Modifications to the Canadian River Basin WAM to Assess Surface Water Supplies in Region A

Introduction

Surface water supplies for the main reservoirs in Region A were initially evaluated with the Water Availability Models (WAM) of the Canadian and Red River Basins. These models were prepared in 2000 by Espey Consultants, Inc[1] and have been subsequently administered and maintained by Texas Commission of Environmental Quality (TCEQ). TWDB guidelines for the assessment of surface water supplies on the Regional Water Plan mandate surface water supplies to be evaluated with the WAM models.

The firm yield obtained with the Canadian River Basin WAM for Lake Meredith and Lake Palo Duro is substantially different from estimates of previous work. A review of the WAM Model identified methodological problems with the flow naturalization which may explain some of the differences in reservoir yields. In addition, Lake Meredith has recorded low storage during 2003 and 2004 due to a new drought of record conditions, but the hydrology of the WAM does not cover recent years. Therefore, as currently published by the TCEQ, the Canadian WAM may not be appropriate for planning purposes.

The following problems were identified in the Canadian WAM that limit its application in water supply planning:

- The hydrologic period starts in 1948, when many reservoirs in west Texas had already been affected by the drought of the 1950s.
- The hydrologic period ends in 1998, while the drought of record has extended through 2004 and may continue in the future.
- The development of naturalized flows does not have any adjustments due to the construction of reservoirs in New Mexico, particularly Ute Reservoir.
- The Canadian WAM does not account for the future development of Ute Reservoir, which would reduce the flow entering into Texas.
- The channel loss factors assumed in the main stem of the Canadian River seem to be high.
- The calculations of naturalized flows is inconsistent with the application of channel loss factors. Adjustments are applied to diversions and return flows, but not to impoundments or evaporation losses.
- The methodology for filling periods with missing records was inappropriate.
- Adjustment for negative incremental flows are very high.

[1] Superscripted numbers match References listed on Appendix A

Freese and Nichols developed more accurate set of naturalized flows for the Canadian WAM and modified the model to include Ute Reservoir. The new period of analysis is 1940-2004 These changes allow a proper assessment of current and future water supply availability.

Hydrologic Data Refinement

Naturalized flow are defined as the flow that would have occurred on a stream in the absence of human activity. Naturalized flows are obtained by adjusting gaged historical flows to remove changes caused by reservoirs, diversions, and return flows. The following are the changes made to the computations of naturalized flows.

Gaged Data

The revised model has six primary control points located at the gages listed on Table 1. The control point at Logan, NM was added to the TCEQ Canadian WAM to locate Ute Reservoir and to facilitate the adjustments due to the development of a proposed water supply project this reservoir. Figure 1 shows the location of the gages.

Table 1
Primary Control Points of the Revised Canadian WAM

Name	USGS number	Period of Record Available	Identifier WAM
Canadian River near Logan (NM)	7227000	1/1909 – 9/2003	NM1000
Canadian River near Amarillo (TX)	7227500	4/1938 – 9/2004 *	A10000
Canadian River near Canadian (TX)	7228000	4/1938 – 9/2004 *	B10000
Coldwater Creek near Guymon (OK) **	7232900	10/1980 – 9/2004 *	C10000
Palo Duro Creek near Spearman (TX)	7233500	8/1945 – 9/1979 6/1999 – 9/2004 *	D10000
Wolf Creek near Lipscomb (TX)	7235000	10/1940 – 9/1942 10/1961 – 9/2004 *	E10000

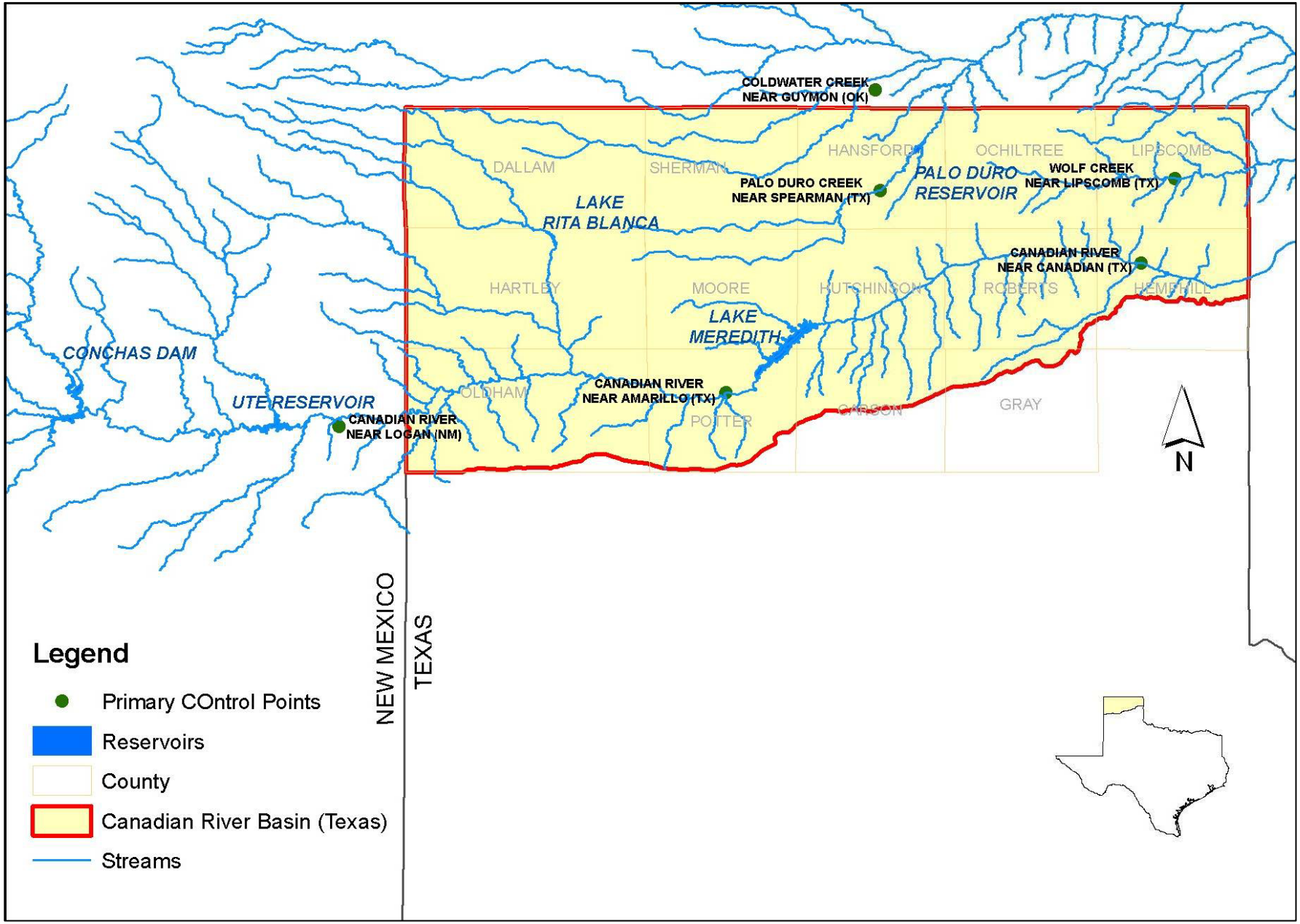
* Records extend to present (September 2005)

** Gaged data are also available for Coldwater near Hardesty (OK) USGS 7233000, 4.5 miles downstream of the gage near Guymon, for the period 10/1940-9/1964. For simplicity, both gages were grouped at Guymon, reducing the Hardesty flows proportionally to drainage area.

Evaporation Data

The WAM models use net evaporation rates, which are calculated as the gross lake evaporation minus precipitation. Net evaporation values were calculated from data compiled by the TWDB, which cover evaporation and precipitation depths at the center of 1-degree quadrangles in Texas. The net evaporation at each reservoir was calculated as the weighted average by distance to the center of the four nearest quadrangles.

Figure 1
Primary Control Points of the Revised Canadian WAM



TWDB data covers the period 1940-2002. For 2003 and 2004, evaporation and precipitation rates were calculated using information from the CRMWA in Lake Meredith[2] and the Corps of Engineers, Albuquerque District[3]. The final net evaporation rates for Lake Meredith and Lake Palo Duro are provided in Appendix B.

Area-Capacity-Elevation Relationships

The TCEQ Canadian WAM includes original area-capacity relationship to model permitted conditions, but the evaluation of water supplies needs to account for sedimentation. Area-Capacity-Elevation tables for Lake Meredith and Lake Palo Duro were developed for 2000 and 2060 conditions. Tables were derived based on the latest volumetric surveys and estimates of sedimentation rates. Table 2 shows the projected storage capacities and sedimentation rates[4,5]. Complete Area-Capacity-Elevation relationships are provided in Appendix C.

Table 2
Projection of Conservation Storage for 2000 and 2060

Reservoir	Conservation Pool Elevation	Capacity Latest Survey* (acre-feet)	Capacity 2000 (acre-feet)	Capacity 2060 (acre-feet)	Sedimentation rate (ac-ft/sq.mi-yr)
Lake Meredith	2936.5	817,970	815,989	790,075	0.088
Lake Palo Duro	2892.0	61,217	59,702	54,422	0.200

* Most recent volumetric survey for Lake Meredith was in 1995 and for Lake Palo Duro was in 1991.

Channel Loss Factors

Logan to Amarillo

Several loss studies have been completed that estimate the losses between Ute Reservoir and the gage near Amarillo[6,7]. A report by Parkhill, Smith and Cooper, Inc.[7] (PSC) analyzed hydrographs of spills from Ute Reservoir and concluded that losses are near 5%. The PSC report indicates that this value is consistent with previous values obtained by HDR Engineering and the U.S. Bureau of Reclamation. Therefore, a loss factor of 5% was assumed for this reach.

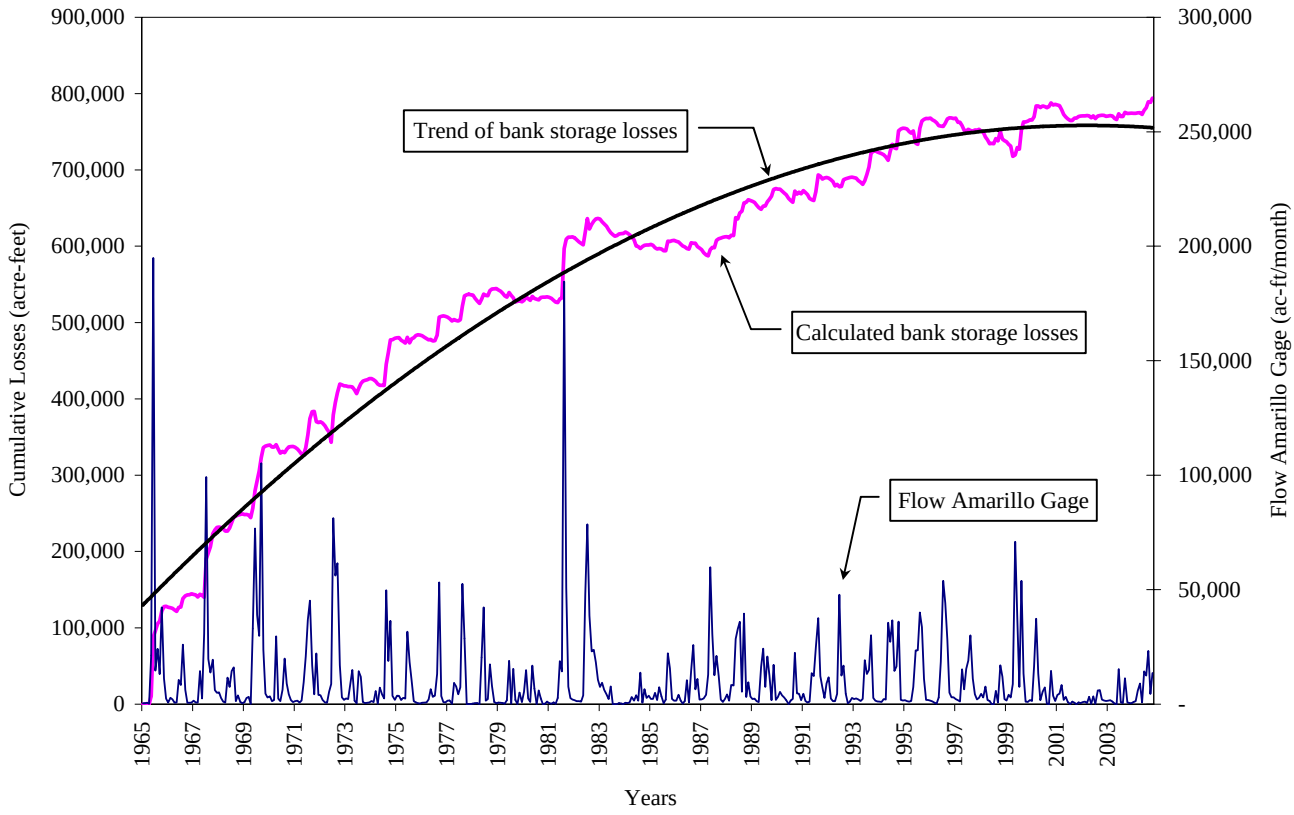
Amarillo to Canadian

As part of the Canadian WAM improvements, Freese and Nichols conducted a loss study with monthly flow data between the gages in the Canadian River near Amarillo and Canadian. The period of analysis covers the years before the construction of Lake Meredith. The data shows that the stream fluctuates between a gaining and losing stream. The periods of gaining flow does not necessarily mean that there are no losses in the river. It means that intervening inflows exceeded channel losses. Analysis of those periods when the river was a losing stream provided that an average of 88% of the flow at the Amarillo gage reaches the Canadian gage. This is equivalent to a loss factor of **12%** between the two gages. The TCEQ Canadian WAM assumed a channel loss factor of 30%.

