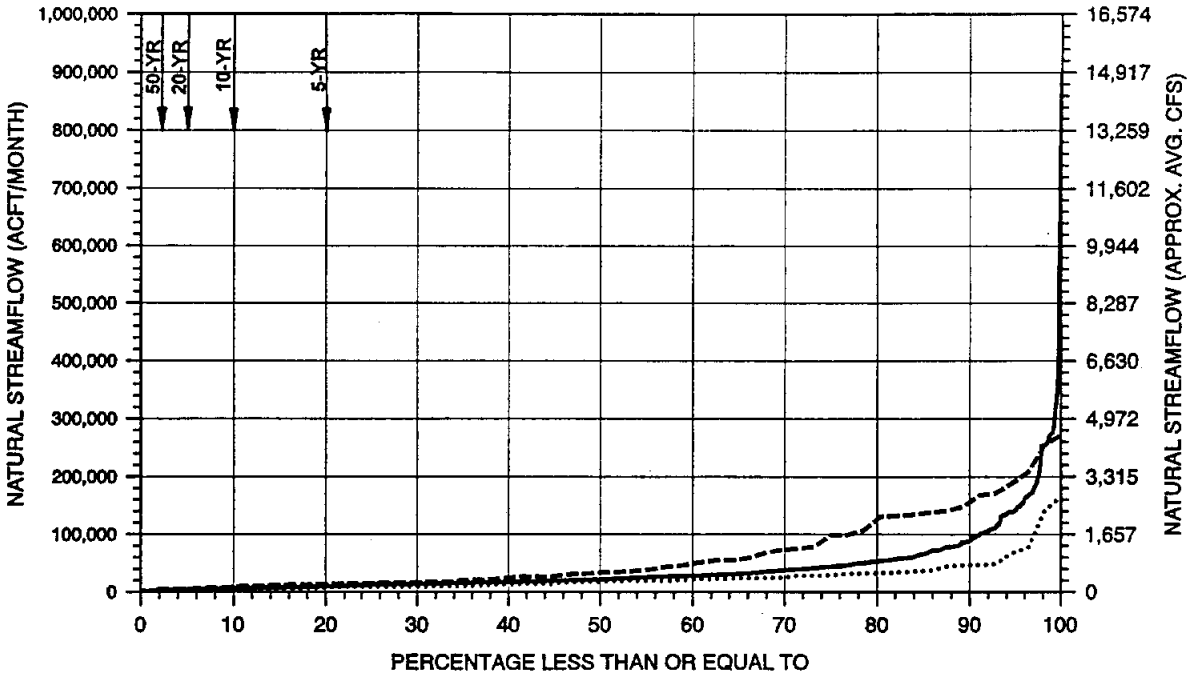


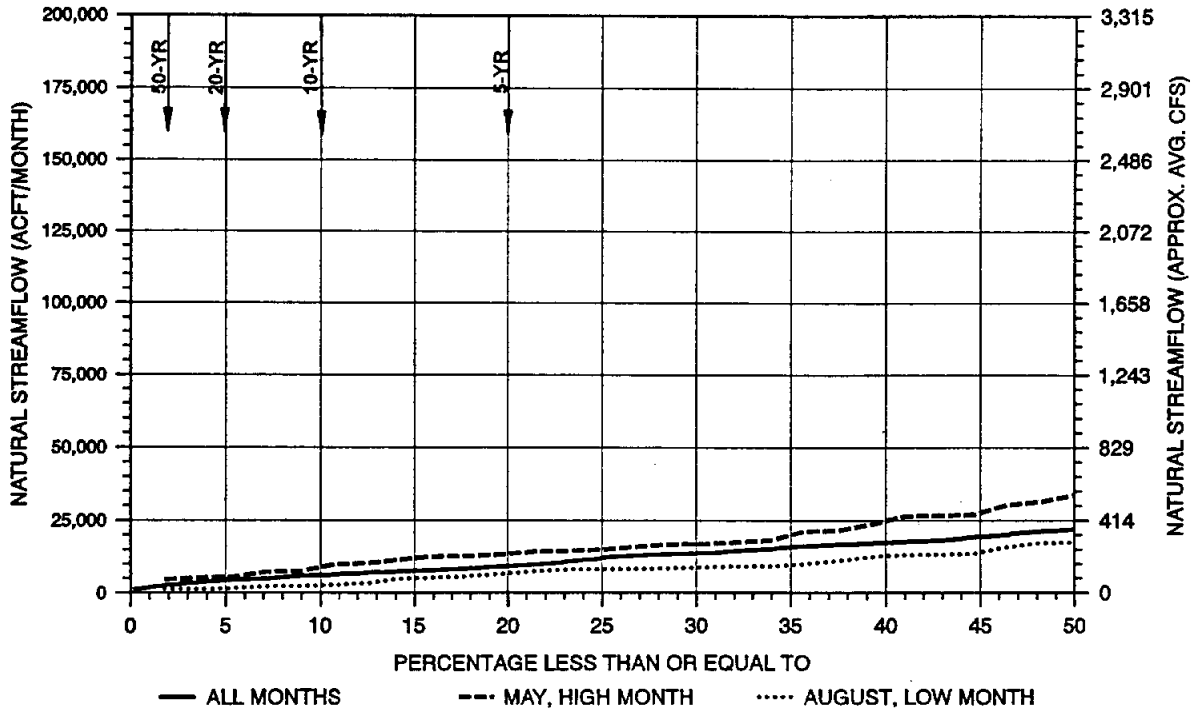


NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW MONTHS ONLY.

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. A2

SAN ANTONIO RIVER @ GOLIAD (USGS #1885)
NATURAL STREAMFLOW FREQUENCY





NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW MONTHS ONLY.

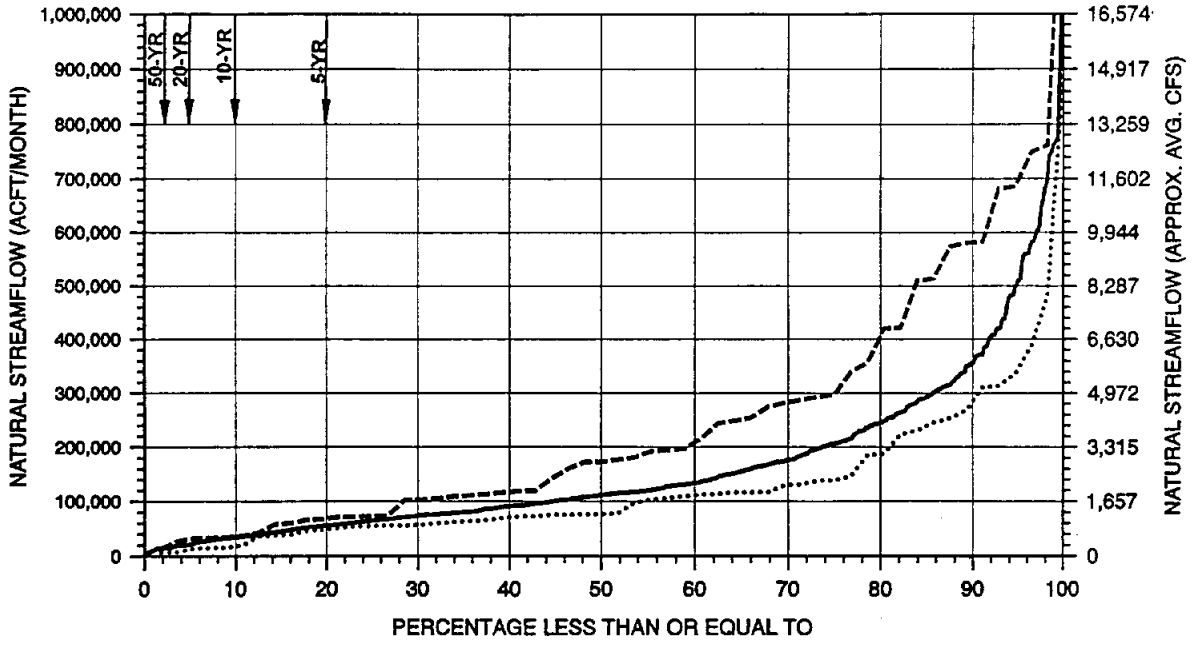
TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA
INSTREAM AND BAY & ESTUARY FLOW CRITERIA

