Volumetric Survey of Cedar Creek Reservoir

July 2005 Survey

Prepared by:

The Texas Water Development Board

April 2007

Texas Water Development Board

J. Kevin Ward, Executive Administrator

Prepared for:

Tarrant Regional Water District

This report was prepared by staff of the Surface Water Resources Division:

Barney Austin, Ph.D.
Jordan Furnans, Ph.D., P.E.
Duane Thomas
Randall Burns
Tony Connell
Holly Weyant

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Executive Summary

In March of 2005, the Texas Water Development Board (TWDB) entered into agreement with the Tarrant Regional Water District (TRWD, formerly the Tarrant County Water Control and Improvement District Number One), for the purpose of performing a volumetric survey of Cedar Creek Reservoir while the reservoir was at or near the top of the conservation pool elevation. The information gathered was converted into updated Elevation-Volume and Elevation-Area Tables. Additionally, the results of the 2005 survey were compared to a previous survey of Cedar Creek Reservoir conducted by TWDB in 1995 and to original design information. All elevations in this report are referenced to the reservoir gauge datum, the National Geodetic Vertical Datum of 1929 (NGVD 1929) or mean sea level (msl). The horizontal datum used in this report is the North American Datum of 1983, using the English units feet.

Initial results of the 2005 TWDB Survey indicated a small decrease in volume from the 1995 TWDB Survey, however during their review; TRWD noticed an apparent increase in volume from 1995 to 2005 above elevations starting near 295 ft, these results seem to be contradictory to known sedimentation processes, prompting the TWDB to re-examine their results. A complete discussion of the examination and subsequent revisions of the TWDB 1995 and 2005 surveys can be found in Appendix I “Analysis of Cedar Creek Survey Results”. The findings of this examination suggest that the increase in volume from 1995 to 2005 is likely due to better data collection in the shallow areas and side arms of the reservoir in the later survey. Additionally, sedimentation appears to be taking place at elevations below the elevation of 294.0 ft, as defined in the 1995 TWDB Survey. **The results of the TWDB revised 2005 Survey indicate Cedar Creek Reservoir has a volume of 644,785 acre-feet and encompasses 32,873 acres at the conservation pool elevation of 322.0 feet above (NGVD 1929).**

Range lines were established throughout the reservoir to facilitate cross sectional comparisons between the revised TWDB 1995 and 2005 surveys. Appendix G contains a map showing range line locations and includes Table 3 listing range line endpoint coordinates. Cross sectional plots are presented in Appendix H.

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Cedar Creek Reservoir General Information

Cedar Creek Reservoir is located on Cedar, Kings, Clear, Caney and Twin Creeks in Kaufman and Henderson Counties, approximately twenty miles east of Corsicana, Texas and three miles northeast of Trinidad, Texas (Figure 1). The dam is owned, maintained, and operated by TRWD and the water rights are allocated to the TRWD under Water Rights Certificate of Adjudication No. 4976 issued May 5, 1987. This certificate allows TRWD to maintain a dam and impound a reservoir known as Cedar Creek Reservoir with a capacity of 678,900 acre-feet and to divert and use not to exceed 175,000 acre-feet of water per annum from said reservoir for municipal and industrial purposes. An amendment to Certificate of Adjudication No. 4976A was granted July 28, 1993. It allocated 2,500 of the 175,000 acre-feet of water per annum (for municipal and industrial purposes) to be used for irrigation purposes until such time as this water is needed for municipal and industrial use.[1] Complete certificates are on file in the Records Division of the Texas Commission on Environmental Quality (TCEQ).

Dam construction commenced in April, 1961, deliberate impoundment of water began July 2, 1965 and the facility was completed in February, 1966. Freese, Nichols and Endress Consulting Engineers designed the project and the general contractor was S. A. Construction Company. The dam structure is a rolled earthfill embankment. The dam is approximately 17,539 feet long and rises 91 feet above the natural streambed.[2]

The service spillway and outlet works are located six miles upstream on the right bank and discharge into the Trinity River. The service spillway consists of a gated concrete chute approximately 400 feet long at elevation 302.0 feet, controlled by eight 40-foot wide tainter gates and two 40-foot wide bascule (automatic) gates. With all 10 gates fully opened, the spillway has a discharge capacity of 105,000 cubic feet per second (cfs) when the reservoir pool elevation is at 322.0 feet above NGVD 1929. The outlet works consist of one 60-inch steel pipe for low flow discharge, one 18-inch valve controlled outlet for water supply, and two 24-inch valves for water supply.

Pertinent information for Joe B. Hogsett Dam and Cedar Creek Reservoir is presented below in Table 1, while a map showing the location of Cedar Creek Reservoir is presented in Figure 1 on the following page.

Table 1. Pertinent Data for Joe B. Hogsett Dam and Cedar Creek Reservoir[2]

Owner of Cedar Creek Reservoir and Facilities
Tarrant County Water Improvement District Number One (Tarrant Regional Water District)
Engineer (Design)
Freese, Nichols, and Endress
Location
On Cedar Creek in Henderson County, 3 miles northeast of Trinidad.
Drainage Area
1,007 square miles.

Dam			
Type	Earthfill		
Length	17,539 ft		
Maximum Height	91 ft		
Top Width	20 ft		
Spillway			
Type	Gated concrete chute		
Control	8 tainter gates, each 40 by 23 ft 2 bascule (automatic) gates; each 40 by 8.5 ft		
Crest length (net)	400 ft		
Crest elevation	302.0 ft above msl		
Outlet Works			
One 60-inch steel pipe for low-flow discharge.			
One 18-inch valve controlled outlet for water supply.			
Two 24-inch valve controlled outlets for water supply.			
General			
Construction started	April 1961		
Deliberate impoundment began	July 2, 1965		
Dam completed	February 1966		
General Contractor for the Dam	S. A. Construction Company		
Ceneral Contractor for the spillway	Gibralter Construction Company		
Estimated cost of dam	$20,500,000		
Reservoir Data (Based on TWDB 2005 revised Volumetric Survey)			
Feature	**Elevation (ft above msl)**	**Capacity (Acre-feet)**	**Area (Acres)**
Top of Dam	340.0	N/A	N/A
Top of tainter gates	325.5	N/A	N/A
Top of bascule (automatic) gates	322.5	N/A	N/A
Top of conservation pool	322.0	644,785	32,873
Spillway Crest automatic gates	314.0	413,817	25,113
Spillway Crest tainter gates	302.0	182,158	13,805
Invert of conduit in the dam	263.5	99	44

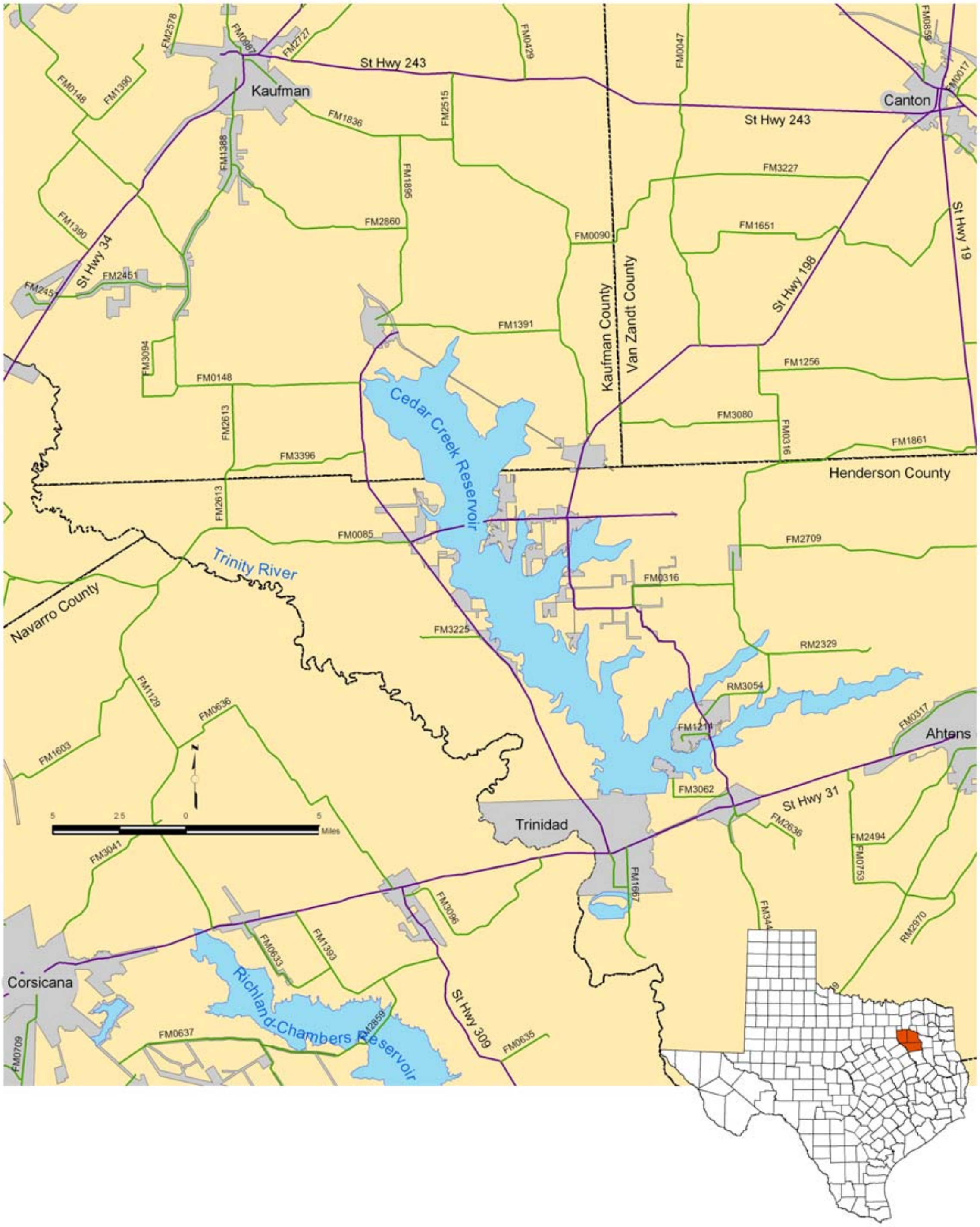


Figure 1. Location of Cedar Creek Reservoir in Henderson and Kaufman counties, near the cities of Corsicana, Trinidad, and Athens.

Volumetric Survey of Cedar Creek Reservoir

Introduction

The TWDB Hydrographic Survey Program was authorized by the state legislature in 1991. The Texas Water Code authorizes the TWDB, at the request of a political subdivision, to perform a survey to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, projected water supply availability, or potential mitigative measures, and to conduct other bathymetric studies.

In August of 2005, the Texas Water Development Board entered into agreement with the Tarrant Regional Water District for the purpose of performing a volumetric survey of Cedar Creek Reservoir while the reservoir was at or near the top of conservation pool elevation (322.0 ft). This information was converted into updated Elevation-Volume and Elevation-Area Tables. Initial results of the 2005 TWDB Survey indicated a small decrease in volume from the 1995 TWDB Survey however, during their review; TRWD noticed an apparent increase in volume from 1995 to 2005 above elevations starting near 295 ft. These results seemed contradictory to known sedimentation processes prompting the TWDB to further investigate their results. The results of the re-examination are presented in this report and herein are referred to as the revised 1995 and 2005 surveys. A complete write up of the re-examination is included in Appendix I of this report. Additionally, the results of the revised 2005 survey are compared to the revised 1995 TWDB Volumetric Survey of Cedar Creek Reservoir, and to the original design information on file. Cross-sectional plots of the revised 1995 and 2005 surveys are presented in Appendix H of this report.

Datum

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gauge USGS 080603010 Cedar Ck Res nr Trinidad, TX.[3] Volume and area calculations in this report are referenced to water levels provided by the USGS gauge. The datum for this gauge is reported as National Geodetic Vertical Datum 1929 (NGVD29)[4] or mean sea level (msl), thus elevations reported here are in feet (ft) above NGVD 1929. The horizontal datum used for this report is North American Datum of 1983 (NAD83) State Plane Texas North Central Zone (feet) however, the revised TIN models were constructed using NAD83 State Plane Texas North Central Zone (meters) and subsequently converted into feet.

Bathymetric Survey

Bathymetric data collection for Cedar Creek Reservoir occurred between July 19th and July 25th of 2005, while the water surface elevation varied between 321.05 ft and 320.93 ft, slightly below the conservation pool elevation of 322.0 ft. The survey team used two boats equipped with survey grade depth sounders, velocity profilers, and integrated Differential Global Positioning System (DGPS) equipment to navigate along pre-planned range lines. The pre-planned range lines were spaced approximately 500 feet apart and positioned in a perpendicular fashion to the original stream channels. A commercially available software package, HYPACK MAX, is used to integrate the depth sounder and GPS equipment into a complete survey system and assist the operators in navigating the boats along the pre-planned lines.

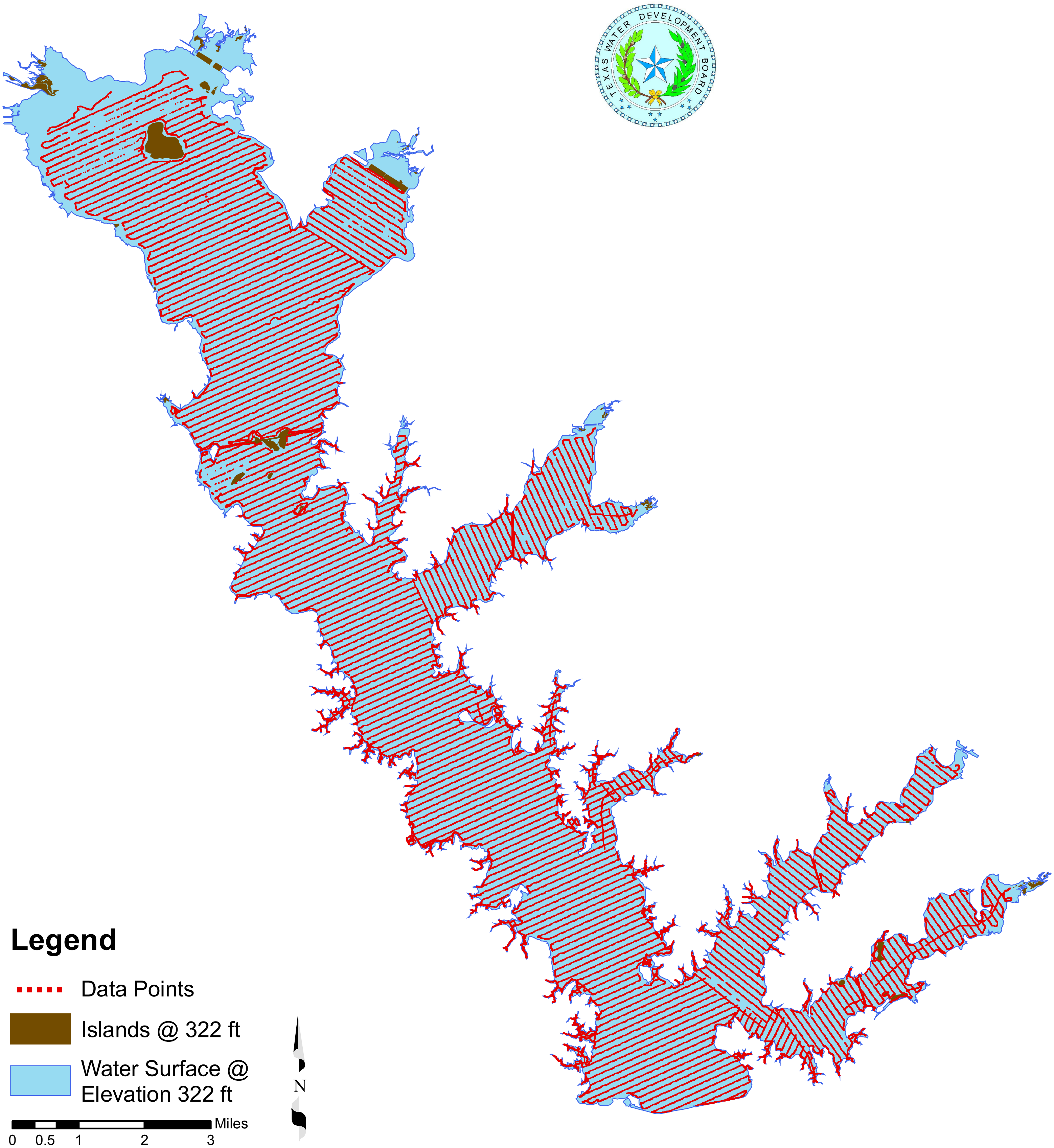
At the beginning of each survey day the depth sounders are calibrated using a velocity profiler. The velocity profiler automatically measures and records a speed-of-sound profile through water column and computes an average speed-of-sound value in a particular survey area. The speed-of-sound is then entered into the depth sounder and a modified bar check, consisting of lowering a weighted tape in water deeper than 15 ft or using a stadia rod (calibrated survey rod) in shallower water, is conducted to verify that the depth sounder is calibrated and reading properly. The data is then spot-checked during the survey day to maintain accuracy.

During the 2005 survey, the team navigated over 630 miles of range lines and collected over 255,040 data points. Figure 2, on page 6, shows the data points collected during the TWDB 2005 survey.

Figure 2

Cedar Creek Reservoir

Data Points Collected During 2005 TWDB Survey



Survey Results

As mention earlier, initial results seemed contradictory to known processes resulting in a re-examination of the initial analysis. Four cases were examined during this investigation and are briefly discussed in the following section on Triangular Irregular Network Model with a comprehensive discussion entitled, “Analysis of Cedar Creek Survey Results”, presented in Appendix G.

The results of the TWDB 2005 Survey indicate Cedar Creek Reservoir has a volume of 644,785 acre-feet and encompasses 32,873 acres at conservation pool elevation. Table 2 presents the results of the revised TWDB 1995 and 2005 surveys along with original design data for Cedar Creek Reservoir in Table 2.

Table 2: Area and Volume Comparisons of Cedar Creek Reservoir

Feature	TRWD Original Design*	TWDB 1995 revised Volumetric Survey	TWDB 2005 revised Volumetric Survey
Year	1965	1995	2005
Area (Acres)	33,750	32,873	32,873
Volume (Acre-feet)	679,200	640,415	644,785

*Original design information from 1965 as reported by the TRWD[2].

Since the revisions for both the 1995 and 2005 surveys used the same boundary for the area calculations, they reflect an approximate reduction in surface area of 878 acres from original design specifications. However, most of that loss is most likely attributed to improved measurement techniques and the use of higher resolution aerial photography to digitize the boundary. The revised TWDB 2005 results would indicate an approximate loss of 5% in total volume since 1965.

The methods used to calculate original design capacities are unknown, while the method used to calculate areas and volumes for this report are described in the following section on Data Processing and in Appendix G. Due to the methodological differences in computing the area and volume, direct comparisons of the TWDB surveys to the original design information for Cedar Creek Reservoir is not recommended and numbers are presented here for informational purposes only.[5]

Data Processing

Model Boundary

The reservoir boundary was digitized from aerial photographs using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software. The aerial photographs, or digital orthophoto quadrangle images (DOQs), used for Cedar Creek Reservoir were Malakoff, Kerens, Mabank, Tool, Prairieville, Kemp, Grays Prairie, Mallard Hill, and Stockard. These images were photographed between March 8th and March 21st of 1995. At the time of the photographs the water surface elevation varied between 321.97 ft and 322.01 ft. At the recommended mapping scale of 1:12,000 for the DOQs, the difference in the land water interface between photos of varying water surface elevations is indiscernible. Therefore, for modeling purposes, the boundary was digitized at the land water interface from the photos, and assigned the conservation pool elevation of 322.0 ft.

VARGIS of Texas LLC produced the DOQs for the Texas Orthoimagery Program (TOP). DOQs produced for the Department of Information Resources and the GIS Planning Council under the TOP reside in the public domain. More information can be obtained on the Internet at http://www.tnris.state.tx.us/DigitalData/doqs.htm.

Triangular Irregular Network (TIN) Model

Upon completion of data collection, the raw data files are edited in HYPACK MAX to remove any data anomalies. The water surface elevations for each respective day are applied and the depths are converted to corresponding elevations and exported as a MASS points file. The MASS points and boundary files are used to create a Triangulated Irregular Network (TIN) model, a function of the 3D Analyst Extension of ArcGIS. The model uses Delauney's criteria for triangulation to place a triangle between three non-uniformly spaced points, including the boundary.[6]

Additionally, TWDB has developed a command line software program, HydroEdit 1.0, which automates the data processing and interpolates depth values in inaccessible shallow areas of the reservoir. A TIN model was constructed from the output of this program and compared to the TIN model constructed from the manually edited HYPACK data. The TIN model produced from the HydroEdit 1.0 program had an overall volume increase of 6,861ac-ft or approximately a 1% increase in volume over the TIN model created from the manually edited data. Analysis of the two TIN models and associated bathymetric data indicate that HydroEdit produces more accurate results. Using Arc/Info software, volumes and areas are calculated from the TIN Models for the entire lake at one-tenth of a foot intervals, from elevation 254.4 ft to elevation 322.0 ft.

Four separate TIN models were created from the 1995 and 2005 data sets in the following manner:

1) The original 1995 TIN was recreated using the original data and boundary and the Elevation-Area and Elevation-Volume Tables (EA-EV Tables) are presented in Appendix A.
2) The original 2005 TIN was created using the manually edited data from HYPACK and boundary digitized from aerial photography. The EA-EV Tables are presented in Appendix B.
3) The revised 1995 TIN was created using the HydroEdit program to interpolate data points in the shallow areas and the 2005 boundary. The EA-EV Tables are presented in Appendix C.
4) The revised 2005 TIN was created using the HydroEdit program's automated data editing feature, the shallow area interpolation feature, and the 2005 boundary. The EA-EV Tables are presented in Appendix D and are considered by the TWDB to be the most up to date as of this report.

Again, a comprehensive description of the HydroEdit procedures and its application to the 1995 and 2005 data set is presented in Appendix I.

The revised 2005 TIN Model was converted to a raster image using a cell size of 10 ft. Using this raster, the TWDB Hydro Survey team produced Figure 3, an Elevation Relief Map representing the topography of the lake bottom, Figure 4, a map showing shaded depth ranges for Cedar Creek Reservoir, both found on the following pages, and Figure 5, a 5 ft contour map located in the rear pocket of this report.

