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REGIONAL WATER SUPPLY PLAN

VOLUME TWO - APPENDICES

1990

PREPARED FOR

TARRANT COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NUMBER ONE

IN CONJUNCTION WITH THE

TEXAS WATER DEVELOPMENT BOARD

FREESE AND NICHOLS, INC.

ALAN PLUMMER AND ASSOCIATES, INC.

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Billy W. Ervin, Outside Services Coordinator, City of Mansfield

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APPENDIX B

PROJECTED POPULATION AND WATER USE

IN THE STUDY AREA THROUGH 2050

Table B-1

Denton County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	County	143,126	189,744	250,246	343,429	439,275	534,216	631,062	686,121	745,984
	Justin	920	1,223	2,766	5,091	5,793	6,527	7,339	7,791	8,271
	Roanoke	910	1,211	2,739	5,041	5,736	6,463	7,267	7,715	8,191
	Southlake (P)	16	18	20	27	31	34	37	40	43
	Trophy Club	1,935	2,800	6,333	11,200	11,200	11,200	11,200	11,200	11,200
	Westlake (P)	214	253	572	1,053	1,198	1,350	1,518	1,612	1,711
	Study area cities	3,995	5,505	12,430	22,412	23,958	25,574	27,361	28,358	29,416
	Other county	25,853	35,554	47,486	47,487	83,644	126,121	172,030	187,399	204,141
	% other in area	15	10	5	4	3	2.5	2	2	2
	# other in area	3,878	3,555	2,374	1,899	2,509	3,153	3,441	3,748	4,083
	Study area	7,873	9,060	14,804	24,311	26,467	28,727	30,802	32,106	33,499
Municipal	City per capita	123	158	158	150	142	138	138	138	138
	Other per capita	105	116	140	133	125	122	122	122	122
	Justin	127	216	490	855	921	1,009	1,134	1,204	1,279
	Roanoke	125	214	485	847	912	999	1,123	1,193	1,266
	Southlake	2	6	4	5	5	5	6	6	7
	Trophy Club	267	496	1,121	1,882	1,781	1,731	1,731	1,731	1,731
	Westlake	29	45	101	177	191	209	235	249	264
	Study area cities	550	977	2,201	3,766	3,810	3,953	4,229	4,383	4,547
	Other County	3,040	4,637	7,442	7,062	11,749	17,198	23,448	25,541	27,821
	Other study area	456	462	372	283	351	431	470	512	558
	Study area	1,006	1,439	2,573	4,049	4,161	4,384	4,699	4,895	5,105
Manufacturing	Study area	0	0	0	0	0	0	0	0	0
Steam Electric	Study area	0	0	0	0	0	0	0	0	0
Mining	Study area	0	0	0	0	0	0	0	0	0
Total	Study area	1,006	1,439	2,573	4,049	4,161	4,384	4,699	4,895	5,105

Table B-2

Ellis County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	Study area	59,743	73,255	86,743	119,158	144,273	166,415	184,482	194,264	204,565
Municipal	Study area	8,641	13,840	16,109	20,636	23,704	26,606	29,516	31,080	32,763
	Per capita	129	169	166	155	147	143	143	143	143
Manufacturing	Study area	2,672	3,595	3,657	4,157	4,979	5,858	6,919	7,650	8,458
Steam Electric	Study area	0	0	0	0	0	0	0	0	0
Mining	Study area	9	87	90	105	120	135	150	165	180
Total	Study area	11,322	17,522	19,856	24,898	28,803	32,599	36,585	38,895	41,401

All of Ellis County is in the study area.

Table B-3

Freestone County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	County	14,830	17,109	17,536	19,035	20,115	23,056	26,482	28,387	30,429
	Fairfield	3,505	4,189	4,545	5,462	5,987	6,695	7,081	7,590	8,136
	Wortham	1,187	1,394	1,435	1,558	1,707	1,908	2,017	2,162	2,317
	Study area cities	4,692	5,583	5,980	7,020	7,694	8,603	9,098	9,752	10,453
	Other county	6,748	7,859	7,782	7,781	7,781	9,265	11,897	12,754	13,673
	% other in area	46	46	46	46	46	46	46	46	46
	# other in area	3,104	3,615	3,580	3,579	3,579	4,262	5,473	5,867	6,290
	Study area	7,796	9,198	9,560	10,599	11,273	12,865	14,571	15,619	16,743
Municipal	City per capita	160	140	154	147	139	135	135	135	135
	Other per capita	105	98	137	130	123	120	119	119	119
	Fairfield	627	686	804	917	951	1,033	1,092	1,171	1,256
	Wortham	213	190	229	236	245	266	281	301	322
	Study area cities	840	876	1,033	1,153	1,196	1,299	1,373	1,472	1,578
	Other county	793	865	1,196	1,135	1,075	1,241	1,588	1,701	1,822
	Other study area	365	397	549	521	493	573	730	782	838
	Study area	1,205	1,273	1,582	1,674	1,689	1,872	2,103	2,254	2,416
Manufacturing	County	128	509	646	970	1,166	1,461	1,797	2,025	2,282
	% in study area	80	80	80	80	80	80	80	80	80
	Study area	102	407	517	776	933	1169	1438	1620	1826
Steam Electric	Study area	14,947	14,016	14,000	14,000	14,000	14,000	14,000	14,000	14,000
Mining	Study area	274	35	22	25	20	14	9	1	1
Total	Study area	16,528	15,731	16,121	16,475	16,642	17,055	17,550	17,875	18,243

Table B-4

Henderson County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	Trinity Basin	31,740	38,134	44,492	51,339	56,904	64,543	73,280	78,222	83,497
	Athens	10,197	11,015	12,540	13,352	14,905	16,638	18,574	19,825	21,160
	Gun Barrel City	2,118	2,827	3,626	4,271	4,768	5,323	5,944	6,343	6,769
	Mabank (P)	156	227	280	370	471	574	687	732	780
	Malakoff	2,082	2,325	2,673	3,149	3,516	3,925	4,383	4,678	4,993
	Tool	1,591	1,977	2,503	2,950	3,293	3,676	4,104	4,381	4,677
	Trinidad	1,130	1,391	1,731	1,844	2,058	2,297	2,563	2,735	2,919
	Other cities	2,444	3,134	3,703	4,113	4,601	5,143	5,750	6,136	6,549
	Study area cities	19,718	22,896	27,056	30,049	33,612	37,576	42,005	44,830	47,847
	Other basin	12,022	15,238	17,436	21,290	23,292	26,967	31,275	33,392	35,650
	Other study area	9,017	11,429	13,077	15,968	17,469	20,225	23,456	25,044	26,738
	Study area	28,735	34,325	40,133	46,017	51,081	57,801	65,461	69,874	74,585
Municipal	City per capita	149	189	166	157	149	145	145	145	145
	Other per capita	210	224	252	234	222	214	212	212	211
	Athens	1,375	2,789	2,347	2,371	2,503	2,715	3,030	3,235	3,454
	Gun Barrel City	595	370	549	613	648	702	784	837	894
	Mabank (P)	28	49	71	89	108	127	152	162	173
	Malakoff	279	349	391	437	462	501	559	597	638
	Tool	354	247	534	597	630	684	763	815	871
	Trinidad	247	369	455	460	485	526	587	627	670
	Other	408	663	689	723	768	835	934	997	1,064
	Study area cities	3,286	4,836	5,036	5,290	5,604	6,090	6,809	7,270	7,764
	Other county	2,823	3,822	4,926	5,592	5,802	6,468	7,431	7,922	8,445
	Other study area	2,121	2,868	3,691	4,185	4,344	4,848	5,570	5,947	6,320
	Study area	5,407	7,704	8,727	9,475	9,948	10,938	12,379	13,217	14,084
Manufacturing	Study area	66	90	110	151	192	240	298	361	437
Steam Electric	Study area	3,191	2,617	2,600	14,000	14,000	14,000	14,000	14,000	14,000
Mining	Basin	291	930	231	172	154	137	119	103	89
	% in study area	95	95	95	95	95	95	95	95	95
	Study area	276	884	219	163	146	130	113	98	85
Total	Study area	8,940	11,295	11,656	23,789	24,286	25,308	26,790	27,676	28,606

Table B-5

Johnson County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	County	67,649	87,673	103,983	136,680	175,630	217,900	270,344	301,300	335,801
	Burleson (P)	10,611	14,443	18,852	23,497	26,120	28,929	32,041	35,709	39,797
	Mansfield (P)	22	130	166	205	224	238	252	281	313
	Study area	10,633	14,573	19,018	23,702	26,344	29,167	32,293	35,990	40,110
Municipal	City per capita	114	107	143	136	129	125	125	125	125
	Burleson (P)	1,360	1,731	3,025	3,576	3,761	4,046	4,481	4,995	5,568
	Mansfield (P)	3	19	28	32	34	35	37	41	45
	Study area	1,363	1,750	3,053	3,608	3,795	4,081	4,518	5,036	5,613
Manufacturing	Study area	0	0	0	0	0	0	0	0	0
Steam Electric	Study area	0	0	0	0	0	0	0	0	0
Mining	Study area	0	0	0	0	0	0	0	0	0
Total	Study area	1,363	1,750	3,053	3,608	3,795	4,081	4,518	5,036	5,613

Table B-6

Kaufman County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	County	39,015	49,304	59,403	73,563	89,585	106,525	125,035	135,500	146,841
	Kemp	1,035	1,309	1,738	2,217	2,831	3,451	4,142	4,488	4,863
	Mabank (P)	1,287	1,858	2,382	3,140	4,007	4,887	5,866	6,356	6,887
	Study area	2,322	3,167	4,120	5,357	6,838	8,338	10,008	10,844	11,750
Municipal	City per capita	156	155	190	181	171	166	166	166	166
	Kemp	166	149	271	328	397	470	564	611	662
	Mabank (P)	239	402	606	758	915	1,084	1,301	1,410	1,528
	Study area	405	551	877	1,086	1,312	1,554	1,865	2,021	2,190
Manufacturing	Study area	0	0	0	0	0	0	0	0	0
Steam Electric	Study area	0	0	0	0	0	0	0	0	0
Mining	Study area	0	0	0	0	0	0	0	0	0
Total	Study area	405	551	877	1,086	1,312	1,554	1,865	2,021	2,190

Table B-7

Navarro County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	County	35,323	39,065	40,598	44,170	46,175	47,523	49,012	49,771	50,542
	Corsicana	21,712	23,638	24,691	26,593	27,828	28,651	29,501	29,958	30,422
	Kerens	1,582	1,723	1,776	1,897	1,984	2,042	2,102	2,133	2,164
	Study area cities	23,294	25,361	26,467	28,490	29,812	30,693	31,603	32,091	32,586
	Other county	12,029	13,704	14,131	15,680	16,363	16,830	17,409	17,680	17,955
	% in study area	72.5	74.6	74.6	74.6	74.6	74.6	74.6	74.6	74.6
	Other study area	8,724	10,217	10,542	11,697	12,207	12,555	12,987	13,189	13,394
	Study area	32,018	35,578	37,009	40,187	42,019	43,248	44,590	45,280	45,980
Municipal	City per capita	205	148	200	190	180	175	175	175	175
	Other per capita	105	106	139	132	125	122	122	122	122
	Corsicana	5,107	4,035	5,663	5,786	5,728	5,729	5,899	5,990	6,082
	Kerens	250	177	273	277	274	274	282	286	290
	Study area cities	5,357	4,212	5,936	6,063	6,002	6,003	6,181	6,276	6,372
	Other county	1,414	1,622	2,207	2,323	2,293	2,291	2,370	2,407	2,445
	Other study area	1,026	1,213	1,641	1,730	1,709	1,716	1,775	1,802	1,830
	Study area	6,383	5,425	7,577	7,793	7,711	7,719	7,956	8,078	8,202
Manufacturing	Study area	896	1,068	1,250	1,720	2,116	2,624	3,201	3,699	4,274
Steam Electric	Study area	0	0	0	0	0	7,000	13,500	13,500	13,500
Mining	Study area	8	94	95	99	110	121	132	143	154
Total	Study area	7,287	6,587	8,922	9,612	9,937	17,464	24,789	25,420	26,130

Table B-8

Parker County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	Trinity Basin	35,062	44,713	54,967	63,238	68,446	70,798	73,249	74,487	75,746
	Weatherford in Brazos Basin	604	785	1,051	1,369	1,579	1,679	1,760	1,811	1,863
	Total	35,666	45,498	56,018	64,607	70,025	72,477	75,009	76,298	77,609
Municipal	Basin per capita	139	106	159	153	146	142	142	142	143
	Weatherford per capita	183	110	184	175	165	161	161	161	161
	Basin use	5,458	5,290	9,809	10,834	11,173	11,262	11,666	11,877	12,092
	Weatherford use in Brazos Basin	124	97	217	268	292	302	317	326	336
	Study area	5,582	5,387	10,026	11,102	11,465	11,564	11,983	12,203	12,428
Manufacturing	Study area	118	228	275	382	497	631	790	989	1,250
Steam Electric	Study area	154	159	200	200	200	200	200	200	200
Mining	Study area	0	56	0	0	0	0	0	0	0
Total	Study area	5,854	5,830	10,501	11,684	12,162	12,395	12,973	13,392	13,878

Table B-9

Tarrant County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Population and Water Use								
		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	Study area	860,880	1,055,994	1,216,898	1,420,630	1,583,299	1,759,365	1,951,916	2,146,330	2,360,108
Municipal	Study area	186,103	208,204	263,479	291,001	305,253	327,497	361,095	391,858	430,861
	Per capita	193	176	193	183	172	166	165	163	163
Manufacturing	Study area	50,311	34,701	42,437	57,263	71,199	86,634	104,461	125,660	151,161
Steam Electric	Study area	4,177	5,412	5,400	5,100	5,100	5,100	5,100	5,100	5,100
Mining	Study area	0	96	0	0	0	0	0	0	0
Total	Study area	240,591	248,413	311,316	353,364	381,552	419,231	470,656	522,618	587,122

Table B-10

Wise County Projected Population and Water Use in the Study Area through 2050

Adjusted TWDB Projections
High Population Series - High per Capita Use with Additional Conservation

- use in acre-feet per year, per capita use in gpcd -

		Historical		Projected						
		1980	1985	1990	2000	2010	2020	2030	2040	2050
Population	County	26,575	31,978	36,801	49,165	57,714	63,721	70,269	73,803	77,515
	Bridgeport	3,737	4,065	4,268	4,829	5,747	6,370	7,059	7,414	7,787
	Decatur	4,104	4,925	5,998	7,533	8,968	9,940	11,016	11,570	12,152
	Briar (P)	642	739	839	922	1,004	1,086	1,175	1,233	1,294
	Study area cities	8,483	9,729	11,105	13,284	15,719	17,396	19,250	20,217	21,233
	Other county	18,092	22,249	25,696	35,881	41,995	46,325	51,019	53,586	56,282
	% in study area	94.7	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
	Other study area	17,136	21,058	24,308	33,943	39,727	43,823	48,264	50,692	53,243
	Study area	25,619	30,787	35,413	47,227	55,446	61,219	67,514	70,909	74,476
Municipal	City per capita	177	137	169	160	152	147	148	148	148
	Other per capita	105	110	140	133	125	122	122	122	122
	Bridgeport	822	560	879	943	1,062	1,143	1,267	1,331	1,398
	Decatur	765	833	1,101	1,311	1,477	1,590	1,762	1,851	1,944
	Briar (P)	97	101	125	130	134	141	152	160	168
	Study area cities	1,684	1,494	2,105	2,384	2,673	2,874	3,181	3,342	3,510
	Other county	2,127	2,745	4,026	5,329	5,899	6,320	6,959	7,309	7,677
	Other study area	2,015	2,595	3,812	5,057	5,562	5,989	6,596	6,927	7,276
	Study area	3,699	4,089	5,917	7,441	8,235	8,863	9,777	10,269	10,786
Manufacturing	Study area	5,524	5,037	6,380	9,565	11,494	14,390	17,692	19,948	22,492
Steam Electric	Study area	0	0	0	0	0	0	0	0	0
Mining	Study area	3,693	638	3,893	4,510	5,173	5,837	6,500	7,167	7,902
Total	Study area	12,916	9,764	16,190	21,516	24,902	29,090	33,969	37,384	41,180

APPENDIX C

PROJECTIONS OF POTENTIAL FUTURE REQUIREMENTS FOR WATER FROM TARRANT COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NUMBER ONE

Table C-1

Denton County: Potential Need for Water from TCWCID#1

Ground water: Southlake, Trophy Club and Westlake have surface water supplies. The other present needs are being met with ground water.

1990 study area use	2,573 AF/Y
Southlake	4 AF/Y
Trophy Club	1,121 AF/Y
Westlake	101 AF/Y

Ground water	1,347 AF/Y

Assume that ground water will be replaced gradually as the area becomes fully developed. Assume 1,347 AF/Y in 1990, 674 AF/Y in 2000 and none thereafter.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Study area total	2,573	4,049	4,161	4,384	4,699	4,895	5,105
b. Ground water use	1,347	674					
c. Net TCWCID#1 potential demand (a-b)	1,226	3,375	4,161	4,384	4,699	4,895	5,105
d. Rounded to nearest 100 AF/Y	1,200	3,400	4,200	4,400	4,700	4,900	5,100

Table C-2

Ellis County: Potential Need for Water from TCWCID#1

The Ellis County regional planning study projects needs for added surface water supply through 2030. Use that projection in place of estimates based on TWDB projection through 2030.

Base estimated additional requirements for 2040 and 2050 on growth predicted by TWDB: 2030 to 2040 = 2,310 AF
2040 to 2050 = 2,521 AF

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Needed from TCWCID#1	4,211	5,107	9,386	17,405	25,346	27,656	30,177
b. Rounded to nearest 100 AF/Y	4,200	5,100	9,400	17,400	25,300	27,700	30,200

Table C-3

Freestone County: Potential Need for Water from TCWCID#1

The existing steam electric power plant already has an adequate water supply.

Wortham has an existing surface water supply.

Ground water: 1,755 AF of municipal use in county in 1980 (TWDB)
1,880 AF of municipal use in county in 1985 (TWDB)
Assume ground water use in 1990 based on balance of supply and demand.
Assume ground water use in 2000 and 2010 based on balance of supply and demand with TCWCID#1 providing water for Fairfield municipal use and half of the study area manufacturing use.
Assume ground water use at 1,000 AF/Y from 2020 on.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Study area total	16,121	16,475	16,642	17,055	17,550	17,875	18,243
b. Steam electric use	14,000	14,000	14,000	14,000	14,000	14,000	14,000
c. Wortham municipal use	229	236	245	266	281	301	322
d. Ground water use	1,892	934	980	1,000	1,000	1,000	1,000
e. Net TCWCID#1 demand (a-b-c-d)	0	1,305	1,417	1,789	2,269	2,574	2,921
f. Rounded to nearest 100 AF/Y	0	1,300	1,400	1,800	2,300	2,600	2,900

Table C-4

Henderson County: Potential Need for Water from TCWCID#1

Yield of Lake Athens: 6,500 AF/Y (LNVA master plan)

Ground water: 2,670 AF in 1980 and 4,159 AF in 1985 for Trinity Basin portion of county (TWDB)
Study area is approximately 20% of Trinity Basin part of county.
Assume 1,000 AF/Y of ground water will be available in study area through 2050.

Assume all manufacturing is in Athens.

Trinidad electric plant has own supply: 2,600 AF/Y in 1990 and 3,000 AF/Y thereafter.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Study area total	9,811	21,732	22,153	22,929	24,058	24,759	25,521
b. Athens supply from Lake Athens	2,347	2,371	2,503	2,715	3,030	3,235	3,454
c. Manufacturing supply from Lake Athens	110	151	192	240	298	361	437
d. Ground water in study area	1,000	1,000	1,000	1,000	1,000	1,000	1,000
e. Trinidad SES supply	2,600	3,000	3,000	3,000	3,000	3,000	3,000
f. Net TCWCID#1 potential demand (a-b-c-d-e)	3,754	15,210	15,458	15,974	16,730	17,163	17,630
g. Rounded to nearest 100 AF/Y	3,800	15,200	15,500	16,000	16,700	17,200	17,600

Table C-5

Johnson County: Potential Need for Water from TCWCID#1

The Johnson County estimates are for parts of Mansfield and Burleson.
Burleson and Mansfield use TCWCID#1 water entirely.
There are no adjustments for use from other sources.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Based on TWDB estimates	3,053	3,608	3,795	4,081	4,518	5,036	5,613
b. Rounded to nearest 100 AF/Y	3,100	3,600	3,800	4,100	4,500	5,000	5,600

Table C-6

Kaufman County: Potential Need for Water from TCWCID#1

The Kaufman County estimates are for the Cities of Kemp and Mabank.
There are no adjustments for use from other sources.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Based on TWDB estimates	877	1,086	1,312	1,554	1,865	2,021	2,190
b. Rounded to nearest 100 AF/Y	900	1,100	1,300	1,600	1,900	2,000	2,200

Table C-7

Navarro County: Potential Need for Water from TCWCID#1

Yield of Navarro Mills Reservoir: 14.7 MGD = 16,460 AF/Y (1974 NCTCOG study)

TRA has contracted 92% of yield of Navarro Mills (15,147 AF/Y) to Dawson & Corsicana (1974 NCTCOG).

Ground water: 327 AF in 1980 and 384 AF in 1985 for county (TWDB).
Study area covers approximately 55% of the county.
Assume 400 AF/Y available in 1990 and 200 AF/Y available thereafter in study area.

Assume manufacturing is all in Corsicana.

Assume that the predicted future generating plant will develop its own water supply.

The TWDB estimates for Corsicana do not allow for effect of Richland-Chambers Lake.
Allow for additional use due to Corsicana growth.
Based on Corsicana response to questionaire, add 4,000 people each decade at the predicted gpcd:
2000: 4,000 x 200 x 366 / 325,851 = 900....2010: 8,000 x 190 x 365 / 325,851 = 1,700 ..... etc.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Study area total	8,922	9,612	9,937	17,464	24,789	25,420	26,130
b. Corsicana supply from Navarro Mills	5,663	5,786	5,728	5,729	5,899	5,990	6,082
c. Manufacturing supply from Navarro Mills	1,250	1,720	2,116	2,624	3,201	3,699	4,274
d. Ground water in study area	400	200	200	200	200	200	200
e. SES supply from other source(s)				7,000	13,500	13,500	13,500
f. Allowance for additional growth due to R/C		900	1,700	2,400	3,100	3,900	4,700
g. Net TCWCID#1 potential demand (a-b-c-d-e=f)	1,609	2,806	3,593	4,311	5,089	5,931	6,774
h. Rounded to nearest 100 AF/Y	1,600	2,800	3,600	4,300	5,100	5,900	6,800

Table C-8

Parker County: Potential Need for Water from TCWCID#1

Yield of Lake Weatherford: 1.5 MGD = 1,680 AF/Y (1974 NCTCOG study)

Ground water: 2,565 AF in study area in 1980 and 2,952 AF in 1985 (TWDB).

Assume 3,000 AF in 1990, 2,500 AF in 2000, and 2,000 AF/Y for rest of study period.

Assume all manufacturing is supplied through Weatherford. For 1990, this use is attributable to Lake Weatherford. From 2000 on, limit Lake Weatherford used to the estimated yield.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Study area total	10,501	11,684	12,162	12,395	12,973	13,392	13,878
b. Lake Weatherford use for steam electric	200	200	200	200	200	200	200
c. Lake Weatherford use for Weatherford	4,325	1,480	1,480	1,480	1,480	1,480	1,480
d. Lake Weatherford use for manufacturing	275						
e. Ground water in study area	3,000	2,500	2,000	2,000	2,000	2,000	2,000
f. Net TCWCID#1 potential demand (a-b-c-d-e)	2,701	7,504	8,482	8,715	9,293	9,712	10,198
g. Rounded to nearest 100 AF/Y	2,700	7,500	8,500	8,700	9,300	9,700	10,200

Table C-9

Tarrant County: Potential Need for Water from TCWCID#1

In 1980, the District provided 180,078 AF in Tarrant County.
TWDB records show that the total 1980 use in Tarrant County, exclusive of irrigation and livestock use, was 240,591 AF.
240,591 - 180,078 = 60,513 AF (a) from sources other than the District or (b) gained from return flows.

In 1985, the District provided 200,097 AF in Tarrant County.
TWDB records show that the total 1985 use in Tarrant County, exclusive of irrigation and livestock use, was 248,413 AF.
248,413 - 200,097 = 48,316 AF (a) from sources other than the District or (b) gained from return flows.

Fort Worth, Arlington, the TRA and Mansfield have all prepared their own water use projections through at least 2010. These compare with the TWDB-based estimates as follows:

	1990	2000	2010
a. Fort Worth (including customers)	159,824	194,992	239,232
b. Arlington	63,954	80,551	97,247
c. Trinity River Authority	24,867	36,517	41,781
d. Mansfield	2,388	4,053	6,464
e. Allowance for other needs from TCWCID#1 in Tarrant County	9,000	10,000	11,000
f. Total based on users' projections	260,033	326,113	395,724

Agreement is good in 1990 and 2000. Add 20,000 AF in 2010 and 10,000 AF in 2020, based on the users' projections.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Projected total use	311,316	353,364	381,552	419,231	470,656	522,618	587,122
b. Non-TCWCID#1 supply and usable return flow	50,000	30,000	20,000	20,000	20,000	20,000	20,000
c. Adjustment based on users' own projections			20,000	10,000			
d. Net TCWCID#1 potential demand (a-b+c)	261,316	323,364	381,552	409,231	450,656	502,618	567,122
e. Rounded to nearest 100 AF/Y	261,300	323,400	381,600	409,200	450,700	502,600	567,100

Table C-10

Wise County: Potential Need for Water from TCWCID#1

In 1980, the District provided 4,393 AF in Wise County.

Based on TWDB records, 1980 use in the study area, exclusive of irrigation and livestock use, was 12,914 AF.

12,914 - 4,393 = 8,521 AF from sources other than the District.

In 1985, the District provided 2,976 AF in Wise County.

Based on TWDB records, 1985 use in the study area, exclusive of irrigation and livestock use, was 9,764 AF.

9,764 - 2,976 = 6,788 AF from sources other than the District.

Ground water: County: 1,802 AF in 1980 and 2,390 AF in 1985.
Study area: 1,705 AF in 1980 and 2,260 AF in 1985.

Allow for a total of 10,500 AF/Y from sources other than TCWCID#1.

Growth of manufacturing use is relatively high in the TWDB estimates for future decades in Wise County.
Percentage growth in manufacturing use from 1980 to 1990: 5,524 AF to 6,427 AF, or 15.5%.
Assume manufacturing increase is 15.5% per decade from 1990 to 2050.

Projection: (AF/Y)	1990	2000	2010	2020	2030	2040	2050
a. Study area total	16,190	21,516	24,902	29,090	33,969	37,384	41,180
b. Sources other than TCWCID#1	10,500	10,500	10,500	10,500	10,500	10,500	10,500
c. Manufacturing per TWDB	6,380	9,565	11,494	14,390	17,692	19,948	22,492
d. Manufacturing at 15.5% per decade	6,380	7,369	8,511	9,830	11,354	13,114	15,147
e. Net TCWCID#1 demand (a-b-c+d)	5,690	8,460	11,419	14,050	17,131	20,050	23,335
f. Rounded to nearest 100 AF/Y	5,700	8,500	11,400	14,100	17,100	20,100	23,300

APPENDIX D

AREA AND CAPACITY DATA

APPENDIX D

AREA AND CAPACITY DATA

Existing Tarrant County Water Control and Improvement District Number One Reservoirs

Existing reservoirs operated as part of the Tarrant County Water Control and Improvement District Number One System include Lake Bridgeport, Eagle Mountain Lake, Lake Benbrook, Lake Arlington, Cedar Creek Reservoir, and Richland-Chambers Reservoir. Area and capacity data for these reservoirs have been developed in previous studies (1,2,14,44,56,57).

Tehuacana Reservoir

The area and capacity data for Tehuacana Reservoir are available from a previous Freese and Nichols report (44). Table D-1 gives area and capacity data for Tehuacana Reservoir.

Tennessee Colony Reservoir

The area and capacity data for Tennessee Colony Reservoir are based on a Corps of Engineers project memorandum (43) with adjustments made to account for the construction of Richland-Chambers Reservoir. It is assumed, however, that Tehuacana Reservoir, also upstream of Tennessee Colony, would not be in place. Therefore, no adjustments are made for Tehuacana Reservoir. The area and capacity data for Tennessee Colony are given in Table D-2.

Table D-1

Tehuacana Reservoir
Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
250	20	73	126	180	233	286	339	392	446	499	Acres
	10	57	156	309	516	775	1,088	1,453	1,872	2,345	Acre-Feet
260	552	675	798	922	1,045	1,168	1,291	1,414	1,538	1,661	Acres
	2,870	3,484	4,220	5,080	6,064	7,170	8,400	9,752	11,228	12,828	Acre-Feet
270	1,784	1,944	2,105	2,265	2,425	2,586	2,746	2,906	3,066	3,227	Acres
	14,550	16,414	18,439	20,624	22,969	25,474	28,140	30,966	33,952	37,099	Acre-Feet
280	3,387	3,650	3,912	4,175	4,438	4,701	4,963	5,226	5,489	5,751	Acres
	40,406	43,924	47,705	51,749	56,055	60,625	65,457	70,551	75,909	81,529	Acre-Feet
290	6,014	6,321	6,629	6,936	7,243	7,551	7,858	8,165	8,472	8,780	Acres
	87,411	93,579	100,054	106,836	113,926	121,323	129,027	137,039	145,357	153,983	Acre-Feet
300	9,087	9,408	9,730	10,051	10,372	10,694	11,015	11,336	11,657	11,979	Acres
	162,917	172,164	181,733	191,624	201,835	212,368	223,223	234,398	245,895	257,713	Acre-Feet
310	12,300	12,828	13,355	13,883	14,410	14,938	15,465	15,993	16,520	17,048	Acres
	269,852	282,416	295,508	309,127	323,273	337,947	353,149	368,878	385,134	401,918	Acre-Feet
320	17,575	18,256	18,938	19,619	20,301	20,982	21,663	22,345	23,026	23,708	Acres
	419,230	437,145	455,742	475,021	494,981	515,622	536,945	558,949	581,634	605,001	Acre-Feet
330	24,389										Acres
	629,050										Acre-Feet

Table D-2

Tennessee Colony Reservoir with Richland-Chambers Reservoir
1990 Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
190	0	0	0	0	0	0	1	2	3	4	Acres
	0	0	0	0	0	1	2	3	6	9	Acre-Feet
200	5	7	8	10	10	10	10	10	20	20	Acres
	10	20	30	40	50	60	70	90	100	120	Acre-Feet
210	20	20	20	20	20	20	20	20	20	20	Acres
	130	150	170	180	200	220	240	250	270	290	Acre-Feet
220	20	40	130	300	470	980	1,240	1,890	2,520	3,260	Acres
	310	340	420	630	1,010	1,720	2,830	4,380	6,580	9,460	Acre-Feet
230	4,170	5,090	6,190	7,340	8,450	9,520	10,800	11,900	13,200	14,500	Acres
	13,200	17,800	23,400	30,200	38,100	47,000	57,200	68,600	81,200	95,100	Acre-Feet
240	15,100	16,900	18,700	20,400	22,100	24,000	25,900	27,700	29,900	31,600	Acres
	109,900	125,800	143,600	163,200	184,400	207,500	232,400	259,200	287,900	318,700	Acre-Feet
250	33,820	35,973	38,226	40,680	42,833	45,386	47,839	50,192	51,546	55,099	Acres
	351,310	386,257	423,356	462,809	504,516	548,575	595,188	644,153	695,072	748,345	Acre-Feet
260	57,252	60,075	62,398	65,022	67,045	69,268	70,991	73,114	74,938	76,661	Acres
	804,570	863,184	924,420	988,180	1,054,064	1,122,170	1,192,400	1,264,752	1,338,228	1,414,828	Acre-Feet
270	78,484	80,444	82,305	84,265	85,425	87,086	88,446	90,106	91,566	94,227	Acres
	1,491,550	1,571,414	1,652,439	1,735,624	1,820,969	1,907,474	1,995,140	2,083,966	2,174,952	2,268,099	Acre-Feet

Table D-2, Continued

	0	1	2	3	4	5	6	7	8	9	
280	94,987	97,150	100,212	101,475	103,938	105,501	108,863	112,326	113,789	116,151	Acres
	2,362,406	2,458,924	2,557,705	2,657,749	2,761,055	2,865,625	2,972,457	3,083,551	3,195,909	3,311,529	Acre-Feet
290	118,414	120,721	123,829	125,236	127,143	129,051	130,858	132,965	134,472	136,580	Acres
	3,428,411	3,548,579	3,670,054	3,794,836	3,920,926	4,049,323	4,179,027	4,311,039	4,444,357	4,579,983	Acre-Feet
300	138,787	139,808	141,830	143,351	144,872	146,694	148,115	149,536	150,957	152,379	Acres
	4,717,917	4,857,164	4,997,733	5,140,624	5,284,835	5,430,368	5,578,223	5,726,398	5,876,895	6,028,713	Acre-Feet
310	153,800	155,328	156,855	158,383	159,910	161,438	162,965	164,293	165,620	166,848	Acres
	6,181,852	6,336,416	6,492,508	6,650,127	6,809,273	6,969,947	7,132,149	7,295,878	7,461,134	7,626,918	Acre-Feet
320	168,075	169,256	170,438	171,519	172,701	173,782	174,863	175,845	176,826	177,808	Acres
	7,794,230	7,963,145	8,132,742	8,303,021	8,474,981	8,648,622	8,822,945	8,997,949	9,174,634	9,352,001	Acre-Feet
330	178,789										Acres
	9,530,050										Acre-Feet

George Parkhouse Reservoir Stage I

The area data for George Parkhouse Reservoir Stage I are based on digitizer measurements on U.S. Geological Survey quadrangles. The capacity is computed using the average area method from the measured area data. Table D-3 gives the area and capacity data for George Parkhouse Reservoir Stage I.

George Parkhouse Reservoir Stage II

The area data for George Parkhouse Reservoir Stage II are also based on digitizer measurements on U.S. Geological Survey quadrangles. Table D-4 gives the area and capacity data for George Parkhouse Reservoir Stage II. Table D-5 gives the area and capacity data for George Parkhouse Reservoir, Stages I and II combined.

Marvin Nichols Reservoir Stage I

The area and capacity data for Marvin Nichols Reservoir Stage I are computed like those for George Parkhouse Reservoir. Table D-6 gives the area and capacity data for Marvin Nichols Reservoir Stage I.

Marvin Nichols II Reservoir Stage II

The area and capacity data for Marvin Nichols Reservoir Stage II are based on digitizer measurements of the area on U.S. Geological Survey quadrangles. The area and capacity data for Marvin Nichols Reservoir Stage II are given in Table D-7. Table D-8 gives the area and capacity data for the combined Marvin Nichols Reservoirs.

Table D-3

George Parkhouse Reservoir Stage I
Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
330	0	0	0	0	0	0	5	10	16	23	Acres
	0	0	0	0	0	0	3	10	23	43	Acre-Feet
340	31	81	131	191	251	311	401	500	600	700	Acres
	70	126	232	393	614	895	1,251	1,701	2,251	2,901	Acre-Feet
350	810	1110	1510	1960	2410	2860	3310	3760	4210	4710	Acres
	3,656	4,616	5,926	7,661	9,846	12,481	15,566	19,101	23,086	27,546	Acre-Feet
360	5250	5550	5950	6350	6750	7150	7550	7990	8440	8890	Acres
	32,526	37,926	43,676	49,826	56,376	63,326	70,676	78,446	86,661	95,326	Acre-Feet
370	9,340	9,790	10,290	10,790	11,290	11,790	12,290	12,790	13,290	13,885	Acres
	104,441	114,006	124,046	134,586	145,626	157,166	169,206	181,746	194,786	208,374	Acre-Feet
380	14,485	15,135	15,785	16,435	17,135	17,885	18,635	19,385	20,135	20,885	Acres
	222,559	237,369	252,829	268,939	285,724	303,234	321,494	340,504	360,264	380,774	Acre-Feet
390	21,660	22,410	23,160	23,910	24,660	25,410	26,160	26,910	27,660	28,440	Acres
	402,046	424,081	446,866	470,401	494,686	519,721	545,506	572,041	599,326	627,376	Acre-Feet
400	29,240	29,740	30,240	30,740	31,240	31,740	32,240	32,740	33,240	33,840	Acres
	656,216	685,706	715,696	746,186	777,176	808,666	840,656	873,146	906,136	939,676	Acre-Feet
410	34,450										Acres
	973,821										Acre-Feet

Table D-4

George Parkhouse Reservoir Stage II
Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
340	0	1	4	9	15	22	30	42	57	78	Acres
	0	1	3	10	22	40	66	102	152	219	Acre-Feet
350	110	160	210	260	310	360	410	460	510	590	Acres
	313	448	633	868	1,153	1,488	1,873	2,308	2,793	3,343	Acre-Feet
360	670	870	1,070	1,270	1,520	1,770	2,020	2,270	2,520	2,820	Acres
	3,973	4,743	5,713	6,883	8,278	9,923	11,818	13,963	16,358	19,028	Acre-Feet
370	3,120	3,220	3,420	3,620	3,870	4,120	4,370	4,620	4,870	5,120	Acres
	21,998	25,168	28,488	32,008	35,753	39,748	43,993	48,488	53,233	58,228	Acre-Feet
380	5,370	5,620	5,870	6,170	6,470	6,770	7,070	7,370	7,670	8,020	Acres
	63,473	68,968	74,713	80,733	87,053	93,673	100,593	107,813	115,333	123,178	Acre-Feet
390	8,400	8,600	8,950	9,300	9,650	10,000	10,350	10,700	11,050	11,450	Acres
	131,388	139,888	148,663	157,788	167,263	177,088	187,263	197,788	208,663	219,913	Acre-Feet
400	11,850	12,250	12,650	13,050	13,350	13,675	14,000	14,325	14,650	14,975	Acres
	231,563	243,613	256,063	268,913	282,113	295,626	309,463	323,626	338,113	352,926	Acre-Feet
410	15,300										Acres
	368,063										Acre-Feet

Table D-5

George Parkhouse Reservoirs Combined
Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
330	0	0	0	0	0	0	5	10	16	23	Acres
	0	0	0	0	0	0	3	10	23	43	Acre-Feet
340	31	82	135	200	266	333	431	542	657	778	Acres
	70	126	235	402	635	935	1,317	1,803	2,403	3,120	Acre-Feet
350	920	1,270	1,720	2,220	2,720	3,220	3,720	4,220	4,720	5,300	Acres
	3,969	5,064	6,559	8,529	10,999	13,969	17,439	21,409	25,879	30,889	Acre-Feet
360	5,920	6,420	7,020	7,620	8,270	8,920	9,570	10,260	10,960	11,710	Acres
	36,499	42,669	49,389	56,709	64,654	73,249	82,494	92,409	103,019	114,354	Acre-Feet
370	12,460	13,010	13,710	14,410	15,160	15,910	16,660	17,410	18,160	19,005	Acres
	126,439	139,174	152,534	166,594	181,379	196,554	212,479	229,514	247,299	265,882	Acre-Feet
380	19,855	20,755	21,655	22,605	23,605	24,655	25,705	26,755	27,805	28,905	Acres
	285,312	305,617	326,822	348,952	372,057	396,187	421,367	447,597	474,877	503,232	Acre-Feet
390	30,060	31,010	32,110	33,210	34,310	35,410	36,510	37,610	38,710	39,890	Acres
	532,714	563,249	594,809	627,469	661,229	696,089	732,049	769,109	807,269	846,569	Acre-Feet
400	41,090	41,990	42,890	43,790	44,590	45,415	46,240	47,065	47,890	48,815	Acres
	887,059	928,599	971,039	1,014,379	1,058,569	1,103,572	1,149,399	1,196,052	1,243,529	1,291,882	Acre-Feet
410	49,750										Acres
	1,341,164										Acre-Feet

Table D-6

Marvin Nichols Reservoir Stage I
Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
240	0	0	0	0	0	0	0	20	40	70	Acres
	0	0	0	0	0	0	0	10	40	95	Acre-Feet
250	108	148	188	233	278	323	368	413	463	528	Acres
	184	312	480	691	946	1,247	1,592	1,983	2,421	2,916	Acre-Feet
260	613	963	1,463	2,063	2,813	3,563	4,313	5,063	5,834	6,634	Acres
	3,487	4,275	5,488	7,251	9,689	12,877	16,815	21,503	26,951	33,185	Acre-Feet
270	7,484	8,488	9,538	10,593	11,653	12,723	13,793	14,838	15,943	17,023	Acres
	40,244	48,230	57,243	67,309	78,432	90,620	103,878	118,208	133,614	150,097	Acre-Feet
280	18,103	19,183	20,263	21,343	22,428	23,513	24,598	25,683	26,768	27,858	Acres
	167,660	186,303	206,026	226,829	248,714	271,685	295,740	320,881	347,106	374,419	Acre-Feet
290	28,954	30,069	31,209	32,369	33,544	34,759	36,009	37,329	38,699	40,119	Acres
	402,825	432,337	462,976	494,765	527,721	561,873	597,257	633,926	671,940	711,349	Acre-Feet
300	41,594	43,129	44,704	46,329	47,979	49,654	51,354	53,064	54,500	56,500	Acres
	752,205	794,567	838,483	884,000	931,154	979,970	1,030,474	1,082,683	1,136,465	1,191,965	Acre-Feet
310	58,294	60,144	62,128	64,187	66,296	68,455	70,616	72,825	75,084	77,378	Acres
	1,249,362	1,308,581	1,369,717	1,432,875	1,498,116	1,565,492	1,635,027	1,706,748	1,780,702	1,856,933	Acre-Feet
320	79,718										Acres
	1,935,481										Acre-Feet

Table D-7

Marvin Nichols Reservoir Stage II
Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
250	0	0	0	40	90	150	220	300	390	490	Acres
	0	0	0	20	85	205	390	650	995	1,435	Acre-Feet
260	600	900	1,300	1,750	2,200	2,650	3,125	3,600	4,075	4,550	Acres
	1,980	2,730	3,830	5,355	7,330	9,755	12,643	16,005	19,843	24,155	Acre-Feet
270	5,031	5,516	6,001	6,491	6,981	7,471	7,966	8,461	8,956	9,456	Acres
	28,946	34,219	39,978	46,224	52,960	60,186	67,904	76,118	84,826	94,032	Acre-Feet
280	9,959	10,464	10,969	11,479	11,995	12,535	13,085	13,635	14,235	14,835	Acres
	103,740	113,951	124,668	135,892	147,629	159,894	172,704	186,064	199,999	214,534	Acre-Feet
290	15,460	16,095	16,740	17,400	18,075	18,775	19,500	20,250	21,050	21,900	Acres
	229,681	245,459	261,876	278,946	296,684	315,109	334,246	354,121	374,771	396,246	Acre-Feet
300	22,810	23,875	24,810	25,910	27,035	28,235	29,485	30,685	31,835	32,935	Acres
	418,601	441,944	466,286	491,646	518,119	545,754	574,614	604,699	635,959	668,344	Acre-Feet
310	33,935	34,925	35,919	36,913	37,907	38,901	39,896	40,891	41,886	42,881	Acres
	701,779	736,209	771,631	808,047	845,457	883,861	923,259	963,653	1,005,041	1,047,425	Acre-Feet
320	43,876										Acres
	1,090,803										Acre-Feet

Table D-8

Marvin Nichols Reservoirs Combined
Area and Capacity

	0	1	2	3	4	5	6	7	8	9	
240	0	0	0	0	0	0	0	20	40	70	Acres
	0	0	0	0	0	0	0	10	40	95	Acre-Feet
250	108	148	188	273	368	473	588	713	853	1,018	Acres
	184	312	480	711	1,031	1,452	1,982	2,633	3,416	4,351	Acre-Feet
260	1,213	1,863	2,763	3,813	5,013	6,213	7,438	8,663	9,909	11,184	Acres
	5,467	7,005	9,318	12,606	17,019	22,632	29,458	37,508	46,794	57,340	Acre-Feet
270	12,515	14,004	15,539	17,084	18,634	20,194	21,759	23,299	24,899	26,479	Acres
	69,190	82,449	97,221	113,533	131,392	150,806	171,782	194,326	218,440	244,129	Acre-Feet
280	28,062	29,647	31,232	32,822	34,423	36,048	37,683	39,318	41,003	42,693	Acres
	271,400	300,254	330,694	362,721	396,343	431,579	468,444	506,945	547,105	588,953	Acre-Feet
290	44,414	46,164	47,949	49,769	51,619	53,534	55,509	57,579	59,749	62,019	Acres
	632,506	677,796	724,852	773,711	824,405	876,982	931,503	988,047	1,046,711	1,107,595	Acre-Feet
300	64,404	67,004	69,514	72,239	75,014	77,889	80,839	83,749	86,335	89,435	Acres
	1,170,806	1,236,511	1,304,769	1,375,646	1,449,273	1,525,724	1,605,088	1,687,382	1,772,424	1,860,309	Acre-Feet
310	92,229	95,069	98,047	101,100	104,203	107,356	110,512	113,716	116,970	120,259	Acres
	1,951,141	2,044,790	2,141,348	2,240,922	2,343,573	2,449,353	2,558,286	2,670,401	2,785,743	2,904,358	Acre-Feet
320	123,594										Acres
	3,026,284										Acre-Feet

APPENDIX E

RUNOFF DATA

APPENDIX E

RUNOFF DATA

Existing Tarrant County Water Control and Improvement District Number One Reservoirs

Existing reservoirs operated as part of the Tarrant County Water Control and Improvement District Number One system include Lake Bridgeport, Eagle Mountain Lake, Lake Benbrook, Lake Arlington, Cedar Creek Reservoir, and Richland-Chambers Reservoir. Runoff data for these lakes have been developed in previous studies (1,2,14,44,56,57). For this study, the runoff data for Bridgeport, Eagle Mountain, Cedar Creek, and Richland-Chambers have been extended through 1986 using methodologies developed in previous studies. Tables E-1 through E-6 give the monthly runoff for Bridgeport, Eagle Mountain, Benbrook, Arlington, Cedar Creek and Richland-Chambers.

Tehuacana Reservoir

The Tehuacana Reservoir site is on Tehuacana Creek, which is a tributary of the Trinity River immediately south of Richland Creek. The reservoir would control a 340 square mile watershed and would be connected to Richland-Chambers Reservoir by a channel. The combined Richland-Chambers-Tehuacana Reservoir would be operated as a single impoundment. Runoff data for Tehuacana from 1940 through 1978 are available from a previous study (44), and the data are extended through 1986 as part of this study. Table E-7 gives the monthly runoff for Tehuacana Reservoir.

Table E-1

Lake Bridgeport Runoff Data

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	40	1,740	1,150	9,780	16,200	60,640	16,210	34,580	5,970	1,100	59,820	26,130	233,360
1941	2,240	36,610	0	62,950	82,680	208,930	6,480	1,270	5,940	117,600	20,880	1,320	546,900
1942	0	0	0	331,600	201,820	111,000	10,910	8,440	5,220	29,110	0	0	698,100
1943	0	0	16,710	15,610	0	11,720	0	0	0	0	0	0	44,040
1944	4,030	21,160	13,780	13,260	14,070	6,840	0	4,260	3,490	7,510	5,880	5,800	100,080
1945	4,550	11,960	93,100	41,530	0	0	36,610	0	7,200	28,140	0	0	223,090
1946	15,920	23,900	12,180	11,990	14,100	5,740	1,550	660	6,050	710	26,770	33,700	153,270
1947	2,050	0	240	17,520	26,130	0	0	0	0	0	0	4,240	50,180
1948	2,750	11,060	7,560	2,380	3,430	9,860	3,620	1,140	320	0	0	0	42,120
1949	0	0	0	210	58,210	31,630	0	1,640	7,270	30,270	390	0	129,620
1950	2,050	4,930	1,690	26,320	57,230	17,710	78,210	42,000	26,230	3,150	0	0	259,520
1951	0	0	0	0	0	42,070	6,110	0	0	0	0	0	48,180
1952	0	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	1,370	6,650	1,810	3,470	0	44,590	2,110	1,360	61,360
1954	1,180	1,160	0	4,020	28,480	4,940	1,870	480	190	14,050	33,180	36,310	125,860
1955	0	0	1,720	1,270	12,930	24,880	2,240	0	21,520	1,560	0	0	66,120
1956	0	0	0	0	8,160	7,780	0	0	0	4,010	2,380	11,050	33,380
1957	0	26,350	4,790	243,400	176,110	7,630	0	0	2,120	14,300	27,060	0	501,760
1958	0	0	0	0	11,460	47,710	0	0	0	0	0	0	59,170
1959	0	0	0	0	0	4,550	7,040	1,100	810	88,070	0	2,080	103,650
1960	16,400	8,630	4,680	1,420	0	4,990	3,540	0	2,040	18,400	0	420	60,520

Table E-1, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	22,510	4,310	11,930	180	0	4,080	6,960	1,800	1,990	2,840	4,540	3,120	64,260
1962	0	0	0	10,320	840	36,170	19,920	0	22,650	0	11,580	8,100	109,580
1963	480	650	1,200	20,860	0	0	0	0	0	0	0	620	23,810
1964	3,930	3,410	450	10,400	23,070	14,650	3,180	4,970	9,710	140	29,330	0	103,240
1965	1,870	2,560	600	1,850	44,270	2,220	0	1,260	15,000	1,890	470	0	71,990
1966	0	3,770	4,790	53,780	32,140	0	0	0	13,580	0	0	0	108,060
1967	0	0	0	0	8,170	15,460	0	0	9,690	0	0	0	33,320
1968	22,000	2,200	52,440	0	0	0	0	0	0	0	0	0	76,640
1969	0	0	39,470	950	33,710	0	0	0	0	0	0	16,850	90,980
1970	5,460	6,460	11,440	10,320	450	0	0	0	4,560	0	0	0	38,690
1971	0	0	750	2,290	4,550	3,250	9,010	8,530	9,040	9,970	1,040	15,440	63,870
1972	650	810	1,820	7,330	71,700	6,180	8,120	9,090	4,080	11,090	7,550	3,940	132,360
1973	10,830	1,980	3,920	11,390	7,920	5,660	10,040	9,080	4,000	22,040	4,970	0	91,830
1974	1,320	1,570	1,730	9,830	6,150	5,920	2,800	10,390	17,930	20,380	36,120	940	115,080
1975	3,010	27,940	10,470	12,840	56,080	84,220	31,920	9,480	0	3,000	2,840	6,340	248,140
1976	6,730	8,120	8,490	25,150	13,110	9,750	6,080	70	24,130	11,840	8,940	1,960	124,370
1977	5,560	7,070	57,670	18,760	32,170	4,220	220	2,660	1,380	0	0	0	129,710
1978	0	0	1,310	5,530	10,000	11,800	0	400	350	340	3,000	200	32,930
1979	1,910	1,040	19,250	13,420	27,880	11,190	1,330	0	0	0	300	1,780	78,100
1980	5,130	4,780	2,260	4,700	14,280	4,110	2,290	1,700	8,850	19,200	800	6,230	74,330
1981	740	10	15,440	11,120	22,610	24,060	510	990	2,760	318,920	18,060	80	415,300
1982	490	2,260	5,670	8,190	247,670	61,330	19,610	2,230	3,260	9,940	9,300	7,430	377,380
1983	6,130	2,980	15,690	3,470	13,520	21,090	7,820	14,330	6,190	0	490	0	91,710
1984	0	1,950	3,010	2,390	1,660	3,130	0	4,130	170	16,390	8,480	23,290	64,600
1985	35,390	7,030	35,060	29,730	12,670	20,030	4,420	0	3,200	46,130	0	0	193,660
1986	0	2,790	1,380	4,370	49,830	58,580	2,300	0	5,300	13,080	4,560	5,280	147,470
1940-86 Avg.	3,944	5,132	9,569	22,605	30,784	21,753	6,654	3,833	5,579	19,357	7,039	4,766	141,315

Table E-2

Eagle Mountain Lake
Runoff Originating Downstream from Lake Bridgeport

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0	450	1,460	3,510	11,830	31,000	36,550	16,770	1,680	1,150	36,440	41,070	181,910
1941	2,950	31,620	18,530	43,810	32,200	156,530	16,940	9,220	14,110	69,040	13,110	17,000	425,060
1942	36,150	3,150	10,620	255,210	0	0	0	0	0	0	0	0	305,130
1943	0	0	0	0	26,250	30,810	1,910	0	0	0	0	0	58,970
1944	1,270	17,250	8,450	19,450	40,460	0	3,890	7,540	6,710	3,640	7,370	8,820	124,850
1945	4,730	55,750	86,360	57,460	22,190	5,720	51,120	3,830	5,450	21,940	14,490	5,140	334,180
1946	29,140	26,420	16,100	9,240	21,330	18,350	3,080	14,720	2,830	5,530	19,840	30,250	196,830
1947	4,530	10,830	6,790	23,410	14,190	5,310	3,040	22,080	8,620	6,710	4,390	16,270	126,170
1948	14,510	34,280	8,440	2,530	2,940	0	4,500	5,560	4,170	0	4,410	6,720	88,060
1949	2,970	2,570	10,660	2,490	51,860	23,300	1,730	5,170	7,440	22,080	1,080	1,130	132,480
1950	4,890	15,150	3,210	21,720	72,670	14,980	60,280	17,830	24,950	0	21,770	10,880	268,330
1951	6,870	4,170	6,650	620	5,990	17,670	13,400	26,220	4,080	0	0	0	85,670
1952	0	0	0	0	0	0	2,890	8,130	6,670	3,250	7,060	1,970	29,970
1953	1,570	770	1,610	5,300	12,720	2,220	4,390	7,020	7,130	12,950	2,340	0	58,020
1954	1,980	1,290	1,010	3,000	2,780	0	5,850	6,930	3,050	0	0	0	25,890
1955	0	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	2,900	4,750	7,650
1957	0	7,150	1,390	98,810	168,170	112,420	9,310	750	1,060	1,360	33,270	14,770	448,460
1958	10,470	4,490	26,210	26,800	122,340	10,180	12,160	6,270	3,170	0	910	4,220	227,220
1959	1,230	1,770	1,850	6,500	5,270	21,560	11,420	120	1,260	114,200	1,830	6,870	173,880
1960	29,540	7,740	4,620	6,450	7,450	5,100	6,450	6,690	620	3,530	3,210	5,180	86,580

Table E-2, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	15,270	6,940	13,710	9,120	4,700	19,250	3,800	2,460	1,950	0	4,770	2,820	84,790
1962	4,370	4,490	5,010	14,930	4,590	22,840	33,380	22,530	114,630	16,920	10,490	23,960	278,140
1963	1,130	1,440	6,840	20,820	21,730	4,620	0	0	2,170	0	320	0	59,070
1964	3,210	2,930	7,160	12,020	7,740	14,040	30	4,340	15,330	90	44,080	2,220	113,190
1965	13,880	16,040	7,040	3,700	30,300	7,170	3,710	0	13,300	3,000	4,500	4,060	106,700
1966	4,000	13,820	7,530	31,670	106,320	29,130	10,290	8,900	15,290	13,110	7,640	3,330	251,030
1967	3,660	3,640	4,140	5,930	4,160	35,600	13,270	5,900	5,810	3,240	1,360	2,680	89,390
1968	12,690	6,160	60,820	72,880	43,200	20,900	12,540	10,010	8,550	3,060	5,870	4,290	260,970
1969	2,740	8,170	47,120	24,850	96,840	26,390	7,880	0	5,850	10,960	4,010	13,920	248,730
1970	15,000	15,490	61,490	42,330	47,500	18,570	6,870	100	25,920	3,270	2,120	5,140	243,800
1971	5,690	5,330	3,720	5,340	5,590	5,700	8,920	6,170	3,250	15,910	5,170	16,840	87,630
1972	4,580	4,490	4,540	8,520	19,500	0	0	0	0	0	6,580	10	48,220
1973	6,410	7,220	6,940	23,450	23,820	17,660	10,270	21,160	9,490	24,400	7,110	4,250	162,180
1974	5,780	6,040	6,640	11,440	5,580	3,950	5,200	5,140	18,830	40,210	81,060	8,280	198,150
1975	7,010	32,630	20,310	29,100	30,050	43,720	18,330	13,040	3,790	0	0	0	197,980
1976	80	0	0	7,110	18,320	15,930	7,530	0	5,940	7,440	7,220	6,070	75,640
1977	6,420	11,860	62,190	33,530	1,910	4,150	2,870	2,940	5,850	2,450	3,590	1,600	139,360
1978	0	0	0	6,420	5,570	2,000	0	0	0	0	0	0	13,990
1979	6,840	3,710	22,150	28,360	47,150	12,760	3,000	2,000	1,000	0	0	0	126,970
1980	0	3,180	80	0	0	1,040	5,490	5,440	8,490	8,220	2,580	4,780	39,300
1981	2,850	2,310	13,210	6,700	29,180	21,000	1,520	2,200	5,830	265,960	145,880	7,000	503,640
1982	7,580	14,060	12,230	8,800	145,670	75,180	43,120	5,070	0	0	0	240	311,950
1983	0	4,330	9,510	5,440	5,020	11,360	440	0	810	4,450	3,860	4,180	49,400
1984	3,570	4,940	7,670	4,490	3,780	6,390	370	6,340	400	9,740	5,640	10,410	63,740
1985	13,480	7,980	21,820	14,250	26,680	16,790	620	4,910	8,000	22,410	4,950	4,630	146,520
1986	6,780	18,020	7,670	7,110	45,090	65,280	4,050	2,990	18,470	17,330	21,660	840	215,290
1940-86 Avg.	6,578	9,286	13,616	22,013	30,280	20,490	9,834	6,351	8,405	16,032	11,104	6,617	160,606