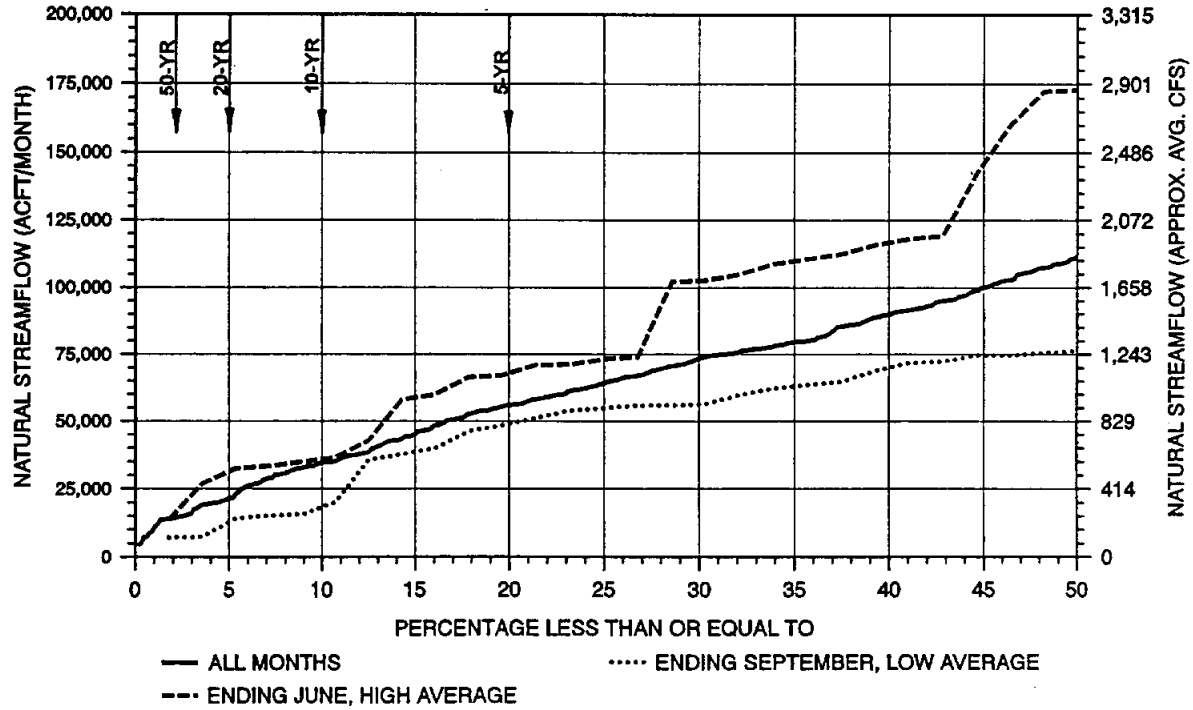
6/95

FIG. A3

APPENDIX B

SALTWATER BARRIER NEAR TIVOLI (USGS #1888)
NATURAL STREAMFLOW FREQUENCY, 2-MONTH DURATION

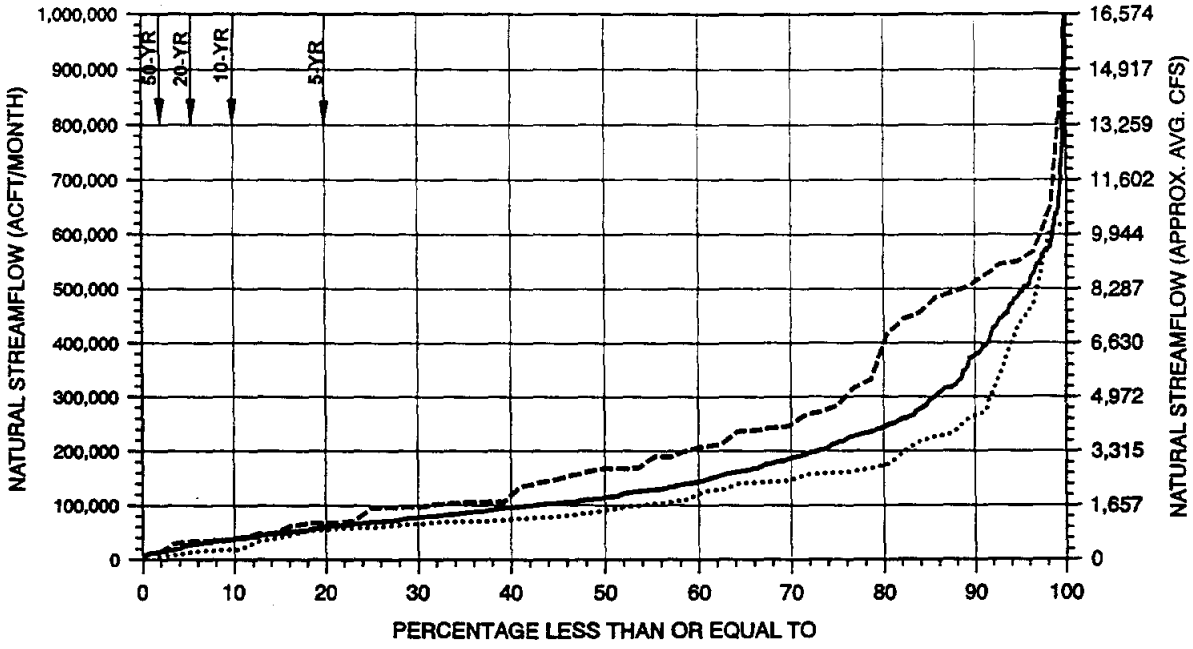


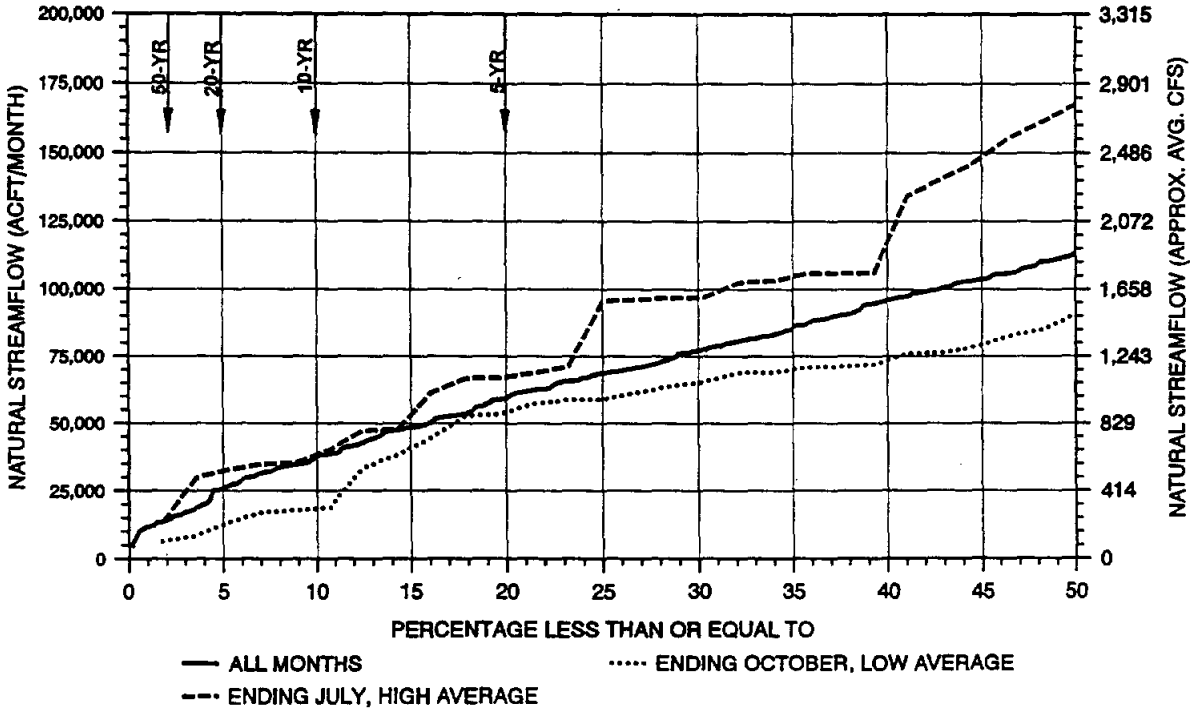


NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. B1

SALTWATER BARRIER NEAR TIVOLI (USGS #1888)
NATURAL STREAMFLOW FREQUENCY, 3-MONTH DURATION





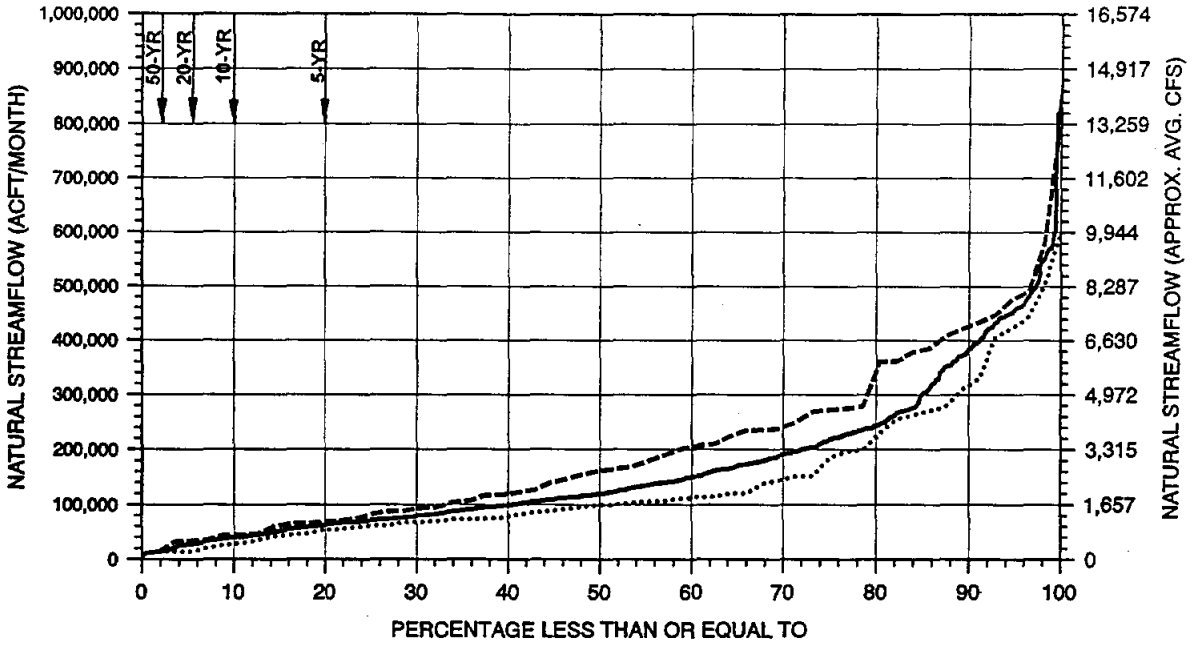
NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

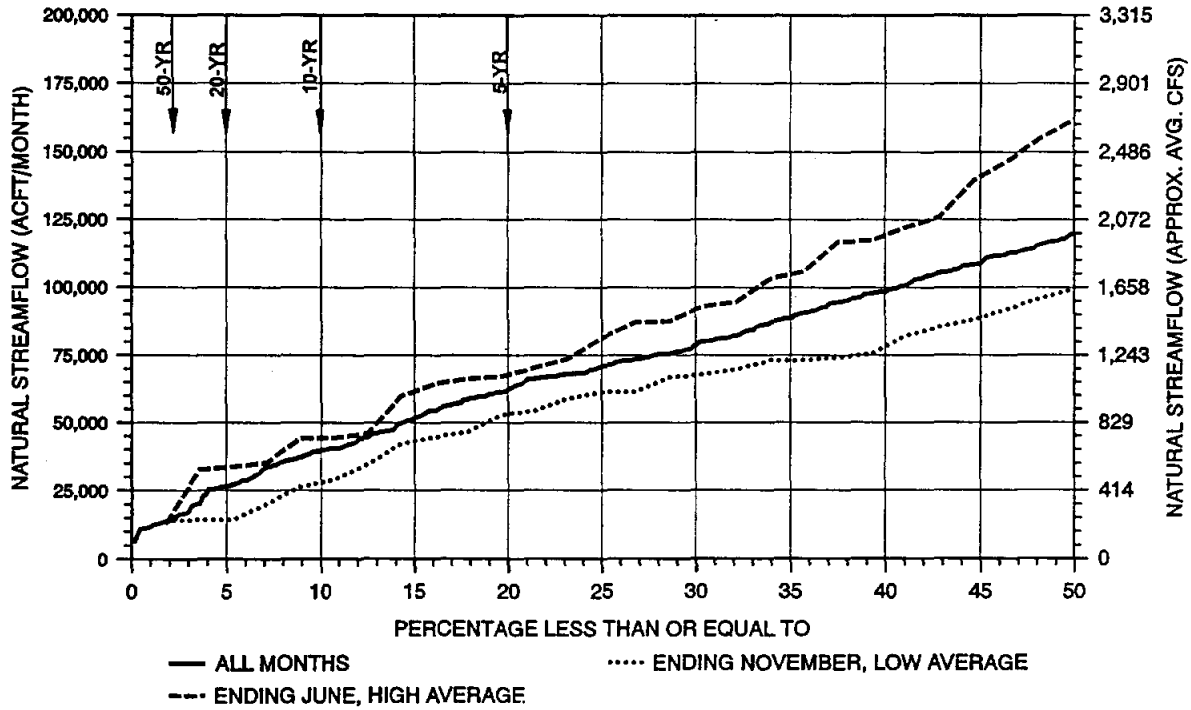
TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA
INSTREAM AND BAY & ESTUARY FLOW CRITERIA