Bank Storage

A comparison between the flow at the Amarillo gage and the change of storage in Lake Meredith suggests that infiltration to the banks and flood plain of the Canadian River may have occurred immediately after impoundment of Lake Meredith. Inflows into Lake Meredith computed by mass balance are generally less than the historical flows at the Amarillo gage after the construction of the reservoir. In some months, the difference is substantial. The difference is greater after the reservoir was completed in 1965 than in recent years. The data indicates that some losses occur between the gage and the reservoir. However, the travel distance is very small to expect large losses. A possible explanation is that the flow filled the banks and flood plain of the river after the impoundment. The PSC report also mentions the possibility of having bank storage and account for this occurrence in the firm yield estimates. The reduction of the losses over time seem to confirm this theory because once the river banks are saturated, less seepage would occur. Figure 2 shows the cumulative losses of the flow at Amarillo that does not reach the reservoir.

Figure 2
Cumulative Losses due Bank Storage after the Initial Impoundment of Lake Meredith



Naturalized flows downstream of Lake Meredith need to consider depletions due to bank storage as these losses are caused directly by the reservoir impoundment. Bank storage estimates for each month were computed as the gaged flow at Amarillo plus any

incremental runoff before the dam minus the actual inflow computed with mass balance. After 2000, these losses are much smaller and seem to be negligible when compared to previous values. Therefore, no adjustment was applied after 2000. It is unclear if losses decreased because of low inflow and storage or because the bank turned saturated after many years of reservoir operation, or a combination of both.

Adjustment for Water Development in New Mexico

Ute Reservoir is located in the Canadian River 24 miles upstream of the Texas-New Mexico Border. It was initially constructed with a conservation capacity of 109,600 acre-feet, and the impoundment started in December 1962. The reservoir was expanded to a capacity of 272,000 acre-feet in 1984. It has not been used for water supply, but the Eastern New Mexico Rural Water Systems has approved plans to supply 24,000 acre-feet per year from the reservoir[8]. This development would impact the flow crossing the New Mexico-Texas border and would reduce available water supplies in Texas.

The TCEQ Canadian WAM did not consider any adjustment due to the construction of Ute Reservoir nor does it consider the impact of future water supply projects. In the modification of the Canadian WAM, new control point was added to locate Ute Reservoir. Naturalized flows were obtained adjusting historical flows at the Logan gage for impoundment and evaporation losses.

Conchas Reservoir is located 45 miles upstream of Ute Reservoir. It was completed in September 1939 and has been used since then to supply water for irrigation supply at an average of 60,000 acre-feet per year. Since the reservoir was completed before the beginning of extended hydrology (1940) and has been used regularly for water supply, no adjustment upstream of Conchas dam are required. In the event that the use from Conchas Reservoir increases, less flow would reach Ute Reservoir and Texas, reducing the yield of Lake Meredith.

Completion of Naturalized Flow Records

The methodology used to fill in periods of missing gaged data was changed when calculating a new set of naturalized flows. In the TCEQ Canadian WAM, missing gaged flows were filled with correlation of historical flows at another location. The filled-in data were then assumed to be truly gaged data, and in some months the filled data were used to fill other missing data. The gaged flows (historical and filled-in) were then adjusted to obtain naturalized flows. This method of filling historical data and then proceeding with the naturalization is not appropriate in most cases. The recommended approach is to obtain the naturalized flows for the months in which historical records are available, and then fill the missing naturalized flows.

Gaged flows are influenced by human activity such as storage, diversions and return flows. In general, the degree of human activity changes at different rates for different gages. If the gage with historical data and the gage with missing data have a different level of human activity, the gage with missing data would mistakenly reflect the characteristics of the activity of the gage used to fill.

A more appropriate method is to adjust gaged values to remove human activities to obtain naturalized flows and then fill in missing data using relationships between naturalized flows at two locations. Correlations are better because data for all gages represent natural conditions. Appendix D shows detailed derivation on the equations used to fill missing historical data

Comparison TCEQ WAM vs Refined Hydrology

Figures 3 through 7 show a comparison of annual naturalized flow between the TCEQ Canadian WAM and the refined hydrology developed for the Region A Water Plan.

Naturalized flows in the main stem of the Canadian (Amarillo and Canadian gages) are similar from 1948 to 1962. Then, the TCEQ flows are lower because flows were not adjusted for Ute Reservoir. The naturalized flows of the refined hydrology reflect flows in the absence of Ute Reservoir. Adjustments for bank storage may also explain the difference for the control point in the Canadian River near Canadian. These adjustments increase the naturalized flows in the river because they reflect the flow that would have reached the Canadian gage in the absence of Lake Meredith. Naturalized flows at Palo Duro near Spearman and Wolf Creek near Lipscomb are similar between the two models.

The most significant discrepancy is for the flow in the Coldwater Creek. The differences are due to the method for filling missing historical data. The TCEQ model assumes that all flow in the Coldwater Creek is proportional to the gaged flow in Palo Duro Creek, and the calculation did not consider any USGS historical flow available in Coldwater Creek near Hardesty or Guymon.

The refined hydrology for Region A considered these gaged flows in calculating naturalized flows, and estimated the missing periods using correlations with Palo Duro and Canadian.

Figure 3 through 7 also show the magnitude of the recent drought. The three lowest annual flows in the Canadian River near Amarillo are 2001, 2002 and 2003. The same observation is valid for Palo Duro near Spearman. These years clearly define a new drought of record, but these years are not included in the TCEQ Canadian WAM. The full set of naturalized flow are included as Appendix E.