Table E-3

Lake Benbrook Runoff

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	9,440	45,970	15,500	14,110	21,060	34,840	3,350	4,180	300	2,850	960	1,590	154,150
1942	1,140	850	950	121,430	50,640	17,910	1,300	1,100	1,800	19,670	4,200	3,760	224,750
1943	2,350	1,470	7,920	6,820	17,660	6,650	220	0	1,970	20	0	210	45,290
1944	480	7,380	4,770	3,630	28,140	2,580	320	940	610	1,520	770	2,270	53,410
1945	5,090	58,080	74,880	59,120	11,210	3,630	3,730	360	240	1,500	920	840	219,600
1946	2,950	9,800	7,110	3,180	13,780	4,830	240	2,240	600	1,390	23,140	21,640	90,900
1947	9,570	4,490	9,990	10,170	4,240	7,860	450	50	490	880	560	6,170	54,920
1948	6,780	29,340	16,580	3,480	4,560	1,810	2,390	40	10	0	0	80	65,070
1949	600	4,770	15,170	6,350	121,820	19,740	2,150	730	830	9,220	1,140	1,150	183,670
1950	5,880	23,010	5,620	24,320	30,810	4,380	8,920	5,010	21,760	2,060	1,210	1,300	134,280
1951	1,230	1,580	1,340	1,040	2,360	12,880	1,770	20	30	60	220	250	22,780
1952	190	330	280	2,620	6,680	430	40	30	30	20	420	10	11,080
1953	0	0	210	1,310	4,460	0	0	0	0	720	0	0	6,700
1954	70	20	0	1,340	290	20	10	250	220	50	30	150	2,450
1955	0	0	0	0	2,890	3,290	420	140	1,610	460	70	10	8,890
1956	0	190	0	80	3,700	0	190	300	300	1,420	220	450	6,850
1957	100	330	60	47,840	121,830	31,850	2,860	1,340	1,550	1,860	4,950	3,330	217,900
1958	3,890	2,250	7,560	18,110	32,620	1,560	2,750	1,070	1,720	1,200	800	1,130	74,660
1959	990	850	860	2,430	200	1,320	250	610	1,410	21,490	3,120	6,200	39,730
1960	17,260	6,640	3,920	2,600	2,870	150	3,560	1,030	430	0	0	0	38,460

Table E-3, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	1,850	4,270	7,430	3,190	870	3,470	460	430	220	1,740	470	970	25,370
1962	730	1,170	930	2,000	370	2,470	9,160	9,100	10,160	2,070	1,050	1,570	40,780
1963	760	740	1,340	5,380	4,700	880	900	480	0	280	0	0	15,460
1964	120	410	2,430	1,830	1,150	0	430	690	5,010	110	8,640	2,560	23,380
1965	7,080	22,590	5,980	4,170	32,560	4,770	1,010	200	2,250	520	620	450	82,200
1966	110	2,260	1,530	29,430	38,170	16,310	1,550	2,450	760	1,910	540	540	95,560
1967	840	170	1,500	620	890	1,440	1,060	50	2,820	0	0	430	9,820
1968	10,560	6,450	38,070	13,340	29,500	4,860	2,190	1,410	460	230	1,060	510	108,640
1969	470	1,210	10,100	12,350	37,950	2,560	1,000	0	2,990	3,860	1,040	4,510	78,040
1970	5,810	13,020	43,370	16,270	10,570	2,790	0	590	870	0	0	0	93,290
1971	220	780	570	1,310	920	470	2,070	600	180	10,600	2,400	47,870	67,990
1972	9,270	3,170	2,220	4,640	1,600	0	0	0	110	2,010	910	680	24,610
1973	4,350	7,910	8,380	19,480	7,740	19,870	6,640	3,850	770	6,700	2,080	1,540	89,310
1974	4,330	2,450	2,230	1,150	2,360	1,000	960	7,610	3,950	19,750	42,050	7,150	94,990
1975	8,590	33,410	7,520	22,990	8,260	43,940	7,450	1,420	30	510	350	850	135,320
1976	850	1,250	1,310	7,560	17,830	3,660	1,770	300	400	2,500	1,530	5,070	44,030
1977	6,460	11,830	44,270	16,200	6,580	880	900	710	570	0	0	130	88,530
1978	300	1,130	1,770	4,500	1,790	660	700	180	210	20	0	0	11,260
1979	1,340	1,140	10,760	23,240	52,070	11,910	860	15,920	1,080	960	330	1,780	121,390
1980	3,720	5,050	3,260	7,410	9,930	2,130	970	640	1,960	390	170	900	36,530
1941-80 Avg.	3,394	7,944	9,192	13,176	18,691	6,995	1,875	1,652	1,768	3,014	2,649	3,201	73,551

Table E-4

Lake Arlington Runoff

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	2,750	12,910	4,500	4,000	6,080	9,860	1,240	1,370	120	1,020	360	550	44,760
1942	420	320	370	34,200	14,430	5,270	510	430	700	6,000	1,380	1,120	65,150
1943	800	540	2,390	2,160	5,020	2,180	80	0	770	10	0	80	14,030
1944	190	2,770	1,700	1,310	7,990	970	130	360	240	590	300	880	17,430
1945	1,830	16,450	21,110	16,730	3,420	1,260	1,280	140	90	580	360	330	63,580
1946	1,130	3,120	2,120	1,090	3,930	1,660	90	870	230	540	7,080	6,150	28,010
1947	2,790	1,420	2,910	2,980	1,360	2,470	440	120	1,030	0	0	1,320	16,840
1948	2,860	16,310	7,100	1,450	1,790	670	330	0	0	0	0	0	30,510
1949	0	5,030	9,370	3,800	53,430	11,820	1,170	270	0	3,740	390	230	89,250
1950	3,290	13,730	2,700	11,440	13,960	1,680	1,690	1,460	9,260	310	250	590	60,360
1951	430	620	230	0	970	3,390	230	0	0	0	0	0	5,870
1952	0	290	520	1,790	1,630	0	0	0	20	0	1,200	580	6,030
1953	350	260	460	2,230	3,210	30	1,010	890	140	1,220	590	230	10,620
1954	380	300	300	260	800	0	0	0	0	0	0	0	2,040
1955	0	0	0	270	1,420	2,040	0	0	0	0	0	0	3,730
1956	0	0	0	680	4,560	720	0	0	0	0	0	0	5,960
1957	0	850	1,240	54,650	38,870	4,550	0	0	1,600	3,570	5,420	1,890	112,640
1958	410	380	2,570	16,200	2,810	100	1,620	40	8,440	3,260	530	300	36,660
1959	500	570	720	1,720	20	4,200	0	0	740	4,450	870	1,350	15,140
1960	4,400	420	600	910	550	0	520	0	0	0	0	310	7,710

Table E-4, continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	3,050	2,550	3,410	390	270	10,480	0	0	130	430	240	910	21,860
1962	180	500	460	420	820	1,770	540	1,770	5,010	140	220	740	12,570
1963	750	780	0	4,520	20	0	220	150	1,300	40	0	0	7,780
1964	1,040	310	4,250	3,120	1,710	0	0	590	3,910	10	5,980	670	21,590
1965	5,030	10,340	520	880	16,710	250	0	0	590	340	550	120	35,330
1966	0	2,790	640	22,380	3,440	2,740	170	1,650	1,070	5,360	210	230	40,680
1967	400	0	560	900	750	1,560	330	0	1,620	740	110	660	7,630
1968	5,500	1,620	16,940	640	11,660	920	450	250	0	0	220	550	38,750
1969	160	710	2,330	970	22,590	0	0	0	550	2,340	650	1,530	31,830
1970	760	7,030	10,360	6,210	2,710	520	0	0	2,040	270	70	0	29,970
1971	50	330	0	1,730	790	0	950	1,270	40	13,180	260	16,430	35,030
1972	1,230	710	460	3,080	1,570	330	0	0	0	2,730	950	100	11,160
1973	1,900	2,830	2,750	14,250	1,720	15,920	3,560	210	0	5,920	1,250	250	50,560
1974	1,600	990	960	220	4,000	1,750	110	3,030	3,420	7,460	5,090	1,320	29,950
1975	3,530	4,370	3,290	8,430	6,190	7,850	3,000	150	0	250	200	0	37,260
1976	0	0	590	13,620	7,570	1,430	910	30	110	1,140	0	1,230	26,630
1977	1,010	2,440	26,260	14,220	1,710	0	220	0	0	0	0	0	45,860
1978	0	700	510	310	1,200	0	0	0	0	0	0	0	2,720
1979	570	780	10,770	3,170	21,220	6,980	130	11,440	230	180	0	1,530	57,000
1980	1,950	1,300	770	2,500	7,730	170	0	0	2,840	0	0	830	18,090
1941-80 Avg.	1,281	2,934	3,669	6,496	7,016	2,639	523	662	1,156	1,646	868	1,075	29,965

Table E-5

Cedar Creek Reservoir Runoff

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	13,120	57,780	68,560	19,930	92,450	270,620	25,490	16,480	330	15,940	10,680	19,110	610,490
1942	6,690	18,050	12,130	423,110	122,940	100,800	450	5,890	25,960	10,030	23,520	60,110	809,680
1943	18,240	9,740	52,950	36,890	67,510	169,460	860	20	2,060	17,690	90	12,170	387,680
1944	48,690	72,950	47,640	15,800	272,960	20,870	960	10	230	80	25,140	93,180	598,510
1945	59,750	125,460	342,380	129,130	3,800	130,910	128,490	1,280	1,930	22,550	14,080	13,300	973,060
1946	78,360	133,100	25,810	8,420	133,460	121,370	150	8,380	3,510	1,700	200,380	29,880	744,520
1947	53,680	3,490	29,930	207,690	7,520	48,340	300	10,850	8,240	180	23,470	147,660	541,350
1948	47,030	59,780	76,670	7,150	109,460	820	2,150	630	150	0	2,260	2,330	308,430
1949	48,920	94,280	24,090	22,700	27,230	8,690	1,640	10	0	9,620	680	480	238,340
1950	43,390	216,940	3,970	47,040	113,970	2,980	17,660	3,220	1,190	0	2,210	60	452,630
1951	13,250	46,860	1,140	1,300	13,370	69,110	3,150	0	580	2,760	440	0	151,960
1952	1,610	1,310	9,030	149,180	105,690	8,130	300	0	0	0	13,620	65,540	354,410
1953	15,170	1,060	28,190	47,830	264,130	170	350	1,330	6,830	120	160	18,920	384,260
1954	45,980	6,060	280	11,220	43,770	1,610	0	0	0	33,400	23,710	1,360	167,390
1955	3,660	24,160	29,050	48,870	4,900	3,740	230	490	1,010	120	0	0	116,230
1956	180	25,820	100	280	34,040	280	0	0	0	0	21,130	1,200	83,030
1957	12,060	25,060	46,890	543,170	213,620	37,840	40	550	8,430	104,990	146,560	16,570	1,155,780
1958	45,570	2,350	37,380	235,980	236,530	2,040	25,240	0	9,580	3,710	2,460	1,340	602,180
1959	900	55,710	17,240	84,700	62,280	21,890	2,360	80	0	39,160	8,140	99,860	392,320
1960	157,040	48,660	20,070	1,440	3,130	4,900	2,870	3,130	1,460	900	7,310	201,480	452,390

Table E-5, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	114,440	70,810	68,720	11,000	3,520	99,130	13,460	790	1,770	270	18,770	40,230	442,910
1962	7,890	20,480	10,580	55,950	30,100	11,800	57,390	5,180	21,960	12,990	30,870	12,610	277,800
1963	5,450	800	1,350	75,430	32,100	230	60	10	0	0	20	60	115,510
1964	120	760	4,980	37,480	6,690	240	0	0	5,410	110	5,530	200	61,520
1965	6,090	85,750	5,040	3,020	125,240	3,910	290	0	4,220	330	6,380	190	240,460
1966	7,760	45,940	4,870	402,040	147,880	2,730	1,250	3,330	6,430	6,210	170	500	629,110
1967	560	370	2,320	14,390	21,600	27,390	11,980	160	14,870	263,570	58,030	97,340	512,580
1968	97,670	50,520	143,130	61,490	134,540	22,070	3,020	220	420	250	6,110	18,830	538,270
1969	5,580	63,590	124,830	26,870	346,250	3,100	220	340	260	14,680	4,450	62,740	652,910
1970	15,870	105,520	194,290	70,160	15,180	16,520	230	280	33,480	69,800	2,920	1,050	525,300
1971	770	7,420	3,120	1,320	3,420	310	74,690	11,480	1,290	188,220	10,430	268,230	570,700
1972	76,020	2,840	1,490	1,170	1,120	6,340	450	170	310	9,450	16,730	16,100	132,190
1973	65,710	53,630	90,200	194,800	149,20	210,710	5,930	590	15,550	101,480	73,740	69,400	896,660
1974	155,550	9,550	4,720	20,250	84,310	94,360	340	1,390	15,900	39,470	147,310	66,950	640,100
1975	21,790	181,980	44,070	98,180	31,740	14,350	2,680	1,030	330	210	290	410	397,060
1976	400	470	2,830	256,620	89,260	28,920	21,960	210	12,290	27,270	2,120	36,960	479,310
1977	21,360	158,510	141,150	80,450	1,470	31,400	530	1,120	440	350	17,670	2,610	457,060
1978	3,520	54,950	53,630	4,160	6,510	260	2,050	1,800	5,890	360	5,320	5,480	143,930
1979	83,110	49,340	80,220	27,840	224,430	14,680	520	10,180	4,350	560	1,020	45,450	541,700
1980	112,540	26,620	10,060	35,440	86,890	3,690	140	130	5,470	4,070	1,210	12,750	299,010
1981	540	470	4,360	910	27,700	270,930	48,200	740	4,460	42,430	11,630	4,310	416,680
1982	2,250	19,020	9,600	2,550	31,630	90,360	7,960	520	380	570	9,920	150,790	325,550
1983	3,380	138,820	123,140	5,930	38,810	50,950	5,660	140	10	190	1,070	1,120	369,220
1984	1,640	12,910	94,970	4,740	370	570	140	90	930	77,690	14,000	109,310	317,360
1985	33,600	31,190	38,640	117,210	48,750	2,960	2,660	160	730	117,610	84,690	269,220	747,420
1986	2,160	177,780	1,670	45,040	94,480	135,870	8,890	1,690	4,800	17,820	173,890	54,790	718,880
1941-86 Avg.	33,893	52,145	46,467	80,354	77,862	47,138	10,508	2,046	5,075	27,368	26,746	46,352	455,954

Table E-6

Richland-Chambers Reservoir Runoff

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0	600	0	110,800	37,500	64,500	119,700	1,400	0	0	327,200	187,700	849,400
1941	54,900	260,900	154,200	88,900	164,200	217,500	162,600	12,300	1,000	21,100	5,300	13,300	1,156,200
1942	600	2,700	10,100	658,300	127,400	81,600	4,200	19,000	154,900	71,300	48,900	69,800	1,248,800
1943	10,000	900	53,200	59,800	246,500	65,600	2,300	0	60,900	50,000	400	6,500	556,100
1944	69,800	185,700	68,900	31,500	583,000	55,900	5,300	200	300	700	8,800	72,400	1,082,500
1945	133,500	226,300	535,200	288,800	14,200	188,500	128,500	8,000	3,300	74,600	18,500	32,000	1,651,400
1946	56,700	163,600	66,600	29,700	311,800	69,000	2,500	10,400	1,800	1,000	59,600	33,600	806,300
1947	181,700	13,300	118,800	115,700	23,500	69,400	900	4,200	9,200	600	2,900	32,900	573,100
1948	14,300	28,200	58,600	21,000	286,900	7,500	15,900	0	0	0	100	200	432,700
1949	6,400	48,300	34,500	30,600	43,000	16,300	5,000	1,100	0	6,300	100	100	191,700
1950	2,900	153,800	5,200	86,700	73,700	5,900	5,300	300	1,000	0	0	0	334,800
1951	100	2,000	100	200	2,600	54,900	200	0	8,100	0	0	0	68,200
1952	0	3,000	5,500	117,100	101,400	2,500	300	0	0	0	13,900	51,500	295,200
1953	6,200	1,100	94,600	25,100	327,500	900	1,800	100	2,800	6,300	1,500	18,100	486,000
1954	7,800	0	100	300	23,400	0	0	0	0	0	2,600	0	34,200
1955	800	8,300	7,700	6,100	13,300	14,300	500	6,300	8,700	600	0	0	66,600
1956	1,200	11,800	0	0	63,700	7,300	0	500	100	300	20,700	1,500	107,100
1957	300	13,300	16,100	728,300	396,700	76,000	800	100	600	59,900	200,700	11,900	1,504,700
1958	25,400	7,900	45,900	127,600	479,000	3,000	9,400	14,000	104,900	10,800	2,800	5,600	836,300
1959	400	39,700	3,200	79,900	193,600	278,800	13,700	1,500	1,200	145,200	10,700	131,500	899,400
1960	208,900	34,700	19,200	9,100	18,200	17,800	1,100	7,800	100	8,900	3,300	281,200	610,300

Table E-6, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	365,300	248,200	128,100	18,200	8,400	149,400	70,700	1,400	3,900	5,600	90,100	61,900	1,151,200
1962	3,000	17,000	9,100	42,400	15,900	71,600	5,300	0	9,500	46,500	8,500	8,100	236,900
1963	1,200	1,000	700	17,900	22,400	2,100	100	0	0	0	0	0	45,400
1964	200	400	700	600	800	1,000	100	0	0	0	12,800	1,600	18,200
1965	1,900	59,800	25,900	12,100	364,400	13,900	200	100	300	0	3,500	600	482,700
1966	700	14,600	2,200	512,600	256,800	3,500	500	4,800	6,600	2,800	0	0	805,100
1967	0	0	0	5,200	1,600	32,500	6,900	0	52,600	207,700	159,000	113,900	579,400
1968	158,700	90,100	183,600	184,400	520,500	131,200	11,200	500	500	2,200	4,500	18,700	1,306,100
1969	0	47,900	166,300	86,600	529,300	19,900	0	0	0	2,600	3,400	37,600	893,600
1970	6,400	78,700	265,200	86,700	22,100	16,300	400	0	6,700	84,400	11,400	2,000	580,300
1971	100	1,000	0	5,100	3,200	0	400	2,400	0	82,200	24,200	275,500	394,100
1972	119,200	7,300	3,200	1,300	3,600	1,600	1,700	100	1,000	22,300	12,400	8,100	181,800
1973	48,300	49,100	164,100	360,700	92,000	295,400	20,700	4,700	28,000	142,100	32,000	23,800	1,260,900
1974	41,500	13,100	10,200	3,500	34,100	2,500	0	3,600	74,400	78,300	407,200	74,300	742,700
1975	41,800	202,000	52,000	179,100	396,100	102,700	15,600	1,800	1,800	600	1,000	1,100	995,600
1976	1,500	2,300	18,300	137,700	153,900	106,800	80,100	1,800	57,300	49,800	10,700	77,300	697,500
1977	8,900	150,800	152,400	269,600	31,400	4,100	500	700	300	0	400	400	619,500
1978	0	5,900	42,600	1,000	10,200	200	0	0	700	0	700	200	61,500
1979	14,100	9,200	57,500	55,300	267,700	89,900	8,200	10,400	1,500	300	400	24,800	539,300
1980	67,100	30,400	3,500	104,000	164,600	4,100	100	0	0	0	0	0	375,400
1981	100	0	0	0	26,700	224,700	6,900	200	300	69,100	4,600	2,000	334,600
1982	1,000	3,100	28,300	8,900	81,600	17,100	2,800	0	0	300	1,300	6,400	150,800
1983	800	70,700	26,900	4,300	8,900	19,600	4,700	1,400	200	6,400	2,400	1,700	148,000
1984	1,100	8,300	92,200	9,700	6,900	1,000	0	0	0	10,300	6,200	126,000	261,700
1985	41,100	42,100	47,800	12,000	5,400	600	200	0	400	174,200	55,600	148,000	527,400
1986	9,700	110,500	0	5,900	109,800	255,600	7,800	600	12,000	56,500	100,400	110,600	779,400
1940-86 Avg.	36,502	52,545	59,117	100,857	141,902	60,947	15,428	2,589	13,126	31,953	35,760	44,170	594,896

Table E-7

Tehuacana Reservoir Runoff

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0	800	0	19,700	2,200	4,500	14,700	100	0	0	81,400	34,300	157,700
1941	11,700	49,700	32,900	16,800	32,900	43,300	40,800	1,100	200	3,400	500	1,400	234,700
1942	700	900	1,300	111,700	10,000	9,200	500	800	33,200	7,000	9,400	13,300	198,000
1943	3,600	900	9,400	11,900	59,500	9,700	300	0	400	16,400	100	1,700	113,900
1944	20,500	40,500	13,800	7,400	116,400	9,400	400	0	0	0	1,700	15,300	225,400
1945	31,100	40,300	103,200	56,700	2,600	17,000	31,400	3,500	1,600	23,500	4,300	11,800	327,000
1946	15,700	31,900	14,900	6,800	89,100	9,100	500	800	100	200	11,800	6,500	187,400
1947	53,200	4,900	33,700	25,300	7,000	3,600	0	0	100	0	0	300	128,100
1948	900	3,000	18,500	3,200	68,100	700	2,500	0	0	0	0	0	96,900
1949	1,200	1,700	4,700	4,700	6,400	2,500	2,200	300	0	2,600	0	0	26,300
1950	1,900	33,800	1,500	17,300	6,700	1,200	1,000	0	200	0	0	0	63,600
1951	100	1,500	100	100	1,900	10,100	0	0	4,500	0	0	0	18,300
1952	0	1,800	3,200	21,500	20,800	500	100	0	0	0	2,000	11,100	61,000
1953	3,900	700	31,200	6,400	87,800	300	500	0	1,500	3,000	600	8,000	143,900
1954	4,600	100	0	300	10,600	0	0	0	0	200	600	0	16,400
1955	500	5,000	4,900	1,700	2,900	3,500	300	900	700	300	0	0	20,700
1956	700	6,200	0	0	28,800	2,500	0	0	0	0	5,900	500	44,600
1957	300	7,300	9,000	182,300	68,300	17,000	200	0	0	12,600	30,600	2,100	329,700
1958	5,800	3,000	4,800	12,300	81,900	600	2,200	5,400	9,200	2,900	0	900	129,000
1959	400	9,600	1,100	17,700	32,700	58,000	2,000	200	400	26,200	2,400	21,000	171,700
1960	40,200	6,600	3,800	2,500	5,600	6,200	400	1,200	0	5,600	2,800	70,200	145,100

Table E-7, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	81,400	37,200	24,900	3,600	900	22,100	7,000	700	1,200	1,100	23,200	10,800	214,100
1962	700	6,000	2,500	21,500	2,100	0	1,100	0	2,000	17,200	1,100	0	54,200
1963	0	0	0	7,600	2,100	200	0	0	0	0	0	0	9,900
1964	100	400	400	100	100	0	0	0	0	0	0	0	1,100
1965	1,100	5,800	11,400	5,500	95,400	4,900	0	0	200	0	1,000	100	125,400
1966	400	9,900	1,200	142,600	43,500	1,100	200	1,900	1,800	0	0	0	202,600
1967	0	0	0	3,300	400	8,000	100	0	21,400	31,800	30,200	32,100	127,300
1968	33,000	23,000	29,700	37,400	78,800	30,000	800	0	100	0	1,300	2,800	236,900
1969	2,700	17,300	47,800	21,800	17,400	100	0	0	0	500	14,400	35,100	157,100
1970	5,000	8,100	7,300	6,600	100	100	0	0	3,500	14,200	100	0	45,000
1971	0	500	100	0	0	0	0	0	7,000	10,700	18,100	55,100	91,500
1972	39,100	1,100	400	100	100	1,500	1,100	0	0	1,700	2,000	7,900	55,000
1973	19,300	2,600	36,000	40,900	600	48,100	1,200	0	3,400	55,800	5,700	8,500	222,100
1974	21,900	7,500	13,400	900	4,200	0	0	400	78,000	12,800	52,900	20,700	212,700
1975	6,800	33,800	6,300	7,800	60,900	1,500	400	0	0	100	0	400	118,000
1976	100	1,000	9,100	79,400	43,400	22,400	5,200	100	600	54,500	600	41,600	258,000
1977	5,600	33,700	19,600	29,500	600	24,900	100	0	1,700	0	0	0	115,700
1978	100	4,800	23,200	100	600	100	0	400	2,000	8,200	7,600	11,100	58,200
1979	9,300	230,800	16,800	45,500	49,300	5,400	300	5,300	9,400	900	200	20,400	393,600
1980	23,600	600	800	11,300	55,300	0	0	0	0	0	0	0	91,600
1981	100	100	400	100	400	55,300	2,300	0	0	23,400	900	200	83,200
1982	800	3,100	22,800	1,400	9,000	300	4,300	0	0	0	6,700	53,400	101,800
1983	1,700	30,900	1,900	200	1,800	500	100	34,400	100	400	300	900	73,200
1984	1,100	5,400	30,700	400	200	0	0	0	0	6,200	1,500	128,000	173,500
1985	3,600	27,600	5,400	1,800	1,500	100	200	0	0	15,200	37,100	50,800	143,300
1986	1,100	123,700	1,200	4,100	17,900	14,500	100	0	100	4,600	23,500	34,600	225,400
1940-86 Avg.	9,694	18,406	12,879	21,266	26,145	9,574	2,649	1,223	3,928	7,728	8,138	15,168	136,798

Tennessee Colony Reservoir

Tennessee Colony Reservoir is a potential project on the main stem of the Trinity River, downstream from Richland and Tehuacana Creeks. The drainage area at the dam site is 12,302 square miles, some of which is controlled by existing impoundments on Trinity River tributaries upstream. Runoff data for Tennessee Colony are based on a Corps of Engineers project memorandum (43), with adjustments for the effect to Richland-Chambers Reservoir. The data are given in Table E-8.

George Parkhouse Reservoir Stage I

The George Parkhouse Reservoir Stage I site is located on the South Fork of the Sulphur River, downstream from Cooper Reservoir. The reservoir would have a total drainage area of 655 square miles, of which 476 square miles would be controlled by Cooper Reservoir. The incremental drainage area downstream from Cooper would be 179 square miles. Table E-9 gives the monthly runoff data for George Parkhouse Reservoir Stage I, including spills from Cooper Reservoir and uncontrolled runoff originating below Cooper. The runoff values in Table E-9 include the impact of diversions for existing water rights in the reservoir's drainage area, which total 1,523 acre-feet per year.

George Parkhouse Reservoir Stage II

George Parkhouse Reservoir Stage II would be located on the North Fork of the Sulphur River and would have a drainage area of 377 square miles. There are no major existing reservoirs upstream from the George

Table E-8

Tennessee Colony Reservoir Runoff, 1990 Conditions

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	403,400	359,500	439,200	335,000	515,900	1,479,500	480,600	23,500	12,900	186,500	63,700	54,200	4,353,900
1942	18,600	40,400	31,500	2,561,000	1,640,600	693,100	35,300	300	77,500	44,800	72,700	71,000	5,286,800
1943	92,810	26,080	28,810	232,330	437,570	442,880	10,810	2,310	300	12,510	6,500	8,910	1,301,820
1944	79,300	243,600	393,800	73,600	1,431,300	226,700	7,400	300	5,800	6,800	9,000	300	2,477,900
1945	254,200	562,500	1,939,100	2,169,400	104,000	430,000	484,500	17,800	5,400	111,300	28,300	56,000	6,162,500
1946	212,330	586,710	407,240	93,030	849,300	855,940	16,010	8,410	58,100	14,210	659,400	491,710	4,252,390
1947	203,490	54,180	204,640	400,100	148,710	89,340	32,610	9,710	28,600	6,210	24,000	164,010	1,365,600
1948	172,110	352,180	361,310	44,400	360,660	15,800	37,210	5,210	2,700	6,010	4,300	5,810	1,367,700
1949	17,410	57,780	343,310	118,400	433,710	345,400	28,310	6,510	2,500	53,610	39,900	10,410	1,457,250
1950	139,010	798,980	76,810	146,900	800,010	118,200	183,610	83,310	365,500	10,810	2,500	4,410	2,730,050
1951	12,310	21,880	20,710	19,900	38,610	175,800	12,010	4,510	2,400	1,910	6,600	6,310	322,950
1952	9,310	16,080	19,810	300	4,410	107,800	5,710	1,810	2,700	310	4,800	33,410	206,450
1953	59,010	16,280	105,310	300	262,610	10,500	4,110	4,410	2,500	4,110	11,600	31,010	511,750
1954	27,710	12,380	6,410	14,400	47,310	5,100	1,510	3,910	900	55,610	37,800	11,610	224,650
1955	24,810	45,080	49,010	46,300	42,010	10,400	3,510	310	300	3,010	2,800	5,210	232,750
1956	9,710	25,480	7,410	8,700	42,910	300	310	310	300	310	300	2,710	98,750
1957	3,400	22,600	28,700	300	1,093,500	992,100	46,400	74,600	18,100	154,900	388,700	66,100	2,889,400
1958	86,500	44,500	81,200	487,800	1,705,200	7,000	23,400	6,400	28,900	21,500	8,100	10,200	2,510,700
1959	12,210	52,080	38,210	77,000	439,660	263,870	40,510	11,810	6,500	160,610	36,500	196,700	1,335,660
1960	528,930	150,230	77,910	24,500	26,710	11,000	19,910	16,010	4,200	19,210	22,000	387,400	1,288,010

Table E-8, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	711,300	443,510	226,790	117,500	24,410	168,110	98,860	5,510	14,300	11,510	300	88,380	1,910,480
1962	37,410	37,980	46,810	26,440	97,210	47,450	21,910	95,410	156,600	37,410	23,400	79,610	707,640
1963	22,410	11,580	20,910	25,400	87,210	25,300	3,310	3,110	300	710	1,400	4,810	206,450
1964	8,710	17,980	36,910	30,000	17,310	15,400	810	4,410	114,900	9,810	143,500	49,310	449,050
1965	78,210	231,980	108,910	96,200	418,710	118,600	5,910	3,510	17,700	6,410	10,600	11,110	1,107,850
1966	17,000	62,900	41,000	468,600	1,289,200	104,900	52,900	34,800	31,900	37,700	16,900	21,400	2,179,200
1967	14,910	11,980	23,110	63,300	53,410	5,900	11,810	35,110	300	310	9,300	117,120	346,560
1968	350,300	264,000	564,100	723,400	1,498,400	317,400	70,900	35,700	23,700	23,000	31,800	66,300	3,969,000
1969	58,600	211,700	695,400	480,900	2,569,700	208,900	44,100	10,500	16,200	17,200	24,700	84,900	4,422,800
1941 - 1986 Avg.	126,393	164,900	221,529	306,393	568,284	251,472	61,526	17,569	34,552	35,114	58,324	73,806	1,919,862

Table E-9

George Parkhouse Reservoir Stage I Runoff, Including Spills from Cooper Reservoir

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	22,400	15,680	43,770	32,900	106,620	62,650	7,470	790	360	1,210	3,020	6,580	303,450
1942	1,230	2,850	7,240	90,040	59,660	30,220	880	1,140	3,830	300	3,010	9,610	210,010
1943	280	1,020	16,080	2,440	7,340	13,610	210	120	140	180	630	1,850	43,900
1944	4,500	13,390	19,360	5,020	60,770	6,020	530	1,230	340	150	2,060	13,400	126,770
1945	5,890	34,780	156,320	32,420	5,110	55,510	16,970	160	3,090	16,060	1,310	220	327,840
1946	12,680	81,330	28,400	18,740	130,220	29,840	310	5,000	230	220	74,210	25,460	406,640
1947	3,160	350	6,200	9,980	23,610	2,080	150	2,370	260	240	6,500	19,460	74,360
1948	13,700	13,910	40,580	6,120	79,740	1,190	1,490	140	140	170	210	960	158,350
1949	35,370	36,670	43,570	10,590	5,900	3,890	1,880	610	480	18,740	310	1,330	159,340
1950	20,400	188,200	2,780	2,930	94,750	6,770	3,220	600	48,600	210	210	220	368,890
1951	510	15,760	420	310	1,680	76,870	3,600	120	140	420	630	320	100,780
1952	1,570	860	1,960	36,430	11,740	2,190	140	120	140	150	5,540	7,870	68,710
1953	4,290	610	9,870	35,940	34,450	150	4,220	300	150	200	3,150	10,310	103,640
1954	15,070	2,500	240	4,320	15,290	1,500	140	120	140	17,550	4,360	400	61,630
1955	660	8,070	8,140	6,380	3,210	170	1,000	1,250	430	680	210	210	30,410
1956	220	7,630	210	340	8,340	660	140	120	140	150	1,070	910	19,930
1957	2,510	5,630	17,640	89,110	210,870	69,110	280	1,590	10,600	10,480	151,880	3,990	573,690
1958	33,140	510	47,650	110,680	163,700	17,980	5,620	150	1,270	350	500	460	382,010
1959	590	4,580	2,960	2,510	950	3,270	7,330	660	630	7,400	6,480	23,360	60,720
1960	17,230	5,860	3,910	970	5,650	7,990	4,140	680	2,850	7,030	480	38,890	95,680

Table E-9, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	23,080	13,640	41,010	3,530	560	5,040	1,410	610	1,740	170	5,350	11,900	108,040
1962	4,870	3,810	2,130	9,010	2,670	12,450	6,980	1,280	23,750	3,590	14,300	1,840	86,680
1963	4,640	290	2,270	2,990	4,380	550	5,850	130	140	150	210	210	21,810
1964	220	250	3,420	8,100	6,360	8,490	140	120	7,780	310	12,510	630	48,330
1965	8,630	40,550	680	410	41,200	1,390	150	130	2,230	160	450	220	96,200
1966	460	9,650	510	79,260	108,210	170	320	940	2,370	800	240	450	203,380
1967	280	250	900	19,280	16,640	26,840	560	160	8,180	12,780	7,350	15,530	108,750
1968	25,210	10,410	117,500	57,460	91,900	33,750	12,850	1,590	7,400	1,160	9,060	15,000	383,290
1969	68,380	117,790	76,810	20,010	215,440	1,020	150	120	140	2,100	1,060	10,190	513,210
1970	3,750	20,420	48,260	70,930	2,340	1,360	160	130	3,230	15,680	1,740	760	168,760
1971	590	3,090	1,540	230	220	190	250	3,680	780	44,020	490	127,140	182,220
1972	1,910	450	2,190	290	450	450	150	120	230	4,960	13,710	6,180	31,090
1973	11,200	11,950	30,480	117,530	4,900	22,810	400	210	27,860	81,350	113,400	35,700	457,790
1974	87,790	1,580	3,390	79,430	5,170	118,160	180	310	29,200	3,430	161,450	76,370	566,460
1975	11,520	166,440	66,570	43,690	86,140	88,970	750	200	160	160	220	280	465,100
1976	220	250	2,150	19,860	12,620	4,800	13,680	290	1,680	8,310	1,440	17,540	82,840
1977	10,000	20,900	133,930	50,740	860	5,920	260	1,300	450	160	1,970	510	227,000
1978	1,920	12,690	11,800	960	1,950	2,610	150	120	140	150	1,420	1,150	35,060
1979	22,280	11,030	19,840	12,240	49,350	35,960	940	1,910	290	220	360	6,950	161,370
1980	11,860	7,680	300	3,290	9,660	480	160	120	1,800	2,190	280	7,350	45,170
1981	250	250	5,910	680	11,340	59,270	700	150	170	34,690	15,440	510	129,360
1982	640	5,190	3,180	3,750	241,280	34,090	2,720	260	340	180	4,610	22,470	318,710
1983	860	57,300	56,040	1,630	5,740	1,280	8,010	190	160	350	530	370	132,460
1984	360	7,170	34,460	5,220	2,310	270	160	130	140	13,370	5,040	26,890	95,520
1985	4,460	7,760	39,520	46,930	72,580	3,360	290	120	140	1,510	22,760	16,620	216,050
1986	280	16,280	340	34,130	7,060	48,980	1,880	150	1,540	2,590	21,100	6,830	141,160
1941-86 Avg.	10,893	21,462	25,270	25,864	44,151	19,790	2,586	690	4,261	6,879	14,832	12,509	189,187

Parkhouse Reservoir Stage site. The reservoir could be operated by itself or combined with George Parkhouse Reservoir Stage I on the South Fork of the Sulphur. Table E-10 gives the monthly runoff for the reservoir, after accounting for diversions for existing water rights in its watershed, which total 102 acre-feet per year.

Marvin Nichols Reservoir Stage I

The Marvin Nichols Reservoir Stage I site is located on the Sulphur River and has a total drainage area of 1,941 square miles. The drainage area of Marvin Nichols I downstream from the existing Cooper Reservoir and the potential George Parkhouse I and George Parkhouse II sites is 858 square miles. Table E-11 shows the monthly runoff for the 858 square mile watershed downstream from other major existing and potential reservoirs. The runoff values include the impact of diversions for the 17,928 acre-feet per year of existing water rights in the watershed.

Marvin Nichols Reservoir Stage II

Marvin Nichols Reservoir Stage II would be located on White Oak Creek, a tributary of the Sulphur River. It has a drainage area of 662 square miles, of which 596 square miles are downstream from the existing White Oak Creek Reservoir (also known as Lake Sulphur Springs). Table E-12 shows the monthly runoff for Marvin Nichols II, including spills from White Oak Creek Reservoir and runoff from the intervening watershed. The runoff values in Table E-12 have been adjusted to account for the impact of diversions for the 1,059 acre-feet per year of existing water rights in the watershed.

Table E-10

George Parkhouse II Reservoir Runoff

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	19,250	14,040	31,800	23,220	70,010	43,680	15,430	1,390	450	2,230	5,910	13,410	112,860
1942	2,130	5,540	14,820	90,250	42,660	27,890	1,530	2,110	7,680	310	5,840	19,590	220,350
1943	130	1,680	33,090	4,670	14,910	28,050	130	0	0	50	880	3,410	86,980
1944	8,920	27,470	39,940	10,040	84,690	12,210	800	2,320	400	0	3,830	27,490	218,110
1945	11,820	60,570	90,640	25,810	10,270	42,520	21,190	70	6,130	33,160	2,270	20	304,470
1946	26,000	56,900	22,600	17,160	78,890	29,330	350	10,170	170	130	88,880	19,770	350,350
1947	6,140	290	12,500	15,820	21,670	4,030	10	4,690	240	170	13,110	40,120	118,790
1948	28,120	25,560	29,830	12,320	50,750	2,160	2,800	40	0	20	0	1,540	153,140
1949	73,260	49,760	31,220	11,800	11,920	7,790	3,620	1,030	700	9,200	100	4,760	205,160
1950	98,440	112,510	1,960	3,570	88,330	5,220	27,510	3,010	46,650	460	130	210	388,000
1951	380	42,770	1,110	3,310	9,980	140,140	2,760	40	480	4,580	790	90	206,430
1952	320	320	12,670	97,290	16,190	4,950	30	0	0	0	14,040	5,840	151,560
1953	4,530	780	22,350	91,290	20,850	40	13,600	1,960	720	700	6,080	16,980	189,880
1954	25,770	13,580	360	10,470	71,540	5,680	0	0	0	47,350	4,290	740	179,780
1955	1,980	8,900	29,240	23,130	7,020	920	9,880	2,450	960	2,430	0	0	86,910
1956	430	53,460	840	3,560	21,930	620	0	0	0	0	2,930	500	84,270
1957	1,410	3,470	27,620	196,970	199,970	69,400	660	5,250	26,220	7,450	114,260	10,990	663,670
1958	28,180	2,050	46,690	77,260	95,460	45,810	2,750	100	600	60	430	450	300,020
1959	330	2,390	3,420	290	480	36,230	48,470	5,590	5,360	14,700	6,360	55,570	179,370
1960	36,410	19,970	19,020	3,020	9,830	24,250	7,900	7,570	15,280	32,610	830	121,770	298,460

Table E-10, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	24,710	14,290	52,240	6,600	4,780	2,190	1,620	280	3,650	30	10,430	24,540	145,360
1962	19,100	7,980	13,680	18,130	3,800	45,740	4,030	350	40,330	19,990	66,650	3,210	242,990
1963	8,510	710	6,400	11,860	1,940	370	3,270	0	0	0	0	20	33,080
1964	0	220	14,650	27,050	19,560	21,590	20	20	25,480	120	25,640	2,630	136,980
1965	13,470	76,910	4,550	1,160	47,140	1,820	10	50	6,400	0	240	50	151,800
1966	110	9,920	730	245,190	31,050	730	80	6,820	6,300	2,130	90	970	304,120
1967	310	670	6,270	75,630	93,960	17,090	4,130	120	26,900	24,320	3,790	42,380	295,570
1968	23,430	17,710	102,700	51,050	74,330	69,530	32,340	2,840	40,550	8,470	26,930	32,360	482,240
1969	60,120	28,850	49,130	11,750	108,960	3,880	130	40	60	8,540	490	30,210	302,160
1970	4,130	80,580	73,550	56,820	7,010	620	10	0	16,040	34,500	11,190	3,640	288,090
1971	3,020	9,440	4,520	970	3,190	90	3,540	13,420	3,050	149,840	5,650	91,920	288,660
1972	4,730	1,340	1,450	230	190	410	50	460	10	23,330	24,660	8,360	65,220
1973	21,960	27,210	69,190	62,880	13,170	23,130	850	240	47,500	103,640	72,280	23,660	465,710
1974	27,210	3,710	2,030	22,770	14,310	67,760	130	530	32,250	41,790	65,230	21,240	298,960
1975	23,170	83,510	23,640	19,100	46,910	44,080	4,890	190	150	0	50	140	245,830
1976	60	50	4,050	14,820	9,770	41,660	73,250	920	1,100	11,290	1,290	11,920	170,120
1977	9,290	23,230	59,060	17,640	890	4,210	90	210	10	0	2,740	780	120,170
1978	2,350	15,190	11,220	1,930	5,240	9,320	0	0	0	0	20,360	19,630	85,240
1979	37,570	31,230	61,760	12,310	56,950	19,440	5,180	6,480	160	1,210	440	15,590	248,320
1980	6,640	11,400	910	1,720	10,190	70	0	0	3,710	25,380	360	16,810	77,190
1981	490	950	15,630	2,520	31,010	104,480	4,120	140	3,410	118,150	44,280	1,820	327,100
1982	10,250	21,140	10,150	14,650	206,800	35,040	11,590	2,340	440	760	9,180	26,590	348,930
1983	2,640	72,480	35,110	2,330	11,080	6,770	20,530	40	90	280	1,270	560	153,180
1984	900	44,290	45,700	12,680	33,280	190	0	0	0	14,640	14,260	50,420	216,360
1985	16,860	22,190	70,800	40,050	44,330	8,120	790	0	0	840	22,460	16,320	124,220
1986	880	28,480	2,380	37,720	25,380	30,600	10,690	0	4,830	9,800	69,080	21,340	241,180
1941-86 Avg.	14,806	24,206	25,813	31,719	39,208	23,187	7,250	1,772	8,431	15,807	16,684	17,440	226,323

Table E-11

Marvin Nichols I Reservoir Runoff
Runoff Originating Downstream from George Parkhouse I and II Reservoirs

\- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	108,030	64,300	134,280	85,640	365,200	260,740	90,730	4,720	890	13,240	32,260	75,130	1,235,160
1942	10,510	29,820	78,830	372,180	248,220	30,860	0	0	0	0	0	0	770,420
1943	88,870	6,450	120,920	86,450	0	26,560	5,260	0	0	540	70	7,030	342,150
1944	31,080	57,130	281,720	99,420	271,550	131,490	0	0	8,370	0	23,630	75,750	980,140
1945	195,560	134,760	451,410	774,950	30,120	119,600	0	1,320	0	78,420	730	0	1,786,870
1946	108,260	238,610	6,420	98,190	148,380	175,200	2,230	0	0	0	245,390	100,140	1,122,820
1947	42,060	6,460	76,370	71,830	157,170	0	70	0	0	0	0	75,320	429,280
1948	107,790	111,570	138,090	13,340	176,370	7,570	0	0	0	0	0	0	554,730
1949	0	116,710	200,980	72,860	72,590	23,370	0	2,390	0	21,570	47,910	21,280	579,660
1950	165,930	375,120	78,270	0	260,650	24,880	0	17,100	211,710	8,520	0	0	1,142,180
1951	20,630	198,070	38,310	11,820	18,990	0	10,810	420	3,410	960	7,570	22,720	333,710
1952	76,760	32,360	49,810	316,260	95,460	37,460	2,890	40	0	0	0	118,520	729,560
1953	54,980	105,560	53,660	0	389,360	0	0	0	0	0	0	5,760	609,320
1954	72,350	54.920	7,940	19,750	166,750	0	0	0	0	0	63,250	3,880	388,840
1955	4,190	19,230	64,170	100,680	8,930	1,320	14,410	3,840	15,300	41,130	0	0	273,200
1956	0	129,270	3,620	0	0	34,640	0	0	0	0	5,930	0	173,460
1957	15,570	45,210	99,230	359,590	562,710	322,580	0	0	12,250	48,150	264,140	23,920	1,753,350
1958	85,430	650	77,010	71,540	411,790	19,280	47,260	740	19,000	2,150	30,680	2,700	768,230
1959	7,400	67,490	26,250	34,780	4,240	96,480	88,000	11,430	8,070	38,150	35,410	218,160	635,860
1960	123,350	21,230	22,510	0	19,260	33,900	78,360	9,930	84,230	83,460	10,110	309,450	795,790

Table E-11, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	107,940	46,110	124,420	91,530	14,180	1,870	9,630	1,210	3,370	50	35,870	81,180	517,360
1962	67,510	36,730	16,950	94,800	36,620	24,530	56,910	520	101,210	62,410	98,160	23,430	619,780
1963	40,910	250	30,060	10,480	15,820	760	6,440	0	0	0	0	0	104,720
1964	0	740	27,970	103,280	0	33,340	0	0	17,830	8,200	67,170	3,260	261,790
1965	56,940	252,360	7,550	4,030	234,400	17,820	0	0	1,190	0	0	0	574,290
1966	730	74,890	630	188,020	387,220	0	0	0	9,300	32,450	0	2,500	695,740
1967	700	820	6,860	293,590	87,470	249,960	57,090	0	9,820	35,450	116,140	147,740	1,005,640
1968	97,250	58,890	316,940	218,750	297,760	212,500	16,930	17,590	43,770	9,680	115,110	210,770	1,615,940
1969	53,210	525,770	286,090	78,520	537,420	6,640	130	0	0	0	4,690	41,800	1,534,270
1970	53,290	121,310	241,860	167,770	26,580	6,380	0	0	5,190	101,320	24,590	3,630	751,920
1971	2,690	12,950	6,260	0	8,900	0	3,260	58,390	510	215,330	4,410	629,680	942,380
1972	15,820	3,800	6,580	600	670	720	0	0	0	2,610	171,040	78,660	280,500
1973	86,990	117,620	454,630	370,970	40,320	120,700	230	0	126,530	157,240	347,610	127,320	1,950,160
1974	124,100	8,090	1,810	27,090	9,700	199,640	0	0	124,540	0	335,470	135,770	966,210
1975	0	184,670	80,120	25,160	115,660	99,180	8,020	1,530	0	0	0	50	514,390
1976	0	0	13,820	119,950	88,690	48,370	212,910	0	4,540	17,810	9,360	107,930	623,380
1977	71,870	147,270	221,290	243,250	4,900	5,640	820	960	0	0	3,480	70	699,550
1978	8,980	29,360	93,380	4,740	11,290	460	0	0	0	0	0	0	148,210
1979	233,890	102,700	119,140	155,350	345,350	165,270	4,230	12,140	190	0	0	100,240	1,238,500
1980	127,780	109,090	1,220	56,900	117,050	7,630	0	0	0	35,320	350	55,080	510,420
1981	170	0	14,490	3,250	121,280	277,680	0	0	0	370,100	175,030	2,010	964,010
1982	0	44,550	73,630	45,750	580,500	181,410	27,740	7,490	820	1,320	130,930	414,990	1,509,130
1983	9,890	193,170	172,660	17,980	40,580	3,630	48,970	0	0	0	0	1,540	488,420
1984	1,410	52,530	329,520	21,180	75,220	480	0	270	50	88,060	29,160	115,680	713,560
1985	8,720	79,560	69,380	19,920	61,390	8,120	3,220	0	0	0	50,840	124,820	425,970
1986	130	81,410	3,090	111,140	36,010	84,870	45,290	0	2,360	11,630	61,110	38,270	475,310
1941-86 Avg.	54,123	89,121	102,829	110,071	145,711	67,468	18,301	3,305	17,705	32,288	55,383	76,221	772,526

Table E-12

Marvin Nichols II Reservoir Runoff, Including Spills from White Oak Creek Reservoir

- Values in Acre-Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	28,740	38,990	106,780	93,530	147,640	48,490	16,120	3,460	1,090	840	6,860	17,910	510,450
1942	2,870	7,640	25,250	319,240	55,380	30,840	2,360	2,050	2,840	420	1,890	31,640	482,420
1943	12,680	6,270	32,770	10,110	17,370	100,670	900	140	760	4,240	0	3,920	189,830
1944	14,290	28,760	105,680	23,010	208,810	27,470	470	0	3,290	520	8,220	35,640	456,160
1945	53,200	119,280	404,250	162,050	41,140	209,210	146,100	3,430	2,630	160,280	19,190	3,130	1,323,890
1946	208,610	305,290	89,560	46,240	349,840	185,490	2,340	2,970	6,190	1,490	191,300	104,760	1,494,080
1947	41,470	4,150	52,020	91,720	143,500	3,150	690	0	2,810	850	63,130	200,400	603,890
1948	2,100	107,250	115,670	20,070	251,520	2,440	3,010	1,580	870	1,290	2,180	1,500	559,480
1949	157,660	156,280	66,730	33,820	66,710	5,270	2,420	870	2,510	316,010	4,180	14,040	826,500
1950	94,440	267,110	52,430	11,230	152,630	12,730	14,480	11,970	82,300	830	350	530	701,030
1951	8,220	92,790	3,820	1,870	8,300	32,060	14,130	0	1,430	1,430	5,020	12,930	182,000
1952	35,060	13,060	18,950	217,420	51,040	2,970	4,720	0	0	0	35,250	82,730	461,200
1953	30,490	15,550	34,610	90,540	163,960	320	24,140	1,120	7,670	1,020	4,590	36,800	410,810
1954	81,640	41,240	2,980	4,340	65,300	110	0	0	0	35,450	22,840	2,550	256,450
1955	5,690	13,450	15,080	46,870	1,190	270	730	1,360	1,660	2,140	0	50	88,490
1956	260	35,400	940	300	20,730	0	0	0	0	0	17,050	0	74,680
1957	9,860	21,300	80,050	293,510	230,540	87,750	920	860	20,780	48,680	210,860	18,910	1,024,020
1958	94,220	3,170	68,090	213,170	220,420	52,320	51,110	2,050	17,170	2,030	13,090	5,060	741,900
1959	1,410	73,450	54,410	36,470	2,310	8,550	11,970	4,120	570	17,770	15,920	130,180	357,130
1960	109,260	29,580	31,540	1,800	730	7,500	8,290	610	8,870	17,570	8,880	179,510	4 04,140

Table E-12, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	72,770	49,620	73,810	43,150	1,400	23,880	17,930	4,060	3,250	920	33,660	59,290	383,740
1962	43,550	38,110	30,640	48,300	33,700	6,160	6,750	1,070	28,720	13,430	41,560	29,240	321,230
1963	25,680	2,290	6,830	9,910	49,760	6,700	2,680	270	10	0	0	150	104,280
1964	100	4,150	10,000	54,350	5,520	13,200	0	2,740	36,640	2,250	13,640	1,260	143,850
1965	4,390	124,980	10,070	3,610	160,320	26,760	20	0	2,820	40	0	20	333,030
1966	5,740	51,640	3,710	283,570	219,530	960	3,020	5,830	12,440	21,800	320	4,480	613,040
1967	3,750	5,070	9,180	65,640	72,200	72,780	5,620	290	1,570	12,030	78,560	65,680	392,370
1968	47,350	37,030	160,030	39,550	152,420	28,060	7,520	260	9,730	30	6,440	50,430	538,850
1969	16,510	173,880	124,160	52,150	199,230	1,880	210	0	0	0	680	8,350	577,050
1970	26,900	57,380	135,450	151,960	10,570	6,280	4,180	1,760	4,510	38,060	9,670	1,450	448,170
1971	3,640	19,870	8,700	570	910	150	18,250	11,630	960	40,950	2,620	327,450	435,700
1972	36,330	9,370	6,930	1,440	920	5,010	330	0	250	19,840	88,880	68,840	238,140
1973	51,550	71,800	179,410	185,020	8,620	72,590	4,020	0	26,770	57,650	203,580	96,070	957,080
1974	134,330	12,630	13,300	85,190	7,460	93,620	620	1,380	64,600	17,350	237,400	99,750	767,630
1975	16,450	214,270	88,760	47,960	136,610	55,550	4,150	3,290	90	100	0	290	567,520
1976	150	540	21,890	96,140	77,320	14,340	119,080	190	2,370	1,510	2,440	17,190	353,160
1977	14,460	76,120	168,740	95,050	2,340	8,750	680	830	0	100	54,030	4,280	425,380
1978	18,020	29,340	56,740	3,410	2,830	240	0	0	0	0	620	660	111,860
1979	60,720	27,400	57,260	87,230	141,830	26,150	9,180	28,470	8,320	440	4,390	78,940	530,330
1980	261,050	62,130	5,400	59,150	73,510	8,560	1,580	1,810	430	5,890	2,780	15,690	497,980
1981	650	2,800	4,390	2,140	89,060	2,300	260	130	137,310	23,980	1,480	467,960	
1982	1,160	5,630	20,250	3,990	44,790	19,620	50,410	670	90	290	24,030	232,720	403,650
1983	14,470	68,930	75,440	11,710	11,380	10,100	16,080	120	20	100	1,880	8,150	218,380
1984	4,600	28,410	90,190	14,380	710	230	190	90	40	99,470	28,940	138,350	405,600
1985	16,400	76,570	67,220	59,710	51,850	11,550	1,370	160	110	170	9,890	124,300	419,300
1986	2,050	103,770	2,500	134,500	49,090	54,830	2,310	210	130	0	11,410	23,280	384,080
1941-86 Avg.	41,847	59,429	60,709	72,980	82,673	34,544	12,682	2,217	7,988	23,535	32,874	50,869	482,347

APPENDIX F

EVAPORATION DATA

APPENDIX F

EVAPORATION DATA

Existing Tarrant County Water Control and Improvement District Number One Reservoirs

Evaporation data for the existing reservoirs operated as part of the Tarrant County Water Control and Improvement District Number One system - Bridgeport, Eagle Mountain, Benbrook, Arlington, Cedar Creek, and Richland-Chambers - have been developed in previous studies (1,2,14,44,56,57). For this study, data for Bridgeport, Eagle Mountain, Cedar Creek, and Richland-Chambers were updated and extended through 1986 using methodologies and data from Texas Water Development Board Report 64 and the Texas Water Oriented Data Bank (58,59). Table F-1 gives evaporation data for Lake Bridgeport and Eagle Mountain Lake, which have similar evaporative losses. Tables F-2, F-3, F-4, and F-5 give evaporation data for Lake Benbrook, Lake Arlington, Cedar Creek Reservoir, and Richland-Chambers Reservoir.

Proposed Reservoirs

Evaporation data for the proposed Tehuacana Reservoir are the same as those for Richland-Chambers and are also included in Table F-5. The data for Tennessee Colony Reservoir are from a Corps of Engineers project memorandum (43) and are given in Table F-6. Monthly net reservoir evaporation rates for the George Parkhouse I and II Reservoirs and the Marvin Nichols I and II Reservoirs were calculated for this study and are given in Tables F-7 and F-8. Methodologies and data from Texas Water

Development Board Report 64 and the Texas Water Oriented Data Bank (58,59) were used to develop the evaporation rates for these proposed reservoirs.