6/95

FIG. B2

SALTWATER BARRIER NEAR TIVOLI (USGS #1888)
NATURAL STREAMFLOW FREQUENCY, 4-MONTH DURATION

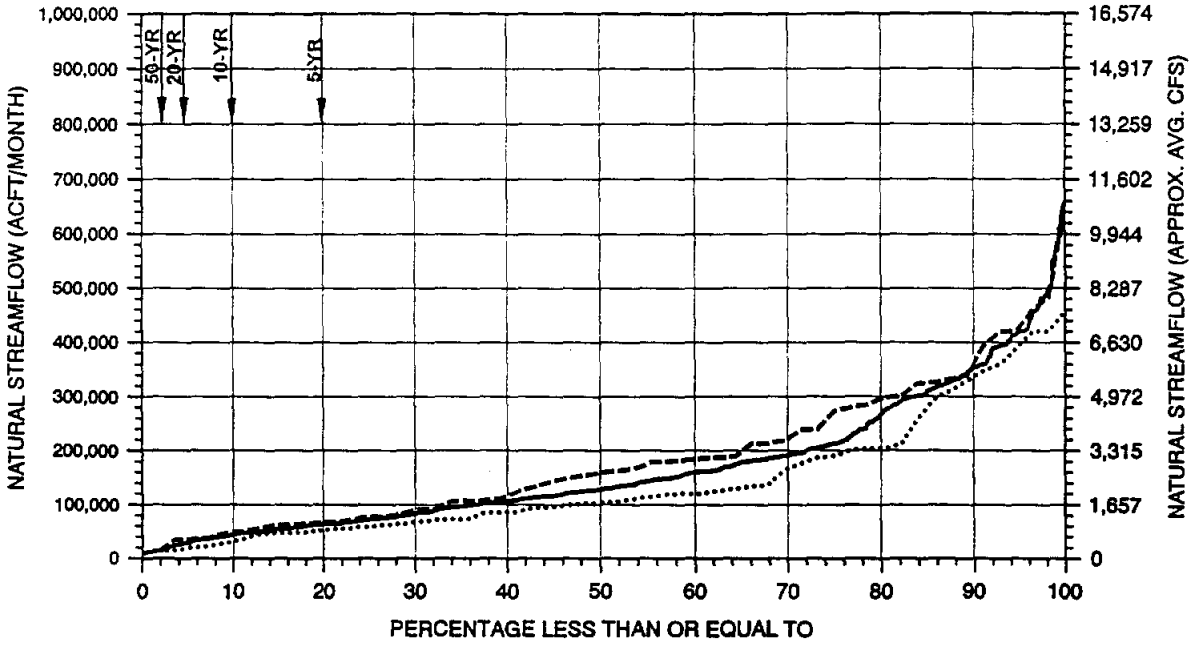


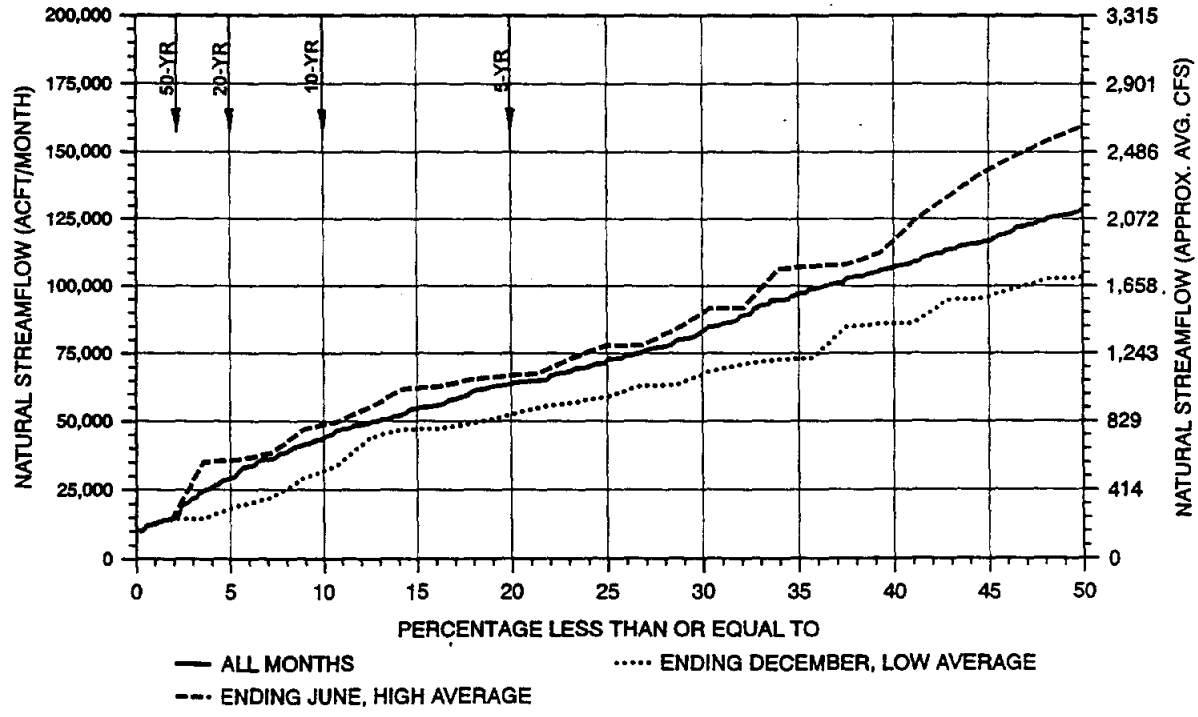


NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. B3

SALTWATER BARRIER NEAR TIVOLI (USGS #1888)
NATURAL STREAMFLOW FREQUENCY, 6-MONTH DURATION

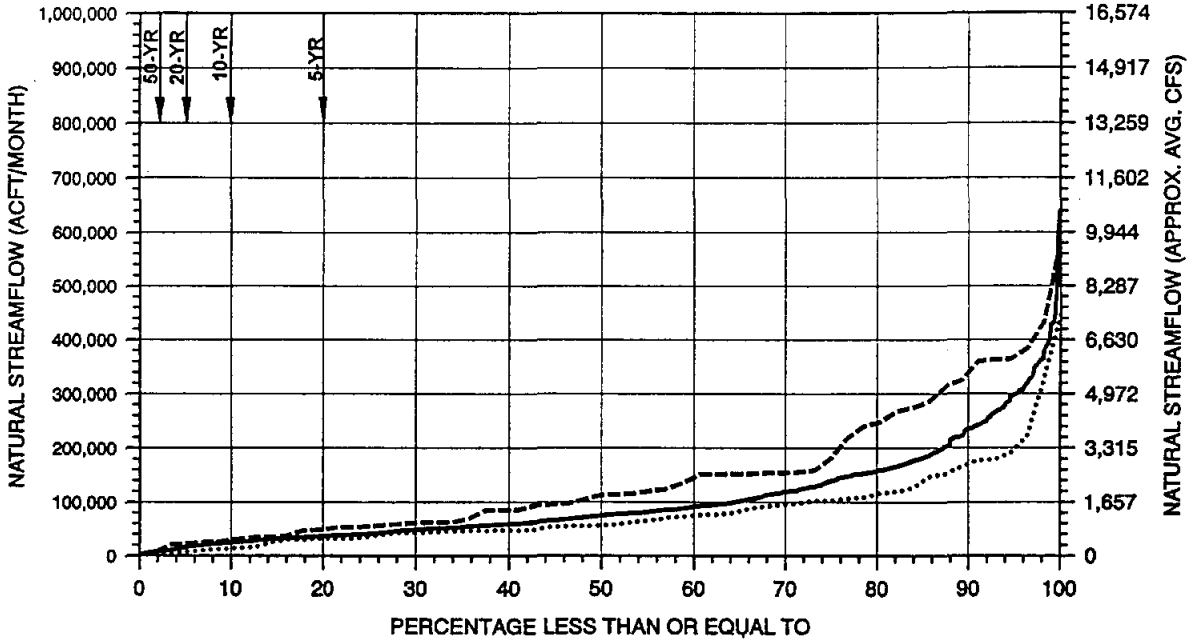


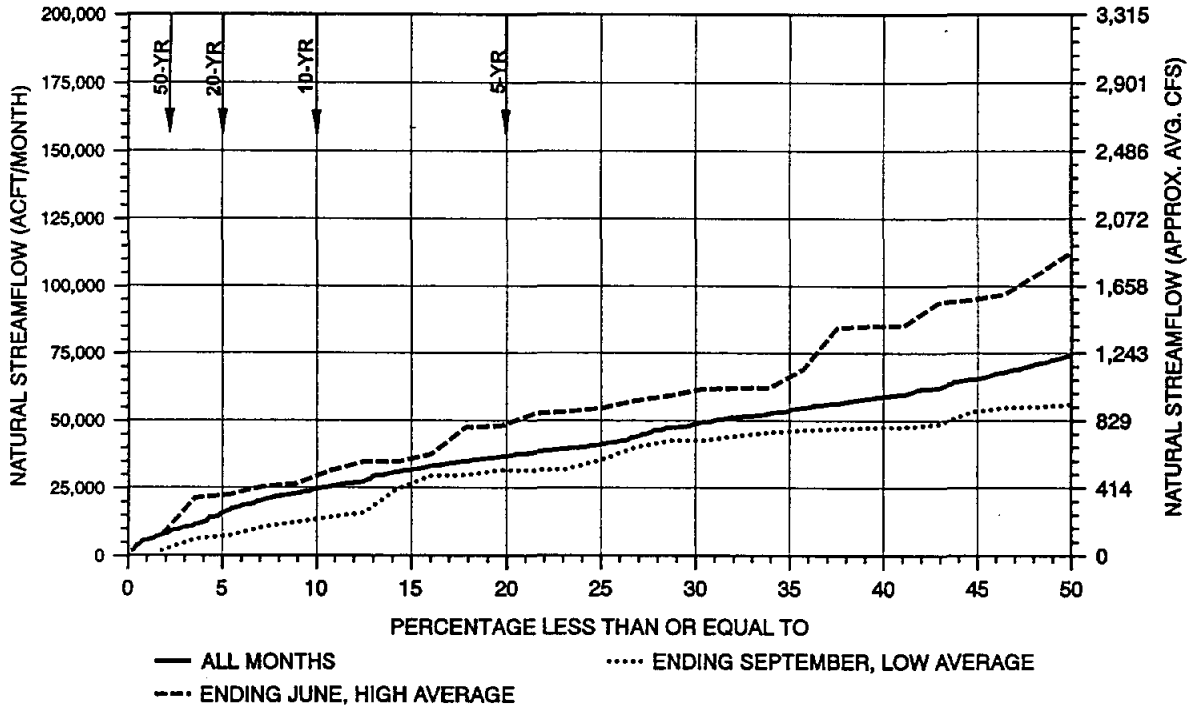


NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. B4

GUADALUPE RIVER AT CUERO (USGS #1758)
NATURAL STREAMFLOW FREQUENCY, 3-MONTH DURATION





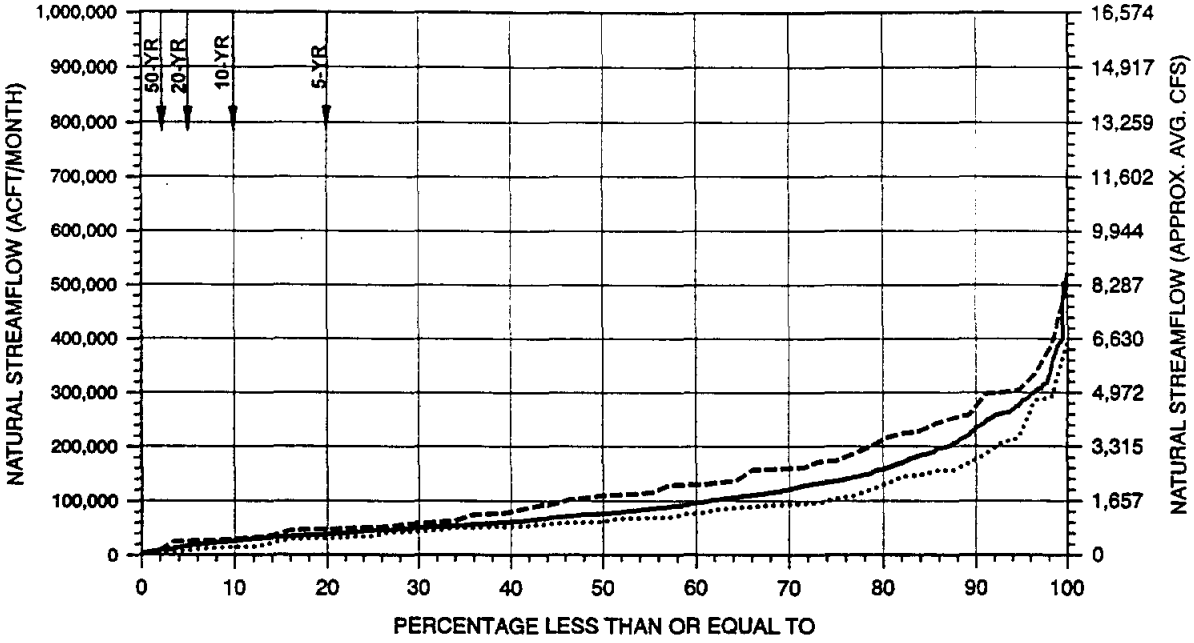
NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