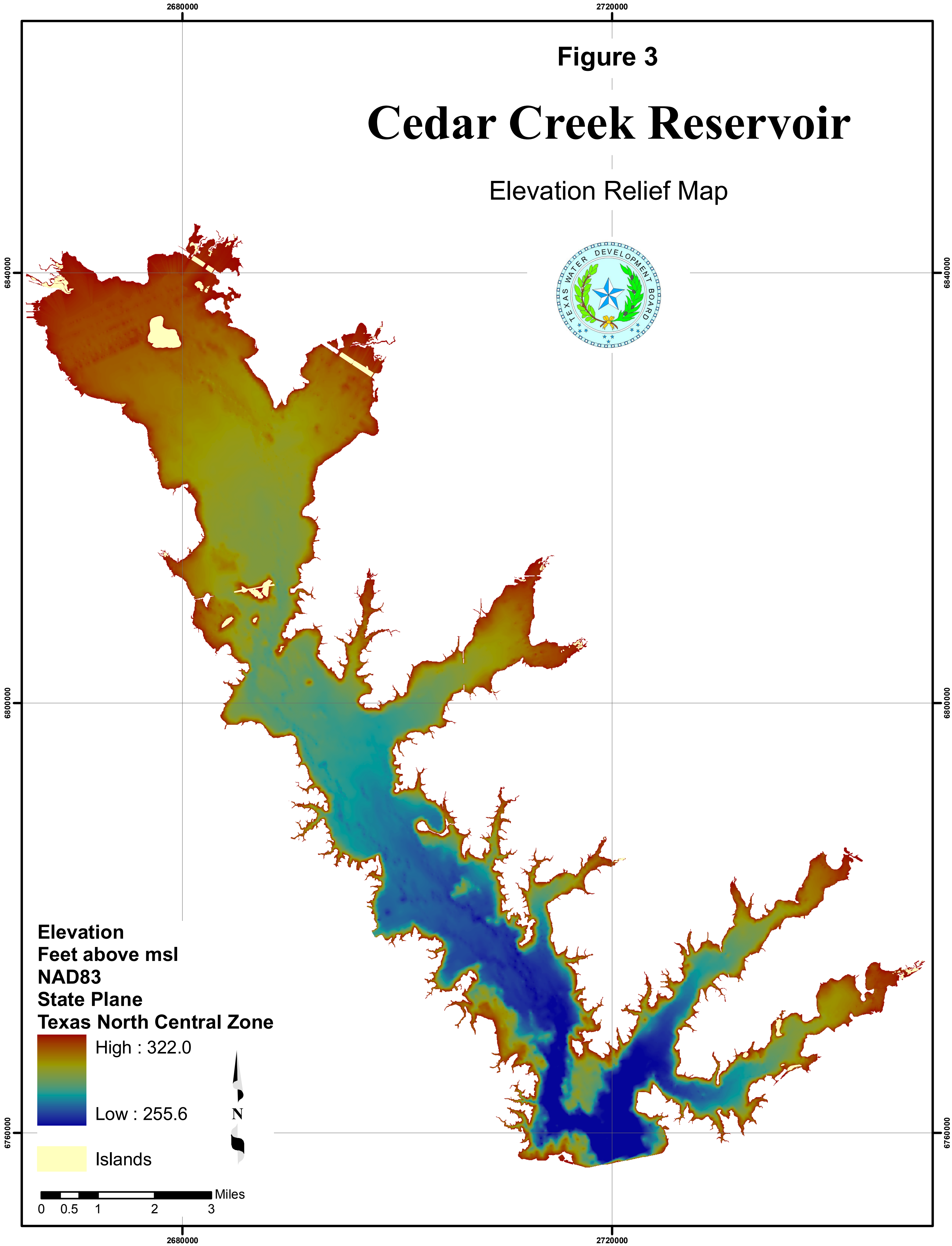


Figure 3

Cedar Creek Reservoir

Elevation Relief Map

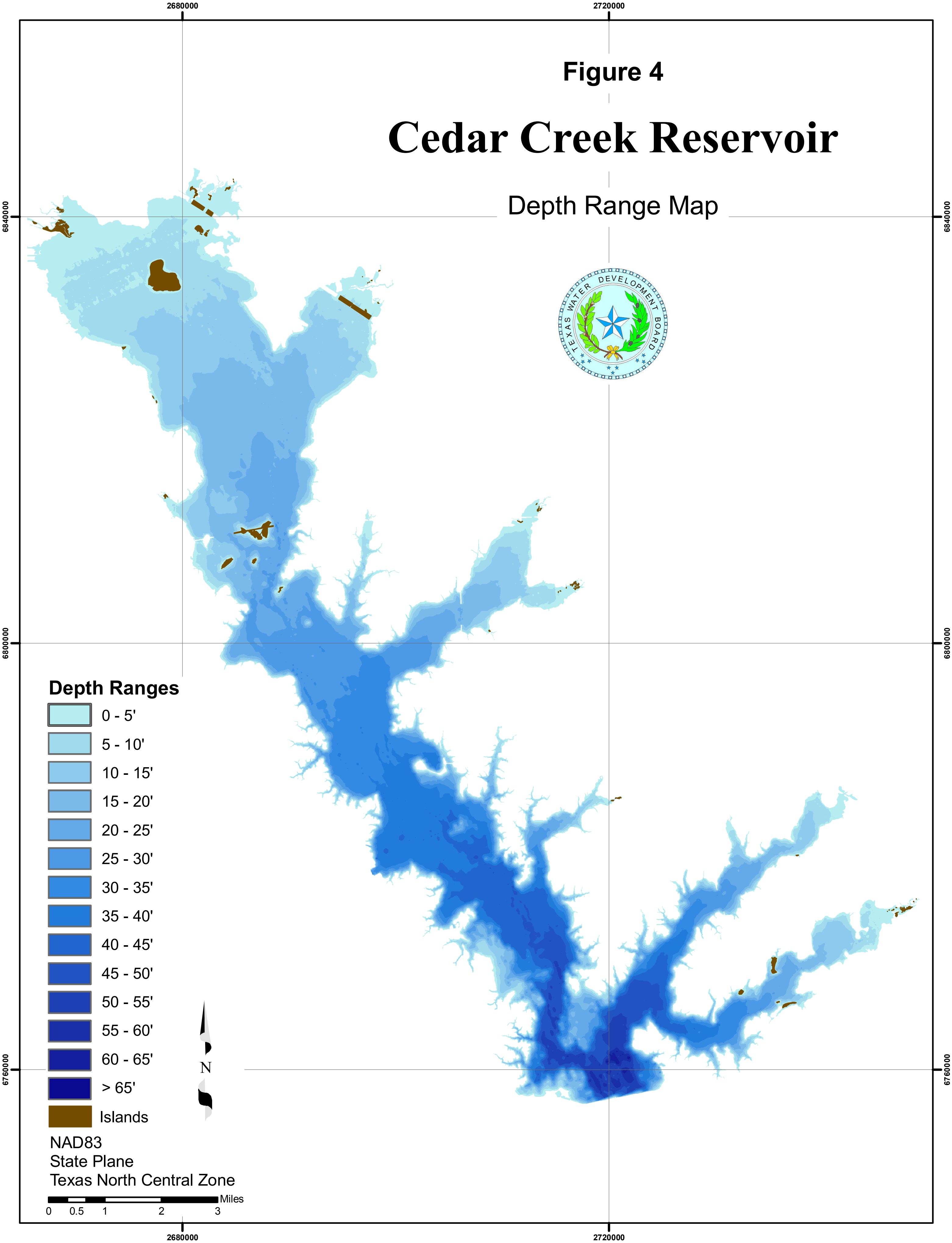


Figure 4

Cedar Creek Reservoir

Depth Range Map

Sediment Range Lines

For comparing and inspecting differences between the revised 1995 and 2005 surveys, 24 range lines were created and depths were extracted, at 5 foot intervals, along each line. The resulting data sets were then plotted as depth verses distance. Appendix G contains both a map showing range line locations and Table 3 listing endpoint coordinates. The cross-sectional plots are presented in Appendix H.

TWDB Contact Information

More information about the Hydrographic Survey Program can be found at: http://www.twdb.state.tx.us/assistance/lakesurveys/volumetricindex.asp. Any questions regarding the TWDB Hydrographic Survey Program may be addressed to Barney Austin, Director of Surface Water Resources, at 512-463-8856, or by email at: Barney.Austin@twdb.state.tx.us.

References

1. Texas Water Commission, 1993, Amendment to Certificate of Adjudication, No. 08-4976A.

2. Texas Water Development Board, Report 126, Engineering Data on Dams and Reservoirs in Texas, Part II, November 1973.

3. United States Geological Survey, http://tx.usgs.gov/, 26 July 2005.

4. National Geodetic Survey, United States Department of Commerce, viewed November 2, 2006, http://www.ngs.noaa.gov/faq.shtml.

5. United States Department of Agriculture, Natural Resource Conservation Service, National Engineering Handbook, Section 3, Sedimentation, Chapter 7, Field Investigations and Surveys, December 1983.

6. ESRI, Environmental Systems Research Institute. 1995. ARC/INFO Surface Modeling and Display, TIN Users Guide.

Appendix A

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

March 1995 Survey - Original

Conservation Pool Elevation 322.0 ft

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
254					0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	1	1	1	1	1	1	1
257	1	2	2	2	3	3	3	4	4	4
258	5	5	6	6	7	7	8	8	8	9
259	9	10	10	11	11	12	12	13	14	14
260	15	15	16	17	18	19	19	20	21	22
261	22	23	24	25	25	26	27	28	29	30
262	31	33	34	35	37	38	40	42	43	45
263	47	48	50	52	54	56	58	60	62	64
264	66	69	71	73	75	77	79	81	84	87
265	89	92	95	98	102	105	109	113	118	122
266	127	132	136	141	147	151	156	161	166	171
267	175	180	185	190	195	200	205	211	216	220
268	225	230	235	240	245	250	256	262	267	273
269	279	286	292	299	306	314	322	330	338	346
270	354	363	373	383	393	404	415	427	440	456
271	474	490	505	520	535	552	569	584	600	618
272	635	652	670	689	708	729	749	767	785	803
273	820	838	856	878	897	915	934	951	970	989
274	1,009	1,029	1,050	1,073	1,094	1,114	1,133	1,153	1,175	1,196
275	1,217	1,240	1,262	1,284	1,306	1,328	1,349	1,372	1,394	1,416
276	1,437	1,458	1,480	1,503	1,526	1,550	1,576	1,601	1,626	1,651
277	1,676	1,703	1,730	1,758	1,788	1,819	1,852	1,886	1,918	1,950
278	1,982	2,017	2,049	2,078	2,107	2,134	2,161	2,189	2,218	2,250
279	2,283	2,315	2,347	2,379	2,410	2,443	2,475	2,505	2,535	2,565
280	2,596	2,627	2,660	2,693	2,725	2,758	2,791	2,827	2,864	2,903
281	2,942	2,981	3,021	3,063	3,107	3,151	3,193	3,233	3,271	3,312
282	3,354	3,397	3,438	3,475	3,515	3,556	3,598	3,643	3,685	3,729
283	3,774	3,819	3,864	3,908	3,951	3,995	4,038	4,080	4,124	4,168
284	4,215	4,263	4,313	4,361	4,413	4,466	4,524	4,581	4,635	4,688
285	4,737	4,790	4,846	4,898	4,949	5,000	5,047	5,091	5,132	5,172
286	5,212	5,251	5,290	5,331	5,374	5,420	5,464	5,506	5,549	5,595
287	5,640	5,682	5,724	5,764	5,805	5,847	5,892	5,939	5,987	6,028
288	6,068	6,106	6,145	6,186	6,230	6,273	6,317	6,361	6,404	6,448
289	6,495	6,542	6,589	6,639	6,690	6,739	6,787	6,838	6,892	6,943
290	6,991	7,039	7,087	7,138	7,188	7,237	7,291	7,350	7,413	7,474
291	7,530	7,585	7,642	7,701	7,757	7,810	7,867	7,925	7,980	8,040
292	8,095	8,150	8,202	8,257	8,316	8,370	8,425	8,480	8,531	8,579
293	8,626	8,672	8,718	8,762	8,806	8,852	8,898	8,942	8,985	9,029
294	9,073	9,116	9,159	9,203	9,247	9,290	9,332	9,379	9,429	9,480
295	9,530	9,580	9,631	9,683	9,737	9,790	9,849	9,906	9,960	10,011
296	10,064	10,120	10,173	10,224	10,273	10,322	10,370	10,418	10,467	10,517
297	10,570	10,624	10,678	10,729	10,779	10,829	10,878	10,929	10,981	11,034
298	11,086	11,136	11,187	11,238	11,288	11,340	11,391	11,442	11,494	11,546
299	11,600	11,654	11,708	11,763	11,814	11,866	11,918	11,972	12,026	12,081
300	12,139	12,198	12,258	12,318	12,380	12,442	12,509	12,579	12,658	12,737
301	12,814	12,890	12,964	13,034	13,101	13,168	13,236	13,309	13,384	13,459
302	13,541	13,633	13,730	13,818	13,901	13,975	14,046	14,114	14,181	14,248
303	14,323	14,401	14,481	14,567	14,655	14,744	14,835	14,923	15,011	15,095
304	15,181	15,270	15,361	15,451	15,544	15,633	15,723	15,811	15,903	15,993
305	16,084	16,177	16,269	16,355	16,441	16,529	16,619	16,706	16,792	16,881
306	16,977	17,066	17,149	17,231	17,319	17,406	17,499	17,596	17,694	17,795
307	17,893	17,990	18,091	18,203	18,316	18,433	18,543	18,644	18,747	18,849
308	18,951	19,050	19,144	19,240	19,338	19,436	19,536	19,634	19,736	19,836

Appendix A (continued)

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

March 1995 Survey - Original

Conservation Pool Elevation 322.0 ft

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
309	19,934	20,028	20,120	20,210	20,298	20,388	20,477	20,569	20,662	20,756
310	20,850	20,950	21,056	21,156	21,251	21,342	21,427	21,510	21,590	21,669
311	21,749	21,834	21,925	22,023	22,123	22,223	22,312	22,403	22,493	22,585
312	22,689	22,797	22,896	22,991	23,087	23,183	23,276	23,365	23,456	23,547
313	23,642	23,739	23,838	23,933	24,026	24,117	24,211	24,307	24,401	24,494
314	24,588	24,683	24,783	24,897	25,014	25,130	25,240	25,343	25,444	25,543
315	25,640	25,735	25,830	25,928	26,026	26,130	26,244	26,353	26,458	26,562
316	26,664	26,766	26,872	26,981	27,090	27,192	27,287	27,379	27,468	27,560
317	27,656	27,759	27,864	27,963	28,060	28,161	28,264	28,369	28,480	28,579
318	28,673	28,767	28,854	28,939	29,021	29,101	29,180	29,259	29,339	29,416
319	29,494	29,579	29,670	29,763	29,818	29,872	29,927	29,982	30,037	30,092
320	30,148	30,204	30,260	30,316	30,372	30,429	30,486	30,543	30,600	30,658
321	30,715	30,773	30,831	30,890	30,948	31,007	31,066	31,125	31,184	31,244
322	32,623									

Appendix A

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — March 1995 Survey - Original

Conservation Pool Elevation 322.0 ft

VOLUME IN ACRE-FT — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
254					0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	1	1	1	1	1
257	1	1	1	2	2	2	2	3	3	3
258	4	4	5	6	6	7	8	8	9	10
259	11	12	13	14	15	16	18	19	20	22
260	23	24	26	28	29	31	33	35	37	39
261	42	44	46	49	51	54	56	59	62	65
262	68	71	75	78	82	85	89	93	98	102
263	107	111	116	121	127	132	138	144	150	156
264	163	170	177	184	191	199	206	215	223	231
265	240	249	259	268	278	288	299	310	322	334
266	346	359	373	387	401	416	431	447	463	480
267	498	515	534	552	572	591	612	633	654	676
268	698	721	744	768	792	817	842	868	894	921
269	949	977	1,006	1,036	1,066	1,097	1,129	1,161	1,195	1,229
270	1,264	1,300	1,336	1,374	1,413	1,453	1,494	1,536	1,579	1,624
271	1,670	1,719	1,768	1,819	1,872	1,927	1,983	2,040	2,099	2,160
272	2,223	2,287	2,353	2,421	2,491	2,563	2,637	2,713	2,790	2,870
273	2,951	3,034	3,119	3,205	3,294	3,385	3,477	3,571	3,667	3,765
274	3,865	3,967	4,071	4,177	4,286	4,396	4,508	4,623	4,739	4,858
275	4,978	5,101	5,226	5,353	5,483	5,615	5,749	5,885	6,023	6,163
276	6,306	6,451	6,598	6,747	6,898	7,052	7,208	7,367	7,528	7,692
277	7,859	8,028	8,199	8,374	8,551	8,731	8,915	9,102	9,292	9,485
278	9,682	9,882	10,085	10,291	10,501	10,713	10,928	11,145	11,365	11,589
279	11,815	12,045	12,278	12,515	12,754	12,997	13,243	13,492	13,744	13,999
280	14,257	14,518	14,782	15,050	15,321	15,595	15,872	16,153	16,438	16,726
281	17,018	17,315	17,615	17,919	18,227	18,540	18,857	19,179	19,504	19,833
282	20,166	20,504	20,846	21,191	21,541	21,894	22,252	22,614	22,980	23,351
283	23,726	24,106	24,490	24,879	25,272	25,669	26,071	26,476	26,887	27,301
284	27,720	28,144	28,573	29,007	29,445	29,889	30,339	30,794	31,255	31,721
285	32,192	32,668	33,150	33,637	34,130	34,627	35,129	35,636	36,148	36,663
286	37,182	37,705	38,232	38,763	39,298	39,838	40,382	40,931	41,484	42,041
287	42,603	43,169	43,739	44,313	44,892	45,474	46,061	46,653	47,249	47,850
288	48,455	49,063	49,676	50,292	50,913	51,538	52,168	52,802	53,440	54,083
289	54,730	55,382	56,038	56,699	57,366	58,037	58,714	59,395	60,081	60,773
290	61,470	62,171	62,878	63,589	64,305	65,026	65,753	66,485	67,223	67,967
291	68,717	69,473	70,235	71,002	71,775	72,553	73,337	74,126	74,921	75,723
292	76,529	77,342	78,159	78,982	79,811	80,645	81,485	82,330	83,180	84,036
293	84,896	85,761	86,631	87,505	88,383	89,266	90,154	91,046	91,942	92,842
294	93,748	94,657	95,571	96,489	97,411	98,338	99,269	100,205	101,145	102,091
295	103,041	103,997	104,957	105,923	106,894	107,870	108,852	109,840	110,833	111,832
296	112,835	113,845	114,859	115,879	116,904	117,934	118,968	120,008	121,052	122,101
297	123,156	124,215	125,281	126,351	127,426	128,507	129,592	130,682	131,778	132,878
298	133,984	135,096	136,212	137,333	138,459	139,591	140,727	141,869	143,015	144,168
299	145,325	146,488	147,656	148,829	150,008	151,192	152,381	153,576	154,775	155,981
300	157,192	158,409	159,632	160,860	162,095	163,336	164,584	165,838	167,100	168,370
301	169,647	170,933	172,226	173,525	174,832	176,145	177,466	178,793	180,127	181,469
302	182,819	184,178	185,546	186,923	188,309	189,703	191,104	192,513	193,927	195,349
303	196,777	198,213	199,657	201,109	202,571	204,040	205,519	207,007	208,504	210,009
304	211,523	213,045	214,577	216,117	217,667	219,226	220,794	222,371	223,956	225,551
305	227,155	228,768	230,390	232,021	233,661	235,309	236,967	238,633	240,308	241,992
306	243,684	245,387	247,098	248,816	250,544	252,280	254,025	255,780	257,544	259,319
307	261,103	262,897	264,702	266,516	268,342	270,179	272,028	273,888	275,756	277,636
308	279,526	281,427	283,337	285,255	287,184	289,123	291,072	293,030	294,998	296,977

Appendix A (continued)

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

March 1995 Survey - Original

Conservation Pool Elevation 322.0 ft

VOLUME IN ACRE-FT

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
309	298,966	300,964	302,971	304,987	307,013	309,047	311,091	313,143	315,204	317,275
310	319,355	321,445	323,546	325,656	327,776	329,906	332,045	334,192	336,346	338,509
311	340,680	342,860	345,047	347,244	349,452	351,669	353,896	356,132	358,376	360,630
312	362,893	365,168	367,453	369,747	372,051	374,364	376,688	379,020	381,360	383,710
313	386,070	388,439	390,818	393,206	395,604	398,011	400,428	402,854	405,289	407,733
314	410,188	412,651	415,125	417,608	420,104	422,611	425,130	427,659	430,198	432,747
315	435,306	437,876	440,454	443,041	445,639	448,247	450,866	453,496	456,135	458,787
316	461,448	464,120	466,802	469,494	472,198	474,912	477,636	480,370	483,111	485,863
317	488,624	491,395	494,176	496,967	499,768	502,579	505,401	508,232	511,074	513,927
318	516,790	519,662	522,544	525,433	528,331	531,237	534,152	537,073	540,003	542,941
319	545,886	548,840	551,803	554,773	557,752	560,737	563,727	566,723	569,723	572,730
320	575,742	578,759	581,783	584,811	587,846	590,886	593,932	596,983	600,040	603,103
321	606,172	609,246	612,327	615,412	618,504	621,602	624,706	627,816	630,930	634,052
322	637,180									

Appendix B

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — JULY 2005 SURVEY (Original)