Table F-1

Lake Bridgeport and Eagle Mountain Lake Net Evaporation

- Values in Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0.13	0.04	0.45	0.16	0.23	0.18	0.68	0.56	0.58	0.46	-0.06	-0.04	3.37
1941	0.08	-0.11	0.17	-0.06	0.15	0.01	0.57	0.46	0.46	-0.40	0.21	0.12	1.66
1942	0.17	0.20	0.32	-0.37	0.37	0.38	0.77	0.58	0.34	0.01	0.32	0.06	3.15
1943	0.19	0.26	0.09	0.27	0.12	0.44	0.83	1.01	0.57	0.43	0.30	-0.08	4.43
1944	-0.02	-0.10	0.16	0.23	0.16	0.64	0.67	0.75	0.56	0.20	0.07	0.03	3.35
1945	0.05	-0.09	-0.10	0.05	0.52	0.31	0.35	0.67	0.39	0.26	0.33	0.20	2.94
1946	-0.07	0.11	0.16	0.30	0.13	0.53	0.88	0.79	0.27	0.34	-0.01	-0.07	3.36
1947	0.14	0.20	0.11	-0.01	0.04	0.46	0.84	0.96	0.79	0.46	0.12	0.03	4.14
1948	0.13	-0.11	0.18	0.44	0.08	0.32	0.72	0.88	0.84	0.48	0.45	0.28	4.69
1949	-0.15	-0.01	0.17	0.21	-0.07	0.41	0.73	0.65	0.23	0.13	0.35	0.11	2.76
1950	0.08	0.10	0.42	0.12	-0.04	0.32	-0.06	0.28	0.15	0.58	0.47	0.26	2.68
1951	0.19	0.02	0.26	0.33	0.04	0.11	0.67	0.84	0.58	0.42	0.23	0.26	3.95
1952	0.18	0.20	0.19	0.15	0.16	0.70	0.80	1.17	0.90	0.76	0.26	0.10	5.57
1953	0.18	0.16	0.12	0.22	0.32	0.78	0.66	0.64	0.77	0.06	0.20	0.25	4.36
1954	0.08	0.34	0.25	0.05	-0.13	0.44	0.94	1.13	0.98	0.53	0.38	0.16	5.15
1955	0.09	0.13	0.26	0.25	0.07	0.14	0.71	0.87	0.30	0.56	0.53	0.31	4.22
1956	0.13	0.16	0.45	0.45	0.26	0.77	1.03	1.08	1.09	0.34	0.28	0.12	6.16
1957	0.13	-0.07	0.06	-0.50	-0.54	0.29	0.77	0.98	0.60	0.26	-0.15	0.22	2.05
1958	0.03	0.10	-0.08	0.00	-0.01	0.47	0.45	0.74	0.47	0.41	0.28	0.17	3.03
1959	0.15	0.16	0.35	0.30	0.20	-0.05	0.27	0.64	0.57	0.01	0.31	0.02	2.93
1960	0.01	0.08	0.16	0.24	0.20	0.51	0.44	0.58	0.45	0.08	0.39	-0.05	3.09

Table F-1, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	0.05	0.02	0.04	0.32	0.24	0.02	0.46	0.58	0.27	0.29	0.11	0.11	2.51
1962	0.13	0.20	0.20	-0.03	0.44	-0.04	0.25	0.65	-0.13	0.32	0.14	0.17	2.30
1963	0.15	0.17	0.19	0.08	0.13	0.34	0.44	0.65	0.40	0.42	0.18	0.13	3.28
1964	0.05	0.09	0.15	0.13	0.00	0.40	0.75	0.51	0.08	0.42	-0.05	0.16	2.69
1965	0.04	0.07	0.17	0.09	-0.24	0.21	0.53	0.39	0.37	0.19	0.25	0.18	2.25
1966	-0.01	0.01	0.29	0.06	0.13	0.37	0.76	0.49	0.00	0.36	0.24	0.09	2.79
1967	0.23	0.09	0.16	-0.03	0.20	0.54	0.59	0.73	0.25	0.46	0.10	0.06	3.38
1968	0.01	0.02	0.03	0.15	0.08	0.41	0.46	0.58	0.37	0.30	0.26	0.16	2.83
1969	0.04	0.08	0.09	-0.08	0.21	0.49	0.59	0.26	0.10	0.30	0.23	0.12	2.43
1970	0.10	0.09	0.04	0.01	0.12	0.37	0.73	0.70	0.20	0.24	0.34	0.19	3.13
1971	0.17	0.15	0.37	0.34	0.35	0.64	0.64	0.24	0.30	0.10	0.21	-0.03	3.48
1972	0.15	0.17	0.39	0.29	0.27	0.52	0.69	0.55	0.37	0.20	0.10	0.14	3.84
1973	-0.05	0.01	0.11	0.09	0.39	0.30	0.33	0.70	0.17	0.18	0.14	0.26	2.63
1974	0.13	0.16	0.28	0.27	0.46	0.63	0.84	0.41	0.10	0.18	0.17	0.08	3.71
1975	0.10	-0.01	0.13	0.22	0.15	0.41	0.39	0.60	0.35	0.50	0.25	0.13	3.22
1976	0.25	0.35	0.28	0.11	0.19	0.49	0.38	0.61	0.19	0.09	0.21	0.12	3.27
1977	-0.02	0.13	0.19	0.24	0.23	0.58	0.76	0.51	0.62	0.46	0.25	0.33	4.28
1978	0.04	-0.06	0.21	0.34	0.30	0.51	0.93	0.49	0.43	0.46	0.03	0.20	3.88
1979	-0.03	0.05	0.10	0.16	0.19	0.43	0.57	0.48	0.54	0.48	0.22	0.05	3.24
1980	0.05	0.08	0.29	0.36	0.20	0.73	1.06	0.97	0.45	0.38	0.17	0.08	4.82

Table F-1, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981	0.19	0.07	0.11	0.15	0.18	0.34	0.73	0.62	0.41	-0.13	0.18	0.20	3.05
1982	0.05	0.05	0.14	0.21	0.02	0.22	0.55	0.71	0.56	0.35	0.12	0.07	3.05
1983	0.04	0.05	0.08	0.25	0.23	0.28	0.70	0.78	0.76	0.25	0.18	0.12	3.72
1984	0.10	0.13	0.15	0.44	0.43	0.64	0.80	0.64	0.60	0.11	0.12	-0.02	4.14
1985	0.03	0.02	0.09	0.23	0.34	0.47	0.64	0.84	0.48	0.15	0.12	0.09	3.50
1986	0.32	0.17	0.28	0.20	0.20	0.29	0.86	0.63	0.32	0.10	0.05	0.00	3.42
1940-86 Avg.	0.09	0.09	0.19	0.16	0.16	0.40	0.64	0.67	0.44	0.29	0.20	0.12	3.45

<u>Table F-2</u>

<u>Lake Benbrook Net Evaporation</u>

- Values in Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1941	0.13	-0.16	0.11	-0.13	0.17	0.07	0.49	0.30	0.57	0.01	0.29	0.07	1.92
1942	0.18	0.23	0.36	-0.54	0.13	0.25	0.68	0.47	0.23	-0.01	0.36	0.11	2.45
1943	0.21	0.29	0.12	0.32	0.02	0.43	0.80	0.94	0.34	0.47	0.34	-0.08	4.20
1944	-0.06	-0.13	0.14	0.17	-0.22	0.65	0.71	0.68	0.59	0.40	0.10	0.04	3.07
1945	0.06	-0.23	-0.17	-0.03	0.23	0.30	0.30	0.63	0.80	0.22	0.27	0.20	2.58
1946	-0.06	0.04	0.07	0.25	-0.13	0.51	0.85	0.61	0.32	0.46	-0.06	0.10	2.96
1947	0.07	0.27	0.11	0.08	0.22	0.42	0.84	0.67	0.69	0.56	0.23	-0.08	4.08
1948	0.07	-0.20	0.24	0.37	0.10	0.37	0.55	0.86	0.67	0.52	0.49	0.27	4.31
1949	-0.22	-0.07	0.12	0.05	-0.16	0.27	0.66	0.57	0.53	0.04	0.40	0.12	2.31
1950	-0.04	-0.03	0.39	0.09	0.14	0.26	0.30	0.65	0.29	0.56	0.52	0.34	3.47
1951	0.19	-0.01	0.28	0.28	0.09	0.06	0.73	0.80	0.57	0.51	0.27	0.27	4.04
1952	0.18	0.15	0.17	-0.13	0.10	0.74	0.81	1.08	0.76	0.72	-0.15	-0.08	4.35
1953	0.23	0.14	0.08	0.10	0.13	0.85	0.55	0.53	0.63	0.10	0.15	0.18	3.67
1954	0.02	0.25	0.29	0.14	0.12	0.69	0.81	1.13	0.92	0.44	0.22	0.35	5.38
1955	0.08	0.02	0.25	0.22	-0.07	0.13	0.72	0.68	0.46	0.64	0.47	0.22	3.82
1956	0.03	-0.03	0.34	0.24	0.29	0.74	1.07	1.12	0.98	0.57	0.43	0.17	5.95
1957	0.12	-0.06	0.03	-0.63	-0.51	0.36	0.86	1.01	0.43	0.04	-0.13	0.18	1.70
1958	0.03	0.06	-0.09	-0.19	0.08	0.56	0.58	0.71	0.31	0.35	0.25	0.15	2.80
1959	0.18	0.01	0.36	0.21	0.16	0.09	0.38	0.75	0.64	-0.21	0.30	0.02	2.89
1960	-0.03	0.05	0.17	0.20	0.26	0.44	0.57	0.65	0.69	0.31	0.36	-0.20	3.47

Table F-2, continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1961	-0.19	-0.08	0.12	0.34	0.39	-0.03	0.48	0.77	0.46	0.28	0.16	0.07	2.77
1962	0.13	0.16	0.23	0.02	0.54	0.09	0.39	0.76	0.13	0.28	0.15	0.15	3.03
1963	0.14	0.19	0.29	0.04	0.16	0.42	0.94	0.86	0.53	0.59	0.14	0.10	4.40
1964	-0.07	0.07	0.03	0.13	0.24	0.53	0.96	0.67	0.07	0.37	-0.08	0.20	3.12
1965	0.00	-0.14	0.16	0.17	-0.34	0.42	0.86	0.60	0.48	0.29	0.12	0.04	2.66
1966	-0.01	-0.02	0.17	0.11	0.20	0.45	0.53	0.45	0.12	0.31	0.26	0.16	2.73
1967	0.22	0.14	0.28	0.11	0.25	0.42	0.55	0.66	0.28	0.15	0.11	0.10	3.27
1968	0.01	0.02	0.07	0.17	0.09	0.38	0.60	0.66	0.25	0.36	0.22	0.18	3.01
1969	0.06	0.05	0.08	-0.08	0.06	0.44	0.79	0.45	0.22	0.36	0.22	0.11	2.76
1970	0.08	0.07	0.04	0.02	0.20	0.49	0.65	0.75	0.14	0.08	0.27	0.13	2.92
1971	0.22	0.15	0.37	0.28	0.36	0.61	0.54	0.28	0.40	0.13	0.21	-0.01	3.54
1972	0.07	0.21	0.39	0.30	0.28	0.46	0.58	0.53	0.37	0.19	0.09	0.12	3.59
1973	-0.06	-0.01	0.14	0.02	0.31	0.22	0.36	0.70	0.22	0.10	0.18	0.24	2.42
1974	0.06	0.18	0.29	0.27	0.31	0.49	0.80	0.33	0.08	0.11	0.04	0.04	3.00
1975	0.05	-0.02	0.12	0.12	0.07	0.36	0.46	0.62	0.48	0.48	0.30	0.12	3.16
1976	0.25	0.31	0.25	0.06	0.16	0.43	0.31	0.56	0.20	0.09	0.19	0.08	2.89
1977	-0.03	0.14	0.10	0.14	0.30	0.51	0.81	0.62	0.71	0.47	0.19	0.33	4.29
1978	0.04	-0.06	0.25	0.24	0.27	0.67	0.98	0.66	0.43	0.56	0.00	0.21	4.25
1979	0.06	0.05	-0.15	-0.21	-0.30	0.45	0.60	0.16	0.52	0.45	0.27	-0.01	1.89
1980	0.00	0.31	0.25	0.19	0.18	0.85	1.05	1.01	0.33	0.51	0.25	0.09	5.02
1941-80 Avg.	0.06	0.06	0.17	0.09	0.12	0.42	0.66	0.67	0.45	0.32	0.21	0.12	3.35

Table F-3

Lake Arlington Net Evaporation

- Values in Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	0.12	-0.11	0.12	-0.10	0.21	-0.02	0.53	0.35	0.53	-0.10	0.24	0.07	1.84
1942	0.16	0.19	0.32	-0.53	0.17	0.26	0.69	0.47	0.27	0.04	0.31	0.07	2.42
1943	0.20	0.26	0.07	0.31	0.00	0.38	0.76	0.93	0.39	0.39	0.30	-0.08	3.91
1944	-0.04	-0.14	0.13	0.17	-0.14	0.62	0.66	0.66	0.55	0.34	0.06	0.01	2.88
1945	0.07	-2.00	-0.20	0.01	0.33	0.27	0.24	0.60	0.53	0.19	0.26	0.18	0.48
1946	-0.07	0.04	0.10	0.21	-0.12	0.44	0.77	0.58	0.30	0.40	-0.14	0.03	2.54
1947	0.09	0.23	0.10	0.03	0.18	0.36	0.81	0.70	0.65	0.44	0.17	-0.07	3.69
1948	0.06	-0.16	0.19	0.38	0.03	0.38	0.56	0.81	0.68	0.47	0.44	0.25	4.09
1949	-0.21	-0.04	0.12	0.11	-0.07	0.30	0.59	0.55	0.39	0.01	0.37	0.10	2.22
1950	-0.05	-0.02	0.36	0.06	0.04	0.24	0.13	0.48	0.19	0.53	0.48	0.30	2.74
1951	0.19	-0.04	0.29	0.29	0.12	0.04	0.64	0.81	0.49	0.40	0.26	0.24	3.73
1952	0.18	0.14	0.13	-0.06	0.11	0.65	0.77	0.96	0.73	0.68	0.04	-0.04	4.29
1953	0.20	0.12	0.06	0.06	0.15	0.74	0.53	0.59	0.62	0.12	0.13	0.19	3.51
1954	0.00	0.29	0.34	0.12	0.04	0.56	0.88	1.03	0.86	0.33	0.27	0.25	4.97
1955	0.10	0.05	0.21	0.20	0.05	0.15	0.69	0.63	0.40	0.61	0.46	0.25	3.80
1956	0.10	0.02	0.36	0.31	0.26	0.68	1.02	1.08	1.00	0.47	0.33	0.14	5.77
1957	0.11	-0.02	0.01	-0.61	-0.44	0.33	0.76	0.81	0.38	0.12	-0.13	0.19	1.51
1958	0.03	0.10	-0.08	-0.15	0.04	0.51	0.54	0.66	0.30	0.34	0.24	0.15	2.68
1959	0.19	0.06	0.32	0.22	0.15	0.05	0.28	0.64	0.54	-0.11	0.31	0.03	2.68
1960	-0.02	0.06	0.17	0.24	0.25	0.41	0.46	0.50	0.54	0.20	0.33	-0.17	2.97

Table F-3, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	-0.09	-0.03	0.04	0.31	0.27	-0.01	0.43	0.64	0.32	0.24	0.11	0.09	2.32
1962	0.12	0.15	0.20	-0.03	0.45	0.00	0.34	0.63	-0.04	0.23	0.12	0.20	2.37
1963	0.15	0.19	0.24	0.01	0.14	0.37	0.67	0.75	0.50	0.54	0.20	0.10	3.86
1964	0.01	0.10	0.04	0.10	0.11	0.47	0.88	0.60	0.03	0.41	-0.06	0.19	2.88
1965	0.02	-0.09	0.14	0.16	-0.27	0.30	0.66	0.49	0.31	0.28	0.15	0.10	2.25
1966	-0.04	-0.01	0.19	0.02	0.13	0.40	0.53	0.40	0.05	0.30	0.25	0.10	2.32
1967	0.20	0.10	0.21	0.06	0.13	0.46	0.52	0.61	0.22	0.19	0.08	0.04	2.82
1968	0.01	0.03	0.03	0.11	0.08	0.32	0.47	0.58	0.26	0.28	0.19	0.16	2.52
1969	0.04	0.01	0.04	-0.08	0.05	0.45	0.75	0.41	0.24	0.33	0.23	0.08	2.55
1970	0.09	0.04	0.05	-0.03	0.15	0.45	0.64	0.71	0.11	0.16	0.30	0.17	2.84
1971	0.19	0.13	0.35	0.28	0.31	0.60	0.54	0.26	0.35	0.10	0.20	-0.04	3.27
1972	0.09	0.19	0.36	0.26	0.29	0.48	0.65	0.55	0.35	0.20	0.08	0.10	3.60
1973	-0.07	-0.01	0.12	0.03	0.32	0.23	0.33	0.68	0.18	0.11	0.14	0.23	2.29
1974	0.06	0.17	0.28	0.27	0.34	0.49	0.81	0.34	0.07	0.12	0.06	0.04	3.05
1975	0.05	-0.03	0.08	0.16	0.10	0.36	0.42	0.59	0.44	0.49	0.27	0.11	3.04
1976	0.25	0.31	0.23	0.07	0.15	0.42	0.33	0.59	0.19	0.10	0.19	0.09	2.92
1977	-0.04	0.12	0.11	0.18	0.30	0.53	0.79	0.55	0.62	0.46	0.19	0.31	4.12
1978	0.02	-0.07	0.22	0.26	0.24	0.56	0.95	0.60	0.43	0.53	0.00	0.17	3.91
1979	-0.12	-0.04	-0.34	0.15	-0.30	0.44	0.63	0.29	0.46	0.40	0.24	-0.13	1.68
1980	0.03	0.16	0.31	0.18	-0.05	0.77	1.08	1.04	0.26	0.41	0.23	0.08	4.50
1941-80 Avg.	0.06	0.01	0.15	0.09	0.11	0.39	0.62	0.63	0.39	0.29	0.20	0.11	3.05 3.05

Table F-4

Cedar Creek Reservoir Net Evaporation

- Values In Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	0.06	-0.07	0.03	0.02	0.18	-0.16	0.34	0.41	0.32	0.09	0.13	0.01	1.36
1942	0.09	0.13	0.18	-0.38	0.14	0.16	0.50	0.32	0.21	0.16	0.15	-0.07	1.59
1943	0.12	0.23	0.04	0.24	-0.10	0.24	0.53	0.69	0.26	0.09	0.24	-0.05	2.53
1944	-0.09	-0.12	0.01	0.10	-0.30	0.44	0.51	0.44	0.42	0.38	-0.08	-0.18	1.53
1945	0.00	-0.12	-0.50	0.07	0.28	0.10	0.10	0.32	0.42	0.07	0.18	0.10	1.02
1946	-0.17	-0.02	0.04	0.09	-0.21	0.30	0.54	0.22	0.34	0.28	-0.28	0.07	1.20
1947	-0.06	0.14	0.02	-0.03	0.17	0.25	0.64	0.42	0.38	0.34	0.08	-0.11	2.24
1948	-0.07	-0.08	0.04	0.21	-0.03	0.44	0.61	0.69	0.61	0.34	0.15	0.06	2.97
1949	-0.34	-0.11	0.04	-0.05	0.14	0.31	0.35	0.41	0.44	-0.27	0.29	0.01	1.22
1950	-0.14	-0.27	0.22	-0.09	-0.07	0.30	0.24	0.47	0.12	0.31	0.30	0.22	1.61
1951	0.06	-0.09	0.19	0.21	0.23	0.13	0.53	0.76	0.01	0.24	0.19	0.07	2.53
1952	0.11	0.00	0.05	-0.15	-0.01	0.43	0.49	0.86	0.73	0.62	-0.17	-0.15	2.81
1953	0.12	0.05	-0.04	-0.05	-0.08	0.54	0.22	0.39	0.36	0.28	0.07	-0.06	1.80
1954	-0.08	0.19	0.21	0.06	-0.03	0.49	0.84	0.91	0.68	0.01	0.12	0.16	3.56
1955	0.03	-0.11	0.05	0.07	0.07	0.33	0.46	0.08	0.18	0.49	0.37	0.16	2.18
1956	0.03	-0.09	0.29	0.18	0.14	0.41	0.82	0.74	0.66	0.37	0.16	0.15	3.86
1957	0.05	-0.02	-0.05	-0.68	-0.18	0.14	0.53	0.38	0.22	-0.05	-0.17	0.12	0.29
1958	0.03	0.10	0.02	-0.20	0.13	0.31	0.38	0.34	-0.10	0.22	0.17	0.17	1.57
1959	0.23	-0.05	0.19	-0.01	-0.14	-0.03	0.20	0.38	0.29	0.00	0.30	-0.11	1.25
1960	-0.07	0.01	0.13	0.18	0.28	0.13	0.30	0.28	0.35	0.12	0.16	-0.39	1.48

Table F-4, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	-0.14	-0.05	-0.02	0.28	0.20	-0.08	0.33	0.48	0.24	0.29	-0.04	0.02	1.51
1962	0.01	-0.01	0.15	-0.09	0.28	-0.01	0.25	0.54	0.03	0.03	0.04	0.11	1.33
1963	0.12	0.16	0.12	-0.17	0.10	0.30	0.49	0.66	0.44	0.60	0.25	0.09	3.16
1964	0.11	0.04	0.00	0.03	0.03	0.37	0.68	0.49	0.10	0.41	0.05	0.11	2.42
1965	0.03	-0.18	0.04	0.19	-0.41	0.27	0.60	0.51	0.12	0.28	0.06	0.00	1.51
1966	-0.01	-0.05	0.09	-0.22	0.06	0.36	0.45	0.21	-0.04	0.24	0.24	0.11	1.44
1967	0.09	0.06	0.17	-0.12	-0.06	0.38	0.35	0.43	0.03	0.11	0.10	0.04	1.58
1968	0.02	0.04	0.00	0.00	-0.01	0.27	0.31	0.60	0.27	0.26	0.18	0.10	2.04
1969	-0.01	-0.02	0.02	-0.01	-0.27	0.41	0.69	0.55	0.36	0.33	0.15	0.02	2.22
1970	0.05	-0.07	-0.05	-0.09	0.04	0.40	0.66	0.62	0.26	0.13	0.26	0.04	2.25
1971	0.22	0.06	0.28	0.26	0.27	0.56	0.46	0.29	0.38	0.12	0.16	-0.07	2.99
1972	-0.02	0.19	0.24	0.21	0.35	0.32	0.52	0.55	0.30	0.19	0.01	0.03	2.89
1973	-0.07	-0.01	0.07	-0.05	0.28	0.18	0.34	0.60	0.14	0.08	0.09	0.13	1.78
1974	-0.10	0.15	0.22	0.25	0.21	0.34	0.67	0.29	0.04	0.12	0.00	0.00	2.19
1975	0.02	-0.04	0.04	0.08	0.09	0.31	0.43	0.56	0.46	0.38	0.22	0.07	2.62
1976	0.17	0.21	0.10	0.05	0.11	0.27	0.25	0.52	0.05	0.09	0.17	0.02	2.01
1977	-0.07	0.04	0.09	0.12	0.34	0.41	0.68	0.47	0.46	0.39	0.07	0.19	3.19
1978	-0.05	-0.07	0.14	0.26	0.19	0.50	0.76	0.57	0.34	0.46	-0.03	0.06	3.13
1979	-0.08	-0.03	0.06	0.14	0.15	0.42	0.40	0.40	0.35	0.39	0.21	0.01	2.42
1980	-0.06	0.07	0.16	0.15	0.18	0.51	0.82	0.78	0.43	0.36	0.15	0.08	3.63

Table F-4, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981	0.10	0.08	0.10	0.22	0.13	0.18	0.49	0.58	0.38	0.08	0.13	0.21	2.68
1982	0.02	0.02	0.11	0.10	0.13	0.21	0.51	0.63	0.57	0.22	0.03	-0.02	2.53
1983	0.12	-0.05	0.07	0.32	0.16	0.24	0.50	0.45	0.50	0.28	0.11	0.05	2.75
1984	0.06	0.08	0.08	0.33	0.38	0.47	0.65	0.66	0.54	0.12	0.11	-0.02	3.46
1985	0.04	0.02	0.11	0.21	0.30	0.40	0.55	0.77	0.45	0.16	0.09	0.09	3.19
1986	0.23	0.02	0.31	0.05	0.14	0.19	0.64	0.55	0.29	0.12	-0.03	-0.03	2.48
1941-86 Avg.	0.02	0.01	0.08	0.05	0.09	0.29	0.49	0.51	0.31	0.22	0.11	0.04	2.22

Table F-5

Richland-Chambers and Tehuacana Reservoirs Net Evaporation

- Values in Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1940	0.04	-0.06	0.23	-0.01	0.09	0.08	0.31	0.43	0.46	0.29	-0.42	-0.14	1.30
1941	0.04	-0.10	0.02	0.06	0.11	-0.08	0.33	0.44	0.33	0.03	0.17	0.00	1.35
1942	0.12	0.12	0.23	-0.31	0.06	0.17	0.45	0.38	0.15	0.17	0.15	-0.04	1.65
1943	0.08	0.22	0.04	0.23	0.07	0.25	0.43	0.64	0.22	0.17	0.20	-0.06	2.49
1944	-0.19	-0.15	-0.02	0.10	-0.36	0.39	0.54	0.46	0.45	0.43	-0.16	-0.16	1.33
1945	-0.03	-0.11	-0.37	-0.05	0.25	0.13	0.14	0.20	0.49	0.02	0.21	0.04	0.92
1946	-0.18	-0.07	-0.04	0.13	-0.23	0.28	0.53	0.31	0.40	0.30	-0.33	0.09	1.19
1947	-0.11	0.15	-0.04	0.03	0.00	0.28	0.59	0.47	0.45	0.42	0.08	-0.11	2.21
1948	-0.10	-0.11	0.06	0.15	0.00	0.42	0.56	0.67	0.58	0.40	0.16	0.08	2.87
1949	-0.30	-0.07	0.02	-0.05	0.15	0.25	0.37	0.37	0.43	-0.23	0.32	-0.04	1.22
1950	-0.10	-0.22	0.23	-0.05	-0.02	0.26	0.30	0.50	0.17	0.35	0.33	0.23	1.98
1951	0.12	-0.06	0.20	0.27	0.25	0.20	0.67	0.87	0.08	0.33	0.20	0.12	3.25
1952	0.08	-0.03	0.06	-0.15	-0.02	0.44	0.45	0.81	0.70	0.62	-0.17	-0.15	2.64
1953	0.10	-0.01	-0.08	-0.10	-0.18	0.50	0.31	0.39	0.35	0.19	0.10	-0.13	1.44
1954	-0.05	0.21	0.22	0.07	-0.01	0.52	0.79	0.85	0.72	0.05	0.14	0.17	3.68
1955	0.01	-0.13	0.08	-0.02	0.07	0.29	0.44	0.21	0.25	0.51	0.40	0.16	2.27
1956	0.02	-0.10	0.21	0.16	0.12	0.38	0.78	0.70	0.65	0.42	0.14	0.12	3.60
1957	0.06	-0.05	-0.10	-0.70	-0.11	0.13	0.54	0.31	0.24	-0.14	-0.17	0.12	0.13
1958	0.00	0.03	0.06	-0.10	0.12	0.29	0.41	0.27	-0.16	0.19	0.16	0.13	1.40
1959	0.20	-0.06	0.21	-0.08	-0.16	0.00	0.15	0.33	0.27	0.04	0.25	-0.08	1.07
1960	-0.07	-0.01	0.11	0.14	0.27	0.03	0.37	0.23	0.38	0.00	0.03	-0.35	1.13

Table F-5, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	-0.19	-0.09	-0.03	0.26	0.21	-0.09	0.24	0.45	0.18	0.29	0.02	-0.02	1.23
1962	-0.02	0.02	0.15	-0.09	0.26	-0.04	0.40	0.57	0.08	0.09	0.03	0.05	1.50
1963	0.09	0.10	0.13	-0.12	0.10	0.27	0.48	0.63	0.39	0.53	0.17	0.04	2.81
1964	0.07	0.04	0.01	0.03	0.11	0.37	0.66	0.45	0.15	0.38	0.06	0.11	2.44
1965	0.03	-0.15	0.01	0.19	-0.38	0.29	0.62	0.54	0.18	0.29	0.02	-0.07	1.57
1966	0.03	0.00	0.12	-0.15	0.05	0.36	0.46	0.27	-0.02	0.31	0.30	0.20	1.93
1967	0.09	0.15	0.25	-0.01	0.04	0.31	0.41	0.53	0.07	0.22	0.10	0.08	2.24
1968	0.00	0.02	0.03	-0.02	-0.07	0.18	0.33	0.47	0.19	0.25	0.13	0.09	1.60
1969	0.05	-0.01	0.03	0.01	-0.16	0.43	0.70	0.56	0.28	0.34	0.22	0.06	2.51
1970	0.02	-0.05	0.04	-0.18	0.11	0.46	0.68	0.57	0.21	0.19	0.32	0.10	2.47
1971	0.22	0.09	0.31	0.24	0.21	0.49	0.48	0.25	0.36	0.13	0.17	-0.05	2.90
1972	-0.01	0.19	0.22	0.19	0.29	0.31	0.44	0.51	0.29	0.19	0.03	0.03	2.68
1973	-0.06	0.00	0.06	-0.03	0.25	0.16	0.34	0.52	0.17	0.06	0.13	0.13	1.73
1974	-0.09	0.17	0.20	0.25	0.21	0.41	0.63	0.30	0.07	0.12	0.00	0.01	2.28
1975	0.03	-0.03	0.06	0.08	0.06	0.31	0.42	0.52	0.40	0.29	0.23	0.07	2.44
1976	0.16	0.20	0.10	0.04	0.11	0.26	0.25	0.54	0.08	0.07	0.13	-0.01	1.93
1977	-0.06	0.05	0.10	0.11	0.33	0.39	0.70	0.50	0.45	0.39	0.09	0.18	3.23
1978	-0.06	-0.06	0.17	0.26	0.22	0.47	0.73	0.60	0.29	0.43	-0.02	0.05	3.08
1979	-0.07	-0.04	0.06	0.10	0.10	0.39	0.32	0.40	0.32	0.39	0.17	0.00	2.14
1980	-0.03	0.07	0.14	0.14	0.15	0.54	0.79	0.77	0.43	0.36	0.12	0.10	3.58

Table F-5, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981	0.10	0.05	0.09	0.20	0.14	0.16	0.46	0.57	0.32	0.08	0.15	0.20	2.52
1982	0.04	0.05	0.10	0.08	0.14	0.25	0.50	0.62	0.56	0.24	0.02	0.00	2.60
1983	0.10	-0.05	0.07	0.34	0.17	0.26	0.46	0.37	0.42	0.29	0.11	0.03	2.57
1984	0.06	0.10	0.11	0.38	0.39	0.40	0.59	0.62	0.51	0.05	0.11	0.00	3.32
1985	0.05	0.03	0.11	0.21	0.31	0.37	0.52	0.76	0.45	0.14	0.09	0.09	3.13
1986	0.21	0.04	0.31	0.09	0.13	0.19	0.67	0.53	0.28	0.12	-0.03	-0.05	2.49
1940-86 Avg.	0.01	0.01	0.09	0.05	0.08	0.28	0.48	0.49	0.31	0.23	0.10	0.03	2.16

Table F-6

Tennessee Colony Reservoir Net Evaporation

- Values in Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	0.02	-0.09	0.05	0.14	0.20	-0.02	0.30	0.51	0.27	0.07	0.06	-0.02	1.49
1942	0.15	0.15	0.31	-0.23	0.12	0.25	0.40	0.40	0.08	0.12	0.12	-0.09	1.78
1943	0.08	0.27	0.08	0.30	-0.14	0.38	0.51	0.60	0.15	0.04	0.17	-0.14	2.30
1944	-0.20	-0.19	0.09	0.23	-0.19	0.52	0.48	0.53	0.41	0.37	-0.19	-0.29	1.57
1945	-0.03	-0.02	-0.27	0.11	0.42	0.31	0.16	0.22	0.27	-0.05	0.18	0.03	1.33
1946	-0.13	-0.01	0.10	0.13	0.02	0.37	0.55	0.28	0.29	0.19	-0.24	0.04	1.59
1947	-0.15	0.13	0.01	0.07	0.09	0.38	0.67	0.49	0.40	0.36	0.05	-0.09	2.41
1948	-0.14	-0.11	0.10	0.31	0.11	0.54	0.64	0.70	0.49	0.31	0.06	0.02	3.03
1949	-0.21	-0.06	0.09	0.15	0.31	0.41	0.28	0.37	0.37	-0.32	0.26	0.01	1.66
1950	-0.11	-0.21	0.29	-0.01	0.13	0.33	0.34	0.47	0.17	0.29	0.27	0.18	2.14
1951	0.02	-0.07	0.25	0.32	0.35	0.28	0.56	0.63	0.07	0.25	0.12	0.13	2.91
1952	0.06	0.00	0.06	-0.02	0.08	0.48	0.44	0.74	0.57	0.51	-0.24	-0.14	2.54
1953	0.15	0.08	-0.06	0.18	-0.15	0.55	0.44	0.39	0.29	0.14	0.04	-0.15	1.90
1954	0.02	0.30	0.33	0.16	0.10	0.61	0.81	0.82	0.60	-0.05	0.07	0.12	3.89
1955	-0.01	-0.11	0.22	0.15	0.27	0.34	0.55	0.03	0.13	0.37	0.37	0.13	2.44
1956	-0.01	-0.07	0.37	0.27	0.19	0.38	0.83	0.64	0.51	0.38	-0.03	0.11	3.57
1957	0.09	0.00	0.08	-0.39	0.10	0.26	0.38	0.24	0.19	0.00	0.00	0.00	0.95
1958	0.07	0.09	0.14	0.17	0.19	0.24	0.27	0.26	0.20	0.16	0.11	0.08	1.98
1959	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.22
1960	0.04	0.05	0.08	0.10	0.11	0.14	0.15	0.15	0.11	0.09	0.06	0.04	1.12

Table F-6, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	0.02	0.02	0.04	0.05	0.05	0.06	0.07	0.07	0.05	0.04	0.03	0.02	0.52
1962	0.07	0.08	0.13	0.16	0.18	0.22	0.26	0.25	0.45	0.38	0.21	0.13	2.52
1963	0.09	0.21	0.34	0.02	0.16	0.50	0.70	0.64	0.37	0.45	0.01	0.03	3.52
1964	-0.03	0.06	0.09	0.25	0.27	0.47	0.76	0.45	0.21	0.30	-0.02	0.12	2.93
1965	-0.05	-0.12	0.13	0.35	-0.42	0.39	0.74	0.46	0.00	0.08	-0.04	-0.03	1.49
1966	0.00	-0.01	0.24	0.61	0.06	0.47	0.58	0.10	0.20	0.30	0.27	0.05	2.87
1967	0.19	0.19	0.37	0.15	0.31	0.29	0.52	0.63	-0.42	-0.16	-0.08	-0.15	1.84
1968	-0.23	-0.04	0.02	-0.13	-0.19	0.00	0.44	0.53	0.09	0.28	-0.06	-0.06	0.65
1969	0.12	-0.08	-0.09	-0.02	-0.07	0.64	0.73	0.30	0.39	0.03	-0.13	-0.27	1.55
1941-69 Avg.	0.00	0.02	0.12	0.12	0.09	0.34	0.47	0.41	0.24	0.17	0.05	-0.01	2.02

Table F-7

George Parkhouse I and II Reservoirs Net Evaporation

- Values in Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	0.10	-0.01	0.05	-0.15	0.17	-0.09	0.22	0.38	0.38	0.00	0.14	0.01	1.20
1942	0.13	0.13	0.14	-0.39	0.13	0.18	0.55	0.33	0.24	0.21	0.16	-0.10	1.71
1943	-0.03	0.20	0.02	0.20	0.11	0.26	0.55	0.68	0.38	0.22	0.19	-0.04	2.74
1944	-0.02	-0.16	0.00	0.13	-0.21	0.39	0.46	0.34	0.40	0.35	-0.11	-0.15	1.42
1945	0.05	-0.27	-0.50	0.12	0.23	-0.01	0.19	0.36	0.26	0.10	0.20	0.15	0.88
1946	-0.15	-0.04	0.03	0.03	-0.26	0.32	0.51	0.34	0.27	0.28	-0.34	0.00	0.99
1947	0.03	0.18	-0.01	-0.12	0.12	0.31	0.58	0.40	0.32	0.28	0.02	-0.17	1.94
1948	-0.05	-0.13	0.03	0.25	-0.20	0.41	0.43	0.59	0.55	0.24	0.19	0.09	2.40
1949	-0.44	-0.13	0.02	-0.03	0.25	0.20	0.32	0.39	0.34	-0.24	0.26	-0.01	0.93
1950	-0.25	-0.25	0.18	0.02	-0.26	0.33	-0.05	0.31	-0.10	0.30	0.31	0.21	0.75
1951	0.03	-0.18	0.23	0.16	0.20	-0.10	0.40	0.46	-0.01	0.15	0.13	0.13	1.60
1952	0.06	0.08	-0.03	-0.29	0.06	0.43	0.41	0.78	0.64	0.57	-0.18	-0.07	2.46
1953	0.03	0.09	-0.03	-0.21	0.05	0.60	0.11	0.40	0.35	0.31	0.05	-0.01	1.74
1954	-0.11	0.17	0.24	0.04	-0.20	0.42	0.80	0.85	0.57	-0.09	0.21	0.12	3.02
1955	0.09	-0.01	0.03	0.00	0.20	0.47	0.39	0.10	0.19	0.33	0.36	0.18	2.33
1956	0.08	-0.21	0.28	0.19	0.29	0.41	0.85	0.84	0.71	0.38	0.16	0.16	4.14
1957	0.03	0.00	-0.12	-0.46	-0.34	0.11	0.52	0.40	0.09	0.17	-0.22	0.10	0.28
1958	-0.02	0.14	-0.07	-0.16	0.05	0.18	0.30	0.33	0.10	0.26	0.07	0.13	1.31
1959	0.22	0.01	0.11	0.12	0.10	0.00	-0.02	0.31	0.31	0.02	0.27	-0.15	1.30
1960	-0.03	0.05	0.13	0.24	0.23	0.20	0.27	0.30	0.19	0.12	0.23	-0.28	1.65

Table F-7, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	0.07	0.02	-0.08	0.25	0.18	0.09	0.24	0.48	0.30	0.32	-0.08	0.00	1.79
1962	-0.02	0.06	0.12	0.02	0.39	-0.14	0.47	0.50	0.04	0.02	0.06	0.17	1.69
1963	0.10	0.17	0.02	-0.10	0.13	0.30	0.18	0.64	0.49	0.54	0.29	0.11	2.87
1964	0.20	0.05	-0.05	-0.11	0.07	0.32	0.76	0.34	0.03	0.45	0.04	0.14	2.24
1965	0.07	-0.27	0.09	0.23	-0.19	0.21	0.63	0.55	0.14	0.30	0.08	0.10	1.94
1966	0.03	-0.02	0.18	-0.18	0.08	0.30	0.28	0.22	0.06	0.32	0.22	0.09	1.58
1967	0.13	0.07	0.12	-0.08	-0.12	0.39	0.10	0.37	0.06	0.10	0.17	0.01	1.32
1968	0.05	0.06	-0.03	0.03	-0.16	0.10	0.23	0.38	0.03	0.22	0.09	0.13	1.13
1969	0.01	-0.02	0.00	-0.05	-0.15	0.25	0.52	0.52	0.18	0.23	0.25	0.03	1.77
1970	0.03	-0.15	-0.01	-0.32	0.02	0.43	0.54	0.53	0.03	0.01	0.16	0.04	1.31
1971	0.12	0.02	0.22	0.23	0.20	0.54	0.39	0.23	0.26	-0.03	0.14	-0.24	2.08
1972	0.05	0.16	0.25	0.24	0.32	0.35	0.54	0.48	0.25	0.09	-0.01	0.03	2.75
1973	-0.09	-0.03	-0.02	-0.02	0.24	0.15	0.33	0.54	0.02	0.05	-0.01	0.06	1.22
1974	-0.09	0.13	0.21	0.15	0.20	0.21	0.55	0.23	-0.12	0.09	-0.03	-0.04	1.49
1975	0.00	-0.05	0.03	0.13	0.10	0.21	0.46	0.56	0.43	0.47	0.18	0.03	2.55
1976	0.18	0.17	0.06	0.06	0.12	0.26	0.25	0.61	0.17	0.07	0.14	0.06	2.15
1977	-0.09	0.03	0.10	0.12	0.29	0.46	0.58	0.36	0.42	0.37	0.04	0.21	2.89
1978	-0.07	-0.08	0.07	0.24	0.19	0.41	0.74	0.66	0.44	0.52	-0.04	0.02	3.10
1979	-0.11	-0.08	0.04	0.10	0.10	0.32	0.31	0.31	0.27	0.25	0.17	0.02	1.70
1980	-0.02	0.08	0.18	0.20	0.18	0.35	0.79	0.79	0.42	0.25	0.16	0.06	3.44

Table F-7, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981	0.15	0.09	0.12	0.19	0.12	0.23	0.48	0.57	0.44	-0.01	0.12	0.22	2.72
1982	0.00	-0.03	0.13	0.12	-0.04	0.21	0.39	0.47	0.50	0.19	-0.02	-0.05	1.87
1983	0.08	-0.05	0.05	0.22	0.16	0.26	0.41	0.50	0.51	0.19	0.13	0.03	2.49
1984	0.05	0.06	0.05	0.21	0.24	0.46	0.46	0.54	0.42	0.05	0.16	0.00	2.70
1985	0.01	-0.01	0.08	0.16	0.25	0.36	0.52	0.71	0.44	0.16	0.05	0.05	2.78
1986	0.22	0.02	0.23	0.01	0.18	0.18	0.55	0.65	0.44	0.07	-0.03	0.00	2.52
1941-86 Avg.	0.02	0.00	0.06	0.04	0.08	0.27	0.42	0.47	0.28	0.20	0.10	0.03	1.97

Table F-8

Marvin Nichols I and II Reservoirs Net Evaporation

- Values in Feet -

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	0.06	-0.02	-0.06	-0.17	0.14	-0.07	0.21	0.30	0.29	0.07	0.07	-0.06	0.76
1942	0.09	0.10	0.06	-0.32	0.08	0.16	0.48	0.13	0.23	0.21	0.18	-0.15	1.25
1943	0.07	0.18	0.01	0.19	0.03	0.28	0.44	0.58	0.30	0.14	0.18	-0.07	2.33
1944	-0.07	-0.20	-0.11	-0.04	-0.27	0.36	0.42	0.14	0.36	0.34	-0.21	-0.28	0.44
1945	0.03	-0.25	-0.68	0.04	0.15	-0.07	0.20	0.29	0.32	0.13	0.14	0.09	0.39
1946	-0.26	-0.09	-0.01	-0.02	-0.34	0.24	0.40	0.32	0.30	0.24	-0.37	0.03	0.44
1947	-0.01	0.14	-0.04	-0.09	0.04	0.24	0.50	0.34	0.23	0.23	-0.13	-0.19	1.26
1948	-0.08	-0.16	-0.05	0.15	-0.23	0.38	0.41	0.52	0.47	0.21	0.05	0.05	1.72
1949	-0.45	-0.09	-0.05	0.00	0.24	0.14	0.19	0.34	0.34	-0.42	0.24	-0.02	0.46
1950	-0.27	-0.38	0.05	-0.03	-0.40	0.26	0.06	0.27	-0.31	0.22	0.26	0.18	-0.09
1951	-0.08	-0.21	0.16	0.06	0.21	0.03	0.30	0.56	-0.09	0.15	0.09	0.08	1.26
1952	-0.04	0.07	-0.10	-0.25	-0.02	0.32	0.32	0.61	0.59	0.50	-0.27	-0.12	1.61
1953	-0.10	0.06	-0.04	-0.18	-0.11	0.51	0.00	0.25	0.32	0.31	0.03	-0.06	0.99
1954	-0.19	0.15	0.20	0.02	-0.28	0.37	0.66	0.78	0.60	-0.03	0.17	0.04	2.49
1955	0.04	-0.08	-0.06	-0.07	0.12	0.40	0.26	0.00	0.11	0.19	0.29	0.12	1.32
1956	0.06	-0.27	0.20	0.14	0.21	0.25	0.66	0.62	0.60	0.33	0.15	0.16	3.11
1957	-0.06	-0.07	-0.14	-0.45	-0.20	0.03	0.42	0.38	0.09	0.03	-0.31	0.05	-0.23
1958	-0.04	0.12	-0.06	-0.41	0.03	0.11	0.17	0.16	0.06	0.19	-0.01	0.16	0.48
1959	0.18	-0.12	0.07	-0.01	0.00	0.07	0.06	0.28	0.24	0.06	0.23	-0.22	0.84
1960	-0.14	-0.02	0.10	0.25	0.17	0.14	0.28	0.29	0.12	0.14	0.21	-0.28	1.26

Table F-8, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1961	0.04	-0.04	-0.16	0.18	0.12	-0.04	0.14	0.39	0.26	0.24	-0.10	-0.12	0.91
1962	-0.11	-0.04	0.07	-0.01	0.36	-0.10	0.51	0.52	0.12	0.01	0.06	0.16	1.55
1963	0.08	0.16	-0.07	-0.12	0.14	0.21	0.14	0.58	0.44	0.52	0.22	0.03	2.33
1964	0.20	0.02	-0.07	-0.22	0.11	0.33	0.65	0.21	0.05	0.43	0.06	0.07	1.84
1965	0.02	-0.35	0.02	0.19	-0.18	0.19	0.52	0.48	0.12	0.31	0.11	0.07	1.50
1966	0.01	-0.04	0.21	-0.12	0.19	0.46	0.37	0.32	0.16	0.25	0.22	-0.09	1.94
1967	0.02	0.08	0.24	-0.10	0.03	0.33	0.25	0.42	0.16	0.19	0.05	-0.10	1.57
1968	-0.04	-0.01	-0.13	0.04	-0.12	0.16	0.29	0.42	0.17	0.16	0.00	0.03	0.97
1969	-0.05	-0.10	-0.07	0.07	0.01	0.37	0.56	0.57	0.21	0.16	0.08	-0.03	1.78
1970	-0.01	-0.15	0.02	-0.29	0.19	0.46	0.56	0.48	0.32	0.08	0.15	-0.02	1.79
1971	0.06	0.00	0.16	0.22	0.23	0.50	0.27	0.23	0.29	0.10	0.07	-0.18	1.95
1972	-0.05	0.14	0.15	0.22	0.27	0.28	0.40	0.48	0.20	0.03	-0.08	-0.05	1.99
1973	-0.11	-0.04	-0.06	-0.06	0.28	0.11	0.29	0.54	0.05	0.01	-0.03	-0.02	0.96
1974	-0.13	0.06	0.19	0.12	0.19	0.16	0.44	0.20	-0.10	0.09	-0.09	-0.08	1.05
1975	0.00	-0.09	0.00	0.08	0.06	0.17	0.42	0.42	0.33	0.35	0.08	-0.01	1.81
1976	0.10	0.08	-0.02	0.08	0.07	0.18	0.27	0.54	0.09	0.03	0.11	0.00	1.53
1977	-0.08	0.00	0.05	0.09	0.34	0.40	0.44	0.34	0.32	0.35	-0.02	0.10	2.33
1978	-0.10	-0.05	0.05	0.20	0.20	0.42	0.66	0.60	0.39	0.36	-0.12	-0.01	2.60
1979	-0.13	-0.05	0.01	0.02	0.07	0.30	0.19	0.25	0.20	0.22	0.07	0.02	1.17
1980	-0.06	0.06	0.08	0.10	0.10	0.27	0.67	0.69	0.31	0.19	0.08	0.10	2.59

Table F-8, Continued

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981	0.14	0.02	0.08	0.22	0.04	0.16	0.35	0.40	0.38	-0.04	0.11	0.16	2.02
1982	-0.01	-0.05	0.11	0.04	0.03	0.12	0.37	0.42	0.43	0.10	-0.07	-0.17	1.32
1983	0.05	-0.05	0.02	0.12	0.11	0.17	0.33	0.47	0.44	0.19	0.02	-0.02	1.85
1984	0.04	0.03	-0.01	0.14	0.20	0.39	0.34	0.33	0.30	-0.11	0.01	-0.05	1.61
1985	-0.03	-0.05	0.01	0.10	0.20	0.26	0.43	0.56	0.30	0.08	-0.01	0.03	1.88
1986	0.21	-0.03	0.16	0.01	0.12	0.11	0.51	0.54	0.19	0.04	-0.10	-0.08	1.68
1941-86 Avg.	-0.03	-0.04	0.01	0.00	0.06	0.23	0.37	0.40	0.25	0.16	0.04	-0.02	1.43

APPENDIX G

RESERVOIR OPERATION STUDIES

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RESERVOIR OPERATION STUDIES

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APPENDIX G

RESERVOIR OPERATION STUDIES

WEST FORK RESERVOIRS

The Tarrant County Water Control and Improvement District Number One owns and operates two reservoirs on the West Fork of the Trinity River - Lake Bridgeport and Eagle Mountain Lake. These lakes are used to supply water to Fort Worth's Holly water treatment plant and to other District customers north and west of Tarrant County. Bridgeport and Eagle Mountain are operated jointly with Fort Worth's Lake Worth. Table G-1 is an annual summary of a monthly operation study of the three reservoirs. The study shows that the reservoirs can provide a total firm yield of 79,000 acre-feet per year - 5,000 acre-feet per year for local use around Lake Bridgeport, 7,000 acre-feet per year for local use around Eagle Mountain Lake, and 67,000 acre-feet per year for Fort Worth.

The West Fork reservoirs are the least expensive source of supply available to the Tarrant County Water Control and Improvement District Number One, since water can flow by gravity to Fort Worth's Holly plant. This makes it desirable to maximize the use of West Fork water and minimize the cost of pumping from East Texas. This can be done by overdrafting the West Fork reservoirs - using more than their firm yield in most years, and taking less than the firm yield when their storage is depleted (56). Table G-2 is an annual summary of an overdraft operation study of the West Fork reservoirs. As in the firm yield operation study, the local demand is

Table G-1

Operation of the West Fork Reservoirs for Dependable Yield

- Quantities in Acre-Feet -

	Lake Bridgeport						Eagle Mountain Lake						Lake Worth				
Year	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Spills	Content
1940	233,360	43,440	5,000	0	184,920	374,836	366,830	29,990	7,000	17,356	312,484	177,520	349,730	11,230	67,000	271,500	37,775
1941	546,900	21,370	5,000	0	521,140	374,226	946,200	14,930	7,000	0	924,270	177,520	970,750	5,700	67,000	898,050	37,775
1942	698,100	40,540	5,000	25,030	637,910	363,846	968,070	27,170	7,000	37,553	919,990	153,877	990,913	10,350	67,000	921,300	30,038
1943	44,040	54,730	5,000	58,050	0	290,106	117,020	36,580	7,000	61,413	21,627	144,277	89,490	14,030	67,000	8,830	29,668
1944	100,080	39,880	5,000	38,550	0	306,756	163,400	28,730	7,000	53,043	46,557	172,347	113,280	10,650	67,000	34,760	30,538
1945	223,090	37,860	5,000	0	119,730	367,256	453,910	26,290	7,000	14,593	400,854	177,520	452,027	10,030	67,000	368,990	36,545
1946	153,270	42,870	5,000	7,610	90,210	374,836	294,650	29,470	7,000	27,963	230,217	177,520	279,670	11,120	67,000	200,320	37,775
1947	50,180	51,380	5,000	12,500	37,980	318,156	176,650	36,520	7,000	43,063	90,780	176,807	147,623	13,190	67,000	74,670	30,538
1948	42,120	54,330	5,000	46,350	0	254,596	134,410	38,250	7,000	59,203	53,227	153,537	122,060	14,710	67,000	40,390	30,498
1949	129,620	32,160	5,000	20,030	0	327,026	152,510	24,190	7,000	39,786	64,444	170,627	118,720	8,940	67,000	42,760	30,518
1950	259,520	33,830	5,000	0	187,690	360,026	456,020	24,090	7,000	3,816	414,221	177,520	447,387	9,090	67,000	364,040	37,775
1951	48,180	49,860	5,000	2,618	13,120	337,608	101,408	35,060	7,000	19,966	63,997	152,905	93,353	13,290	67,000	20,470	30,368
1952	0	57,560	5,000	78,000	0	197,048	107,970	41,880	7,000	81,120	0	130,875	84,400	17,240	67,000	0	30,528
1953	61,360	33,040	5,000	78,000	0	142,368	136,020	33,090	7,000	74,040	0	152,765	80,390	13,460	67,000	0	30,458
1954	125,860	34,100	5,000	78,000	0	151,128	103,890	40,310	7,000	79,540	0	129,805	82,370	15,960	67,000	0	29,868
1955	66,120	29,290	5,000	78,000	0	104,958	78,000	28,980	7,000	78,520	0	93,305	78,520	12,680	67,000	0	28,708

Table G-1, Continued

Year	Lake Bridgeport						Eagle Mountain Lake						Lake Worth				
	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Spills	Content
1956	33,380	28,330	5,000	76,636	0	28,372	84,286	33,500	7,000	79,136	0	57,955	79,976	16,280	67,000	0	25,404
1957	501,760	26,970	5,000	39,490	104,906	353,766	592,856	17,960	7,000	40,653	407,678	177,520	497,401	6,500	67,000	411,530	37,775
1958	59,170	38,260	5,000	12,190	29,310	328,176	268,720	26,270	7,000	29,443	229,010	154,517	283,313	9,880	67,000	213,700	30,508
1959	103,650	33,320	5,000	38,410	0	355,096	212,290	24,890	7,000	38,073	119,324	177,520	176,407	9,310	67,000	96,120	34,485
1960	60,520	39,250	5,000	22,608	5,770	342,988	114,958	26,780	7,000	43,943	52,730	162,025	106,173	9,950	67,000	33,170	30,538
1961	64,260	31,940	5,000	19,018	4,532	346,758	108,340	21,780	7,000	37,903	46,027	157,655	93,210	8,090	67,000	18,140	30,518
1962	109,580	29,000	5,000	8,090	39,412	374,836	325,642	20,280	7,000	20,110	258,387	177,520	308,917	7,710	67,000	226,950	37,775
1963	23,810	41,040	5,000	31,970	14,160	306,476	105,200	27,460	7,000	49,236	53,367	145,657	109,073	10,320	67,000	39,400	30,128
1964	103,240	31,680	5,000	41,410	0	331,626	154,600	22,940	7,000	60,050	32,747	177,520	105,177	8,310	67,000	26,180	33,815
1965	71,990	28,440	5,000	11,360	4,720	354,096	122,780	19,470	7,000	36,983	76,460	160,387	125,093	7,130	67,000	54,270	30,508
1966	108,060	35,490	5,000	0	65,860	355,806	316,890	25,010	7,000	23,003	244,744	177,520	295,197	9,320	67,000	213,470	35,915
1967	33,320	42,210	5,000	6,810	0	335,106	96,200	29,910	7,000	34,649	43,464	158,697	87,893	11,090	67,000	15,190	30,528
1968	76,640	35,500	5,000	4,320	30,850	336,076	296,140	25,230	7,000	31,143	225,687	165,777	285,360	9,320	67,000	209,050	30,518
1969	90,980	30,690	5,000	0	29,360	362,006	278,090	21,310	7,000	38,093	206,737	170,727	272,040	7,940	67,000	197,100	30,518
1970	38,690	39,220	5,000	12,200	16,350	327,926	272,350	27,790	7,000	21,996	213,814	172,477	262,480	10,310	67,000	185,180	30,508
1971	63,870	40,390	5,000	31,330	0	315,076	118,960	29,370	7,000	66,060	11,487	177,520	87,127	10,690	67,000	2,170	37,775
1972	132,360	47,660	5,000	41,898	5,870	347,008	95,988	32,750	7,000	46,083	33,440	154,235	84,793	12,280	67,000	12,780	30,508
1973	91,830	33,830	5,000	4,840	24,062	371,106	191,082	23,650	7,000	9,150	127,997	177,520	154,897	9,240	67,000	74,350	34,815
1974	115,080	47,560	5,000	23,610	35,650	374,366	257,410	32,510	7,000	29,103	188,797	177,520	239,580	12,160	67,000	157,460	37,775
1975	248,140	41,450	5,000	3,358	206,400	366,298	407,738	28,590	7,000	17,703	377,630	154,335	416,983	10,870	67,000	346,550	30,338

Table G-1, Continued

Year	Lake Bridgeport						Eagle Mountain Lake						Lake Worth				
	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Spills	Content
1976	124,370	42,000	5,000	37,030	31,802	374,836	144,472	28,120	7,000	40,203	45,964	177,520	86,977	10,420	67,000	2,120	37,775
1977	129,710	53,210	5,000	35,588	109,520	301,228	284,468	36,610	7,000	48,763	215,870	153,745	266,163	13,630	67,000	193,470	29,838
1978	32,930	40,110	5,000	78,000	0	211,048	91,990	30,460	7,000	77,590	0	130,685	77,940	11,740	67,000	0	29,038
1979	78,100	32,000	5,000	45,290	0	206,858	172,260	27,660	7,000	50,203	64,425	153,657	116,218	10,400	67,000	37,688	30,168
1980	74,330	39,930	5,000	78,000	0	158,258	117,300	36,980	7,000	80,110	0	146,867	80,530	14,660	67,000	0	29,038
1981	415,300	27,120	5,000	33,430	136,052	371,956	673,122	26,150	7,000	40,183	569,136	177,520	614,829	9,810	67,000	529,282	37,775
1982	377,380	39,140	5,000	17,928	323,460	363,808	653,338	26,750	7,000	27,223	614,640	155,245	645,263	10,160	67,000	575,710	30,168
1983	91,710	47,570	5,000	44,738	26,602	331,608	120,740	31,240	7,000	62,283	16,837	158,625	79,650	11,680	67,000	1,200	29,938
1984	64,600	46,240	5,000	67,250	0	277,718	130,990	35,570	7,000	78,370	0	170,675	79,140	12,580	67,000	0	29,498
1985	193,660	44,650	5,000	12,580	37,782	371,366	196,882	30,580	7,000	23,793	128,664	177,520	154,127	11,630	67,000	69,010	35,985
1986	147,470	43,660	5,000	12,010	92,530	365,636	319,830	30,220	7,000	23,543	259,067	177,520	284,950	11,460	67,000	208,280	34,195
Average	141,313	39,023	5,000	30,088	67,397	310,469	257,082	28,751	7,000	42,463	178,868	160,275	235,267	10,990	67,000	157,353	32,414

Note: The critical period is from September 1951 through April 1957. The minimum combined content of Lake Bridgeport and Eagle Mountain Lake is 76,067 acre-feet.