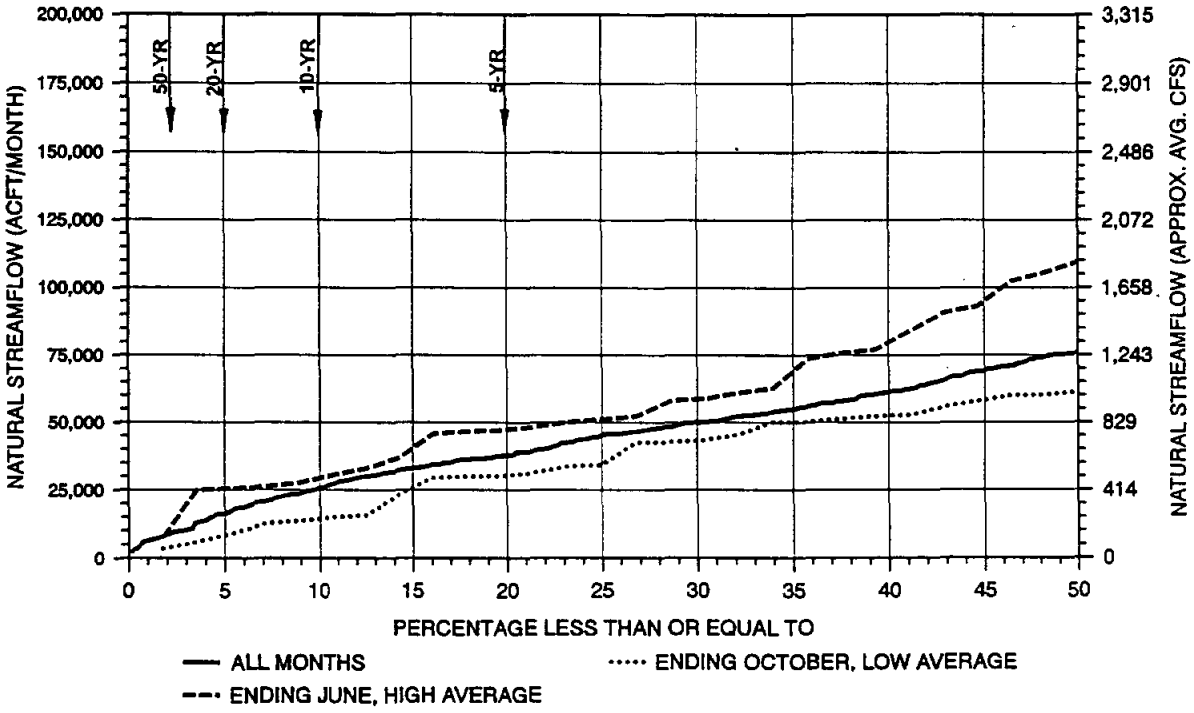
TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA
INSTREAM AND BAY & ESTUARY FLOW CRITERIA

6/95

FIG. B5

GUADALUPE RIVER AT CUERO (USGS #1758)
NATURAL STREAMFLOW FREQUENCY, 4-MONTH DURATION

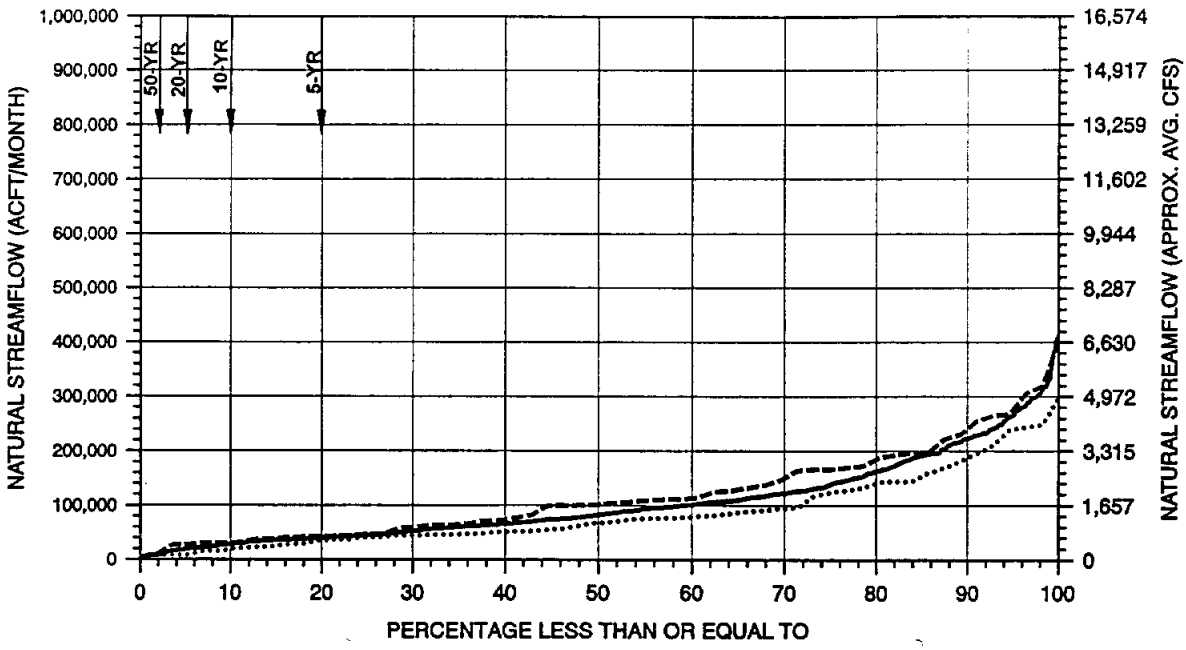


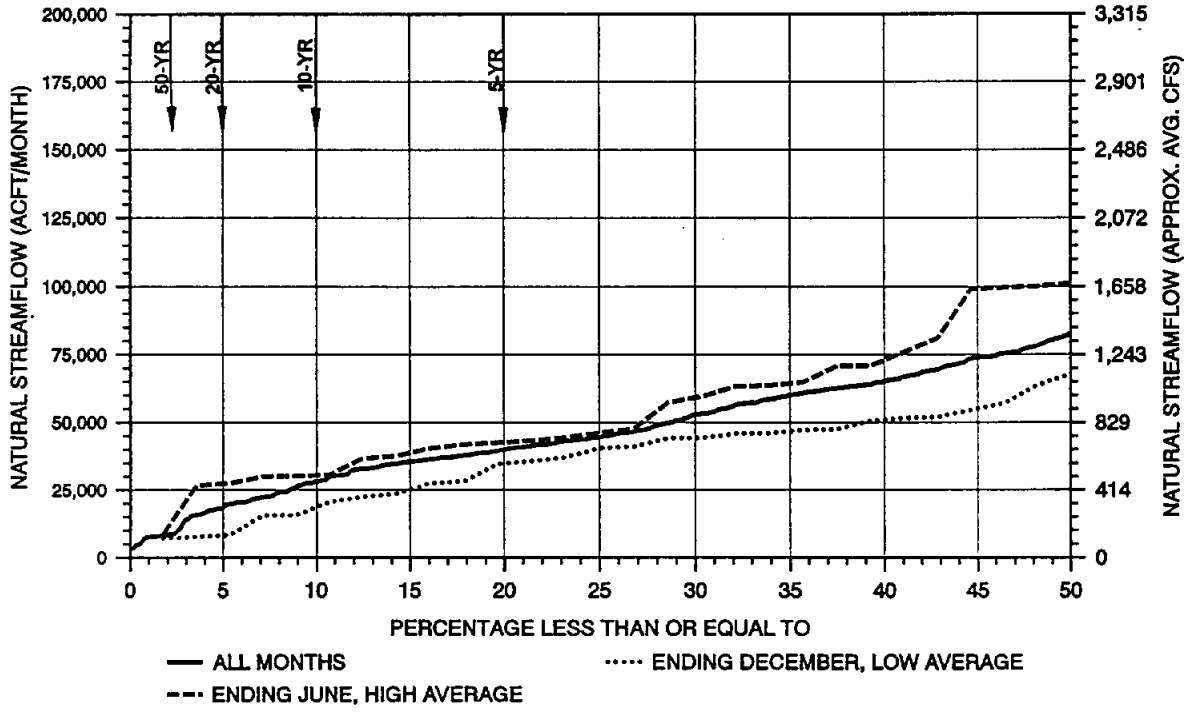


NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

TRANS-TEXAS WATER PROGRAM **WEST CENTRAL STUDY AREA** **INSTREAM AND BAY & ESTUARY FLOW CRITERIA**	6/95 FIG. B6

GUADALUPE RIVER AT CUERO (USGS #1758)
NATURAL STREAMFLOW FREQUENCY, 6-MONTH DURATION





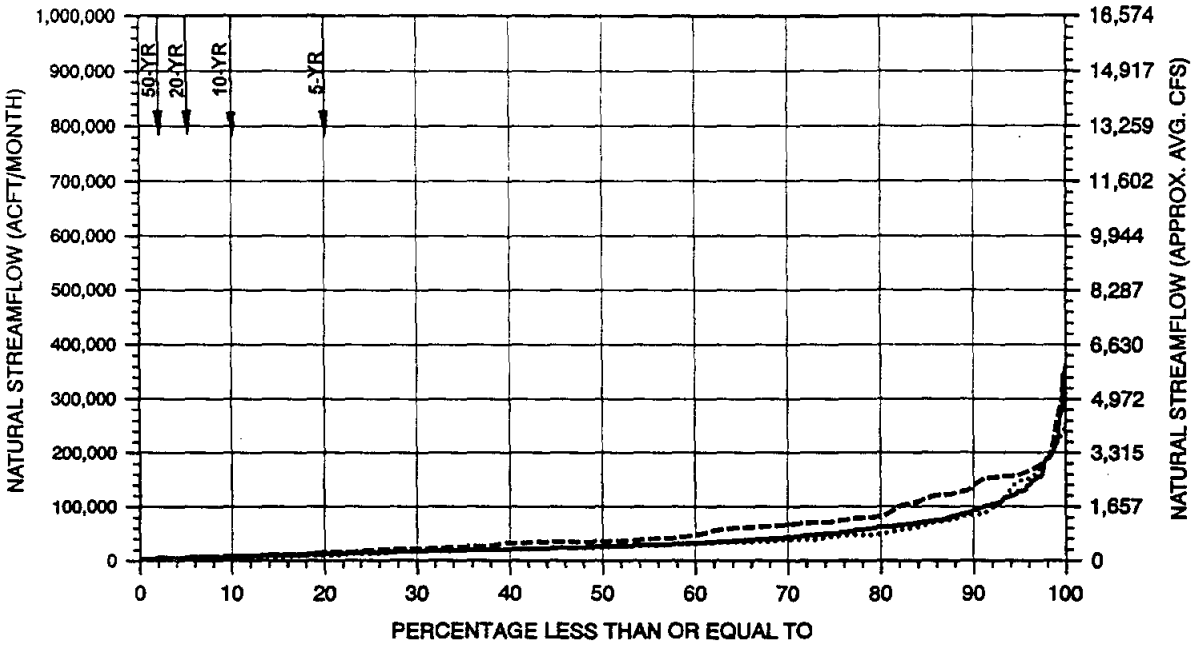
NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

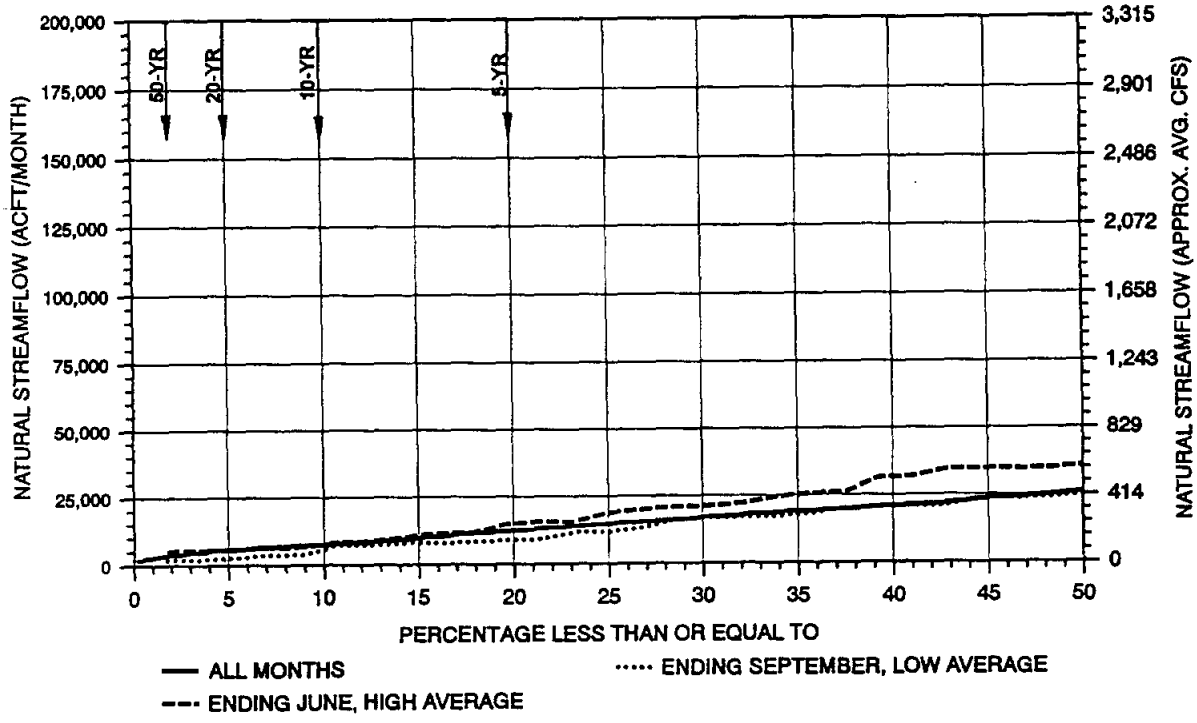
TRANS-TEXAS WATER PROGRAM
WEST CENTRAL STUDY AREA
INSTREAM AND BAY & ESTUARY FLOW CRITERIA