Figure 3
Comparison of Naturalized Flows for the Canadian River near Amarillo

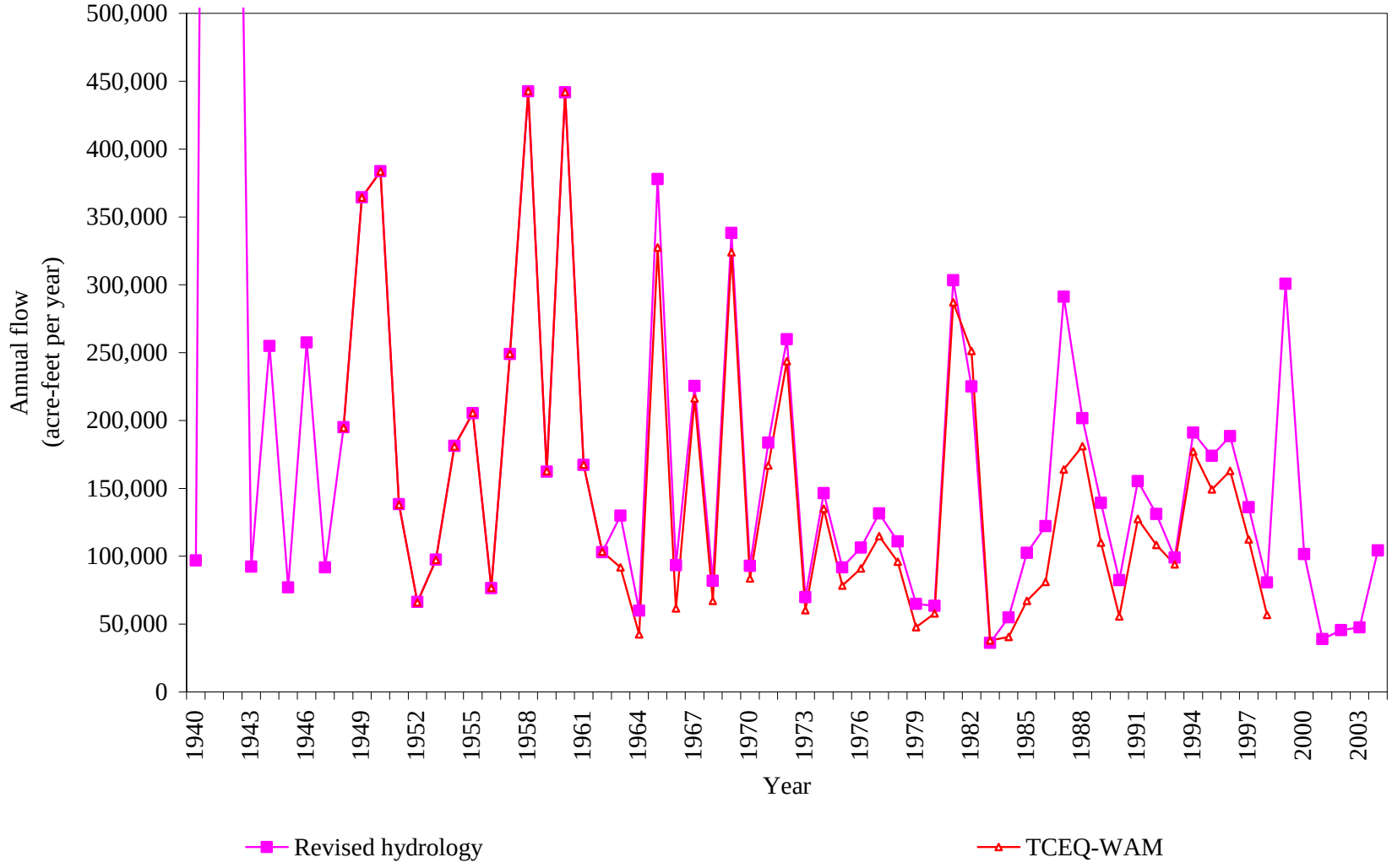


Figure 4
Comparison of Naturalized Flows for the Canadian River near Canadian

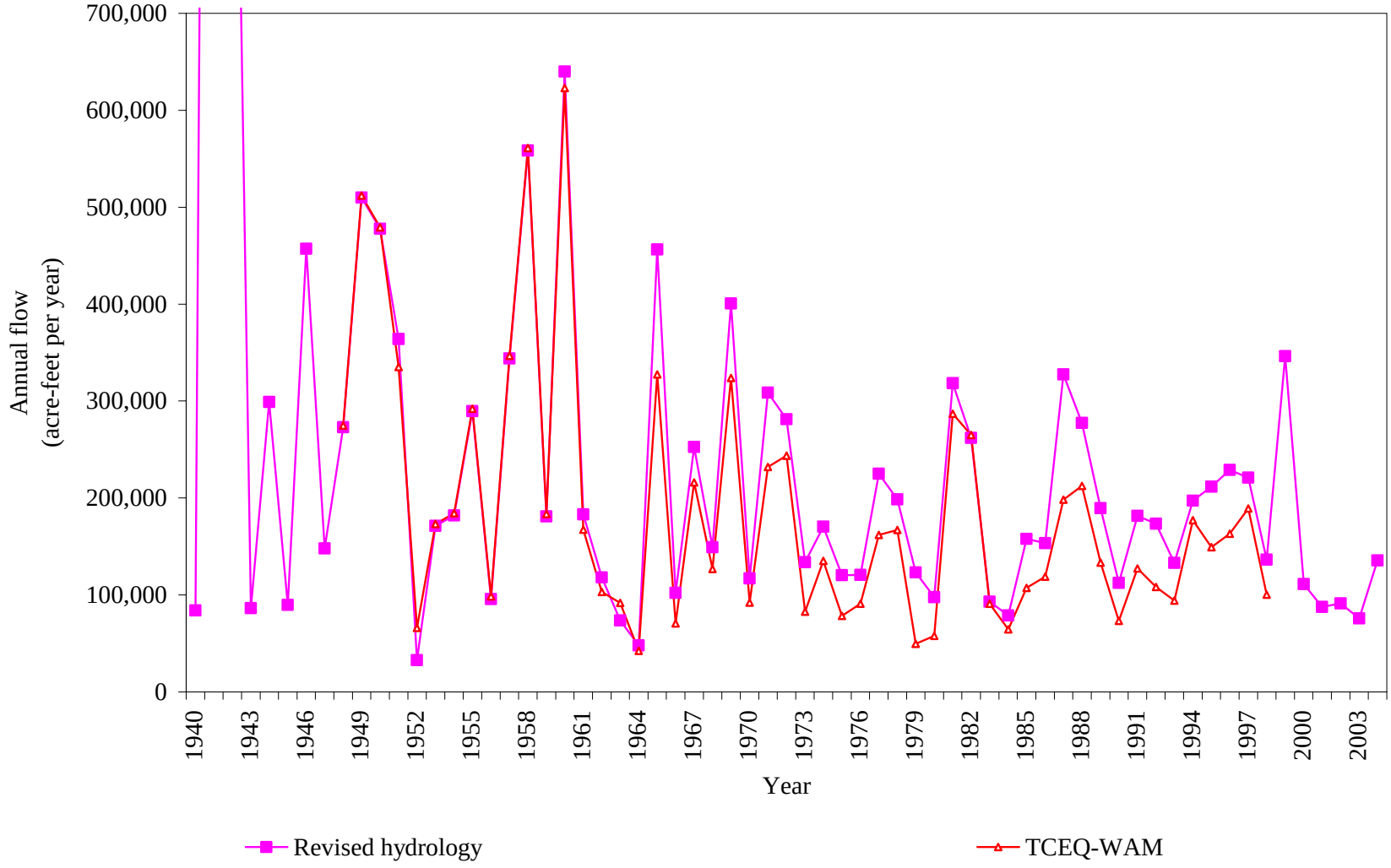


Figure 5
Comparison of Naturalized Flows for the Coldwater Creek

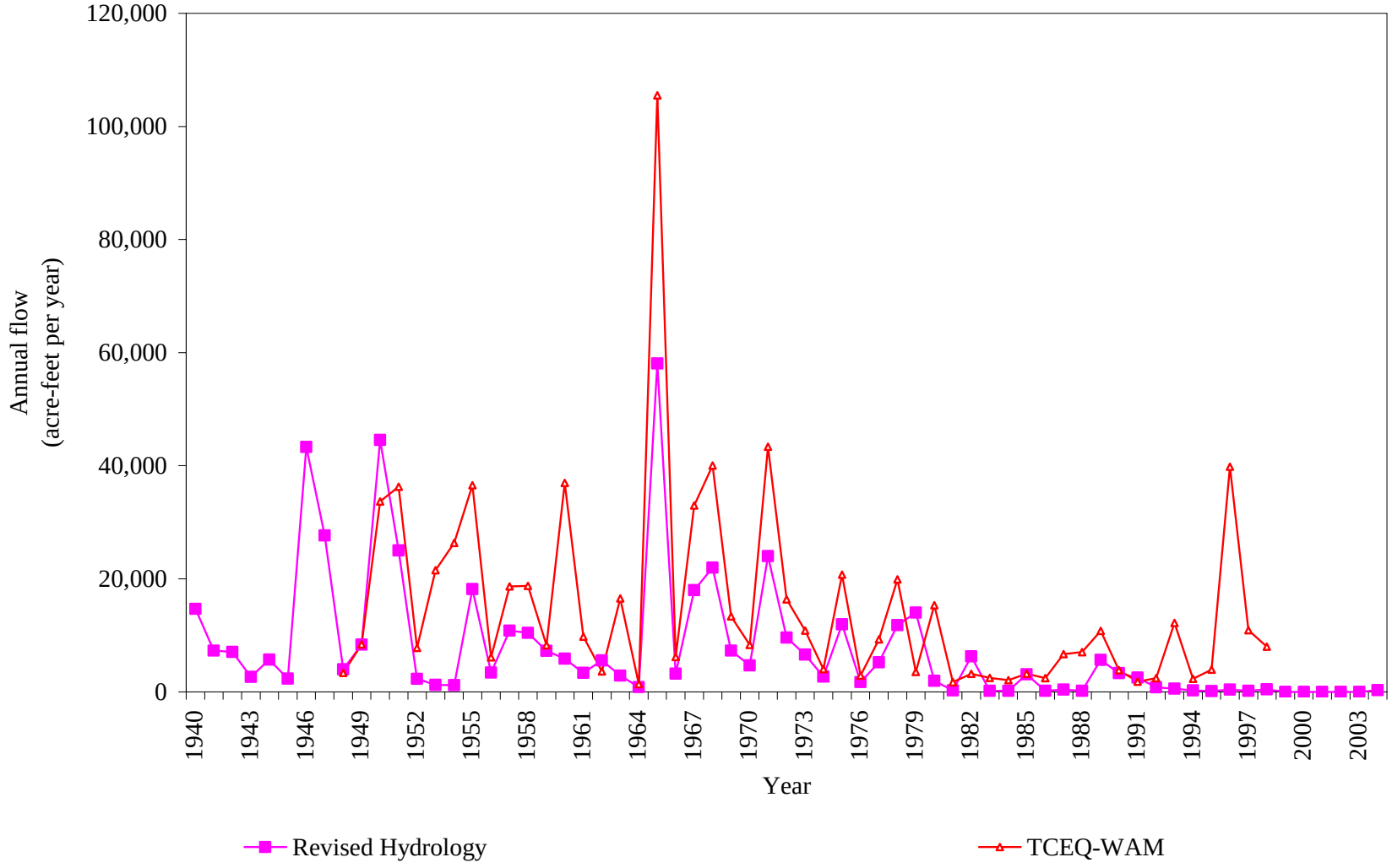


Figure 6
Comparison of Naturalized Flows for the Palo Duro Creek near Spearman

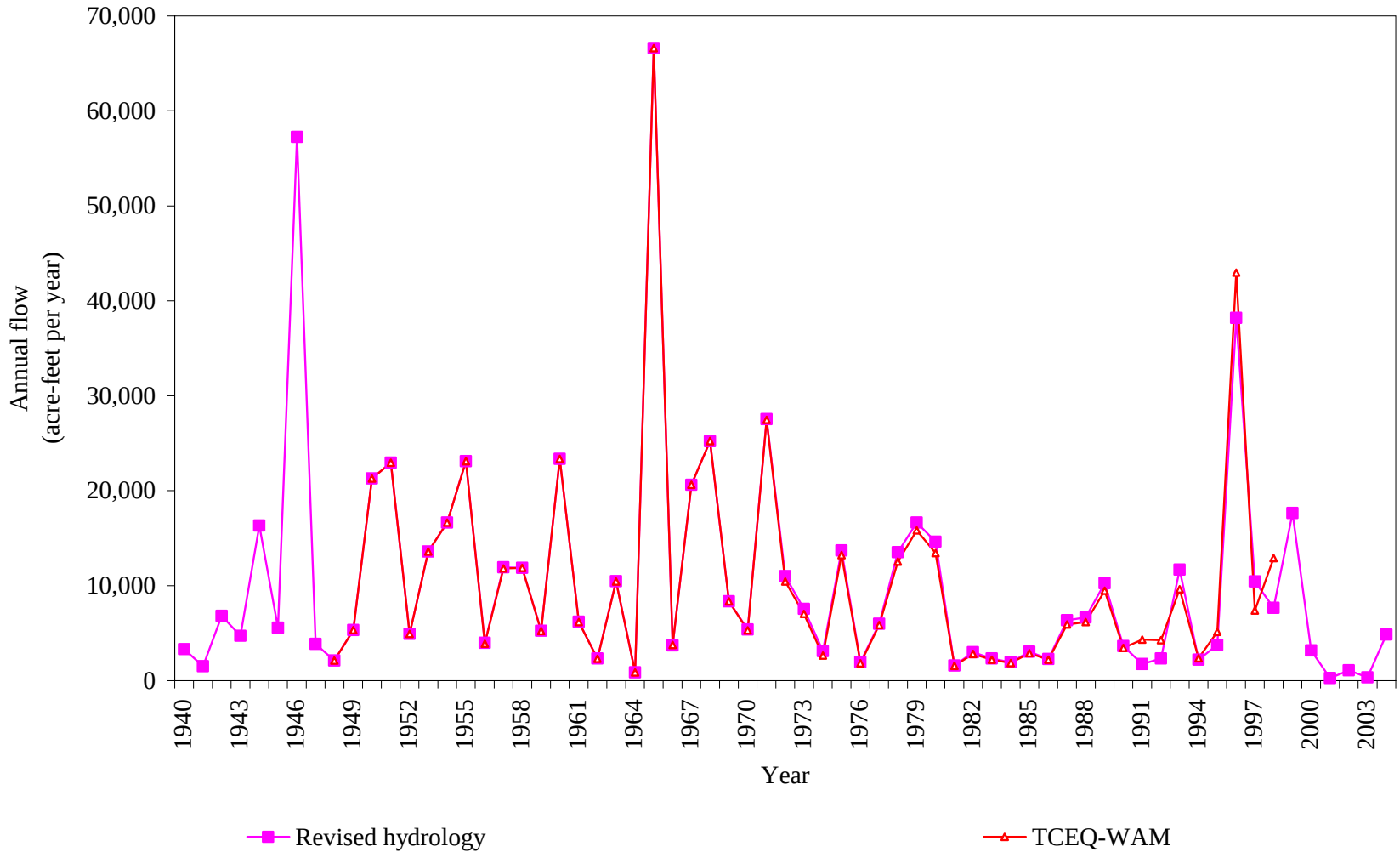
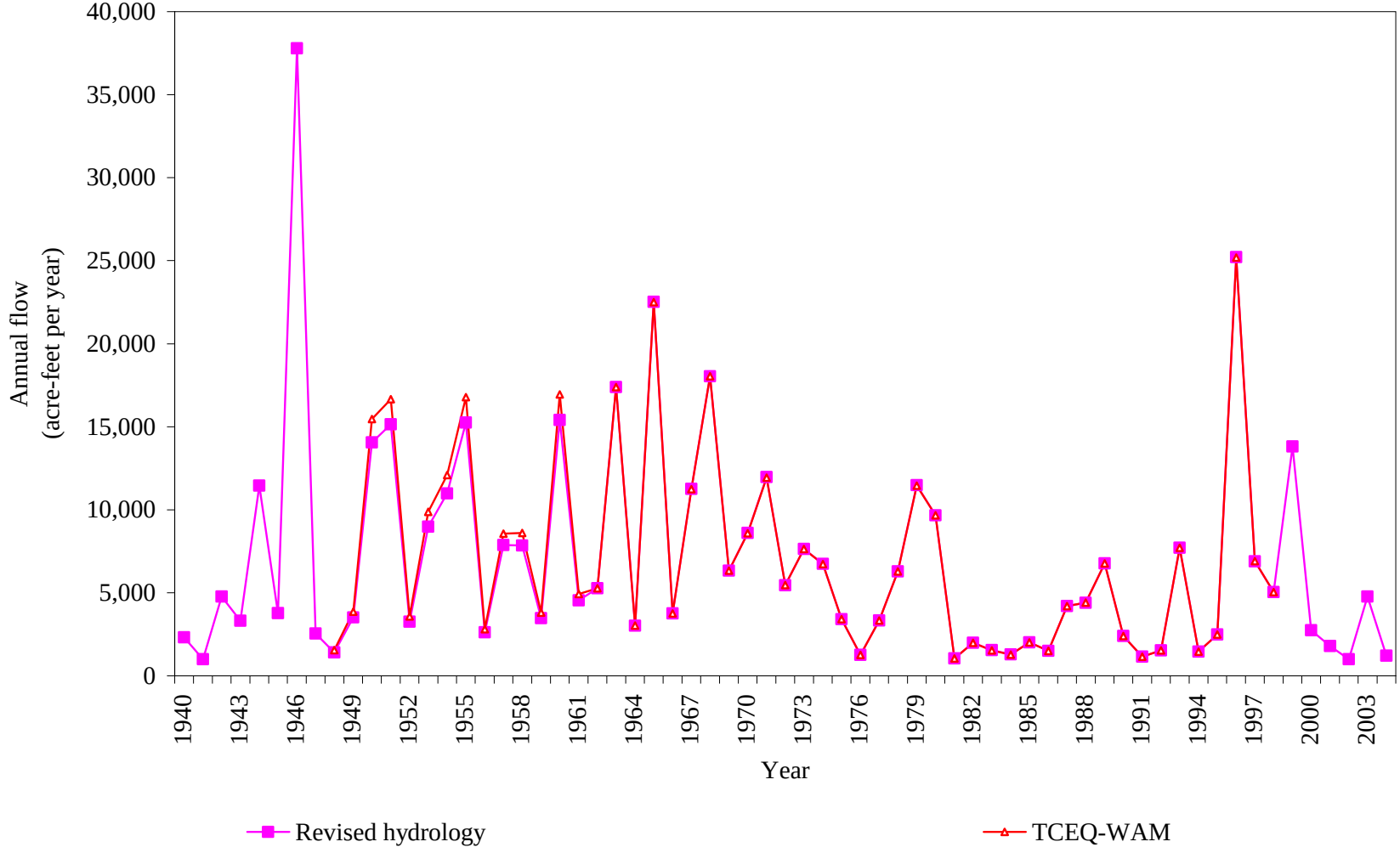


Figure 7
Comparison of Naturalized Flows for the Wolf Creek near Lipscomb



Results of Available Supplies

Available supplies for Region A are expressed as firm yield for reservoirs and minimum annual diversions for run-of-the-river water rights. Firm yield of main reservoirs are:

Table 4-1
Firm Yield for Reservoirs in the Canadian River Basin

Reservoir	Firm yield 2000 (acre-feet per year)	Firm yield 2060 (acre-feet per year)
Lake Meredith	69,750	69,750
Lake Palo Duro	4,000	3,750

The following assumptions are made for the calculation of the firm yield:

- Flows in Texas are reduced due to the development of 24,000 acre-feet per year in Ute Reservoir.
- Losses due to bank storage around Lake Meredith would be substantially lower than historically estimated.
- The storage in Lake Meredith is limited to the permitted amount of 500,000 acre-feet, although the total conservation capacity is 797,000 acre-feet.
- No diversions are allowed from Lake Meredith below elevation 2860 feet.
- The conservation pool of the reservoirs is full at the beginning of the critical period.
- The critical period is represented by the hydrology from October 1972 to September 2004.

The firm yield (mainly of Lake Meredith) would change if any of these assumptions are not valid. The first four assumptions are likely to be valid during the planning horizon. The other two assumptions depend on future hydrology. Although Lake Meredith or Lake Palo Duro have not spilled, hydrologic records show that there is the possibility of having runoff high enough to fill the reservoirs. Lake Meredith would have filled in 1942 and during 1958-1960, and Palo Duro in 1946 and 1965.

The most uncertain variable is related to the duration of the critical period. If the current drought continues past 2005, the firm yield of both reservoirs would be reduced. The firm yield of Lake Meredith and Lake Palo cannot be truly estimated from historical records until inflows are high enough to fill the conservation storage. However, assessment of reliability of water supply from the reservoirs under low storage conditions could be assessed by a vulnerability assessment. These type of analyses is a probability analysis that provides the likelihood of a reservoirs to meet the demand given low storage and a range of possible inflow for a period of 1 to 5 years.