Table G-2

Operation of the West Fork Reservoirs in Overdrafting Mode

- Quantities in Acre-Feet -

Year	Lake Bridgeport						Eagle Mountain Lake						Lake Worth				
	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Spills	Content
1940	233,360	43,440	5,000	16,640	168,280	374,836	366,830	29,640	7,000	38,336	291,854	177,520	350,080	11,170	100,000	238,910	37,775
1941	546,900	21,370	5,000	0	521,140	374,226	946,200	14,810	7,000	20,253	904,137	177,520	970,870	5,470	100,000	865,400	37,775
1942	698,100	40,490	5,000	43,070	630,230	353,536	978,430	26,660	7,000	56,323	919,990	145,977	1,009,683	10,270	100,000	907,410	29,778
1943	44,040	52,310	5,000	78,000	0	262,266	136,970	36,170	7,000	93,743	12,917	133,117	113,110	13,710	100,000	0	29,178
1944	100,080	36,480	5,000	67,130	0	253,736	191,980	28,010	7,000	81,663	43,647	164,777	138,990	10,580	100,000	27,050	30,538
1945	223,090	38,040	5,000	10,640	55,890	367,256	400,710	26,110	7,000	28,466	326,391	177,520	391,437	9,960	100,000	277,420	34,595
1946	153,270	42,750	5,000	24,690	73,250	374,836	294,770	29,120	7,000	43,083	215,567	177,520	280,140	11,100	100,000	165,860	37,775
1947	50,180	51,090	5,000	28,898	37,980	302,048	193,048	35,610	7,000	65,693	90,780	171,485	170,253	13,120	100,000	64,370	30,538
1948	42,120	51,110	5,000	75,910	0	212,148	163,970	38,130	7,000	86,633	47,905	155,787	144,168	14,620	100,000	29,608	30,478
1949	129,620	29,050	5,000	37,780	0	269,938	170,260	23,800	7,000	63,696	64,744	166,807	142,930	8,940	100,000	33,960	30,508
1950	259,520	32,830	5,000	0	131,602	360,026	399,932	23,930	7,000	18,543	339,746	177,520	387,639	8,850	100,000	272,542	36,755
1951	48,180	49,780	5,000	14,538	13,120	325,768	113,328	34,710	7,000	51,469	46,674	150,995	107,533	12,680	100,000	1,490	30,118
1952	0	54,440	5,000	78,000	0	188,328	107,970	40,620	7,000	114,200	0	97,145	117,480	17,080	100,000	0	30,518
1953	61,360	30,690	5,000	78,000	0	135,998	136,020	29,340	7,000	89,910	0	106,915	96,260	13,470	82,870	0	30,438
1954	125,860	32,710	5,000	78,000	0	146,148	103,890	34,550	7,000	75,660	0	93,595	78,490	15,980	62,860	0	30,088
1955	66,120	29,780	5,000	67,456	0	110,032	67,456	23,950	7,000	60,786	0	69,315	60,786	11,760	53,710	0	25,404

Table G-2, Continued

Year	Lake Bridgeport Inflow	Evap.	Use	Releases	Spills	Content	Eagle Mountain Lake Inflow	Evap.	Use	Releases	Spills	Content	Lake Worth Inflow	Evap.	Use	Spills	Content
1956	33,380	29,310	5,000	78,000	0	31,102	85,650	30,440	7,000	60,435	0	57,090	61,275	15,520	46,000	0	25,159
1957	501,760	26,830	5,000	46,455	110,931	343,646	605,846	17,450	7,000	52,198	408,768	177,520	510,036	6,470	87,610	403,340	37,775
1958	59,170	38,080	5,000	27,930	19,190	312,616	274,340	25,760	7,000	55,403	211,760	151,937	292,023	9,670	100,000	189,630	30,498
1959	103,650	31,320	5,000	70,520	0	309,426	244,400	24,400	7,000	72,483	114,934	177,520	206,427	9,120	100,000	97,180	30,625
1960	60,520	36,110	5,000	51,710	0	277,126	138,290	26,120	7,000	79,703	41,930	161,057	131,133	9,650	100,000	21,560	30,548
1961	64,260	28,480	5,000	36,828	0	271,078	121,618	21,360	7,000	69,126	29,474	155,715	107,880	7,920	100,000	0	30,508
1962	109,580	25,320	5,000	19,520	0	330,818	297,660	20,280	7,000	30,400	218,175	177,520	278,995	7,710	100,000	164,018	37,775
1963	23,810	38,100	5,000	60,490	0	251,038	119,560	27,500	7,000	77,866	32,947	151,767	117,283	10,250	100,000	14,990	29,818
1964	103,240	27,890	5,000	61,720	0	259,668	174,910	22,230	7,000	89,410	30,517	177,520	132,307	8,280	100,000	21,980	31,865
1965	71,990	24,930	5,000	29,228	0	272,500	135,928	18,890	7,000	59,543	71,740	156,275	142,933	7,010	100,000	37,290	30,498
1966	108,060	33,660	5,000	6,520	0	335,380	257,550	24,640	7,000	65,033	152,065	165,087	244,548	9,050	100,000	135,468	30,528
1967	33,320	39,550	5,000	41,470	0	282,680	130,860	29,370	7,000	84,853	16,047	158,677	110,680	10,680	100,000	0	30,528
1968	76,640	34,030	5,000	15,568	0	304,722	276,538	24,680	7,000	53,473	193,317	156,745	275,320	9,150	100,000	166,200	30,498
1969	90,980	29,590	5,000	28,848	0	332,264	277,578	21,220	7,000	60,603	177,665	167,835	265,478	7,920	100,000	157,538	30,518
1970	38,690	38,200	5,000	16,790	0	310,964	260,590	27,240	7,000	49,156	184,962	160,067	260,788	10,110	100,000	150,698	30,498
1971	63,870	37,150	5,000	70,010	0	262,674	157,640	29,020	7,000	97,090	7,077	177,520	113,747	10,690	100,000	0	33,555
1972	132,360	43,010	5,000	68,848	0	278,176	117,068	32,260	7,000	95,836	7,197	152,295	108,303	11,750	100,000	0	30,108
1973	91,830	29,890	5,000	12,880	0	322,236	175,060	23,640	7,000	45,063	74,132	177,520	136,945	8,780	100,000	25,608	32,665
1974	115,080	43,470	5,000	46,130	0	342,716	244,280	31,850	7,000	58,546	146,884	177,520	227,110	11,650	100,000	110,350	37,775
1975	248,140	41,330	5,000	15,138	174,810	354,578	387,928	28,290	7,000	31,723	346,040	152,395	399,413	10,700	100,000	296,300	30,188

Table G-2, Continued

Year	Lake Bridgeport						Eagle Mountain Lake						Lake Worth				
	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Releases	Spills	Content	Inflow	Evap.	Use	Spills	Content
1976	124,370	41,120	5,000	77,750	0	355,078	153,390	26,710	7,000	108,740	0	163,335	109,550	9,950	100,000	0	29,788
1977	129,710	52,620	5,000	55,338	89,782	282,048	284,480	36,040	7,000	81,813	171,157	151,805	254,500	13,540	100,000	141,350	29,398
1978	32,930	37,180	5,000	78,000	0	194,798	91,990	29,610	7,000	109,950	0	97,235	110,300	11,570	100,000	0	28,128
1979	78,100	28,990	5,000	76,980	0	161,928	203,950	26,500	7,000	84,573	38,625	144,487	124,788	10,180	100,000	12,928	29,808
1980	74,330	33,100	5,000	78,000	0	120,158	117,300	35,400	7,000	96,750	0	122,637	97,170	14,460	84,230	0	28,288
1981	415,300	23,830	5,000	68,570	66,102	371,956	638,312	24,780	7,000	81,580	470,069	177,520	557,159	9,120	94,230	446,132	35,965
1982	377,380	39,100	5,000	27,550	323,460	354,226	662,960	26,410	7,000	41,333	614,640	151,097	659,373	10,120	100,000	555,250	29,968
1983	91,710	46,440	5,000	78,000	0	316,496	127,400	29,360	7,000	109,700	0	132,437	110,230	11,260	100,000	0	28,938
1984	64,600	42,380	5,000	78,000	0	255,716	141,740	31,280	7,000	110,520	0	125,377	111,290	12,210	100,000	0	28,018
1985	193,660	43,270	5,000	46,390	0	354,716	192,910	29,710	7,000	82,303	29,167	170,107	113,140	11,070	100,000	0	30,088
1986	147,470	43,290	5,000	16,610	76,210	361,076	308,110	29,680	7,000	69,786	194,231	177,520	266,357	10,980	100,000	153,230	32,235
Average	141,313	37,105	5,000	46,480	53,021	283,505	259,098	27,814	7,000	69,222	155,061	152,056	238,220	10,751	95,990	131,597	31,379

Note: The critical period is from September 1951 through April 1957. The minimum combined content of Lake Bridgeport and Eagle Mountain Lake is 76,447 acre-feet.

5,000 acre-feet per year from Bridgeport and 7,000 acre-feet per year from Eagle Mountain. The amount supplied to Fort Worth is 100,000 acre-feet per year when the combined content of Bridgeport and Eagle Mountain is greater than 250,000 acre-feet. When the combined content is less than 250,000 acre-feet, Fort Worth gets only 46,000 acre-feet per year.

Overdrafting operation increases the average supply available to Fort Worth from the West Fork reservoirs from 67,000 acre-feet per year (Table G-1) to 95,990 acre-feet per year (Table G-2). The additional average supply of 28,990 acre-feet per year decreases the amount of water needed from the East Texas reservoirs in most years. Overdrafting is possible because the East Texas reservoirs can supply extra water to Fort Worth in the few years during which the West Fork supply must be cut back.

EAST TEXAS RESERVOIRS AND DIVERSIONS FROM THE TRINITY RIVER

The Tarrant County Water Control and Improvement District Number One currently owns and operates Cedar Creek Reservoir and Richland-Chambers Reservoir in East Texas. As part of this long range water supply plan, several alternatives which would increase the yield of these reservoirs were considered. They include:

- Diversions from the Trinity River
- System operation
- Construction of Tehuacana Reservoir
- Diversions from Lake Palestine to Cedar Creek Reservoir

These alternatives were analyzed by monthly mass balance operation studies of the reservoirs. Hydrologic data needed for the operation studies include reservoir area and capacity, runoff, and evaporation. These data and demands from the reservoirs are used on a monthly basis to calculate evaporative losses, diversions of makeup water (if applicable), spills, and end-of-month contents. The hydrologic data for Cedar Creek, Richland-Chambers and Tehuacana Reservoirs are presented in previous appendices.

The base case for the District's East Texas reservoirs is the currently permitted diversion of 175,000 acre-feet per year from Cedar Creek Reservoir and 210,000 acre-feet per year from Richland-Chambers Reservoir (60). Tables G-3 and G-4 give annual summaries of the monthly operation studies for Cedar Creek and Richland-Chambers operating at their currently permitted diversions.

Under currently permitted operation, Cedar Creek Reservoir would have a reserve of 154,685 acre-feet in storage at the end of its historical critical period (June 1953 through January 1957). Richland-Chambers Reservoir would have a reserve of 175,597 acre-feet at the end of its critical period (June 1948 through February 1957).

Diversions from the Trinity River

The yield of the existing East Texas reservoirs could be increased by diverting water from the Trinity River into the reservoirs. For this study, the increased yield provided by diversions from the Trinity is

Table G-3

Annual Summary of Operation Study for Cedar Creek Reservoir as Currently Permitted

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1941	44,975	175,000	610,490	439,978	622,237
1942	51,607	175,000	809,680	543,399	661,911
1943	81,955	175,000	387,680	238,846	553,790
1944	49,078	175,000	598,510	285,078	643,144
1945	32,920	175,000	973,060	798,601	609,683
1946	39,002	175,000	744,520	468,501	671,700
1947	72,422	175,000	541,350	293,928	671,700
1948	92,287	175,000	308,430	229,753	483,090
1949	39,190	175,000	238,340	0	507,240
1950	51,489	175,000	452,630	203,412	529,969
1951	73,181	175,000	151,960	0	433,748
1952	84,281	175,000	354,410	0	528,877
1953	56,882	175,000	384,260	145,800	535,455
1954	99,297	175,000	167,390	0	428,548
1955	53,085	175,000	116,230	0	316,693
1956	66,611	175,000	83,030	0	158,112
1957	14,170	175,000	1,155,780	456,152	668,570
1958	50,731	175,000	602,180	483,999	561,020
1959	39,406	175,000	392,320	67,234	671,700
1960	46,581	175,000	452,390	230,809	671,700
1961	49,051	175,000	442,910	280,913	609,646
1962	43,874	175,000	277,800	17,849	650,723
1963	97,818	175,000	115,510	15,408	478,007
1964	58,707	175,000	61,520	0	305,820
1965	37,903	175,000	240,460	0	333,377
1966	46,417	175,000	629,110	205,677	535,393
1967	45,236	175,000	512,580	156,037	671,700
1968	65,330	175,000	538,270	418,209	551,431
1969	69,123	175,000	652,910	388,487	571,731
1970	72,570	175,000	525,300	237,093	612,368

Table G-3, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1971	88,508	175,000	570,700	247,860	671,700
1972	87,708	175,000	132,190	61,852	479,330
1973	58,886	175,000	896,660	470,404	671,700
1974	72,031	175,000	640,100	393,069	671,700
1975	83,001	175,000	397,060	303,357	507,402
1976	63,691	175,000	479,310	106,294	641,727
1977	100,952	175,000	457,060	309,883	512,952
1978	87,728	175,000	143,930	0	394,154
1979	77,492	175,000	541,700	111,399	571,963
1980	114,084	175,000	299,010	86,952	494,937
1981	83,387	175,000	416,680	42,614	610,616
1982	80,362	175,000	325,550	9,104	671,700
1983	88,810	175,000	369,220	251,840	525,270
1984	97,195	175,000	317,360	0	570,435
1985	102,221	175,000	747,420	368,934	671,700
1986	81,190	175,000	718,880	462,690	671,700
Avg.	67,227	175,000	455,953	213,726	

Note: The critical period is from June 1953 through January 1957. The minimum content is 154,685 acre-feet.

Table G-4

Annual Summary of Operation Study for Richland-Chambers Reservoir as Currently Permitted

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1940	56,982	210,000	849,400	3,622	578,796	1,181,886
1941	59,567	210,000	1,156,200	3,622	969,829	1,095,068
1942	72,262	210,000	1,248,800	3,622	876,098	1,181,886
1943	109,504	210,000	556,100	3,622	297,984	1,116,876
1944	57,402	210,000	1,082,500	3,622	841,556	1,086,796
1945	40,542	210,000	1,651,400	3,622	1,305,358	1,178,674
1946	51,655	210,000	806,300	3,622	600,748	1,118,949
1947	95,650	210,000	573,100	3,622	347,162	1,035,615
1948	121,973	210,000	432,700	3,622	179,354	953,366
1949	49,033	210,000	191,700	3,622	0	882,411
1950	81,730	210,000	334,800	3,622	0	921,859
1951	112,219	210,000	68,200	3,622	0	664,218
1952	85,495	210,000	295,200	3,622	0	660,301
1953	57,742	210,000	486,000	3,622	0	874,937
1954	119,239	210,000	34,200	3,622	0	576,276
1955	56,658	210,000	66,600	3,622	0	372,596
1956	69,089	210,000	107,100	3,622	0	196,985
1957	20,416	210,000	1,504,700	3,622	298,337	1,169,310
1958	61,574	210,000	836,300	3,622	608,025	1,122,389
1959	46,667	210,000	899,400	3,622	579,614	1,181,886
1960	49,220	210,000	610,300	3,622	347,458	1,181,886
1961	53,943	210,000	1,151,200	3,622	883,635	1,181,886
1962	65,653	210,000	236,900	3,622	48,198	1,091,313
1963	109,055	210,000	45,400	3,622	0	814,036
1964	74,350	210,000	18,200	3,622	0	544,264
1965	58,440	210,000	482,700	3,622	0	754,902
1966	81,322	210,000	805,100	3,622	275,475	989,583
1967	84,960	210,000	579,400	3,622	88,515	1,181,886
1968	69,295	210,000	1,306,100	3,622	1,163,880	1,041,189
1969	106,672	210,000	893,600	3,622	610,061	1,004,434
1970	106,378	210,000	580,300	3,622	201,161	1,063,573

Table G-4, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1971	110,387	210,000	394,100	3,622	0	1,133,664
1972	111,456	210,000	181,800	3,622	53,305	937,081
1973	76,916	210,000	1,260,900	3,622	726,697	1,180,746
1974	98,002	210,000	742,700	3,622	429,936	1,181,886
1975	105,806	210,000	995,600	3,622	852,522	1,005,536
1976	83,271	210,000	697,500	3,622	224,257	1,181,886
1977	137,504	210,000	619,500	3,622	506,254	944,006
1978	109,433	210,000	61,500	3,622	0	682,451
1979	85,247	210,000	539,300	3,622	0	922,882
1980	149,913	210,000	375,400	3,622	8,250	926,497
1981	98,611	210,000	334,600	3,622	0	948,864
1982	97,882	210,000	150,800	3,622	0	788,160
1983	85,632	210,000	148,000	3,622	0	636,906
1984	94,971	210,000	261,700	3,622	0	590,013
1985	89,485	210,000	527,400	3,622	0	814,306
1986	101,764	210,000	779,400	3,622	96,434	1,181,886
Avg.	83,425	210,000	594,896	3,622	297,849	

Note: The critical period is from June 1948 through February 1957.
The minimum content is 175,597 acre-feet.

limited to 30 percent of the yield of the projects without diversions. For Cedar Creek, the yield with the proposed diversions would therefore be 1.3 x 175,000, or 227,500 acre-feet per year. For Richland-Chambers, the yield would be 1.3 x 210,000, or 273,000 acre-feet per year. The combined yield of the two reservoirs with diversions from the Trinity would be 500,500 acre-feet per year, an increase of 115,500 acre-feet per year from the currently permitted amount.

Tables G-5 and G-6 give summaries of operation studies for Cedar Creek Reservoir and Richland-Chambers Reservoir with diversions from the Trinity. No diversions are made from the Trinity River when either reservoir is within 5 feet of the top of conservation storage. When Cedar Creek Reservoir is drawn down more than 5 feet, 5,360 acre-feet per month is diverted from the Trinity. When Richland-Chambers is drawn down more than 5 feet, 6,050 acre-feet per month is diverted. This would leave the same reserve at the end of the critical period as would the currently permitted operation and would allow Cedar Creek to supply 227,500 acre-feet per year and Richland-Chambers to supply 273,000 acre-feet per year.

System Operation

The critical period for Cedar Creek Reservoir with diversions from the Trinity River is the same as that with the currently permitted operation - June 1953 through January 1957. Richland-Chambers Reservoir has a longer critical period than Cedar Creek - June 1948 through

Table G-5

Annual Summary of Operation Study for Cedar Creek Reservoir with Diversions from the Trinity River

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1941	44,615	227,500	610,490	0	415,838	594,237
1942	51,105	227,500	809,680	0	491,461	633,851
1943	81,019	227,500	387,680	0	187,152	525,860
1944	48,868	227,500	598,510	0	236,485	611,517
1945	32,631	227,500	973,060	0	738,395	586,051
1946	38,866	227,500	744,520	0	392,505	671,700
1947	71,940	227,500	541,350	0	241,910	671,900
1948	91,235	227,500	308,430	10,720	209,356	462,759
1949	37,483	227,500	238,340	26,800	0	462,916
1950	50,961	227,500	452,630	10,720	149,005	498,800
1951	70,498	227,500	151,960	53,600	0	406,362
1952	81,530	227,500	354,410	48,240	0	499,982
1953	56,272	227,500	384,260	26,800	117,997	509,273
1954	95,389	227,500	167,390	48,240	0	402,014
1955	51,659	227,500	116,230	64,320	0	303,405
1956	65,802	227,500	83,030	64,320	0	157,453
1957	13,946	227,500	1,155,780	21,440	429,354	663,873
1958	50,149	227,500	602,180	0	458,903	529,501
1959	38,654	227,500	392,320	5,360	0	661,027
1960	45,757	227,500	452,390	10,720	179,180	671,700
1961	48,661	227,500	442,910	0	256,818	581,631
1962	42,073	227,500	277,800	0	0	589,858
1963	90,412	227,500	115,510	21,440	0	408,896
1964	52,917	227,500	61,520	64,320	0	254,319
1965	35,488	227,500	240,460	64,320	0	296,111
1966	45,907	227,500	629,110	21,440	169,351	503,903
1967	44,086	227,500	512,580	53,600	126,797	671,700
1968	64,567	227,500	538,270	0	397,240	520,663
1969	68,290	227,500	652,910	21,440	348,012	551,211
1970	71,673	227,500	525,300	0	198,526	578,812

Table G-5, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1971	84,425	227,500	570,700	37,520	203,407	671,700
1972	85,905	227,500	132,190	21,440	57,400	454,525
1973	58,680	227,500	896,660	10,720	404,025	671,700
1974	71,684	227,500	640,100	0	340,916	671,700
1975	82,016	227,500	397,060	5,360	282,949	481,655
1976	62,945	227,500	479,310	21,440	78,279	613,681
1977	99,694	227,500	457,060	10,720	265,133	489,134
1978	84,485	227,500	143,930	48,240	0	369,319
1979	76,572	227,500	541,700	21,440	82,344	546,043
1980	112,704	227,500	299,010	10,720	40,942	474,627
1981	32,601	227,500	416,680	32,160	26,324	587,042
1982	76,354	227,500	325,550	16,080	0	624,818
1983	88,042	227,500	369,220	5,360	181,020	502,836
1984	94,451	227,500	317,360	53,600	0	551,845
1985	101,273	227,500	747,420	0	298,792	671,700
1986	80,836	227,500	718,880	0	410,544	671,700
Avg.	65,763	227,500	455,953	20,275	182,964	

Notes: a. Diversions are made from the Trinity River at the rate of 5,360 acre-feet per month (57 mgd) when the reservoir is below 317.0 (content of 516,112 acre-feet).
b. The critical period is from June 1953 through January 1957. The minimum content is 154,934 acre-feet.

Table G-6

Annual Summary of Operation Study for Richland-Chambers Reservoir with Diversions from the Trinity River

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1940	56,770	273,000	849,400	0	3,622	516,008	1,181,886
1941	59,364	273,000	1,156,200	0	3,622	935,551	1,066,549
1942	71,845	273,000	1,248,800	0	3,622	784,996	1,181,886
1943	108,999	273,000	556,100	0	3,622	269,121	1,083,244
1944	57,369	273,300	1,082,500	0	3,622	778,710	1,053,043
1945	40,306	273,000	1,651,400	0	3,622	1,237,305	1,150,210
1946	51,468	273,000	806,300	0	3,622	543,254	1,085,166
1947	95,209	273,000	573,100	0	3,622	284,373	1,002,062
1948	120,862	273,000	432,700	6,050	3,622	121,372	921,956
1949	47,478	273,000	191,700	48,400	3,622	0	837,956
1950	78,303	273,000	334,800	36,300	3,622	0	854,131
1951	106,689	273,000	68,200	72,600	3,622	0	611,620
1952	82,041	273,000	295,200	72,600	3,622	0	620,757
1953	56,358	273,000	486,000	66,550	3,622	0	840,327
1954	116,417	273,000	34,200	72,600	3,622	0	554,088
1955	55,791	273,000	66,600	72,600	3,622	0	360,875

Table G-6, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1956	68,524	273,000	107,100	72,600	3,622	0	195,429
1957	20,289	273,000	1,504,700	30,250	3,622	269,794	1,163,674
1958	61,320	273,000	836,300	0	3,622	556,535	1,105,497
1959	46,395	273,000	899,400	0	3,622	499,994	1,181,886
1960	48,595	273,000	610,300	0	3,622	285,083	1,181,886
1961	53,719	273,000	1,151,200	0	3,622	823,923	1,178,822
1962	65,217	273,000	236,900	0	3,622	16,324	1,057,559
1963	104,705	273,000	45,400	36,300	3,622	0	757,932
1964	71,033	273,000	18,200	72,600	3,622	0	501,077
1965	57,018	273,000	482,700	72,600	3,622	0	722,737
1966	80,446	273,000	805,100	24,200	3,622	243,105	951,864
1967	83,145	273,000	579,400	60,500	3,622	50,111	1,181,886
1968	68,822	273,000	1,306,100	0	3,622	1,134,913	1,007,629
1969	105,706	273,000	893,600	6,050	3,622	552,082	972,869
1970	105,329	273,000	580,300	6,050	3,622	153,769	1,023,499
1971	106,954	273,000	394,100	60,500	3,622	0	1,094,523
1972	109,866	273,000	181,800	24,200	3,622	8,817	905,218
1973	76,721	273,000	1,260,900	12,100	3,622	649,765	1,175,110
1974	96,713	273,000	742,700	0	3,622	362,589	1,181,886
1975	105,172	273,000	995,600	0	3,622	823,555	972,137

Table G-6, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1976	82,615	273,000	697,500	18,150	3,622	146,664	1,181,886
1977	136,320	273,000	619,500	12,100	3,622	484,933	915,611
1978	107,679	273,000	61,500	72,600	3,622	0	665,410
1979	83,948	273,000	539,300	48,400	3,622	0	892,540
1980	146,943	273,000	375,400	42,350	3,622	0	886,725
1981	96,064	273,000	334,600	60,500	3,622	0	909,139
1982	95,679	273,000	150,800	72,600	3,622	0	760,238
1983	84,078	273,000	148,000	72,600	3,622	0	620,138
1984	94,074	273,000	261,700	72,600	3,622	0	583,742
1985	89,539	273,000	527,400	72,600	3,622	0	817,581
1986	102,044	273,000	779,400	36,300	3,622	72,729	1,181,886
Avg.	82,126	273,000	594,896	32,052	3,622	268,199	

Notes: a. Diversions are made from the Trinity River at the rate of 6,050 acre-feet per month (65 mgd) when the reservoir is below 310.0 (content of 971,753 acre-feet).
b. The critical period is from June 1948 through February 1957. The minimum content is 175,875 acre-feet.

February 1957 - with or without diversions from the Trinity. Because Cedar Creek Reservoir has less storage per square mile of drainage area than Richland-Chambers, it spills more often. In 1950 and 1953, the operation studies show major spills from Cedar Creek during the critical period of Richland-Chambers; in these years, water is spilling from Cedar Creek Reservoir when there is storage available in Richland-Chambers Reservoir. With diversions from the Trinity River, the spills from Cedar Creek Reservoir during the Richland-Chambers critical period total 267,002 acre-feet.

In this situation, system operation can be used to decrease the spills from Cedar Creek Reservoir and to increase the combined yield of the two reservoirs. The principle of system operation is to overdraft the reservoir which is more likely to spill (Cedar Creek) by diverting more than its firm yield whenever it is full or nearly full. This would leave more storage available in Cedar Creek Reservoir to hold inflows. During periods of low inflow, when Cedar Creek Reservoir is drawn down, diversions from Cedar Creek would be decreased, and Richland-Chambers Reservoir would be used more heavily.

Tables G-7 and G-8 give summaries of operation studies of Cedar Creek Reservoir and Richland-Chambers Reservoir under system operation with diversions from the Trinity River. The operation policy for the two reservoirs is as follows:

- The yield of the two reservoirs with system operation and diversions from the Trinity River is 533,300 acre-feet per

Table G-7

Annual Summary of Operation Study for Cedar Creek Reservoir with Diversions from the Trinity River and System Operation

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1941	43,960	320,300	610,490	0	373,187	544,743
1942	50,147	320,300	809,680	13,100	412,830	584,246
1943	78,976	320,300	387,680	6,550	96,118	483,082
1944	48,343	320,300	598,510	26,200	170,346	568,803
1945	32,149	320,300	973,060	0	645,137	544,277
1946	38,661	320,300	744,520	0	259,306	670,530
1947	70,898	320,300	541,350	6,550	189,700	637,532
1948	89,414	320,300	308,430	19,650	139,076	416,822
1949	33,301	310,307	238,340	52,400	0	363,954
1950	50,433	310,845	452,630	26,200	24,759	456,747
1951	63,954	290,237	151,960	78,600	0	333,116
1952	73,544	264,883	354,410	65,500	0	414,599
1953	55,178	320,300	384,260	45,850	7,938	461,293
1954	86,050	280,001	167,390	78,600	0	341,232
1955	47,027	224,688	116,230	78,600	0	264,347
1956	62,431	208,800	83,030	78,600	0	154,746
1957	13,632	284,922	1,155,780	26,200	382,603	655,569
1958	49,126	320,300	602,180	6,550	414,511	480,362
1959	35,414	320,300	392,320	45,850	0	562,818
1960	44,469	320,300	452,390	26,200	46,507	630,132
1961	48,063	320,300	442,910	0	172,572	532,107
1962	38,799	320,300	277,800	45,850	0	496,658
1963	79,433	290,237	115,510	78,600	0	321,098
1964	45,931	208,800	61,520	78,600	0	206,487
1965	33,321	216,727	240,460	78,600	0	275,499
1966	44,894	284,922	629,110	39,300	152,768	461,325
1967	39,813	300,040	512,580	65,500	27,852	671,700
1968	63,164	320,300	538,270	13,100	361,172	478,434
1969	67,052	320,300	652,910	39,300	278,385	504,907
1970	69,888	320,300	525,300	13,100	135,819	517,300

Table G-7, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1971	75,724	300,877	570,700	58,950	98,649	671,700
1972	82,620	320,300	132,190	32,750	49,531	384,189
1973	58,263	310,845	896,660	19,650	259,691	671,700
1974	71,022	320,300	640,100	0	248,778	671,700
1975	80,260	320,300	397,060	13,100	246,879	434,421
1976	61,065	311,670	479,310	26,200	5,898	561,298
1977	97,438	320,300	457,060	19,650	183,222	437,048
1978	75,870	280,001	143,930	78,600	0	303,707
1979	74,773	302,126	541,700	45,850	15,842	498,516
1980	106,624	320,300	299,010	32,750	0	403,352
1981	77,252	278,489	416,680	39,300	0	503,591
1982	68,523	310,307	325,550	72,050	0	522,361
1983	86,546	320,300	369,220	19,650	42,929	461,456
1984	85,953	290,047	317,360	78,600	0	481,416
1985	95,097	320,300	747,420	32,750	174,489	671,700
1986	80,169	320,300	718,880	0	318,411	671,700
Avg.	62,493	301,462	455,953	37,022	129,020	

Notes:
a. Diversions from the reservoir are 320,300 acre-feet per year when the reservoir is above elevation 312.0 and 208,800 acre-feet per year when the reservoir is below elevation 312.0.
b. Diversions are made from the Trinity River at the rate of 6,550 acre-feet per month when the reservoir is below elevation 317.0.
c. The critical period is from June 1953 through December 1956. The minimum content is 154,746 acre-feet.

Table G-8

Annual Summary of Operation Study for Richland-Chambers Reservoir with Diversions from the Trinity River and System Operation

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1940	56,974	213,000	849,400	0	3,622	575,804	1,181,886
1941	59,558	213,000	1,156,200	0	3,622	968,197	1,093,709
1942	72,243	213,000	1,248,800	0	3,622	871,758	1,181,886
1943	109,480	213,000	556,100	0	3,622	296,611	1,115,273
1944	57,401	213,000	1,082,500	0	3,622	838,562	1,085,188
1945	40,530	213,000	1,651,400	0	3,622	1,302,118	1,177,318
1946	51,648	213,000	806,300	0	3,622	598,010	1,117,338
1947	95,629	213,000	573,100	0	3,622	344,170	1,034,017
1948	121,921	213,000	432,700	0	3,622	176,592	951,582
1949	49,377	222,990	191,700	28,125	3,622	0	895,418
1950	82,406	222,456	334,800	16,875	3,622	0	938,609
1951	116,712	243,060	68,200	67,500	3,622	0	710,915
1952	89,524	268,415	295,200	67,500	3,622	0	712,054
1953	60,607	213,000	486,000	39,375	3,622	0	960,200
1954	131,326	253,296	34,200	67,500	3,622	0	673,656
1955	61,543	308,610	66,600	67,500	3,622	0	433,981

Table G-8, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1956	73,702	324,499	107,100	67,500	3,622	0	206,758
1957	20,474	248,379	1,504,700	28,125	3,622	298,066	1,169,042
1958	61,562	213,000	836,300	0	3,622	605,574	1,121,584
1959	46,654	213,000	899,400	0	3,622	575,822	1,181,886
1960	49,189	213,000	610,300	0	3,622	344,489	1,181,886
1961	53,933	213,000	1,151,200	0	3,622	880,645	1,181,886
1962	65,639	213,000	236,900	0	3,622	46,819	1,089,706
1963	108,879	243,060	45,400	22,500	3,622	0	802,045
1964	71,890	324,499	18,200	67,500	3,622	0	487,734
1965	55,362	316,571	482,700	67,500	3,622	0	662,379
1966	81,126	248,379	805,100	22,500	3,622	169,067	987,785
1967	86,212	233,260	579,400	50,625	3,622	112,830	1,181,886
1968	69,274	213,000	1,306,100	0	3,622	1,162,501	1,039,589
1969	106,627	213,000	893,600	0	3,622	607,296	1,002,644
1970	106,335	213,000	580,300	0	3,622	198,205	1,061,782
1971	110,724	232,423	394,100	45,000	3,622	0	1,154,113
1972	111,404	213,000	181,800	16,875	3,622	73,502	951,260
1973	76,901	222,456	1,260,900	5,625	3,622	734,329	1,180,477
1974	97,941	213,000	742,700	0	3,622	426,728	1,181,886
1975	105,776	213,000	995,600	0	3,622	851,143	1,003,945

Table G-8, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1976	83,253	221,630	697,500	11,250	3,622	222,304	1,181,886
1977	137,467	213,000	619,500	5,625	3,622	505,089	947,833
1978	112,530	253,296	61,500	67,500	3,622	0	707,385
1979	37,055	231,175	539,300	33,750	3,622	0	958,583
1980	150,315	213,000	375,400	16,875	3,622	47,990	935,931
1981	98,764	254,812	334,600	39,375	3,622	0	952,708
1982	100,081	222,990	150,800	56,250	3,622	0	833,065
1983	91,473	213,000	148,000	67,500	3,622	0	740,470
1984	107,497	243,250	261,700	67,500	3,622	0	715,301
1985	103,666	213,000	527,400	67,500	3,622	0	989,913
1986	106,212	213,000	779,400	0	3,622	264,593	1,181,886
Avg.	84,996	231,436	594,896	25,133	3,622	299,975	

Notes:
a. Diversions from the reservoir are 213,000 acre-feet per year when Cedar Creek Reservoir is above elevation 312.0 and 324,500 acre-feet per year when Cedar Creek is below 312.0.
b. Diversions are made from the Trinity River at the rate of 5,625 acre-feet per month when Richland-Chambers Reservoir is below elevation 310.0.
c. The critical period is from June 1948 through February 1957. The minimum content is 175,814 acre-feet.

year, an increase of 32,800 acre-feet per year over the yield with diversions from the Trinity without system operation.

- As long as Cedar Creek Reservoir is above elevation 312.0 (10 feet below the top of conservation storage), the annual diversion from Cedar Creek is 320,300 acre-feet. The annual diversion from Richland-Chambers is 213,000 acre-feet.
- Whenever Cedar Creek Reservoir is below elevation 312.0, its annual diversion is decreased to 208,800 acre-feet per year, and the diversion from Richland-Chambers is increased to 324,500 acre-feet per year.
- Whenever Cedar Creek Reservoir is below elevation 317.0 (5 feet below the top of conservation storage), a diversion of 6,550 acre-feet per month is made from the Trinity River.
- Whenever Richland-Chambers Reservoir is below elevation 310.0 (5 feet below the top of conservation storage), a diversion of 5,625 acre-feet per month is made from the Trinity River.

The operation studies summarized in Table G-7 and G-8 show that the reservoirs could supply 533,300 acre-feet per year with diversions from the Trinity River and system operation, while maintaining the same reserves at the end of the critical period as the currently permitted operation. The spills from Cedar Creek Reservoir during the critical period of Richland-Chambers Reservoir would be reduced to 32,697 acre-feet by system operation, compared to 267,002 acre-feet without system operation.

Construction of Tehuacana Reservoir

Tehuacana Reservoir is a proposed 337,947 acre-foot reservoir on Tehuacana Creek. It would be connected to Richland-Chambers Reservoir by a channel, and Richland-Chambers-Tehuacana Reservoir would function as a single impoundment. Table G-9 is a summary of an operation study of Richland-Chambers-Tehuacana Reservoir with diversions from the Trinity River and system operation with Cedar Creek reservoir. (The operation of Cedar Creek Reservoir in this situation is shown in Table G-7.) The combined yield of Cedar Creek and Richland-Chambers-Tehuacana Reservoirs would be 622,000 acre-feet per year, an increase of 88,700 acre-feet per year over system operation with diversions from the Trinity without Tehuacana. This represents the 68,400 acre-feet per year diversion from Tehuacana allowed in the Lake Livingston water right and 20,300 acre-feet per year in additional diversions from the Trinity River.

Diversions from Lake Palestine to Cedar Creek Reservoir

No operation studies were conducted for the diversion of water from Lake Palestine on the Neches River to Cedar Creek Reservoir. If water were available to the Tarrant County Water Control and Improvement District Number One from Lake Palestine, it would probably be Dallas' 114,337 acre-feet per year share of the lake's yield. The use of water from Lake Palestine would also make it possible to divert additional water from the Trinity River into Cedar Creek Reservoir. These additional diversions would be .3 x 114,337 = 34,301 acre-feet per year. The total additional

Table G-9

Annual Summary of Operation Study for Richland-Chambers-Tehuacana Reservoir with Diversions from the Trinity River and System Operation

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1940	75,739	301,700	1,007,100	0	3,622	626,039	1,519,833
1941	79,162	301,700	1,390,900	0	3,622	1,142,358	1,383,891
1942	95,827	301,700	1,446,800	0	3,622	909,709	1,519,833
1943	145,305	301,700	670,000	0	3,622	337,670	1,401,536
1944	76,374	301,700	1,307,800	0	3,622	957,100	1,370,540
1945	53,906	301,700	1,978,400	0	3,622	1,484,161	1,505,551
1946	68,544	301,700	993,800	0	3,622	716,730	1,408,755
1947	126,851	301,700	701,200	0	3,622	379,854	1,297,928
1948	160,974	301,700	529,600	7,180	3,622	161,723	1,206,689
1949	62,835	311,691	217,800	43,080	3,622	0	1,089,421
1950	103,539	311,155	398,400	43,080	3,622	0	1,112,585
1951	144,140	331,761	86,500	86,160	3,622	0	805,722
1952	108,057	357,115	356,200	86,160	3,622	0	779,288
1953	74,363	301,700	629,900	71,800	3,622	0	1,101,303
1954	158,884	341,997	50,600	86,160	3,622	0	733,560
1955	72,411	397,311	87,300	86,160	3,622	0	433,676

Table G-9, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1956	80,037	413,200	151,700	86,160	3,622	0	174,677
1957	30,113	337,078	1,834,400	35,900	3,622	174,800	1,499,364
1958	81,804	301,700	965,300	0	3,622	647,834	1,429,704
1959	61,905	301,700	1,071,110	0	3,622	613,744	1,519,833
1960	65,066	301,700	755,400	0	3,622	385,012	1,519,833
1961	71,679	301,700	1,365,300	0	3,622	988,299	1,519,833
1962	87,195	301,700	291,100	0	3,622	34,716	1,383,700
1963	141,316	331,761	55,300	35,900	3,622	0	998,201
1964	92,878	413,200	19,300	86,160	3,622	0	593,961
1965	71,059	405,272	608,100	86,160	3,622	0	808,268
1966	107,307	337,078	1,007,700	28,720	3,622	145,975	1,250,706
1967	111,806	321,960	706,700	64,620	3,622	64,805	1,519,833
1968	91,778	301,700	1,543,000	0	3,622	1,351,524	1,314,209
1969	140,716	301,700	1,050,700	0	3,622	617,813	1,301,058
1970	139,923	301,700	625,300	0	3,622	158,386	1,322,727
1971	142,284	321,124	485,600	64,620	3,622	0	1,405,917
1972	146,669	301,700	236,800	21,540	3,622	19,074	1,193,192
1973	102,239	311,155	1,483,000	14,360	3,622	756,498	1,517,038
1974	130,242	301,700	955,400	0	3,622	517,041	1,519,833
1975	140,107	301,700	1,113,600	0	3,622	919,840	1,268,164

Table G-9, Continued

Year	Evaporative Loss (Ac-Ft)	Use (Ac-Ft)	Inflow (Ac-Ft)	Diversions from Trinity (Ac-Ft)	Downstream Release (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Ac-Ft)
1976	110,394	310,330	955,500	21,540	3,622	301,025	1,519,833
1977	182,897	301,700	735,200	0	3,622	561,239	1,205,575
1978	147,326	341,997	119,700	86,160	3,622	0	918,490
1979	118,424	319,874	810,500	35,900	3,622	0	1,322,970
1980	199,426	301,700	467,000	14,360	3,622	118,764	1,180,818
1981	127,877	343,512	417,800	64,620	3,622	0	1,188,227
1982	128,863	311,691	252,600	78,980	3,622	0	1,075,631
1983	121,023	301,700	221,200	86,160	3,622	0	956,646
1984	141,773	331,951	321,800	86,160	3,622	0	887,260
1985	132,394	301,700	670,700	86,160	3,622	0	1,206,404
1986	140,957	301,700	1,004,800	14,360	3,622	259,452	1,519,833
Avg.	110,519	320,136	726,679	34,220	3,622	326,621	

Notes:
a. Diversions from the reservoir are 301,700 acre-feet per year when Cedar Creek Reservoir is above elevation 312.0 and 413,200 acre-feet per year when Cedar Creek is below 312.0.
b. Diversions are made from the Trinity River at the rate of 7,180 acre-feet per month when Richland-Chambers-Tehuacana Reservoir is below elevation 310.0.
c. The critical period is June 1948 through February 1957. The minimum content is 142,108 acre-feet.

yield due to diversions from Lake Palestine and added diversions from the River would be 148,638 acre-feet per year.

Summary of East Texas Diversions and Existing Reservoirs

Table G-10 is a summary of the yield of the District's East Texas reservoirs with the changes to operation discussed above.

TENNESSEE COLONY RESERVOIR

The proposed Tennessee Colony Reservoir site is on the main stem of the Trinity River downstream from Richland and Tehuacana Creeks. Table G-11 is an annual summary of a monthly operation study for Tennessee Colony Reservoir. Runoff and area-capacity data used in the operation study are based on the assumption that Richland-Chambers Reservoir is in place but that Tehuacana Reservoir is not built. The operation study summarized in Table G-11 is based on natural runoff for Tennessee Colony Reservoir.

PROPOSED RESERVOIRS IN THE SULPHUR RIVER BASIN

Several of the proposed new reservoirs considered as part of this study would be located in the Sulphur River basin in northeast Texas. Figure G-1 is a schematic diagram of the basin, showing the relative location of major streams and the existing and proposed reservoirs. The existing Wright Patman Lake is operated by the U. S. Army Corps of Engineers for water supply, flood control, and recreation. The City of Texarkana, Texas, holds water rights in the reservoir. Cooper Reservoir is under construction by the Corps of Engineers, and water rights are

Table G-11

Annual Summary of Operation Study for Tennessee Colony Reservoir with Natural Runoff Including Spills from Existing Upstream Reservoirs

Year	Evaporative Loss (Acre-Feet)	Use (Ac-Ft)	Inflow (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Acre-Feet)
1941	102,217	300,100	4,353,900	3,951,583	1,122,170
1942	122,007	300,100	5,286,800	4,864,693	1,122,170
1943	155,894	300,100	1,301,820	1,061,440	906,556
1944	107,482	300,100	2,477,900	2,081,101	895,773
1945	91,719	300,100	6,162,500	5,544,284	1,122,170
1946	107,947	300,100	4,252,390	3,844,343	1,122,170
1947	161,912	300,100	1,365,600	931,793	1,093,965
1948	198,438	300,100	1,367,700	1,141,749	821,378
1949	116,016	300,100	1,457,250	832,947	1,029,565
1950	147,292	300,100	2,730,050	2,288,699	1,023,524
1951	190,034	300,100	322,950	0	856,340
1952	140,740	300,100	206,450	0	621,950
1953	110,501	300,100	511,750	0	723,099
1954	182,461	300,100	224,650	0	465,188
1955	96,312	300,100	232,750	0	301,526
1956	77,476	300,100	98,750	0	22,700
1957	77,624	300,100	2,889,400	1,412,206	1,122,170
1958	133,306	300,100	2,510,700	2,257,538	941,926
1959	14,927	300,100	1,335,660	840,389	1,122,170
1960	75,792	300,100	1,288,010	912,118	1,122,170
1961	35,706	300,100	1,910,480	1,604,168	1,092,676
1962	173,932	300,100	707,640	204,114	1,122,170
1963	230,383	300,100	206,450	9,328	788,809
1964	153,780	300,100	449,050	0	783,979
1965	101,917	300,100	1,107,850	561,940	927,872
1966	194,835	300,100	2,179,200	1,564,875	1,047,262
1967	121,788	300,100	346,560	0	971,934
1968	44,768	300,100	3,969,000	3,481,906	1,114,160
1969	106,204	300,100	4,422,800	4,050,615	1,080,041
Avg.	123,221	300,100	1,919,863	1,497,995	

Note: The critical period is from October 1950 through April 1957. The minimum content is 133 acre-feet.

SCHEMATIC DIAGRAM OF EXISTING AND PROPOSED RESERVOIRS
IN THE SULPHUR RIVER BASIN

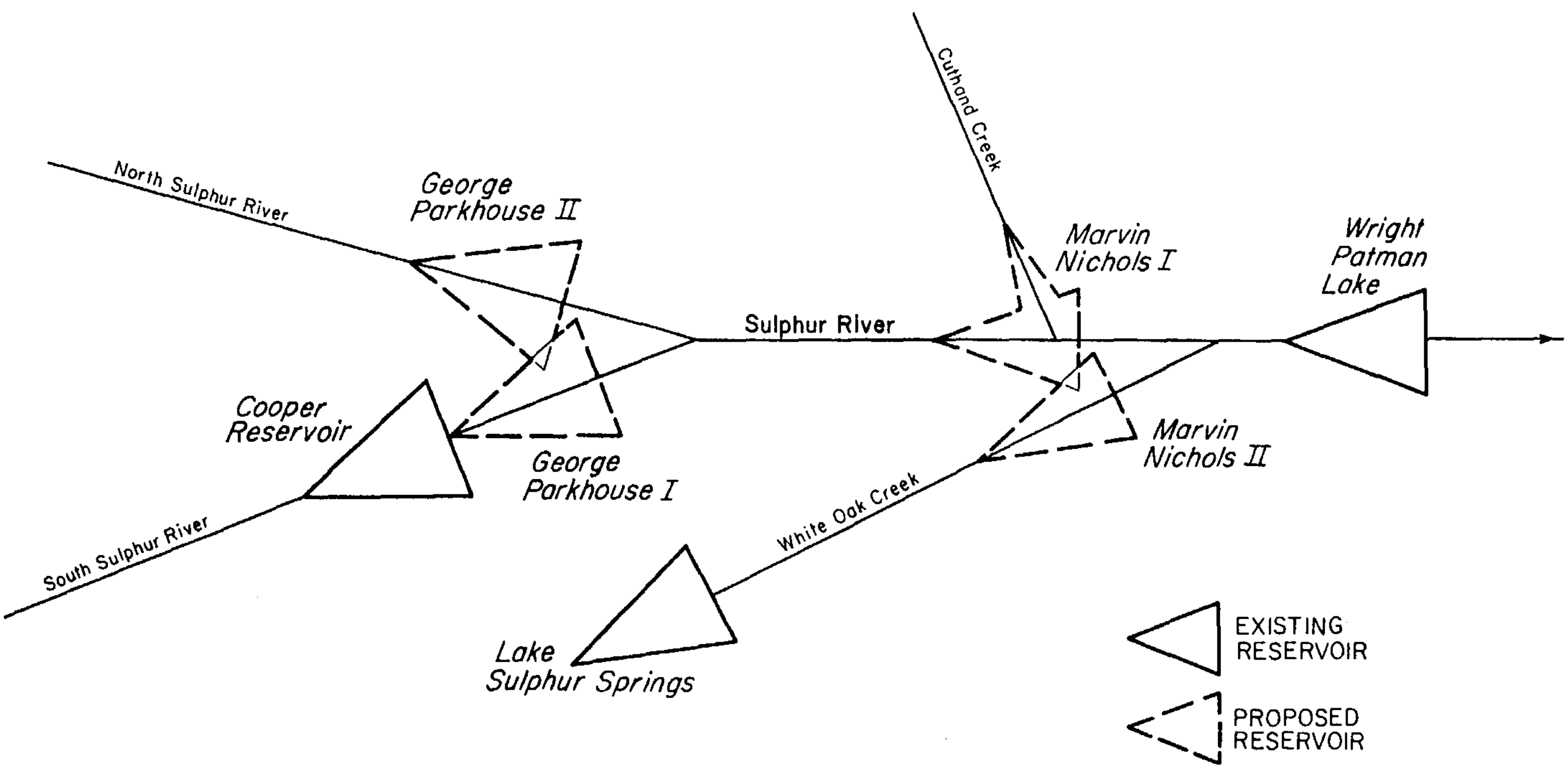

FIGURE G-1

Table G-12

Water Rights for Existing Reservoirs in the Sulphur River Basin

Adjudication Certificate No.	Permit Holder	Reservoir	Storage (Ac-Ft)	Use	Diversion (Ac-Ft/Yr)	Priority Date
03-4797	Sulphur River MWD	Cooper	81,470	(Mun	26,960	11/19/65
				(Ind	11,560	
03-4798	North Texas MWD	Cooper	114,265	Mun	54,000	11/19/65
03-4799	Irving	Cooper	114,265	(Mun	44,820	11/19/65
				(Ind	9,180	
Cooper Total			310,000		146,520	
03-4811	Sulphur Springs WD	Sulphur Springs	2,100	(Mun	2,000	7/24/51
			11,900	(Mun	7,800	11/25/68
			2,260			11/30/70
			1,578			9/26/83
Sulphur Springs Total			17,838		9,800	
03-4836	Texarkana, Texas	Wright Patman	386,900[b]	(Mun	45,000	3/ 5/51
				(Ind	135,000	2/17/57
Texarkana Total			386,900		180,000	

Notes: a. Water rights are from records of the Texas Water Commission (61,62).
b. The permitted storage for Wright Patman Lake varies with the season, from 265,300 acre-feet to 386,900 acre-feet.

- Cooper Reservoir and Lake Sulphur Springs are operated at their full permitted diversions. Spills from these reservoirs are available for use downstream.
- Releases are made from the reservoirs immediately upstream from Lake Wright Patman to keep that reservoir's yield at its current level of 160,800 acre-feet per year.
- Other existing water rights are assumed to make full use of available flows to the extent of their permits.

With these assumptions, operation studies were made with various combinations of new reservoirs constructed to determine the additional yield they would make available. Table G-13 summarizes the results of these operation studies. Table G-14 is an annual summary of the operation of George Parkhouse II with no other new reservoirs in the basin. Table G-15 is a similar summary of the operation of Marvin Nichols I with no other new reservoirs in the basin.

Table G-13

Summary of Sulphur River Basin Operation Studies

Reservoir(s)	Yield in Acre-Feet per Year
George Parkhouse I	123,000
George Parkhouse II	136,700
Marvin Nichols I	624,400
Marvin Nichols II	294,800
George Parkhouse I and George Parkhouse II	270,500
Marvin Nichols I and Marvin Nichols II	916,800
George Parkhouse II and Marvin Nichols I	666,900
George Parkhouse II, Marvin Nichols I, and Marvin Nichols II	958,800
George Parkhouse I, George Parkhouse II, and Marvin Nichols I	764,500
George Parkhouse I, George Parkhouse II, Marvin Nichols I, and Marvin Nichols II	1,056,800

Table G-14

Annual Summary of Operation Study for George Parkhouse Reservoir Stage II

Year	Evaporative Loss (Acre-Feet)	Use (Ac-Ft)	Inflow (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Acre-Feet)
1941	13,867	136,700	240,820	141,035	192,831
1942	19,144	136,700	220,350	68,886	188,451
1943	26,860	136,700	86,980	0	111,871
1944	16,283	136,700	218,110	0	176,998
1945	10,358	136,700	304,470	123,170	211,240
1946	11,253	136,700	350,350	170,024	243,613
1947	21,545	136,700	118,790	7,557	196,601
1948	25,274	136,700	153,140	54,222	133,545
1949	11,208	136,700	205,160	26,292	164,505
1950	8,875	136,700	388,000	202,160	204,770
1951	17,851	136,700	206,430	94,860	161,789
1952	26,212	136,700	151,650	0	150,527
1953	19,194	136,700	189,880	11,091	173,422
1954	32,606	136,700	179,780	3,753	180,143
1955	21,933	136,700	86,910	0	108,420
1956	27,580	136,700	84,270	0	28,410
1957	5,414	136,700	663,670	306,353	243,613
1958	14,475	136,700	300,020	234,060	158,398
1959	11,542	136,700	179,370	0	189,526
1960	19,038	136,700	298,460	88,635	243,613
1961	19,224	136,700	145,360	65,079	167,970
1962	17,984	136,700	242,990	19,758	236,518
1963	27,495	136,700	33,080	0	105,403
1964	16,175	136,700	136,980	0	89,508
1965	16,922	136,700	151,800	0	87,686
1966	16,452	136,700	304,120	84,192	154,462
1967	14,818	136,700	295,570	54,901	243,613
1968	13,679	136,700	482,240	331,861	243,613
1969	18,653	136,700	302,160	214,945	175,475
1970	14,025	136,700	288,090	116,773	196,067

Table G-14, Continued

Year	Evaporative Loss (Acre-Feet)	Use (Ac-Ft)	Inflow (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Acre-Feet)
1971	18,690	136,700	288,660	85,724	243,613
1972	27,567	136,700	64,220	0	143,566
1973	14,676	136,700	465,710	214,287	243,613
1974	17,728	136,700	298,960	144,532	243,613
1975	28,265	136,700	245,830	175,156	149,322
1976	20,593	136,700	170,120	0	162,149
1977	29,483	136,700	120,170	0	116,136
1978	13,467	136,700	57,530	0	23,499
1979	16,224	136,700	248,320	0	118,895
1980	19,213	136,700	77,190	0	40,172
1981	18,486	136,700	327,100	0	212,086
1982	21,612	136,700	348,930	201,718	200,986
1983	27,538	136,700	153,180	40,677	149,251
1984	28,459	136,700	216,360	0	200,452
1985	31,062	136,700	275,990	98,659	210,021
1986	29,000	136,700	241,180	41,888	243,613
Avg.	19,522	136,700	230,618	74,397	

Note: The critical period is from July 1975 through October 1978. The minimum content is 4 acre-feet.

Table G-15

Annual Summary of Operation Study for Marvin Nichols Reservoir Stage I

Year	Evaporative Loss (Acre-Feet)	Use (Ac-Ft)	Inflow (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Acre-Feet)
1941	45,038	624,400	1,779,430	1,269,267	1,210,422
1942	71,954	624,400	1,197,180	740,866	970,402
1943	116,271	624,400	472,990	0	702,721
1944	33,649	624,400	1,324,360	235,179	1,133,853
1945	18,044	624,400	2,418,920	1,814,167	1,096,162
1946	24,850	624,400	1,879,480	956,675	1,369,717
1947	72,765	624,400	619,700	239,091	1,053,161
1948	94,003	624,400	865,340	340,652	859,446
1949	33,517	624,400	942,660	63,793	1,080,396
1950	-6,288	624,400	1,896,750	1,157,039	1,201,995
1951	73,804	624,400	620,810	106,674	1,017,927
1952	91,406	624,400	949,900	205,377	1,046,644
1953	55,434	624,400	897,510	335,490	928,830
1954	129,274	624,400	629,290	0	804,446
1955	52,859	624,400	390,500	0	517,687
1956	73,079	624,400	198,030	0	18,238
1957	15,101	624,400	2,989,270	1,000,148	1,367,859
1958	26,709	624,400	1,450,210	1,074,146	1,092,814
1959	43,892	624,400	875,900	0	1,300,422
1960	74,329	624,400	1,189,240	421,216	1,369,717
1961	50,933	624,400	770,750	385,410	1,079,724
1962	87,566	624,400	949,430	0	1,317,188
1963	116,948	624,400	158,770	0	734,610
1964	67,604	624,400	445,770	0	488,376
1965	70,112	624,400	821,330	0	615,194
1966	106,858	624,400	1,201,860	157,818	927,978
1967	89,681	624,400	1,409,830	254,010	1,369,717
1968	58,160	624,400	2,481,500	1,798,940	1,369,717
1969	98,867	624,400	2,349,070	2,034,870	960,650
1970	99,363	624,400	1,208,610	396,426	1,049,071

Table G-15, Continued

Year	Evaporative Loss (Acre-Feet)	Use (Ac-Ft)	Inflow (Ac-Ft)	Spills (Ac-Ft)	End-of-Year Content (Acre-Feet)
1971	83,481	624,400	1,412,960	384,433	1,369,717
1972	105,383	624,400	372,330	0	1,012,264
1973	58,124	624,400	2,873,650	1,833,673	1,369,717
1974	63,298	624,400	1,830,380	1,142,682	1,369,717
1975	103,639	624,400	1,223,940	919,568	946,050
1976	81,232	624,400	875,620	0	1,116,038
1977	128,181	624,400	1,046,470	590,072	819,855
1978	96,678	624,400	200,000	0	298,777
1979	72,239	624,400	1,647,410	128,092	1,121,456
1980	144,421	624,400	632,420	0	985,055
1981	110,450	624,400	1,419,780	343,410	1,326,575
1982	78,174	624,400	2,176,000	1,430,284	1,369,717
1983	105,723	624,400	772,430	480,042	931,982
1984	92,504	624,400	1,025,310	0	1,240,388
1985	107,890	624,400	917,570	248,461	1,177,207
1986	99,418	624,400	857,550	48,573	1,262,366
Avg.	76,448	624,400	1,188,440	489,925	

Note: The critical period is from June 1953 through January 1957. The minimum content is 237 acre-feet.

APPENDIX H

EXAMINATION OF WATER QUALITY

OF EXISTING AND POTENTIAL RESERVOIRS

APPENDIX H

EXAMINATION OF WATER QUALITY OF EXISTING AND POTENTIAL RESERVOIRS

This appendix discusses the water quality of several existing and potential reservoirs which are possible sources of additional water supply for the Tarrant County Water Control and Improvement District Number One. The existing reservoirs considered are Lake Palestine and Lake Texoma. Potential reservoirs considered are George Parkhouse Reservoir Stage I and Stage II, Marvin Nichols Reservoir Stage I and Stage II, Tehuacana Reservoir, and Tennessee Colony Reservoir.

The examination of water quality is based upon existing water quality and streamflow information provided by the U.S. Geological Survey (USGS) and the Texas Water Commission (TWC). The water quality analyses include an evaluation of inorganic parameters and examination of data on metals and biological contaminants, if available.

The physical and inorganic parameters which are considered include:

Dissolved Oxygen	pH
Turbidity	Fluoride
Hardness	Alkalinity
Calcium	Sulfate
Magnesium	Chloride
Sodium	Total Dissolved Solids (TDS)

The metals which are included in the analysis include:

Arsenic	Zinc
Barium	Manganese
Cadmium	Mercury
Chromium	Nickel
Copper	Selenium
Iron	Silver
Lead	

For existing reservoirs, the analysis is based on water quality at the monitoring site closest to the dam. For potential reservoirs, streamflow water quality data from a gage near the reservoir site are used in the analysis. Flow-weighted averages of streamflow data provide the best estimate of reservoir quality and are used in this discussion. Table H-1 presents a summary of the monitoring sites for the existing and proposed reservoirs. Tables H-2 and H-3 present a summary of the water quality data for the potential water supply sources.

The water quality standards considered in this study are taken from the following sources: 1) EPA National Primary Drinking Water Regulations, 2) EPA Secondary Drinking Water Regulations, 3) 1986 EPA Quality Criteria for Water, 4) Texas Department of Health Primary and Secondary Drinking Water Regulations, and 5) 1988 Texas Surface Water Quality Standards (TSWQS). The water quality data are also compared to the current treated Fort Worth water quality and the raw water quality of Lake Worth and Cedar Creek Reservoir, which are existing water supply sources for Tarrant County District customers. The comparison gives an indication of the degree of treatment which would be required for the various water supply sources studied. Table H-4 summarizes the 1988 Texas Surface Water Quality Criteria for physical, chemical, and heavy metals parameters for the potential water supply sources. Table H-5 summarizes the existing federal and state Drinking Water Standards, the current treated Fort Worth water quality, the raw water quality for Lake Worth and Cedar Creek Reservoir,

Table H-1

Summary of Water Quality Monitoring Sites for Potential Water Supply Reservoirs

Potential Water Supply Reservoir	Water Quality Monitoring Site Location	Period of Record: Physical and Chemical Data	Period of Record: Heavy Metals Data
Lake Texoma	Lake Texoma near Dam	3/78-3/89	-
Lake Palestine	Lake Palestine near Frankston, Texas	1/81-8/84	-
George Parkhouse Reservoir Stage I	South Sulphur River near Cooper, Texas	12/79-7/87	1/80-7/87
George Parkhouse Reservoir Stage II	North Sulphur River near Cooper, Texas	10/79-7/87	-
Marvin Nichols Reservoir Stage I	Sulphur River near Talco, Texas	10/79-7/87	1/80-7/87
Marvin Nichols Reservoir Stage II	White Oak Creek near Talco, Texas	11/79-7/87	2/83-9/85
Wright Patman Lake[1]	Wright Patman Lake near Dam	10/79-9/84	10/79-9/81
Tehuacana Reservoir	Tehuacana Creek near Streetman, Texas	10/79-5/85	-
Tennessee Colony Reservoir	Trinity River near Trinidad, Texas	10/79-9/87	1/80-7/87

Note: [1] Wright Patman Lake is not a potential water supply source in this study. It has been included for comparison with Marvin Nichols Reservoir Stages I and II.