6/95

FIG. B7

SAN ANTONIO RIVER AT GOLIAD (USGS #1885)
NATURAL STREAMFLOW FREQUENCY, 3-MONTH DURATION

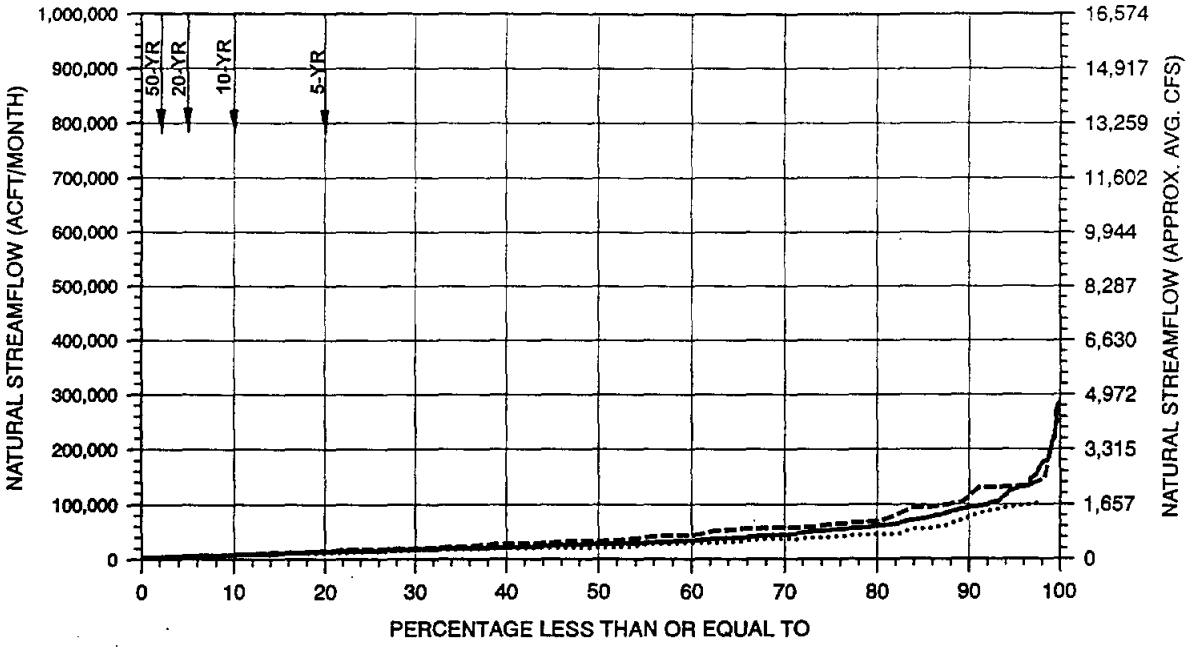


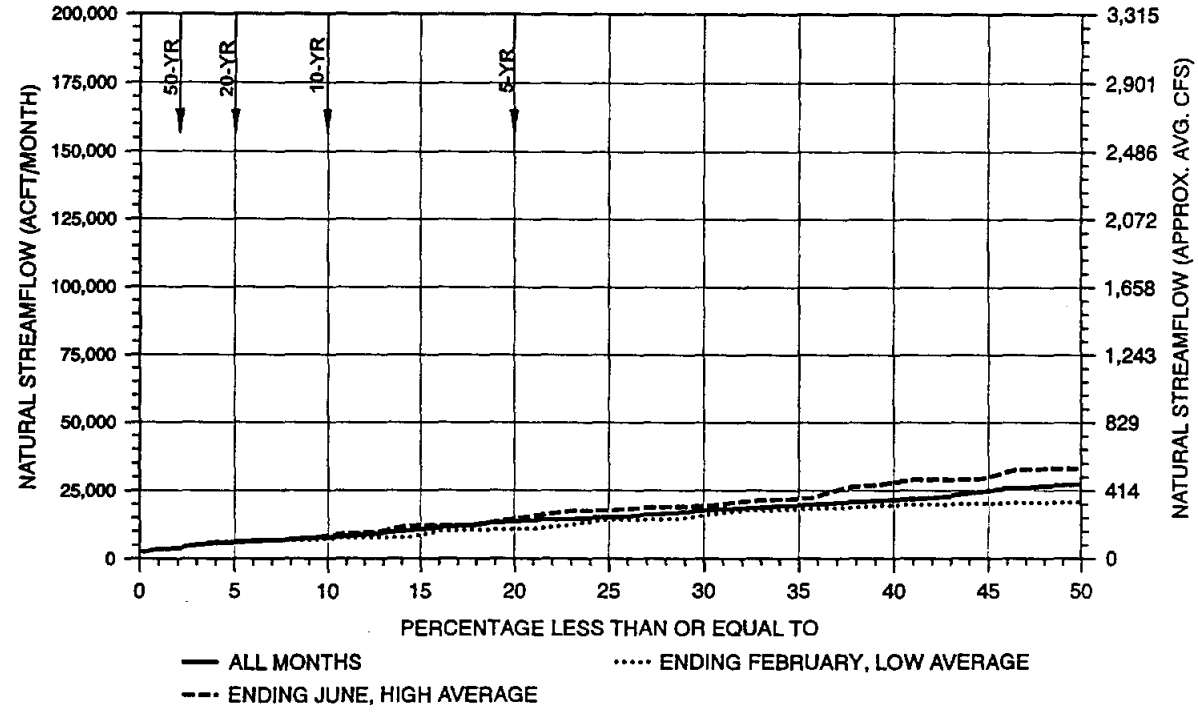


NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. B8

SAN ANTONIO RIVER AT GOLIAD (USGS #1885)
NATURAL STREAMFLOW FREQUENCY, 4-MONTH DURATION

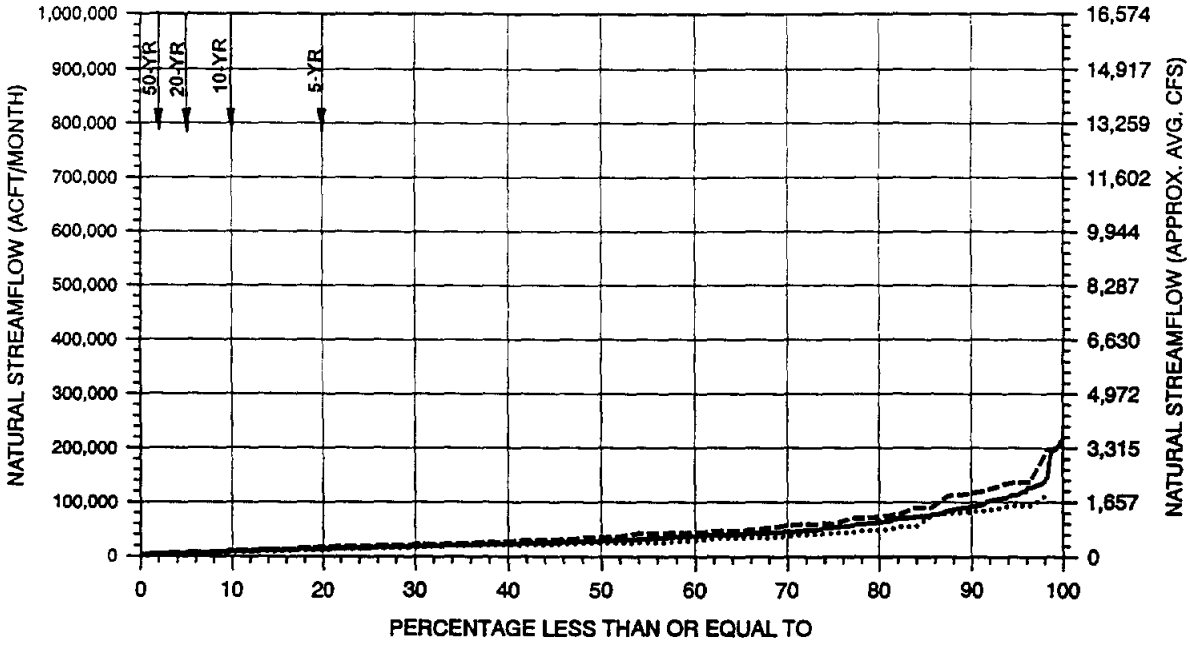


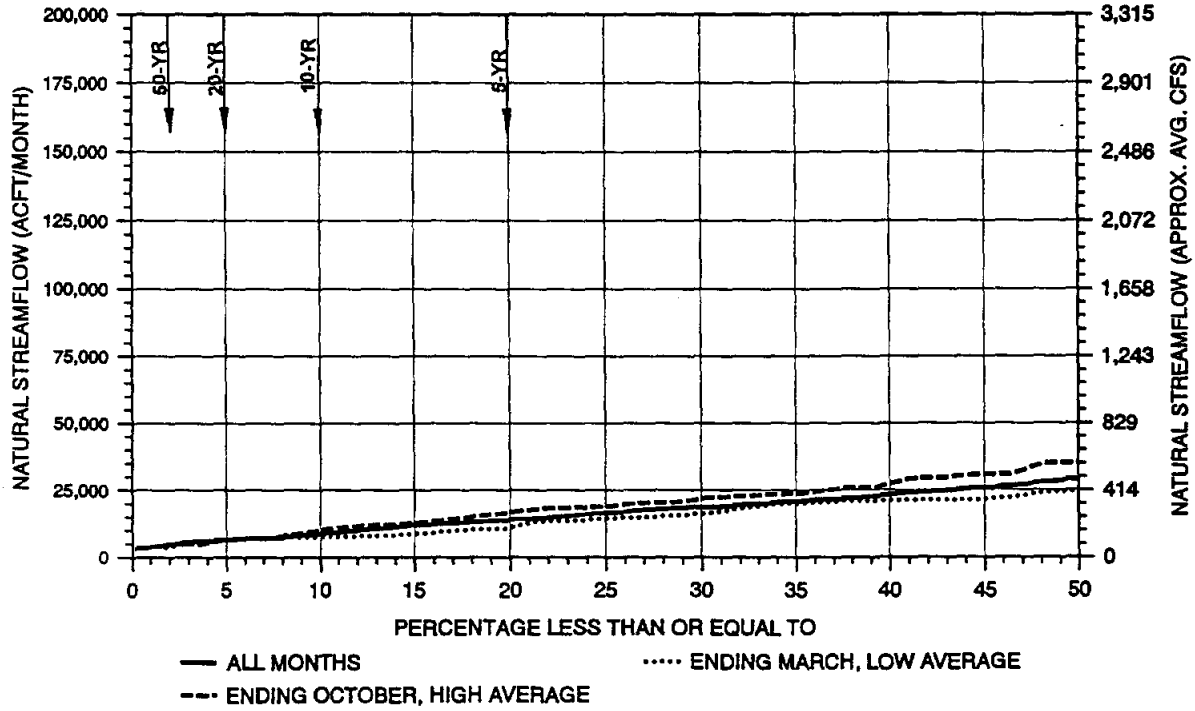


NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

TRANS-TEXAS WATER PROGRAM **WEST CENTRAL STUDY AREA** **INSTREAM AND BAY & ESTUARY FLOW CRITERIA**	6/95 **FIG. B9**

SAN ANTONIO RIVER AT GOLIAD (USGS #1885)
NATURAL STREAMFLOW FREQUENCY, 6-MONTH DURATION





NOTE: INDICATED RETURN PERIODS APPLICABLE TO HIGH AND LOW AVERAGES ONLY.