APPENDIX A

REFERENCES

(1) *Water Availability Models for the Red and Canadian River Basins*. Prepared by Espey Consultants, Inc., Austin, Texas, March 2002.

(2) *Historical Data of Lake Meredith.* Provided by Canadian River Municipal Water Authority. December 2004.

(3) *Monthly Reservoir Reports for Conchas Lake.* Prepared by the Corps of Engineers, Albuquerque District. Available (as of December 6, 2005) at http://www.spa.usace.army.mil/wc/adbb/monthly.htm

(4) *Volumetric Survey Lake Meredith*. Texas Water Development Board, September 1995.

(5) *Engineering Report on Palo Duro Reservoir*. Prepared by Freese and Nichols, Inc. for the Palo Duro River Authority. June 1986.

(6) *Streamflow, Reservoir Yield, and Storage Projection Analyses for Lake Meredith.* HDR Engineering, Inc., 1987

(7) *Firm Yield of Lake Meredith.* Prepared by Parkhill, Smith and Copper, Inc. for the Canadian River Municipal Water Authority. February 1993.

(8) *Information on the Eastern New Mexico Rural Water System.* Prepared by the Eastern New Mexico Rural Water Authority. Available at http://www.enmrwa.com

Table B-1
Net Evaporation Rates in Lake Meredith
Values are Depth in feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1940	0.009	0.185	0.426	0.398	0.394	0.580	0.902	0.588	0.610	0.550	0.053	0.181	4.876
1941	0.109	0.107	0.128	0.317	-0.077	0.153	0.231	0.395	0.270	-0.206	0.231	0.175	1.833
1942	0.147	0.181	0.299	0.096	0.501	0.258	0.651	0.382	0.345	-0.076	0.397	0.129	3.310
1943	0.180	0.256	0.336	0.382	0.475	0.595	0.428	0.700	0.561	0.489	0.257	0.004	4.663
1944	0.017	0.107	0.352	0.233	0.314	0.547	0.393	0.545	0.439	0.291	0.194	-0.009	3.423
1945	0.046	0.168	0.334	0.270	0.642	0.627	0.516	0.416	0.402	0.287	0.350	0.196	4.254
1946	0.191	0.204	0.353	0.446	0.483	0.619	0.740	0.396	0.236	-0.011	0.064	0.172	3.893
1947	0.207	0.251	0.264	0.276	0.133	0.529	0.640	0.605	0.724	0.425	0.200	0.064	4.318
1948	0.091	-0.033	0.215	0.505	0.337	0.433	0.532	0.313	0.621	0.367	0.140	0.349	3.870
1949	0.076	0.134	0.311	0.251	0.106	0.292	0.315	0.443	0.379	0.324	0.332	0.144	3.107
1950	0.257	0.190	0.399	0.384	0.493	0.344	-0.089	0.303	0.113	0.445	0.316	0.257	3.412
1951	0.100	0.158	0.325	0.438	-0.108	0.352	0.779	0.887	0.837	0.614	0.310	0.226	4.918
1952	0.238	0.287	0.333	0.270	0.468	0.800	0.786	0.856	0.875	0.808	0.364	0.211	6.296
1953	0.267	0.253	0.507	0.598	0.728	0.903	0.748	0.594	0.954	0.346	0.287	0.062	6.247
1954	0.123	0.344	0.398	0.381	0.064	0.637	0.680	0.517	0.712	0.330	0.339	0.261	4.786
1955	0.135	0.216	0.415	0.532	0.061	0.457	0.642	0.513	0.333	0.450	0.345	0.236	4.335
1956	0.161	0.059	0.487	0.566	0.534	0.648	0.524	0.635	0.727	0.484	0.311	0.244	5.380
1957	0.145	0.146	-0.012	0.089	-0.021	0.476	0.763	0.281	0.423	0.085	0.080	0.251	2.706
1958	0.026	0.074	-0.087	0.169	0.130	0.491	0.113	0.502	0.334	0.363	0.183	0.120	2.418
1959	0.140	0.184	0.361	0.369	0.088	0.466	0.327	0.335	0.519	0.137	0.202	-0.172	2.956
1960	-0.009	0.034	0.185	0.426	0.390	0.126	0.091	0.363	0.048	-0.064	0.253	0.109	1.952
1961	0.072	0.056	0.038	0.404	0.391	0.252	0.276	0.347	0.378	0.355	-0.025	0.150	2.694
1962	0.018	0.197	0.328	0.329	0.547	0.086	0.185	0.433	0.224	0.366	0.214	0.109	3.036
1963	0.058	0.150	0.469	0.643	0.358	0.407	0.636	0.376	0.363	0.464	0.300	0.060	4.284
1964	0.060	-0.007	0.304	0.574	0.475	0.582	0.794	0.596	0.312	0.451	0.095	0.089	4.325
1965	0.090	0.129	0.067	0.398	0.319	0.033	0.560	0.563	0.582	0.448	0.336	0.101	3.626
1966	0.040	0.067	0.461	0.581	0.817	0.449	0.836	0.275	0.352	0.415	0.346	0.163	4.802
1967	0.293	0.273	0.541	0.419	0.685	0.420	0.304	0.459	0.475	0.576	0.202	0.134	4.781
1968	0.069	0.123	0.274	0.559	0.427	0.317	0.462	0.425	0.609	0.382	0.176	0.114	3.937
1969	0.237	0.101	0.138	0.507	0.284	0.357	0.583	0.531	0.202	0.182	0.184	0.145	3.451
1970	0.131	0.283	0.217	0.482	0.898	0.871	0.875	0.644	0.616	0.340	0.315	0.227	5.899
1971	0.176	0.191	0.514	0.613	0.778	0.775	0.682	0.468	0.251	0.271	0.110	0.127	4.956
1972	0.249	0.271	0.584	0.752	0.463	0.461	0.399	0.569	0.532	0.290	-0.019	0.039	4.590
1973	0.086	0.149	-0.036	0.253	0.569	0.817	0.556	0.764	0.292	0.405	0.274	0.147	4.276
1974	0.089	0.314	0.298	0.697	0.632	0.731	0.893	0.057	0.343	-0.004	0.227	0.075	4.352
1975	0.131	0.004	0.345	0.448	0.523	0.428	0.245	0.676	0.379	0.530	0.155	0.165	4.029

Table B-1
Net Evaporation Rates in Lake Meredith
Values are Depth in feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1976	0.241	0.390	0.391	0.403	0.529	0.775	0.634	0.488	-0.183	0.311	0.153	0.169	4.301
1977	0.197	0.270	0.553	0.335	0.088	0.732	0.832	0.106	0.491	0.422	0.295	0.255	4.576
1978	0.127	0.147	0.388	0.636	0.223	0.540	0.921	0.633	0.352	0.411	0.112	0.162	4.652
1979	0.178	0.218	0.297	0.414	0.180	0.320	0.700	0.419	0.448	0.388	0.217	0.268	4.047
1980	0.041	0.156	0.202	0.442	0.207	0.608	0.975	0.812	0.532	0.494	0.177	0.116	4.762
1981	0.131	0.305	0.227	0.520	0.357	0.552	0.684	0.252	0.218	0.155	0.093	0.164	3.658
1982	0.297	0.247	0.414	0.572	0.281	0.093	0.101	0.619	0.425	0.413	0.242	0.061	3.765
1983	0.040	-0.039	0.170	0.406	0.398	0.497	0.834	0.743	0.688	0.204	0.204	0.072	4.217
1984	0.092	0.251	0.241	0.459	0.741	0.611	0.825	0.248	0.536	0.098	0.166	0.037	4.305
1985	0.057	0.130	0.185	0.269	0.565	0.504	0.774	0.540	0.282	0.109	0.099	0.091	3.605
1986	0.228	0.165	0.443	0.589	0.473	0.158	0.710	0.504	0.272	0.116	0.042	0.051	3.751
1987	0.104	0.165	0.156	0.496	0.194	0.328	0.626	0.473	0.179	0.310	0.179	0.090	3.300
1988	0.140	0.233	0.336	0.296	0.383	0.480	0.386	0.430	0.083	0.408	0.316	0.206	3.697
1989	0.197	0.265	0.468	0.583	0.336	0.240	0.692	0.483	0.415	0.445	0.341	0.022	4.487
1990	0.076	0.174	0.272	0.477	0.626	1.016	0.627	0.517	0.220	0.388	0.239	0.119	4.751
1991	0.046	0.325	0.490	0.597	0.424	0.385	0.235	0.419	0.354	0.430	0.066	-0.100	3.671
1992	0.088	0.218	0.417	0.258	0.361	0.108	0.606	0.073	0.542	0.474	0.134	0.040	3.319
1993	-0.016	0.106	0.311	0.421	0.487	0.460	0.478	0.628	0.568	0.405	0.220	0.207	4.275
1994	0.303	0.160	0.366	0.455	0.367	0.655	0.593	0.511	0.524	0.206	-0.208	0.156	4.088
1995	0.108	0.259	0.410	0.400	0.097	0.340	0.572	0.716	0.256	0.425	0.308	0.101	3.992
1996	0.118	0.349	0.416	0.720	0.810	0.580	0.107	0.222	0.102	0.360	0.140	0.199	4.123
1997	0.140	0.085	0.468	-0.170	0.327	0.428	0.623	0.219	0.385	0.362	0.114	0.011	2.992
1998	0.124	0.069	0.220	0.484	0.589	0.967	0.586	0.469	0.561	0.039	0.173	0.157	4.438
1999	0.077	0.360	0.178	0.221	0.111	0.544	0.567	0.528	0.447	0.363	0.301	0.160	3.857
2000	0.230	0.332	0.076	0.442	0.665	0.258	0.734	0.940	0.799	-0.051	0.120	0.067	4.612
2001	0.059	0.048	0.081	0.626	0.336	0.693	0.929	0.558	0.492	0.461	0.167	0.200	4.650
2002	0.130	0.218	0.472	0.467	0.681	0.599	0.480	0.454	0.481	-0.135	0.241	0.134	4.222
2003	0.201	0.171	0.317	0.761	0.718	0.014	0.958	0.744	0.447	0.405	0.284	0.263	5.283
2004	0.208	0.144	0.334	0.407	0.865	0.108	0.583	0.803	0.460				
Average	0.129	0.180	0.310	0.431	0.411	0.476	0.575	0.497	0.427	0.318	0.204	0.133	4.084

Table B-2
Net Evaporation Rates in Palo Duro Reservoir
Values are Depth in feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1940	-0.001	0.190	0.436	0.394	0.357	0.574	0.901	0.621	0.604	0.559	0.086	0.176	4.897
1941	0.087	0.074	0.152	0.285	-0.024	0.230	0.249	0.376	0.332	-0.216	0.225	0.187	1.957
1942	0.154	0.177	0.284	0.048	0.502	0.187	0.648	0.389	0.346	-0.084	0.395	0.131	3.177
1943	0.177	0.249	0.340	0.331	0.446	0.569	0.473	0.731	0.534	0.469	0.262	-0.007	4.574
1944	-0.001	0.107	0.335	0.198	0.314	0.659	0.374	0.594	0.447	0.287	0.201	-0.048	3.467
1945	0.037	0.150	0.306	0.235	0.601	0.558	0.485	0.419	0.398	0.303	0.342	0.186	4.020
1946	0.205	0.163	0.345	0.453	0.435	0.629	0.755	0.358	0.269	-0.038	0.031	0.182	3.787
1947	0.207	0.254	0.247	0.231	0.096	0.472	0.628	0.590	0.740	0.402	0.196	0.063	4.126
1948	0.098	-0.043	0.206	0.508	0.373	0.329	0.550	0.323	0.578	0.363	0.159	0.364	3.808
1949	0.072	0.120	0.277	0.266	0.034	0.199	0.313	0.436	0.404	0.294	0.325	0.149	2.889
1950	0.267	0.192	0.401	0.393	0.434	0.363	-0.211	0.244	0.118	0.442	0.308	0.257	3.208
1951	0.101	0.144	0.296	0.411	-0.133	0.296	0.751	0.884	0.812	0.588	0.297	0.240	4.687
1952	0.236	0.271	0.297	0.267	0.443	0.823	0.730	0.835	0.845	0.773	0.355	0.199	6.074
1953	0.257	0.247	0.493	0.576	0.684	0.821	0.665	0.583	0.915	0.361	0.279	0.063	5.944
1954	0.154	0.340	0.373	0.393	0.030	0.750	0.752	0.637	0.753	0.330	0.356	0.269	5.137
1955	0.126	0.178	0.398	0.555	-0.043	0.364	0.735	0.509	0.351	0.458	0.334	0.210	4.175
1956	0.168	0.094	0.398	0.565	0.479	0.702	0.534	0.672	0.776	0.507	0.309	0.225	5.429
1957	0.105	0.146	-0.094	0.117	-0.116	0.350	0.722	0.380	0.368	0.107	0.081	0.241	2.407
1958	0.032	0.088	-0.066	0.174	0.182	0.455	0.116	0.408	0.338	0.396	0.208	0.109	2.440
1959	0.138	0.163	0.352	0.348	0.040	0.503	0.301	0.400	0.514	0.117	0.206	-0.108	2.974
1960	0.004	-0.002	0.206	0.438	0.325	0.242	0.225	0.458	0.049	-0.017	0.263	0.060	2.251
1961	0.091	0.070	0.035	0.404	0.275	0.280	0.343	0.378	0.406	0.337	0.007	0.150	2.776
1962	0.024	0.198	0.323	0.302	0.545	0.001	0.286	0.440	0.169	0.340	0.204	0.109	2.941
1963	0.061	0.161	0.466	0.578	0.332	0.460	0.640	0.560	0.373	0.516	0.299	0.079	4.525
1964	0.062	0.000	0.330	0.609	0.373	0.562	0.809	0.638	0.431	0.452	-0.010	0.058	4.314
1965	0.096	0.105	0.124	0.472	0.258	-0.100	0.588	0.407	0.310	0.250	0.272	0.084	2.866
1966	0.047	-0.026	0.444	0.388	0.512	0.555	0.492	0.159	0.197	0.466	0.390	0.118	3.742
1967	0.097	0.185	0.469	0.399	0.377	0.201	0.170	0.302	0.358	0.547	0.193	0.115	3.413
1968	-0.015	0.017	0.293	0.401	0.014	0.397	0.544	0.380	0.554	0.300	0.105	0.050	3.040
1969	0.055	0.007	0.028	0.381	0.138	0.328	0.548	0.471	0.112	0.184	0.217	0.061	2.530
1970	0.087	0.187	0.123	0.241	0.597	0.569	0.577	0.458	0.458	0.239	0.163	0.120	3.819
1971	0.226	0.115	0.375	0.444	0.413	0.500	0.472	0.447	0.274	0.230	-0.048	0.077	3.525
1972	0.162	0.266	0.496	0.475	0.064	0.381	0.469	0.389	0.320	0.235	-0.078	0.197	3.376
1973	0.061	0.115	-0.238	0.126	0.304	0.575	0.302	0.593	0.127	0.360	0.209	0.200	2.734
1974	0.172	0.373	0.234	0.530	0.460	0.538	0.944	0.148	0.202	0.171	0.182	0.104	4.058
1975	0.032	0.035	0.210	0.334	0.122	0.300	0.359	0.438	0.243	0.585	-0.003	0.179	2.834