Table H-2

Historical Physical and Chemical Water Quality Data for Potential Water Supply Sources

Parameter	Lake Texoma		Lake Palestine		George Parkhouse Reservoir Stage I		George Parkhouse Reservoir Stage II		Marvin Nichols Reservoir Stage I		Marvin Nichols Reservoir Stage II		Wright Patman(b) Lake		Tehuacana Reservoir		Tennessee Colony Reservoir	
	Average	Range of Data	Average	Range of Data	Flow-wtd. Average	Range of Data	Flow-wtd. Average	Range of Data	Flow-wtd. Average	Range of Data	Flow-wtd. Average	Range of Data	Average	Range of Data	Flow-wtd. Average	Range of Data	Flow-wtd. Average	Range of Data
Dissolved Oxygen (mg/l)	9.0	0.0-12.4	-	-	6.9	3.4-13.0	-	-	7.76	2.2-12	7.2	3.4-11.3	6.9	.1-13	-	-	6.24	0.6-11.8
Turbidity (NTU)	-	-	-	-	83	4.5-1,000	-	-	80.8	4.5-1,000	46.5	5.1-90	-	-	-	-	70.14	1.1-300
Total Hardness (mg/l as CaCO3)	316	190-450	32.3	24-47	63	42-250	107	99-590	92.5	31-350	27.9	15-140	74	51-91	47.6	30-770	132.3	110-190
Fecal Coliform (#/100 ml)(a)	3	1-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	428	21-180,000
Calcium (mg/l as CaCO3)	-	-	13.8	6.2-27.4	53.2	35-212	96.5	105-473	81	19.4-298	16.9	9.2-85	62.2	42-77	29.9	18.9-423	115.5	97-197
Magnesium (mg/l)	-	-	4.5	4.2-4.8	2.3	1.5-10	2.3	1.9-30	2.7	2.1-11	2.7	1.8-14	2.83	2-3.4	4.2	2.6-83	3.82	2.7-6.1
Sodium (mg/l)	-	-	20.3	19-21	8.5	4.5-93	10.5	8.2-230	11.8	6.4-100	6.9	2.4-80	11.91	7.7-18	14.2	6.1-590	25.9	12-120
Total Alkalinity (mg/l as CaCO3)	149	102-410	12.0	5-24	61	31-251	93	54-200	84.8	21-281	19	11-140	69	48-79	38.7	30-290	112.0	97-187
Sulfate (mg/l)	202	19-316	27.3	25-31	15.2	5-95	30	19-750	26.3	7-220	17	7-110	20	5-36	16.3	4.8-500	47.3	25-130
Chloride (mg/l)	361	185-835	28.8	26-31	5.5	3.6-58	5.6	3.1-260	6.9	4.2-67	8.3	3.9-80	11.8	7.4-19	16.6	6.2-560	23.0	10-89
Fluoride (mg/l)	-	-	.15	0.1-.20	.18	.1-.5	.15	.1-.7	.24	.2-.4	.08	.1-.5	.16	.1-.2	.125	.1-.6	.423	0.2-1.8
Total Dissolved Solids (mg/l)	926	661-1,105	108	99-127	105	69-470	160	143-1,500	148.5	110-608	65	58-356	120	86-150	103	61-2,430	232.1	179-517
Nitrate (mg/l)	.07	.0005-.44	-	-	1.5	.02-4.9	-	-	.93	.08-4.2	.3	.13-.78	.09	.05-.28	-	-	1.21	.34-6.28
Iron (mg/l)	-	-	-	-	127.3	5-160	-	-	36.5	1.5-190	373.6	36-540	79.8	5-480	-	-	24.9	1.5-71
Manganese (mg/l)	-	-	-	-	5.4	4-90	-	-	21.8	9-800	50.7	28-810	164.3	2-2,200	-	-	4.75	.5-70
pH	-	7.2-8.4	-	6.5-7.6	-	7-8.4	-	7.7-8.1	-	7.3-8.1	-	6.7-7.7	-	6.5-8.8	-	6.8-7.1	-	7.1-8.5
Langelier Index(c)		None		Strong		Moderate		Moderate		Moderate		Strong		Strong		Moderate		Low

Notes: (a) Geometric mean of data.
(b) Wright Patman is not a potential water supply source in this study. It has been included for comparison with Marvin Nichols Reservoir Stages I and II.
(c) Indicates the tendency of the raw water to become corrosive.

Table H-3

Historical Heavy Metals Water Quality Data for Potential Water Supply Sources

Parameter	George Parkhouse Reservoir Stage I		Marvin Nichols Reservoir Stage I		Marvin Nichols Reservoir Stage II		Wright Patman[1] Lake		Tennessee Colony Reservoir	
	Flow-wtd. Average	Range of Data	Flow-wtd. Average	Range of Data	Flow-wtd. Average	Range of Data	Average	Range of Data	Flow-wtd. Average	Range of Data
Arsenic (ug/l)	4.72	1-31	3.9	.5-7	.59	.5-2	4.3	1-24	2.46	2-11
Barium (ug/l)	51.4	40-110	56.5	40-140	48.5	37-100	41.7	30-70	41.2	20-80
Cadmium (ug/l)	.78	.5-11	.22	.5-2	.86	.5-2	.63	.5-1.0	.862	.5-2
Chromium (ug/l)	4.3	4-10	6.2	5-50	5.0	-	10	-	3.60	.5-10
Copper (ug/l)	4.7	.5-7	1.5	.5-5	4.2	.5-5	4.5	3-5	4.42	1-8
Lead (ug/l)	1.1	.5-6	1.9	.5-15	.78	.5-5	3.5	1-5	1.91	.5-12
Mercury (ug/l)	.05	.1-.7	.02	.05-.1	.08	.05-.2	.1	-	.079	.05-.4
Nickel (ug/l)	-	-	-	-	-	-	-	-	5.61	5-10
Selenium (ug/l)	.45	.4-1.0	.3	.5-1	.54	.5-1	1	-	.518	.5-2.0
Silver (ug/l)	.5	-	.2	.5-1	.5	-	-	-	-	.5-5.0
Zinc (ug/l)	13.9	1.5-38	8.8	1.5-30	14.4	1.5-34	9.1	1.5-30	-	1.5-40

Note: [1] Wright Patman Lake is not a potential water supply source in this study. It has been included for comparison with Marvin Nichols Reservoir Stages I and II.

Table H-4

1988 Texas Surface Water Quality Standards
for Potential Water Supply Sources

Parameter	Lake Texoma	Lake Palestine	George Parkhouse Reservoir Stage I	George Parkhouse Reservoir Stage II	Marvin Nichols Reservoir Stages I&II	Wright Patman(d) Lake	Tehuacana Reservoir	Tennessee Colony Reservoir
Dissolved Oxygen (mg/l)(a)	5.0	5.0	5.0	5.0	5.0	5.0	-	5.0
Fecal Coliform (#/100 ml)(b)	200	200	200	200	200	200	-	2,000
Sulfate (mg/l)(c)	300	30	150	475	150	475	-	150
Chloride (mg/l)(c)	600	50	60	190	60	190	-	150
Total Dissolved Solids (mg/l)(c)	1,500	150	600	1,320	600	1,320	-	600
pH	6.5-9.0	6-8.5	6-8.5	6-8.5	6-8.5	6-8.5	-	6.5-9.0
Arsenic (ug/l)	-	-	360/190	360/190	360/190	360/190	360/190	360/190
Cadmium (ug/l)	-	-	32.9/1.12	32.9/1.12	32.9/1.12	32.9/1.12	32.2/1.1	32.2/1.1
Chromium (ug/l)	-	-	1,708/203	1,708/203	1,708/203	1,708/203	1,679/200	1,679/200
Copper (ug/l)	-	-	18.8/12.6	18.8/12.6	18.8/12.6	18.8/12.6	18.5/12.4	18.5/12.4
Lead (ug/l)	-	-	79.6/3.1	79.6/3.1	79.6/3.1	79.6/3.1	77.5/3.02	77.5/3.02
Mercury (ug/l)	-	-	2.4/.012	2.4/.012	2.4/.012	2.4/.012	2.4/.012	2.4/.012
Nickel (ug/l)	-	-	1,394/155	1,394/155	1,394/155	1,394/155	1,370/152	1,370/152
Selenium (ug/l)	-	-	260/35	260/35	260/35	260/35	260/35	260/35
Silver (ug/l)	-	-	3.92/.49	3.92/.49	3.92/.49	3.92/.49	3.8/.49	3.8/.49
Zinc (ug/l)	-	-	115/104	115/104	115/104	115/104	-	-

Notes: (a) No measurements should fall below this value.
(b) Thirty-day geometric mean not to exceed this value.
(c) Annual average not to exceed this value.
(d) Wright Patman Lake is not a potential water supply source in this study. It has been included for comparison with Marvin Nichols Reservoir Stages I and II.
(e) Standards for arsenic and subsequent parameters are expressed as acute limit/chronic limit.

Table H-5

Summary of Existing Drinking Water Standards
Treated and Raw Water Quality

	Existing Standards: Primary Drinking Water Standards	Existing Standards: Secondary Drinking Water Standards	1986 EPA Quality Criteria for Water (Human Health Criteria)	Existing Treated Water Quality: Fort Worth Holly WTP 1988	Existing Treated Water Quality: Ft. Worth Rolling Hills WTP 1988	Existing Treated Water Quality: Fort Worth 1989	Raw Water Quality of Existing Water Supply Sources: Cedar Creek Reservoir	Raw Water Quality of Existing Water Supply Sources: Lake Worth
Dissolved Oxygen (mg/l)	-	-	-	-	-	-	6.2	6.9
Turbidity (NTU)	1.0	-	-	.27	.26	.25	-	10.5
Total Hardness (mg/l as $CaCO_3$)	-	-	-	153	82	-	68	139
Fecal Coliform (#/100 ml)	0	-	-	0	0	0	-	11.5
Calcium (mg/l as $CaCO_3$)	-	-	-	124	70	-	50	104
Magnesium (mg/l)	-	-	50	8	4	-	4.3	8
Sodium (mg/l)	-	-	-	30	26	35	-	-
Total Alkalinity (mg/l as $CaCO_3$)	-	-	-	126	55	-	56	117
Sulfate (mg/l)	-	250 EPA 300 TDH	250	29	36	40	25	22
Chloride (mg/l)	-	250 EPA 300 TDH	250	44	26	-	18	49
Fluoride (mg/l)	4.0	2.0	-	.76	.81	1.0	.2	.3
Total Dissolved Solids (mg/l)	-	500 EPA 1,000 TDH	-	248	157	-	123	215
Nitrate (mg/l)	10.0	-	10	-	-	<0.05	-	.08

Table H-5, Continued

	Existing Standards		1986 EPA Quality Criteria for Water (Human Health Criteria)	Existing Treated Water Quality			Raw Water Quality of Existing Water Supply Sources	
	Primary Drinking Water Standards	Secondary Drinking Water Standards		Fort Worth Holly WTP 1988	Ft. Worth Rolling Hills WTP 1988	Fort Worth 1989	Cedar Creek Reservoir	Lake Worth
Iron (mg/l)	-	300	0.3	140	200	-	12.4-569	-
Manganese (mg/l)	-	50	-	20	20	-	5.3-1,139	-
pH	-	>7.0	5-9	8.0	8.6	-	6.6-8.6	7.3-8.8
Arsenic (ug/l)	50	-	0	<20	<20	<20	1-19	-
Barium (ug/l)	1,000	-	1,000	60	30	200	40-90	-
Cadmium (ug/l)	10	-	10	<10	<10	<10	.5-2	-
Chromium (ug/l)	50	-	50	20	20	20	-	-
Copper (ug/l)	-	1,000	1,000	20	10	20	1-5	-
Lead (ug/l)	5	-	50	10	10	2	5-14	-
Mercury (ug/l)	2	-	144[2]	<.2	<.2	<.2	0-4	-
Nickel (ug/l)	-	-	-	-	-	-	-	-
Selenium (ug/l)	20	-	10	<10	<10	<10	-	-
Silver (ug/l)	50	-	50	<10	<10	<10	-	-
Zinc (ug/l)	-	5,000	5,000	10	10	<50	1.5-8.7	-

Notes: [1] Average treated water quality for both Fort Worth water treatment plants.
[2] Measured in ng/l.

and the 1986 EPA Quality Criteria for Water.

Hardness is an important parameter to industry as an indicator of potential precipitation problems, including carbonates in cooling towers or boilers, soaps and dyes in cleaning and textile industries, and emulsifiers in photographic development. Waters of 0 to 75 mg/l hardness (expressed as $CaCO_3$) are generally designated as "soft," of 75 to 150 mg/l as "moderately hard," of 150 to 300 mg/l as "hard," and of 300 mg/l or more as "very hard" (1986 EPA Quality Criteria for Water).

LAKE TEXOMA

One of the alternatives considered in this study involves diversion of 50,000 acre-feet per year of water from Lake Texoma in the Red River Basin to Eagle Mountain Lake in the Trinity River Basin. Since Lake Texoma water quality is characterized by relatively high concentrations of TDS, an evaluation was performed to determine the impact of such a diversion on TDS levels in Eagle Mountain Lake. The evaluation involved the use of a completely mixed reservoir model of Eagle Mountain Lake to assess the increase in TDS associated with various amounts of diversion from Lake Texoma. Eagle Mountain Lake volumes and inflows used in the model were taken from an operations study performed by Freese and Nichols for the West Fork of the Trinity River System. TDS concentrations for Eagle Mountain Lake were based on U.S. Geological Survey (USGS), Texas Water Commission, and City of Fort Worth data collected from 1980 through 1988. TDS concentrations for Eagle Mountain Lake inflow were flow-weighted concentrations based on Texas Water Commission data collected from 1980 through 1987. TDS concentrations for Lake Texoma diversions were based on USGS records of the quality of lake releases from 1950 through 1979. The concentrations of TDS associated with each of the inputs to Eagle Mountain Lake were held constant for the simulations.

The average of the annual concentrations of TDS in Eagle Mountain Lake increased from in excess of 250 mg/l to somewhat above 475 mg/l for a 50,000 acre-feet per year diversion from Lake Texoma to Eagle Mountain Lake considering a 1949 to 1957 simulation period. This quantity of flow diversion increased the maximum annual average TDS concentration from in excess of 300 mg/l to in excess of 600 mg/l during the maximum drought year. The projections indicate that the Texas Surface Water Quality Standards for TDS in Eagle Mountain Lake would be exceeded during the maximum drought year without diversions from Lake Texoma. With the diversion of 50,000 acre-feet per year from Texoma, the standards would be exceeded in five of the six years simulated. The federal drinking water standard for TDS is 500 mg/l and the State of Texas criterion is 1,000 mg/l. The federal drinking water standard for TDS would be exceeded during three of the six drought years examined with a Texoma diversion of 50,000 acre-feet per year. Reducing the diversion to 20,000 acre-feet would eliminate any annual average TDS concentrations above 500 mg/l.

Physical and Inorganic Parameters

The average total hardness in Lake Texoma is 316 mg/l as $CaCO_3$, which is considered very hard. The average total alkalinity is approximately 149 mg/l as $CaCO_3$. Total hardness and total alkalinity in Lake Texoma are significantly higher than in the existing Fort Worth water supply sources.

Chloride, sulfate, and dissolved oxygen in Lake Texoma occasionally fail to meet the Texas Surface Water Quality Standards. Average concentrations of chloride, sulfate, and TDS in Lake Texoma exceed the average concentrations for these parameters in the existing water supply sources.

A Langelier Saturation Index analysis performed for Lake Texoma predicts the ability of the water to deposit or dissolve calcium carbonate. The analysis shows that the water in Lake Texoma is very stable and that the probability of corrosive water developing is very low.

Heavy Metals

No heavy metals data are available for Lake Texoma.

LAKE PALESTINE

Physical and Inorganic Parameters

The water quality in Lake Palestine is generally very good. Sulfate is the only parameter which has exceeded the TSWQS, and it did so on only one occasion.

The average concentrations for most of the parameters are comparable to those in the existing water supply sources, except for total hardness, total alkalinity and calcium. The average concentrations for total hardness, total alkalinity, and calcium are 32.3, 12.0, and 13.8 mg/l as $CaCO_3$, respectively, and are well below the average levels found in the existing water supply sources. A value of 32.3 mg/l as $CaCO_3$ for total hardness is considered soft.

Cedar Creek Reservoir water has been shown to exhibit corrosive characteristics, and the water quality data in Cedar Creek Reservoir and Lake Palestine are comparable. The low total alkalinity for this potential reservoir, which is comparable to that of Cedar Creek Reservoir, suggests that this water might have a low buffering capacity, which would increase the chances for corrosion.

An analysis on the Lake Palestine water quality data using the Langelier Saturation Index shows that the water in Lake Palestine has a strong tendency to be corrosive.

Heavy Metals

No heavy metals data are available for Lake Palestine.

GEORGE PARKHOUSE RESERVOIR STAGE I

Physical and Inorganic Parameters

USGS and TWC quality data indicate that elevated levels of pH, chloride, sulfate, TDS, fecal coliform bacteria, and low dissolved oxygen levels have occasionally exceeded the TSWQS in streamflows near the reservoir site. The flow-weighted average concentrations for these parameters indicate acceptable water quality for reservoir development.

The flow-weighted average alkalinity is 61 mg/l as $CaCO_3$. The flow-weighted average hardness is 63 mg/l as $CaCO_3$, which is considered soft.

The flow-weighted average concentrations for all parameters except turbidity are comparable to the existing water supply sources. This indicates that water from this proposed reservoir would be expected to require similar treatment to that from the existing sources.

The Langelier Saturation Index for this reservoir indicates that there is a moderate tendency for the water to become corrosive, especially during cold weather periods.

Heavy Metals

The available quality data indicate that the heavy metals pose no threat to the suitability of this potential water supply source.

GEORGE PARKHOUSE RESERVOIR STAGE II

Physical and Inorganic Parameters

USGS and TWC quality data indicate that TSWQS for pH, chloride, sulfate, TDS, fecal coliform bacteria, and dissolved oxygen are occasionally exceeded in streamflows near the reservoir site. The flow-weighted average concentrations for these parameters indicate acceptable water quality for reservoir development.

The flow-weighted average concentrations for all of the parameters are comparable to the water quality of existing water supply sources. This indicates that the type and degree of treatment used for the existing sources should be adequate for the water from this potential reservoir.

The flow-weighted average alkalinity is 93 mg/l as $CaCO_3$, and the flow-weighted average hardness is 107 mg/l as $CaCO_3$, which is considered moderately hard.

A moderate tendency toward corrosiveness during cold weather periods exists for this reservoir, as indicated by the Langelier Saturation Index.

Heavy Metals

The available quality data indicate that the heavy metals pose no threat to the suitability of this potential water supply source.

MARVIN NICHOLS RESERVOIR STAGE I

Physical and Inorganic Parameters

The USGS and TWC data indicate that the TSWQS for pH, chloride, sulfate, TDS, fecal coliform bacteria, and dissolved oxygen are occasionally violated in streamflow measurements near the reservoir site. The flow-weighted average concentrations indicate acceptable water quality for reservoir development. With the exception of turbidity, the flow-weighted averages for this reservoir are comparable to the water quality of the existing water supply sources. This indicates that the impounded water would be a suitable potential water supply source.

The flow-weighted average for hardness is 92.5 mg/l as $CaCO_3$, which is considered moderately hard.

The Langelier Saturation Index indicates that there would be a moderate tendency for water to become corrosive during cold weather periods.

Wright Patman Lake is downstream of this potential reservoir and close in proximity. Water quality problems now occurring in Wright Patman Lake may occur in this reservoir as well. Wright Patman occasionally experiences low dissolved oxygen levels and elevated pH levels. During periods when Wright Patman is stratified, elevated iron and manganese levels are not uncommon, especially in the bottom samples. This occurs because iron and manganese are reduced and released from the sediments, and then dissolved into the hypolimnion under anoxic conditions. An analysis using the Langelier Saturation Index indicates that the water in Wright Patman Lake has a strong tendency to become corrosive under normal conditions throughout the year.

Heavy Metals

The available quality data indicate that heavy metals pose no threat to the suitability of this potential water supply source.

MARVIN NICHOLS RESERVOIR STAGE II

Physical and Inorganic Parameters

The flow-weighted average concentrations for most of the parameters from the White Oak Creek USGS data, are very comparable to, or better than, the existing water supply source data.

The flow-weighted average concentration for hardness for this potential water supply source is 27.9 mg/l as $CaCO_3$, which is considered soft.

The water in this reservoir would have a strong tendency to become corrosive under normal conditions throughout the year, as indicated by the Langelier Saturation Index.

The same water quality problems that exist in Wright Patman Lake, and which are described in the Marvin Nichols I section, might also occur in this potential water supply source.

Heavy Metals

The available quality data indicate that heavy metals pose no threat to the suitability of this potential water supply source.

TEHUACANA RESERVOIR

Physical and Inorganic Parameters

All of the flow-weighted quality data are either very comparable to or lower than the data from the existing water supply sources. This suggests that no significant changes to the existing treatment processes would be required to treat water from this potential source.

This potential reservoir is in the vicinity of Cedar Creek Reservoir. Since the flow-weighted calcium and total alkalinity concentrations and pH levels are well below those for Cedar Creek Reservoir, the potential for corrosive water may exist. The low average total alkalinity suggests that this potential reservoir would have a low buffering capacity. If conditions are right (low calcium, high TDS, and low pH levels, cool winter temperatures), this water may have a tendency to become corrosive.

An analysis was performed on the flow-weighted quality data using the Langelier Saturation Index to predict the stability of this water under reservoir conditions. Although data are very limited, the analysis shows that the water might become corrosive, especially during periods of low temperature.

Heavy Metals

No heavy metals data are available for this potential reservoir site.

TENNESSEE COLONY RESERVOIR

Another alternative considered in this study is the construction of Tennessee Colony Reservoir on the Trinity River and the transport of water from Tennessee Colony Reservoir to Richland-Chambers Reservoir, and on to Tarrant County.

As pointed out in previous studies of the Tennessee Colony project, the river flow at the Tennessee Colony site, particularly under summer conditions or in low flow years, is largely treated municipal wastewater. The flow in the Trinity River at Rosser can be about 50 percent wastewater about 50 percent of the time. In summer months, municipal effluent often makes up 90 percent of the river flow. Because of this, an analysis was performed to determine the possible water quality of Tennessee Colony Reservoir. In performing this analysis, the completely mixed reservoir model was used to determine the possible effects of high percentages of wastewater in Tennessee Colony inflows.

Tennessee Colony Reservoir would tend to reduce constituent concentrations of withdrawals from the Trinity River system by increasing the effects of reactions and/or dilution. The influence of dilution alone could reduce the concentrations of conservative substances in the treated sewerage effluent from 35 to 90 percent. Considering treatment plant effluent sources, total phosphorus concentrations of diversions from the Trinity River might be reduced by 95 percent, while reductions of less reactive substances would be approximately 80 to 90 percent. The total phosphorus concentration in Tennessee Colony Reservoir would be high, and the associated issue of eutrophication requires further analysis.

Physical and Inorganic Parameters

The TWC and USGS quality data for the Trinity River indicate that there were numerous violations of the TSWQS, for dissolved oxygen and fecal coliform bacteria. There were occasional violations of the TSWQS for low pH levels.

The presence of a large reservoir would reduce the variability in water quality and eliminate some high values. However, low dissolved oxygen and high fecal coliform bacteria levels may continue to be a problem, especially in the hypolimnion during periods of lake stratification. These problem levels may remain after the reservoir fills due to the large amount of wastewater discharged into the Trinity River upstream of this site.

The flow-weighted average concentration for hardness is 132.3 mg/l as $CaCO_3$, which is considered moderately hard.

The water in Tennessee Colony Reservoir would have a slight tendency to become corrosive during cold weather periods, as indicated by the Langelier Saturation Index.

Heavy Metals

Comparison of the available flow-weighted streamflow data with the existing standards and the water quality data from the existing water supply sources indicates that the heavy metals pose no threat to the suitability of this potential water supply source.

SUMMARY DISCUSSION

Lake Palestine, George Parkhouse Reservoir Stage I, and Marvin Nichols Reservoir Stages I and II have existing or projected water quality which can meet probable long-range receiving water and water supply criteria.

Tehuacana Reservoir and George Parkhouse Reservoir Stage II also have projected (flow-weighted average) concentrations which can meet probable long-range receiving water and water supply criteria. However, the water quality data for gages near these lakes contain one or more concentration measurements which substantially exceed probable long-range receiving water and/or water supply criteria. It would, therefore, be prudent to examine water quality for these reservoirs in greater detail (particularly with water quality data collected over time).

Lake Texoma waters require dilution to minimize high values of total dissolved solids.

Water from Tennessee Colony will contain a substantial percentage of treated wastewater from the Dallas-Fort Worth metropolitan area. For significant time periods in late summer and/or early fall the percentage of wastewater entering the reservoir can exceed 90 percent, which could produce elevated chlorophyll a concentrations in the reservoir. Blending of water from Tennessee Colony with other sources would tend to reduce problems with water treatment operations and lower the concentrations of substances, such as trihalomethanes (THM), heavy metals, et al, which produce public health concerns in drinking water.

With the exception of waters from Lake Texoma and Tennessee Colony, waters from all existing and potential reservoirs are judged to be moderately to strongly corrosive.

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COSTS

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APPENDIX I

COSTS

The opinions of probable cost developed for this study are intended to allow comparison among the alternative sources of new water supply. They are preliminary in nature and are based on available information, previous experience with similar projects, and preliminary project planning. All costs are based on 1989 prices.

This appendix includes a discussion of the methods used to develop opinions of cost, followed by the opinions of cost for the various alternatives. The appendix concludes with life cycle cost analyses for selected scenarios of water supply development.

I-1 METHODOLOGY

RESERVOIR COSTS

The capital costs of reservoir development include permitting and pre-construction costs, acquisition of land, resolution of conflicts with existing facilities, reservoir construction, and related costs.

Permitting and Pre-Construction

Permitting and pre-construction costs include engineering and environmental studies, archaeological surveys and testing, costs of the permitting process, and design of the dam and spillway. For this study, the cost of final design is assumed to be 3.75 percent of the construction cost of the project. The cost of other engineering and environmental studies, archaeology, and permitting is estimated based on recent experience with the development of major reservoirs in Texas. The cost of permitting a major reservoir is difficult to predict because of changing regulations and because of variations in the level of opposition from project to project. A 25 percent contingency allowance is included in the permitting costs. The cost of mitigation measures associated with reservoir development is difficult to predict because the measures required vary greatly from project to project. These opinions of cost do not include mitigation for cultural resources, terrestrial habitat, or instream flows. These items could be expected to add to the cost of all new reservoirs.

Land Acquisition

The acquisition of land includes the purchase of land in the conservation pool, the purchase of flood easements for land above the conservation pool subject to flooding, the purchase of lignite rights, if any, the costs associated with acquisition, and an allowance for contingencies. The assumed average cost per acre of land for each reservoir is given in Table I-1. (The cost for individual parcels will vary for each reservoir, and the cost of land can change quite rapidly.) It is assumed that the average cost of flood easements would equal 75 percent of the average cost of land.

Some of the potential reservoir sites considered in this study overlie minable deposits of lignite. For this report, the cost of the rights to the lignite is assumed to be $425 per acre-foot of estimated reserves

Table I-1

Assumed Average Land Cost per Acre for Potential Reservoirs

Reservoir	Land Cost per Acre
George Parkhouse I	$ 550
George Parkhouse II	550
Marvin Nichols I	550
Marvin Nichols II	550
Tehuacana	1,000
Tennessee Colony	800

(about $0.25 per short ton). Table I-2 shows the estimated amount of lignite at each reservoir, based on available data on lignite deposits at the sites (63, 64, 65, 66). (In this study, the Marvin Nichols I and Marvin Nichols II dam sites are a short distance upstream from their locations in previous studies by others. The sites have been changed to minimize conflicts with potential lignite deposits.)

Acquisition costs are assumed to be 15 percent of the total of land purchase, easements, and lignite rights. A 25 percent allowance for contingencies is also included in the total land acquisition cost.

Conflict Resolution

Conflict costs include the cost of necessary improvements to and protection for highways, county roads, oil and gas pipelines, oil and

Table I-2

Estimated Amount of Lignite Underlying Potential Reservoirs

Reservoir	Estimated Amount of Minable Lignite (Acre-Feet)
George Parkhouse I	0
George Parkhouse II	0
Marvin Nichols I	3,540
Marvin Nichols II	324
Tehuacana	18,800
Tennessee Colony	158,800

gas wells, cemeteries, power lines, and other facilities affected by the reservoir. With the exception of conflicts with oil and gas wells, the opinions of cost for conflict resolution are based on a preliminary design of the resolution, with construction costs based on previous experience with similar projects.

Opinions of cost for oil and gas wells are based on available Texas Railroad Commission maps (67) and proration reports (68, 69, 70, 71) and estimated costs of plugging wells and purchasing wells and mineral rights. Table I-3 shows the number of well locations, abandoned wells, and producing wells in each potential water supply reservoir, as determined from Texas Railroad Commission maps. The cost of plugging producing and abandoned wells is based on recent experience. The cost of purchasing wells and mineral rights is based on county tax appraisal values of the wells.

Table I-3

Number of Oil and Gas Wells Inundated by Potential Reservoirs

Description	George Parkhouse I	George Parkhouse II	Marvin Nichols I	Marvin Nichols II	Tehuacana	Tennessee Colony
Producing oil wells	0	0	7	117	1	42
Producing gas wells	0	0	0	1	17	13
Special wells[b]	0	0	4	19	1	12
Locations, abandoned locations, abandoned oil wells, etc.	6	1	84	316	19	241
Abandoned gas wells	0	0	2	0	13	60
	6	1	97	453	51	368

Notes: a. Well counts are from records and maps maintained by the Texas Railroad Commission.
b. Special wells include water injection and disposal wells.

Construction Cost

The construction cost of the reservoirs is based on a preliminary design of the dam and spillway. Quantities of material are estimated based on the preliminary designs and U.S. Geological Survey topographic maps. Unit costs are based on the cost of recent dam and spillway construction in Texas.

Interest during Construction and Financing

The cost of interest during construction is added to the capital cost for each reservoir. It is assumed that interest would accrue during construction at a compound rate of 8.5 percent per year, on an average balance equal to one-half of the total capital cost not including interest. Table I-4 shows the assumed construction time for each reservoir, based on past experience with projects of similar size.

Project financing is based on 30 year bonds, with an interest rate of 8.5 percent per annum. Assuming 30 equal annual payments of principal and interest, each payment would equal 9.305 percent of the project's total capital cost, including interest during construction.

Operation and Maintenance

Operation and maintenance costs for the reservoirs are based on Tarrant County Water Control and Improvement District Number One experience with existing reservoirs.

Table I-4

Assumed Construction Time for Reservoirs

Reservoir	Construction Time in Years
George Parkhouse I	4
George Parkhouse II	3
Marvin Nichols I	4
Marvin Nichols II	3
Tehuacana	2
Tennessee Colony	7

WATER TRANSMISSION COSTS

Water transmission costs include the capital costs of pipelines and pump stations, interest during construction, operation and maintenance and power. In all cases, the costs are based on a preliminary design of the transmission system.

Pipeline Capital Costs

Pipeline capital costs are developed from estimated unit costs of pipeline construction. The unit costs are based on 1989 pipe prices and on recent experience with pipeline construction costs. Table I-5 shows the unit costs used to develop pipeline capital costs for various sizes and classes of pipe.

Engineering and contingency costs for the pipelines are assumed to equal 25 percent of the construction costs. Right of way acquisition is

Table I-5

Unit Costs for Pipelines, Including Construction

- 1989 Prices in Dollars per Linear Foot -

Pipe Diameter (Inches)	Class of Pipe			
	100	150	200	250
36	$ 78	$ 82	$ 85	$ 88
39	90	93	96	99
42	107	110	117	122
45	115	120	126	131
48	128	136	142	149
54	184	189	195	202
60	203	210	218	224
66	238	245	253	262
72	251	259	270	280
78	291	301	312	331
84	326	338	349	370
90	395	408	421	445
96	429	443	453	478
102	469	478	504	523
108	509	518	549	587
120	602	624	651	693

assumed to be $1,000 per acre in the country and $100,000 per acre in urban areas. The right-of-way is 100 feet wide for single pipelines and 180 feet wide for parallel pipes.

Pump Station Capital Costs

Pump station construction costs are based on current prices for representative pumps and on recent experience with pump station construction in Texas. As with pipelines, the capital costs include a 25 percent allowance for engineering and contingencies. The design heads for the pump stations are based on an assumed maximum flow 1.25 times greater than the average flow and a pipeline Hazen-Williams "C" factor of 130.

Interest during Construction and Financing

As with the reservoirs, the cost of interest during construction is added to the capital cost for transmission systems. It is assumed that interest would accrue during construction at a compound rate of 8.5 percent per year, on an average balance equal to one-half of the total capital cost not including interest. Table I-6 shows the assumed construction time for various water transmissions systems, based on past experience with projects of similar size.

Project financing is based on 30 year bonds, with an interest rate of 8.5 percent per annum. Assuming 30 equal annual payments of principal and interest, each payment would equal 9.305 percent of the project's total capital cost, including interest during construction.

Table I-6

Assumed Construction Time for Transmission Systems

System	Pipeline Length in Miles	Construction Time in Years
Trinity River - Cedar Creek	2	2
Trinity River - Richland Creek	2	2
Cedar Creek - Ennis	26	2
Richland Creek - Ennis	30	2
Lake Palestine - Cedar Creek	29	2
Ennis - Tarrant County	42	2
Tennessee Colony - Tarrant County	92	2
Texoma - Eagle Mountain	83	2
George Parkhouse - Tarrant County	120	3
Marvin Nichols - Tarrant County	153	4

Operation and Maintenance

Operation and maintenance costs for pipelines are assumed to be $2,000 per mile of pipe per year for individual pipes and $3,000 per mile per year for parallel pipes. The operation and maintenance cost for pump stations is assumed to be $5 per design horsepower.

Power

The power for pump station operation is assumed to cost $0.05 per kilowatt-hour of electricity used, with the amount of electricity calculated from the flow and the average pumping head, assuming a "C" factor of 130 and a combined pump and motor efficiency of 75 percent. The head loss associated with the average design flow for the system is used to compute power costs.

TREATMENT COSTS

The Tarrant County Water Control and Improvement District Number One supplies its customers with raw water, which they treat and distribute. Since the water supply sources considered in the scenarios of water supply development would not have significant differences in water quality or treatment costs, treatment costs are considered only for the recommended scenario of water supply development. The construction costs for additional treatment capacity in Tarrant County are estimated based on recent experience with treatment plant construction. Treatment costs are discussed in Section 10.

I-2 COSTS FOR THE ALTERNATIVES

Eleven alternative sources of water supply are explored in detail in this report:

- Diversions from the Trinity River to Cedar Creek Reservoir
- Diversions from the Trinity River to Richland-Chambers Reservoir
- System operation of the District's East Texas reservoirs
- Lake Texoma
- Lake Palestine
- Tehuacana Reservoir

- George Parkhouse Reservoir Stage I
- George Parkhouse Reservoir Stage II
- Marvin Nichols Reservoir Stage I
- Marvin Nichols Reservoir Stage II
- Tennessee Colony Reservoir

The costs associated with each of these alternatives are discussed below.

Trinity River Diversions to Cedar Creek and Richland-Chambers Reservoirs

Trinity River diversions to each reservoir would require construction of a pump station on the Trinity River and a pipeline to the reservoir. It is possible that water diverted from the Trinity would require pretreatment before it is released in the District's reservoirs. For this study, that treatment is assumed to consist of a detention basin which would allow time for pollutants to settle from the Trinity River water. The diversions would also require permitting by the Texas Water Commission and by the U.S. Army Corps of Engineers.

Additional transmission capacity would be needed to bring the water diverted from the Trinity River to Tarrant County. This additional capacity would be developed by construction of additional pump stations and parallel pipelines from Cedar Creek Reservoir to Ennis and Ennis to Tarrant County. (It is assumed that the expansion to the Richland-Chambers Reservoir to Ennis and Ennis to Tarrant County systems currently planned for early in the next century will be carried out.) In order to lower the cost of this alternative, it is proposed not to parallel the existing pipeline from Richland-Chambers Reservoir to Ennis. If this approach is adopted, the transmission system from Richland-Chambers to Ennis will have less capacity than desirable to meet peak demands. To compensate, the system from Cedar Creek to Ennis is designed with extra peaking capacity.

Table I-7 shows the elements which provide the raw water supply for this alternative, their capital cost, and the annual cost of raw water. Table I-8 gives the same information for the elements of the transmission system. The probable total capital cost for this alternative is $312,190,000, and the probable total annual cost is $36,261,000. Based on these estimates, the unit cost of raw water when this alternative is fully developed would be $0.96 per thousand gallons, delivered to Tarrant County.

It is possible that water diverted from the Trinity would require more extensive water treatment than the settling ponds before it is released to the District's reservoirs. Stringent pre-treatment requirements would add about $76,000,000 to the capital cost for this alternative and $0.20 to $0.25 per thousand gallons to the unit cost. The level of treatment necessary will depend on the possible impact of nutrients in Trinity River water on the District's reservoirs. These impacts will be considered during planning and permitting for the diversions before a final decision is made on treatment requirements.

System Operation of Cedar Creek and Richland-Chambers Reservoirs

Appendix G discusses the benefits of system operation of the Tarrant County Water Control and Improvement District Number One's existing

Table I-7

Opinion of Probable Raw Water Cost for Diversions from the Trinity

Yield in Acre-Feet per Year = 115,500

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Cost (1989 $)
Permitting and analysis	-	-	-	-	$ 3,000,000
Trinity River to Richland-Chambers pump station	81	101	-	-	6,550,000
Trinity River to Richland-Chambers pipeline	-	-	66	2.0	3,163,000
Richland-Chambers settling basin	-	-	-	-	5,000,000
Trinity River to Cedar Creek pump station	71	95	-	-	6,381,000
Trinity River to Cedar Creek pipeline	-	-	60	1.7	2,299,000
Cedar Creek settling basin	-	-	-	-	5,000,000
Subtotal					$31,393,000
Interest during construction					2,782,000
TOTAL					$34,175,000
Debt service					3,180,000
Operation and maintenance					340,000
Power					335,000
Total raw water annual cost					$ 3,855,000
Unit cost of raw water without transmission					
- per acre-foot					$33.38
- per 1,000 gallons					$0.1024

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-8

Opinion of Probable Transmission Cost for Diversions from the Trinity

Yield in Acre-Feet per Year = 115,500

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Cost (1989 $)
Cedar Creek to Ennis pump station	203	323	-	-	$ 15,375,000
Cedar Creek to Ennis pipeline	-	-	96	25.6	77,444,000
Ennis to Waxahachie pump station	202	273	-	-	11,325,000
Waxahachie to Tarrant County pump station	202	222	-	-	9,748,000
Ennis to Tarrant County pipeline	-	-	96	48.3	141,493,000
Subtotal					$255,385,000
Interest during construction					22,630,000
TOTAL					$278,015,000
Debt service					25,869,000
Operation and maintenance					348,000
Power					6,189,000
Total transmission annual cost					$ 32,406,000
Unit cost of transmission					
- per acre-foot					$280.57
- per 1,000 gallons					$0.8610

Note: Capital costs include engineering and contingencies at 25 percent.

reservoirs in East Texas. Because system operation would increase the yield of the existing reservoirs, it would also increase the potential for diversions from the Trinity River. The combination of system operation and increased diversions from the Trinity River would increase the District's yield by 148,300 acre-feet per year, which is 32,800 acre-feet per year more than the 115,500 acre-feet per year increase due to Trinity diversions alone. System operation would therefore provide 32,800 acre-feet per year of new water supply.

System operation of existing facilities requires over-sizing transmission facilities so that extra water can be diverted from Cedar Creek in most years and so that extra water can be diverted from Richland-Chambers when Cedar Creek is drawn down. Because of the small increment to yield due to system operation and the large transmission capacities it requires, this alternative is not economical by itself. However, if diversions from the Trinity are implemented, the additional capacity required to incorporate system operation would be more economical because the incremental cost of additional transmission capacity is low when transmission capacity is already being built. Consequently, this alternative is considered as an increment to diversions from the Trinity.

The combination of diversions from the Trinity River and system operation would require slightly larger pump stations and pipelines to divert water from the Trinity than would diversions without system operation. The additional transmission capacity needed from Cedar Creek to Ennis and Ennis to Tarrant County would be greater, and it would be necessary to parallel the pipeline from Richland-Chambers Reservoir to Ennis.

Table I-9 summarizes the opinion of probable cost for the raw water facilities associated with system operation and Trinity River diversions. The table also gives the incremental cost of system operation. Table I-10 gives the same information for the water transmission system associated with system operation and Trinity River diversions. The probable incremental cost of system operation totals $106,431,000 for raw water and transmission. The probable annual cost totals $11,338,000, which would give a unit cost of $1.06 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

Lake Texoma

Because Lake Texoma is an existing reservoir, development of raw water from this source would require purchase of storage in the reservoir from the U. S. Army Corps of Engineers and permitting by the Texas Water Commission and the Corps. (The amount of storage needed to assure 50,000 acre-feet per year of water supply and the cost per acre-foot of storage are based on the Corp's current policy for Lake Texoma.) This alternative would also require construction of a pipeline and pump stations to bring the water from Lake Texoma to Eagle Mountain Lake. Tables I-11 and I-12 give the probable costs for raw water and for transmission for this alternative.

The probable capital cost of water from Lake Texoma totals $159,600,000 for raw water and transmission. The probable annual cost

Table I-9

Opinion of Probable Raw Water Cost for System Operation
(with Diversions from the Trinity)

Incremental Yield in Acre-Feet per Year = 32,800

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for System Operation (1989 $)
Permitting and analysis	-	-	-	-	$ 3,300,000	$300,000
Trinity River to Richland-Chambers pump station	75	106	-	-	6,475,000	(75,000)
Trinity River to Richland-Chambers pipeline	-	-	60	2.0	2,713,000	(450,000)
Richland-Chambers settling basin	-	-	-	-	5,000,000	0
Trinity River to Cedar Creek pump station	88	89	-	-	6,475,000	94,000
Trinity River to Cedar Creek pipeline	-	-	72	2.7	2,836,000	537,000
Cedar Creek settling basin	-	-	-	-	5,000,000	0
Subtotal					$31,799,000	$406,000

Table I-9, Continued

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for System Operation (1989 $)
Subtotal					$31,799,000	$406,000
Interest during construction					2,818,000	36,000
TOTAL					$34,617,000	$442,000
Debt service					3,221,000	41,000
Operation and maintenance					342,000	2,000
Power					371,000	36,000
Total raw water annual cost					$ 3,934,000	$ 79,000
Unit cost of raw water without transmission						
- per acre-foot					$26.53	$2.41
- per 1,000 gallons					$0.0814	$0.0074

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-10

Opinion of Probable Transmission Cost for System Operation
(with Diversions from the Trinity)

Incremental Yield in Acre-Feet per Year = 32,800

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for System Operation (1989 $)
Cedar Creek to Ennis pump station	251	302	-	-	$ 15,413,000	$ 38,000
Cedar Creek to Ennis pipeline	-	-	108	25.6	90,902,000	13,458,000
Richland-Chambers to Ennis pump station	131	381	-	-	12,825,000	12,825,000
Richland-Chambers to Ennis pipeline	-	-	78	29.8	60,930,000	60,930,000
Ennis to Waxahachie pump station	244	293	-	-	11,625,000	300,000
Waxahachie to Tarrant County pump station	244	261	-	-	11,363,000	1,615,000
Ennis to Tarrant County pipeline	-	-	102	48.3	149,689,000	8,196,000
Subtotal					$352,747,000	$ 97,362,000

Table I-10, Continued

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for System Operation (1989 $)
Subtotal					$352,747,000	$ 97,362,000
Interest during construction					31,257,000	8,627,000
TOTAL					$384,004,000	$105,989,000
Debt service					35,732,000	9,862,000
Operation and maintenance					509,000	149,000
Power					7,437,000	1,248,000
Total transmission annual cost					$ 43,678,000	$ 11,259,000
Unit cost of transmission						
- per acre-foot					$294.52	$343.26
- per 1,000 gallons					$0.9039	$1.0534

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-11

Opinion of Probable Raw Water Cost for Lake Texoma

Yield in Acre-Feet per Year = 50,000

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Cost (1989 $)
Permitting and analysis	-	-	-	-	$ 500,000
Purchase of storage in Lake Texoma	-	-	-	-	10,100,000
Subtotal					$10,600,000
Interest during construction (only on permitting)					44,000
TOTAL					$10,644,000
Debt service					990,000
Operation and maintenance					100,000
Power					0
Total raw water annual cost					$ 1,090,000
Unit cost of raw water without transmission					
- per acre-foot					$21.80
- per 1,000 gallons					$.0669

Table I-12

Opinion of Probable Transmission Cost for Lake Texoma

Yield in Acre-Feet per Year = 50,000

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Cost (1989 $)
Lake Texoma pump station	56	420	-	-	$ 9,488,000
Booster pump station	56	301	-	-	7,031,000
Lake Texoma to Eagle Mountain Lake pipeline	-	-	60	83.4	120,312,000
Subtotal					$136,831,000
Interest during construction					12,125,000
TOTAL					$148,956,000
Debt service					13,860,000
Operation and maintenance					217,000
Power					1,698,000
Total transmission annual cost					$ 15,775,000
Unit cost of transmission					
- per acre-foot					$315.50
- per 1,000 gallons					$0.9682

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-13

Opinion of Probable Raw Water Cost for Lake Palestine
(with System Operation and Diversions from the Trinity)

Incremental Yield in Acre-Feet per Year = 148,600

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Lake Palestine (1989 $)
Permitting and analysis	-	-	-	-	$ 3,400,000	$ 100,000
Trinity River to Richland-Chambers pump station	75	106	-	-	6,475,000	0
Trinity River to Richland-Chambers pipeline	-	-	60	2.0	2,713,000	0
Richland-Chambers settling basin	-	-	-	-	5,000,000	0
Trinity River to Cedar Creek pump station	144	91	-	-	7,019,000	544,000
Trinity River to Cedar Creek pipeline	-	-	84	1.7	3,681,000	845,000
Cedar Creek settling basin	-	-	-	-	5,000,000	0
Purchase of water rights in Lake Palestine	-	-	-	-	131,445,000	131,445,000
Subtotal					$164,734,000	$132,934,000

Table I-13, Continued

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Lake Palestine (1989 $)
Subtotal					$164,734,000	$132,934,000
Interest during construction					2,950,000	132,000
TOTAL					$167,684,000	$133,066,000
Debt service					15,603,000	12,382,000
Operation and maintenance					1,098,000	756,000
Power					507,000	136,000
Total raw water annual cost					$ 17,208,000	$ 13,274,000
Unit cost of raw water without transmission						
- per acre-foot					$65.16	$89.33
- per 1,000 gallons					$0.2000	$0.2741

Note: Capital costs include engineering and contingencies at 25 percent.

facilities associated with Lake Palestine, system operation, and diversions from the Trinity. The table also gives the incremental cost of Lake Palestine raw water. Table I-14 gives the same information for the water transmission system associated with Lake Palestine, system operation, and Trinity River diversions. The probable incremental cost of Lake Palestine totals $440,704,000 for raw water and transmission. The probable annual cost totals $49,453,000, which would give a unit cost of $1.02 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

Tehuacana Reservoir and Additional Diversions from the Trinity

Tehuacana Reservoir would be operated as a single impoundment with Richland-Chambers Reservoir and would provide 68,400 acre-feet per year of additional yield. The development of Tehuacana Reservoir would also make it possible to increase the yield of diversions from the Trinity River by 20,300 acre-feet per year, for a total gain in water supply of 88,700 acre-feet per year.

Raw water costs for this alternative include the development of Tehuacana Reservoir and the construction of the diversion facilities on the Trinity River. Transmission costs include the extra capacity needed in transmission systems from Richland Creek to Ennis and Ennis to Tarrant County. The incremental costs for this alternative, in addition to the cost of diversions from the Trinity and system operation, are considered.

Table I-15 summarizes the opinion of probable cost for the raw water

Table I-14

Opinion of Probable Transmission Cost for Lake Palestine
(with System Operation and Diversions from the Trinity River)

Incremental Yield in Acre-Feet per Year = 148,600

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Lake Palestine (1989 $)
Lake Palestine to Cedar Creek Reservoir pump station	125	382	-	-	$ 7,694,000	$ 7,694,000
Lake Palestine to Cedar Creek Reservoir pipeline	-	-	72	29.3	51,050,000	51,050,000
Cedar Creek to Ennis pump station	432	302	-	-	25,200,000	9,787,000
Cedar Creek to Ennis pipeline	-	-	2-102	25.6	167,415,000	76,513,000
Richland-Chambers to Ennis pump station	131	381	-	-	12,825,000	0
Richland-Chambers to Ennis pipeline	-	-	78	29.8	60,930,000	0
Ennis to Waxahachie pump station	424	295	-	-	21,809,000	10,184,000

Table I-14, Continued

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Lake Palestine (1989 $)
Waxahachie to Tarrant County pump station	424	264	-	-	20,288,000	8,925,000
Ennis to Tarrant County pipeline	-	-	2-96	48.3	268,132,000	118,443,000
Subtotal					$635,343,000	$282,596,000
Interest during construction					56,299,000	25,042,000
TOTAL					$691,642,000	$307,638,000
Debt service					64,357,000	28,626,000
Operation and maintenance					872,000	363,000
Power					14,627,000	7,190,000
Total transmission annual cost					$ 79,856,000	$ 36,179,000
Unit cost of transmission						
- per acre-foot					$302.37	$243.47
- per 1,000 gallons					$0.9279	$0.7472

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-15

Opinion of Probable Raw Water Cost for Tehuacana Reservoir (with System Operation and Diversions from the Trinity)

Incremental Yield in Acre-Feet per Year = 88,700

Item	Capacity (MGD)	Head (Ft.)	Size	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Tehuacana Reservoir (1989 $)
Permitting and analysis (excluding Tehuacana Reservoir)	-	-	-	-	$ 3,300,000	$ 0
Trinity River to Richland-Chambers pump station	96	100	-	-	6,644,000	169,000
Trinity River to Richland-Chambers pipeline	-	-	72	2.0	3,341,000	628,000
Richland-Chambers settling basin	-	-	-	-	5,000,000	0
Trinity River to Cedar Creek pump station	88	89	-	-	6,475,000	0
Trinity River to Cedar Creek pipeline	-	-	72	1.7	2,836,000	0
Cedar Creek settling basin	-	-	-	-	5,000,000	0
Tehuacana Reservoir	-	-	-	-	113,121,000	113,121,000
Subtotal					$145,717,000	$113,918,000

Table I-15, Continued

Item	Capacity (MGD)	Head (Ft.)	Size	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Tehuacana Reservoir (1989 $)
Subtotal					$145,717,000	$113,918,000
Interest during construction					12,912,000	10,095,000
TOTAL					$158,629,000	$124,013,000
Debt service					14,760,000	11,539,000
Operation and maintenance					544,000	202,000
Power					422,000	51,000
Total raw water annual cost					$ 15,726,000	$ 11,792,000
Unit cost of raw water without transmission						
- per acre-foot					$77.01	$132.94
- per 1,000 gallons					$0.2363	$0.4080

Note: Capital costs for pump stations and pipelines include engineering and contingencies at 25 percent.

facilities associated with Tehuacana Reservoir, system operation, and diversions from the Trinity. The table also gives the incremental cost of Tehuacana Reservoir raw water. Table I-16 gives more detail on the opinion of probable cost for the reservoir. Table I-17 shows the quantities and unit costs used to develop the opinion of probable cost of construction for the reservoir. Table I-18 gives the opinion of probable cost for the water transmission system associated with Tehuacana Reservoir, system operation, and Trinity River diversions. The probable incremental cost of water from Tehuacana Reservoir totals $274,526,000 for raw water and transmission. The probable annual cost totals $30,377,000, which would give a unit cost of $1.05 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

George Parkhouse Reservoir Stage I

George Parkhouse Reservoir Stage I has a yield of 123,000 acre-feet per year. It is assumed that the Tarrant County Water Control and Improvement District Number One would use all of this water if it develops this alternative. Table I-19 summarizes the opinion of probable cost for George Parkhouse Reservoir Stage I. Table I-20 gives the quantities and unit costs used to develop the opinion of probable construction cost for the reservoir. Table I-21 gives the opinion of probable cost for the water transmission system associated with George Parkhouse Reservoir Stage I.