Conservation Pool Elevation 322.0 ft

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
255						0	0	0	0	0
256	0	0	0	0	0	0	0	0	0	0
257	0	0	0	1	1	2	2	2	3	3
258	4	4	4	5	5	5	6	6	7	7
259	8	9	9	10	10	10	11	11	12	12
260	12	13	13	14	14	15	15	16	16	17
261	18	18	19	20	20	21	21	22	23	24
262	24	25	26	27	28	29	30	31	33	34
263	36	37	39	40	42	44	45	47	49	51
264	54	56	58	60	63	64	66	68	70	72
265	74	76	78	80	82	85	87	90	93	96
266	99	103	106	111	115	120	125	130	135	140
267	146	151	156	162	167	171	176	181	185	190
268	194	199	204	209	214	220	225	231	237	243
269	249	255	262	269	277	285	293	301	309	317
270	326	334	344	354	365	378	391	405	420	438
271	454	469	484	499	515	531	549	567	586	604
272	623	641	659	677	695	714	732	750	769	789
273	809	829	849	867	885	902	918	934	951	968
274	985	1,002	1,019	1,037	1,055	1,071	1,087	1,103	1,120	1,137
275	1,154	1,172	1,190	1,208	1,228	1,247	1,269	1,290	1,310	1,329
276	1,347	1,365	1,384	1,403	1,422	1,441	1,461	1,482	1,503	1,525
277	1,549	1,574	1,599	1,624	1,650	1,676	1,702	1,727	1,753	1,782
278	1,810	1,842	1,873	1,906	1,936	1,967	1,999	2,032	2,066	2,099
279	2,130	2,164	2,199	2,234	2,268	2,299	2,330	2,362	2,395	2,428
280	2,462	2,496	2,531	2,564	2,597	2,630	2,663	2,698	2,736	2,778
281	2,821	2,861	2,902	2,940	2,979	3,018	3,057	3,096	3,137	3,183
282	3,230	3,273	3,314	3,354	3,398	3,441	3,485	3,530	3,574	3,618
283	3,661	3,704	3,745	3,785	3,826	3,868	3,910	3,953	4,000	4,048
284	4,099	4,144	4,190	4,234	4,277	4,321	4,364	4,409	4,458	4,520
285	4,583	4,644	4,702	4,758	4,813	4,868	4,921	4,973	5,020	5,062
286	5,101	5,138	5,174	5,210	5,249	5,287	5,327	5,373	5,421	5,467
287	5,517	5,565	5,611	5,656	5,700	5,745	5,788	5,832	5,876	5,921
288	5,964	6,007	6,047	6,087	6,128	6,171	6,214	6,259	6,303	6,345
289	6,386	6,428	6,470	6,513	6,558	6,605	6,657	6,709	6,758	6,805
290	6,851	6,898	6,948	6,998	7,049	7,101	7,153	7,209	7,263	7,318
291	7,374	7,430	7,489	7,550	7,608	7,671	7,732	7,791	7,849	7,905
292	7,962	8,017	8,074	8,130	8,189	8,254	8,321	8,384	8,439	8,491
293	8,543	8,598	8,654	8,708	8,764	8,819	8,873	8,926	8,976	9,025
294	9,073	9,120	9,170	9,222	9,279	9,336	9,391	9,441	9,489	9,536
295	9,583	9,632	9,683	9,739	9,793	9,849	9,904	9,958	10,014	10,068
296	10,120	10,174	10,232	10,288	10,340	10,389	10,439	10,489	10,540	10,592
297	10,645	10,697	10,749	10,801	10,853	10,902	10,951	11,002	11,054	11,106
298	11,161	11,216	11,271	11,326	11,381	11,435	11,489	11,543	11,594	11,642
299	11,691	11,739	11,789	11,841	11,890	11,939	11,985	12,031	12,078	12,125
300	12,174	12,223	12,275	12,327	12,379	12,434	12,494	12,554	12,615	12,682
301	12,755	12,844	12,949	13,059	13,165	13,259	13,353	13,440	13,517	13,595
302	13,678	13,764	13,842	13,914	13,984	14,053	14,122	14,196	14,277	14,361
303	14,458	14,547	14,632	14,715	14,800	14,880	14,956	15,027	15,096	15,168
304	15,250	15,340	15,426	15,511	15,597	15,684	15,776	15,875	15,978	16,090
305	16,209	16,318	16,416	16,508	16,595	16,680	16,767	16,855	16,946	17,037
306	17,135	17,235	17,326	17,416	17,503	17,590	17,682	17,775	17,868	17,967
307	18,071	18,164	18,251	18,342	18,431	18,521	18,616	18,712	18,812	18,917
308	19,025	19,126	19,222	19,317	19,412	19,504	19,598	19,692	19,789	19,886
309	19,986	20,084	20,179	20,272	20,371	20,476	20,582	20,694	20,807	20,912

Appendix B (continued)

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

JULY 2005 SURVEY (Original)

Conservation Pool Elevation 322.0 ft

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
310	21,013	21,113	21,210	21,300	21,387	21,473	21,561	21,655	21,759	21,857
311	21,953	22,046	22,137	22,227	22,316	22,407	22,503	22,599	22,699	22,801
312	22,901	23,000	23,103	23,208	23,315	23,424	23,532	23,639	23,742	23,844
313	23,942	24,039	24,134	24,230	24,330	24,434	24,536	24,637	24,735	24,831
314	24,923	25,013	25,106	25,193	25,281	25,371	25,466	25,560	25,655	25,746
315	25,839	25,935	26,029	26,122	26,216	26,314	26,418	26,524	26,623	26,723
316	26,825	26,932	27,049	27,168	27,282	27,401	27,512	27,620	27,733	27,853
317	27,963	28,063	28,161	28,254	28,339	28,418	28,493	28,568	28,641	28,715
318	28,787	28,857	28,927	28,996	29,064	29,132	29,199	29,266	29,332	29,399
319	29,465	29,531	29,597	29,664	29,732	29,800	29,867	29,935	30,002	30,069
320	30,135	30,202	30,270	30,338	30,406	30,475	30,544	30,614	30,684	30,754
321	30,825	30,896	30,968	31,040	31,113	31,186	31,259	31,333	31,407	31,482
322	32,873									

Appendix B

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — JULY 2005 SURVEY (Original)

Conservation Pool Elevation 322.0 ft

VOLUME IN ACRE-FEET — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
255						0	0	0	0	0
256	0	0	0	0	0	0	0	0	0	0
257	0	0	0	0	0	1	1	1	1	2
258	2	2	3	3	4	4	5	5	6	7
259	7	8	9	10	11	12	13	14	15	16
260	18	19	20	22	23	24	26	28	29	31
261	33	34	36	38	40	42	44	46	49	51
262	53	56	58	61	64	67	70	73	76	79
263	83	86	90	94	98	102	107	112	116	121
264	127	132	138	144	150	156	163	169	176	183
265	191	198	206	214	222	230	239	248	257	266
266	276	286	297	308	319	331	343	356	369	383
267	397	412	427	443	459	476	494	512	530	549
268	568	587	608	628	649	671	693	716	740	764
269	788	813	839	866	893	921	950	980	1,010	1,041
270	1,074	1,107	1,141	1,175	1,211	1,249	1,287	1,327	1,368	1,411
271	1,456	1,502	1,549	1,598	1,649	1,701	1,755	1,811	1,869	1,928
272	1,990	2,053	2,118	2,185	2,253	2,324	2,396	2,470	2,546	2,624
273	2,704	2,786	2,870	2,955	3,043	3,132	3,223	3,316	3,410	3,506
274	3,604	3,703	3,804	3,907	4,012	4,118	4,226	4,335	4,446	4,559
275	4,674	4,790	4,908	5,028	5,150	5,274	5,399	5,527	5,657	5,789
276	5,923	6,059	6,196	6,335	6,477	6,620	6,765	6,912	7,061	7,213
277	7,366	7,523	7,681	7,842	8,006	8,172	8,341	8,513	8,687	8,863
278	9,043	9,226	9,411	9,600	9,792	9,988	10,186	10,387	10,592	10,801
279	11,012	11,227	11,445	11,667	11,892	12,120	12,351	12,586	12,824	13,065
280	13,309	13,557	13,809	14,063	14,322	14,583	14,848	15,116	15,387	15,663
281	15,943	16,227	16,515	16,807	17,103	17,403	17,707	18,014	18,326	18,642
282	18,962	19,288	19,617	19,950	20,288	20,630	20,976	21,327	21,682	22,042
283	22,406	22,774	23,146	23,523	23,903	24,288	24,677	25,070	25,468	25,870
284	26,277	26,690	27,106	27,527	27,953	28,383	28,817	29,256	29,699	30,148
285	30,603	31,065	31,532	32,005	32,484	32,968	33,457	33,952	34,451	34,956
286	35,464	35,976	36,491	37,011	37,534	38,060	38,591	39,126	39,666	40,210
287	40,759	41,313	41,872	42,436	43,003	43,576	44,152	44,733	45,319	45,908
288	46,503	47,101	47,704	48,311	48,921	49,536	50,156	50,779	51,407	52,040
289	52,676	53,317	53,962	54,611	55,265	55,923	56,586	57,254	57,927	58,606
290	59,288	59,976	60,668	61,365	62,068	62,775	63,488	64,206	64,930	65,659
291	66,393	67,134	67,880	68,631	69,389	70,153	70,924	71,700	72,482	73,269
292	74,063	74,862	75,666	76,476	77,292	78,114	78,943	79,778	80,619	81,466
293	82,318	83,175	84,037	84,905	85,779	86,658	87,543	88,433	89,328	90,228
294	91,133	92,042	92,957	93,876	94,801	95,732	96,669	97,610	98,557	99,508
295	100,464	101,425	102,390	103,361	104,338	105,320	106,308	107,301	108,300	109,304
296	110,313	111,328	112,348	113,374	114,405	115,442	116,483	117,530	118,581	119,638
297	120,700	121,767	122,839	123,916	124,999	126,087	127,180	128,277	129,380	130,488
298	131,601	132,720	133,845	134,974	136,110	137,250	138,397	139,548	140,705	141,867
299	143,034	144,205	145,382	146,563	147,749	148,941	150,137	151,338	152,543	153,754
300	154,969	156,189	157,413	158,643	159,879	161,119	162,366	163,618	164,876	166,141
301	167,413	168,693	169,983	171,283	172,594	173,915	175,246	176,586	177,933	179,289
302	180,653	182,025	183,406	184,793	186,188	187,590	188,999	190,415	191,838	193,270
303	194,711	196,161	197,621	199,088	200,563	202,048	203,540	205,039	206,545	208,058
304	209,579	211,108	212,647	214,193	215,749	217,313	218,886	220,468	222,061	223,664
305	225,279	226,906	228,543	230,189	231,844	233,508	235,180	236,861	238,551	240,250
306	241,959	243,677	245,405	247,142	248,888	250,643	252,407	254,180	255,961	257,753
307	259,555	261,367	263,188	265,017	266,856	268,704	270,561	272,427	274,303	276,189
308	278,087	279,994	281,912	283,838	285,775	287,721	289,676	291,641	293,614	295,598
309	297,592	299,595	301,609	303,631	305,663	307,705	309,758	311,822	313,897	315,983
310	318,079	320,186	322,302	324,427	326,561	328,705	330,856	333,017	335,187	337,368

Appendix B (continued)

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

JULY 2005 SURVEY (Original)

Conservation Pool Elevation 322.0 ft

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
311	339,559	341,759	343,968	346,186	348,413	350,650	352,895	355,150	357,415	359,690
312	361,975	364,270	366,575	368,890	371,217	373,554	375,902	378,261	380,629	383,008
313	385,398	387,797	390,206	392,623	395,052	397,490	399,939	402,398	404,866	407,344
314	409,832	412,329	414,835	417,349	419,873	422,406	424,948	427,499	430,060	432,630
315	435,209	437,798	440,396	443,003	445,620	448,247	450,884	453,531	456,188	458,855
316	461,533	464,220	466,920	469,630	472,353	475,087	477,833	480,590	483,356	486,136
317	488,927	491,729	494,540	497,360	500,190	503,028	505,874	508,727	511,587	514,455
318	517,330	520,212	523,102	525,997	528,900	531,810	534,727	537,650	540,580	543,516
319	546,460	549,410	552,366	555,329	558,299	561,275	564,259	567,249	570,245	573,249
320	576,259	579,277	582,300	585,330	588,367	591,412	594,463	597,521	600,585	603,657
321	606,736	609,822	612,916	616,015	619,123	622,238	625,361	628,491	631,627	634,771
322	637,924									

Appendix C

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

March 1995 SURVEY (Revised)

Conservation Pool Elevation 322.0 ft

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
254					0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	1	1	1	1	1	1	1	1
257	1	2	2	2	2	3	3	3	4	4
258	5	5	6	6	7	7	8	8	9	9
259	10	10	10	11	12	12	13	13	14	14
260	15	16	16	17	18	19	19	20	21	21
261	22	23	24	25	25	26	27	28	29	30
262	32	33	35	37	38	40	41	43	44	46
263	47	49	51	53	55	57	59	61	63	65
264	68	70	73	75	77	80	82	85	87	90
265	93	96	99	103	106	110	115	119	124	128
266	133	138	143	148	153	158	163	167	172	177
267	182	187	191	196	201	205	210	214	219	224
268	228	233	238	244	249	254	259	265	271	278
269	284	291	298	305	312	319	327	334	342	350
270	358	367	376	386	396	407	418	431	444	460
271	477	492	507	522	537	554	572	589	604	621
272	638	656	675	693	714	736	755	773	790	809
273	827	845	864	886	905	923	943	962	981	999
274	1,018	1,039	1,059	1,080	1,103	1,125	1,146	1,166	1,187	1,207
275	1,230	1,253	1,274	1,296	1,316	1,337	1,359	1,381	1,403	1,425
276	1,446	1,467	1,489	1,511	1,534	1,558	1,583	1,608	1,634	1,659
277	1,685	1,712	1,741	1,770	1,800	1,831	1,864	1,897	1,930	1,962
278	1,994	2,025	2,057	2,087	2,115	2,141	2,168	2,197	2,226	2,257
279	2,289	2,321	2,352	2,384	2,415	2,446	2,478	2,509	2,541	2,571
280	2,601	2,632	2,665	2,699	2,730	2,764	2,798	2,835	2,872	2,911
281	2,950	2,989	3,029	3,070	3,114	3,159	3,201	3,240	3,280	3,321
282	3,364	3,407	3,448	3,485	3,525	3,566	3,608	3,651	3,692	3,735
283	3,779	3,823	3,866	3,908	3,952	3,996	4,040	4,083	4,127	4,173
284	4,218	4,265	4,316	4,367	4,419	4,472	4,530	4,588	4,642	4,693
285	4,743	4,796	4,850	4,903	4,955	5,004	5,050	5,096	5,139	5,180
286	5,221	5,262	5,302	5,343	5,386	5,432	5,478	5,521	5,564	5,608
287	5,652	5,695	5,737	5,778	5,821	5,863	5,908	5,955	6,003	6,045
288	6,084	6,121	6,159	6,199	6,242	6,286	6,329	6,372	6,414	6,459
289	6,505	6,551	6,598	6,646	6,696	6,745	6,792	6,842	6,894	6,946
290	6,994	7,040	7,089	7,141	7,192	7,244	7,298	7,357	7,418	7,479
291	7,536	7,591	7,648	7,706	7,762	7,816	7,873	7,928	7,984	8,043
292	8,100	8,157	8,212	8,269	8,325	8,379	8,435	8,490	8,541	8,590
293	8,637	8,684	8,731	8,775	8,818	8,864	8,910	8,954	8,997	9,042
294	9,085	9,129	9,174	9,219	9,264	9,309	9,354	9,400	9,450	9,501
295	9,551	9,601	9,652	9,704	9,759	9,814	9,871	9,926	9,980	10,033
296	10,088	10,144	10,198	10,250	10,300	10,348	10,395	10,443	10,491	10,541
297	10,593	10,646	10,699	10,751	10,801	10,850	10,900	10,952	11,004	11,057
298	11,108	11,160	11,212	11,263	11,314	11,366	11,419	11,471	11,524	11,578
299	11,632	11,686	11,742	11,798	11,852	11,905	11,959	12,012	12,067	12,124
300	12,183	12,241	12,302	12,363	12,424	12,486	12,552	12,623	12,700	12,779
301	12,858	12,935	13,009	13,078	13,147	13,214	13,283	13,357	13,433	13,510
302	13,592	13,679	13,778	13,866	13,950	14,025	14,099	14,170	14,237	14,305
303	14,378	14,456	14,538	14,627	14,716	14,802	14,890	14,978	15,069	15,156
304	15,242	15,334	15,426	15,518	15,613	15,705	15,798	15,892	15,985	16,075
305	16,164	16,253	16,340	16,425	16,510	16,599	16,687	16,776	16,863	16,952
306	17,046	17,135	17,219	17,301	17,386	17,473	17,565	17,662	17,760	17,859
307	17,957	18,053	18,155	18,265	18,381	18,499	18,610	18,713	18,816	18,922
308	19,027	19,127	19,223	19,320	19,419	19,519	19,615	19,712	19,814	19,914
309	20,014	20,109	20,202	20,292	20,382	20,470	20,561	20,653	20,746	20,840

Appendix C (continued)

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

March 1995 SURVEY (Revised)

Conservation Pool Elevation 322.0 ft

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
310	20,935	21,036	21,144	21,245	21,339	21,430	21,515	21,598	21,677	21,756
311	21,835	21,921	22,014	22,107	22,211	22,309	22,400	22,490	22,581	22,675
312	22,778	22,883	22,982	23,076	23,172	23,265	23,357	23,447	23,539	23,630
313	23,724	23,822	23,920	24,014	24,106	24,195	24,288	24,383	24,477	24,569
314	24,664	24,762	24,864	24,977	25,092	25,206	25,312	25,416	25,517	25,616
315	25,714	25,809	25,904	26,002	26,103	26,205	26,316	26,424	26,527	26,631
316	26,735	26,842	26,947	27,055	27,162	27,264	27,357	27,449	27,538	27,632
317	27,726	27,822	27,923	28,030	28,135	28,243	28,351	28,459	28,572	28,674
318	28,772	28,868	28,959	29,048	29,135	29,219	29,303	29,387	29,474	29,559
319	29,646	29,739	29,841	29,933	30,008	30,083	30,159	30,236	30,314	30,393
320	30,473	30,554	30,636	30,718	30,800	30,883	30,967	31,051	31,137	31,224
321	31,312	31,401	31,492	31,585	31,682	31,782	31,886	31,995	32,112	32,239
322	32,873									

Appendix C

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

March 1995 SURVEY **(Revised)**

Conservation Pool Elevation 322.0 ft

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
254					0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	1	1	1	1	1
257	1	1	1	2	2	2	2	3	3	4
258	4	4	5	6	6	7	8	8	9	10
259	11	12	13	14	15	16	18	19	20	22
260	23	25	26	28	30	32	33	35	37	39
261	42	44	46	49	51	54	56	59	62	65
262	68	71	75	78	82	86	90	94	99	103
263	108	113	118	123	128	134	140	146	152	158
264	165	172	179	186	194	202	210	218	227	236
265	245	254	264	274	284	295	307	318	330	343
266	356	370	384	398	413	429	445	461	478	496
267	514	532	551	570	590	610	631	652	674	696
268	719	742	765	790	814	839	865	891	918	945
269	973	1,002	1,032	1,062	1,093	1,124	1,157	1,190	1,224	1,258
270	1,294	1,330	1,367	1,405	1,444	1,484	1,526	1,568	1,612	1,657
271	1,704	1,752	1,802	1,854	1,906	1,961	2,017	2,075	2,135	2,196
272	2,259	2,324	2,390	2,459	2,529	2,602	2,676	2,753	2,831	2,911
273	2,992	3,076	3,161	3,249	3,338	3,430	3,523	3,618	3,715	3,814
274	3,915	4,018	4,123	4,230	4,339	4,450	4,564	4,680	4,797	4,917
275	5,039	5,163	5,289	5,418	5,548	5,681	5,816	5,953	6,092	6,233
276	6,377	6,522	6,670	6,820	6,973	7,127	7,284	7,444	7,606	7,771
277	7,938	8,108	8,280	8,456	8,634	8,816	9,000	9,189	9,380	9,575
278	9,772	9,973	10,177	10,385	10,595	10,807	11,023	11,241	11,462	11,686
279	11,914	12,144	12,378	12,615	12,855	13,098	13,344	13,593	13,846	14,101
280	14,360	14,622	14,886	15,155	15,426	15,701	15,979	16,260	16,546	16,835
281	17,128	17,425	17,726	18,031	18,340	18,653	18,971	19,294	19,619	19,949
282	20,284	20,622	20,965	21,312	21,662	22,017	22,376	22,738	23,106	23,477
283	23,853	24,233	24,617	25,006	25,399	25,796	26,198	26,604	27,015	27,430
284	27,849	28,273	28,702	29,136	29,576	30,020	30,470	30,926	31,388	31,854
285	32,326	32,803	33,286	33,773	34,266	34,764	35,267	35,774	36,286	36,802
286	37,322	37,846	38,374	38,906	39,443	39,984	40,529	41,079	41,633	42,192
287	42,755	43,322	43,894	44,469	45,049	45,634	46,222	46,815	47,413	48,015
288	48,622	49,232	49,846	50,464	51,086	51,713	52,343	52,978	53,617	54,261
289	54,909	55,562	56,220	56,882	57,549	58,221	58,898	59,580	60,266	60,958
290	61,655	62,357	63,063	63,775	64,491	65,213	65,940	66,673	67,412	68,156
291	68,907	69,664	70,426	71,193	71,967	72,745	73,530	74,320	75,115	75,917
292	76,724	77,537	78,355	79,179	80,009	80,844	81,685	82,531	83,383	84,239
293	85,101	85,967	86,838	87,713	88,592	89,476	90,365	91,258	92,156	93,058
294	93,964	94,875	95,790	96,710	97,634	98,562	99,496	100,433	101,375	102,323
295	103,276	104,233	105,196	106,164	107,137	108,115	109,100	110,090	111,085	112,085
296	113,092	114,103	115,120	116,142	117,170	118,203	119,240	120,282	121,328	122,380
297	123,437	124,499	125,566	126,638	127,716	128,798	129,886	130,979	132,076	133,179
298	134,288	135,401	136,520	137,643	138,772	139,906	141,045	142,190	143,339	144,495
299	145,655	146,821	147,993	149,169	150,352	151,540	152,733	153,932	155,135	156,345
300	157,560	158,781	160,009	161,242	162,481	163,726	164,978	166,237	167,503	168,777
301	170,059	171,349	172,646	173,950	175,261	176,579	177,904	179,236	180,575	181,923
302	183,278	184,641	186,014	187,396	188,787	190,186	191,592	193,005	194,425	195,853
303	197,287	198,728	200,178	201,636	203,103	204,579	206,064	207,557	209,059	210,570
304	212,090	213,619	215,157	216,704	218,261	219,827	221,402	222,986	224,580	226,183
305	227,795	229,416	231,046	232,683	234,330	235,986	237,650	239,323	241,005	242,696
306	244,396	246,105	247,823	249,548	251,282	253,025	254,777	256,539	258,309	260,090
307	261,881	263,682	265,492	267,313	269,145	270,989	272,844	274,711	276,587	278,474
308	280,371	282,279	284,197	286,123	288,060	290,007	291,964	293,930	295,906	297,893
309	299,889	301,895	303,911	305,935	307,969	310,012	312,063	314,124	316,193	318,273