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. B10

APPENDIX C

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA COMPUTER FILE LISTING	
FILENAME	**DESCRIPTION OF CONTENTS**
DIVERSION LOCATION: USGS #1758 GUADALUPE RIVER AT CUERO	
AVAILABILITY	
A-0.C	NO TRANS-TEXAS CRITERIA
A-E.C	EXISTING TRANS-TEXAS CRITERIA
A-I-35.C	B&E AND INSTREAM TO 10%, 35% TRIGGER
A-I-25.C	B&E AND INSTREAM TO 10%, 25% TRIGGER
A-I-15.C	B&E AND INSTREAM TO 10%, 15% TRIGGER
A-B-35.C	B&E TO I/S REQS, 35% TRIGGER
A-B-25.C	B&E TO I/S REQS, 25% TRIGGER
A-B-15.C	B&E TO I/S REQS, 15% TRIGGER
NATURAL FLOWS AT POINT OF DIVERSION	
N.C	NATURAL FLOWS
MODIFIED FLOWS AT POINT OF DIVERSION	
M-B.C	BASELINE CONDITIONS
M-0-C.C	NO TRANS-TEXAS CRITERIA
M-E-C.C	EXISTING TRANS-TEXAS CRITERIA
M-I-35-C.C	B&E AND INSTREAM TO 10%, 35% TRIGGER
M-I-25-C.C	B&E AND INSTREAM TO 10%, 25% TRIGGER
M-I-15-C.C	B&E AND INSTREAM TO 10%, 15% TRIGGER
M-B-35-C.C	B&E TO I/S REQS, 35% TRIGGER
M-B-25-C.C	B&E TO I/S REQS, 25% TRIGGER
M-B-15-C.C	B&E TO I/S REQS, 15% TRIGGER
MODIFIED FLOWS AT TIVOLI	
M-0-T.C	NO TRANS-TEXAS CRITERIA
M-E-T.C	EXISTING TRANS-TEXAS CRITERIA
M-I-35-T.C	B&E AND INSTREAM TO 10%, 35% TRIGGER
M-I-25-T.C	B&E AND INSTREAM TO 10%, 25% TRIGGER
M-I-15-T.C	B&E AND INSTREAM TO 10%, 15% TRIGGER
M-B-35-T.C	B&E TO I/S REQS, 35% TRIGGER
M-B-25-T.C	B&E TO I/S REQS, 25% TRIGGER
M-B-15-T.C	B&E TO I/S REQS, 15% TRIGGER
DIVERSION LOCATION: USGS #1885 SAN ANTONIO RIVER AT GOLIAD	
AVAILABILITY	
A-0.G	NO TRANS-TEXAS CRITERIA
A-E.G	EXISTING TRANS-TEXAS CRITERIA
A-I-35.G	B&E AND INSTREAM TO 10%, 35% TRIGGER
A-I-25.G	B&E AND INSTREAM TO 10%, 25% TRIGGER
A-I-15.G	B&E AND INSTREAM TO 10%, 15% TRIGGER
A-B-35.G	B&E TO I/S REQS, 35% TRIGGER
A-B-25.G	B&E TO I/S REQS, 25% TRIGGER
A-B-15.G	B&E TO I/S REQS, 15% TRIGGER
NATURAL FLOWS AT POINT OF DIVERSION	
N.G	NATURAL FLOWS

MODIFIED FLOWS AT POINT OF DIVERSION	
M-B.G	BASELINE CONDITIONS
M-0-G.G	NO TRANS-TEXAS CRITERIA
M-E-G.G	EXISTING TRANS-TEXAS CRITERIA
M-I-35-G.G	B&E AND INSTREAM TO 10%, 35% TRIGGER
M-I-25-G.G	B&E AND INSTREAM TO 10%, 25% TRIGGER
M-I-15-G.G	B&E AND INSTREAM TO 10%, 15% TRIGGER
M-B-35-G.G	B&E TO I/S REQS, 35% TRIGGER
M-B-25-G.G	B&E TO I/S REQS, 25% TRIGGER
M-B-15-G.G	B&E TO I/S REQS, 15% TRIGGER
MODIFIED FLOWS AT TIVOLI	
M-0-T.G	NO TRANS-TEXAS CRITERIA
M-E-T.G	EXISTING TRANS-TEXAS CRITERIA
M-I-35-T.G	B&E AND INSTREAM TO 10%, 35% TRIGGER
M-I-25-T.G	B&E AND INSTREAM TO 10%, 25% TRIGGER
M-I-15-T.G	B&E AND INSTREAM TO 10%, 15% TRIGGER
M-B-35-T.G	B&E TO I/S REQS, 35% TRIGGER
M-B-25-T.G	B&E TO I/S REQS, 25% TRIGGER
M-B-15-T.G	B&E TO I/S REQS, 15% TRIGGER
DIVERSION LOCATION: USGS #1888 SALTWATER BARRIER NEAR TIVOLI	
AVAILABILITY	
A-0.T	NO TRANS-TEXAS CRITERIA
A-E.T	EXISTING TRANS-TEXAS CRITERIA
A-I-35.T	B&E AND INSTREAM TO 10%, 35% TRIGGER
A-I-25.T	B&E AND INSTREAM TO 10%, 25% TRIGGER
A-I-15.T	B&E AND INSTREAM TO 10%, 15% TRIGGER
A-B-35.T	B&E TO I/S REQS, 35% TRIGGER
A-B-25.T	B&E TO I/S REQS, 25% TRIGGER
A-B-15.T	B&E TO I/S REQS, 15% TRIGGER
NATURAL FLOWS AT POINT OF DIVERSION	
N.T	NATURAL FLOWS
MODIFIED FLOWS AT POINT OF DIVERSION	
M-B.T	BASELINE CONDITIONS
M-0.T	NO TRANS-TEXAS CRITERIA
M-E.T	EXISTING TRANS-TEXAS CRITERIA
M-I-35.T	B&E AND INSTREAM TO 10%, 35% TRIGGER
M-I-25.T	B&E AND INSTREAM TO 10%, 25% TRIGGER
M-I-15.T	B&E AND INSTREAM TO 10%, 15% TRIGGER
M-B-35.T	B&E TO I/S REQS, 35% TRIGGER
M-B-25.T	B&E TO I/S REQS, 25% TRIGGER
M-B-15.T	B&E TO I/S REQS, 15% TRIGGER

A = AVAILABILITY	E = EXISTING TRANS-TEXAS CRITERIA
N = NATURAL FLOWS	0 = NO TRANS-TEXAS CRITERIA
M = MODIFIED FLOWS	I = B&E AND INSTREAM DROUGHT CONTINGENCY
C = CUERO	B = B&E DROUGHT CONTINGENCY
G = GOLIAD	15, 25, 35 = DROUGHT CONTINGENCY TRIGGER
T = TIVOLI	

APPENDIX D

APPENDIX D

Potential Off-Channel Storage Requirements Under Alternative Environmental Criteria

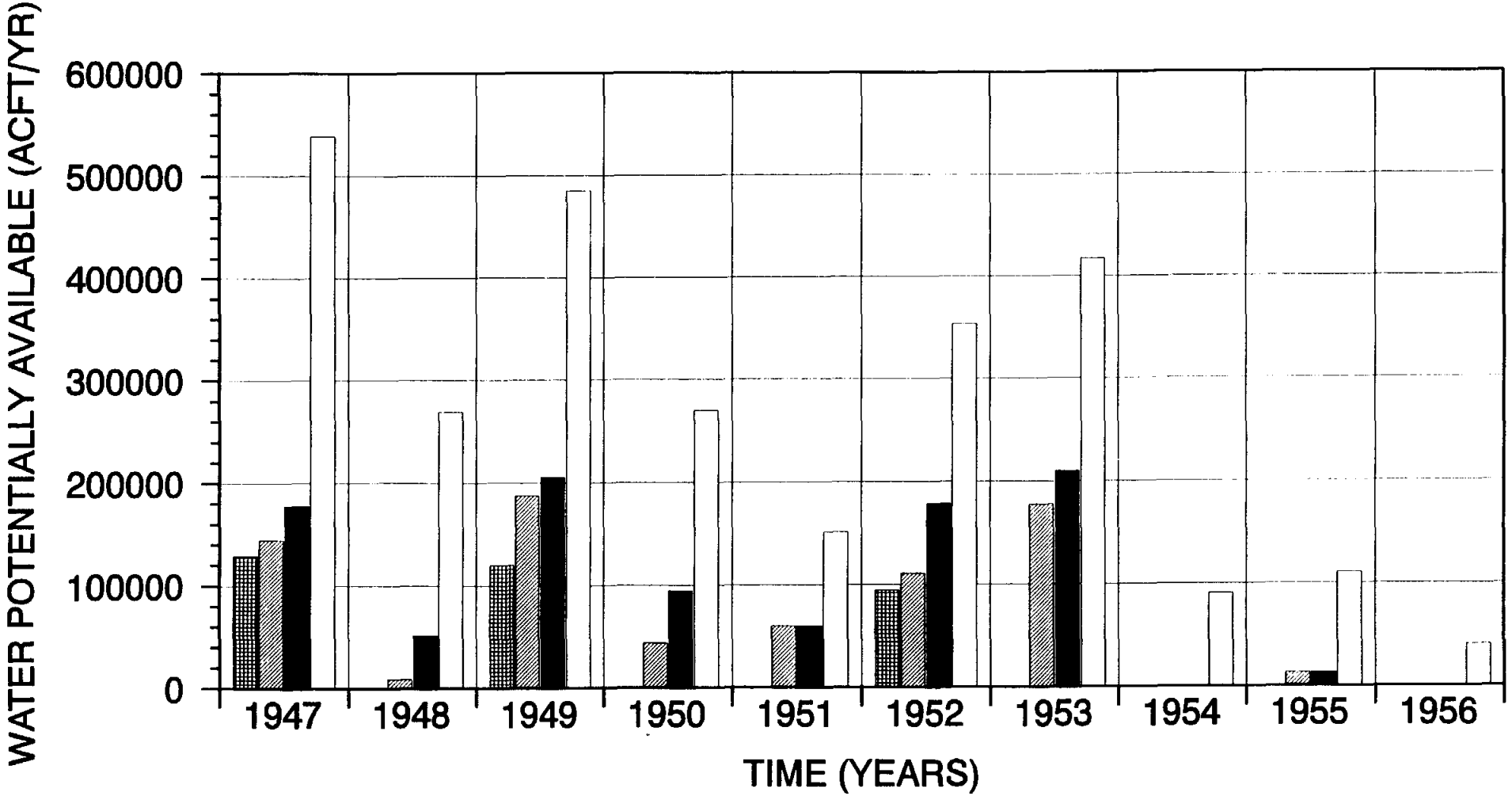
In order to provide some perspective as to the ramifications of adoption of alternative Trans-Texas Environmental Criteria for Freshwater Inflows to Bays & Estuaries and for Instream Flows, Appendix D summarizes the examination of potential off-channel storage requirements necessary to convert run-of-the-river diversions to firm yield. The examples presented herein are based on run-of-the-river diversions from the Guadalupe River near Cuero and delivery at a maximum rate of 60,000 acft/month to off-channel storage reservoirs of various sizes located at the site of the proposed Lindenau Reservoir. Off-channel reservoir contents fluctuations and firm yields subject to monthly evaporative losses were simulated using the Reservoir Operating and Quality Routing Program RESOP-II (Texas Department of Water Resources, 1978). For this example, Trans-Texas Environmental Criteria for New Reservoirs were not applied when operating the off-channel reservoir.

Figures D1 and D2 summarize water potentially available during the 1947-56 historical period under a range of alternative environmental criteria using the 35th (Figure D1) and 15th (Figure D2) percentile 4-month moving average streamflows as triggers for drought contingency provisions. Referring to these figures, it is apparent that water would be available for diversion (after honoring existing water rights) in only 3 out of 10 years under the existing criteria, 8 out of 10 years under alternative criteria with drought contingency provisions, and all 10 years without environmental criteria. As there would be very little water available for diversion with the application of environmental criteria during the most severe portion of the drought (1954-56), it is clear that significant storage will be required to develop firm yield from these run-of-the-river diversions. Comparison of Figures D1 and D2 shows that the effect of the assumed trigger for drought contingency provisions is most apparent in 1953 when the 35th percentile trigger would allow diversion of between 177,000 acft (5 months) and 210,000 acft (6 months), while the 15th percentile trigger would allow diversion of only 60,000 acft (1 month).