Table B-2
Net Evaporation Rates in Palo Duro Reservoir
Values are Depth in feet

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1976	0.247	0.366	0.400	0.204	0.189	0.624	0.686	0.711	0.279	0.312	0.223	0.243	4.484
1977	0.099	0.265	0.467	0.159	0.021	0.602	0.722	0.240	0.478	0.437	0.300	0.251	4.041
1978	0.083	0.053	0.386	0.554	-0.124	0.418	0.910	0.734	0.471	0.444	0.083	0.211	4.223
1979	0.048	0.110	0.176	0.293	-0.015	0.365	0.424	0.477	0.531	0.439	0.190	0.207	3.245
1980	0.079	0.180	0.261	0.329	0.010	0.626	1.103	0.757	0.606	0.471	0.209	0.159	4.790
1981	0.184	0.272	0.152	0.483	0.288	0.678	0.468	0.361	0.376	0.129	0.115	0.202	3.708
1982	0.180	0.170	0.395	0.384	0.118	0.149	0.436	0.645	0.579	0.406	0.205	0.088	3.755
1983	0.100	0.022	0.194	0.328	0.225	0.221	0.922	0.817	0.629	0.233	0.243	0.071	4.005
1984	0.137	0.335	0.100	0.327	0.411	0.557	0.753	0.561	0.632	0.112	0.226	0.024	4.175
1985	0.090	0.040	0.192	0.301	0.336	0.422	0.769	0.598	0.120	0.033	0.128	0.004	3.033
1986	0.286	0.256	0.489	0.408	0.353	0.359	0.771	0.375	0.382	0.140	0.036	0.082	3.937
1987	0.099	0.063	0.150	0.469	-0.003	0.246	0.722	0.487	0.127	0.346	0.194	0.074	2.974
1988	0.085	0.215	0.134	0.209	0.341	0.480	0.388	0.498	0.199	0.343	0.328	0.272	3.492
1989	0.220	0.080	0.409	0.441	0.070	-0.025	0.548	0.309	0.353	0.502	0.472	0.177	3.556
1990	0.114	0.074	0.112	0.158	0.286	0.792	0.636	0.670	0.353	0.336	0.157	0.120	3.808
1991	0.132	0.280	0.420	0.550	0.301	0.506	0.685	0.724	0.500	0.535	0.144	0.100	4.877
1992	0.094	0.267	0.357	0.294	0.252	0.057	0.485	0.286	0.643	0.483	0.171	0.145	3.534
1993	0.078	0.134	0.279	0.370	0.322	0.407	0.637	0.626	0.542	0.442	0.282	0.187	4.306
1994	0.232	0.207	0.357	0.337	0.327	0.697	0.665	0.607	0.545	0.391	0.320	0.186	4.871
1995	0.000	0.000	0.376	0.333	0.037	0.247	0.400	0.533	0.208	0.474	0.395	0.289	3.292
1996	0.254	0.306	0.439	0.634	0.293	0.395	0.113	0.137	0.012	0.420	0.297	0.387	3.687
1997	0.257	0.179	0.601	-0.056	0.217	0.369	0.625	0.298	0.400	0.346	0.224	-0.018	3.442
1998	0.235	0.167	0.274	0.448	0.496	0.947	0.512	0.504	0.633	0.094	0.146	0.146	4.602
1999	0.058	0.209	0.159	0.157	0.239	0.309	0.642	0.514	0.368	0.404	0.460	0.394	3.913
2000	0.239	0.320	0.083	0.448	0.518	0.193	0.698	0.889	0.835	0.007	0.301	0.186	4.717
2001	0.118	0.156	0.064	0.414	0.130	0.750	0.905	0.586	0.511	0.541	0.123	-0.005	4.293
2002	0.143	0.034	0.125	0.455	0.513	0.707	0.567	0.552	0.437	-0.036	0.170	-0.046	3.621
2003	0.191	0.151	0.276	0.728	0.658	0.110	0.981	0.621	0.434	0.385	0.255	0.240	5.030
2004	0.163	0.127	0.262	0.360	0.857	0.178	0.519	0.722	0.468				
Average	0.125	0.156	0.274	0.366	0.276	0.431	0.568	0.506	0.426	0.325	0.214	0.144	3.802

Table C-1
Elevation-Area-Capacity for Lake Meredith

	Year 2000		**Year 2060**	
Elevation (Feet msl)	Area (Acres)	Capacity (Acre-Feet)	Area (Acres)	Capacity (Acre-Feet)
2,819	0	0	0	0
2,820	3	1	0	0
2,830	870	4,217	645	2,339
2,840	1,607	16,968	1,382	12,833
2,850	2,694	37,534	2,469	31,142
2,860	4,218	72,269	3,993	63,620
2,870	5,401	120,607	5,176	109,701
2,880	6,318	179,111	6,093	165,948
2,890	8,278	248,057	8,053	232,638
2,900	10,457	338,265	10,232	320,589
2,910	11,767	448,911	11,542	428,977
2,920	13,547	572,632	13,322	550,442
2,930	15,061	714,892	14,836	690,445
2,936.5	16,382	815,989	16,157	790,075

Top of conservation pool: 2936.5 feet

Table C-2
Elevation-Area-Capacity for Lake Palo Duro

	Year 2000		**Year 2060**	
Elevation (Feet msl)	Area (Acres)	Capacity (Acre-Feet)	Area (Acres)	Capacity (Acre-Feet)
2,810	0	0	0	0
2,820	0	0	0	0
2,830	82	275	4	14
2,840	229	1,773	151	613
2,850	403	4,896	325	2,939
2,860	802	10,813	724	8,053
2,870	1,201	20,765	1,123	17,216
2,880	1,698	35,193	1,620	30,856
2,890	2,281	55,021	2,203	49,897
2,892	2,400	59,702	2,322	54,422

Top of Conservation Pool: 2892

APPENDIX D

EQUATIONS USED TO FILLED PERIODS WITH MISSING HISTORICAL DATA

CR-LG = Canadian River near Logan (NM)
CR-AM = Canadian River near Amarillo
CR-CN = Canadian River near Canadian
CC-GU = Coldwater Creek near Guymon (OK)
PD-SP = Palo Duro near Spearman
WC-LP = Wolf Creek near Lipscomb

Canadian River near Logan:

Period: October 2003 to September 2004:

Nat flow CR-LG = 0.6656 x Nat flow CR-AM by scatter x-y plot

Coldwater Creek near Guymon (OK)

Period: October 1964 – September 1979

Nat flow CR-GU = 0.8718 x Nat flow PD-SP by double mass curve

Period: October 1979 – September 1980

Nat flow CC-CU = 0.0206 x Nat flow CR-CN by double mass curve

Palo Duro near Spearman

Period: January 1940- September 1940 and October 1942 – July 1945

Nat flow PD-SP = 0.0546 x CR-CN by double mass curve

Period October 1940-September 1042 and October 1979 – May 1999

Nat flow PD-SP = 1.515 x Nat flow WC-LP by double mass curve

Wolf Creek near Lipscomb

Period: January 1940- September 1940 and October 1942 – July 1945

Nat flow WC-LP = 0.038 x CR-CN by double mass curve

August 1945 – September 1961:

Nat flow WC-LP = 0.66 x Nat flow PD-DP by double mass curve

Table E-1
Revised Naturalized Flows for Canadian River at Logan (NM)

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	123	201	315	0	2,841	3,817	653	8,855	30	0	54	409	17,298
1941	95	28	2,575	13,773	224,547	279,736	138,662	64,222	477,751	297,997	39,454	29,329	1,568,169
1942	11,531	8,791	5,867	412,476	163,980	6,394	27,949	42,630	271,040	41,049	25,084	3,323	1,020,114
1943	23,889	1,059	518	0	1,415	3,258	10,041	11,279	292	95	10	452	52,308
1944	2,178	435	448	212	29,681	32,728	13,898	31,728	29,962	2,551	1,361	2,974	148,156
1945	2,647	1,585	546	1,716	1,290	1,113	4,547	18,836	825	1,744	258	425	35,532
1946	748	377	298	18	35,692	3,222	1,331	10,773	43,563	45,182	2,512	845	144,561
1947	1,627	1,218	986	20	33,732	4,478	24,774	8,182	95	0	135	236	75,483
1948	186	3,705	3,535	367	1,559	78,354	6,117	16,035	10	67	375	6	110,316
1949	454	2,131	1,042	6,837	11,317	28,498	24,570	19,804	5,892	171	24	524	101,264
1950	278	151	73	905	14	7,172	82,515	15,352	14,051	621	26	129	121,287
1951	234	379	764	67	29,220	8,156	24,288	1,436	792	484	399	206	66,425
1952	113	11	546	496	349	389	8,113	22,207	1,141	111	163	185	33,824
1953	171	79	63	12	212	2	10,555	32,522	1,492	2	899	270	46,279
1954	145	30	0	8	6,315	3,286	1,682	6,496	2,202	42,069	210	135	62,578
1955	214	117	2	1,458	30,470	135	17,552	11,874	7,829	60	8	103	69,822
1956	186	243	0	20	4,053	6,990	20,130	3,772	0	0	0	0	35,394
1957	54	125	65	1,990	5,418	3,242	20,126	32,974	5,863	5,527	405	260	76,049
1958	446	232	2,234	2,040	50,820	44,118	21,566	35,994	25,179	621	373	383	184,006
1959	899	516	226	573	1,149	1,492	4,121	38,127	807	1,551	484	5,412	55,357
1960	1,921	893	659	292	258	26,550	74,223	22,963	2,674	23,731	1,516	5,180	160,860
1961	3,532	15,654	11,491	12,511	4,934	1,351	15,277	10,351	22,014	2,496	1,976	1,032	102,619
1962	1,188	3,547	1,958	1,240	1,799	4,133	21,574	4,853	2,788	558	448	313	44,399
1963	327	655	560	2,860	8,793	4,741	3,777	13,611	4,502	934	342	292	41,394
1964	419	852	312	546	1,713	291	736	3,509	10,252	139	1,049	217	20,035
1965	104	86	213	190	9,376	15,489	17,097	29,017	7,739	9,325	480	0	89,116
1966	75	688	877	855	706	9,959	6,276	20,787	164	103	0	0	40,490
1967	0	607	282	846	6,505	11,586	32,323	5,892	6,100	601	149	45	64,936
1968	0	98	706	1,561	193	1,460	4,043	8,153	841	601	0	0	17,656
1969	0	228	0	1,070	11,264	41,729	14,806	8,747	46,234	1,870	1,731	213	127,892
1970	1,546	0	790	4,553	1,450	889	5,564	4,558	2,008	82	0	95	21,535
1971	122	700	1,222	1,924	7,960	5,480	9,574	16,113	306	389	1,400	130	45,320
1972	631	189	1,138	981	555	1,488	32,234	18,099	20,226	1,373	588	1,220	78,722
1973	220	699	503	7,328	838	1,914	5,377	1,948	1,075	448	0	0	20,350
1974	1,469	926	660	928	914	207	654	2,159	2,461	3,729	0	95	14,202
1975	230	505	877	355	717	4,764	5,818	2,123	372	143	238	239	16,381
1976	492	1,265	32	1,213	188	2,339	7,823	866	4,199	0	0	66	18,483
1977	0	902	290	5,838	9,866	1,615	4,381	18,797	1,978	83	0	0	43,750
1978	220	320	1,084	543	373	8,064	1,438	117	0	0	5,327	213	17,699
1979	291	729	553	946	6,416	2,422	6,600	12,379	2,045	143	585	434	33,543
1980	196	1,090	1,104	1,766	5,645	981	573	4,113	4,837	260	378	513	21,456
1981	437	671	523	493	1,728	734	2,627	65,508	8,080	0	231	357	81,389
1982	490	751	1,055	755	5,707	25,936	40,141	25,688	4,712	10,454	1,116	1,468	118,273
1983	1,851	2,590	1,608	836	1,167	4,906	266	172	737	423	0	48	14,604
1984	0	104	420	750	386	2,317	1,206	8,989	543	2,433	1,240	948	19,336
1985	421	1,015	2,393	1,392	4,695	2,517	345	4,530	593	22,988	699	813	42,401
1986	1,348	2,243	1,600	768	222	13,208	559	2,572	8,425	4,589	10,111	1,665	47,310
1987	2,619	8,238	45,655	59,831	88,713	15,546	4,584	7,567	3,107	372	252	389	236,873
1988	1,386	1,954	1,960	1,115	3,321	10,885	4,532	1,961	6,369	1,400	855	1,552	37,290
1989	1,946	552	3,662	1,324	3,981	14,582	5,762	9,532	3,767	288	1,153	484	47,033
1990	2,090	1,581	2,899	1,176	1,781	542	2,193	18,641	1,482	187	576	13	33,161
1991	2,869	3,098	1,536	1,843	3,997	3,854	4,110	16,707	13,311	1,348	2,303	4,183	59,159
1992	2,019	2,527	2,335	2,001	2,686	8,730	3,150	6,474	1,381	1,460	0	492	33,255
1993	0	1,491	2,412	1,380	1,088	13,566	7,104	4,708	0	0	849	749	33,347
1994	329	1,338	2,379	3,328	51,450	36,750	4,870	2,012	1,303	3,066	1,117	1,589	109,531
1995	73	0	2,384	960	2,701	42,868	31,278	2,878	13,677	0	1,016	2,638	100,473
1996	2,392	0	2,921	2,394	1,520	4,925	28,623	10,850	1,868	522	2,364	1,748	60,127
1997	1,704	1,996	3,230	8,072	4,407	39,367	4,538	10,825	2,539	391	1,074	1,608	79,751
1998	2,590	2,469	4,891	2,198	1,971	1,912	3,919	6,120	603	1,642	1,240	0	29,555
1999	3,659	1,939	2,467	3,228	117,917	20,969	4,687	41,631	3,263	1,456	2,225	3,337	206,778
2000	4,023	3,765	1,610	2,374	2,178	4,108	2,772	1,704	415	16,246	225	1,516	40,936
2001	212	2,619	3,288	1,568	475	1,075	306	6,852	1,861	0	0	0	18,256
2002	0	15	0	768	1,746	9,377	4,712	4,836	790	0	132	4	22,380
2003	460	1,868	271	1,382	1,983	7,590	3,057	1,529	0	0	287	0	18,427
2004	574	1,822	4,413	8,051	1,134	12,629	15,951	21,835	2,945				69,355
Total	92,693	96,692	141,326	599,321	1,021,491	962,925	914,650	926,374	1,113,402	556,175	117,506	81,504	6,624,060
Mean	1,426	1,488	2,174	9,220	15,715	14,814	14,072	14,252	17,129	8,690	1,836	1,274	102,090
Max	23,889	15,654	45,655	412,476	224,547	279,736	138,662	65,508	477,751	297,997	39,454	29,329	1,568,169
Min	0	0	0	0	14	2	266	117	0	0	0	0	14,202