Appendix C (continued)

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

March 1995 SURVEY **(Revised)**

Conservation Pool Elevation 322.0 ft

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
310	320,362	322,460	324,569	326,688	328,818	330,956	333,104	335,260	337,423	339,595
311	341,774	343,962	346,159	348,364	350,580	352,806	355,042	357,287	359,539	361,802
312	364,075	366,358	368,652	370,954	373,266	375,588	377,920	380,260	382,609	384,967
313	387,335	389,712	392,100	394,496	396,902	399,317	401,741	404,175	406,618	409,070
314	411,532	414,003	416,485	418,976	421,480	423,995	426,521	429,057	431,603	434,160
315	436,727	439,303	441,889	444,484	447,089	449,705	452,331	454,968	457,615	460,273
316	462,941	465,620	468,310	471,009	473,720	476,442	479,173	481,914	484,662	487,421
317	490,189	492,967	495,754	498,551	501,359	504,179	507,008	509,849	512,700	515,563
318	518,435	521,317	524,209	527,108	530,018	532,936	535,862	538,797	541,739	544,691
319	547,651	550,621	553,600	556,588	559,585	562,590	565,602	568,622	571,648	574,684
320	577,727	580,779	583,839	586,906	589,982	593,066	596,159	599,260	602,368	605,487
321	608,614	611,749	614,894	618,047	621,211	624,384	627,568	630,762	633,966	637,184
322	640,415									

Appendix D

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

JULY 2005 SURVEY (Revised)

Conservation Pool Elevation 322.0 ft

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
254					0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	0	0	0	0	0
257	0	0	0	0	1	1	1	2	2	2
258	3	3	4	4	4	5	5	6	7	7
259	7	8	8	9	9	10	10	10	11	11
260	12	12	13	13	14	14	15	15	16	17
261	17	18	19	19	20	20	21	22	22	23
262	24	24	25	26	27	28	29	30	32	33
263	35	36	38	40	42	44	46	48	50	52
264	55	57	59	61	64	66	67	69	71	73
265	75	77	79	81	83	85	88	90	93	96
266	100	104	109	113	118	122	127	132	137	142
267	147	153	157	162	167	171	176	180	184	189
268	193	198	203	208	213	218	224	229	235	241
269	247	253	260	266	273	280	288	296	304	312
270	320	329	339	350	361	374	386	398	412	428
271	448	465	480	496	513	530	547	564	582	601
272	621	639	656	674	691	709	727	744	762	780
273	798	817	835	856	876	896	915	933	951	970
274	988	1,007	1,028	1,048	1,067	1,085	1,104	1,123	1,143	1,164
275	1,184	1,203	1,223	1,241	1,259	1,278	1,297	1,316	1,337	1,357
276	1,377	1,397	1,416	1,435	1,456	1,476	1,496	1,516	1,536	1,556
277	1,578	1,600	1,623	1,647	1,672	1,698	1,723	1,749	1,775	1,802
278	1,831	1,860	1,892	1,924	1,956	1,987	2,019	2,052	2,087	2,120
279	2,151	2,183	2,217	2,250	2,281	2,313	2,344	2,376	2,409	2,443
280	2,477	2,513	2,549	2,582	2,614	2,646	2,680	2,714	2,751	2,794
281	2,840	2,885	2,927	2,967	3,006	3,045	3,083	3,121	3,160	3,202
282	3,253	3,304	3,351	3,393	3,434	3,474	3,517	3,560	3,602	3,645
283	3,688	3,734	3,776	3,817	3,857	3,900	3,945	3,988	4,032	4,080
284	4,129	4,176	4,221	4,268	4,312	4,354	4,396	4,441	4,488	4,546
285	4,615	4,681	4,742	4,798	4,852	4,909	4,964	5,019	5,073	5,120
286	5,161	5,200	5,240	5,283	5,323	5,362	5,404	5,450	5,500	5,549
287	5,596	5,639	5,681	5,724	5,764	5,805	5,847	5,888	5,929	5,973
288	6,017	6,060	6,101	6,141	6,182	6,225	6,267	6,310	6,353	6,395
289	6,438	6,482	6,525	6,568	6,612	6,660	6,718	6,773	6,822	6,870
290	6,918	6,967	7,016	7,067	7,120	7,170	7,221	7,276	7,333	7,390
291	7,445	7,502	7,564	7,622	7,683	7,751	7,820	7,882	7,942	8,000
292	8,055	8,110	8,167	8,225	8,282	8,343	8,405	8,469	8,529	8,586
293	8,636	8,683	8,733	8,783	8,831	8,881	8,934	8,984	9,033	9,083
294	9,132	9,180	9,228	9,276	9,328	9,383	9,438	9,490	9,539	9,586
295	9,634	9,685	9,738	9,797	9,856	9,915	9,972	10,029	10,084	10,138
296	10,190	10,242	10,300	10,357	10,412	10,466	10,517	10,568	10,619	10,671
297	10,723	10,775	10,828	10,882	10,936	10,986	11,038	11,090	11,142	11,194
298	11,248	11,305	11,364	11,421	11,477	11,529	11,580	11,632	11,684	11,733
299	11,782	11,832	11,881	11,932	11,979	12,026	12,075	12,123	12,172	12,221
300	12,271	12,321	12,373	12,427	12,480	12,534	12,594	12,655	12,714	12,780
301	12,850	12,931	13,030	13,144	13,254	13,355	13,451	13,545	13,633	13,720
302	13,805	13,892	13,977	14,050	14,118	14,181	14,246	14,313	14,383	14,463
303	14,558	14,660	14,747	14,824	14,905	14,987	15,065	15,139	15,214	15,288
304	15,372	15,462	15,552	15,638	15,726	15,812	15,904	16,003	16,108	16,225
305	16,352	16,474	16,574	16,663	16,747	16,832	16,916	17,000	17,090	17,184
306	17,283	17,382	17,478	17,573	17,670	17,768	17,866	17,965	18,073	18,188
307	18,307	18,417	18,519	18,613	18,705	18,796	18,888	18,979	19,074	19,181
308	19,297	19,399	19,492	19,586	19,679	19,771	19,867	19,968	20,071	20,182

Appendix D (continued)

Cedar Creek Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

JULY 2005 SURVEY (Revised)

Conservation Pool Elevation 322.0 ft

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
309	20289	20391	20490	20585	20680	20779	20881	20982	21076	21173
310	21,270	21,366	21,459	21,544	21,632	21,720	21,809	21,901	22,004	22,114
311	22,216	22,311	22,404	22,495	22,583	22,671	22,761	22,857	22,953	23,054
312	23,155	23,251	23,346	23,440	23,539	23,641	23,746	23,858	23,970	24,075
313	24,173	24,270	24,364	24,456	24,546	24,637	24,730	24,830	24,935	25,029
314	25,113	25,191	25,267	25,344	25,423	25,505	25,591	25,683	25,781	25,873
315	25,965	26,058	26,150	26,243	26,339	26,438	26,544	26,652	26,760	26,869
316	26,980	27,089	27,202	27,313	27,422	27,529	27,634	27,735	27,835	27,935
317	28,035	28,134	28,232	28,327	28,422	28,513	28,603	28,692	28,782	28,871
318	28,959	29,047	29,134	29,223	29,313	29,404	29,496	29,585	29,674	29,762
319	29,853	29,946	30,026	30,106	30,188	30,269	30,352	30,435	30,520	30,606
320	30,693	30,780	30,868	30,957	31,045	31,136	31,229	31,323	31,418	31,514
321	31,612	31,711	31,813	31,916	32,022	32,132	32,244	32,360	32,482	32,616
322	32,873									

Appendix D

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — JULY 2005 SURVEY (Revised)

Conservation Pool Elevation 322.0 ft

VOLUME IN ACRE-FEET — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
254					0	0	0	0	0	0
255	0	0	0	0	0	0	0	0	0	0
256	0	0	0	0	0	0	0	0	0	0
257	0	0	0	0	0	0	1	1	1	1
258	1	2	2	2	3	3	4	4	5	6
259	6	7	8	9	10	11	12	13	14	15
260	16	17	18	20	21	22	24	25	27	28
261	30	32	34	36	38	40	42	44	46	48
262	51	53	56	58	61	64	66	69	72	76
263	79	83	86	90	94	99	103	108	113	118
264	123	129	134	141	147	153	160	167	174	181
265	188	196	204	212	220	228	237	246	255	264
266	274	284	295	306	318	330	342	355	369	382
267	397	412	427	443	460	477	494	512	530	549
268	568	588	608	628	649	671	693	716	739	763
269	787	812	838	864	891	919	947	976	1,006	1,037
270	1,069	1,101	1,135	1,169	1,205	1,241	1,279	1,318	1,359	1,401
271	1,445	1,490	1,538	1,586	1,637	1,689	1,743	1,798	1,856	1,915
272	1,976	2,039	2,104	2,170	2,239	2,309	2,380	2,454	2,529	2,606
273	2,685	2,766	2,848	2,933	3,020	3,108	3,199	3,291	3,385	3,481
274	3,579	3,679	3,781	3,885	3,990	4,098	4,207	4,319	4,432	4,547
275	4,665	4,784	4,905	5,029	5,154	5,280	5,409	5,540	5,672	5,807
276	5,944	6,083	6,223	6,366	6,510	6,657	6,806	6,956	7,109	7,263
277	7,420	7,579	7,740	7,904	8,070	8,238	8,409	8,583	8,759	8,938
278	9,119	9,304	9,491	9,682	9,876	10,073	10,274	10,477	10,684	10,894
279	11,108	11,325	11,545	11,768	11,995	12,224	12,457	12,693	12,932	13,175
280	13,421	13,670	13,924	14,180	14,440	14,703	14,969	15,239	15,512	15,789
281	16,071	16,357	16,648	16,943	17,241	17,544	17,850	18,161	18,475	18,793
282	19,116	19,443	19,776	20,113	20,455	20,800	21,150	21,504	21,862	22,224
283	22,591	22,962	23,337	23,717	24,101	24,489	24,881	25,278	25,678	26,084
284	26,495	26,910	27,330	27,754	28,183	28,616	29,054	29,496	29,942	30,394
285	30,852	31,317	31,788	32,265	32,747	33,235	33,729	34,228	34,733	35,243
286	35,757	36,275	36,797	37,323	37,853	38,387	38,926	39,468	40,016	40,568
287	41,125	41,687	42,253	42,823	43,398	43,976	44,559	45,146	45,737	46,332
288	46,931	47,535	48,143	48,755	49,371	49,992	50,616	51,245	51,878	52,516
289	53,157	53,803	54,454	55,108	55,767	56,431	57,100	57,774	58,454	59,139
290	59,828	60,522	61,222	61,925	62,635	63,349	64,069	64,794	65,524	66,260
291	67,002	67,750	68,503	69,262	70,027	70,799	71,578	72,363	73,154	73,951
292	74,754	75,562	76,376	77,195	78,021	78,852	79,689	80,533	81,383	82,239
293	83,100	83,966	84,837	85,712	86,593	87,479	88,369	89,265	90,166	91,072
294	91,983	92,898	93,819	94,744	95,674	96,610	97,551	98,497	99,448	100,405
295	101,366	102,332	103,303	104,279	105,262	106,251	107,245	108,245	109,251	110,262
296	111,278	112,300	113,327	114,360	115,398	116,442	117,491	118,546	119,605	120,669
297	121,739	122,814	123,894	124,979	126,070	127,166	128,268	129,374	130,485	131,602
298	132,724	133,852	134,986	136,125	137,270	138,420	139,576	140,736	141,902	143,073
299	144,249	145,429	146,615	147,805	149,001	150,201	151,406	152,616	153,831	155,051
300	156,275	157,505	158,740	159,979	161,225	162,475	163,732	164,994	166,263	167,537
301	168,819	170,108	171,406	172,714	174,034	175,365	176,706	178,056	179,414	180,782
302	182,158	183,543	184,937	186,338	187,746	189,161	190,583	192,011	193,445	194,888
303	196,339	197,800	199,270	200,748	202,235	203,730	205,232	206,743	208,260	209,785
304	211,318	212,860	214,411	215,970	217,538	219,115	220,701	222,297	223,902	225,518
305	227,147	228,789	230,441	232,103	233,774	235,453	237,140	238,836	240,540	242,254
306	243,977	245,711	247,454	249,206	250,968	252,740	254,522	256,314	258,115	259,928
307	261,753	263,590	265,437	267,293	269,159	271,034	272,919	274,812	276,714	278,627
308	280,551	282,486	284,431	286,384	288,348	290,320	292,302	294,294	296,295	298,308
309	300,332	302,366	304,410	306,464	308,527	310,600	312,683	314,776	316,879	318,991

Appendix D (continued)

Cedar Creek Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

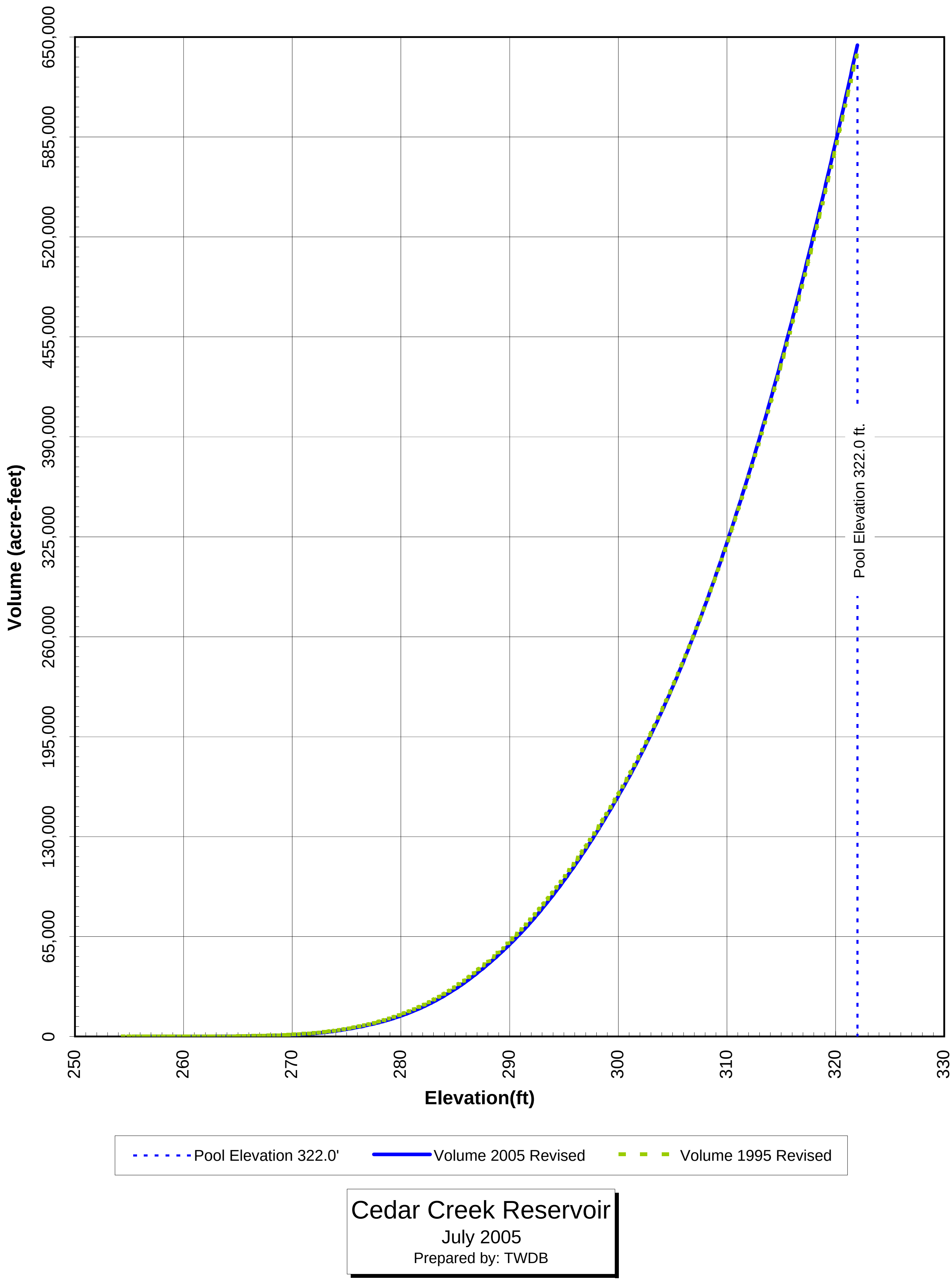
JULY 2005 SURVEY (Revised)

Conservation Pool Elevation 322.0 ft

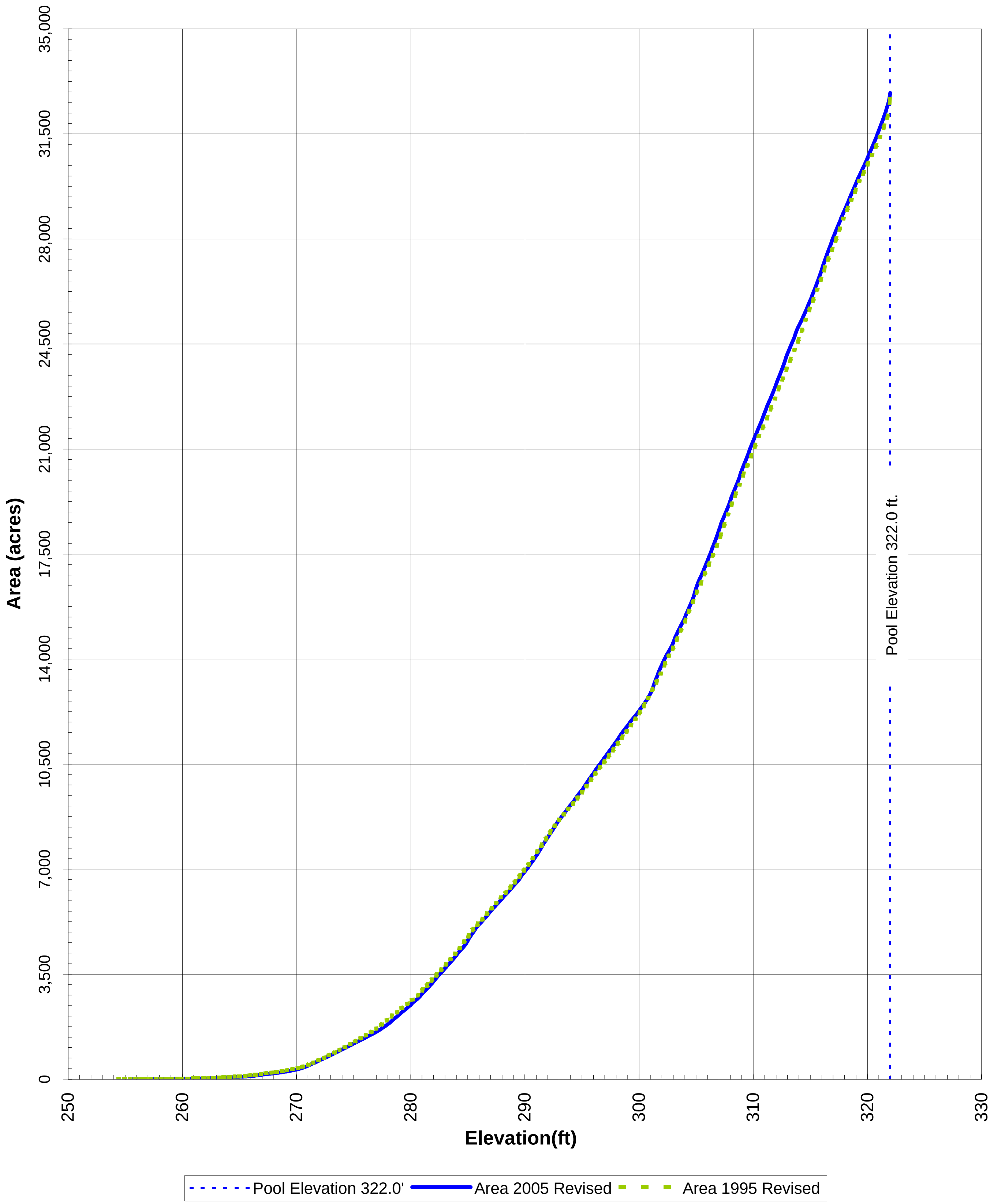
VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
310	321,114	323,246	325,387	327,537	329,696	331,863	334,040	336,226	338,420	340,626
311	342,843	345,069	347,305	349,550	351,804	354,067	356,338	358,619	360,909	363,210
312	365,520	367,841	370,171	372,510	374,859	377,218	379,587	381,968	384,358	386,761
313	389,173	391,596	394,028	396,468	398,918	401,377	403,846	406,324	408,812	411,310
314	413,817	416,333	418,856	421,386	423,924	426,471	429,026	431,589	434,162	436,745
315	439,337	441,938	444,549	447,168	449,797	452,436	455,085	457,745	460,415	463,097
316	465,789	468,493	471,208	473,933	476,670	479,418	482,176	484,945	487,722	490,511
317	493,310	496,118	498,937	501,764	504,602	507,449	510,305	513,170	516,043	518,925
318	521,817	524,718	527,627	530,544	533,471	536,407	539,352	542,306	545,269	548,240
319	551,221	554,212	557,211	560,217	563,231	566,254	569,286	572,325	575,372	578,429
320	581,494	584,568	587,650	590,741	593,841	596,950	600,069	603,196	606,333	609,480
321	612,636	615,802	618,979	622,164	625,361	628,569	631,788	635,019	638,260	641,515
322	644,785									