The probable capital cost for water from George Parkhouse Reservoir Stage I totals $497,414,000 for raw water and transmission. The probable

Table I-16

Opinion of Probable Raw Water Cost for Tehuacana Reservoir

- All Values Are Based on 1989 Prices -

Yield in Acre-Feet per Year = 68,300

TCWCID #1 Share of the Yield in Acre-Feet per Year = 68,300

Conservation Storage in Acre-Feet = 337,947

Surface Area at Top of Conservation Storage in Acres = 14,938

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
1. Water rights permit	$ 800,000	$ 800,000	
2. Continuing environmental investigations	200,000	200,000	
3. Archaeological survey	176,000	176,000	$10.00/acre in the PMF pool.
4. Engineering pre-design coordination	100,000	100,000	
5. Detailed geotechnical investigation	457,000	457,000	
6. Hydraulic model study	0	0	
7. Section 404 application	20,000	20,000	

Table I-16, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
8. Section 404 permit & related environmental & archaeological work			
- Archaeological testing	527,000	527,000	$30.00/acre in the PMF pool.
- Monitor 404 process	100,000	100,000	
- Special studies	200,000	200,000	Endangered species, habitat, water quality.
9. Permitting contingencies	506,000	506,000	25% of permitting costs.
10. Final design	856,000	856,000	3.75% of construction.
Pre-Construction Subtotal (1-10)	$ 3,942,000	$ 3,942,000	
11. Land acquisition			
- Land purchase	14,938,000	14,938,000	Top of conservation pool. $1000/ac.
- Easements	1,582,000	1,582,000	Top of conservation pool + 5'. $750/acre.
- Lignite	7,990,000	7,990,000	$425/ac-ft of estimated reserves.
- Acquisition costs	3,677,000	3,677,000	15% of land and minerals.
- Contingencies	7,047,000	7,047,000	25% of above 4 items.
Subtotal for Item 11	$ 35,234,000	$ 35,234,000	
12. Conflicts			
- Roads and railroads	18,502,000	18,502,000	
- Pipelines & powerlines	7,359,000	7,359,000	
- Oil fields	8,974,000	8,974,000	
- Other	523,000	523,000	
- Contingencies & engineering	8,840,000	8,840,000	
Subtotal for Item 12	$ 44,198,000	$ 44,198,000	

Table I-16, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
13. Advertising and bidding	5,000	5,000	
14. Construction			
- Construction	22,835,000	22,835,000	
- Contingencies	4,795,000	4,795,000	20% of construction, design, & gen. rep.
- General representation	285,000	285,000	1.25% of construction.
- Resident representation & Field laboratory	1,827,000	1,827,000	8% of construction.
Subtotal for Item 14	$ 29,742,000	$ 29,742,000	
TOTAL	$113,121,000	$113,121,000	

Table I-17

Opinion of Probable Construction and Related Costs for Tehuacana Reservoir

- All Values Based on 1989 Prices -

Item No.	Description	Quantity	Units	Unit Prices	Total Price
1.	Excavation				
	a. Channel	2,250,000	C.Y.	$ 1.31	$ 2,948,000
	b. Core trench & borrow	1,764,000	C.Y.	1.20	2,117,000
2.	Fill				
	a. Embankment	3,488,000	C.Y.	1.75	6,104,000
	b. Waste	80,000	C.Y.	1.75	140,000
3.	Filter, 1 & 2 (Foundation drainage)	181,800	C.Y.	10.00	1,818,000
4.	Roadway	59,555	S.Y.	4.60	274,000
5.	Cutoff slurry trench	514,800	S.F.	3.50	1,802,000
6.	Soil cement with cement	137,800	C.Y.	16.00	2,205,000
7.	Guard posts	1,680	Ea.	18.00	30,000
8.	Grassing	34	Ac.	3,700.00	126,000
Subtotal					$17,564,000
9.	Mobilization (5% of subtotal)				878,000
10.	Clearing/grubbing, care of water (6% of subtotal)				1,054,000
Subtotal					$19,496,000
11.	Land clearing	6,242	Ac.	535.00	3,339,000
Construction Subtotal (including land clearing)					$22,835,000
12.	Engineering, 5%	1	L.S.		1,142,000
13.	Resident representation & testing, 8%	1	L.S.		1,827,000
14.	Geotechnical services, 2%	1	L.S.		457,000
TOTAL					$26,261,000

Table I-18

Opinion of Probable Transmission Cost for Tehuacana Reservoir
(with System Operation and Diversions from the Trinity River)

Incremental Yield in Acre-Feet per Year = 88,700

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Tehuacana Reservoir (1989 $)
Cedar Creek to Ennis pump station	251	302	-	-	$ 15,413,000	$ 0
Cedar Creek to Ennis pipeline	-	-	108	25.6	90,902,000	0
Richland-Chambers to Ennis pump station	241	350	-	-	12,975,000	150,000
Richland-Chambers to Ennis pipeline	-	-	102	29.8	95,791,000	34,861,000
Ennis to Waxahachie pump station	354	295	-	-	15,019,000	3,394,000
Waxahachie to Tarrant County pump station	354	262	-	-	14,681,000	3,318,000
Ennis to Tarrant County pipeline	-	-	2-90	48.3	246,227,000	96,538,000
Subtotal					$491,008,000	$138,261,000
Interest during construction					43,509,000	12,252,000
TOTAL					$534,517,000	$150,513,000

Table I-18, Continued

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	Incremental Cost for Tehuacana Reservoir (1989 $)
Debt service					49,737,000	14,005,000
Operation and maintenance					651,000	154,000
Power					11,863,000	4,426,000
Total transmission annual cost					$ 62,251,000	$ 18,585,000
Unit cost of transmission						
- per acre-foot					$304.85	$209,53
- per 1,000 gallons					$0.9356	$0.6430

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-19

Opinion of Probable Raw Water Cost for George Parkhouse Reservoir Stage I

- All Values Are Based on 1989 Prices -

Yield in Acre-Feet per Year =	123,000
TCWCID #1 Share of the Yield in Acre-Feet per Year =	123,000
Conservation Storage in Acre-Feet =	685,706
Surface Area at Top of Conservation Storage in Acres =	29,740

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
1. Water right permit	$ 1,400,000	$ 1,400,000	
2. Continuing environmental investigations	300,000	300,000	
3. Archaeological survey	361,000	361,000	$10.00/acre in the PMF pool.
4. Engineering pre-design coordination	140,000	140,000	
5. Detailed geotechnical investigation	1,042,000	1,042,000	
6. Hydraulic model study	100,000	100,000	
7. Section 404 application	30,000	30,000	

Table I-19, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
8. Section 404 permit & related environmental & archaeological work			
- Archaeological testing	1,084,000	1,084,000	$30.00/acre in the PMF pool.
- Monitor 404 process	140,000	140,000	
- Special studies	300,000	300,000	Endangered species, habitat, water quality.
9. Permitting contingencies	904,000	904,000	25% of permitting costs.
10. Final design	1,954,000	1,954,000	3.75% of construction.
Pre-Construction Subtotal (1-10)	$ 7,755,000	$ 7,755,000	
11. Land acquisition			
- Land purchase	16,357,000	16,357,000	Top of conservation pool. $550/ac.
- Easements	1,031,000	1,031,000	Top of conservation pool + 5'. $412.50/acre.
- Lignite	0	0	
- Acquisition costs	2,608,000	2,608,000	15% of land and minerals.
- Contingencies	4,999,000	4,999,000	25% of above 4 items.
Subtotal for Item 11	$ 24,995,000	$ 24,995,000	
12. Conflicts			
- Highways	10,640,000	10,640,000	
- County roads	167,000	167,000	
- Pipelines	2,332,000	2,332,000	
- Oil fields	96,000	96,000	
- Other	1,030,000	1,030,000	
- Contingencies & engineering	3,566,000	3,566,000	
Subtotal for Item 12	$ 17,831,000	$ 17,831,000	

Table I-19, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
13. Advertising and bidding	5,000	5,000	
14. Construction			
- Construction	52,110,000	52,110,000	
- Contingencies	10,943,000	10,943,000	20% of construction, design, & gen. rep.
- General representation	651,000	651,000	1.25 of construction.
- Resident representation & Field laboratory	4,169,000	4,169,000	8% of construction.
Subtotal for Item 14	67,873,000	67,873,000	
Subtotal	$118,459,000	$118,459,000	
Interest during construction	22,854,000	22,854,000	4 years at half of 8.5%.
TOTAL	$141,313,000	$141,313,000	
Debt service	13,149,000	13,149,000	30-year bonds at 8.5% interest.
Operation and maintenance	750,000	750,000	
Total annual cost	$ 13,899,000	$ 13,899,000	
Unit cost of raw water			
- per acre-foot	$113.00	$113.00	
- per 1,000 gallons	$0.3468	$0.3468	

Table I-20

Opinion of Probable Construction and Related Costs for George Parkhouse Reservoir Stage I

- All Values Based on 1989 Prices -

Item No.	Description	Quantity	Units	Unit Prices	Total Price
1.	Excavation				
	a. Approach channel	140,200	C.Y.	$ 1.31	$ 184,000
	b. Channel	123,000	C.Y.	1.31	161,000
	c. Spillway	289,300	C.Y.	1.20	347,000
	d. Emergency spillway	434,300	C.Y.	1.20	521,000
2.	Fill				
	a. Impervious	1,567,800	C.Y.	1.75	2,744,000
	b. Random	7,169,400	C.Y.	1.75	12,546,000
3.	Filter, 1 & 2 (Foundation drainage)	668,200	C.Y.	10.00	6,682,000
4.	Bridge	190	L.F.	720.00	137,000
5.	Roadway	63,067	S.Y.	4.60	290,000
6.	Cutoff slurry trench	800,000	S.F.	3.50	2,800,000
7.	Soil cement	394,130	C.Y.	16.00	6,306,000
8.	Elevator	1	Ea.	100,000.00	100,000
9.	Barrier warning system	456	L.F.	12.00	5,000
10.	Gates				
	a. Gate & anchor (Install/paint)	2,240	S.F.	200.00	448,000
	b. Stop gate & lift beam	160	L.F.	1,450.00	232,000
	c. Hoist	4	Ea.	118,000.00	472,000
11.	Electrical	1	L.S.	320,000.00	320,000
12.	Power drop	1	L.S.	144,000.00	144,000
13.	Low flow system	1	L.S.	1,000,000.00	1,000,000
14.	Monorail system	190	L.F.	640.00	122,000
15.	Embankment internal drainage	25,800	L.F.	38.00	980,000
16.	Guardrail	380	L.F.	18.00	7,000
17.	Grassing	54	Ac.	3,700.00	200,000
18.	Concrete (mass)	52,000	C.Y.	125.00	6,500,000
19.	Concrete (walls)	5,600	C.Y.	200.00	1,120,000
Subtotal					$44,368,000
20.	Mobilization (5% of subtotal)				2,218,000
21.	Clearing/grubbing, care of water (6% of subtotal)				2,662,000
Subtotal					$49,248,000

Table I-20, Continued

Item No.	Description	Quantity	Units	Unit Prices	Total Price
Subtotal					$49,248,000
22.	Land clearing	5,350	Ac.	535.00	2,862,000
Construction Subtotal (including land clearing)					$52,110,000
23.	Engineering, 5%	1	L.S.		2,606,000
24.	Resident representation & testing, 8%	1	L.S.		4,169,000
25.	Geotechnical services, 2%	1	L.S.		1,042,000
TOTAL					$59,927,000

Table I-21

Opinion of Probable Transmission Cost
for George Parkhouse Reservoir Stage I

Yield in Acre-Feet per Year = 123,000

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Cost (1989 $)
George Parkhouse Reservoir pump station	152	363	-	-	$ 12,863,000
Booster pump station number 1	152	316	-	-	11,213,000
Booster pump station number 2	152	363	-	-	10,875,000
George Parkhouse Reservoir to Tarrant County pipeline	-	-	84	119.6	277,790,000
Subtotal					$312,741,000
Interest during construction					43,360,000
TOTAL					$356,101,000
Debt service					33,135,000
Operation and maintenance					410,000
Power					5,833,000
Total transmission annual cost					$ 39,378,000
Unit cost of transmission					
- per acre-foot					$320.15
- per 1,000 gallons					$0.9825

Note: Capital costs include engineering and contingencies at 25 percent.

annual cost totals $53,277,000, which would give a unit cost of $1.33 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

George Parkhouse Reservoir Stage II

George Parkhouse Reservoir Stage II would supply 136,700 acre-feet per year. It is assumed that the Tarrant County Water Control and Improvement District Number One would use all of this water if it develops this alternative. Table I-22 summarizes the opinion of probable cost for George Parkhouse Reservoir Stage II. Table I-23 gives the quantities and unit costs used to develop the opinion of probable construction cost for the reservoir. Table I-24 gives the opinion of probable cost for the water transmission system associated with George Parkhouse Reservoir Stage II.

The probable capital cost for water from George Parkhouse Reservoir Stage II totals $455,565,000 for raw water and transmission. The probable annual cost totals $50,032,000, which would give a unit cost of $1.12 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

Marvin Nichols Reservoir Stage I

Marvin Nichols Reservoir Stage I would supply 624,400 acre-feet per year of yield. It is assumed that the Tarrant County Water Control and Improvement District Number One would use 35 percent of this water (218,600 acre-feet per year) if it develops this alternative. Table I-25 summarizes the opinion of probable cost for Marvin Nichols Reservoir Stage I and shows

Table I-22

Opinion of Probable Raw Water Cost
for George Parkhouse Reservoir Stage II

- All Values Are Based on 1989 Prices -

Yield in Acre-Feet per Year =	136,700
TCWCID #1 Share of the Yield in Acre-Feet per Year =	136,700
Conservation Storage in Acre-Feet =	243,613
Surface Area at Top of Conservation Storage in Acres =	12,250

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
1. Water right permit	$ 800,000	$ 800,000	
2. Continuing environmental investigations	200,000	200,000	
3. Archaeological survey	174,000	174,000	$10.00/acre in the PMF pool.
4. Engineering pre-design coordination	100,000	100,000	
5. Detailed geotechnical investigation	1,019,000	1,019,000	
6. Hydraulic model study	100,000	100,000	
7. Section 404 application	20,000	20,000	

Table I-22, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
8. Section 404 permit & related environmental & archaeological work			
- Archaeological testing	521,000	521,000	$30.00/acre in the PMF pool.
- Monitor 404 process	100,000	100,000	
- Special studies	200,000	200,000	Endangered species, habitat, water quality.
9. Permitting contingencies	504,000	504,000	25% of permitting costs.
10. Final design	1,911,000	1,911,000	3.75% of construction.
Pre-Construction Subtotal (1-10)	$ 5,649,000	$ 5,649,000	
11. Land acquisition			
- Land purchase	6,738,000	6,738,000	Top of conservation pool. $550/ac.
- Easements	722,000	722,000	Top of conservation pool + 5'. $412.50/acre.
- Lignite	0	0	
- Acquisition costs	1,119,000	1,119,000	15% of land and minerals.
- Contingencies	2,145,000	2,145,000	25% of above 4 items.
Subtotal for Item 11	$10,724,000	$10,724,000	
12. Conflicts			
- Highways	2,595,000	2,595,000	
- County roads	0	0	
- Pipelines	0	0	
- Oil fields	16,000	16,000	
- Other	1,076,000	1,076,000	
- Contingencies & engineering	922,000	922,000	

Table I-22, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
Subtotal for Item 12	$ 4,609,000	$ 4,609,000	
13. Advertising and bidding	5,000	5,000	
14. Construction			
- Construction	50,953,000	50,953,000	
- Contingencies	10,700,000	10,700,000	20% of construction, design, & gen. rep.
- General representation	637,000	637,000	1.25% of construction.
- Resident representation & Field laboratory	4,076,000	4,076,000	8% of construction.
Subtotal for Item 14	$66,366,000	$66,366,000	
Subtotal	$87,353,000	$87,353,000	
Interest during construction	12,111,000	12,111,000	3 years at half of 8.5%.
TOTAL	$99,464,000	$99,464,000	
Debt service	9,255,000	9,255,000	30-year bonds at 8.5% interest.
Operation and maintenance	750,000	750,000	
Total annual cost	$10,005,000	$10,005,000	
Unit cost of raw water			
- per acre-foot	$73.19	$73.19	
- per 1,000 gallons	$0.2246	$0.2246	

Table I-23

Opinion of Probable Construction and Related Costs for George Parkhouse Reservoir Stage II

- All Values Based on 1989 Prices -

Item No.	Description	Quantity	Units	Unit Prices	Total Price
1.	Excavation				
	a. Approach channel	107,400	C.Y.	$ 1.31	$ 141,000
	b. Discharge channel	114,600	C.Y.	1.31	150,000
	c. Spillway	472,200	C.Y.	1.20	567,000
2.	Fill				
	a. Impervious	1,107,200	C.Y.	1.75	1,938,000
	b. Random	4,790,900	C.Y.	1.75	8,384,000
3.	Filter, 1 & 2 (Foundation drainage)	558,600	C.Y.	10.00	5,586,000
4.	Bridge	390	L.F.	720.00	281,000
5.	Roadway	96,067	S.Y.	4.60	442,000
6.	Cutoff slurry trench	1,092,500	S.F.	3.50	3,824,000
7.	Soil cement	324,340	C.Y.	16.00	5,189,000
8.	Elevator	1	Ea.	100,000.00	100,000
9.	Barrier warning system	936	L.F.	12.00	11,000
10.	Gates				
	a. Gate & anchor (Install/paint)	4,480	S.F.	155.00	694,000
	b. Stop gate & lift beam	160	L.F.	1,450.00	232,000
	c. Hoist	8	Ea.	118,000.00	944,000
11.	Electrical	1	L.S.	320,000.00	320,000
12.	Power drop	1	L.S.	144,000.00	144,000
13.	Low flow system	1	L.S.	1,000,000.00	1,000,000
14.	Monorail system	390	L.F.	640.00	250,000
15.	Embankment internal drainage	39,300	L.F.	38.00	1,493,000
16.	Guardrail	780	L.F.	18.00	14,000
17.	Grassing	28	Ac.	3,700.00	104,000
18.	Concrete (mass)	97,000	C.Y.	125.00	12,238,000
19.	Concrete (walls)	7,000	C.Y.	200.00	1,400,000
Subtotal					$45,446,000
20.	Mobilization (5% of Subtotal)				2,272,000
21.	Clearing/grubbing, care of water (6% of Subtotal)				2,727,000
Subtotal					$50,445,000

Table I-23, Continued

Item No.	Description	Quantity	Units	Unit Prices	Total Price
22.	Land clearing	950	Ac.	535.00	508,000
Construction Subtotal (including land clearing)					$50,953,000
23.	Engineering, 5%	1	L.S.		2,548,000
24.	Resident representation & testing, 8%	1	L.S.		4,076,000
25.	Geotechnical services, 2%	1	L.S.		1,019,000
TOTAL					$58,596,000

Table I-24

Opinion of Probable Transmission Cost
for George Parkhouse Reservoir Stage II

Yield in Acre-Feet per Year = 136,700

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Cost (1989 $)
George Parkhouse Reservoir pump station	152	363	-	-	$ 12,863,000
Booster pump station number 1	152	316	-	-	11,213,000
Booster pump station number 2	152	363	-	-	10,875,000
George Parkhouse Reservoir to Tarrant County pipeline	-	-	84	119.6	277,790,000
Subtotal					$312,741,000
Interest during construction					43,360,000
TOTAL					$356,101,000
Debt service					33,135,000
Operation and maintenance					410,000
Power					6,482,000
Total transmission annual cost					$ 40,027,000
Unit cost of transmission					
- per acre-foot					$292.81
- per 1,000 gallons					$0.8986

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-25

Opinion of Probable Raw Water Cost for Marvin Nichols Reservoir Stage I

- All Values Are Based on 1989 Prices -

Yield in Acre-Feet per Year =	624,400
TCWCID #1 Share of the Yield in Acre-Feet per Year =	218,600
Conservation Storage in Acre-Feet =	1,369,717
Surface Area at Top of Conservation Storage in Acres =	62,128

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
1. Water right permit	$ 2,000,000	$ 700,000	
2. Continuing environmental investigations	500,000	175,000	
3. Archaeological survey	776,000	272,000	$10.00/acre in the PMF pool.
4. Engineering pre-design coordination	200,000	70,000	
5. Detailed geotechnical investigation	1,938,000	678,000	
6. Hydraulic model study	120,000	42,000	
7. Section 404 application	50,000	18,000	

Table I-25, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
8. Section 404 permit & related environmental & archaeological work			
- Archaeological testing	$ 2,328,000	$ 815,000	$30.00/acre in the PMF pool.
- Monitor 404 process	200,000	70,000	
- Special studies	500,000	175,000	Endangered species, habitat, water quality.
9. Permitting contingencies	1,589,000	556,000	25% of permitting costs.
10. Final design	3,634,000	1,272,000	3.75% of construction.
Pre-Construction Subtotal (1-10)	$13,835,000	$ 4,843,000	
11. Land acquisition			
- Land purchase	34,170,000	11,963,000	Top of conservation pool, $550/ac.
- Easements	4,413,000	1,545,000	Top of conservation pool + 5'. $412.50/acre.
- Lignite	1,505,000	527,000	$425/estimated acre-foot.
- Acquisition costs	6,013,000	2,105,000	15% of land and minerals.
- Contingencies	11,525,000	4,035,000	25% of above 4 items.
Subtotal for Item 11	$57,626,000	$20,175,000	

Table I-25, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
12. Conflicts			
- Highways	$12,122,000	$ 4,244,000	
- County roads	5,942,000	2,080,000	
- Pipelines	4,120,000	1,442,000	
- Oil fields	2,021,000	708,000	
- Other	2,006,000	702,000	
- Contingencies & engineering	6,553,000	2,294,000	
Subtotal for Item 12	$32,764,000	$11,470,000	
13. Advertising and bidding	5,000	2,000	
14. Construction			
- Construction	$96,901,000	$33,925,000	
- Contingencies	20,349,000	7,124,000	20% of construction, design, & gen. rep.
- General representation	1,211,000	424,000	1.25% of construction.
- Resident representation & Field laboratory	7,752,000	2,714,000	8% of construction.
Subtotal for Item 14	$126,213,000	$44,187,000	
Subtotal	$230,443,000	$80,677,000	
Interest during construction	44,459,000	15,565,000	4 years at half of 8.5%.
TOTAL	274,902,000	$96,242,000	

Table I-25, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
Debt Service	$25,580,000	$ 8,955,000	30-year bonds at 8.5% interest.
Operation and Maintenance	1,550,000	543,000	
Total annual cost	$27,130,000	$ 9,498,000	
Unit cost of raw water			
- per acre-foot	43.45	43.45	
- per 1,000 gallons	$0.1333	$0.1333	

the District's share of the cost. Table I-26 gives the quantities and unit costs used to develop the opinion of probable construction cost for the reservoir. Table I-27 gives the opinion of probable cost for the water transmission system associated with Marvin Nichols Reservoir Stage I.

The District's share of the probable capital cost for water from Marvin Nichols Reservoir Stage I totals $702,613,000 for raw water and transmission. The District's share of the probable annual cost totals $81,191,000, which would give a unit cost of $1.14 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

<u>Marvin Nichols Reservoir Stage II</u>

Marvin Nichols Reservoir Stage II would supply 294,800 acre-feet per year of yield. It is assumed that the Tarrant County Water Control and Improvement District Number One would use 218,600 acre-feet per year (74.15 percent of the yield) if it develops this alternative. Table I-28 summarizes the opinion of probable cost for Marvin Nichols Reservoir Stage II and shows the District's share of the cost. Table I-29 gives the quantities and unit costs used to develop the opinion of probable construction cost for the reservoir. The water transmission system associated with Marvin Nichols Reservoir Stage II would be the same as that associated with Marvin Nichols Reservoir Stage 1, and the opinion of probable transmission cost is given in Table I-27.

The District's share of the probable capital cost for water from Marvin Nichols Reservoir Stage II totals $753,251,000 for raw water and

Table I-26

Opinion of Probable Construction and Related Costs for Marvin Nichols Reservoir Stage I

- All Values Are Based on 1989 Prices -

Item No.	Description	Quantity	Units	Unit Prices	Total Price
1.	Excavation				
	a. Approach channel	320,000	C.Y.	$ 1.31	$ 419,000
	b. Discharge channel	310,000	C.Y.	1.31	406,000
	c. Spillway	2,425,600	C.Y.	1.20	2,911,000
2.	Fill				
	a. Impervious	1,511,300	C.Y.	1.75	2,645,000
	b. Random	6,508,300	C.Y.	1.75	11,390,000
3.	Filter, 1 & 2 (Foundation drainage)	795,000	C.Y.	10.00	7,950,000
4.	Bridge	940	L.F.	720.00	677,000
5.	Roadway	126,900	S.Y.	4.60	584,000
6.	Cutoff slurry trench	2,061,000	S.F.	3.50	7,214,000
7.	Soil cement	482,900	C.Y.	16.00	7,726,000
8.	Elevator	1	Ea.	100,000.00	100,000
9.	Barrier warning system	2,256	L.F.	12.00	27,000
10.	Gates				
	a. Gate & anchor (Install & paint)	22,800	S.F.	120.00	2,736,000
	b. Stop gate & lift beam	480	L.F.	1,450.00	696,000
	c. Hoist	19	Ea.	118,000.00	2,242,000
11.	Electrical	1	L.S.	340,000.00	340,000
12.	Power drop	1	L.S.	144,000.00	144,000
13.	Low flow system	1	L.S.	1,000,000.00	1,000,000
14.	Monorail system	940	L.F.	640.00	602,000
15.	Embankment internal drainage	51,900	L.F.	38.00	1,972,000
16.	Guardrail	1,880	L.F.	18.00	34,000
17.	Grassing	40	Ac.	3,700.00	148,000
18.	Concrete (Mass)	223,900	C.Y.	125.00	27,988,000
19.	Concrete (Walls)	3,600	C.Y.	200.00	720,000
Subtotal					$ 80,671,000
20.	Mobilization (5% of Subtotal)				4,034,000
21.	Clearing/grubbing, care of water (5% of Subtotal)				4,840,000
Construction Subtotal					$ 89,545,000

Table I-26, Continued

Item No.	Description	Quantity	Units	Unit Prices	Total Price
22.	Land clearing	13,750	Ac.	535.00	$ 7,356,000
Subtotal (including land clearing)					$ 96,901,000
23.	Engineering, 5%	1	L.S.		$ 4,845,000
24.	Resident representation & testing, 8%	1	L.S.		7,752,000
25.	Geotechnical services, 2%	1	L.S.		1,938,000
TOTAL					$111,436,000

Table I-27

Opinion of Probable Transmission Cost for Marvin Nichols Reservoir Stage I

Yield in Acre-Feet per Year = 218,600

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	TCWCID #1 Share of Cost (1989 $)
Marvin Nichols Reservoir pump station	625	322	-	-	$ 21,300,000	$ 7,455,000
Booster pump station number 1	625	241	-	-	15,919,000	5,572,000
Booster pump station number 2	625	276	-	-	16,300,000	5,705,000
Booster pump station number 3	244	208	-	-	11,138,000	11,138,000
Booster pump station number 4	244	117	-	-	10,600,000	10,600,000
Marvin Nichols Reservoir to Lake Lavon pipeline	-	-	2-120	91.7	761,611,000	266,564,000
Lake Lavon to Tarrant County pipeline	-	-	102	60.9	201,270,000	201,270,000
Subtotal					$1,038,138,000	$508,304,000
Interest during construction					200,287,000	98,067,000
TOTAL					$1,238,425,000	$606,371,000

Table I-27, Continued

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Total Cost (1989 $)	TCWCID #1 Share of Cost (1989 $)
Debt service					115,235,000	56,423,000
Operation and maintenance					1,103,000	525,000
Power					31,235,000	14,745,000
Total transmission annual cost					$ 147,573,000	$ 71,693,000
Unit cost of transmission						
- per acre-foot						$327.96
- per 1,000 gallons						$1.0065

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-28

Opinion of Probable Raw Water Cost for Marvin Nichols Reservoir Stage II

- All Values Are Based on 1989 Prices -

Yield in Acre-Feet per Year =	294,800
TCWCID #1 Share of the Yield in Acre-Feet per Year =	218,600
Conservation Storage in Acre-Feet =	771,631
Surface Area at Top of Conservation Storage in Acres =	35,919

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
1. Water right permit	$ 1,400,000	$1,038,000	
2. Coantinuing environmental investigations	300,000	222,000	
3. Archaeological survey	433,000	321,000	$10.00/acre in the PMF pool.
4. Engineering pre-design coordination	140,000	104,000	
5. Detailed geotechnical investigation	1,234,000	915,000	
6. Hydraulic model study	100,000	74,000	
7. Section 404 application	30,000	22,000	

Table I-28, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
8. Section 404 permit & related environmental & archaeological work			
- Archaeological testing	$ 1,298,000	$ 962,000	$30.00/acre in the PMF pool.
- Monitor 404 process	140,000	104,000	
- Special studies	300,000	222,000	Endangered species, habitat, water quality.
9. Permitting contingencies	975,000	723,000	25% of permitting costs.
10. Final design	2,314,000	1,716,000	3.75% of construction.
Pre-Construction Subtotal (1-10)	$ 8,664,000	$ 6,423,000	
11. Land acquisition			
- Land purchase	19,755,000	14,649,000	Top of conservation pool, $550/ac.
- Easements	2,051,000	1,521,000	Top of conservation pool + 5'. $412.50/acre.
- Lignite	138,000	102,000	$300/estimated acre-foot.
- Acquisition costs	3,292,000	2,441,000	15% of land and minerals.
- Contingencies	6,309,000	4,678,000	25% of above 4 items.
Subtotal for Item 11	$31,545,000	$23,391,000	

Table I-28, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
12. Conflicts			
- Highways	$ 22,561,000	$ 16,729,000	
- County roads	611,000	453,000	
- Pipelines	6,120,000	4,538,000	
- Oil fields	13,406,000	9,941,000	
- Other	0	0	
- Contingencies & Engineering	10,675,000	7,916,000	
Subtotal for Item 12	$ 53,373,000	$ 39,577,000	
13. Advertising and bidding	5,000	4,000	
14. Construction			
- Construction	$ 61,708,000	$ 45,758,000	
- Contingencies	12,959,000	9,609,000	20% of construction, design, & gen. rep.
- General representation	771,000	572,000	1.25% of construction.
- Resident representation & Field laboratory	4,937,000	3,661,000	8% of construction.
Subtotal for Item 14	$ 80,375,000	$ 59,600,000	
Subtotal	$173,962,000	$128,995,000	
Interest during construction	24,119,000	17,885,000	3 years at half of 8.5%
TOTAL	$198,081,000	$146,880,000	

Table I-28, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
Debt Service	$18,431,000	$13,667,000	30-year bonds at 8.5% interest.
Operation and Maintenance	1,200,000	890,000	
Total annual cost	$19,631,000	$14,557,000	
Unit cost of raw water			
- per acre-foot	66.59	66.59	
- per 1,000 gallons	$0.2044	$0.2044	

Table I-29

Opinion of Probable Construction and Related Costs for Marvin Nichols Reservoir Stage II

Item No.	Description	Quantity	Units	Oct 1989 Unit Prices	Total Price
1.	Excavation				
	a. Approach channel	521,000	C.Y.	$ 1.31	$ 683,000
	b. Discharge channel	233,800	C.Y.	1.31	306,000
	c. Spillway	103,500	C.Y.	1.20	124,000
2.	Fill				
	a. Impervious	817,600	C.Y.	1.75	1,431,000
	B. Random	3,393,000	C.Y.	1.75	5,938,000
3.	Filter, 1 & 2 (Foundation drainage)	484,500	C.Y.	10.00	4,845,000
4.	Bridge	490	L.F.	720.00	353,000
5.	Roadway	91,177	S.Y.	4.60	419,000
6.	Cutoff slurry trench	1,404,000	S.F.	3.50	4,914,000
7.	Soil cement	306,390	C.Y.	16.00	4,902,000
8.	Elevator	1	Ea.	100,000.00	100,000
9.	Barrier warning system	1,176	L.F.	12.00	14,000
10.	Gates				
	a. Gate & anchor (Install & paint)	10,000	S.F.	145.00	1,450,000
	b. Stop gate & lift beam	240	L.F.	1,450.00	348,000
	c. Hoist	10	Ea.	118,000.00	1,180,000
11.	Electrical	1	L.S.	340,000.00	340,000
12.	Power drop	1	L.S.	144,000.00	144,000
13.	Low flow system	1	L.S.	1,000,000.00	1,000,000
14.	Monorail system	490	L.F.	640.00	314,000
15.	Embankment internal drainage	37,300	L.F.	38.00	1,417,000
16.	Guardrail	980	L.F.	18.00	18,000
17.	Grassing	25	Ac.	3,700.00	93,000
18.	Concrete (Mass)	140,100	C.Y.	125.00	17,513,000
19.	Concrete (Walls)	5,600	C.Y.	200.00	1,120,000
Subtotal					$48,966,000
20.	Mobilization (5% of Subtotal)				2,448,000
21.	Clearing/grubbing, care of water (5% of Subtotal)				2,938,000
Construction Subtotal					$54,352,000

Table I-29, Continued

Item No.	Description	Quantity	Units	Oct 1989 Unit Prices	Total Price
22.	Land clearing	13,750	Ac.	535.00	$ 7,356,000
Subtotal (including land clearing)					$61,708,000
23.	Engineering, 5%	1	L.S.		$ 3,085,000
24.	Resident representation & testing, 8%	1	L.S.		4,937,000
25.	Geotechnical services, 2%	1	L.S.		1,234,000
	TOTAL				$70,964,000

transmission. The District's share of the probable annual cost totals $86,250,000, which would give a unit cost of $1.21 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

Tennessee Colony Reservoir

Tennessee Colony Reservoir would supply 300,100 acre-feet per year of yield based on the natural flow of the Trinity River. It is assumed that the Tarrant County Water Control and Improvement District Number One would use 216,500 acre-feet per year (72.14 percent of the yield) if it develops this alternative. Table I-30 summarizes the opinion of probable cost for Tennessee Colony Reservoir and shows the District's share of the cost. Table I-31 gives the quantities and unit costs used to develop the opinion of probable construction cost for the reservoir. The opinion of probable cost for the water transmission system associated with Tennessee Colony Reservoir is given in Table I-32.

The District's share of the probable capital cost for water from Tennessee Colony Reservoir totals $826,032,000 for raw water and transmission. The District's share of the probable annual cost totals $92,702,000, which would give a unit cost of $1.31 per thousand gallons of water delivered to Tarrant County when the alternative is fully developed.

Comparison of the Alternatives

Table I-33 is a summary comparison of the raw water and transmission costs for the alternatives described above. The cost per thousand gallons for new supplies delivered to Tarrant County ranges from $0.96 (for

Table I-30

Opinion of Probable Raw Water Cost for Tennessee Colony Reservoir

- All Values Are Based on 1989 Prices -

Yield in Acre-Feet per Year =	300,100
TCWCID #1 Share of the Yield in Acre-Feet per Year =	216,500
Conservation Storage in Acre-Feet =	1,115,000
Surface Area at Top of Conservation Storage in Acres =	60,100

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
1. Water right permit	$ 2,000,000	$1,443,000	
2. Continuing environmental investigations	500,000	361,000	
3. Archaeological survey	1,278,000	922,000	$10.00/acre in the PMF pool.
4. Engineering pre-design coordination	200,000	144,000	
5. Detailed geotechnical investigation	2,543,000	1,835,000	
6. Hydraulic model study	150,000	108,000	
7. Section 404 application	50,000	36,000	

Table I-30, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
8. Section 404 permit & related environmental & archaeological work			
- Archaeological testing	$ 3,834,000	$ 2,766,000	$30.00/acre in the PMF pool.
- Monitor 404 process	200,000	144,000	
- Special studies	500,000	361,000	Endangered species, habitat, water quality.
9. Permitting contingencies	2,091,000	1,509,000	25% of permitting costs.
10. Final design	4,768,000	3,440,000	3.75% of construction.
Pre-Construction Subtotal (1-10)	$ 18,114,000	$ 13,069,000	
11. Land acquisition			
- Land purchase	54,480,000	39,303,000	Top of conservation pool, $800/ac.
- Easements	5,160,000	3,723,000	Top of conservation pool + 5'. $600/acre.
- Lignite	67,490,000	48,689,000	$425/estimated acre-foot.
- Acquisition costs	19,070,000	13,758,000	15% of land and minerals.
- Contingencies	36,550,000	26,368,000	25% of above 4 items.
Subtotal for Item 11	$182,750,000	$131,841,000	

Table I-30, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
12. Conflicts			
- Highways	$ 14,935,000	$ 10,775,000	
- County roads	2,173,000	1,568,000	
- Pipelines	11,578,000	8,353,000	
- Oil fields	28,537,000	20,587,000	
- Other	8,350,000	6,024,000	
- Contingencies & engineering	16,393,000	11,826,000	
Subtotal for Item 12	$ 81,966,000	$ 59,133,000	
13. Advertising and bidding	5,000	4,000	
14. Construction			
- Construction	$127,139,000	$ 91,721,000	
- Contingencies	26,699,000	19,261,000	20% of construction, design, & gen. rep.
- General representation	1,589,000	1,146,000	1.25% of construction.
- Resident representation & Field laboratory	10,171,000	7,338,000	8% of construction.
Subtotal for Item 14	$165,598,000	$119,466,000	
Subtotal	$448,433,000	$323,513,000	
Interest during construction	172,679,000	124,575,000	7 years at half of 8.5%
TOTAL	$621,112,000	$448,088,000	

Table I-30, Continued

Item	Estimated Total Cost	Estimated TCWCID #1 Share	Comments
Debt Service	$57,794,000	$41,694,000	30-year bonds at 8.5%.
Operation and Maintenance	1,500,000	1,082,000	
Total annual cost	$59,294,000	$42,776,000	
Unit cost of raw water			
- per acre-foot	197.58	197.58	
- per 1,000 gallons	$0.6063	$0.6063	

Table I-31

Opinion of Probable Construction and Related Costs for Tennessee Colony Reservoir

- All Values Are Based on 1989 Prices -

Item No.	Description	Quantity	Units	Unit Prices	Total Price
1.	Excavation				
	a. Channel	1,137,343	C.Y.	$ 1.31	$ 1,490,000
	b. Spillway	2,786,737	C.Y.	1.20	3,344,000
2.	Fill				
	A. Impervious	2,816,322	C.Y.	1.75	4,929,000
	B. Random	15,145,170	C.Y.	1.75	26,504,000
3.	Filter, 1 & 2 (Foundation drainage)	1,150,578	C.Y.	10.00	11,506,000
4.	Bridge	1,070	L.F.	720.00	770,000
5.	Roadway	93,240	S.Y.	4.60	429,000
6.	Cutoff slurry trench	2,101,000	S.F.	3.50	7,353,000
7.	Soil cement	708,004	C.Y.	16.00	11,328,000
8.	Elevator	1	Ea.	100,000.00	100,000
9.	Barrier warning system	2,568	L.F.	12.00	31,000
10.	Gates				
	a. Gate & anchor (Install & paint)	11,700	S.F.	200.00	2,340,000
	b. Stop gate & lift beam	200	L.F.	1,450.00	290,000
	c. Hoist	18	Ea.	118,000.00	2,124,000
11.	Electrical	1	L.S.	340,000.00	340,000
12.	Power drop	1	L.S.	144,000.00	144,000
13.	Low flow system	1	L.S.	1,000,000.00	1,000,000
14.	Monorail system	1,070	L.F.	640.00	685,000
15.	Embankment internal drainage	37,930	L.F.	38.00	1,441,000
16.	Guardrail	2,140	L.F.	18.00	39,000
17.	Grassing	57	Ac.	3,700.00	211,000
18.	Concrete (Mass)	190,289	C.Y.	125.00	23,786,000
19.	Concrete (Walls)	6,820	C.Y.	200.00	1,364,000
Subtotal					$101,548,000
20.	Mobilization (5% of Subtotal)				5,077,000
21.	Clearing/grubbing, care of water (6% of Subtotal)				6,093,000
Subtotal					$112,718,000

Table I-31, Continued

Item No.	Description	Quantity	Units	Unit Prices	Total Price
22.	Land clearing	26,955	Ac.	535.00	$ 14,421,000
Construction Subtotal (including land clearing)					$127,139,000
23.	Engineering, 5%	1	L.S.		$ 6,357,000
24.	Resident representation & testing, 8%	1	L.S.		10,171,000
25.	GEOTECHNICAL SERVICES, 2%	1	L.S.		2,543,000
Total					$146,210,000

Table I-32

Opinion of Probable Transmission Cost for Tennessee Colony Reservoir

District Yield in Acre-Feet per Year = 216,500

Item	Capacity (MGD)	Head (Ft.)	Size (In.)	Length (Miles)	Cost (1989 $)
Tennessee Colony Reservoir pump station	245	195	-	-	$ 12,675,000
Richland-Chambers Reservoir pump station	245	335	-	-	15,450,000
Ennis booster pump station	245	295	-	-	11,625,000
Waxahachie booster pump station	245	250	-	-	11,363,000
Tennessee Colony Reservoir-Tarrant County pipeline	-	-	102	92.3	296,067,000
Subtotal					$347,180,000
Interest during construction					30,764,000
TOTAL					$377,944,000
Debt service					35,168,000
Operation and maintenance					494,000
Power					14,264,000
Total transmission annual cost					$ 49,926,000
Unit cost of transmission - per acre-foot - per 1,000 gallons					 $230.61 $0.7077

Note: Capital costs include engineering and contingencies at 25 percent.

Table I-33, Continued

Item	Trinity R. Diversions	System Operation	Lake Texoma	L. Palestine w/ Add. Div.	Tehuacana w/ Add. Div.	George Parkhouse I	George Parkhouse II	Marvin Nichols I	Marvin Nichols II	Tennessee Colony
TRANSMISSION COSTS										
- Pipelines & Right-of-Way	218,937,000	82,584,000	120,312,000	246,006,000	131,399,000	277,790,000	277,790,000	467,834,000	467,834,000	296,067,000
- Pump Stations	36,448,000	14,778,000	16,519,000	36,590,000	6,862,000	34,951,000	34,951,000	40,470,000	40,470,000	51,113,000
- Interest during Construction	22,630,000	8,627,000	12,125,000	25,042,000	12,252,000	43,360,000	43,360,000	98,067,000	98,067,000	30,764,000
Total Transmission Capital Cost	278,015,000	105,989,000	148,956,000	307,638,000	150,513,000	356,101,000	356,101,000	606,371,000	606,371,000	377,944,000
Annual Transmission Costs										
- Debt Service	25,869,000	9,862,000	13,860,000	28,626,000	14,005,000	33,135,000	33,135,000	56,423,000	56,423,000	35,168,000
- Operation and Maintenance	348,000	149,000	217,000	363,000	154,000	410,000	410,000	525,000	525,000	494,000
- Power	6,189,000	1,248,000	1,698,000	7,190,000	4,426,000	5,833,000	6,482,000	14,745,000	14,745,000	14,264,000
Total Annual Transmission Cost	32,406,000	11,259,000	15,775,000	36,179,000	18,585,000	39,378,000	40,027,000	71,693,000	71,693,000	49,926,000
Unit Cost of Transmission										
- per Acre-Foot	$280.57	$343.26	$315.50	$243.47	$209.53	$320.15	$292.81	$327.96	$327.96	$230.61
- per 1,000 Gallons	$0.8610	$1.0534	$0.9682	$0.7472	$0.6430	$0.9825	$0.8986	$1.0065	$1.0065	$0.7077
TOTAL CAPITAL COST	312,190,000	106,431,000	159,600,000	440,704,000	274,526,000	497,414,000	455,565,000	702,613,000	753,251,000	826,032,000
TOTAL ANNUAL COST	36,261,000	11,338,000	16,865,000	49,453,000	30,377,000	53,277,000	50,032,000	81,191,000	86,250,000	92,702,000
TOTAL UNIT COST										
- per Acre-Foot	$313.95	$345.67	$337.30	$332.79	$342.47	$433.15	$366.00	$371.41	$394.56	$428.18
- per 1,000 Gallons	$0.9635	$1.0608	$1.0351	$1.0213	$1.0510	$1.3293	$1.1232	$1.1398	$1.2108	$1.3141
Rank (by cost)	1	4	2	2	4	9	6	6	8	9

Notes:
=====

a. System operation costs and yield are incremental to Trinity Diversions.
b. Lake Palestine with additional diversion costs and yield are incremental to system operation with Trinity diversions.
c. Tehuacana with additional diversion costs and yield are incremental to system operation with Trinity diversions.
d. The costs assume that Trinity water is put in detention ponds before it is put in Cedar Creek and Richland-Chambers.

diversions from the Trinity River) to $1.33 (for George Parkhouse Reservoir Stage I). With the exception of Tehuacana Reservoir, the alternatives which involve construction of new reservoirs are somewhat more expensive than those which do not.

I-3 COMPARISON OF WATER SUPPLY SCENARIOS

Four scenarios of future water supply development for the Tarrant County Water Control and Improvement District Number One are considered in this study:

- Scenario 1 - Diversions from the Trinity River, system operation, and development of Tehuacana Reservoir.
- Scenario 2 - Diversions from the Trinity River and development of George Parkhouse Reservoir Stage II.
- Scenario 3 - Marvin Nichols Reservoir Stage I.
- Scenario 4 - Tennessee Colony Reservoir.

This section gives the capital investment, the timing of development, and the unit cost of new water supplies for each scenario. It should be noted that the total Tarrant County District water supply will include the District's approximately 460,000 acre-feet per year from existing sources. The unit cost to the District's customers will therefore be less than the unit cost of new supplies discussed in this section.

The capital costs of the scenarios are based on the opinions of 1989 costs discussed above, without allowance for inflation. In the tabulation of unit costs, it is assumed that the discount rate and the inflation rate are equal at 6 percent per year. Since inflation is offset by the discount

Table I-34

Capital Investment for Scenario 1

Year Construction Begins	Project	Capital Cost (1989 $)	Year Completed
2014	Trinity diversion to Richland-Chambers Reservoir (96 mgd)	$ 18,708,000	2016
2014	Pump Stations and first 90" pipeline from Ennis to Tarrant County	173,093,000	2016
2018	Pump Station and 102" pipeline from Richland-Chambers to Ennis	118,404,000	2020
2026	Trinity diversion to Cedar Creek (88 mgd)	16,777,000	2028
2026	Pump Station and 108" pipeline from Cedar Creek to Ennis	115,736,000	2028
2030	Additional pumps and parallel 90" pipeline from Ennis to Tarrant County	127,285,000	2030
2040	Tehuacana Reservoir	123,145,000	2042
TOTAL		$693,148,000	

Table I-35

Unit Costs for Scenario 1

(1989 Present Worth, Discount Rate = Inflation Rate = 6 Percent per Year)

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014		191,801						
2015								
2016	3,400		16,837	411	183	17,431	$15.73	$15.73
2017	6,800		15,884	411	366	16,661	$7.52	$10.26
2018	10,200	118,404	14,985	411	550	15,946	$4.80	$7.53
2019	13,600		14,137	411	733	15,281	$3.45	$5.90
2020	17,000		23,730	531	916	25,177	$4.55	$5.45
2021	22,800		22,387	531	1,229	24,147	$3.25	$4.77
2022	28,600		21,120	531	1,541	23,192	$2.49	$4.13
2023	34,500		19,924	531	1,859	22,314	$1.98	$3.59
2024	40,300		18,797	531	2,172	21,500	$1.64	$3.15
2025	46,100		17,733	531	2,484	20,748	$1.38	$2.78
2026	51,900	132,513	16,729	531	2,797	20,057	$1.19	$2.48
2027	57,700		15,782	531	3,110	19,423	$1.03	$2.23
2028	63,600		26,521	840	3,345	30,706	$1.48	$2.11
2029	69,400		25,020	840	3,650	29,510	$1.30	$1.99
2030	75,200	127,285	23,604	840	3,955	28,399	$1.16	$1.87
2031	81,400		22,268	840	4,282	27,390	$1.03	$1.76
2032	87,700		32,180	995	4,613	37,788	$1.32	$1.71
2033	93,900		30,359	995	4,939	36,293	$1.19	$1.65
2034	100,100		28,640	995	5,265	34,900	$1.07	$1.58
2035	106,400		27,019	995	5,597	33,611	$0.97	$1.52

Table I-35, Continued

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2036	112,600		25,489	995	5,923	32,407	$0.88	$1.46
2037	118,800		24,047	995	6,249	31,291	$0.81	$1.39
2038	125,000		22,686	995	6,575	30,256	$0.74	$1.33
2039	131,300		21,402	995	6,906	29,303	$0.68	$1.28
2040	137,500	123,145	20,190	995	7,232	28,417	$0.63	$1.22
2041	145,100		19,048	995	7,632	27,675	$0.59	$1.17
2042	152,600		28,780	1,195	8,019	37,994	$0.76	$1.14
2043	160,200		27,150	1,195	8,404	36,749	$0.70	$1.11
2044	167,700		25,614	1,195	8,785	35,594	$0.65	$1.07
2045	175,300		24,164	1,195	9,171	34,530	$0.60	$1.04
2046	182,800		19,865	1,195	9,552	30,612	$0.51	$1.00
2047	190,400		18,740	1,195	9,937	29,872	$0.48	$0.97
2048	197,900		17,679	1,195	10,318	29,192	$0.45	$0.93
2049	205,500		16,679	1,195	10,704	28,578	$0.43	$0.90
2050	213,000		13,925	1,195	11,085	26,205	$0.38	$0.87
Total	3,426,300	693,148	759,114	29,957	180,078	969,149	$0.87	

Table I-36

Capital Investment for Scenario 2

Year Construction Begins	Project	Capital Cost (1989 $)	Year Completed
2014	Trinity diversion to Richland-Chambers (81 mgd)	$ 18,194,000	2016
2014	Pump Stations and 96" pipeline from Ennis to Tarrant County	176,971,000	2016
2018	Pump Station and 96" pipeline from Cedar Creek to Ennis	101,044,000	2020
2026	Trinity diversion to Cedar Creek (71 mgd)	15,981,000	2028
2034	George Parkhouse Reservoir Stage II	99,464,000	2037
2034	Pump Stations and 84" pipeline from George Parkhouse Reservoir Stage 2 to Tarrant County	356,101,000	2037
TOTAL		$767,755,000	

Scenario 1, the first source of new water would be diversions from the Trinity River into Richland-Chambers Reservoir. In this scenario, the transmission system from Richland-Chambers to Ennis would not be expanded. The system from Ennis to Tarrant County would be expanded in 2016. In order to maintain adequate peaking capacity, the system from Cedar Creek Reservoir to Ennis would be expanded in 2020. The supply would be supplemented by diversions from the Trinity into Cedar Creek in 2028 and by the development of George Parkhouse Reservoir Stage II in 2037. The total capital cost of this scenario is $767,755,000. Table I-37 shows the unit cost of raw water for this scenario, which averages $0.90 per thousand gallons from 2016 through 2050.

Costs for Scenario 3

Table I-38 describes the capital investments for Scenario 3, in which the District's future needs would be met by development of the proposed Marvin Nichols Reservoir Stage I. The reservoir and the initial transmission system to Tarrant County would begin operation in 2016, and the transmission system would be expanded in 2034. The total capital cost of this scenario for the Tarrant County Water Control and Improvement District Number One is $702,613,000. Table I-39 shows the unit cost of raw water, which averages $0.96 per thousand gallons from 2016 through 2050.

Unlike Scenarios 1 and 2, the development of Marvin Nichols Reservoir Stage I would require a significant investment by other water users, since the Tarrant County District would use only 35 percent of the supply the

Table I-37

Unit Costs for Scenario 2

(1989 Present Worth, Discount Rate = Inflation Rate = 6 Percent per Year)

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2006								
2007								
2008								
2009								
2010								
2011								
2012								
2013								
2014		195,165						
2015								
2016	3,400		17,132	395	191	17,718	$15.99	$15.99
2017	6,800		16,162	395	381	16,938	$7.64	$10.43
2018	10,200	101,044	15,248	395	572	16,215	$4.88	$7.65
2019	13,600		14,385	395	763	15,543	$3.51	$5.99
2020	17,000		22,440	523	953	23,916	$4.32	$5.44
2021	22,800		21,170	523	1,278	22,971	$3.09	$4.71
2022	28,600		19,972	523	1,604	22,099	$2.37	$4.06
2023	34,500		18,841	523	1,935	21,299	$1.89	$3.51
2024	40,300		17,775	523	2,260	20,558	$1.57	$3.07
2025	46,100		16,769	523	2,585	19,877	$1.32	$2.71
2026	51,900	15,981	15,819	523	2,910	19,252	$1.14	$2.41
2027	57,700		14,924	523	3,235	18,682	$0.99	$2.17
2028	63,600		15,403	689	3,610	19,702	$0.95	$1.97
2029	69,400		14,531	689	3,939	19,159	$0.85	$1.80
2030	75,200		13,708	689	4,268	18,665	$0.76	$1.66
2031	81,400		12,932	689	4,620	18,241	$0.69	$1.53
2032	87,700		12,200	689	4,977	17,866	$0.63	$1.42
2033	93,900		11,510	689	5,329	17,528	$0.57	$1.32
2034	100,100	455,565	10,858	689	5,681	17,228	$0.53	$1.23
2035	106,400		10,244	689	6,039	16,972	$0.49	$1.16

Table I-37, Continued

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2036	112,600		9,664	689	6,391	16,744	$0.46	$1.09
2037	118,800		47,959	1,849	6,712	56,520	$1.46	$1.12
2038	125,000		45,245	1,849	7,006	54,100	$1.33	$1.14
2039	131,300		42,684	1,849	7,304	51,837	$1.21	$1.15
2040	137,500		40,268	1,849	7,598	49,715	$1.11	$1.14
2041	145,100		37,988	1,849	7,959	47,796	$1.01	$1.13
2042	152,600		35,838	1,849	8,315	46,002	$0.93	$1.12
2043	160,200		33,809	1,849	8,675	44,333	$0.85	$1.10
2044	167,700		31,896	1,849	9,031	42,776	$0.78	$1.07
2045	175,300		30,090	1,849	9,391	41,330	$0.72	$1.05
2046	182,800		25,404	1,849	9,747	37,000	$0.62	$1.02
2047	190,400		23,966	1,849	10,107	35,922	$0.58	$0.99
2048	197,900		22,610	1,849	10,463	34,922	$0.54	$0.96
2049	205,500		21,330	1,849	10,823	34,002	$0.51	$0.93
2050	213,000		18,578	1,849	11,179	31,606	$0.46	$0.90
Total	3,426,300	767,755	779,352	37,851	187,831	1,005,034	$0.90	

Table I-38

Capital Investment for Scenario 3

Year Construction Begins	Project	Capital Cost of District Share (1989 $)	Year Completed
2012	Marvin Nichols 1 Reservoir	$ 96,242,000	2016
2012	District's share of pump stations and first 120" pipeline from Marvin Nichols to Lake Lavon	180,125,000	2016
2012	Pump stations and 102" pipeline from Lake Lavon to Tarrant County	266,033,000	2016
2030	Additional pumps and parallel 120" from Marvin Nichols to Lake Lavon	160,213,000	2034
TOTAL		$702,613,000	

Table I-39

Unit Costs for Scenario 3

(1989 Present Worth, Discount Rate = Inlfation Rate = 6 Percent per Year)

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2006								
2007								
2008								
2009								
2010								
2011								
2012		542,400						
2013								
2014								
2015								
2016	3,400		44,918	1,036	229	46,183	$41.69	$41.69
2017	6,800		42,376	1,036	459	43,871	$19.80	$27.09
2018	10,200		39,977	1,036	688	41,701	$12.55	$19.82
2019	13,600		37,714	1,036	917	39,667	$8.95	$15.47
2020	17,000		35,580	1,036	1,147	37,763	$6.82	$12.59
2021	22,800		33,566	1,036	1,538	36,140	$4.86	$10.20
2022	28,600		31,666	1,036	1,929	34,631	$3.72	$8.39
2023	34,500		29,873	1,036	2,327	33,236	$2.96	$7.02
2024	40,300		28,182	1,036	2,718	31,936	$2.43	$5.98
2025	46,100		26,587	1,036	3,110	30,733	$2.05	$5.17
2026	51,900		25,082	1,036	3,501	29,619	$1.75	$4.52
2027	57,700		23,662	1,036	3,892	28,590	$1.52	$4.00
2028	63,600		22,323	1,036	4,290	27,649	$1.33	$3.57
2029	69,400		21,060	1,036	4,681	26,777	$1.18	$3.22
2030	75,200	160,213	19,867	1,036	5,072	25,975	$1.06	$2.92
2031	81,400		18,743	1,036	5,491	25,270	$0.95	$2.66
2032	87,700		17,682	1,036	5,916	24,634	$0.86	$2.44
2033	93,900		16,681	1,036	6,334	24,051	$0.79	$2.25
2034	100,100		29,005	1,068	6,752	36,825	$1.13	$2.12
2035	106,400		27,363	1,068	7,177	35,608	$1.03	$2.01

Table I-39, Continued

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2036	112,600		25,814	1,068	7,595	34,477	$0.94	$1.90
2037	118,800		24,353	1,068	8,013	33,434	$0.86	$1.80
2038	125,000		22,975	1,068	8,432	32,475	$0.80	$1.71
2039	131,300		21,674	1,068	8,856	31,598	$0.74	$1.62
2040	137,500		20,447	1,068	9,275	30,790	$0.69	$1.55
2041	145,100		19,290	1,068	9,787	30,145	$0.64	$1.47
2042	152,600		18,198	1,068	10,293	29,559	$0.59	$1.40
2043	160,200		17,168	1,068	10,806	29,042	$0.56	$1.34
2044	167,700		16,196	1,068	11,312	28,576	$0.52	$1.28
2045	175,300		15,279	1,068	11,824	28,171	$0.49	$1.22
2046	182,800		6,594	1,068	12,330	19,992	$0.34	$1.16
2047	190,400		6,221	1,068	12,843	20,132	$0.32	$1.10
2048	197,900		5,868	1,068	13,349	20,285	$0.31	$1.05
2049	205,500		5,536	1,068	13,861	20,465	$0.31	$1.00
2050	213,000		5,223	1,068	14,367	20,658	$0.30	$0.96
Total	3,426,300	702,613	802,743	36,804	231,111	1,070,658	$0.96	

reservoir provides.

Costs for Scenario 4

Table I-40 describes the capital investments for Scenario 4, in which the District's future needs would be met by development of the proposed Tennessee Colony Reservoir. The reservoir and the transmission system to Tarrant County would begin operation in 2016. The total capital cost of this scenario for the District is $826,032,000. Table I-41 shows the unit cost of raw water, which averages $1.13 per thousand gallons from 2016 through 2050.

Comparison of the Scenarios

Figure I-1 shows a comparison of the unit costs of new supplies of raw water from Scenarios 1, 2, 3, and 4. Figure I-2 shows a comparison of cumulative unit costs for all water supplied up to a given year. Table I-42 gives a summary comparison of the 4 scenarios. The comparisons show that Scenario 1 has the lowest capital cost and total unit costs. Scenarios 3 and 4, in which the entire supply needed through 2050 is developed by 2016, show very high unit costs for new water in the early years of operation.