Table E-2
Revised Naturalized Flows for Canadian River near Amarillo

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	955	1,738	115	109	33,825	8,098	3,316	23,944	11,072	48	11,334	2,272	96,827
1941	1,139	672	1,815	12,387	429,798	314,859	300,240	163,061	477,102	348,407	48,471	28,199	2,126,150
1942	13,586	10,715	10,039	356,432	177,669	36,306	43,918	44,174	271,558	66,139	21,451	8,008	1,059,995
1943	31,995	1,829	478	1,445	1,048	75	38,958	10,926	131	283	385	4,794	92,347
1944	9,980	4,226	2,079	2,129	49,810	58,484	29,896	34,704	49,040	3,204	930	10,392	254,874
1945	8,141	2,331	324	324	283	4,143	2,671	40,878	6,065	11,024	357	433	76,974
1946	444	471	409	313	28,771	8,283	1,515	18,588	70,294	120,166	5,885	2,260	257,399
1947	2,873	788	2,410	1,469	46,259	6,111	23,919	6,258	227	381	399	630	91,726
1948	589	5,993	6,225	515	6,685	111,039	9,666	46,153	776	1,735	5,215	379	194,969
1949	975	2,973	2,386	9,677	96,194	104,099	79,511	39,098	23,453	2,399	2,793	969	364,527
1950	1,137	491	795	2,678	1,280	39,543	200,728	48,521	78,178	8,361	907	1,047	383,668
1951	1,484	2,689	1,857	926	72,413	13,409	34,715	4,725	1,915	912	2,466	756	138,266
1952	808	585	782	3,888	2,045	1,445	16,665	33,812	3,999	647	687	848	66,211
1953	1,061	589	685	625	608	565	31,926	48,516	1,952	8,745	1,066	1,169	97,506
1954	1,060	731	807	3,029	49,308	2,096	38,678	16,653	1,903	65,173	1,119	691	181,247
1955	943	805	562	36,675	75,478	18,998	27,627	24,346	14,974	3,449	698	794	205,347
1956	962	935	941	660	34,336	7,123	25,448	3,954	439	448	543	689	76,477
1957	577	663	1,031	7,620	46,364	39,547	13,708	104,130	12,976	19,210	2,091	1,084	248,999
1958	2,365	2,955	9,304	8,145	62,227	48,656	169,756	64,206	68,863	2,358	1,591	2,089	442,515
1959	2,040	2,134	613	871	5,563	17,791	24,440	74,280	3,694	4,692	746	25,461	162,325
1960	8,524	7,813	4,861	978	640	79,118	202,491	51,467	23,533	48,058	3,282	11,045	441,809
1961	4,135	10,403	24,787	12,731	7,283	4,752	33,272	17,888	30,844	4,165	13,155	3,771	167,186
1962	3,769	3,264	2,507	2,282	1,895	14,778	32,821	28,966	7,097	2,073	1,493	2,081	103,028
1963	1,183	1,885	1,625	3,401	14,220	36,810	17,344	32,495	17,656	1,489	842	949	129,901
1964	1,076	3,995	1,122	858	2,997	994	1,154	6,370	37,874	724	2,081	620	59,864
1965	396	370	681	414	30,558	209,732	30,922	51,694	9,201	32,282	9,569	2,110	377,930
1966	652	3,341	2,867	1,253	1,397	20,494	14,340	41,085	6,261	803	428	430	93,350
1967	1,047	1,661	811	15,617	8,770	38,254	101,327	20,611	15,399	13,470	3,561	4,964	225,492
1968	4,826	2,752	1,652	2,011	11,897	8,974	18,322	23,827	1,989	5,035	314	207	81,807
1969	673	3,096	2,784	1,219	43,883	84,102	41,765	31,292	101,986	18,103	6,196	3,050	338,148
1970	4,761	1,065	2,417	33,904	3,680	2,027	9,257	18,977	10,283	3,969	1,700	822	92,862
1971	1,312	2,098	1,710	3,346	17,233	23,911	39,519	45,292	17,318	4,559	23,262	3,994	183,554
1972	4,341	1,927	1,774	1,423	6,064	10,213	97,244	61,089	52,565	17,016	3,335	2,883	259,873
1973	2,593	2,687	8,911	17,545	2,129	1,993	18,943	11,681	1,754	962	0	542	69,740
1974	2,975	1,620	6,349	987	8,245	4,486	3,065	52,319	21,239	39,973	3,160	1,962	146,382
1975	3,805	4,012	2,539	3,098	3,056	36,041	23,905	12,055	1,560	767	539	403	91,781
1976	900	1,706	702	3,249	6,839	5,417	11,132	14,272	57,313	3,098	855	834	106,318
1977	0	2,293	328	14,684	17,138	5,939	8,678	58,031	24,323	0	0	0	131,413
1978	247	508	1,296	437	21,156	50,049	2,832	2,524	17,541	7,502	6,304	447	110,843
1979	880	1,166	836	1,073	7,708	21,449	3,695	23,534	2,135	47	1,265	1,101	64,890
1980	2,570	6,654	3,241	2,536	22,069	7,712	305	9,807	6,891	0	225	1,292	63,302
1981	626	659	1,039	0	716	20,237	16,504	204,823	46,655	7,376	2,669	2,081	303,387
1982	1,817	1,725	2,005	1,580	9,099	57,419	81,079	32,762	10,538	16,791	3,129	7,036	224,979
1983	5,451	8,735	6,918	2,458	3,043	9,081	0	0	150	270	0	77	36,183
1984	0	467	870	3,655	1,599	5,947	2,346	22,521	771	8,802	3,596	4,389	54,962
1985	2,428	3,047	6,963	2,819	11,378	5,467	163	5,818	22,590	37,110	2,594	1,968	102,345
1986	2,324	5,761	2,776	729	1,138	23,173	1,155	17,470	33,688	10,463	20,150	3,188	122,014
1987	4,293	9,910	47,183	56,078	99,017	23,366	3,605	28,018	14,676	1,882	929	2,118	291,076
1988	4,858	2,921	9,951	8,761	31,419	42,903	39,938	6,918	44,719	4,077	950	4,287	201,703
1989	3,696	2,545	4,478	1,757	19,934	37,594	12,727	29,588	15,681	1,710	7,409	2,036	139,156
1990	4,780	6,589	6,161	3,693	3,141	237	3,372	19,685	23,977	4,545	4,806	1,352	82,338
1991	6,962	4,103	1,708	2,485	17,157	15,838	27,437	52,212	10,686	3,095	4,332	9,240	155,257
1992	9,853	4,542	3,263	2,725	6,924	55,934	15,316	21,799	5,354	1,681	581	3,107	131,078
1993	1,664	3,768	4,165	2,080	3,090	31,710	17,541	13,594	15,197	2,584	1,923	1,634	98,950
1994	914	1,856	4,135	581	63,546	45,545	22,176	3,331	4,921	38,721	2,568	2,694	190,987
1995	1,662	334	3,373	2,136	9,763	51,850	36,444	24,969	27,507	8,150	3,833	3,902	173,924
1996	3,513	627	2,912	2,086	4,031	23,305	74,568	44,829	18,192	5,070	4,928	4,374	188,435
1997	3,330	3,277	3,911	22,335	10,456	42,697	8,794	26,939	3,300	4,306	2,861	3,954	136,160
1998	6,641	4,978	11,975	3,638	2,968	1,565	3,427	11,539	937	18,439	13,049	1,553	80,709
1999	4,950	5,794	4,934	11,460	139,217	39,974	11,088	58,416	15,957	1,761	2,547	4,613	300,712
2000	4,819	6,305	22,246	12,310	3,618	9,325	5,220	1,444	0	30,142	3,600	2,530	101,559
2001	3,833	6,774	10,998	3,069	3,290	1,705	0	7,129	1,773	0	241	0	38,813
2002	645	1,071	0	4,060	1,401	12,462	4,213	10,922	8,467	0	1,339	974	45,555
2003	1,628	3,286	1,137	1,026	1,558	22,789	3,318	1,456	10,734	432	0	94	47,458
2004	862	2,738	6,631	12,095	1,703	18,974	23,965	32,806	4,425				104,199
Total	215,330	200,445	287,193	736,576	1,908,024	2,107,014	2,244,030	2,145,189	1,904,268	1,079,283	278,735	203,674	13,309,761
Mean	3,313	3,084	4,418	11,332	29,354	32,416	34,524	33,003	29,296	16,864	4,355	3,182	205,141
Max	31,995	10,715	47,183	356,432	429,798	314,859	300,240	204,823	477,102	348,407	48,471	28,199	2,126,150
Min	0	334	0	0	283	75	0	0	0	0	0	0	36,183