Appendix E Elevation vs. Volume



Cedar Creek Reservoir

July 2005

Prepared by: TWDB

Appendix F Elevation vs. Area

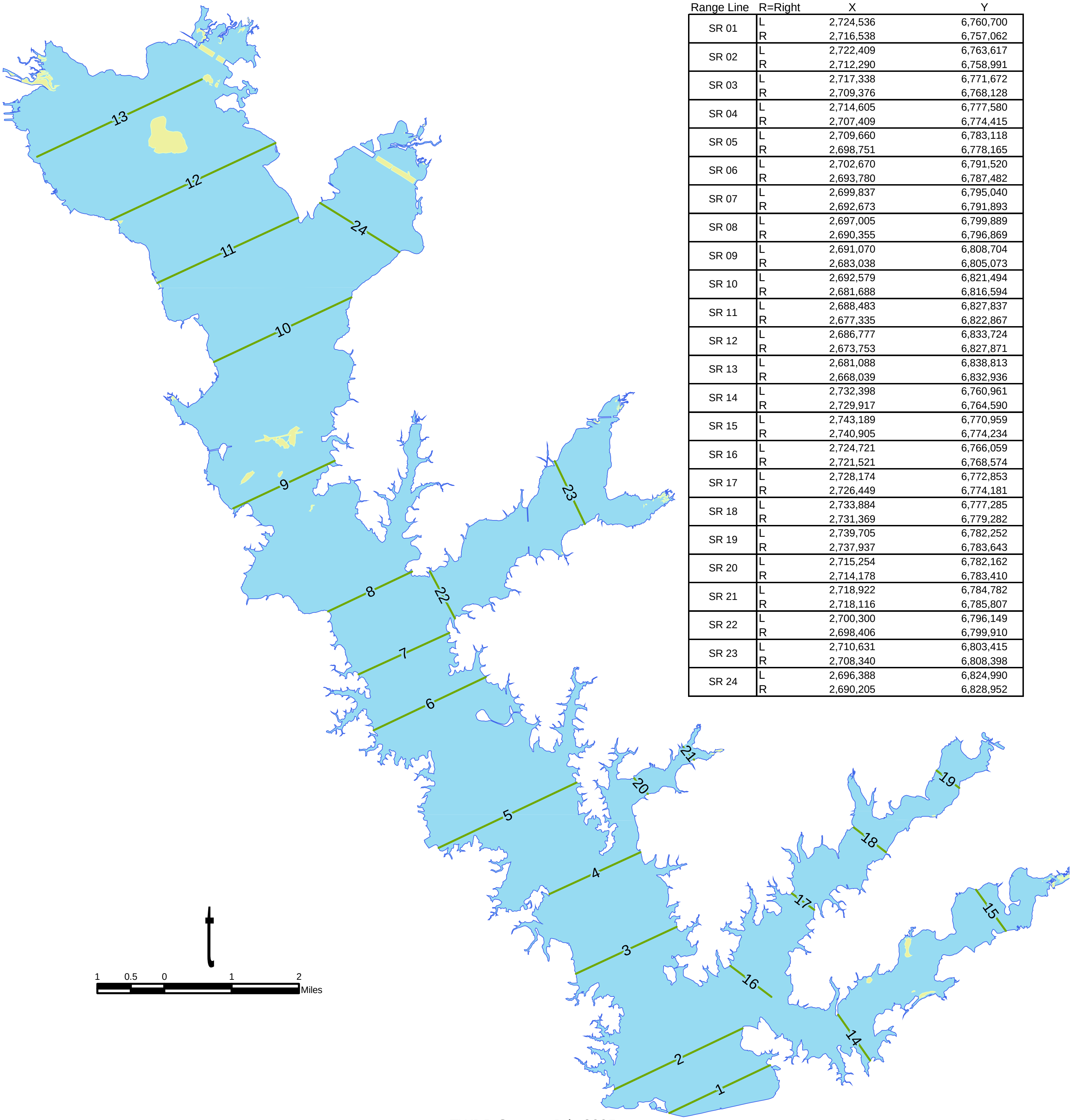
Appendix G

CEDAR CREEK RESERVOIR

Range Lines

Table 3
Endpoint Coordinates for Cedar Creek Reservoir Coordinates in NAD83 (feet) State Plane Texas North Central Zone, est. 2006
TWDB

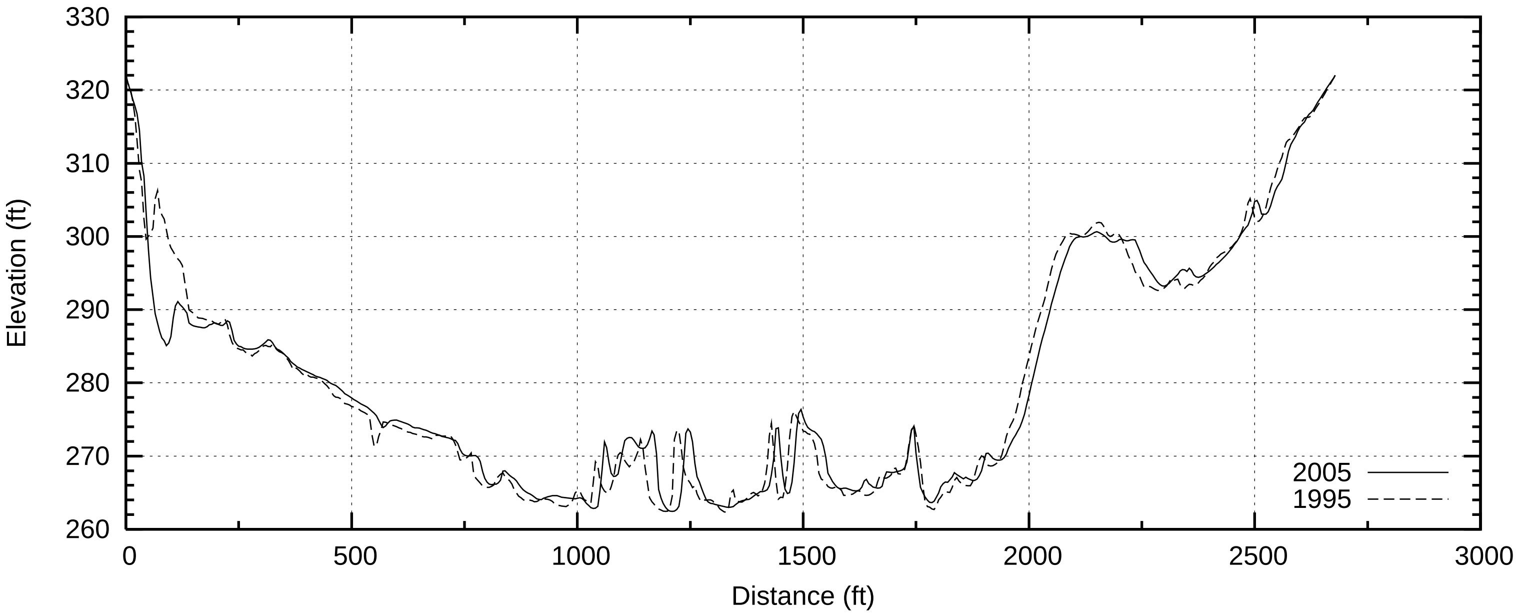
Range Line	L = Left R=Right	X	Y
SR 01	L	2,724,536	6,760,700
	R	2,716,538	6,757,062
SR 02	L	2,722,409	6,763,617
	R	2,712,290	6,758,991
SR 03	L	2,717,338	6,771,672
	R	2,709,376	6,768,128
SR 04	L	2,714,605	6,777,580
	R	2,707,409	6,774,415
SR 05	L	2,709,660	6,783,118
	R	2,698,751	6,778,165
SR 06	L	2,702,670	6,791,520
	R	2,693,780	6,787,482
SR 07	L	2,699,837	6,795,040
	R	2,692,673	6,791,893
SR 08	L	2,697,005	6,799,889
	R	2,690,355	6,796,869
SR 09	L	2,691,070	6,808,704
	R	2,683,038	6,805,073
SR 10	L	2,692,579	6,821,494
	R	2,681,688	6,816,594
SR 11	L	2,688,483	6,827,837
	R	2,677,335	6,822,867
SR 12	L	2,686,777	6,833,724
	R	2,673,753	6,827,871
SR 13	L	2,681,088	6,838,813
	R	2,668,039	6,832,936
SR 14	L	2,732,398	6,760,961
	R	2,729,917	6,764,590
SR 15	L	2,743,189	6,770,959
	R	2,740,905	6,774,234
SR 16	L	2,724,721	6,766,059
	R	2,721,521	6,768,574
SR 17	L	2,728,174	6,772,853
	R	2,726,449	6,774,181
SR 18	L	2,733,884	6,777,285
	R	2,731,369	6,779,282
SR 19	L	2,739,705	6,782,252
	R	2,737,937	6,783,643
SR 20	L	2,715,254	6,782,162
	R	2,714,178	6,783,410
SR 21	L	2,718,922	6,784,782
	R	2,718,116	6,785,807
SR 22	L	2,700,300	6,796,149
	R	2,698,406	6,799,910
SR 23	L	2,710,631	6,803,415
	R	2,708,340	6,808,398
SR 24	L	2,696,388	6,824,990
	R	2,690,205	6,828,952