Table I-41

Unit Costs for Scenario 4

(1989 Present Worth, Discount Rate = Inflation Rate = 6 Percent per Year)

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2006								
2007								
2008								
2009		448,088						
2010								
2011								
2012								
2013								
2014		377,944						
2015								
2016	3,400		67,179	1,576	224	68,979	$62.26	$62.26
2017	6,800		63,377	1,576	448	65,401	$29.52	$40.43
2018	10,200		59,789	1,576	672	62,037	$18.67	$29.55
2019	13,600		56,405	1,576	896	58,877	$13.29	$23.04
2020	17,000		53,212	1,576	1,120	55,908	$10.09	$18.73
2021	22,800		50,200	1,576	1,502	53,278	$7.17	$15.16
2022	28,600		47,359	1,576	1,884	50,819	$5.45	$12.45
2023	34,500		44,678	1,576	2,273	48,527	$4.32	$10.40
2024	40,300		42,149	1,576	2,655	46,380	$3.53	$8.84
2025	46,100		39,763	1,576	3,037	44,376	$2.95	$7.62
2026	51,900		37,513	1,576	3,419	42,508	$2.51	$6.66
2027	57,700		35,389	1,576	3,802	40,767	$2.17	$5.88
2028	63,600		33,386	1,576	4,190	39,152	$1.89	$5.24
2029	69,400		31,496	1,576	4,572	37,644	$1.66	$4.71
2030	75,200		29,714	1,576	4,955	36,245	$1.48	$4.26
2031	81,400		28,032	1,576	5,363	34,971	$1.32	$3.87
2032	87,700		26,445	1,576	5,778	33,799	$1.18	$3.54
2033	93,900		24,948	1,576	6,187	32,711	$1.07	$3.25
2034	100,100		23,536	1,576	6,595	31,707	$0.97	$3.00
2035	106,400		22,204	1,576	7,010	30,790	$0.89	$2.78

Table I-41, Continued

Year	New Water Needed (Acre-Feet)	Capital Investment ($ 1,000)	Discounted Debt Service ($ 1,000)	Operation & Maintenance ($ 1,000)	Power Cost ($ 1,000)	Total Annual Cost ($ 1,000)	Cost per 1,000 Gallons	Cumulative Cost per 1,000 Gallons
2036	112,600		20,947	1,576	7,419	29,942	$0.82	$2.58
2037	118,800		19,761	1,576	7,827	29,164	$0.75	$2.41
2038	125,000		18,643	1,576	8,236	28,455	$0.70	$2.25
2039	131,300		17,587	1,576	8,651	27,814	$0.65	$2.11
2040	137,500		16,592	1,576	9,059	27,227	$0.61	$1.98
2041	145,100		15,653	1,576	9,560	26,789	$0.57	$1.87
2042	152,600		14,767	1,576	10,054	26,397	$0.53	$1.76
2043	160,200		13,931	1,576	10,555	26,062	$0.50	$1.67
2044	167,700		13,142	1,576	11,049	25,767	$0.47	$1.58
2045	175,300		12,398	1,576	11,550	25,524	$0.45	$1.50
2046	182,800		0	1,576	12,044	13,620	$0.23	$1.41
2047	190,400		0	1,576	12,544	14,120	$0.23	$1.33
2048	197,900		0	1,576	13,039	14,615	$0.23	$1.26
2049	205,500		0	1,576	13,539	15,115	$0.23	$1.19
2050	213,000		0	1,576	14,033	15,609	$0.22	$1.13
Total	3,426,300	826,032	980,195	55,160	225,741	1,261,096	$1.13	

Comparison of Cost Per Thousand Gallons For Four Scenarios

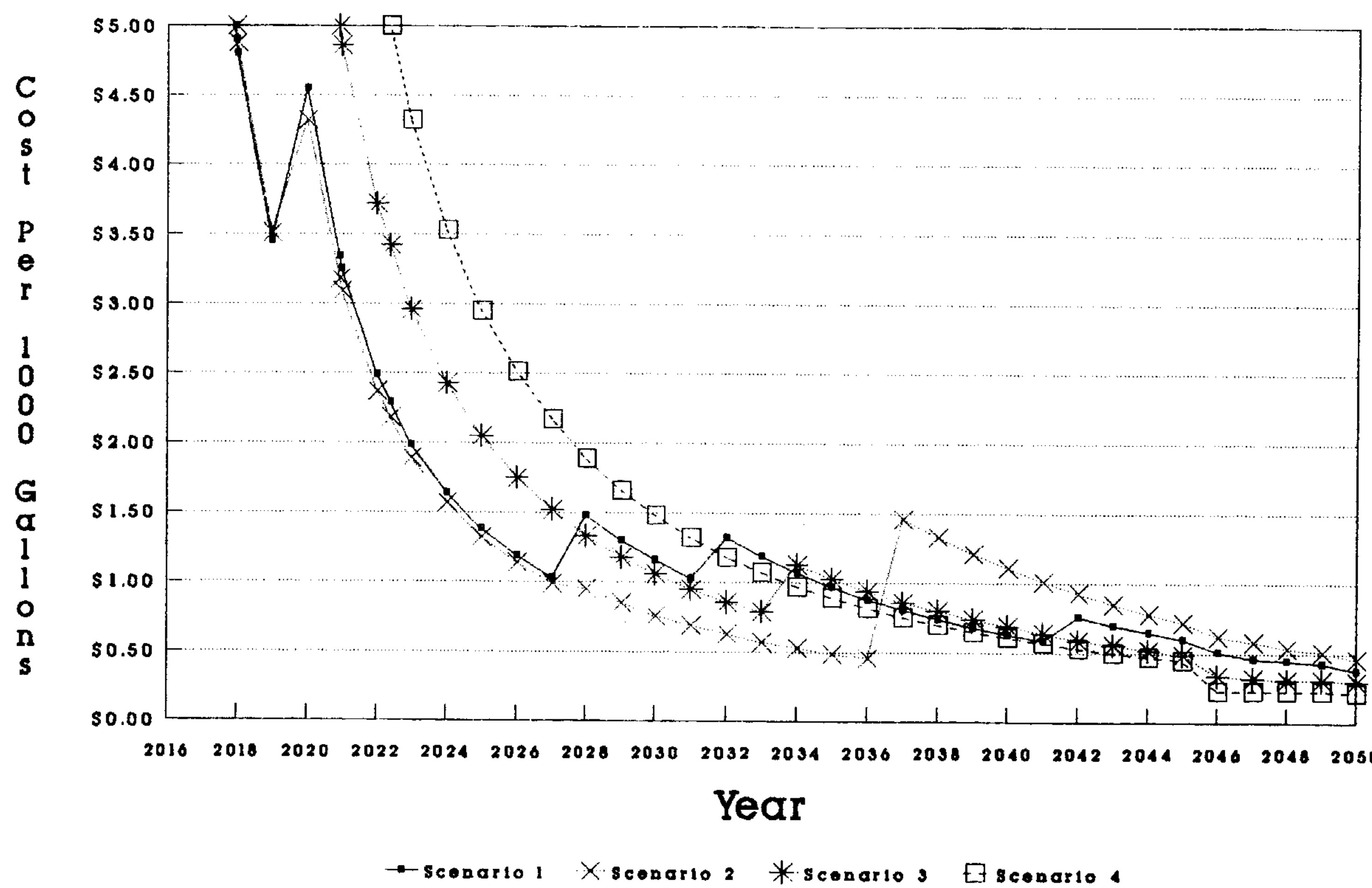

FIGURE I-1

Cumulative Cost Per Thousand Gallons Comparison of Four Scenarios

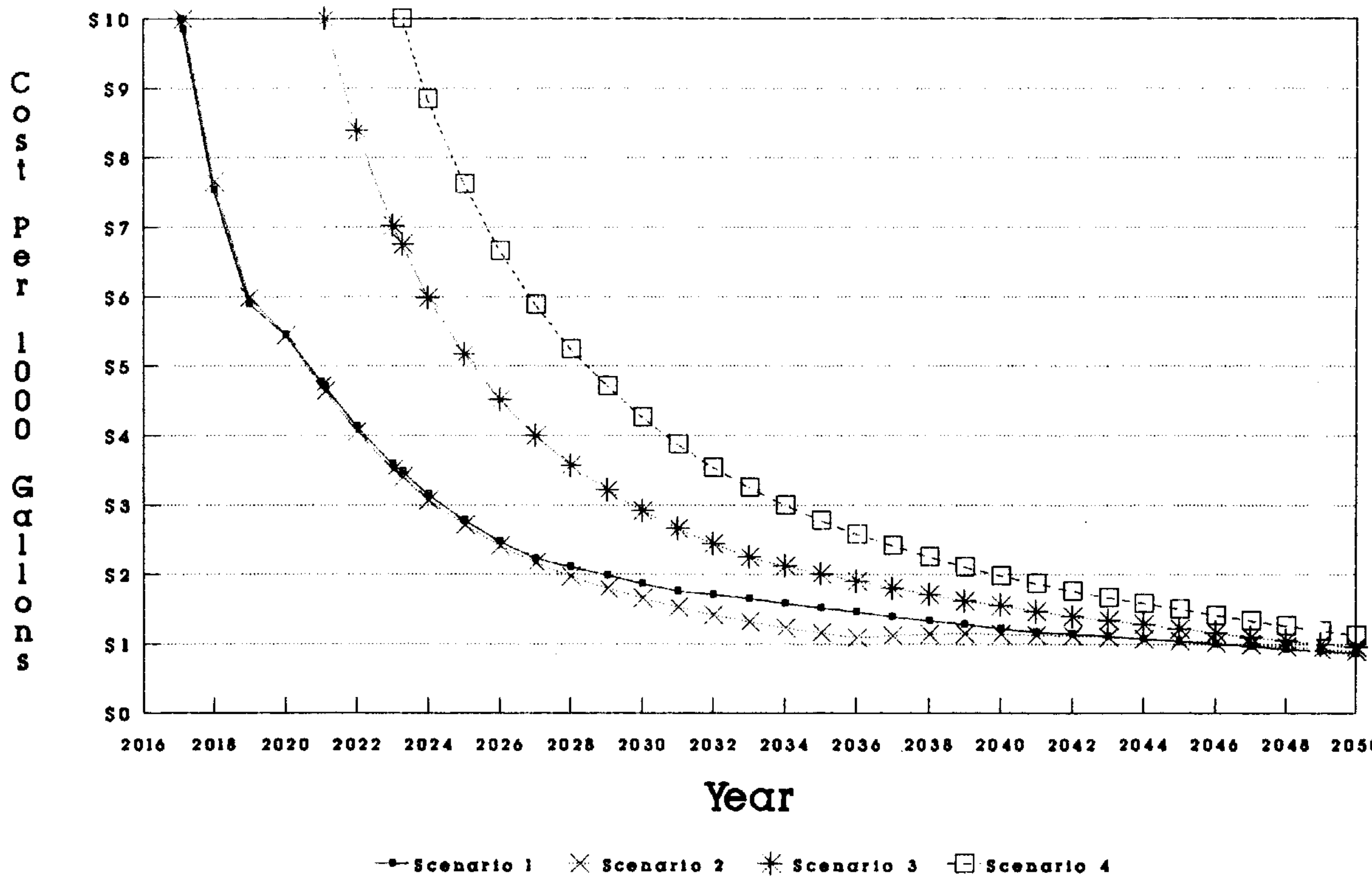

FIGURE I-2

Table I-42

Comparison of Present Value Costs for Scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Capital Cost	$693,148,000	$ 767,755,000	$ 702,613,000	$ 826,032,000
Total Costs, 2016-2050				
Debt Service	759,114,000	779,352,000	802,743,000	980,195,000
Operation & Maintenance	29,957,000	37,851,000	36,804,000	55,160,000
Power	180,078,000	187,831,000	231,111,000	225,741,000
Total	$967,954,000	$1,005,034,000	$1,070,658,000	$1,261,096,000
Unit Cost per 1,000 Gallons				
2016-2020	$5.45	$5.44	$12.59	$18.73
2020-2024	1.99	1.90	2.97	4.33
2025-2030	1.24	0.92	1.34	1.90
2031-2035	1.11	0.57	0.96	1.07
2036-2040	0.74	1.12	0.80	0.70
2041-2045	0.66	0.85	0.56	0.50
2046-2050	0.45	0.90	0.31	0.23
2016-2050	$0.87	$0.90	$0.96	$1.13

APPENDIX J

PRELIMINARY ANALYSIS

OF ENVIRONMENTAL FACTORS

APPENDIX J

PRELIMINARY ANALYSIS OF ENVIRONMENTAL FACTORS

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APPENDIX J

PRELIMINARY ANALYSIS OF ENVIRONMENTAL FACTORS

J-1 ENVIRONMENTAL CONSIDERATIONS

Environmental issues are increasingly important in evaluating the feasibility of new water supply projects, especially new reservoir and pipeline projects. Environmental groups may sustain long and costly opposition against projects which they perceive as having major environmental impacts. Existing federal and state permits include extensive environmental review and mitigation requirements. All of these factors should be addressed early in the project development process.

Environmental issues which are expected to be most important for water supply projects are the loss of terrestrial wildlife habitat, impacts on aquatic habitats, potential effects on endangered and threatened species, loss of prime farmland soils, impacts on public lands, and loss of cultural resources. Short-term construction impacts, such as the degradation of air quality and increased noise levels, will probably become additional issues, but are not expected to be significant concerns.

J-1.1 Wildlife Habitat

During the water rights permit review (and possibly again during the 404 permit process), the potential terrestrial habitat impacts and recommended mitigation requirements will be evaluated by an interagency team of biologists which may include representatives of the Tarrant County Water Control and Improvement District Number One (TCWCID No. 1), Texas

Water Commission (TWC), Texas Water Development Board (TWDB), U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (USFWS) and Texas Parks and Wildlife Department (TPWD). The project will be evaluated by use of models such as the Habitat Evaluation Procedure (HEP) or the Wildlife Habitat Appraisal Procedure (WHAP). These procedures are based on evaluations of existing vegetation cover in the project area and its relative value as habitat for selected species. Expected gains or losses in habitat value are estimated for future conditions with and without the proposed project. Under federal review, wildlife habitat impacts are assessed over the entire reservoir area, but only at the channel crossings of pipelines. In order to compensate for the project impacts, TCWCID No. 1 will be required to purchase and arrange management for a wildlife mitigation area. Because TWC and USACE are authorized to consider project benefits as offsetting some of the project impacts, the required percent compensation (which determines the size of the mitigation area) is usually less than one hundred percent. However, in previous reservoir projects, the permit required compensation has been as high as acre-for-acre replacement.

Of particular concern will be the loss of or impact on wetlands which are considered critically scarce habitats. Wetland impacts are already regulated by USACE. Recent trends indicate that in the near future these areas may become protected by more stringent laws requiring no net loss of wetlands. This would require development projects to either avoid impacts to wetlands or to replace impacted wetland acreage with reconstructed wetlands. Losses of bottomland hardwood forests will also come under close scrutiny. The U.S. Fish and Wildlife Service (1984) has already developed a Bottomland Hardwood Preservation Program which has identified priority areas for preservation in East Texas.

For any reservoir project, TCWCID No. 1 should coordinate with the resource agencies at an early date to begin documenting and evaluating the various habitats within a proposed reservoir area and for some distance upstream and downstream. This documentation should include an inventory of the number of acres which may be affected, as well as their relative habitat value. Also important are documentation of existing land use and forecast of future activities which are likely to change the area and/or value of the habitat within the reservoir boundaries.

Preliminary estimates of mitigation requirements should be made for the purpose of identifying candidate sites and determining their potential costs. When possible, early agreement and acquisition of mitigation land may save costs in the long-term. Early involvement with USACE at the water rights phase may avoid reopening the mitigation evaluation during the 404 process. However, it should be recognized that agreement on a mitigation proposal which satisfies the environmental agencies at a reasonable cost will require significant effort and time.

J-1.2 Aquatic Habitat

In addition to mitigation of terrestrial habitat impacts, TCWCID No. 1 will be required to provide mitigation for the aquatic habitat impacts of any new reservoir project. Again, these impacts will be evaluated by an interagency team of biologists through use of models such as the Instream Flow Incremental Methodology (IFIM), Aquatic Habitat Evaluation Procedure (Aquatic HEP) or TWDB's Hydraulic Field Survey and Macrohabitat Assessment Technique. Mitigation of aquatic impacts usually consists of required downstream releases, but may also include habitat improvements.

Fisheries resources in the vicinity of the proposed project should be surveyed to evaluate their ecological and recreational importance. From these data, a determination can be made of the minimum cost-effective flow to maintain the downstream fishery while protecting reservoir fish populations and maintaining an appropriate reservoir water level for water supply and recreational activities.

An issue related to reservoir fishery is the development of a reservoir clearing plan. This plan must balance the need to protect water quality, public safety, and the structural integrity of the reservoir outlet works and spillway with the need for maintaining vegetation within the reservoir to provide cover for reservoir fish.

In addition, the water quality of a proposed reservoir is commonly evaluated, not only for the impact on water users, but also for the potential quality of downstream releases. The reservoir is evaluated in terms of the existing concentrations of inorganic constituents such as chlorides, sulfates and dissolved solids and the potential concentration of these substances that may result when stream waters are impounded. In addition, data collected in the reservoir watershed are usually examined for the potential for high nutrient loading and resulting eutrophication conditions that may occur in the reservoir. Due to the common phenomenon of summer stratification and anaerobic hypolimnetic water, the project will be evaluated for potential low dissolved oxygen levels in the downstream releases. Low dissolved oxygen releases can usually be mitigated through use of a multi-port outlet structure and an appropriate reservoir operation plan.

The pipeline projects may generate concerns about potential impacts on a lake fishery by entrainment or impingement of fish through the intake structure or by the alteration of fish habitats through lake level fluctuations or changes in lake stratification. It will be important to address these impacts during the design phase of the project and to incorporate mitigation measures in the design and operation of the intake structure.

Interbasin transfer of organisms (i.e., non-native fish, fish pathogens, etc.) will also be a concern with all but the Trinity River diversion pipeline projects. Although innumerable interbasin projects have operated without major environmental impact, the issue remains sensitive and will likely be a concern to the reviewing agencies. TCWCID No. 1 will probably be required to address this issue in the permitting process.

J-1.3 Endangered and Threatened Species

If any of the federally listed endangered or threatened species (FWS, 1989a) or candidate species for listing are found to occur within a project

J-1.4 Prime Farmland Soils

The Farmland Protection Policy Act requires that federal agencies address the effects of a project on acreage of prime and unique farmland. The act requires consultation with the Soil Conservation Service to determine the significance of the lost farmland and whether an alternate project design might lessen the impact. The losses associated with most reservoir projects are likely to be substantial since many bottomland soils are classified as prime farmland. Since inundation of bottomland is inherent in any reservoir project, reservoirs cannot be redesigned to substantially reduce the number of farmland acres affected. In most cases, the losses associated with pipeline projects should be minimal due to the narrow right-of-way and the capability to readjust the routes.

J-1.5 Public Lands and Recreation Areas

Any water supply project will be scrutinized for potential effects on public lands and particularly on public recreation areas. Depending on the extent of impact, TCWCID No. 1 may be required to demonstrate that there is no prudent or feasible alternative to the taking of public lands. In addition, the District may be required to purchase replacement lands and to transfer these properties in fee title to the appropriate public agency. Condemnation of public lands or recreation areas may also create additional opposition to a project from various public-interest groups.

J-1.6 Cultural Resources

To comply with the various archeological and antiquities regulations, all project lands must be surveyed in detail to identify potentially important archeological and historical remains. This would include geomorphology, historical background, preliminary oral interviews, shovel testing and report preparation. The survey would identify those sites which may be potentially eligible for the National Register of Historical Places. A testing and evaluation phase would then be conducted to determine actual eligibility. Finally, those sites which are determined to be eligible must be protected or mitigated prior to the construction of a dam or pipeline or by inundation of a reservoir. Typically, mitigation consists of detailed excavation and recovery of material from the site.

Although it is not expected that cultural resources would preclude construction of any of the alternative projects, the number and significance of archeological sites can increase the time and cost of mitigation.

J-2 PRELIMINARY ENVIRONMENTAL ANALYSIS OF THE ALTERNATIVES

J-2.1 New Reservoir Projects

Reservoir development results in two kinds of environmental impacts, those which are common to all reservoirs and those which are specific to the project site. Typical issues facing all new reservoirs include inundation of wildlife habitats, changes in flow and fish populations within the stream above and below the new dam, effects on water quality, and inundation of archeological and historical sites which may be within the new reservoir. Examples of site specific controversial issues may include adverse effects on an endangered species or inundation of an existing recreation area. It is important that project planning minimize all such impacts and include appropriate mitigation measures where possible.

Tehuacana Reservoir

The proposed Tehuacana dam site is located a short distance south of the existing Richland Creek Reservoir dam at mile 7.3 on Tehuacana Creek. At elevation 315.0 feet msl, the Tehuacana Reservoir conservation pool would inundate approximately 14,938 surface acres in Freestone County and approximately 23.2 miles of Tehuacana Creek. The flood pool would inundate approximately 19,619 surface acres and 25.2 river miles at elevation 320.3 msl. Tehuacana Reservoir would be operated in conjunction with Richland Creek Reservoir and pipeline by construction of a 9,000-foot interconnecting channel (Freese and Nichols, 1979).

Tehuacana Reservoir would result in a loss of approximately 14,938 acres of wildlife habitat, including extensive areas of water oak-elm-hackberry forest and post oak woods, forest and grassland mosaic (Frye, et al., 1984). According to Texas Parks and Wildlife Department, the reservoir site contains 6,993 acres of mixed bottomland hardwood forest, 5,491 acres of mixed post oak forest and 2,320 acres of other categories of cover (Frye and Curtis, 1987). Based on TPWD statewide estimates (Frye and Curtis, 1987), losses of bottomland hardwood forest from the Tehuacana project represent 2.3 percent of the total bottomland hardwood acreage in the Trinity River system and 0.12 percent of the statewide total of 5,973,000 acres. None of the bottomlands in the project area have been identified for priority status in the Texas Bottomland Hardwood Preservation Program (FWS, 1984).

Since neither the U.S. Army Corps of Engineers (USACE) nor the Texas Water Commission (TWC) has yet required greater than acre-for-acre compensation, it is unlikely that the Tehuacana project would require more than 14,938 acres in mitigation. A likely worst case scenario might involve acre-for-acre replacement of approximately 15,000 acres including 7,000 acres of bottomland habitat.

U.S. Fish and Wildlife Service (1989b) lists the bald eagle as the only federally endangered or threatened species for Freestone County. Texas Parks and Wildlife Department (1989) lists nine additional federal and/or state endangered and threatened species, occurring or potentially occurring in the county. Of these species, only the bald eagle, timber rattlesnake and Texas horned lizard are known to occur in Freestone County. Impacts from the construction of Tehuacana Reservoir would be considered insignificant to any of the listed species.

The Texas Natural Heritage Program (TPWD, 1989) lists one plant and two plant communities as elements of concern occurring in Freestone County. These elements are not currently protected by law, but could become state or federally listed in the future, depending on further biological research or depletion of the resource. In addition to listing rare plants, animals and plant communities, the Natural Heritage Program also tracts examples of native Texas communities which are not necessarily rare or imperiled. The Brazos mint (Brazoria pulcherrima) is a former federal category 2 candidate species, but was rejected for listing because it is more common than previously thought; however, it is still considered rare in the state. The mint is known from a locality approximately 17 miles southeast of the Tehuacana Reservoir site. Although the localities of the plant communities are listed as occurring outside of the project area, it is likely that these elements also occur within the reservoir site because of their broad range of occurrence. Both the Post Oak-Blackjack Oak Series and Sugarberry-Elm Series are common and widely occurring plant communities. They are not imperiled, as indicated by their respective conservation rankings of "secure" and "apparently secure." Losses of areas of these two communities would be considered insignificant to the representation of the series statewide.

Energy resources in the project site include natural gas, oil and lignite (Kier, et al., 1977; Ohl and McBride, 1987). The Stewards Mill Oil Field, located in the vicinity of Cottonwood Creek, primarily produces natural gas. For the purpose of this report, it is assumed that oil and gas wells and rights will be purchased and production discontinued if the reservoir is built. Based on exploratory boring information obtained by the U.S. Army Corps of Engineers, there appear to be extensive deposits of commercially minable lignite in the Cottonwood Creek area. The planned reservoir would cover a portion of this lignite. For the purpose of this report, it is assumed that rights to the lignite will be purchased if the reservoir is built.

Other mineral resources in the reservoir site are limited to sand, gravel and industrial clays which are not currently mined in the project area (Kier, et al., 1977; Ohl and McBride, 1987).

Although a listing of prime and unique farmland soils is available for Freestone County (SCS, 1982), modern soil survey maps have never been published. Based on the large amount of forested habitat, the reservoir site is not expected to contain a significant amount of prime farmland.

A preliminary estimate indicates that the project will displace three houses and require relocation of the Harp and Greenbriar cemeteries and partial relocation of the Old Anglan cemetery. The project will inundate approximately four miles of federal, state and county roads, including portions of I-45, US 75, SH 80, SH 416, SH 833 and FM 2547. Approximately one mile of the Burlington Railroad tracks will also be affected. In addition, the reservoir site is crossed by at least eight underground pipelines (gas and crude) and two powerlines. No towns or public lands occur within the reservoir pool.

The area of the proposed reservoir has not been systematically surveyed for cultural resources, but physiographic and other conditions suggest a high probability of historic and prehistoric cultural materials occurring in the area. An archival search at the Texas Archeological Research laboratory (TARL) was conducted to determine the extent of known cultural resources. Although only four sites are recorded from within the Tehuacana Reservoir site, the survey conducted for the nearby Richland Creek Reservoir resulted in extensive findings. It is expected that similar sites occur in the Tehuacana area.

George Parkhouse I Reservoir and Pipeline

The proposed George Parkhouse I site would be located at river mile 3.0 on the South Sulphur River. At elevation 401.0 feet msl, the conservation pool would inundate approximately 27,970 surface acres and 20.3 river miles in Delta and Hopkins Counties. At the flood pool elevation of 411.0 feet msl, the reservoir would inundate approximately 35,100 surface acres, but no additional river miles (due to the Cooper Reservoir dam, now under construction). The project would also require construction of approximately 112 miles of pipeline to convey water to a site in Tarrant County. George Parkhouse I Reservoir has been designed as a paired reservoir with George Parkhouse II Reservoir on the North Sulphur River. The George Parkhouse II dam would be a continuation of the George Parkhouse I dam. As a stand-alone project, George Parkhouse I Reservoir would require the construction of a 3,000-foot dike between the South and North Sulphur River watersheds.

Construction of George Parkhouse I Reservoir would result in a loss of approximately 27,970 acres of wildlife habitat, including extensive areas of post oak woods, forest and grassland mosaic; water oak-elm-hackberry woods; crops; and native or introduced grass (Frye, et al., 1984). The pipeline construction would result in the loss of approximately 1,754 additional acres of wildlife habitat in a 130-foot right-of-way across Hopkins, Hunt, Collin, Denton, Dallas and Tarrant Counties. According to Texas Parks and Wildlife Department, the reservoir site contains 10,690 acres of mixed bottomland hardwood forest, 4,553 acres of crops, 8,204 acres of grasses and 4,525 acres of other categories of cover (Frye and Curtis, 1987). Based on TPWD statewide estimates (Frye and Curtis, 1987), losses of bottomland hardwood forest from the George Parkhouse I project represent 6.1 percent of the total bottomland hardwood acreage in the Sulphur River system and 0.18 percent of the statewide total. None of the bottomlands in the project area have been identified for priority status in the Texas Bottomland Hardwood Preservation program (FWS, 1984).

Based on previously permitted projects, it is unlikely that the project would require more than 38,557 acres for mitigation. A likely worst case scenario might involve acre-for-acre replacement of approximately 30,000 acres (for the conservation pool and pipeline) including 11,000 acres of bottomland habitat.

U.S. Fish and Wildlife Service (1989b) has no listings of endangered or threatened species for Delta or Hopkins Counties. Texas Parks and Wildlife Department (1989) lists 15 additional federal and/or state endangered or threatened species occurring or potentially occurring in the two counties. Of these species, only the bald eagle, alligator snapping turtle, Texas horned lizard and creek chubsucker have ever been recorded from the two-county area. It should be noted that the bald eagle is a federally protected species. The turtle and lizard are both federal category 2 candidate species for listing as endangered or threatened depending on further biological study or future depletion of the resource. Several additional species are listed by USFWS and/or TPWD for the counties along the pipeline route. It is unlikely that a pipeline project would affect endangered or threatened species. Due to the narrow right-of-way, it should be possible to readjust the pipeline route should any significant impacts be identified.

The Texas Natural Heritage Program (TPWD, 1989) lists three plant communities in the project vicinity as elements of concern to their program. These elements are not currently protected by law, but could become state or federally protected in the future. A locality of the Sugarberry-Elm Series is listed from an area within the Cooper Reservoir site. This plant community is common and could also occur in the George Parkhouse I site. It is not imperiled, as indicated by its conservation ranking of "apparently secure." The Silveanus Dropseed Series is listed as occurring in Hopkins County approximately 3.5 miles from the proposed pipeline route. The plant community has a conservation ranking of "threatened." It is possible, but unlikely, that other locations of the series could occur along the pipeline. The Little Bluestem-Indiangrass Series is also listed as occurring in the vicinity of the pipeline in Collin County approximately six miles from the proposed route. This community has a conservation ranking of "endangered". Again, it is possible, but unlikely, that other locations of the series could occur along the pipeline. If an exemplary area of this or other plant communities did occur, the pipeline route could be readjusted to avoid the community.

Although the location of the outfall structure has yet to be determined, the project will involve an interbasin transfer from the Sulphur River watershed to the Trinity River watershed. USACE has already developed plans involving interbasin transfer between the two systems for the Cooper Reservoir project which includes a pipeline to Lake Lavon on the East Fork Trinity River. In addition, the Sulphur River is a tributary of the Red River and USACE has already set a precedent for interbasin transfer between these two systems by permitting the North Texas Municipal Water District's Lake Texoma diversion project to Sister Grove Creek and, ultimately, to Lake Lavon on the East Fork Trinity River.

There are no known energy resources occurring in the reservoir site or along the pipeline route (Kier, et al., 1977).

There are no known mineral resources occurring in the reservoir site; however, the pipeline route crosses areas of chalk deposits in Collin, Denton and Dallas Counties and an area of gypsum quarries in Dallas and

Tarrant Counties (Kier, et al., 1977; Ohl and McBride, 1987). Extensive sand and gravel operations also occur in the vicinity of the Denton Creek and Elm Fork Trinity River crossings. The pipeline would have an insignificant impact on these mineral resources.

Although the Texas Parks and Wildlife cover type estimates include 4,553 acres of cropland and 8,204 acres of pastureland (native and introduced grasses), the majority of this area is not classified as prime or unique farmland soil (SCS, 1977; 1979; 1982).

A preliminary estimate indicates that the project will displace 35 houses and one church, and require relocation of Kensington Cemetery and an isolated grave site. (This estimate assumes that the George Parkhouse I pipeline can be routed to avoid any displacements or relocations). The project will inundate approximately seven miles of state and county roads, including SH 19, SH 69, SH 154, SH 895, FM 1529 and FM 1536. The pipeline will require at least 28 additional major road crossings, including US 75/I-35E, I-635, SH 121 and SH 114 in the vicinity of Dallas-Fort Worth. The reservoir is crossed by at least one underground pipeline (approximately 2 miles in length). In addition, the George Parkhouse I pipeline will cross at least eight railroads, eight underground pipelines, nine powerlines and 40 major creeks.

Although the pipeline will be planned to minimize conflicts, it is currently routed through the corporate boundaries of a number of communities in the Dallas-Fort Worth area.

Acquisition of the reservoir site would require taking a portion of public lands from the U.S. Army Corps of Engineers' Cooper Reservoir project (USACE, 1977; 1989). The George Parkhouse I Reservoir site includes an estimated 1,200 acres of the Cooper Reservoir wildlife management area located between the Cooper dam site and SH 19/154. Included in this acreage is the Cooper Reservoir outlet works (under construction). The George Parkhouse I pipeline route also crosses approximately 2,200 feet of public lands at USACE's Lake Lavon project. This crossing would require acquisition of approximately seven acres of public lands. Acquisition of these areas would require at least replacement compensation for the loss of Cooper Reservoir mitigation land and any improvements that may have been made on it.

The area of the proposed reservoir has not been systematically surveyed for cultural resources, but physiographic and other conditions suggest a high probability of historic and prehistoric cultural materials occurring in the area. An archival search at the Texas Archeological Research laboratory (TARL) was conducted to determine the extent of known cultural resources. The six recorded sites within the George Parkhouse I Reservoir site include two older excavations (at Old Chapman Farm and the Bert Davis/Jess Alford site) and four sites discovered during the survey of the Cooper Reservoir dam embankment area (Geomarine, 1988; Perttula, 1988). The completed Cooper Reservoir surveys have resulted in extensive findings (Hyatt and Doehner, 1973; Doehner and Larson, 1975; 1978; Doehner, et al., 1978; Bousman, et al., 1988; Geomarine, 1988; Lebo, 1988; McGregor, et al., 1988; Pettula, 1988; Moir, et al., 1988). The additional surveys planned for the Cooper downstream flowage easement could result in additional discoveries within the George Parkhouse I site. In the vicinity of the pipeline route, sites are recorded from cultural resources investigations at Cooper Reservoir, Lake Lavon, Lake Lewisville and Denton Creek.

George Parkhouse II Reservoir

The proposed George Parkhouse II dam site is located at river mile 5.0 on the North Sulphur River just north of the George Parkhouse I dam site. At the conservation pool level of 401.0 feet msl, the reservoir would be continuous with George Parkhouse I Reservoir. Construction and filling of George Parkhouse II Reservoir would inundate 11,018 acres and 15.5 river miles in Delta and Lamar Counties. At the flood pool elevation of 411.0 feet msl, the reservoir would inundate 15,600 surface acres and 17.8 river miles.

George Parkhouse II Reservoir would result in a loss of approximately 11,018 acres of wildlife habitat, including post oak woods, forest and grassland mosaic and cropland (Frye et al., 1984). According to Texas Parks and Wildlife Department, the reservoir site contains 1,865 acres of mixed bottomland hardwood forest, 4,120 acres of grasses, 3,057 acres of cropland and 1,976 acres of other categories of cover (Frye and Curtis, 1987). Based on TPWD statewide estimates (Frye and Curtis, 1987), losses of bottomland hardwood forest from the George Parkhouse II project represent 1.1 percent of the total bottomland hardwood acreage in the Sulphur River system and 0.03 percent of the statewide total. None of the bottomlands in the project area have been identified for priority status in the Texas Bottomland Hardwood Preservation Program (FWS, 1984).

Based on previously permitted projects, it is likely that a worst case scenario would involve acre-for-acre replacement of approximately 11,000 acres in mitigation, including 2,000 acres of bottomland habitat.

U.S. Fish and Wildlife Service (1989b) lists the bald eagle as the only federally endangered or threatened species for Delta or Lamar County. Texas Parks and Wildlife lists 13 additional federal and/or state endangered and threatened species occurring or potentially occurring in the two counties. Of these species, only the bald eagle, interior least tern, paddlefish, Texas horned lizard, timber rattlesnake and blue sucker have been recorded from the two-county area. It is unlikely that the project would significantly impact populations or habitats of these species. Although wintering populations of the bald eagle, a federally protected species, are recorded from Lamar County, the species is not known to breed in the area. The interior least tern, another federally protected species, migrates across the eastern two-thirds of Texas; however, it is not known to nest in the two-county area. Both the paddlefish and blue sucker are recorded from the Red River in Lamar County; there are no records of the species from the Sulphur River. The Texas horned lizard, a federal category 2 candidate species, occurs throughout a broad range in Texas and adjoining states. The decline in populations of the species is suspected to be related more to the use of pesticides and intensive agriculture than loss of critical habitat. The timber rattlesnake is also a widely distributed species. It occurs across the eastern third of Texas in a variety of habitats including bottomlands, uplands and urban areas (Tennant, 1984).

The Texas Natural Heritage Program has no elements of concern listed in the vicinity of the George Parkhouse II Reservoir site (TPWD, 1989).

There are no known energy resources or mineral resources occurring in the reservoir site (Kier, et al., 1977).

The majority of the soils in the reservoir site are classified as prime or unique farmland soil (SCS, 1979; 1982). Based on the Texas Parks and Wildlife Department cover type estimates, the reservoir contains 3,057 acres of cropland and 4,120 acres of pastureland (native or introduced grasses).

A preliminary estimate indicates that the project will displace 15 houses and one church, and require relocation of the Union cemetery. The project will inundate approximately two miles of state and county roads, including portions of SH 19/24, FM 1184 and FM 1498. No towns or public lands occur within the reservoir site.

The area of the proposed reservoir has not been systematically surveyed for cultural resources, but physiographic and other conditions suggest a high probability of historic cultural materials occurring in the area. An archival search at the Texas Archeological Research laboratory (TARL) was conducted to determine the extent of known cultural resources. Although only five sites are recorded within the George Parkhouse II Reservoir site, the surveys conducted for the nearby Cooper Reservoir resulted in extensive findings (Perttula, 1988). It is expected that similar sites occur in the George Parkhouse II area.

Marvin Nichols I Reservoir and Pipeline

The proposed Marvin Nichols I Reservoir dam site is located at river mile 114.7 on the Sulphur River. At elevation 312.0 feet msl, the conservation pool would inundate approximately 66,521 surface acres and 57.5 river miles in Bowie, Red River, Morris, Titus and Franklin Counties. The flood pool would inundate approximately 84,500 surface acres and 63.7 river miles at elevation 322.0 feet msl. The project would also require construction of approximately 130 miles of pipeline to convey water to a site in Tarrant County. Marvin Nichols I Reservoir has been designed as a paired reservoir with Marvin Nichols II Reservoir on White Oak Creek. The Marvin Nichols II dam would be a continuation of the Marvin Nichols I dam. As a stand-alone project, Marvin Nichols I Reservoir would require the additional construction of a 3.5-mile dike between the Sulphur River and White Oak Creek watersheds.

Construction of Marvin Nichols I Reservoir would result in a loss of approximately 66,521 acres of wildlife habitat, including extensive areas of post oak woods, forest and grassland mosaic; post oak woods/forest; water oak-elm-hackberry forest; and native or introduced grasses (Frye, et al., 1984). The pipeline construction would result in the loss of approximately 2,038 additional acres of wildlife habitat in a 130-foot right-of-way across Titus, Franklin, Hopkins, Hunt, Collin, Denton, Dallas and Tarrant Counties. According to Texas Parks and Wildlife Department, the reservoir site contains 30,041 acres of mixed bottomland hardwood forest, 15,469 acres of mixed post oak forest, 12,723 acres of grasses and 8,288 acres of other categories of cover (Frye and Curtis, 1987). Based on TPWD statewide estimates (Frye and Curtis, 1987), losses of bottomland hardwood forest from the Marvin Nichols I project represent 17.2 percent of the total bottomland hardwood acreage in the Sulphur River system and 0.50 percent of the statewide total.

A large portion of the bottomlands in the reservoir site have been preliminarily listed with Priority 1 status in the Texas Bottomland Hardwood Preservation Program (FWS, 1984). It is estimated that the conservation pool would inundate approximately 19,000 acres of the Sulphur River Bottoms West site. This area has been identified as having high value for wintering waterfowl, medium to high value for waterfowl production, value to wintering bald eagles and medium to high value for other special recognition species.

Since neither USACE nor TWC has yet required greater than acre-for-acre compensation, it is unlikely that the project would require more than 66,521 acres in mitigation. A likely worst case scenario might involve acre-for-acre replacement of approximately 69,000 acres (for the conservation pool and pipeline), including 30,000 acres of bottomland habitat.

U.S. Fish and Wildlife Service (1989b) lists the bald eagle and red-cockaded woodpecker as the only federally endangered or threatened species occurring in Bowie, Franklin, Morris, Red River or Titus Counties. Texas Parks and Wildlife Department (1989) lists 21 additional federal and/or state endangered and threatened species occurring or potentially occurring in the counties. Of these species, 13 have been sighted in the five-county area. Several additional species are listed by USFWS and/or TPWD for the counties along the pipeline route. It is unlikely that a pipeline project would affect populations of endangered or threatened species. Due to the narrow right-of-way, it should be possible to adjust the pipeline route to avoid significant impacts.

The Texas Natural Heritage Program (TPWD, 1989) lists one plant and three plant communities as elements of concern occurring in the project vicinity. These elements are not currently protected by law, but could become state or federally protected in the future, depending on further biological study or further depletion of the resource. Houston meadow-rue (Thalictrum texanum) was collected in 1948 from a locality within the Marvin Nichols I conservation pool. This species is a federal category 2 candidate for listing as endangered or threatened upon further biological research. It has been noted that this particular collection is within the range of Thalictrum arkansanum and since the specimen is only vegetative, it may be misidentified (TPWD, 1989). A locality of the Sugarberry-Elm Series was listed from the area within the Cooper Reservoir site. This plant community is widely occurring and likely occurs within the Marvin Nichols I site. However, it is not imperiled, as indicated by its conservation ranking of "apparently secure". The Silveanus Dropseed Series is listed as occurring in Hopkins County approximately 3.5 miles from the proposed pipeline route. The plant community has a conservation ranking of "threatened". It is possible, but unlikely, that other locations of the series could occur along the pipeline. The Little Bluestem-Indiangrass Series is also listed as occurring in the vicinity of the pipeline in Collin County approximately six miles from the proposed route. This community has a conservation ranking of "endangered". Again, it is possible, but unlikely, that other locations of the series could occur along the pipeline. If an exemplary area of these or other plant communities did occur, the pipeline could be routed to avoid the community.

Although the location of the outfall structure has yet to be determined, the project will involve an interbasin transfer from the Sulphur River watershed to the Trinity River watershed. USACE has already developed plans involving interbasin transfer between the two systems for the Cooper Reservoir project which includes a pipeline to Lake Lavon on the East Fork Trinity River. In addition, the Sulphur River is a tributary of the Red River and USACE has set a precedent for interbasin transfer between these two systems by permitting the North Texas Municipal Water District's Lake Texoma diversion project to Sister Grove Creek and, ultimately, to Lake Lavon on the East Fork Trinity River.

Energy resources in the project area are limited to oil production (Kier, et al., 1977) in the area of the Trix-Liz Oil Field northwest of Wilkinson. For the purpose of this report, it is assumed that the oil wells and rights would be purchased if the reservoir is built. It should be noted that the proposed location of the Marvin Nichols I dam has been redesigned to avoid extensive lignite deposits east of the reservoir site.

No additional energy resources are known to occur along the pipeline route.

No other mineral resources are known to occur in the reservoir site (Kier, et al., 1977; Ohl and McBride, 1987; Bureau of Economic Geology, 1977; 1985). The pipeline route crosses areas of chalk deposits in Collin, Denton and Dallas Counties and an area of gypsum quarries in Dallas and Tarrant Counties. Extensive sand and gravel operations also occur in the vicinity of the Denton Creek and Elm Fork Trinity River crossings. The pipeline would have an insignificant impact on these mineral resources.

Although listings of prime and unique farmland soils are available for Bowie, Red River, Morris, Titus and Franklin Counties (SCS, 1982), modern soil survey maps have been published for only Bowie and Red River Counties (SCS, 1977; 1980). From the available surveys, it appears that that site contains a very small percentage of prime farmland soils. The Texas Parks and Wildlife cover type estimates include 12,723 acres of pasture land, but no cropland acreage.

A preliminary estimate indicates that the project will displace 27 houses and one church and require relocation of Cedar Creek Cemetery, Evergreen Cemetery near Pewitt Ranch, Evergreen Cemetery near Turner Lake and an unnamed cemetery near Flat Creek. (These estimates assume that the pipeline can be routed to avoid any displacements or relocations.) The project will inundate approximately six miles of federal, state, and county roads, including portions of US 271, SH 37, SH 44 and SH 412. The pipeline will cross at least 34 additional major roads, including US 75/I-35E, I-635, SH 121 and SH 114 in the vicinity of Dallas-Fort Worth. The reservoir site is crossed by at least two underground pipelines (approximately nine miles total length), one powerline (approximately two miles in length) and an aqueduct (approximately 3 miles in length). In addition, the pipeline will cross at least eight railroads, 12 underground pipelines, eight powerlines and 43 major creeks.

Although the pipeline will be planned to minimize conflicts, it is currently routed through the corporate boundaries of a number of communities in the Dallas-Fort Worth area.

The pipeline route also crosses approximately 2,200 feet of project lands at the U.S. Army Corps of Engineers' Lake Lavon. This would require acquisition of approximately seven acres of public lands which could involve replacement compensation.

The area of the proposed reservoir has been partially surveyed for cultural resources. An archival search at the Texas Archeological Research Laboratory was conducted to determine the extent of known cultural resources. Currently, 78 sites are recorded from within the Marvin Nichols I Reservoir area. Many of these sites were discovered during cultural resources investigations for the central Sulphur River Basin, Harts Bluff and Angelina Farms levee construction projects (ETSU, 1971; Heartfield, Price and Greene, 1982a; 1982B). It is expected that additional undiscovered sites remain in the Marvin Nichols I area. In the vicinity of the pipeline route, sites are recorded from cultural resources investigations near Hagansport and at Cooper Reservoir, Lake Lavon, Lake Lewisville and Denton Creek.

Marvin Nichols II Reservoir

The proposed Marvin Nichols II dam site is located at river mile 19.2 on White Oak Creek, just south of the Marvin Nichols I dam site. At the conservation pool level of 312.0 feet msl, the reservoir would be continuous with Marvin Nichols I Reservoir. Construction and filling of Marvin Nichols II Reservoir would add 35,919 surface acres to the Marvin Nichols I conservation pool, and inundate 47.2 river miles. The reservoir would add 46,200 surface acres to the Marvin Nichols I flood pool in Morris, Titus and Franklin Counties.

Marvin Nichols II Reservoir would result in a loss of approximately 36,000 acres of wildlife habitat, including an estimated 20,000 acres of water oak-elm hackberry forest; 4,000 acres of pine hardwood forest; 1500 acres of post oak woods/forest; 2,000 acres of post oak woods, forest and grassland mosaic, and 8,500 acres of native or introduced grasses. Based on TPWD statewide estimates (Frye and Curtis, 1987), losses of bottomland hardwood forest from the Marvin Nichols II project represent 11.4 percent of the total bottomland hardwood acreage in the Sulphur River system and 0.33 percent of the statewide total.

All of the bottomlands in the reservoir site (approximately 20,000 acres) have been preliminarily listed with Priority 1 status in the Texas Bottomland Hardwood Preservation Program (FWS, 1984). The bottomlands are included as part of the Sulphur River Bottoms West site which also occurs within the Marvin Nichols I Reservoir site. These areas have been identified as having high value for key waterfowl species, wintering bald eagles and other special recognition species, including white-tailed deer, squirrels, furbearers, turkey, and other migratory birds.

Assuming a worst case scenario of acre-for-acre replacement of habitat losses, mitigation of terrestrial wildlife impacts would require approximately 36,000 acres including 20,000 acres of bottomland habitat.

U.S. Fish and Wildlife Service (1989b) lists the bald eagle as the only federally endangered or threatened species for Morris, Titus and Franklin Counties. Texas Parks and Wildlife Department (1989) lists 18 additional federal and/or state endangered and threatened species occurring or potentially occurring in the three counties. Of these species only seven have been sighted in the three-county area: the black bear, bald eagle, wood stork, Texas horned lizard, alligator snapping turtle, creek chubsucker and blackside darter.

The Texas Natural Heritage Program (TPWD, 1989) lists one element of concern, a plant community, as occurring in the project vicinity. The Water Oak-Willow Oak Series is listed from a locality within the Marvin Nichols II conservation pool. The series is common throughout the river bottom areas of East Texas. It is not imperiled, as indicated by a conservation ranking of "apparently secure".

The only known energy resource in the reservoir site is oil (Kier, et al., 1977). Two major oil fields, the Pewitt Ranch Oil Field and the Talco Oil Field, occur within the site. A large oil refinery, located near Talco, occurs within the flood pool. As with other projects, it is assumed that oil wells and rights would be purchased if the reservoir is built.

II Reservoir area. These sites were discovered during various cultural resources investigations.

Tennessee Colony Reservoir

The proposed Tennessee Colony dam site is located at river mile 341.7 on the Trinity River. At elevation 265.0 feet msl, the conservation pool would inundate approximately 68,100 surface acres and 73 river miles in Anderson, Freestone, Henderson and Navarro Counties. The flood pool elevation of 291.0 feet msl, as proposed by the U.S. Army Corps of Engineers, would inundate 114,400 surface acres and 103 river miles. Since the flood storage features of the USACE design would not be incorporated in a water supply reservoir project, the Tennessee Colony site would be redesigned with a significantly smaller flood pool.

Construction of Tennessee Colony Reservoir would result in a loss of approximately 68,100 acres of wildlife habitat, including extensive areas of post oak - black hickory forest; mesquite-elm/mesquite woods; elm-hackberry forest; water oak-elm/pecan-elm/willow-oak-blackgum forest; riparian and wetland habitats; grasses; and cultivated fields (USACE, 1979). According to Texas Parks and Wildlife Department, the reservoir contains 34,767 acres of mixed bottomland hardwood forest, 19,143 acres of post oak-water oak-elm forest, 9,600 acres of grasses and 21,543 acres of other categories of cover (Frye and Curtis, 1987). Based on TPWD statewide estimates (Frye and Curtis, 1987), losses of bottomland hardwood forest from the Tennessee Colony project represent 6.3 percent of the total bottomland hardwood acreage in the Trinity River system and 0.32 percent of

No other known mineral resources occur in the reservoir area (Kier, et al., 1977; Ohl and McBride, 1987).

Although listings of prime and unique farmland soils are available for Morris, Titus and Franklin Counties (SCS, 1982), modern soil survey maps have never been published. Texas Parks and Wildlife Department (Frye, et al., 1984) has mapped approximately 8,500 acres of native or introduced grasses within the site; no cropland is shown to occur in the area.

A preliminary estimate indicates that the reservoir will inundate approximately 76 houses and 14 miles of federal, state and county roads, including portions of US 271, SH 37, SH 71, FM 1402 and FM 2152. In addition, the reservoir is crossed by at least two underground pipelines (approximately 12 miles in total length).

Acquisition of the reservoir site would require a portion of public lands from the U.S. Army Corps of Engineers' Cooper Reservoir project. The Marvin Nichols II Reservoir site includes an estimated 2,500 acres of the White Oak Creek Mitigation Area. (It should be noted that the mitigation area corresponds to portions of the Sulphur River Bottom West Bottomland Hardwoods site.) Acquisition of this area would require at least replacement compensation for the loss of Cooper Reservoir mitigation land and any existing improvements.

The area of the proposed reservoir has been partially surveyed for cultural resources. An archival search at the Texas Archeological Research laboratory was conducted to determine the extent of known cultural resources. Currently, 39 sites are recorded from within the Marvin Nichols

II Reservoir area. These sites were discovered during various cultural resources investigations.

Tennessee Colony Reservoir

The proposed Tennessee Colony dam site is located at river mile 341.7 on the Trinity River. At elevation 265.0 feet msl, the conservation pool would inundate approximately 68,100 surface acres and 73 river miles in Anderson, Freestone, Henderson and Navarro Counties. The flood pool elevation of 291.0 feet msl, as proposed by the U.S. Army Corps of Engineers, would inundate 114,400 surface acres and 103 river miles. Since the flood storage features of the USACE design would not be incorporated in a water supply reservoir project, the Tennessee Colony site would be redesigned with a significantly smaller flood pool.

Construction of Tennessee Colony Reservoir would result in a loss of approximately 68,100 acres of wildlife habitat, including extensive areas of post oak - black hickory forest; mesquite-elm/mesquite woods; elm-hackberry forest; water oak-elm/pecan-elm/willow-oak-blackgum forest; riparian and wetland habitats; grasses; and cultivated fields (USACE, 1979). According to Texas Parks and Wildlife Department, the reservoir contains 34,767 acres of mixed bottomland hardwood forest, 19,143 acres of post oak-water oak-elm forest, 9,600 acres of grasses and 21,543 acres of other categories of cover (Frye and Curtis, 1987). Based on TPWD statewide estimates (Frye and Curtis, 1987), losses of bottomland hardwood forest from the Tennessee Colony project represent 6.3 percent of the total bottomland hardwood acreage in the Trinity River system and 0.32 percent of the statewide total of 5,973,000 acres.

A large portion of the bottomlands in the reservoir site have been preliminarily listed in the Texas Bottomland Hardwood Preservation Program (FWS, 1984). These bottomlands include the entire 7,555 acres of the Tehuacana Creek Priority 5 site and an estimated 6,400 acres of the Boone Fields Priority 5 site. It should be noted that Priority 5 sites are proposed for elimination from further study because of poor quality and/or the absence of waterfowl benefits. For this reason, these sites should not deter permitting for Tennessee Colony Reservoir. A third bottomland area, the Big Lake Priority 2 site, is located downstream of the Tennessee Colony dam site. This 9,446-acre area corresponds to the downstream overflow lands in the U.S. Army Corps of Engineers' design of the Tennessee Colony project. The flood control features of the USACE design would not be incorporated in a water supply reservoir project, thus eliminating the impact or need for downstream overflow lands.

Based on previously permitted projects, it is unlikely that the project would require more than 68,100 acres in mitigation. A likely worst-case scenario might involve acre-for-acre replacement of approximately 68,000 acres, including 35,000 acres of bottomland habitat.

U.S. Fish and Wildlife Service (1989b) lists the bald eagle as the only endangered or threatened species for Anderson, Freestone, Henderson or Navarro Counties. A rare aster (<u>Aster</u> <u>puniceus</u> ssp. <u>elliotii</u> var. <u>scabricaulis</u>) is listed from Anderson County as a category 1 candidate species. USFWS has sufficient biological data to demonstrate the need for to varying degrees by land acquisition for the lake. USACE projected that many of the fields would be nearing depletion by 1979 and that most, if not all, of the wells of the largest oil field, the Cayuga Field, would be depleted by the year 2010. As with other projects, it is assumed that active oil wells and oil rights would be purchased if the reservoir is built. According to the Corps report, the project area also contains approximately 425 million tons of commercially or marginally commercially recoverable lignite coal. The amount of lignite affected by the conservation pool is somewhat less. In recent years, a small fraction of the reservoir conservation pool area (approximately 700 acres) has been permitted for mining. Portions of this area are currently being mined and reclaimed. The permitted areas are part of Texas Utilities Generating Company's Big Brown Lignite Mine which extends from Tehuacana Creek near Amerada's Camp to S.H. 488 near Ward Prairie. For the purpose of this report, it is assumed that the rights to any remaining lignite would be purchased if the reservoir is built.

Other mineral resources in the project area include sand, gravel and industrial clay (Kier, et al., 1977; USACE, 1979; Ohl and McBride, 1987).

Although listings of prime and unique farmland soils are available for all four counties in the project area (SCS, 1982), modern soil survey maps have been published for only Anderson, Henderson and Navarro Counties (SCS, 1974; 1975; 1979). From the available surveys, it appears that the majority of the soils in the reservoir site are not classified as prime or unique farmlands. USACE (1979) estimated that there were approximately

2,300 acres of active cropland within the project area.

The USACE report also estimated that the Tennessee Colony project would result in the relocation of approximately 300 families, 20.5 miles of roads, 3.4 miles of railroad, 40.3 miles of powerlines and 89.6 miles of pipelines. In addition, it will take approximately 3,700 acres from the Coffield State Prison Farm.

At the conservation pool elevation of 265 msl, Tennessee Colony Reservoir would extend up to the existing dams at Tarrant County Water Control and Improvement District Number One's Richland Creek Reservoir (inundating the outlet works and spillway) and Texas Utilities Generating Company's Lake Fairfield (inundating a portion of the spillway). Tennessee Colony Reservoir also extends partially into the Tehuacana Reservoir site.

Acquisition of the reservoir site would require 13,760 acres of public lands set aside for mitigation of the Richland Creek Reservoir project. The Tennessee Colony Reservoir site contains the entire Richland Creek Wildlife Mitigation Area administered by Texas Parks and Wildlife Department. The Final Environmental Impact Statement for Richland Creek Reservoir (USACE, 1982) stated that "should future construction of the Tennessee Colony project inundate all or part of the Richland Creek mitigation lands, compensation for the acreage would be required by the Corps and the local sponsor(s) prior to determination of mitigation requirements specifically for Tennessee Colony Lake."

A reconnaissance survey and limited testing for cultural resources were conducted for the USACE study of the Tennessee Colony project (Richner and Lee, 1977; USACE, 1979; Richner, 1982). Based on site density predictions and sites recorded in the reconnaissance survey, it was estimated that there are between 480 and 1,440 archeological and historical sites within the project site. It was also expected that most of the sites, both known and unknown, would meet criteria for eligibility to the National Register of Historic Places. USACE expected that about 12 percent of the identified archeological sites which would be affected by construction would justify detailed testing and recovery of data. Additional sites have been discovered in the project area during archeological investigations for the Big Brown Lignite Mine project (Wooldridge, 1979; Pliska, et al., 1980)

J-2.2 Pipelines Not Associated with New Reservoirs

As with reservoir projects, underground pipeline construction results in two kinds of environmental issues, those which are common to all pipeline projects and those which are specific to a particular pipeline route. Typical issues facing all underground pipeline projects include loss of wildlife habitat, disturbance of cultural resources, and changes in the water regime and possible water quality of the source and receiving water bodies. Common short-term impacts associated with all pipeline construction include the temporary generation of noise, dust and truck traffic. Examples of route specific controversial issues may include the adverse effects of stream crossings, temporary obstruction of flood flows, and interbasin transfer of organisms.

Since pipeline rights-of-way are usually purchased as easements and maintained with some type of vegetative cover (seeded grass, volunteer old field vegetation, agricultural crop, etc.), impacts on wildlife habitats are relatively small compared to reservoir projects. In addition, the relatively narrow right-of-way required for underground pipelines allows for adjustment of the pipeline route to minimize environmental impacts.

Trinity River Diversions

The proposed Trinity River diversion project would involve construction of two underground pipelines. The proposed 42-inch diameter Cedar Creek Reservoir pipeline would divert water approximately 1.7 miles from the Trinity River to an outfall structure located on the west side of the Cedar Creek Reservoir dam. This project is located entirely in Henderson County. The proposed 48-inch diameter Richland Creek pipeline, located in Freestone County, would divert water approximately 2.0 miles from the Trinity River to an outfall structure on the north side of the Richland Creek Reservoir dam. The two intake structures would be located within 13 miles of each other.

Construction of the pipelines would require 130-foot right-of-ways and would result in the loss of approximately 57 acres of wildlife habitat, including water oak-elm-hackberry forest; post oak woods forest and grassland mosaic; and native or introduced grasses (Frye, et al., 1984). There are no areas of priority bottomland hardwood forest along either route (FWS, 1984).

U.S. Fish and Wildlife Service (1989b) lists the bald eagle as the only endangered or threatened species in Henderson and Freestone Counties.

Texas Parks and Wildlife Department (1989) lists 13 additional federal and/or state endangered and threatened species occurring or potentially occurring in the two counties. Of these species, only the bald eagle, Texas horned lizard, northern scarlet snake, timber rattlesnake and alligator snapping turtle are recorded from the two-county area. It is unlikely that a pipeline project would have any affect on populations of the endangered or threatened species. Due to the narrow right-of-way, it should be possible to readjust the pipeline route should any significant impacts be identified.

The Texas Natural Heritage Program (1989) has no records of any elements of concern to their program occurring in the vicinity of the two pipeline routes.

According to the Bureau of Economic Geology (Kier, et al., 1977), energy resources within the project area include lignite and oil along the Richland Creek pipeline route; however, there is no active mining or production.

Mineral resources include sand, gravel and industrial clay along the Cedar Creek pipeline route (Kier, et al., 1977).

The pipelines should have minimal impact on prime farmland soils due to the relatively narrow rights-of-way.

Assuming that the pipelines can be adjusted to avoid residences or businesses, a preliminary estimate indicates that the two routes will cross at least one underground pipeline, four electric powerlines and two major roads (US 287 and SH 274). Although the pipelines will be planned to minimize conflicts, the Cedar Creek pipeline is currently routed through the corporate boundary of the City of Trinidad.

The Richland Creek pipeline will cross one additional creek and both pipelines involve floodplain encroachments. Construction of the pipelines may involve temporary obstruction of flood flows during the placement of segments below stream grade. These impacts will be short-term and the original floodplain contours will be restored upon completion of the pipeline segment.

Acquisition of the pipeline right-of-way would require a portion of public lands from the Richland Creek Reservoir Wildlife Mitigation area administered by Texas Parks and Wildlife Department. The pipeline crosses approximately 9,300 feet and would require approximately 28 acres of public land. Acquisition of these areas may require replacement compensation for the loss of the Richland Creek Reservoir mitigation land and any existing improvements.

Although no cultural resources are recorded from along the pipeline routes, extensive findings were discovered during cultural resources investigations at Cedar Creek and Richland Creek Reservoirs. Similar sites may occur along the pipeline routes.

Lake Texoma Diversion

The proposed 66-inch diameter pipeline to divert water from Lake Texoma to Eagle Mountain Lake would require a right-of-way 130 feet wide and approximately 84 miles long. The pipeline route would begin near the existing North Texas Municipal Water District's Wisdom Cove pump station on

Lake Texoma. The proposed route crosses Grayson, Cooke, Denton and Wise Counties to an outfall structure located at the upper end of Eagle Mountain Lake near the Tarrant County line.

Construction of the pipeline would result in the loss of approximately 1,315 acres of wildlife habitat, including post oak woods, forest and grassland mosaic; silver bluestem-Texas wintergrass grassland; native and introduced grasses; and cropland (Frye, et al., 1984). There are no areas of priority bottomland hardwood forest along the route (USFWS, 1984).

U.S. Fish and Wildlife Service (1989b) lists four endangered or threatened species for Grayson, Cooke, Denton, Wise or Tarrant Counties; the bald eagle, whooping crane, black-capped vireo and piping plover. Texas Parks and Wildlife Department (1989) lists 16 additional federal and/or state endangered or threatened species occurring or potentially occurring in the five counties, three of which have never been recorded from the area. Most of these species would not be affected by the loss of habitat or construction impacts of a pipeline project. Two of the aquatic species are known only from historic records prior to the closing of Dennison dam. Since most of the birds are migratory through north central Texas, a pipeline project would not impact their migration routes, stopover points, or nesting areas. Although unlikely, it is possible that the pipeline route could cross habitat for the back-capped vireo which prefers oak-juniper woodlands and is more commonly associated with the Edwards Plateau region. Other listed species are widespread and known from several habitat types. Their depleted populations are attributed more to pesticide use and agricultural practices than to loss of habitat. It is unlikely that a pipeline project would have any effect on populations of these or other endangered or threatened species. Due to the narrow right-of-way, it should be possible to route the pipeline to avoid significant impacts.

The Texas Natural Heritage Program (TPWD, 1989) lists one plant and two plant communities as elements of concern occurring in the vicinity of the pipeline route. Three locality listings of the Comanche-Peak prairie-clover (Dalea reverchonii) are recorded from Wise County within 4,500 to 6,000 feet of the proposed route. It is possible that the plant could occur in similar habitats along the pipeline route. The plant is a federal category 2 candidate species for possible listing upon further documentation. The Sugarberry-Elm Series locality occurs in Hagerman National Wildlife Refuge approximately five miles from the proposed route and could occur in similar bottomland habitats along the pipeline route. However, it is not imperiled, as indicated by a conservation ranking of "apparently secure". The Silver Bluestem-Indiangrass Series, however, has been given a conservation ranking of "endangered". Five localities of this prairie community occur within five miles of the proposed pipeline, with the current route crossing one of these localities. If this locality is an exemplary stand of the plant community, the pipeline could be routed to avoid the locality.

Energy resources along the pipeline route include oil and natural gas fields (Kier, et al., 1977) in the vicinity of Collinsville, Sherman and Pottsboro.