Table E-3
Revised Naturalized Flows for Canadian River near Canadian

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	600	11,690	460	180	11,790	11,530	1,050	14,620	8,650	70	17,090	6,300	84,030
1941	6,601	11,913	13,560	20,650	512,097	534,340	376,391	216,914	440,400	628,274	83,229	40,130	2,884,499
1942	27,991	17,734	27,790	355,840	237,760	120,756	33,513	29,011	278,530	90,981	20,020	8,583	1,248,509
1943	33,321	5,204	3,510	2,095	9,550	800	23,009	2,870	40	83	127	5,855	86,464
1944	23,833	10,454	3,220	3,709	51,720	59,298	37,359	15,847	50,617	8,434	1,740	32,794	299,025
1945	23,565	6,202	4,870	1,610	400	1,208	10	37,042	1,455	12,785	73	500	89,720
1946	3,190	1,840	124	80	33,410	18,376	63	19,078	105,341	257,125	6,549	12,048	457,224
1947	18,262	2,310	15,591	15,588	66,084	11,747	17,550	110	30	98	253	339	147,962
1948	863	8,554	17,559	0	1,882	156,293	5,715	72,714	785	0	8,038	618	273,021
1949	968	7,625	3,038	6,344	227,226	149,416	58,897	35,092	15,949	3,384	523	1,618	510,080
1950	4,355	2,820	0	46	4,518	28,876	236,434	77,870	110,206	4,376	876	7,260	477,637
1951	10,833	15,563	6,266	1,867	191,733	69,253	46,791	1,820	6,470	1,910	8,665	2,919	364,090
1952	3,477	1,491	964	959	0	0	2,097	19,928	1,949	0	0	1,891	32,756
1953	9,145	2,445	1,302	0	0	6,955	56,040	62,919	0	26,493	4,032	1,967	171,298
1954	10,339	6,558	4,185	7,764	77,995	0	24,919	11,845	35	38,409	32	72	182,153
1955	2,208	1,660	0	172	172,918	58,843	28,050	15,268	8,435	1,881	0	0	289,435
1956	765	4,077	20	0	54,141	24,814	11,901	0	0	0	0	0	95,718
1957	0	1,372	8,208	23,177	127,650	40,030	13,751	92,995	14,068	14,036	5,949	2,613	343,849
1958	8,316	5,640	15,587	10,212	54,117	58,143	267,705	68,248	68,105	12	667	1,735	558,487
1959	3,049	1,333	43	1,776	22,189	8,702	32,555	60,708	4,693	2,233	1,203	42,386	180,870
1960	29,449	21,575	7,147	690	0	125,590	224,872	108,341	28,324	80,615	4,112	9,238	639,953
1961	4,225	6,555	36,069	11,567	6,383	27,516	27,978	10,597	17,745	1,809	13,741	18,902	183,087
1962	11,168	6,714	970	5,165	0	6,413	19,022	60,247	3,128	616	890	3,875	118,208
1963	2,193	5,708	1,782	2,309	8,351	17,862	4,450	16,389	13,982	435	0	310	73,771
1964	1,841	9,817	955	68	2,366	10,428	240	2,639	9,249	0	4,687	5,597	47,887
1965	6,873	3,169	5,500	459	35,823	266,975	28,327	52,902	9,217	32,591	10,110	4,493	456,439
1966	2,299	7,412	3,661	1,448	761	18,525	16,462	39,278	10,767	214	125	1,200	102,152
1967	4,131	3,185	1,549	16,773	20,805	41,873	105,621	20,539	15,108	12,647	3,567	6,930	252,728
1968	9,144	5,647	4,568	1,340	19,549	30,658	19,133	23,597	1,334	30,277	1,762	2,324	149,333
1969	5,235	8,801	12,093	2,507	75,124	90,785	39,466	31,736	101,894	18,600	7,649	6,874	400,764
1970	6,844	3,363	6,576	36,957	3,034	1,254	7,673	17,291	24,947	3,804	2,360	2,928	117,031
1971	3,894	6,696	4,449	3,592	15,589	35,089	43,047	44,228	25,637	20,740	72,450	33,274	308,685
1972	21,402	9,521	3,492	1,636	8,260	10,491	92,309	60,521	49,627	15,905	4,273	3,847	281,284
1973	3,956	6,107	36,946	48,691	5,373	1,427	18,327	10,563	863	155	0	1,498	133,906
1974	4,330	4,069	25,456	2,634	8,222	4,593	2,198	51,153	20,179	39,707	4,699	3,230	170,470
1975	8,100	9,516	5,918	6,083	8,360	37,838	27,058	14,042	0	287	1,236	2,076	120,514
1976	3,460	3,634	4,503	7,111	10,690	5,241	9,445	13,233	55,955	3,278	1,867	2,128	120,545
1977	0	4,971	1,964	20,002	78,049	24,678	7,459	59,819	25,504	91	1,093	1,324	224,954
1978	1,664	6,110	4,677	2,458	52,518	87,895	2,233	3,409	20,748	7,459	6,826	2,611	198,608
1979	6,872	4,554	12,304	3,379	28,808	31,969	5,714	21,684	1,508	0	3,369	3,197	123,358
1980	6,564	11,700	7,939	9,802	37,280	8,346	0	8,393	5,390	0	0	2,212	97,626
1981	2,342	2,079	5,001	44	4,822	26,068	15,517	194,693	45,300	10,808	6,879	4,924	318,477
1982	4,580	6,642	6,822	3,485	21,029	70,524	77,909	32,545	10,007	15,417	3,950	9,085	261,995
1983	8,102	14,996	16,822	8,523	7,475	36,439	0	0	0	641	0	0	92,998
1984	4,949	3,719	4,873	8,199	3,624	7,735	1,759	20,743	37	9,305	5,284	8,650	78,877
1985	6,136	7,835	16,773	11,994	19,092	9,345	0	5,326	22,085	46,227	6,626	6,318	157,757
1986	6,696	10,032	5,775	1,715	2,256	25,255	2,399	19,100	33,748	13,307	25,152	7,924	153,359
1987	10,025	15,126	51,410	53,197	96,965	32,666	7,611	27,046	18,616	4,633	3,534	6,614	327,443
1988	14,678	8,405	25,835	24,232	40,331	50,345	46,161	7,700	45,327	5,405	2,472	6,621	277,512
1989	6,598	5,576	8,024	4,042	33,649	53,292	15,313	30,542	16,361	2,730	8,825	4,451	189,403
1990	9,906	13,025	13,722	9,790	8,026	1,464	2,549	17,308	22,939	5,202	5,945	2,632	112,508
1991	9,213	6,095	4,023	4,099	18,710	25,354	28,489	50,506	10,103	2,960	6,528	15,477	181,557
1992	16,713	8,849	6,777	11,124	10,789	64,956	16,686	21,370	5,131	1,453	1,799	7,749	173,396
1993	7,490	10,059	10,939	8,360	8,835	33,997	17,568	12,741	14,554	2,678	2,811	3,000	133,032
1994	3,028	3,839	7,210	5,285	60,747	42,822	20,984	2,445	4,171	39,261	1,512	5,873	197,177
1995	4,797	3,076	6,732	5,429	16,688	65,383	34,756	25,415	27,071	10,898	5,480	5,965	211,690
1996	6,021	3,269	5,232	3,615	7,013	25,347	76,948	49,306	24,114	8,360	9,331	10,493	229,049
1997	8,224	9,894	8,535	54,964	26,954	45,828	9,553	29,659	5,175	6,099	5,532	10,637	221,054
1998	15,068	12,539	26,089	10,563	8,072	1,699	2,760	11,719	643	19,491	21,665	6,194	136,502
1999	9,501	13,416	16,444	27,677	142,140	40,028	15,743	53,576	15,451	3,116	1,833	7,395	346,320
2000	7,017	5,211	14,494	16,756	8,410	14,719	7,217	1,080	0	23,665	8,043	4,525	111,137
2001	10,018	15,733	22,633	13,307	12,788	5,854	2,062	3,684	0	0	1,672	0	87,751
2002	4,024	4,649	2,474	6,594	12,934	13,467	8,522	8,511	16,014	0	4,661	9,375	91,225
2003	7,062	7,116	6,198	7,023	5,312	21,469	7,745	1,607	6,477	2,972	891	1,965	75,837
2004	3,697	5,512	13,709	18,678	6,135	27,447	25,209	27,202	7,918				135,507
Total	521,210	472,001	621,361	955,435	2,865,321	2,986,329	2,418,294	2,179,324	1,908,106	1,594,442	444,307	433,563	17,399,693
Mean	8,019	7,262	9,559	14,699	44,082	45,944	37,205	33,528	29,355	24,913	6,942	6,774	268,282
Max	33,321	21,575	51,410	355,840	512,097	534,340	376,391	216,914	440,400	628,274	83,229	42,386	2,884,499
Min	0	1,333	0	0	0	0	0	0	0	0	0	0	32,756

Table E-4
Revised Naturalized Flows for Coldwater near Guymon

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	0	85	124	274	8,945	3,256	0	581	1,052	0	255	111	14,683
1941	184	302	270	263	2,864	887	910	497	15	443	360	296	7,290
1942	373	261	437	1,219	353	2,384	437	13	0	1,110	159	330	7,076
1943	328	189	197	328	144	0	1,453	0	0	0	0	0	2,641
1944	608	360	345	458	2,620	88	1,031	0	0	0	2	205	5,717
1945	326	323	378	147	59	307	193	387	0	62	26	122	2,330
1946	152	199	215	108	545	70	3,808	0	109	36,328	1,232	548	43,316
1947	576	424	685	612	718	21,397	2,466	330	0	0	145	306	27,660
1948	285	541	749	264	162	479	188	541	54	34	350	323	3,970
1949	193	431	472	371	1,417	578	4,100	47	37	84	248	364	8,341
1950	309	370	333	327	218	71	20,504	6,307	12,698	2,484	414	502	44,536
1951	507	546	530	484	19,531	1,268	245	1,436	0	7	202	274	25,031
1952	266	292	465	347	154	3	673	95	0	0	0	15	2,309
1953	265	205	210	138	79	4	297	0	0	0	0	35	1,232
1954	236	139	137	166	299	105	0	129	0	0	0	0	1,212
1955	8	88	140	143	9,540	5,869	1,815	341	0	0	50	184	18,179
1956	283	301	269	185	763	323	692	462	0	0	3	129	3,412
1957	290	290	815	559	1,217	3,963	290	2,813	0	82	235	292	10,847
1958	321	277	390	421	322	44	701	7,010	254	119	293	275	10,428
1959	571	447	369	337	677	600	3,792	213	0	0	79	176	7,259
1960	150	407	302	235	84	295	19	6	1,310	2,655	204	225	5,893
1961	178	269	471	394	754	615	237	7	0	12	177	234	3,348
1962	289	257	291	321	120	2,072	1,322	266	57	120	221	239	5,576
1963	138	249	259	193	162	566	610	10	534	0	8	142	2,871
1964	149	167	219	161	48	81	0	0	0	0	0	0	825
1965	0	0	0	0	7,719	45,599	1,110	2,101	239	1,115	87	105	58,075
1966	13	18	58	31	11	1,823	648	104	487	14	18	19	3,245
1967	17	17	88	495	41	8,508	5,521	2,793	223	86	155	42	17,986
1968	44	33	36	30	1,147	1,458	2,209	3,919	406	12,329	274	100	21,983
1969	12	3	22	6	329	101	166	2,005	4,560	34	3	35	7,275
1970	9	9	42	768	38	2,154	672	590	74	137	130	63	4,684
1971	23	12	77	92	709	6,770	3,336	770	751	236	11,050	173	23,997
1972	32	21	82	591	1,134	2,356	3,008	1,579	461	194	83	43	9,584
1973	14	41	2,032	1,289	1,186	167	295	592	592	128	218	41	6,595
1974	0	0	357	327	133	550	92	1,025	52	98	78	0	2,710
1975	0	0	101	72	2,560	654	5,632	2,258	287	178	156	55	11,953
1976	11	1	46	888	390	132	110	43	65	16	7	0	1,710
1977	0	0	39	142	1,881	731	612	1,771	44	13	0	0	5,233
1978	0	0	39	15	2,860	4,093	173	3,635	736	173	58	0	11,784
1979	123	189	449	299	9,166	1,046	1,751	567	297	0	69	66	14,021
1980	135	241	164	202	768	172	0	173	111	0	0	0	1,966
1981	0	0	17	30	30	30	49	117	0	0	0	0	273
1982	0	0	17	30	3,922	2,198	40	44	8	10	0	0	6,268
1983	0	0	17	30	30	30	30	30	0	0	0	0	167
1984	0	0	17	30	30	30	30	30	0	0	0	0	167
1985	0	0	17	30	30	30	30	30	1,638	1,295	0	0	3,099
1986	0	0	17	30	30	30	30	30	0	0	0	0	167
1987	0	0	17	30	273	30	31	30	0	0	0	0	411
1988	0	0	17	30	30	30	30	30	0	0	0	0	167
1989	0	0	17	30	5,319	30	40	40	155	9	0	0	5,640
1990	0	0	17	3,165	30	30	30	30	0	0	0	0	3,302
1991	0	0	0	0	0	2,519	0	0	0	0	0	0	2,519
1992	0	0	0	0	0	332	0	445	0	20	0	0	796
1993	0	0	0	0	0	235	0	336	0	0	0	0	570
1994	0	0	0	0	267	0	0	0	0	0	0	0	267
1995	0	0	0	0	0	0	0	78	72	0	0	0	150
1996	0	0	0	0	0	103	10	270	36	0	0	0	419
1997	0	0	0	0	3	0	1	162	0	0	0	0	166
1998	0	0	0	0	0	0	0	0	0	233	192	0	425
1999	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	9	0	0	0	0	9
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	292	32	0	0				323
Total	7,416	8,009	12,873	17,136	91,862	127,586	71,501	47,124	27,413	59,860	17,243	6,068	494,090
Mean	114	123	198	264	1,413	1,963	1,100	725	422	935	269	95	7,621
Max	608	546	2,032	3,165	19,531	45,599	20,504	7,010	12,698	36,328	11,050	548	58,075
Min	0	0	0	0	0	0	0	0	0	0	0	0	0