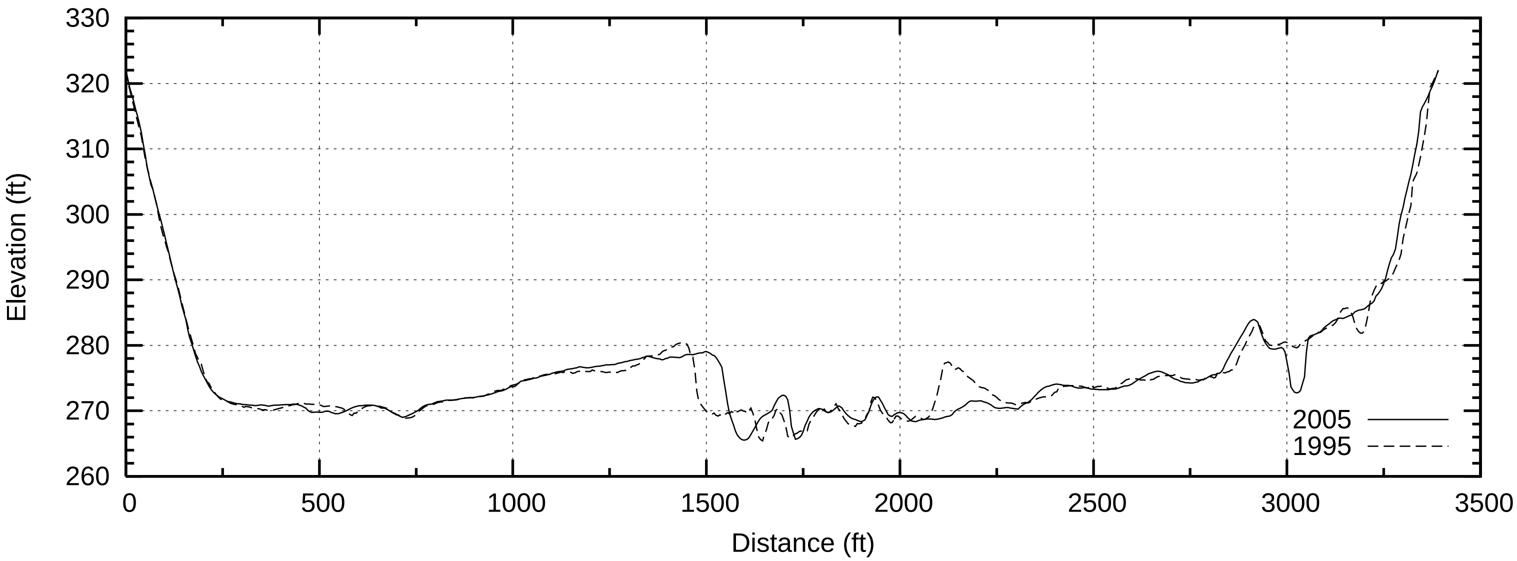
TWDB Survey July 2005

Cedar Creek Reservoir

Range Line SR01



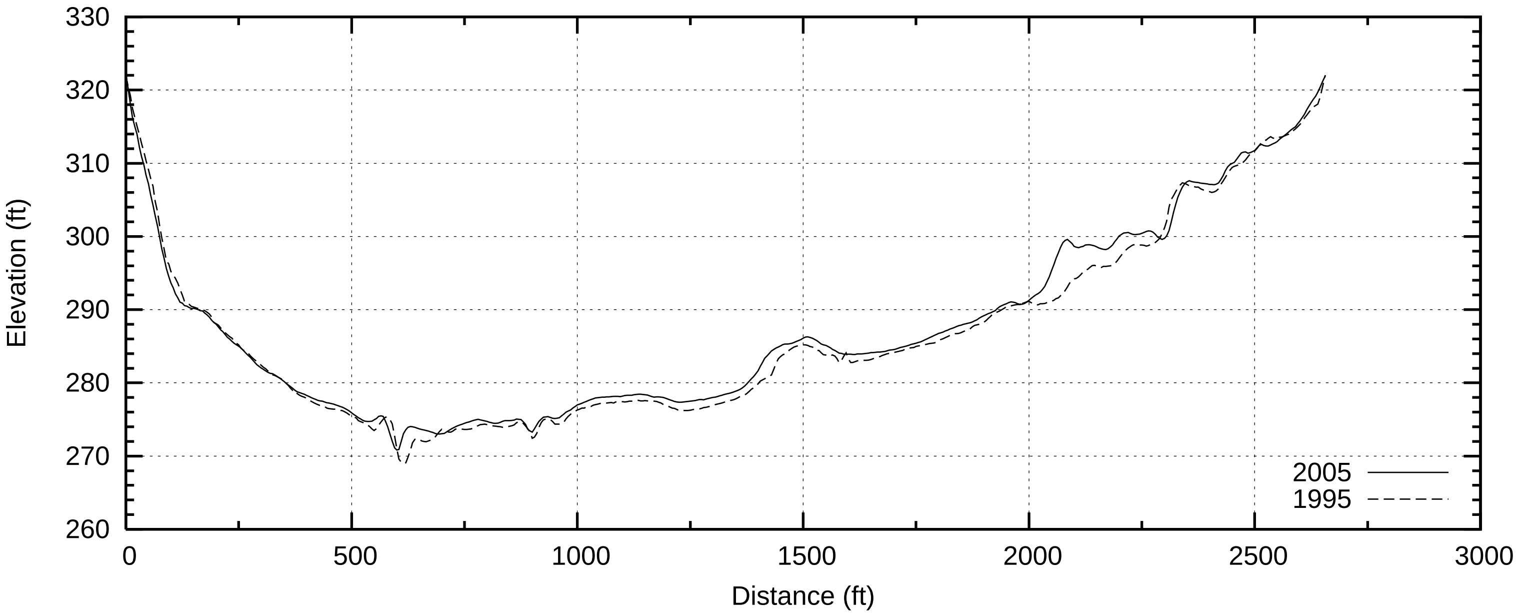
Range Line SR02



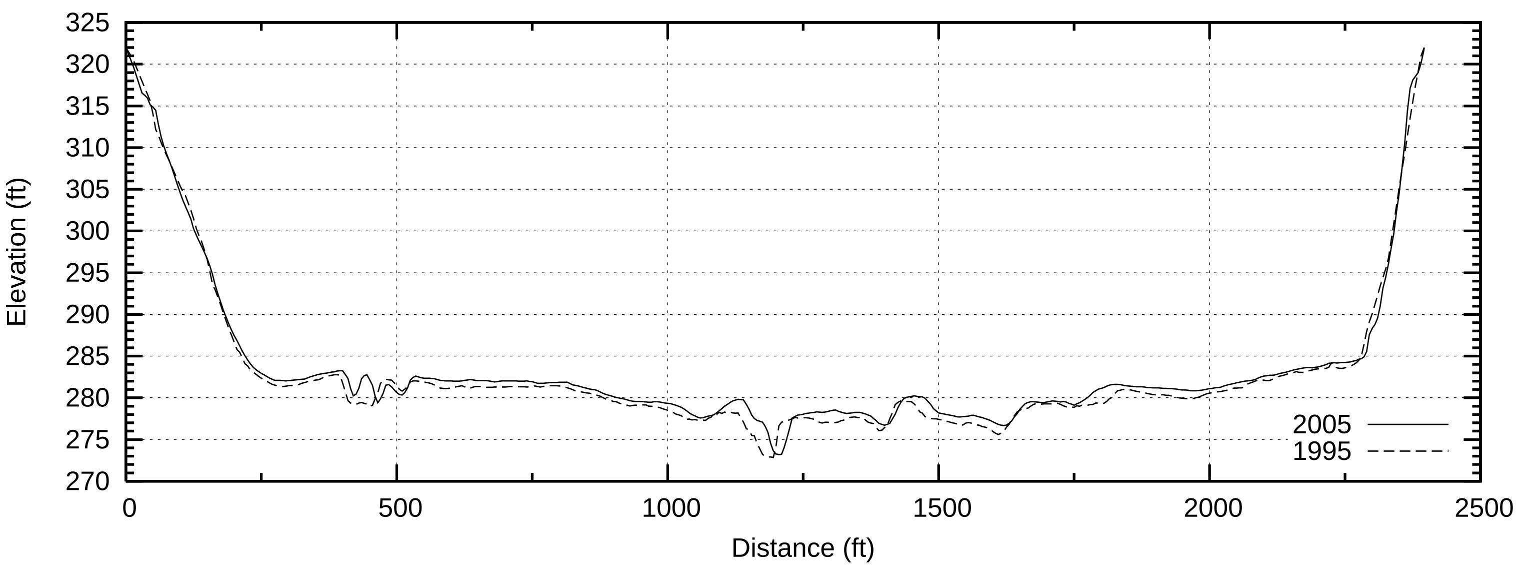
Appendix H

Cedar Creek Reservoir

Range Line SR03

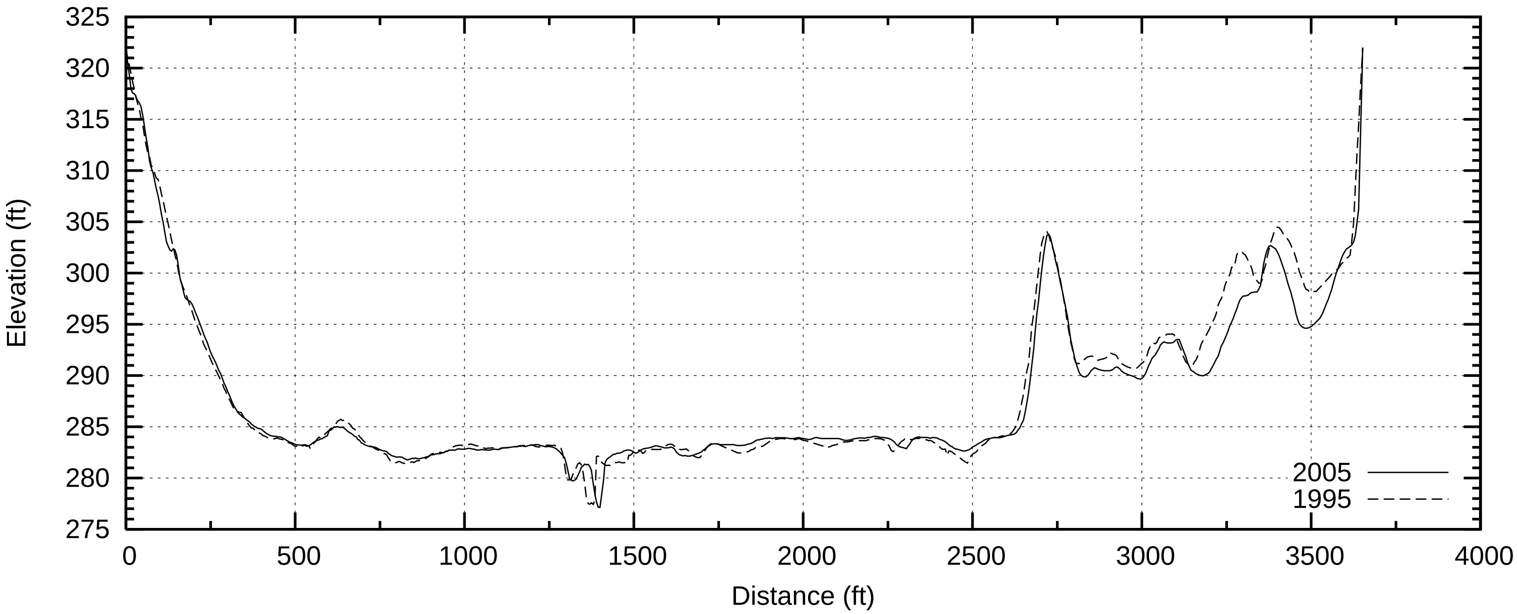


Range Line SR04

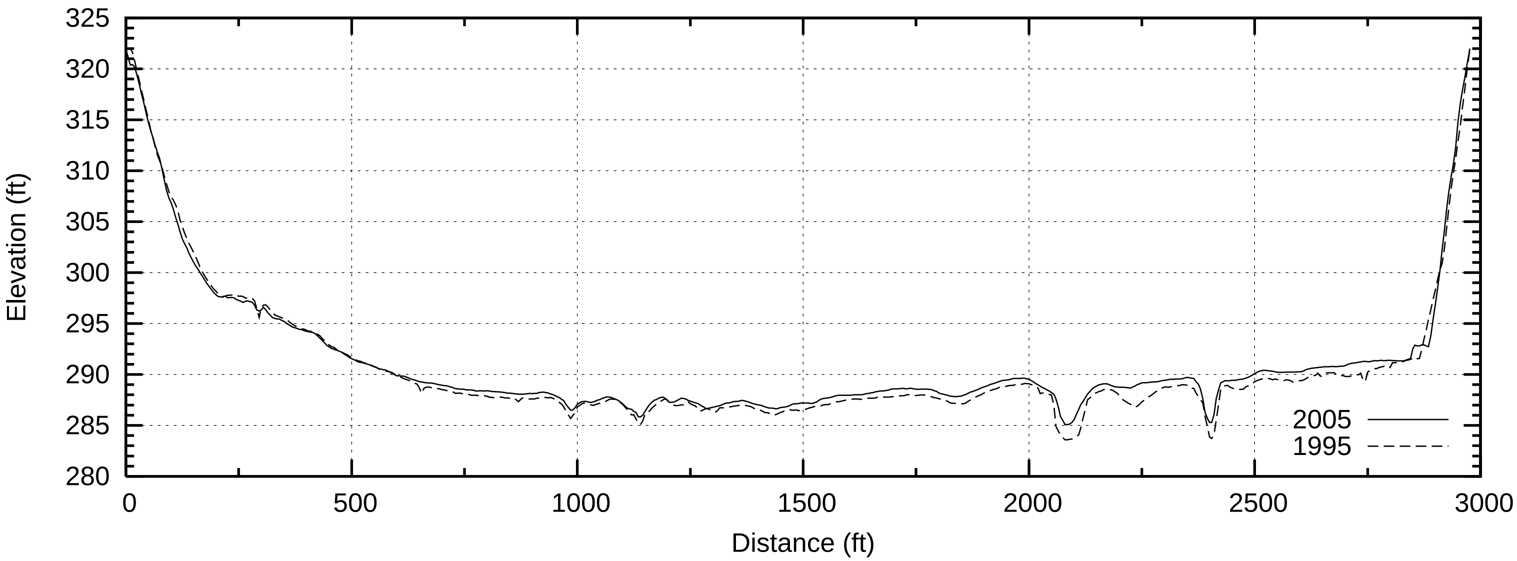


Cedar Creek Reservoir

Range Line SR05

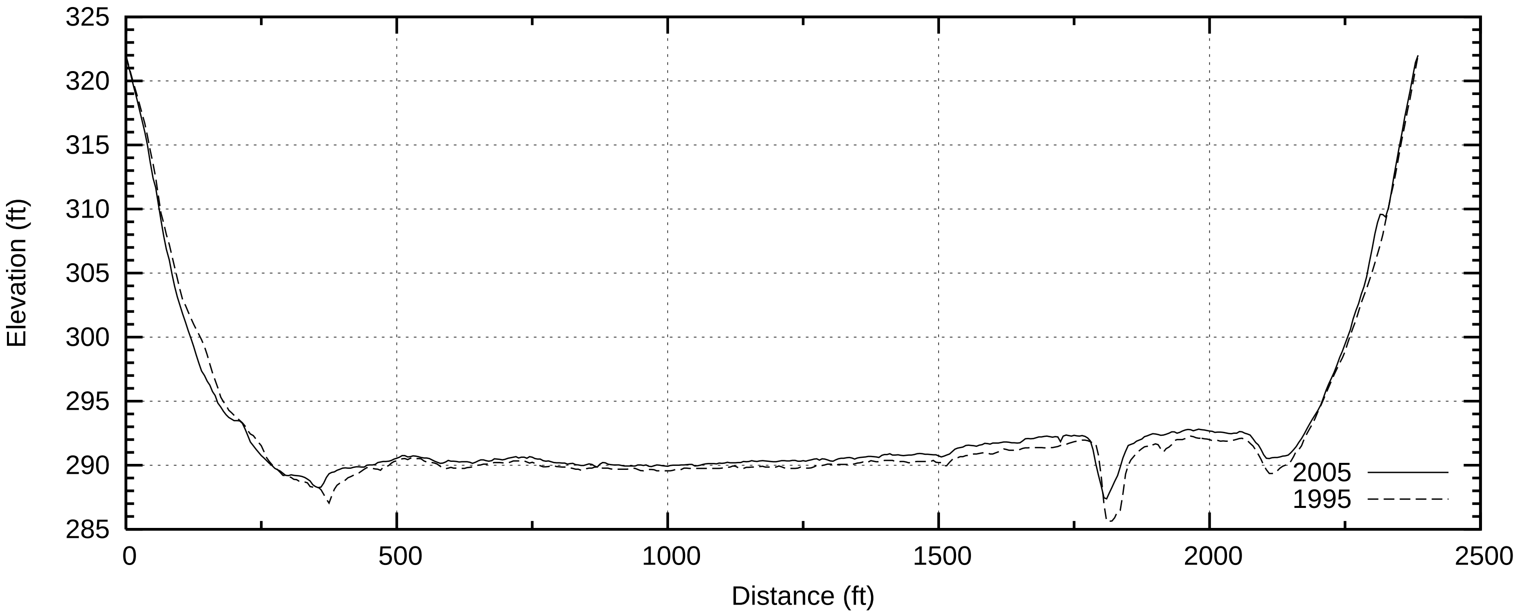


Range Line SR06

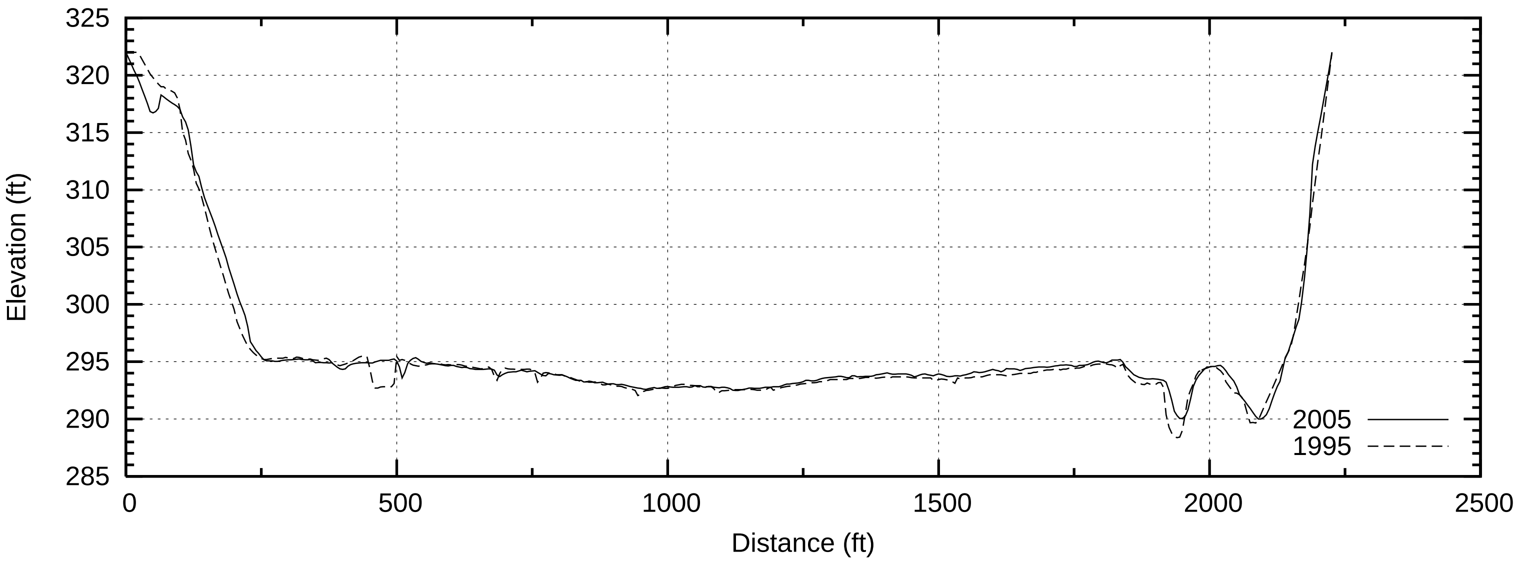


Cedar Creek Reservoir

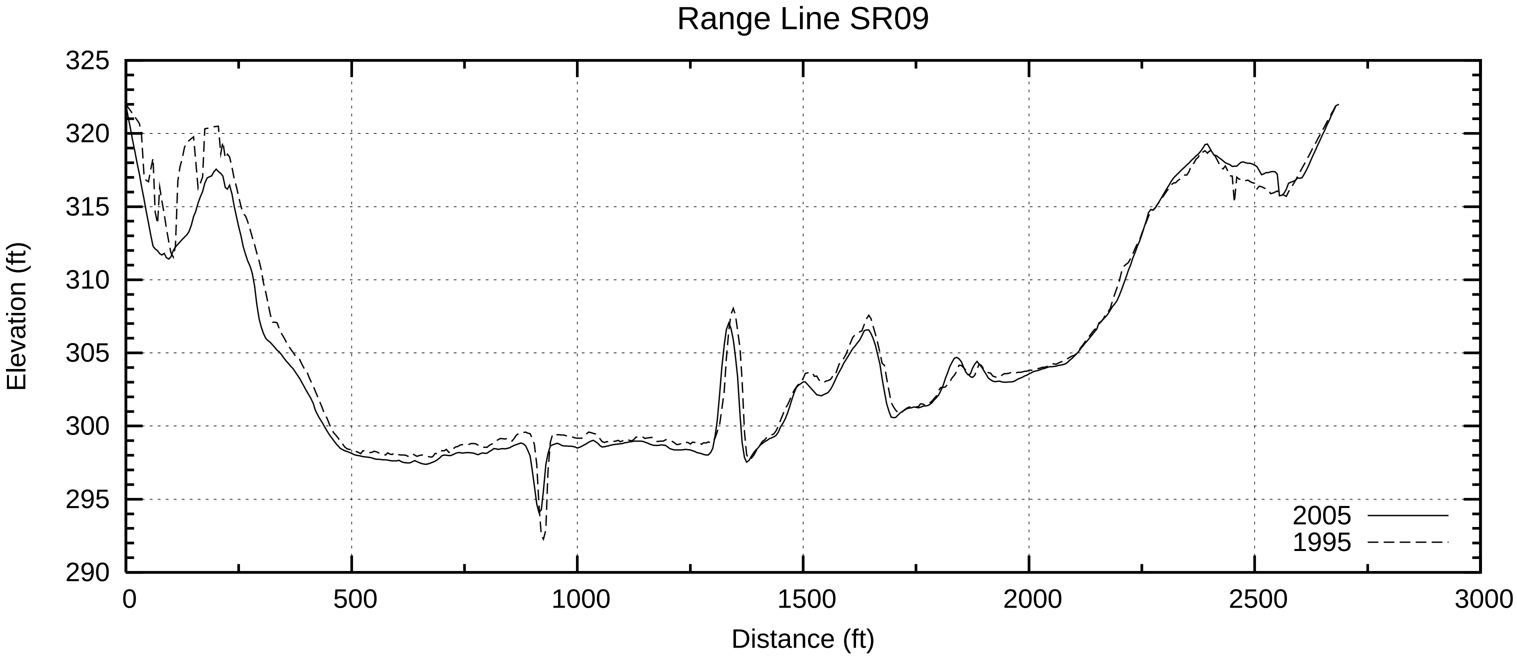
Range Line SR07

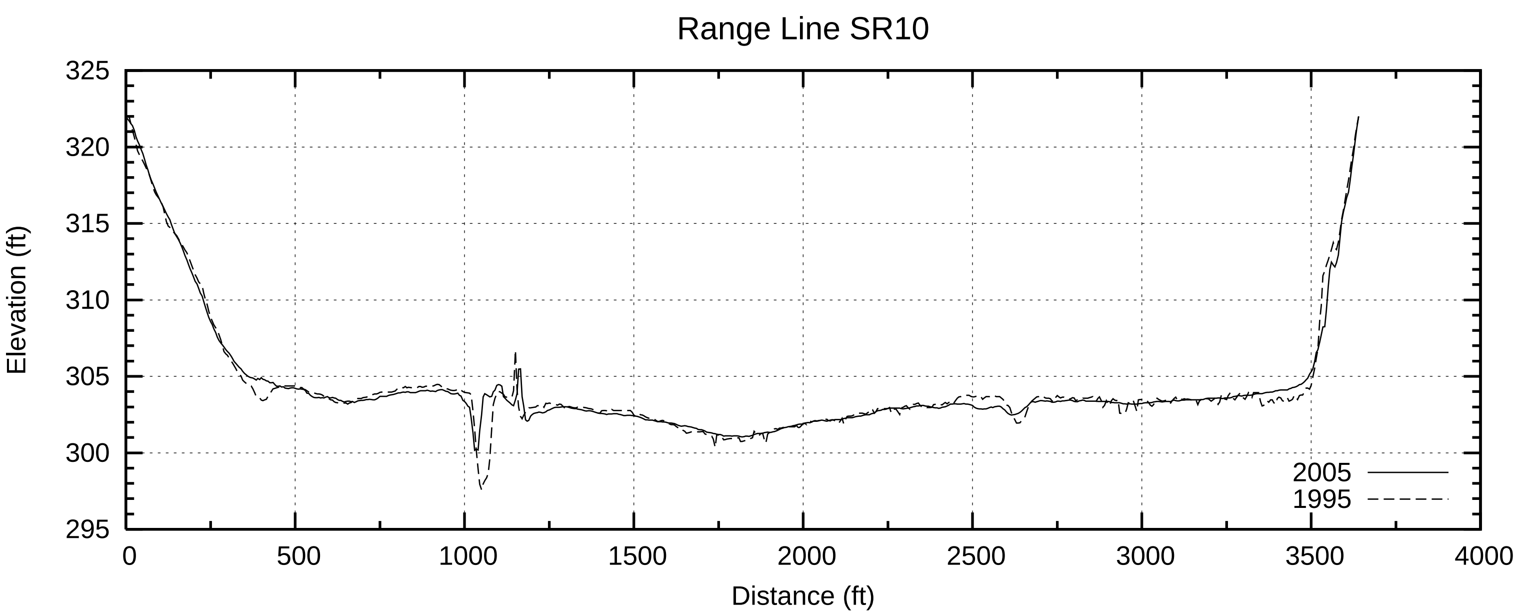


Range Line SR08



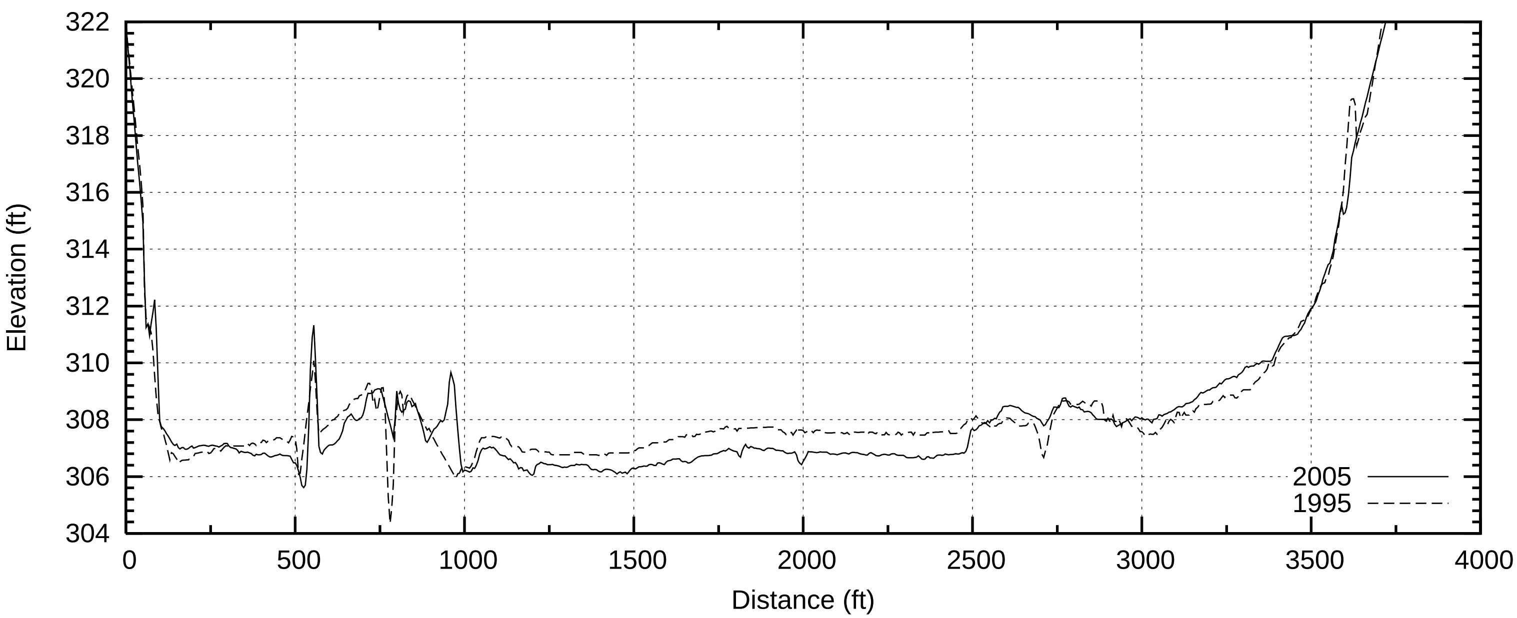
Cedar Creek Reservoir



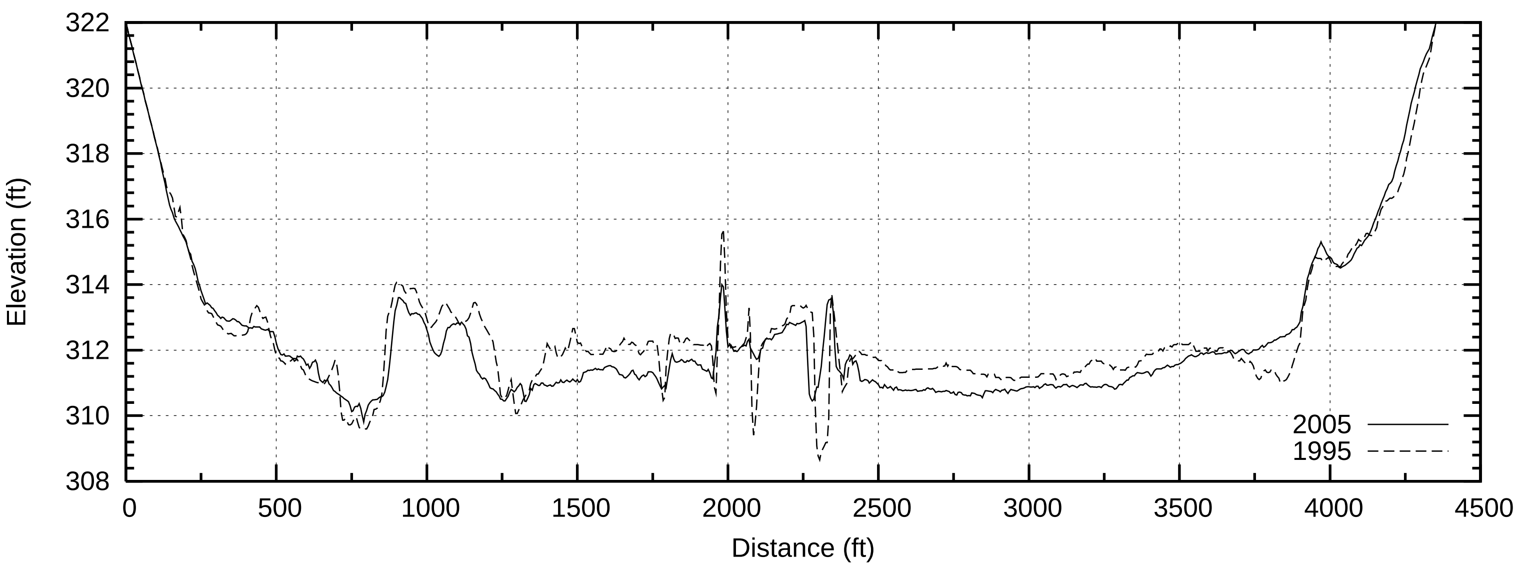


Cedar Creek Reservoir

Range Line SR11

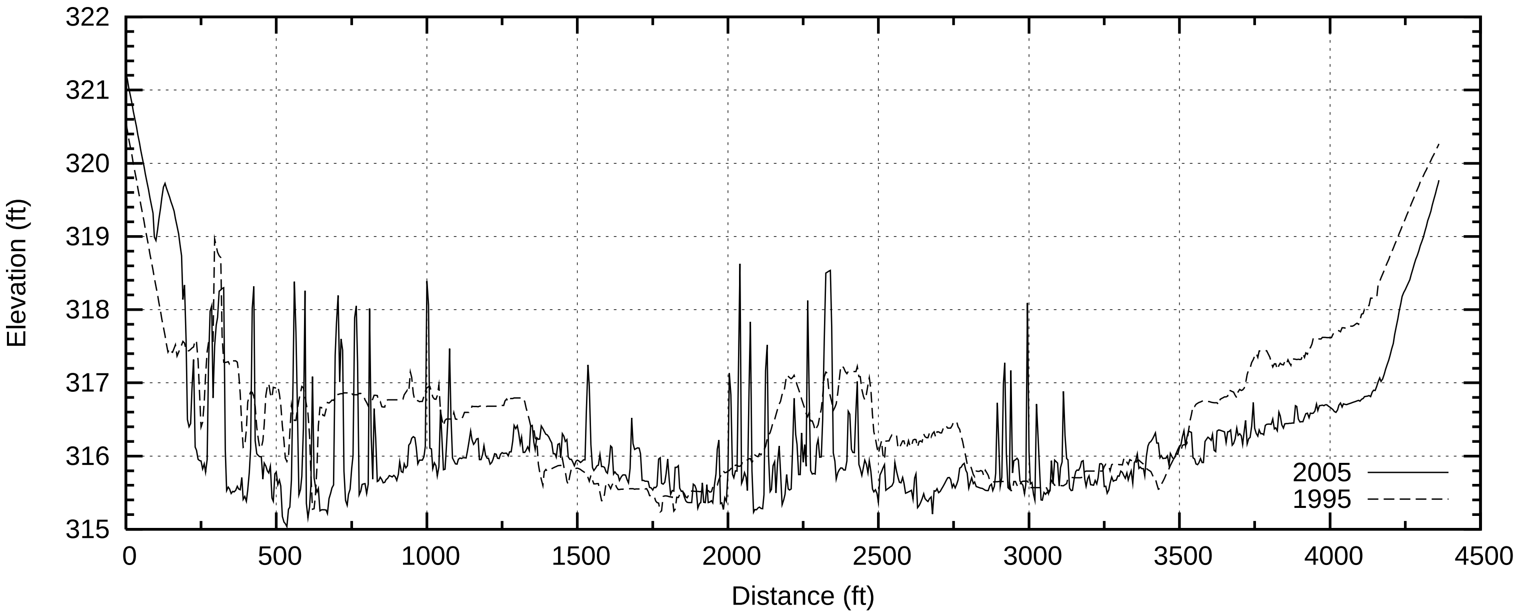


Range Line SR12

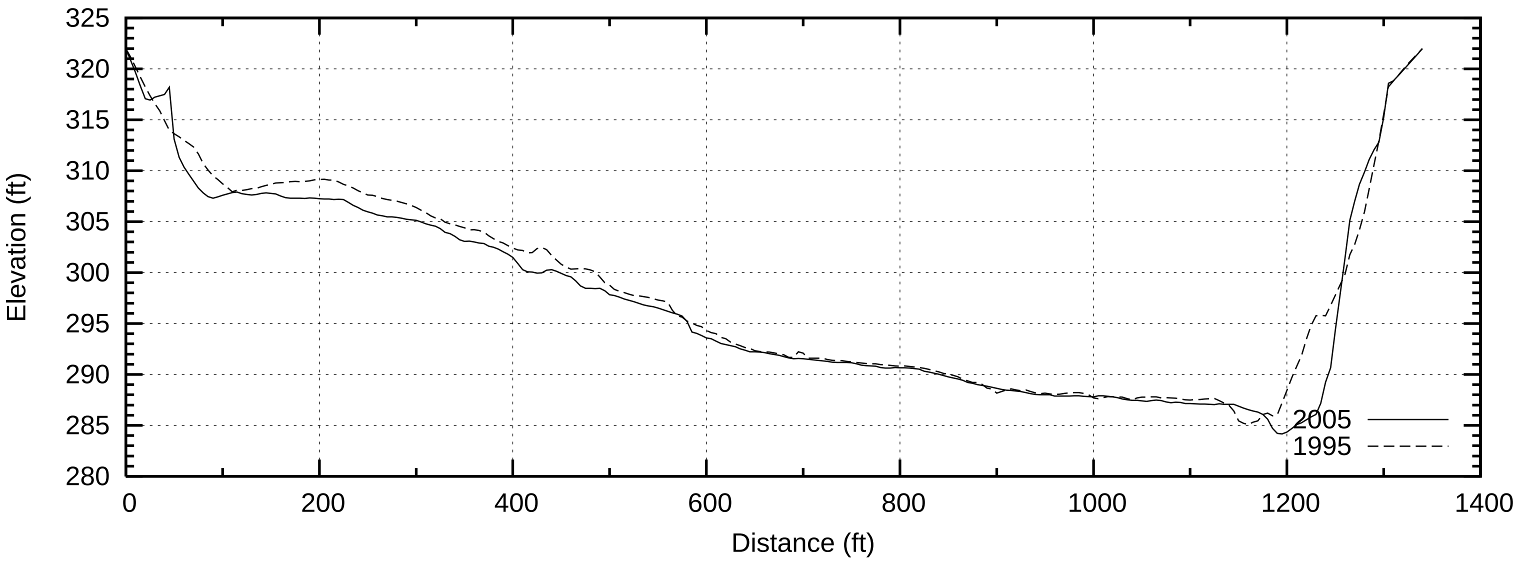


Cedar Creek Reservoir

Range Line SR13



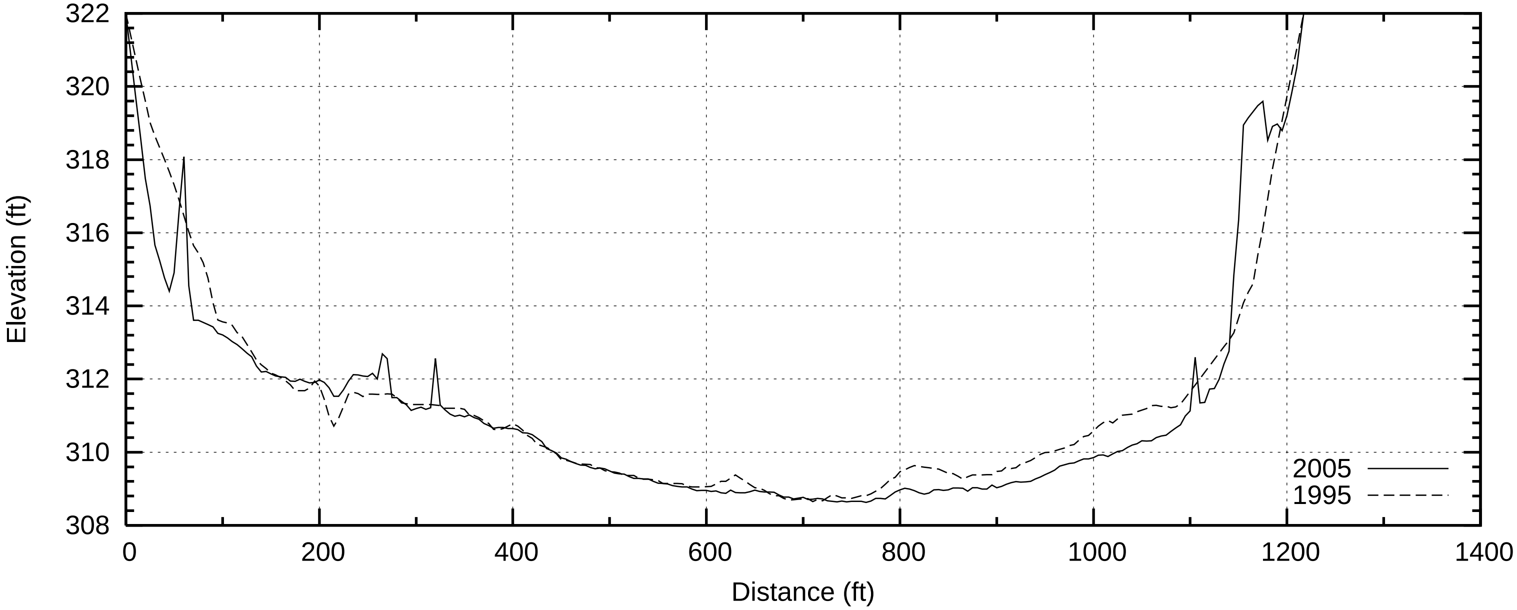
Range Line SR14



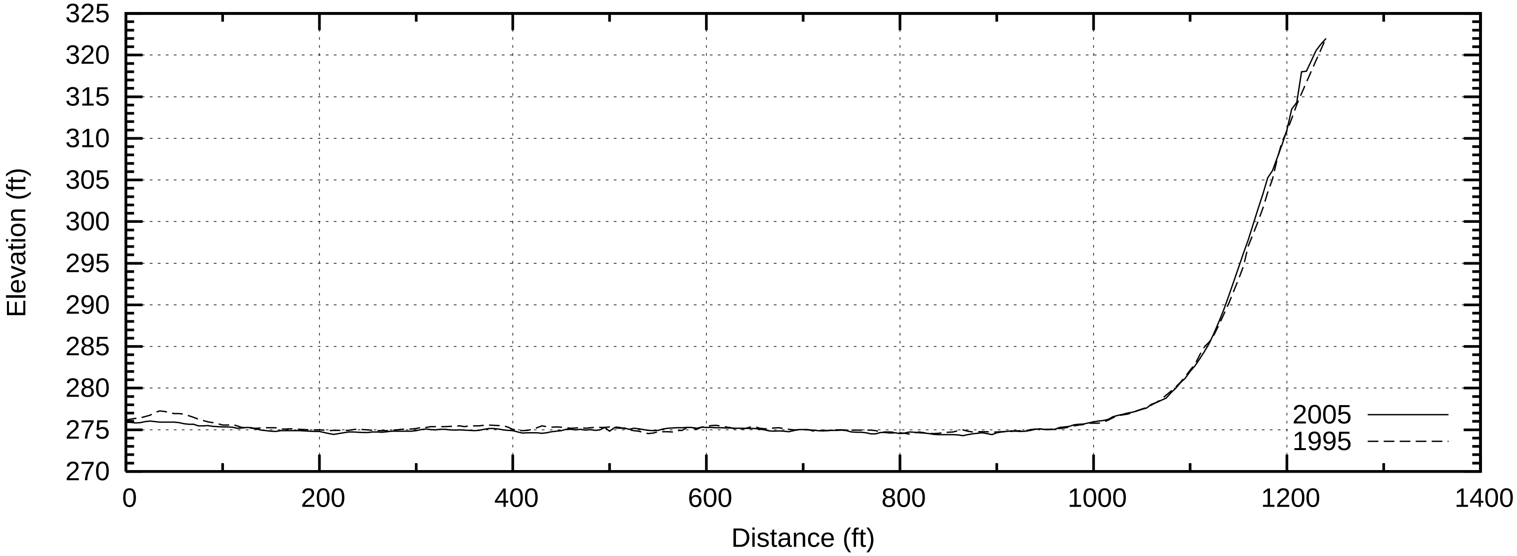
Appendix H

Cedar Creek Reservoir

Range Line SR15

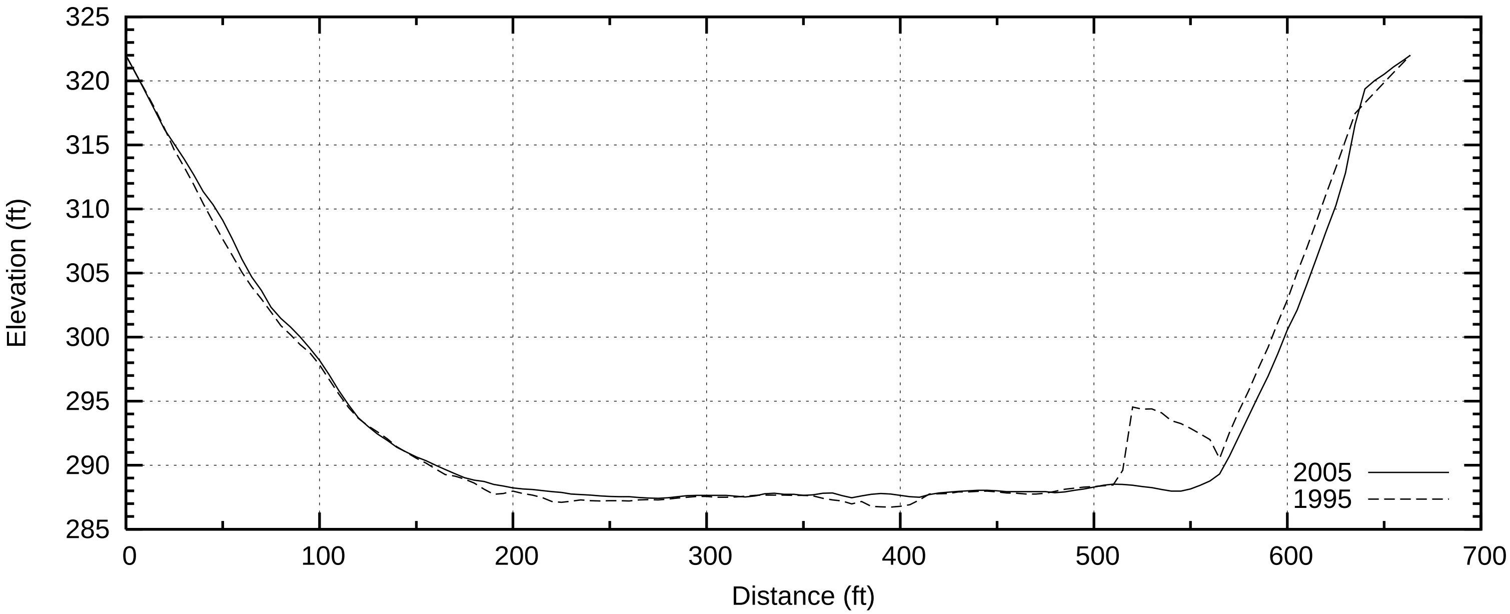


Range Line SR16

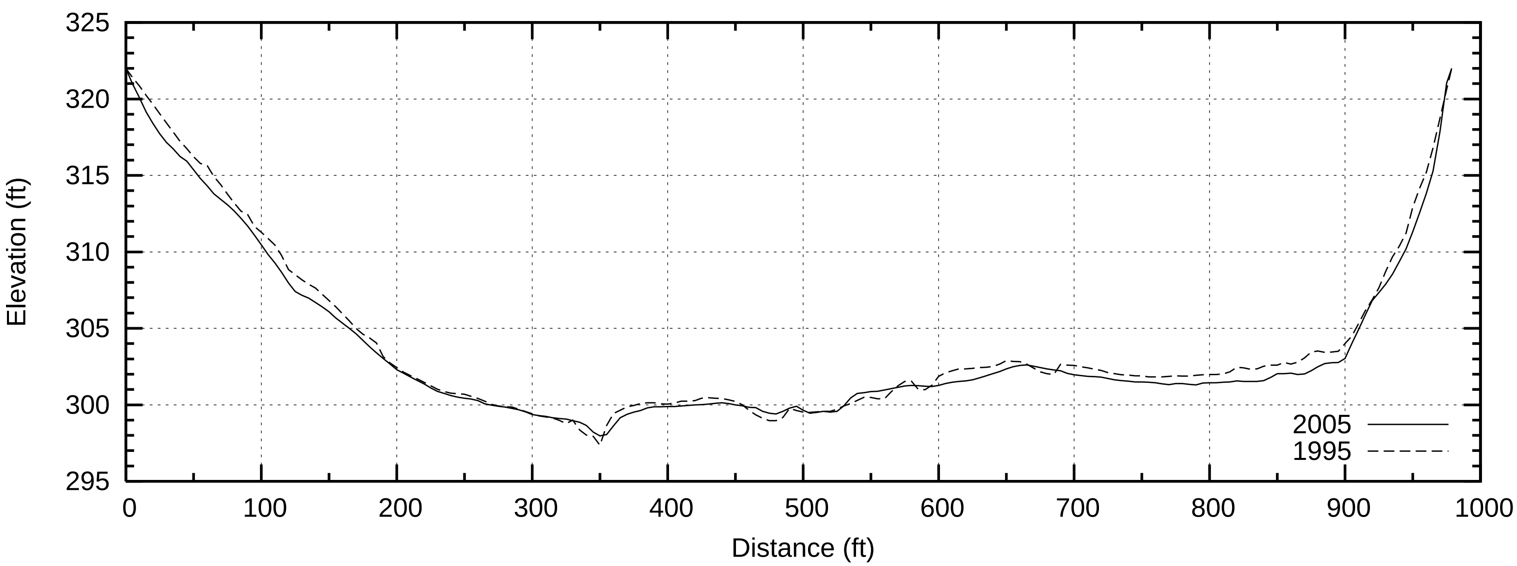


Cedar Creek Reservoir

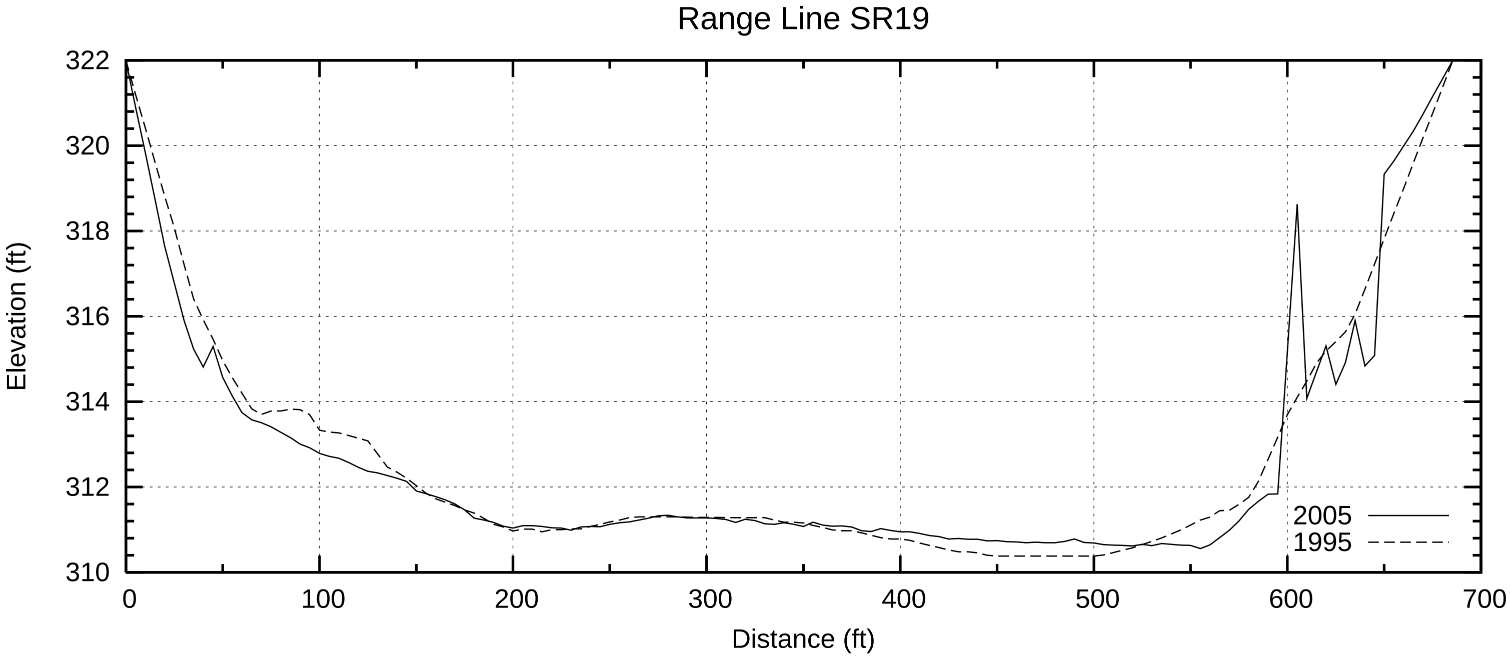
Range Line SR17

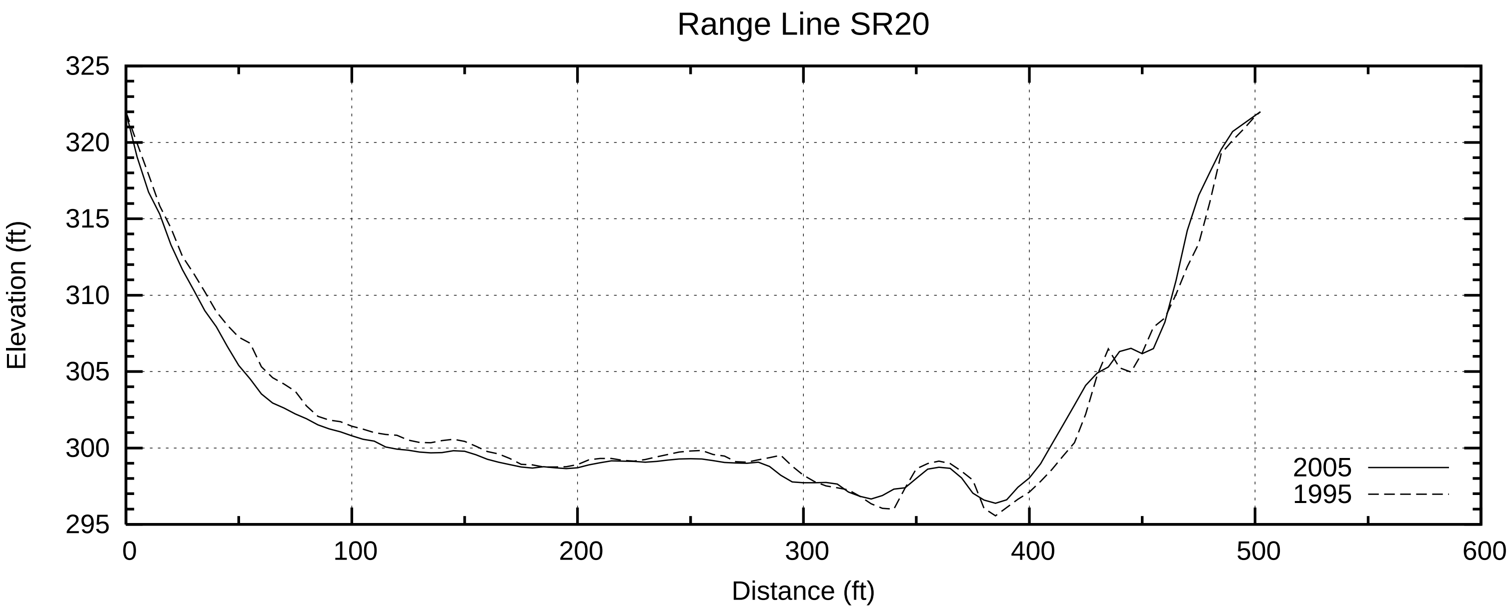


Range Line SR18

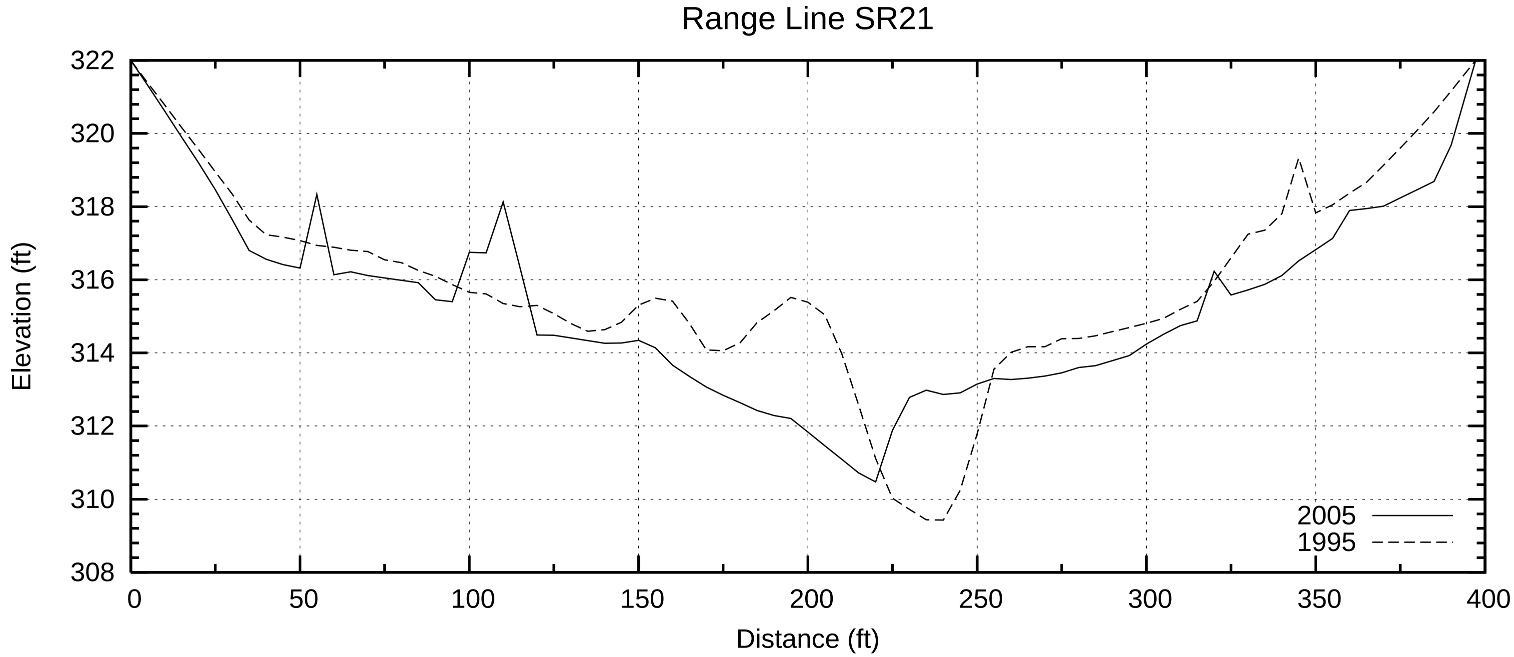


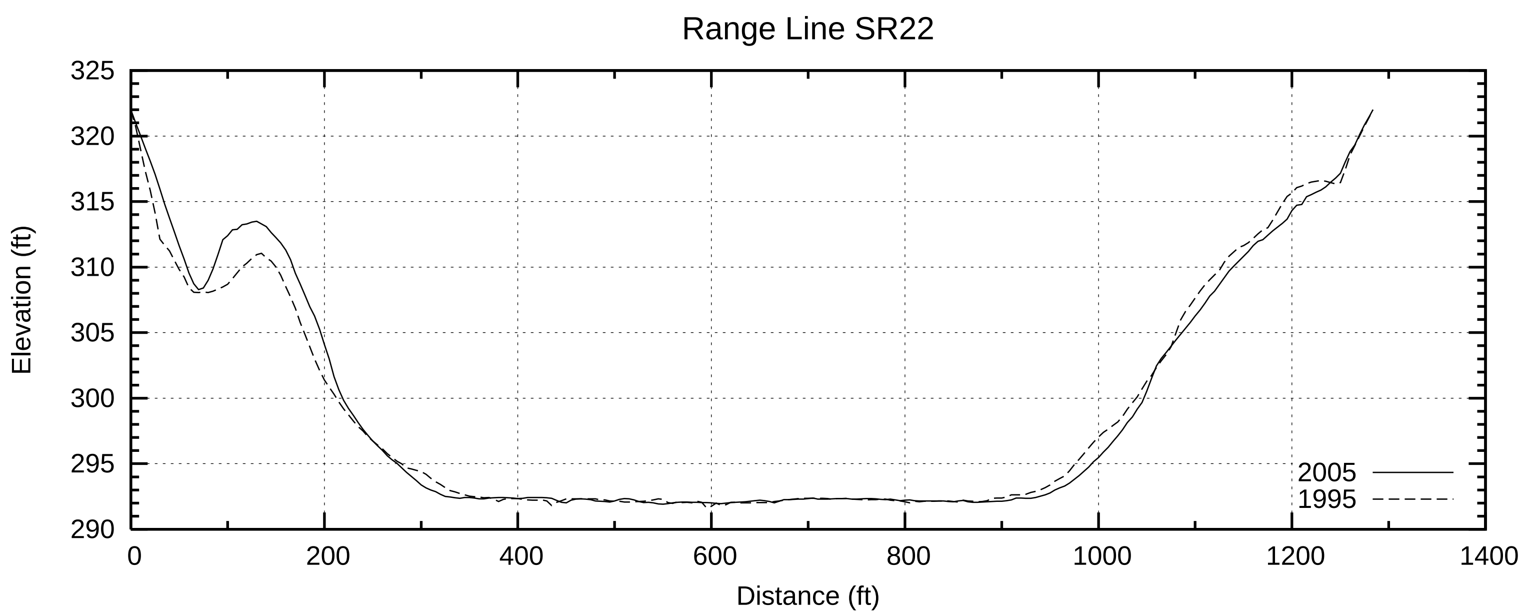
Cedar Creek Reservoir





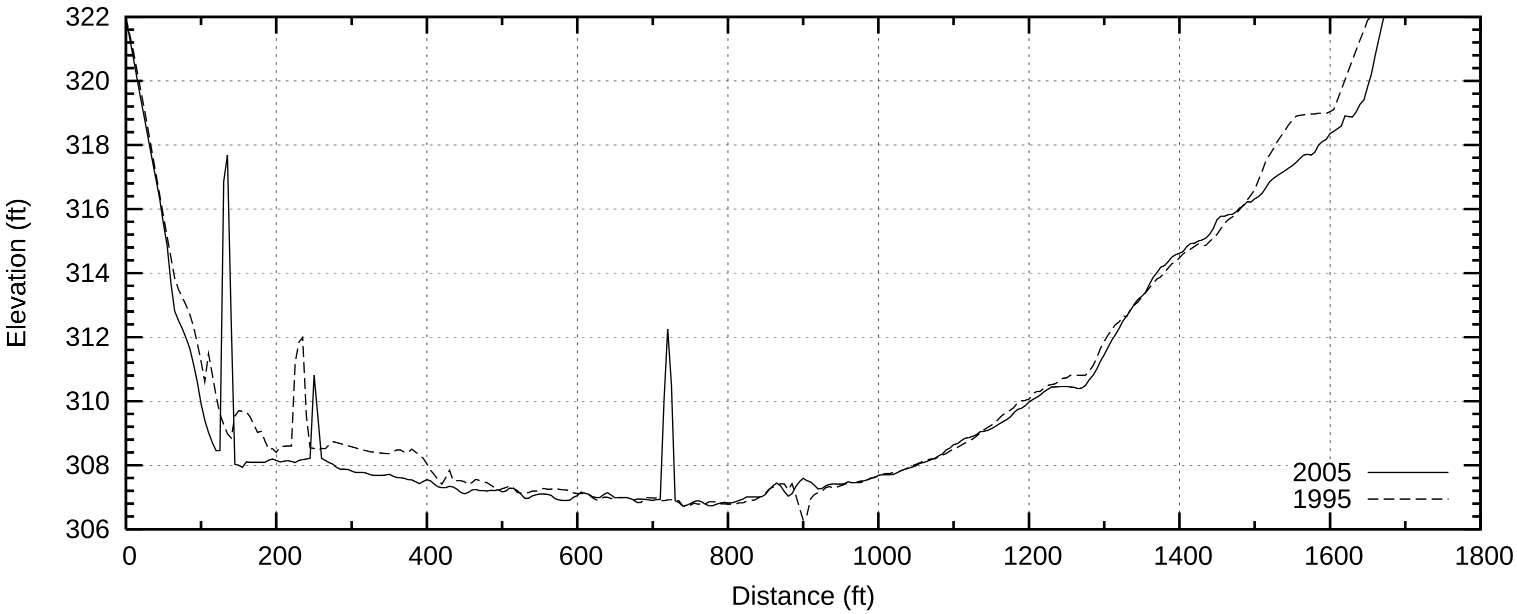
Cedar Creek Reservoir



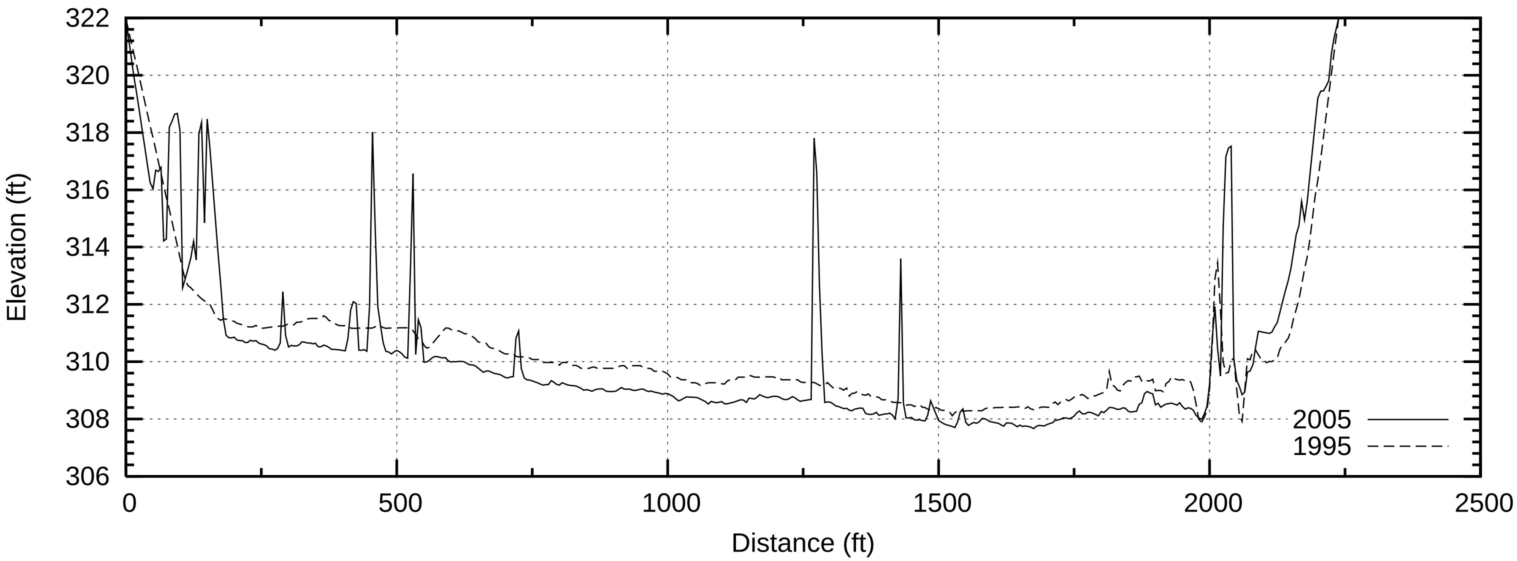


Cedar Creek Reservoir

Range Line SR23



Range Line SR24



Appendix I

Analysis of Cedar Creek Hydrographic Survey Results
From 1995 and 2005

Analysis of Cedar Creek Hydrographic Survey Results
From
1995 and 2005

Jordan Furnans, Ph.D., P.E.

August 31, 2006

Executive Summary

The Texas Water Development Board (TWDB) completed volumetric surveys of Cedar Creek Reservoir in 1995 and in 2005. This brief report documents the analysis performed on both the 1995 and 2005 Cedar Creek Reservoir volumetric survey results and raw-data sets, and discusses conclusions regarding sedimentation that may be gleaned from this re-analysis.

Results of the re-analysis of both the 1995 and 2005 volumetric survey reports suggest:

- The increase in overall reservoir volume between 2005 and 1995 is likely due to the 2005 survey’s better capturing of reservoir depths in shallower waters and in lake sidearms.
- Improved methods of editing raw volumetric survey data produced greater reservoir capacity for both the 1995 and 2005 surveys.
- Sedimentation is occurring in portions of the reservoir where the 1995 reservoir bottom was at elevations below approximately 294 ft.
- Maps of sediment scour and deposition within the reservoir are more indicative of vagaries in the sampling/TIN generation methodology than of sediment deposition/scour patterns.
- On a percentage volume basis, volume changes between the 1995 and 2005 surveys are only significant at elevations below approximately 294 ft.

Introduction

The Texas Water Development Board (TWDB) completed volumetric surveys of Cedar Creek Reservoir in 1995 and in 2005. The results of these surveys include tabulations of reservoir areas and volumes as related to reservoir water surface elevation (WSE). The reservoir volume and area tables from the 1995 survey report are reproduced in Appendix A of this report. The reservoir volume and area tables from the 2005 survey report are reproduced in Appendix B of this report. These volume and area tables are herein referred to as the “original” volume and area tables for their respective survey years.