Freese and Nichols, Inc. and Alan Plummer, Inc. (1986). During the 1950's drought, water was also diverted from the headwaters of Lake Texoma to Lake Dallas on the Elm Fork Trinity River. In addition, future diversions are planned from Lake Hubert H. Moss on Fish Creek, a tributary of the Red River, to the City of Gainesville which discharges into the Elm Fork Trinity River.

Acquisition of the pipeline right-of-way would require taking a portion of public lands from the USACE's Lake Ray Roberts project. The pipeline crosses approximately 7,000 feet along the Elm Fork Trinity River, Timber Creek and Jordon Creek and would require taking approximately 21 acres of public land. Acquisition of these areas may require replacement compensation for the loss of Lake Ray Roberts mitigation land and any existing improvements.

An archival search at the Texas Archeological Research Laboratory revealed that the only recorded cultural resources along the pipeline route occur in the vicinity of the USACE Lake Ray Roberts project.

<u>Lake Palestine Diversion</u>

The proposed 84-inch diameter pipeline to divert water from Lake Palestine to Cedar Creek Reservoir would require a right-of-way 130 feet wide and approximately 29 miles long. The pipeline route would begin at a new pump station on Flat Bay on Lake Palestine. The proposed pipeline is routed across Henderson County to an outfall structure on the Caney Creek arm of Cedar Creek Reservoir.

Construction of the pipeline would result in the loss of approximately

There are no known mineral resources occurring along the route (Kier, et al., 1977).

The pipeline should have minimal impact on prime farmland soils due to the relatively narrow right-of-way.

Assuming that the pipeline can be adjusted to avoid residences or businesses, a preliminary estimate indicates that the route will cross at least six railroads, five underground pipelines, six powerlines and 18 major roads, including I-35, US 82, US 287 and US 377. Although the pipeline will be planned to minimize conflicts, it is currently routed through the corporate boundaries of the Cities of Rhome, Valley View and Pottsboro.

The pipeline will cross at least 23 major creek crossings including the Elm Fork Trinity River and Denton Creek. Several of these creek crossings involve floodplain encroachments. Construction of the pipeline may involve temporary obstruction of flood flows during the placement of segments below stream grade. These impacts will be short-term and the original floodplain contours will be restored upon completion of the pipeline segment.

The project will involve an interbasin transfer from the Red River watershed to the Trinity River watershed. USACE has already set a precedent for interbasin transfer between the two systems by permitting the North Texas Municipal Water District's Lake Texoma diversion project to Sister Grove Creek and, ultimately, to Lake Lavon on the East Fork Trinity River. Impacts from this project were addressed in a report prepared by

Freese and Nichols, Inc. and Alan Plummer, Inc. (1986). During the 1950's drought, water was also diverted from the headwaters of Lake Texoma to Lake Dallas on the Elm Fork Trinity River. In addition, future diversions are planned from Lake Hubert H. Moss on Fish Creek, a tributary of the Red River, to the City of Gainesville which discharges into the Elm Fork Trinity River.

Acquisition of the pipeline right-of-way would require taking a portion of public lands from the USACE's Lake Ray Roberts project. The pipeline crosses approximately 7,000 feet along the Elm Fork Trinity River, Timber Creek and Jordon Creek and would require taking approximately 21 acres of public land. Acquisition of these areas may require replacement compensation for the loss of Lake Ray Roberts mitigation land and any existing improvements.

An archival search at the Texas Archeological Research Laboratory revealed that the only recorded cultural resources along the pipeline route occur in the vicinity of the USACE Lake Ray Roberts project.

Lake Palestine Diversion

The proposed 84-inch diameter pipeline to divert water from Lake Palestine to Cedar Creek Reservoir would require a right-of-way 130 feet wide and approximately 29 miles long. The pipeline route would begin at a new pump station on Flat Bay on Lake Palestine. The proposed pipeline is routed across Henderson County to an outfall structure on the Caney Creek arm of Cedar Creek Reservoir.

Construction of the pipeline would result in the loss of approximately

461 acres of wildlife habitat, including pine-hardwood forest and post oak woods, forest and grassland mosaic (Frye, et al., 1984). There are no areas of priority bottomland hardwood forest along the project route (FWS, 1984).

U.S. Fish and Wildlife Service (1989b) lists the bald eagle as the only endangered or threatened species for Henderson County. Texas Parks and Wildlife Department (1989) lists 13 additional federal and/or state endangered or threatened species occurring or potentially occurring in the county. Of these species, only the bald eagle, Texas horned lizard, northern scarlet snake, timber rattlesnake, and alligator snapping turtle are recorded from Henderson County. It is unlikely that a pipeline project would have any effect on populations of the endangered or threatened species. Due to the narrow right-of-way, it should be possible to route the pipeline to avoid significant environmental impacts.

Although the Texas Natural Heritage Program (1989) lists two plant communities as elements of concern occurring in the vicinity of the pipeline route, both the Shortleaf Pine-Oak Series and the Post Oak-Black Hickory Series are widely occurring communities and have respective conservation rankings of "secure" and "apparently secure".

Energy resources along the project route consist of areas of surface and near surface lignite coal located across the western half of the pipeline route (Kier, et al., 1977). The narrow right-of-way required for the project should have minimal impact on any future recovery of these deposits.

Mineral resources include industrial clays (Kier, et al., 1977) which are mined in the vicinity of Athens.

The pipeline should have minimal impact on prime farmland soils due to the relatively narrow right-of-way.

Assuming that the pipeline can be adjusted to avoid residences or businesses, a preliminary estimate indicates that the route will cross at least two railroads, 10 underground pipelines, three electric powerlines and seven major roads, including US 175. Although the pipeline will be planned to minimize conflicts, it is currently routed through the corporate boundaries of the Cities of Moore Station and Athens.

The pipeline will cross at least eight major creeks and may involve floodplain encroachments. Construction of the pipeline may involve temporary obstruction of flood flows during the placement of the segments below stream grade. These impacts will be short-term and the original floodplain contours will be restored upon completion of the pipeline segment.

The project will involve an interbasin transfer between the Neches River watershed and the Trinity River watershed. Precedence has been set for diversions between the two systems by the pipeline from Lake Athens in the Neches watershed to the City of Athens which discharges into Walnut Creek in the Trinity watershed.

A preliminary search revealed no public lands located along the pipeline route.

An archival search at the Texas Archeological Research Laboratory revealed no known cultural resources along the proposed pipeline route. Nearby sites are recorded from the cultural resources investigations at Cedar Creek Reservoir and Lake Palestine. Additional historic sites occur within the City of Athens. It is expected that similar sites occur along the pipeline route.

J-2.3 System Operation

The system operation alternative will involve drawing heavily from Cedar Creek Reservoir during years when other system reservoir levels are high. The additional 32,800 acre-feet per year average that will be provided by this alternative would otherwise be lost as downstream releases or evaporation.

Although this alternative has relatively minor environmental impact, the changes in downstream releases and lake levels should be scrutinized for potential affects on downstream aquatic habitats and lake fisheries. It is anticipated that any impacts of the system operation alternative would not preclude its implementation.

J-3 PERMITTING REQUIREMENTS

Four permits will be required before construction of any of the new reservoir or pipeline alternatives can begin. Of these, the most significant are the (a) water rights permit from the Texas Water Commission which is required for appropriation of state water, and (b) Section 404 permit from the U.S. Army Corps of Engineers which covers the discharge of dredged and fill material into waters of the United States and their adjacent wetlands. Since the Tennessee Colony Reservoir site and the Trinity River diversions are within the limit of navigability on the Trinity River as defined by USACE, it will be necessary to obtain a Section 10 permit relating to construction in navigable waters. The Lake Texoma diversion may also require a Section 10 permit if the intake structure requires construction in Lake Texoma which is within the limit of navigability on the Red River. These projects will be reviewed for Section 10 compliance during the Section 404 permit process; only one permit application is needed for the two permits. Two additional permits will be needed from state agencies other than the Water Commission - an antiquities permit from the Texas Antiquities Committee and a sand and gravel permit from the Texas Parks and Wildlife Department. Table 3.1 summarizes these permit requirements.

If hydroelectric facilities are included in any of the new reservoir projects, a license from the Federal Energy Regulatory Commission (FERC) becomes the primary federal permit required, and the Section 404 permit becomes secondary to the FERC permit by interagency agreement. Based on

Table J-3.1

Summary of Permitting Requirements

Permit	Issuing Agency	Summary of Requirements
Water Rights	Texas Water Commission	Engineering report; environmental effects report on water quality and fish and wildlife; water conservation plan; public hearing; may include mitigation requirements
Section 404*/Section 10	U.S. Army Corps of Engineers	Description of proposed fill activities; preparation of environmental impact statement; may require special studies from applicant, including archeological survey, water quality studies, ecological studies; may include mitigation requirements
Antiquities Permit	Texas Antiquities Committee	Archeological survey, testing and evaluation, and mitigation of important sites
Sand and Gravel Permit	Texas Parks and Wildlife Department	$0.20 per cubic yard of sand, gravel or marl excavated from river channel

*Includes Section 401 Certification of Water Quality from State Agency (TWC).

recent experience in Texas, the FERC license may involve substantially more effort and take longer to process than a Section 404 permit. The permitting cost estimate included in the following section of this report assumes that FERC permits will not be involved.

J-3.1 Texas Water Rights Permit

The Texas Water Code requires a permit from the Texas Water Commission for construction of a project designed to impound (or convey) and use surface water. Before granting a permit, the TWC will require evidence demonstrating that (a) there is a present or future need for the requested water appropriation, (b) there is unappropriated water available in the amount applied for, (c) the proposed project is feasible and (d) the appropriation being sought is consistent with the public welfare. For a major project, much of the supporting material to establish these points is typically provided in the form of an engineering report and an environmental assessment. These are submitted for review by the TWC staff along with the application.

After TWC staff review and determination that an application is administratively complete, public notice of the requested appropriation is published in newspapers of general circulation in the area of the proposed project. Additionally, all holders of existing water rights in the same river basin are notified by mail that the matter is to be brought before TWC for consideration at a public hearing.

If there is no opposition, TWC customarily takes action during the initial hearing, based on recommendations by the staff. However, in cases where formal protests have been filed by parties objecting to an application, TWC typically refers the matter to a hearings examiner for more detailed hearings on the merits of the applicant's request. Such hearings can be lengthy and demanding, and some recent reservoir projects have taken several years from submittal of the application until a final decision by TWC.

J-3.2 Federal Section 404 Permit

The U.S. Army Corps of Engineers has the responsibility to review reservoir projects and issue or deny permits in accordance with Section 404 of the Clean Water Act, which deals with regulation of dredge and fill discharges into waters of the United States and their adjacent wetlands. As part of the USACE review, attention is also given to compliance with (a) the National Environmental Policy Act (NEPA), which requires identification and assessment of significant impacts on the environment, (b) the National Historic Preservation Act, which requires that a federal permitting agency take into account effects on cultural resources, (c) the Farmland Protection Policy Act, which requires federal permitting agencies to consider adverse effects on the preservation of farmland, (d) the Endangered Species Act, which requires such agencies to act in a way that will properly protect endangered or threatened species and their critical habitat, and (e) the Fish and Wildlife Coordination Act, which provides that USACE consult with the U.S. Fish and Wildlife Service (USFWS) regarding potential impacts of a proposed water project.

In accordance with the latter of these guidelines, USACE will request comments from the appropriate area Ecological Services office of the USFWS (Fort Worth, TX), with particular emphasis on recommended ways to mitigate possible adverse effects of a project. The USACE District Engineer has authority to establish mitigation requirements based on the overall USACE review process, but the input from the USFWS is given considerable weight in determining which mitigation measures are to be included as conditions of a Section 404 permit. If the USFWS disagrees with the District Engineer's decision regarding mitigation, it has the option of requesting that a permit be "elevated" for review at higher levels of USACE. In such cases, issues are considered and resolved at the regional or national level, through joint consultation by the Department of the Army and the Department of the Interior.

Included as part of the 404 process is the requirement of a Section 401 water quality certification which determines the project impacts on potential violations of state water quality standards. In Texas, the 401 certification will be handled by the Texas Water Commission. The granting or waiver of the 401 certification is considered prerequisite for issuance of the 404 permit.

All of the alternative projects will fall under the jurisdiction of the USACE Fort Worth District. The Lake Texoma diversion also occurs within the jurisdiction of the Tulsa District and would likely require coordination with both offices.

The standard application format for the Section 404 permit involves basic information on the proposed project, together with drawings showing the location, plan and profile of principal structures. In some instances, the District Engineer will request additional information which he deems necessary to reach proper decisions on environmental issues or other questions relating to matters of public interest. USACE may also hold public hearings to give the public an opportunity to comment on a project. Consideration of these comments is part of the public interest review.

Because of the nature and scope of a new reservoir project, it is expected that USACE would determine that a detailed environmental impact statement (EIS) should be prepared. The pipeline projects would probably require a less comprehensive environmental assessment (EA). TCWCID No. 1 may find it beneficial to develop its own EA prior to the federal permitting process. Early development of an EA allows timely identification and analysis of significant issues and may provide opportunities to mitigate these before they create substantial controversy or delay. It is especially important to address controversial issues prior to a public hearing to minimize public opposition to the project.

J-3.3 Other Necessary Authorizations

The Antiquities Code of Texas specifies that any archeological or historical sites located on lands of the state or its political subdivisions are to be considered state archeological landmarks, which cannot be altered, damaged or excavated without permission from the Texas

Antiquities Committee. Because the Tarrant County Water Control and Improvement District Number One is a subdivision of the state, its projects are generally interpreted as requiring antiquities permits. Where a federal Section 404 permit is required, the state antiquities permit is usually considered to be an administrative action in support of the federal archeological and historical requirements. Under the federal procedures, the State Historical Preservation Officer becomes the lead state archeological reviewer, rather than the Antiquities Committee.

Title 31 of the Texas Administrative Code requires a permit from the Texas Parks and Wildlife Department for removal of marl, sand or gravel from the public waters of the state. Excavation for construction of a dam is currently construed as coming under this requirement. The Texas Parks and Wildlife Department assesses a charge of $.20 per cubic yard for sand and gravel removed from a stream bed. A TPWD permit will also be required for pipeline projects that cross streambeds greater than 30 feet in width. TPWD assesses the project only for excess material that is displaced or removed from the streambed.

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SCENARIO 2

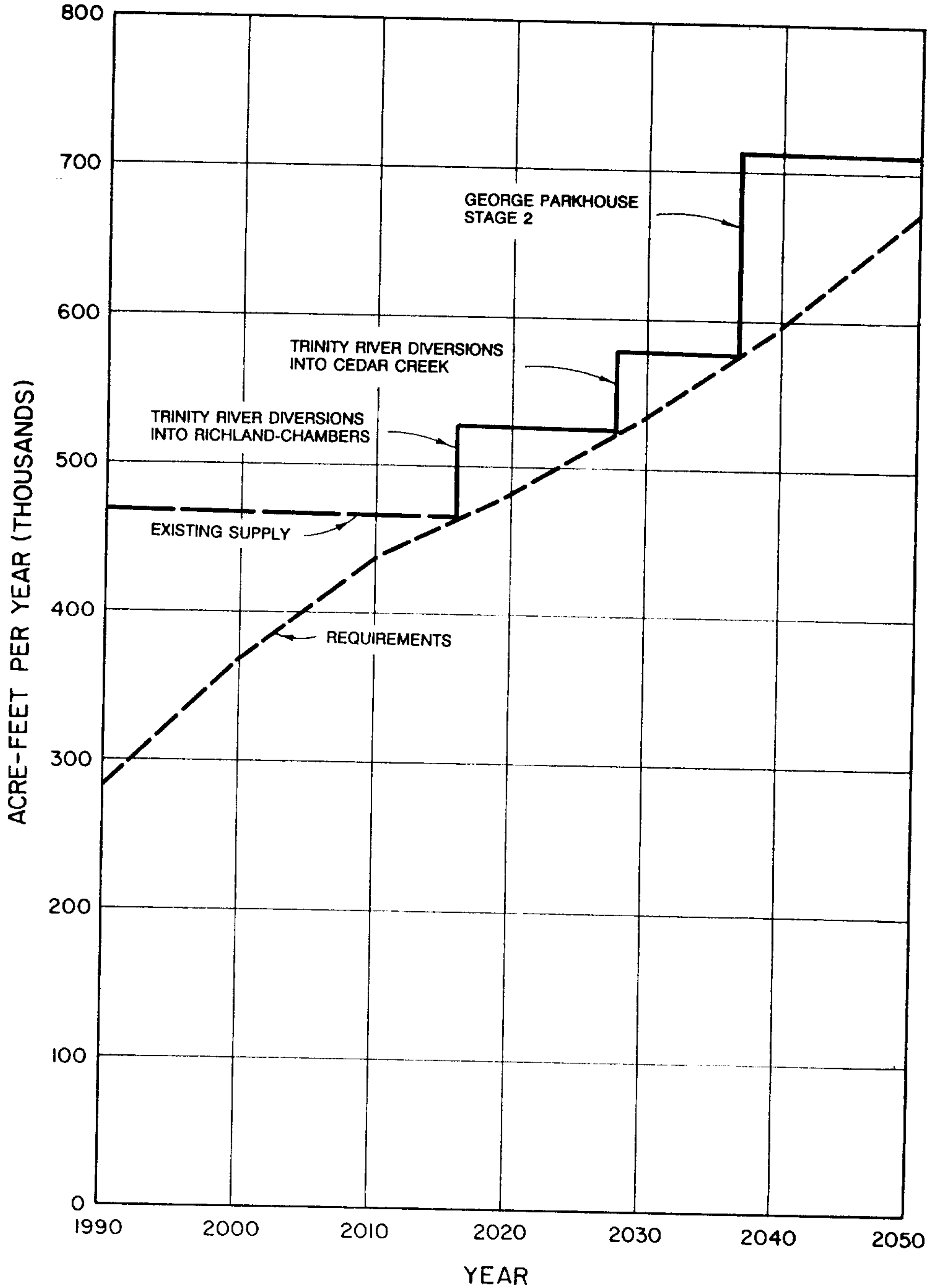


FIGURE 10.3

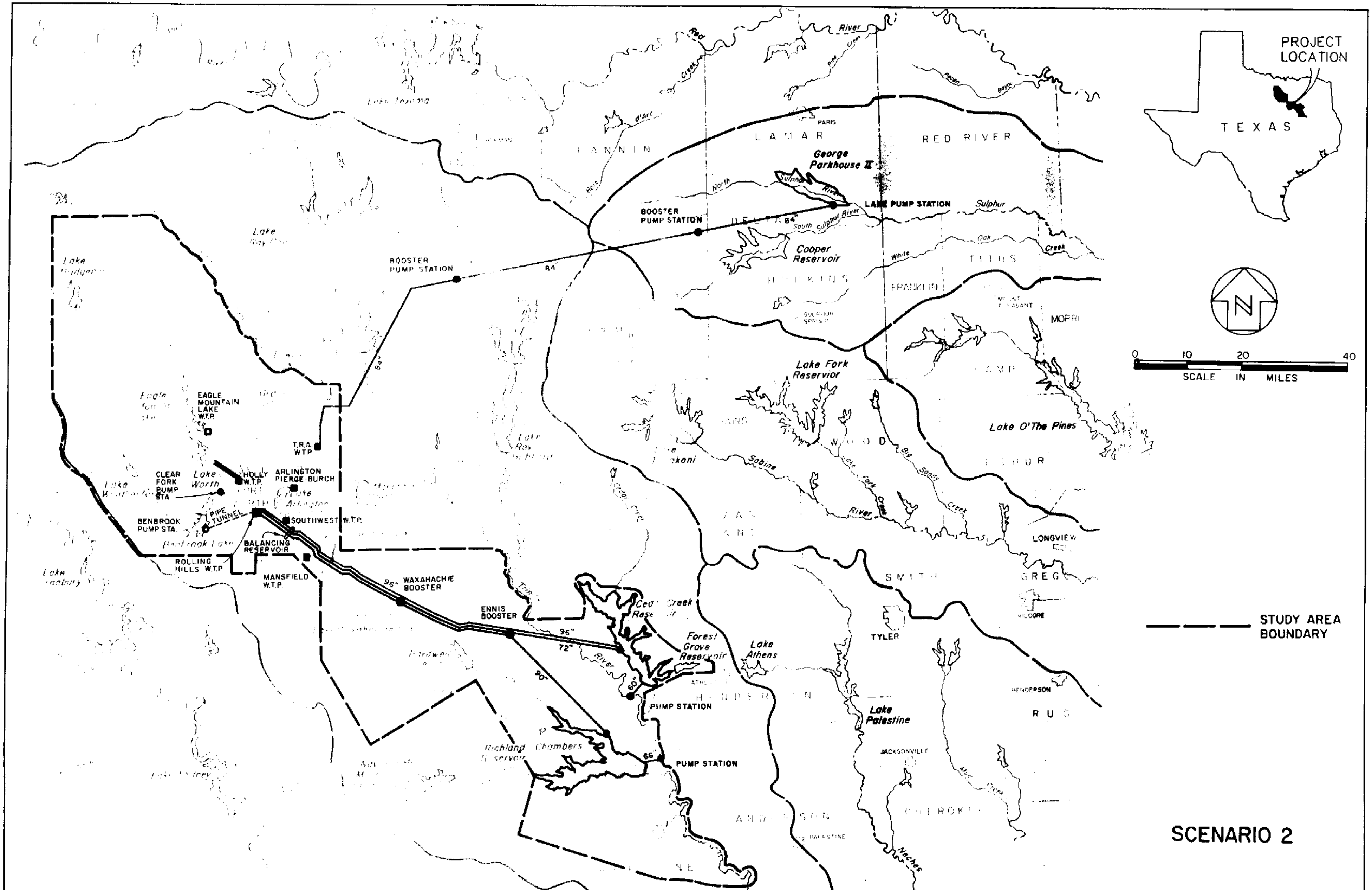

PROJECT LOCATION
TEXAS
SCALE IN MILES
0
10
20
40
STUDY AREA BOUNDARY
SCENARIO 2
LAMAR
RED RIVER
George Parkhouse II
LAKE PUMP STATION
BOOSTER PUMP STATION
84"
Cooper Reservoir
Lake Fork Reservoir
Lake O'The Pines
EAGLE MOUNTAIN LAKE W.T.P.
T.R.A. W.T.P.
CLEAR FORK PUMP STA.
Lake Worth
HOLLY W.T.P.
ARLINGTON PIERCE-BURCH
BENBROOK PUMP STA.
PIPE TUNNEL
SOUTHWEST W.T.P.
BALANCING RESERVOIR
ROLLING HILLS W.T.P.
MANSFIELD W.T.P.
96"
WAXAHACHIE BOOSTER
ENNIS BOOSTER
72"
90"
60"
66"
Forest Grove Reservoir
PUMP STATION
Richland Chambers Reservoir
Lake Athens
TYLER
Lake Palestine
JACKSONVILLE
LONGVIEW
HENDERSON
Sabine River
Sulphur
White
Big Sandy Creek

FIGURE 10.4

Scenario 4 is basically similar to Scenario 3, but shows the large increment of supply in 2016 coming from a 72 percent share of the Tennessee Colony project. Figure 10.5 is a graph of Scenario 3, and Figure 10.6 is a map of the new facilities needed for Scenario 3. Similarly, Figure 10.7 shows the comparison of supply and demand for Scenario 4, and Figure 10.8 is a map of Scenario 4. Table 10.3 is a summary of the yield increments and anticipated scheduling for each of the four scenarios.

Life Cycle Cost Analyses

Included among the cost evaluations in Appendix I are life cycle present worth cost analyses for each of the four scenarios, covering the incremental costs of the raw water provided by each scenario. Table 10.4 is a summary of the results of those studies.

Water Treatment Requirements and Costs

The Tarrant County Water Control and Improvement District Number One supplies raw water to its customers, who treat the water and distribute it to the consumers. For this study, it is assumed that this arrangement will continue, with water customers developing capacity for treatment of water supplied by the District. Table 10.5 shows the treatment capacity needed for the projected District raw water supplies. It is assumed that water treatment capacity will equal twice the average-day supply in order to meet peak-day water requirements.

The District's four largest customers in Tarrant County (Fort Worth, Arlington, the Trinity River Authority, and Mansfield) will all need to

SCENARIO 3

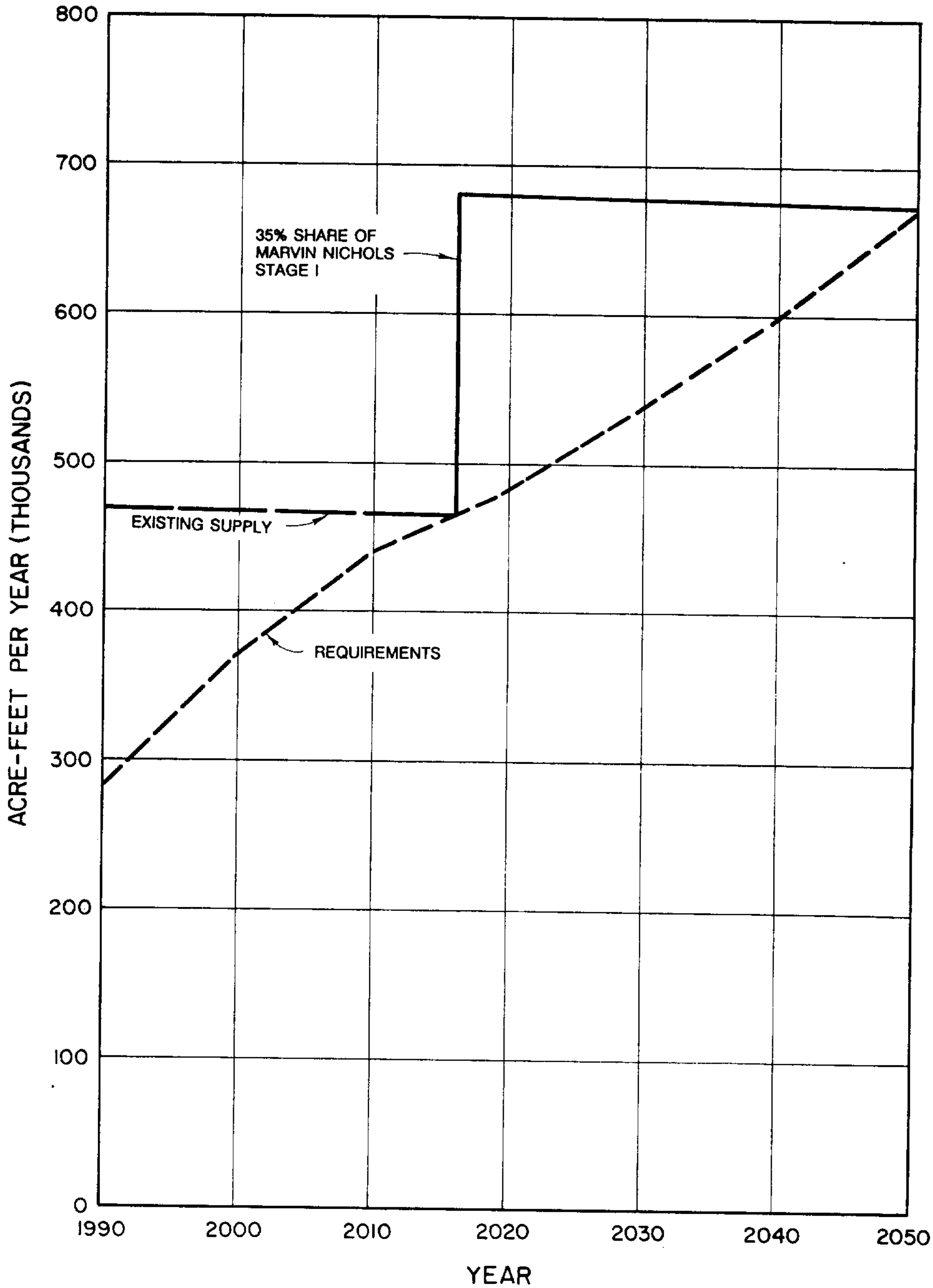
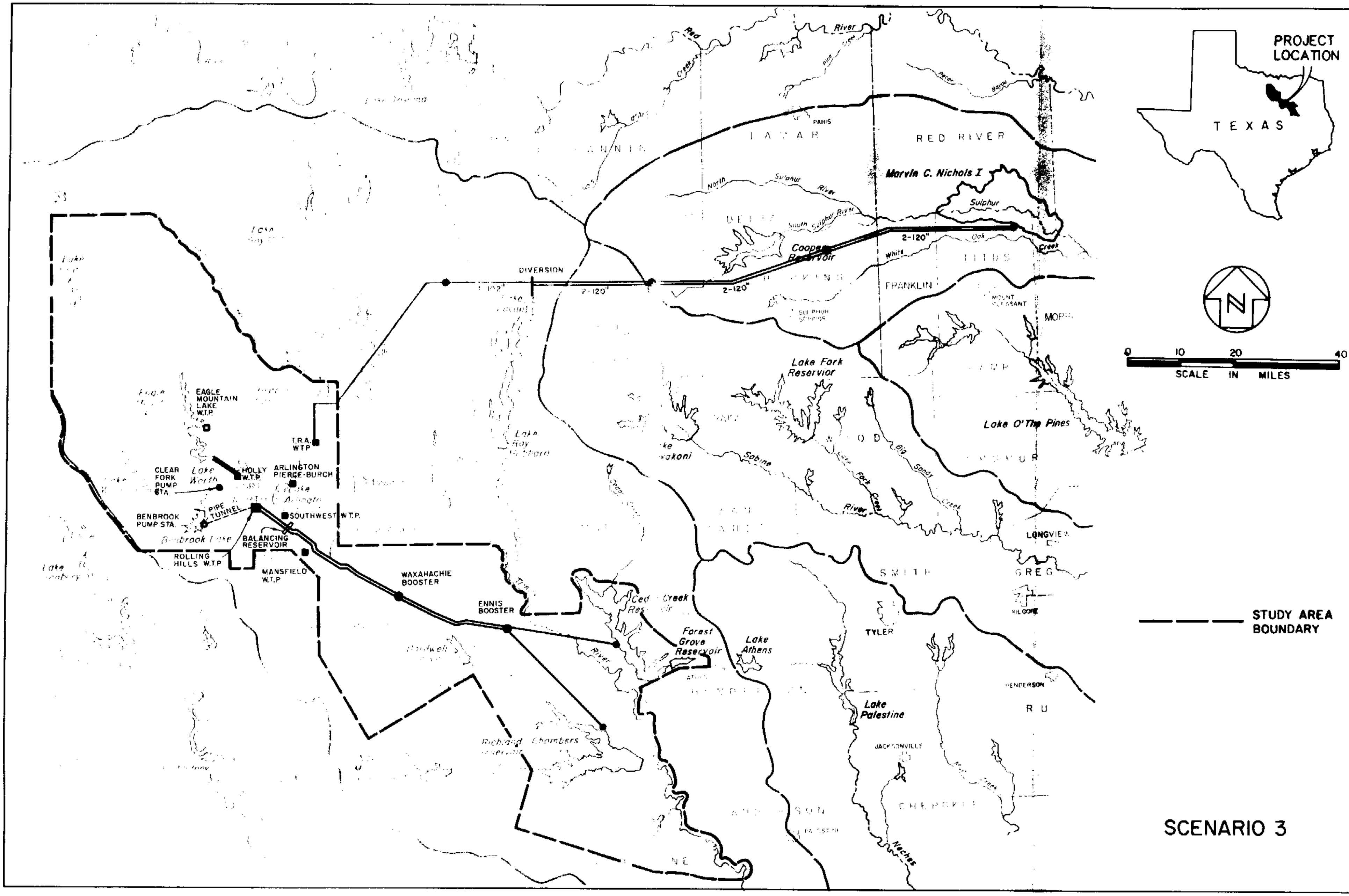


FIGURE 10.5



SCENARIO 3

FIGURE 10.6

SCENARIO 4

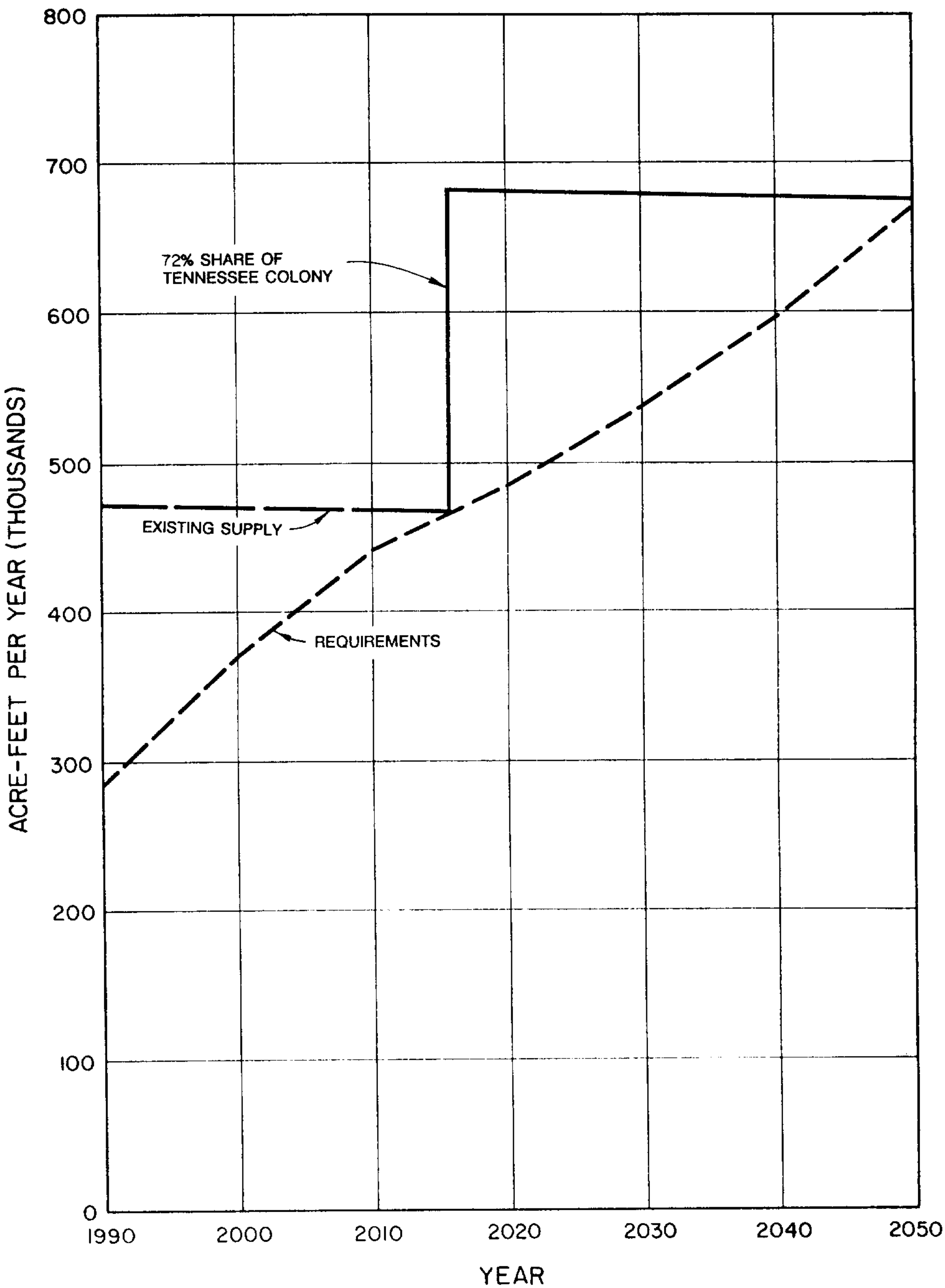


FIGURE 10.7

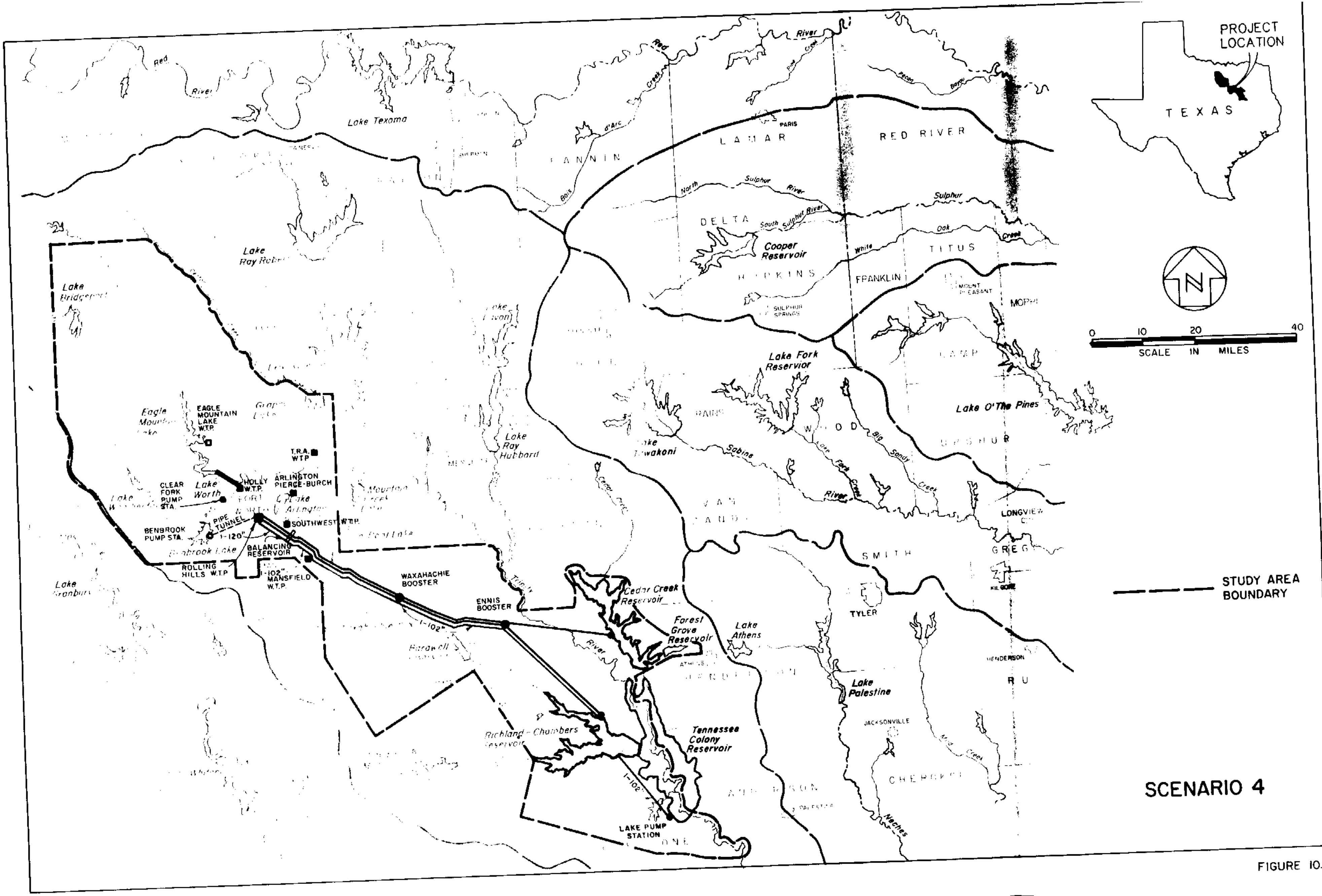

PROJECT LOCATION
TEXAS
0 10 20 40
SCALE IN MILES
STUDY AREA BOUNDARY
Lake Texoma
Red River
RED RIVER
LAMAR
PARIS
FANNIN
DELTA
HOPKINS
FRANKLIN
TITUS
Cooper Reservoir
Lake Fork Reservoir
Lake O'The Pines
WOOD
Lake Tawakoni
Sabine River
Big Sandy Creek
VAN ZANDT
SMITH
GREGG
LONGVIEW
TYLER
HENDERSON
Lake Athens
Lake Palestine
JACKSONVILLE
Neches
Lake Ray Roberts
Lake Bridgeport
Eagle Mountain Lake
EAGLE MOUNTAIN LAKE W.T.P.
T.R.A. W.T.P.
HOLLY W.T.P.
ARLINGTON PIERCE-BURCH
CLEAR FORK PUMP STA.
Lake Worth
PIPE TUNNEL
1-120"
BENBROOK PUMP STA.
Benbrook Lake
BALANCING RESERVOIR
SOUTHWEST W.T.P.
ROLLING HILLS W.T.P.
1-102"
MANSFIELD W.T.P.
WAXAHACHIE BOOSTER
ENNIS BOOSTER
Lake Ray Hubbard
Lake Granbury
Cedar Creek Reservoir
Forest Grove Reservoir
Tennessee Colony Reservoir
Richland - Chambers Reservoir
LAKE PUMP STATION
SCENARIO 4

FIGURE 10.8

Table 10.3

Summary of Water Supply Development Scenarios

- Yields in Acre-Feet per Year -

		New Yield	Total New Supply
Scenario 1			
2016:	Supplemental diversions from the Trinity River into Richland-Chambers Reservoir	63,000	63,000
2028:	Supplemental diversions from the Trinity River into Cedar Creek Reservoir	52,500	115,500
2037:	Coordinated System Operation of Richland-Chambers Reservoir and Cedar Creek Reservoir	32,800	148,300
2042:	Tehuacana Reservoir basic yield	68,300	216,600
	plus added Trinity diversions	20,400	237,000
Scenario 2			
2016:	Supplemental diversions from the Trinity River into Richland-Chambers Reservoir	63,000	63,000
2028:	Supplemental diversions from the Trinity River into Cedar Creek Reservoir	52,500	115,500
2037:	George Parkhouse Res. Stage II	136,700	252,200
Scenario 3			
2016:	Marvin Nichols Reservoir Stage I (35% share)	218,600	218,600
Scenario 4			
2016:	Tennessee Colony Reservoir (72% share)	216,500	216,500

Table 10.4

Summary of Life Cycle Present Worth Cost Analyses for the Four Water Supply Development Scenarios

- Unit Costs per 1,000 Gallons -

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2016-2020	$5.45	$5.44	$12.59	$18.73
2021-2025	1.99	1.90	2.97	4.33
2026-2030	1.24	0.92	1.34	1.90
2031-2035	1.11	0.57	0.96	1.07
2036-2040	0.74	1.12	0.80	0.70
2041-2045	0.66	0.85	0.56	0.50
2046-2050	0.45	0.54	0.31	0.23
2016-2050	$0.87	$0.90	$ 0.96	$ 1.13

Note: All cost amounts are present worth values in 1989 dollars.

Table 10.5

Capacity Needed to Treat Water Supplied by TCWCID#1

Location	Required Treatment Capacity in MGD						
	1990	2000	2010	2020	2030	2040	2050
Fort Worth	285	348	427	447	492	549	619
Arlington	114	144	174	186	205	229	258
Trinity River Authority	44	65	75	82	90	101	113
Mansfield	4	7	12	15	16	18	21
Ellis County	7	9	17	31	45	49	54
Freestone County	0	2	2	3	4	5	5
Henderson County	7	27	28	29	30	31	31
Kaufman County	2	2	2	3	3	4	4
Navarro County	3	5	6	8	9	11	12
Parker County	5	13	15	16	17	17	18
Other Tarrant Co.	27	25	25	25	25	25	25
Wise County	10	15	20	25	31	36	42
	508	662	803	870	967	1,075	1,202

Notes:
a. Denton County use of TCWCID#1 water is assumed to be supplied by Fort Worth and TRA. Johnson County use is assumed to be supplied by Fort Worth and Mansfield.
b. The required capacity is assumed to be double the average-day use, so that peak-day demands can be met.

increase their treatment capacities between now and 2050. The City of Fort Worth currently has three water treatment plants operating or under construction - Rolling Hills, Holly, and Eagle Mountain. The treatment capacities at these plants are 160 MGD at Rolling Hills, 150 MGD at Holly, and 30 MGD at Eagle Mountain, which is scheduled to be completed this year. These plants will meet Fort Worth's projected treatment capacity requirements until the late 1990's. Fort Worth is projected to need 619 MGD of treatment capacity by 2050, which will require 279 MGD in addition to the current facilities. The Rolling Hills plant is capable of being expanded by 160 MGD, and current plans allow for a 30 MGD expansion of the Eagle Mountain plant. The additional 89 MGD which will not be developed by the currently planned expansions can be provided by additional expansions at the existing plants and/or by new plant construction, depending on the areas to be served and other factors. Based on an estimated unit cost for treatment facilities of $0.50 per gallon per day of plant capacity, the 279 MGD in additional capacity needed for Fort Worth will probably cost on the order of $139,500,000.

The City of Arlington's two water treatment plants are the Pierce Burch plant and the Southwest plant. Their current capacities are 136 MGD for the Pierce Burch plant and 25 MGD for the Southwest plant, for a total of 161 MGD. Planned expansions of the Southwest plant will increase this total by 75 MGD, to 236 MGD. The projected 2050 treatment capacity requirement for Arlington is 258 MGD. The additional 22 MGD of treatment capacity which will not be provided by the planned expansions will probably come from additional expansions at one of the existing plants. Based on an estimated unit cost for treatment facilities of $0.50 per gallon of daily capacity, the 97 MGD in additional capacity needed for Arlington will probably cost on the order of $48,500,000.

Trinity River Authority's Tarrant County Water Project provides water to the cities of Euless, Bedford, and Colleyville, and portions of Grapevine and North Richland Hills. The plant currently has a capacity of 42 MGD with a planned expansion to 87 MGD. It is projected that the Trinity River Authority will need 113 MGD of treatment capacity by 2050. The additional 26 MGD of capacity not provided by the planned expansion can be provided by additional expansions or by construction of a new plant. Based on an estimated unit cost for treatment facilities of $0.50 per gallon of daily plant capacity, the 71 MGD in additional capacity needed for the Trinity River Authority Tarrant County Water Project will probably cost on the order of $35,500,000.

The City of Mansfield's water treatment plant currently has a capacity of 10 MGD. The projected 2050 treatment capacity requirement for Mansfield is 21 MGD, requiring 11 MGD of additional capacity. It is anticipated that this will be provided by expansion of the existing facility. Based on an estimated unit cost for treatment facilities of $0.75 per gallon of daily capacity (for this smaller facility), the 11 MGD in additional capacity needed by Mansfield will probably cost on the order of $8,250,000.

Table 10.6 summarizes the capacity expansions required for the District's four major Tarrant County customers and the estimated cost of those expansions. Since it is not yet certain how service will be provided in other counties, cost estimates for treatment capacity were not developed.

Table 10.6

Projected Water Treatment Capacity Expansions and Costs for Tarrant County

Customer	Projected 2050 Treatment Capacity (MGD)	Current Treatment Capacity (MGD)	Expansion Required (MGD)	Approximate Cost of Expansion
Fort Worth	619	340	279	$139,500,000
Arlington	258	161	97	48,500,000
Trinity River Authority	113	42	71	35,500,000
Mansfield	21	10	11	8,250,000
Total	1,011	553	458	$231,750,000

Note: All costs are based on 1989 prices.

11. SUMMARY OF FINDINGS

Supply and Demand

a. The District's existing water supply system has an estimated total dependable yield of 470,800 AF/Y as of 1990. This yield will decrease slightly with time, due to sediment accumulation in the reservoirs.

b. The District's water requirements are projected to equal the available dependable supply about the year 2016. By that time, it is estimated that the total dependable yield of the existing reservoirs will be 465,500 AF/Y and the potential requirements under drought conditions will be 465,200 AF/Y.

c. The total requirements are projected to reach 671,000 AF/Y by 2050. Approximately 85 percent of the 2050 demand is predicted to be in Tarrant County.

d. As of 2050, the dependable yield of the District's present reservoir system is estimated at 458,000 AF/Y.

e. To keep pace with the projected future water requirements, the District should plan to develop approximately 213,000 AF/Y of new supply by the year 2050 (671,000 - 458,000 = 213,000).

f. There are several suitable alternatives that could provide the required additional water supply for the District.

System Operation

g. The combined yield of Cedar Creek Reservoir and Richland-Chambers Reservoir can be increased if the two facilities are operated as a coordinated system rather than as two independent reservoirs. The potential gain in yield is estimated at 24,300 AF/Y for the reservoirs as they are now and 32,800 AF/Y if their individual yields are increased 30 percent due to supplemental diversions from the Trinity River (see paragraphs "k" and "l" below).

Diversions from the Trinity River

h. Federal and state requirements for treatment of municipal wastewater are becoming more and more strict, until the resulting quality of the reclaimed water is in some respects better than the quality of the natural runoff. It is probable that some form of water reuse will make up part of the supply for many areas of Texas within the period covered by this study.

i. Although in some places direct reuse of reclaimed water is now being investigated, that is clearly the most difficult approach, and it is neither necessary nor desirable for the District at this time.

j. Indirect reuse due to return of reclaimed water to a reservoir is presently being done in some water supply systems. The best-known example is probably the Upper Occoquan Sewage Authority in Virginia. The North Texas MWD is operating on that basis at Lake Lavon.

k. In the Tarrant County District's case, there is a more conservative option which involves some reuse of reclaimed water but is even more indirect. This alternative is to make supplemental diversions from the Trinity River into Richland-Chambers Reservoir and Cedar Creek Reservoir.

l. The supplemental Trinity River diversions could potentially increase the Richland-Chambers and Cedar Creek yields by at least 30 percent, a gain of 115,500 AF/Y. More detailed water quality study (see "u" below) may show that a higher gain in yield is feasible.

Existing Reservoirs

m. Of the existing reservoir alternatives considered, Lake Texoma was found to have the potential for providing a significant amount of additional supply at a competitive level of cost.

n. It would be possible to divert up to 50,000 AF/Y from Lake Texoma into Eagle Mountain Lake. However, to do so would raise the concentrations of total dissolved solids, chlorides and sulphates in Eagle Mountain. Because of water quality concerns and because water from Lake Texoma is not significantly less expensive than several other alternatives, this was not included in the potential development scenarios.

o. Lake Palestine would be a good source of added yield if it were possible to purchase Dallas' share of that project - approximately 114,300 AF/Y. However, the new Dallas long-range water supply plan (3) recommends that the Lake Palestine yield be the next increment of supply for Dallas and that a pipeline to bring the water to Dallas be built by the year 2001. There appears to be relatively little chance that the District could obtain the Lake Palestine supply.

New Reservoirs

p. The proposed Tehuacana Reservoir would provide 68,300 AF/Y of basic yield or 88,700 AF/Y with supplemental diversions from the Trinity River.

q. The other most promising new reservoir projects are the George Parkhouse and Marvin Nichols Reservoirs in the Sulphur River Basin, each of which could be developed in two stages. Together, these projects are capable of providing a total additional yield of more than a million acre-feet per year.

Recommended Development Scenario

r. The most economical development scenario for the District would involve the following four steps:

Step 1: Construct facilities to divert supplemental water from the Trinity River into Richland-Chambers Reservoir by about 2016.

Step 2: Construct facilities to divert supplemental water from the Trinity River into Cedar Creek Reservoir by about 2028.

Step 3: Construct facilities to allow the Richland-Chambers and Cedar Creek Reservoirs to operate as a system by about the year 2037.

Step 4: Construct Tehuacana Reservoir and a facility to divert supplemental water from the Trinity River into Tehuacana Reservoir by about 2042.

s. The above four-step program would provide an estimated new supply of 237,000 AF/Y, or slightly more than the projected need of 213,000 AF/Y as of 2050.

t. Of the various available ways to increase the District's total supply to meet expected requirements through 2050, the Trinity diversion approach outlined in paragraph "r" above is believed to involve the least environmental impact, provided the District can be satisfied that it is safe from the public health standpoint.

u. Before reaching a final decision on the Trinity diversion concept, a program of further water quality testing, analysis and pilot-scale operation should be carried out, as described in the next chapter.

v. The third and fourth steps in the Trinity diversion scenario could be replaced by George Parkhouse Reservoir Stage II with relatively little effect on the long-term costs of supply.

w. The needed total incremental supply of 213,000 AF/Y through 2050 could also be provided from George Parkhouse Reservoir Stages I and II or from either stage of the Marvin Nichols Reservoir project. Because of the size and cost of Marvin Nichols Stage I, it probably would be necessary to join with others and share the costs and yield of that project.

x. The District has time to investigate the public health aspect of the Trinity River diversions in a deliberate and careful manner before making a final decision. However, development of a significant amount of new water supply is already a slow and difficult process, and it may become slower and more difficult in the future. It would be prudent to set a target date to make a definite decision by no later than the year 2000.

y. The selected plan should be reviewed and updated at approximately 10-year intervals in the future. Because the plan is to be implemented in a number of separate steps over a 60-year period, it is relatively flexible and can be adjusted to allow for new conditions when and if they occur. In general, the individual steps can be rearranged, or substitutions can be made where appropriate, without losing the benefit of steps already completed.

12. IMPLEMENTATION PLAN

Based on the projections of the District's future water requirements, it will be 20 years or more before construction should be started on facilities for the next increment of supply. Present indications are that the best choice will be to increase the dependable yields of Richland-Chambers Reservoir and Cedar Creek Reservoir by 30 percent through diverting supplemental water from the Trinity River into the lakes. It is estimated that the 30 percent gain in yield should be made available at Richland-Chambers by about the year 2016, followed by Cedar Creek in about the year 2028. The yield increases at the two reservoirs are expected to meet the growth in requirements until about the year 2037. The balance of the projected future needs through 2050 can be met by system operation of Richland-Chambers and Cedar Creek Reservoirs, beginning about 2037, and construction of Tehuacana Reservoir in about 2042.

From the results of this study, the above scenario is indicated to be the most economical available alternative, and it also would have the least environmental impact. However, available information is not conclusive as to water quality in the Trinity River. The District should reserve judgment at this time, until it can confirm that the Trinity diversions would be safe in terms of water quality and public health. The District should plan to resolve this question and reach a definite decision by the year 2000.

To be able to provide the new supply when it is needed, the following activities should be started and completed by the indicated dates:

Water Quality - 1990-1995

a. Beginning in 1990 or 1991, perform additional detailed water quality monitoring of the Trinity River in the area of the proposed diversions, to develop more data on specific constituents at varying flow conditions.

b. Continue to monitor the water quality of Richland-Chambers and Cedar Creek Reservoirs. Expand the existing quality monitoring program in the areas of the lakes that would receive the diversions.

c. Set up a program of water quality sampling on Tehuacana Creek at or close to the proposed Tehuacana Dam site.

d. Calibrate and verify the eutrophication computer model for Richland-Chambers and Cedar Creek Reservoirs.

e. Using the total body of available data, including the additional data obtained under "a" above, run additional computer model simulations to show the effect of the Trinity diversions on the quality of water in Richland-Chambers and Cedar Creek Reservoirs.

f. Perform a preliminary investigation of possible treatment methods applicable to the Trinity River water, based on available water quality data.

g. Carry out a pilot-scale diversion demonstration project at Richland-Chambers Reservoir to determine whether there would be a need to pre-treat the river water as it is diverted and, if pre-treatment is needed, to determine the effectiveness of alternative methods such as natural systems, detention basins, chemical clarifiers, etc.

h. Develop a conceptual design of the required diversion facilities and pre-treatment facilities (if needed).

i. Prepare an updated opinion of probable diversion system costs.

Permits - 1990-1992

a. Confer with legal counsel and with the Texas Water Commission regarding a water right permit to cover the pilot-scale tests of diversion operation. Outline the over-all plan to the Commission.

b. Confer with the U.S. Army Corps of Engineers to determine whether a Section 404 permit will be needed for the pilot-scale testing program.

c. Apply for the necessary permits and assist the permitting agencies during their review if requested.

Environmental Information - 1990-1992

a. Assemble environmental information pertinent to the pilot-scale testing program.

b. Provide environmental information to the Texas Water Commission and the Corps of Engineers as needed during their reviews of permit applications for the pilot-scale testing program.

Decision on Trinity River Diversions - 1990-2000

a. Conduct a screening-level analysis of the environmental impacts of the main alternative sources of additional water supply for the District, to check the basic environmental acceptability of the Trinity diversion approach.

b. Make a final decision on the feasibility of supplemental diversions from the Trinity River into Richland-Chambers and Cedar Creek Reservoirs by the year 2000.

c. If the river diversions are found to require pretreatment beyond the basic settling pond stage assumed in the cost analyses of this report, prepare and consider a revised opinion of the probable cost of the diversion operation.

d. If the Trinity diversion approach is still found to be the preferred alternative, proceed with the activities described below under the heading "Permits - 2005-2010."

e. If it is determined that the diversion concept is not desirable or that the required degree of pre-treatment makes it uneconomical, proceed with development of the needed additional supply (213,000 AF/Y) in the Sulphur River Basin.

<u>Permits - 2005-2010</u>

a. Submit an application to the Texas Water Commission for water rights to divert supplemental water from the Trinity River into Richland-Chambers Reservoir sufficient to increase the dependable yield from 210,000 AF/Y to 273,000 AF/Y.

b. When the TWC permit is granted, submit an application to the Corps of Engineers for a Section 404 permit covering the diversions into Richland-Chambers Reservoir.

c. Provide additional information to the Commission and the Corps as required for their review of the applications. Present evidence and testimony as required at hearings on the applications.

Environmental Information - 2005-2010

a. Prepare an Environmental Information Document (EID) covering the environmental effects of the proposed diversions from the Trinity River into Richland-Chambers Reservoir.

b. Furnish the EID to the Texas Water Commission and the Corps of Engineers along with the permit applications described above.

Richland-Chambers Additional Yield - 2010-2015

a. Prepare construction plans and specifications for the facilities to divert Trinity River water to Richland-Chambers Reservoir.

b. Construct facilities for Trinity diversions into Richland-Chambers.

c. Design and construct additional pump station and pipeline facilities for delivery of the increased yield to Tarrant County.

Transmission Improvements - 2015-2025

Design and construct further additional capacity in the transmission facilities for delivery of raw water from Richland-Chambers and Cedar Creek Reservoirs.

Cedar Creek Additional Yield - 2022-2027

a. Obtain permits from the Texas Water Commission and the Corps of Engineers for construction of Trinity diversion facilities at Cedar Creek Reservoir sufficient to increase the dependable yield from

175,000 AF/Y to 227,500 AF/Y.

b. Design and construct the Trinity River diversion facilities at Cedar Creek Reservoir.

Additional Transmission Capacity - 2026-2030

Design and construct additional pump and pipeline capacity for delivery of raw water from Richland-Chambers and Cedar Creek Reservoirs.

System Operation - 2037

Begin coordinated system operation of Richland-Chambers and Cedar Creek Reservoirs.

Tehuacana Reservoir - 2030-2042

a. Obtain the necessary permits for construction of Tehuacana Reservoir.

b. Design and construct Tehuacana Reservoir.

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