The volumes of off-channel storage required to develop various quantities of firm yield under a range of alternative environmental criteria are presented in Figures D3 and D4 for the 35th and 15th percentile drought contingency triggers, respectively. Key observations upon consideration of Figure D3 include:

1) Development of a 40,000 acft/yr firm yield under existing Trans-Texas Environmental Criteria would require off-channel storage in excess of 600,000 acft which is comparable to about 150 percent of the conservation storage in Canyon Lake.
2) Development of a 40,000 acft/yr firm yield under alternative environmental criteria including drought contingency provisions triggered at the 35th percentile of 4-month moving average streamflow would require off-channel

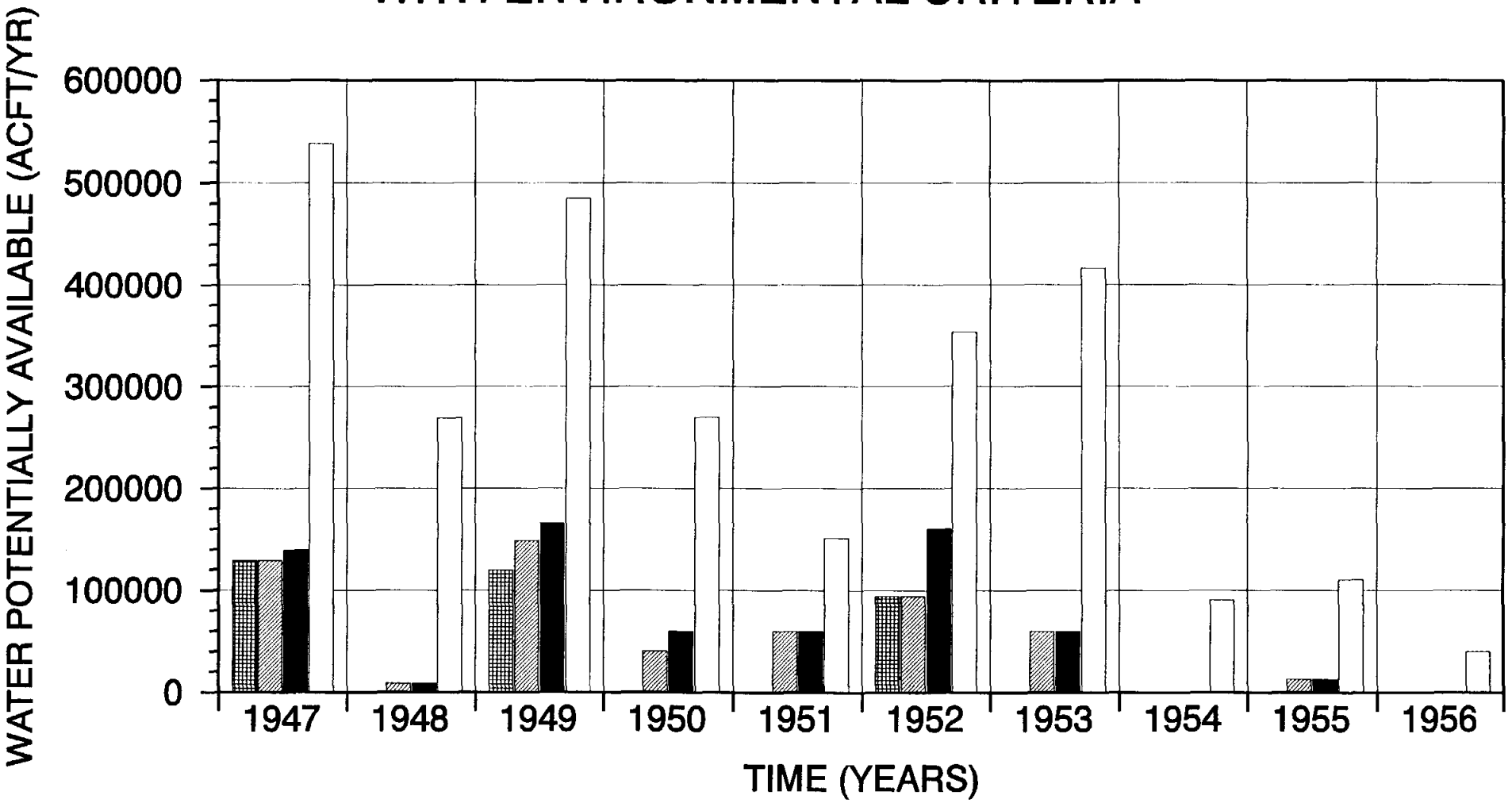
WATER AVAILABILITY DURING DROUGHT WITH ENVIRONMENTAL CRITERIA



60,000 ACFT/MONTH MAXIMUM DIVERSION
DROUGHT CONTINGENCY TRIGGER:
35th PERCENTILE, 4-MONTH MOVING AVERAGE

TRANS-TEXAS WATER PROGRAM	6/95
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	FIG. D1

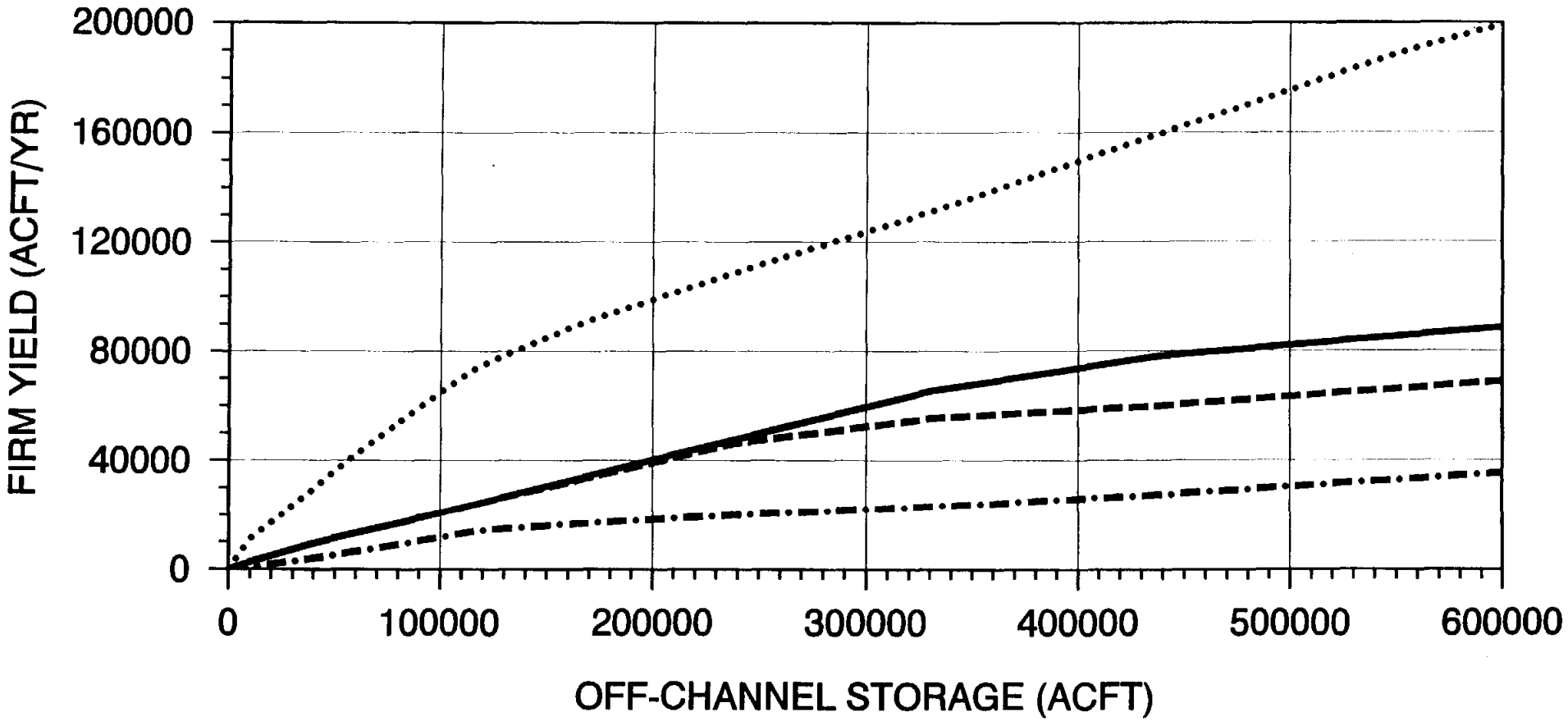
WATER AVAILABILITY DURING DROUGHT WITH ENVIRONMENTAL CRITERIA



60,000 ACFT/MONTH MAXIMUM DIVERSION
DROUGHT CONTINGENCY TRIGGER:
15th PERCENTILE, 4-MONTH MOVING AVERAGE

TRANS-TEXAS WATER PROGRAM	6/95
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	FIG. D2

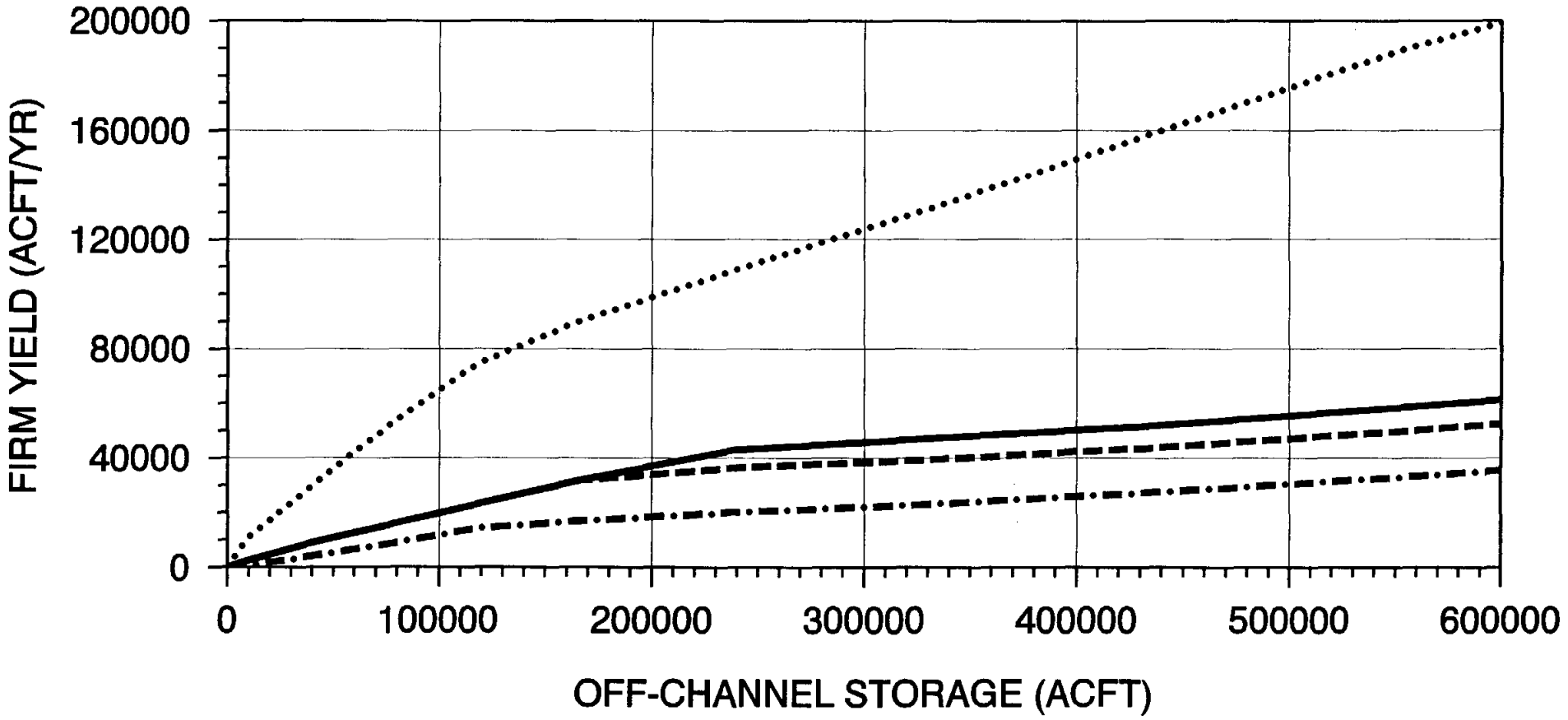
OFF-CHANNEL RESERVOIR FIRM YIELD WITH DIVERSIONS FROM GUADALUPE RIVER @ CUERO UNDER ENVIRONMENTAL CRITERIA



60,000 ACFT/MONTH MAXIMUM DIVERSION
DROUGHT CONTINGENCY TRIGGER:
35th PERCENTILE, 4-MONTH MOVING AVERAGE

TRANS-TEXAS WATER PROGRAM	6/95
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	FIG. D3

OFF-CHANNEL RESERVOIR FIRM YIELD WITH DIVERSIONS FROM GUADALUPE RIVER @ CUERO UNDER ENVIRONMENTAL CRITERIA



60,000 ACFT/MONTH MAXIMUM DIVERSION
DROUGHT CONTINGENCY TRIGGER:
15th PERCENTILE, 4-MONTH MOVING AVERAGE

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. D4

storage of about 200,000 acft which is comparable to about 50 percent of the conservation storage in Canyon Lake or to about 80 percent of the conservation storage in Medina Lake.