In an email to Dr. Barney Austin of TWDB dated April 4, 2006, Mr. David Marshall of the Tarrant Regional Water District (TRWD) pointed out that cursory comparisons of the results from both surveys suggest volume in Cedar Creek Reservoir has increased since 1995. Mr. Marshall also stated he would “expect the loss of volume in the deepest part of the reservoir would be sustained and the total losses increase up to conservation level.” At Mr. Marshall’s request, Dr. Austin initiated a re-examination of the Cedar Creek Reservoir volumetric survey results in attempt to address the issues posed by Mr. Marshall. This brief report documents the analysis performed on both the 1995 and 2005 Cedar Creek Reservoir volumetric survey results and raw-data sets, and discusses conclusions regarding sedimentation that may be gleaned from this re-analysis.

Problem Identification

To address Mr. Marshall’s concerns, a comparison of volume table data from the 1995 and 2005 surveys was made (Figure 1). This comparison is similar to the sketch provided by Mr. Marshall in his email to Dr. Austin, and was (hopefully) developed using the same type of analysis Mr. Marshall conducted. The data shown in Figure 1 was calculated from values out of the original volume tables using the formula:

$$Data = V_{1995} - V_{2005}$$

with “V” representing reservoir volume “Data” representing the data points plotted against elevation. Negative data values therefore indicate increases in volume from 1995 to 2005, whereas positive data values indicate decreases in volume over this time period. Figure 1 confirms Mr. Marshall’s assertion that reservoir capacity appears to have increased (by approximately 800 acre-ft) since 1995. Such an increase is unlikely to be “physically based” given that it would require:

1. Sediment to be removed from the reservoir (via dredging or in outflow), or
2. Little incoming sediment along with compaction of existing sediments

Possibility #1 is unlikely because TWDB is not aware of any dredging that occurred in Cedar Creek Reservoir between the two surveys and there was not any evidence of dredging discernible from analysis of the 2005 bathymetry. It is also unlikely that sediment was lost within the reservoir outflow as this water usually flows out from a location near the base of the dam, where waters are free from sediment (these waters typically have residence times greater than the times required for settling out of any sediments the waters once contained). Possibility #2 is unlikely because sediment compaction occurs over timescales much greater than 10 years, and compaction is not likely to increase reservoir volume (Meckel et al, 2006) in such a short time.

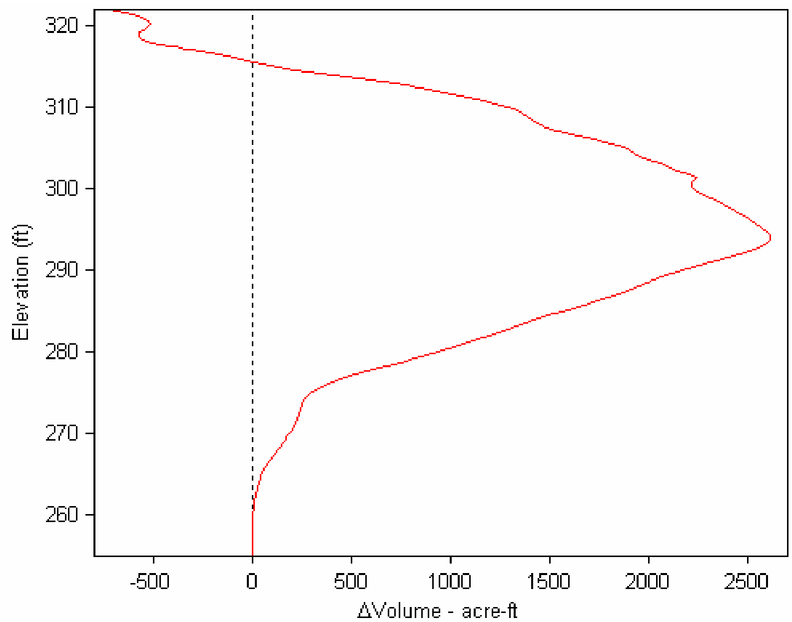


Figure 1 – Comparisons of Cedar Creek Reservoir volumes with water surface elevation. Data shown as $X_{1995} – X_{2005}$ where X is area or volume.

Given that the observed increase in reservoir volume is not likely physically-based, it is logical to assume that the increase is due to differences in survey methodologies in 1995 and 2005, including the methodologies used in editing/processing the raw survey data. This possibility is explored in the next section.

Before discussing the data-editing process used in this re-analysis, the analysis methodology used in creating Figure 1 must be discussed. In 1995, the TIN representation of Cedar Creek Reservoir bathymetry was created from 1995 survey sounding points and reservoir boundary files (for discussion, the boundary file is referred to as “Boundary95”). In 2005, the TIN representation of Cedar Creek Reservoir bathymetry was created from 2005 survey sounding points and reservoir boundary files (for discussion, the boundary file is referred to as “Boundary05”). In order to properly compare reservoir volumes vs. elevations from each survey, the boundary files used for creating each TIN model must be identical (i.e. Boundary95 = Boundary05). As shown in Figure 2, the reservoir boundary files used in each survey were not identical. The difference in boundary files occurs mainly in the shallower areas of the lake, and likely contributes to the increase in lake area and volume at elevations near conservation pool between the 1995 and 2005 surveys (Figure 1).