Table E-5
Revised Naturalized Flows for Palo Duro near Spearman

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	33	638	25	10	643	629	57	798	472	0	3	4	3,312
1941	6	15	11	43	206	183	79	78	33	773	60	30	1,516
1942	19	20	17	32	49	82	11	35	25	4,966	1,093	468	6,819
1943	1,819	284	192	114	521	44	1,256	157	2	5	7	320	4,719
1944	1,301	571	176	202	2,823	3,236	2,039	865	2,763	460	95	1,790	16,320
1945	1,286	338	266	88	22	66	1	350	2,463	625	30	42	5,577
1946	62	38	43	305	207	181	650	358	3,474	51,374	359	194	57,245
1947	185	129	117	146	268	2,498	210	13	0	281	5	12	3,864
1948	9	18	26	26	181	177	378	836	19	2	431	25	2,128
1949	18	23	39	51	3,954	333	229	303	15	257	43	55	5,320
1950	31	41	52	46	47	1,148	6,395	5,645	7,260	333	144	155	21,296
1951	154	146	121	127	21,459	554	167	64	20	19	58	53	22,942
1952	52	66	61	3,636	93	18	34	922	3	0	4	34	4,923
1953	26	23	49	17	17	893	11,560	342	33	515	71	55	13,601
1954	45	30	30	58	119	9,342	1,310	935	25	4,507	113	129	16,641
1955	130	71	49	6,307	12,359	325	1,513	2,318	32	3	0	0	23,107
1956	15	55	92	11	634	288	1,192	1,615	16	4	15	27	3,964
1957	38	26	87	2,535	5,878	1,006	1,205	977	52	20	60	44	11,929
1958	58	64	57	221	7	533	9,381	1,150	212	36	61	108	11,887
1959	165	64	73	70	70	316	3,382	472	57	41	42	491	5,244
1960	77	76	52	15	39	1,297	972	156	11,187	9,100	223	152	23,345
1961	123	77	114	24	501	888	4,004	114	96	38	133	98	6,209
1962	61	33	35	42	79	219	905	679	191	3	36	55	2,339
1963	39	38	5	9	1,198	2,634	1,324	264	4,727	116	61	49	10,463
1964	65	200	26	36	18	495	24	0	0	0	0	0	863
1965	0	0	0	0	8,854	52,304	1,273	2,410	274	1,279	100	121	66,615
1966	15	21	66	36	12	2,092	744	119	559	17	21	22	3,722
1967	19	20	101	568	47	9,759	6,333	3,204	255	98	178	49	20,631
1968	50	37	41	35	1,316	1,672	2,533	4,495	465	14,142	314	114	25,215
1969	14	4	25	7	377	115	190	2,300	5,230	39	4	41	8,345
1970	10	10	48	881	43	2,471	771	676	85	157	149	72	5,373
1971	26	13	88	105	813	7,766	3,826	884	861	271	12,674	198	27,526
1972	37	24	94	678	1,300	2,702	3,451	1,811	529	223	95	50	10,994
1973	16	47	2,330	1,479	1,360	192	338	679	679	146	251	47	7,564
1974	0	0	409	375	152	631	105	1,176	60	113	89	0	3,109
1975	0	0	116	82	2,936	750	6,460	2,590	329	204	179	63	13,711
1976	12	1	53	1,019	448	152	126	49	75	19	8	0	1,962
1977	0	0	45	163	2,157	838	703	2,031	50	15	0	0	6,002
1978	0	0	45	17	3,281	4,695	199	4,170	845	199	66	0	13,517
1979	141	217	515	343	10,513	1,199	2,009	650	340	138	223	354	16,643
1980	407	373	478	6,233	4,343	1,571	382	182	110	142	185	227	14,633
1981	225	194	270	239	154	82	50	89	53	50	103	82	1,590
1982	70	93	141	146	386	1,545	242	81	44	69	71	115	3,002
1983	131	191	275	279	248	735	198	55	50	46	66	68	2,342
1984	120	97	126	247	139	677	200	57	19	48	55	163	1,948
1985	195	210	274	727	742	207	197	100	39	52	140	160	3,043
1986	51	50	102	85	61	85	119	303	375	400	318	330	2,280
1987	498	424	932	822	1,110	852	538	144	263	167	249	363	6,363
1988	429	461	1,222	1,467	1,470	529	234	76	136	191	200	234	6,650
1989	250	298	274	202	5,378	1,830	710	423	197	213	222	263	10,261
1990	335	392	620	585	751	317	122	123	73	59	90	167	3,634
1991	215	231	235	217	224	251	84	35	43	36	54	120	1,744
1992	201	140	210	338	121	257	464	115	66	84	69	257	2,320
1993	291	504	1,135	1,605	1,473	503	5,099	343	136	176	160	256	11,680
1994	282	327	453	286	380	224	35	28	42	44	45	56	2,201
1995	95	109	178	163	186	2,181	399	109	57	72	74	140	3,763
1996	170	142	169	140	66	30	1,481	1,450	29,165	2,390	1,632	1,365	38,200
1997	948	924	757	2,262	2,344	1,554	288	247	162	213	277	475	10,450
1998	854	821	1,624	1,179	755	153	1,164	118	64	153	400	368	7,652
1999	445	612	898	9,829	5,834	0	0	34	7	0	0	0	17,660
2000	0	0	42	0	0	2,861	53	0	0	62	165	0	3,183
2001	0	169	0	0	0	0	0	76	1	0	10	0	256
2002	0	0	0	1	4	1,068	1	1	0	0	0	0	1,075
2003	0	0	0	0	3	338	0	0	0	0	0	0	341
2004	0	0	0	0	0	4,750	94	7	0				4,851
Total	12,366	10,239	16,207	47,009	111,176	137,323	89,488	50,883	74,917	95,205	22,083	10,727	677,624
Mean	190	158	249	723	1,710	2,113	1,377	783	1,153	1,488	345	168	10,456
Max	1,819	924	2,330	9,829	21,459	52,304	11,560	5,645	29,165	51,374	12,674	1,790	66,615
Min	0	0	0	0	0	0	0	0	0	0	0	0	256

Table E-6
Revised Naturalized Flows for Wolf Creek near Lipscomb

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	23	447	18	7	451	441	40	560	331	0	2	2	2,323
1941	4	10	7	28	136	121	52	52	22	510	40	20	1,001
1942	13	13	11	21	33	54	8	23	17	3,483	766	329	4,770
1943	1,276	199	134	80	366	31	881	110	2	3	5	224	3,310
1944	912	400	123	142	1,980	2,270	1,430	607	1,938	323	67	1,255	11,447
1945	902	237	186	62	15	46	0	231	1,626	413	20	28	3,766
1946	41	25	28	201	137	119	429	236	2,293	33,907	237	128	37,782
1947	122	85	77	96	177	1,649	139	9	0	185	3	8	2,550
1948	6	12	17	17	120	117	250	552	13	1	284	16	1,404
1949	12	15	26	33	2,609	220	151	200	10	170	28	37	3,511
1950	20	27	34	30	31	758	4,221	3,725	4,791	220	95	102	14,055
1951	101	96	80	84	14,163	366	110	42	13	13	38	35	15,142
1952	34	44	41	2,400	61	12	23	609	2	0	2	22	3,249
1953	17	15	32	11	11	589	7,629	226	22	340	47	36	8,977
1954	30	20	20	38	78	6,166	864	617	16	2,975	75	85	10,983
1955	86	47	32	4,163	8,157	215	998	1,530	21	2	0	0	15,251
1956	10	36	61	7	418	190	787	1,066	11	3	10	18	2,616
1957	25	17	58	1,673	3,880	664	795	645	35	13	39	29	7,873
1958	38	42	38	146	5	352	6,192	759	140	24	40	71	7,846
1959	109	43	48	46	46	209	2,232	312	37	27	28	324	3,461
1960	51	50	34	10	26	856	641	103	7,383	6,006	147	101	15,408
1961	81	51	75	16	331	586	2,642	75	63	185	223	223	4,550
1962	366	436	386	330	70	1,450	267	641	830	128	159	204	5,267
1963	108	607	367	214	5,819	5,523	408	190	3,677	78	141	259	17,389
1964	391	467	286	130	116	805	26	0	25	6	226	535	3,013
1965	426	316	400	341	1,080	12,274	1,027	4,771	667	501	299	417	22,519
1966	343	554	402	367	186	44	1,060	252	209	31	123	189	3,758
1967	110	237	274	334	193	1,128	5,088	2,974	227	110	233	336	11,247
1968	375	291	326	332	567	560	612	3,000	181	10,276	927	597	18,043
1969	724	579	694	574	526	325	40	1,040	1,033	257	249	292	6,332
1970	369	321	381	464	144	1,812	97	330	3,646	304	311	429	8,607
1971	389	313	485	306	257	1,847	123	89	42	671	6,692	754	11,970
1972	458	388	433	334	1,976	530	204	372	258	34	181	283	5,451
1973	302	345	1,749	3,099	956	477	137	40	77	94	129	228	7,633
1974	286	279	3,260	442	187	86	20	1,554	263	118	141	99	6,736
1975	138	209	264	252	1,400	216	127	636	30	28	49	64	3,413
1976	80	102	151	229	227	129	68	9	95	34	36	90	1,250
1977	88	89	118	128	1,898	788	50	37	26	25	38	50	3,334
1978	91	100	89	102	4,544	1,073	85	53	28	31	34	63	6,292
1979	102	158	342	237	7,657	803	1,311	306	92	91	147	234	11,479
1980	268	246	315	4,114	2,867	1,037	252	120	73	94	122	150	9,658
1981	149	128	178	158	101	54	33	59	35	33	68	54	1,050
1982	46	61	93	96	255	1,020	160	54	29	45	47	76	1,981
1983	86	126	181	184	163	485	131	36	33	31	44	45	1,546
1984	79	64	83	163	92	447	132	38	13	31	36	108	1,286
1985	129	139	181	480	490	137	130	66	26	35	92	106	2,009
1986	34	33	67	56	40	56	79	200	248	264	210	218	1,505
1987	329	280	615	542	733	562	355	95	174	110	164	239	4,200
1988	283	304	807	968	970	349	155	50	90	126	132	155	4,389
1989	165	197	181	134	3,550	1,208	469	279	130	141	147	174	6,773
1990	221	259	409	386	496	209	81	81	48	39	60	110	2,398
1991	142	152	155	143	148	165	55	23	28	24	35	79	1,151
1992	133	92	138	223	80	170	306	76	44	55	45	169	1,532
1993	192	333	749	1,059	972	332	3,366	226	90	116	106	169	7,710
1994	186	216	299	189	251	148	23	18	28	29	30	37	1,452
1995	63	72	118	108	123	1,440	263	72	38	48	49	92	2,484
1996	112	94	112	93	43	20	977	957	19,251	1,577	1,077	901	25,215
1997	626	610	500	1,493	1,548	1,026	190	163	107	140	183	313	6,898
1998	564	542	1,072	778	498	101	768	78	42	101	264	243	5,051
1999	294	404	593	6,488	3,851	889	548	219	102	100	142	189	13,817
2000	206	227	419	409	302	444	229	83	58	91	125	143	2,736
2001	201	316	364	307	212	97	43	38	29	47	65	63	1,783
2002	109	170	139	104	22	7	2	5	32	124	96	182	994
2003	177	164	187	165	117	3,559	204	35	36	42	43	49	4,777
2004	93	111	298	203	75	197	114	94	32				1,216
Total	13,946	13,060	19,843	36,572	79,030	60,058	50,328	31,746	51,005	65,060	15,692	12,278	448,619
Mean	215	201	305	563	1,216	924	774	488	785	1,017	245	192	6,924
Max	1,276	610	3,260	6,488	14,163	12,274	7,629	4,771	19,251	33,907	6,692	1,255	37,782
Min	4	10	7	7	5	7	0	0	0	0	0	0	994

APPENDIX F

REVIEW OF PREVIOUS HYDROLOGIC STUDIES FOR UTE AND CONCHAS RESERVOIRS

Conchas Dam

Conchas Dam is located on the Canadian River, 34 miles northwest of Tucumcari, New Mexico. The reservoir has a capacity of 315,700 acre-feet at the crest of the irrigation and service spillway (Elevation 4201 feet). It has a drainage area of 7,409 sq. miles, of which 433 sq. miles are probably noncontributing. The reservoir is used for irrigation, flood control, and recreation and is own by the Corps of Engineers.

Historical diversions from the reservoir to the Bell Ranch Canal have been at rate of 60,000 acre-feet per year. As mentioned in the PSC report[1], previous studies for Ute Reservoir and Lake Meredith have assumed that diversions from Conchas Dam and the amount of water spilled from Conchas Dam would not change under future conditions. Conchas Dam started impoundment in December 1939, which is prior to the period of record of the extended hydrology. This assumptions is still valid. Under this assumption, no adjustment is necessary to the hydrology below Conchas for the development of a new set of naturalized flows in Texas from 1940-2004.

Ute Reservoir[2]

Ute Reservoir is located in the Canadian River 24 miles upstream of the Texas-New Mexico Border. It was initially constructed with a conservation capacity of 109,600 acre-feet, and the impoundment started in December 1962. The reservoir was built to increase water supplies in North Eastern New Mexico in recognition of groundwater level declines.

The proposed water supply from Ute Reservoir evolved from a series of studies performed between 1965 and 1998 by the US Bureau of Reclamation (USBR), Interstate Stream Commission (ISC), and Eastern Plains Council of Government (EPCOG). The reservoir was expanded to a capacity of 272,000 acre-feet in 1984. After the expansion, the Interstate Stream Commission estimated the firm annual yield to be 24,000 acre-feet per year in all but extreme drought years.

These studies have assumed no change on spills and releases coming from upstream reservoirs above Conchas Dam. Therefore, inflows into and available supply from Ute reservoir are not expected to change in the future.

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[1] Firm Yield of Lake Meredith. Prepared by Parkhill, Smith and Copper, Inc. for the Canadian River Municipal Water Authority. February 1993.

[2] Information on the Eastern New Mexico Rural Water System. Prepared by the Eastern New Mexico Rural Water Authority. Available at http://www.enmrwa.com

The water supply project has not been built to date, but plans are in place for the construction of a lakeside intake pump station, a 39 mgd water treatment plant, near 180 miles of transmission and lateral pipelines, storage tanks, and pump stations.

Historical records of spills and releases reflect conditions of minimal withdrawal from the reservoir. Once the water supply from Ute Reservoir is completed, releases and spills would be reduced, which would reduce the inflow and the firm of Lake Meredith.