3) Development of a 40,000 acft/yr firm yield without application of environmental criteria would require off-channel storage of about 60,000 acft which is comparable to Calaveras Lake on Calaveras Creek near Elmendorf.

Similar observations with respect to off-channel storage requirements under alternative environmental criteria with drought contingency provisions triggered at the 15th percentile of 4-month moving average streamflow can be made upon consideration of Figure D4. It should be noted in these figures that there is essentially no difference between the firm yields which can be developed with drought contingency provisions applicable only to criteria for Freshwater Inflow to Bays & Estuaries versus those applicable to criteria for both Instream Flows and Freshwater Inflow to Bays & Estuaries for off-channel storage volumes less than approximately 200,000 acft. This is because a minimum storage of approximately 200,000 acft is necessary to provide for firm yield delivery during the worst years of the drought (1954-56) and additional storage is necessary to effectively utilize run-of-the-river diversions made earlier in the drought.

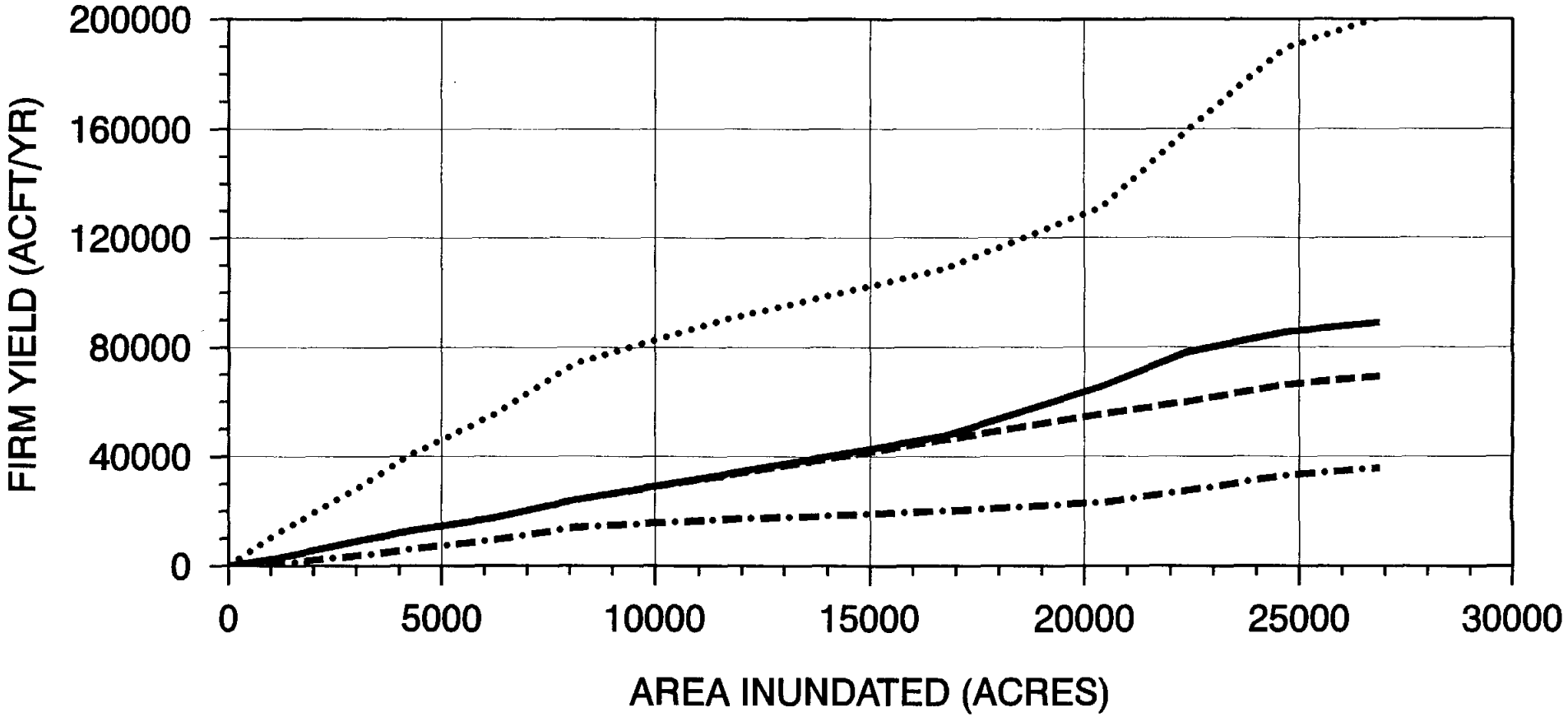
The acreage inundated associated with the off-channel storages required to develop various quantities of firm yield under a range of alternative environmental criteria are presented in Figures D5 and D6 for the 35th and 15th percentile drought contingency triggers, respectively. Key observations upon consideration of Figure D5 include:

1) Development of a 40,000 acft/yr firm yield without application of environmental criteria would require inundation of approximately 4000 acres.
2) Development of a 40,000 acft/yr firm yield under existing Trans-Texas Environmental Criteria would require inundation of approximately 28,000 acres which is 7 times that required without application of environmental criteria.
3) Development of a 40,000 acft/yr firm yield under alternative environmental criteria including drought contingency provisions triggered at the 35th percentile of 4-month moving average streamflow would require inundation of approximately 14,000 acres which is 3.5 times that required without application of environmental criteria, but is one-half that required under existing Trans-Texas Environmental Criteria.

Similar observations with respect to inundated acreage requirements under alternative environmental criteria with drought contingency provisions triggered at the 15th percentile of 4-month moving average streamflow can be made upon consideration of Figure D6.

Appendix D was prepared in an effort to illustrate by example the potential effects of various environmental criteria intended in part to protect estuarine and riverine habitats on terrestrial habitat when considering the development of dependable water supply through run-of-the-river diversions and off-channel storage. Adoption of alternative environmental criteria including drought contingency provisions will likely result in significant reductions in the unit costs reported in Phase I of the Trans-Texas Water Program in the West Central Study Area (San Antonio River Authority, etal., 1994) for development of run-of-the-river diversion projects for municipal and industrial water supply.

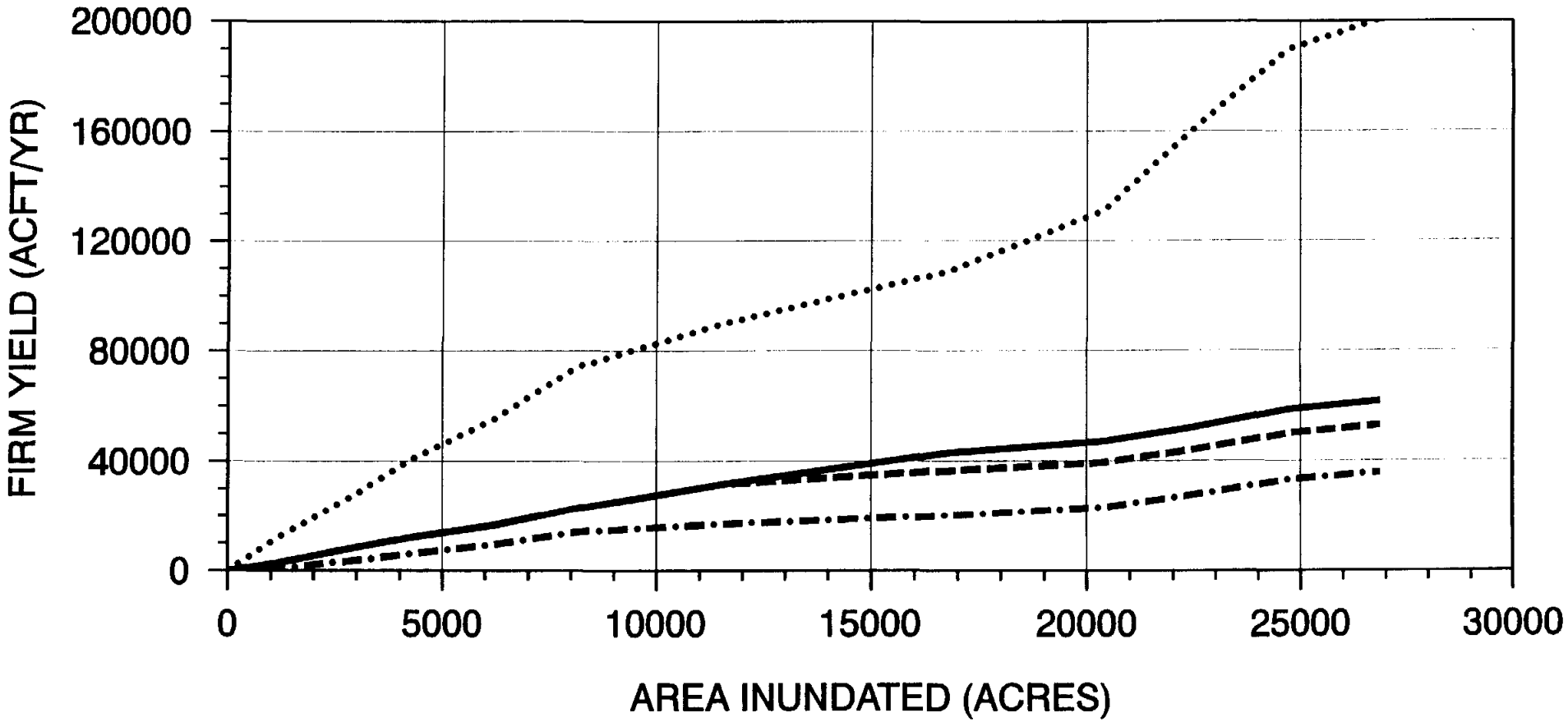
OFF-CHANNEL RESERVOIR FIRM YIELD WITH DIVERSIONS FROM GUADALUPE RIVER @ CUERO UNDER ENVIRONMENTAL CRITERIA



60,000 ACFT/MONTH MAXIMUM DIVERSION
DROUGHT CONTINGENCY TRIGGER:
35th PERCENTILE, 4-MONTH MOVING AVERAGE

TRANS-TEXAS WATER PROGRAM WEST CENTRAL STUDY AREA INSTREAM AND BAY & ESTUARY FLOW CRITERIA	6/95 FIG. D5

OFF-CHANNEL RESERVOIR FIRM YIELD WITH DIVERSIONS FROM GUADALUPE RIVER @ CUERO UNDER ENVIRONMENTAL CRITERIA



60,000 ACFT/MONTH MAXIMUM DIVERSION
DROUGHT CONTINGENCY TRIGGER:
15th PERCENTILE, 4-MONTH MOVING AVERAGE

TRANS-TEXAS WATER PROGRAM	6/95
WEST CENTRAL STUDY AREA	
INSTREAM AND BAY & ESTUARY FLOW CRITERIA	FIG. D6