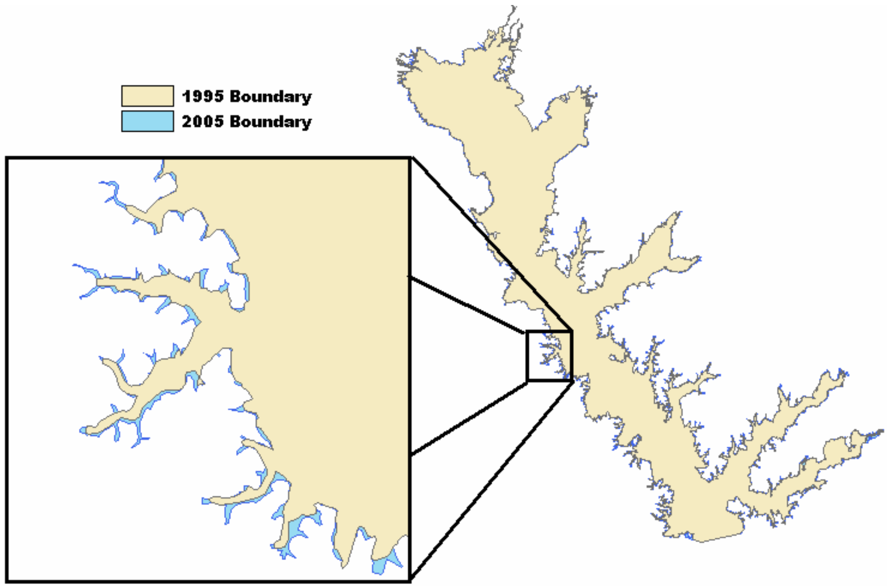


Figure 2 – Different Lake Boundary files used in the 1995 and 2005 Surveys of Cedar Creek Reservoir.

Additional complications in drawing conclusions from Figure 1 arise from the method for calculating the volume differences at each elevation. The data presented in Figure 1 was calculated by subtracting volumes at equal elevations, i.e. the difference in volume at elevation 280ft is the 1995 volume at 280ft elevation minus the 2005 volume at 280ft elevation. This analysis (herein referred to as "simple") MAY reflect sediment deposition or scour activities, but it is not guaranteed to do so because the control-volumes used in computing the reservoir volumes for each survey may not be identical.

To better capture sediment deposition or scour processes in the analysis methodology, changes in water column depth at specific locations are needed. These locations should be based on the water column depths computed for any given water surface elevations and the TIN model derived from the EARLIEST survey to be compared. For example, say the amount of sediment deposition or scour is to be computed for the instance when the water surface elevation in Cedar Creek Reservoir is at 280ft. The first step would be to determine locations within the reservoir where the bathymetric surface computed from the 1995 survey are less than 280ft (called "WET" surfaces). Deposition and scour are then computed by comparing water column depths between the 1995 and 2005 bathymetric surfaces only at the locations of the "WET" surfaces. The resulting volumetric tally may be verbally described as follows: "For the 1995 reservoir surfaces submerged when the water surface elevation is 280ft, comparisons with the 2005 surfaces indicate a net deposition/scour of sediment equal to X." (Where X would be plotted against elevation as in Figure 1). To summarize this methodology another way, plots of volume change vs. elevation computed in this fashion reflect the changes in reservoir volume between surveys as evidenced through control volumes defined by the earliest survey. For the remainder of this document, this new methodology is referred to as the "equal-area" analysis.

The final complication addressed herein relating to the analysis of Figure 1 has to do Mr. Marshall's assertion that he would "expect the loss of volume in the deepest part of the reservoir would be sustained and the total losses increase up to conservation level." For this situation to occur, sedimentation would have to be uniform throughout the reservoir, which is not likely given sedimentation processes and fluctuating reservoir water levels. In truth, sedimentation is not immediately obvious from Figure 1, which presents the cumulative volume loss at each elevation. Elevations at which sedimentation (S) is occurring are better determined with the first-derivative of the volume change vs. elevation plot:

$$S = \frac{\partial \Delta V}{\partial E}$$

where ΔV is the change in volume between two surveys and E is the water surface elevation at which the volume change is calculated. Sediment deposition is indicated where S is positive, and scour is indicated where S is negative. Figure 3 presents the same data as shown in Figure 1, but includes a plot of S vs Elevation. (Note: data presented in Figure 4 were generated using the simple analysis methodology and a standard central-differencing approximation for the derivative of the ΔV vs. Elevation relationship.)

Based on the original survey report data presented in Figure 3-right, between 1995 and 2005 sedimentation occurred in Cedar Creek Reservoir at elevations below 294 ft, between 300 ft and 301 ft, and between 319 ft and 320 ft. The remainder of this document discusses edits made to the 1995 and 2005 dataset and presents a reassessment of the edited 1995 and 2005 survey data.

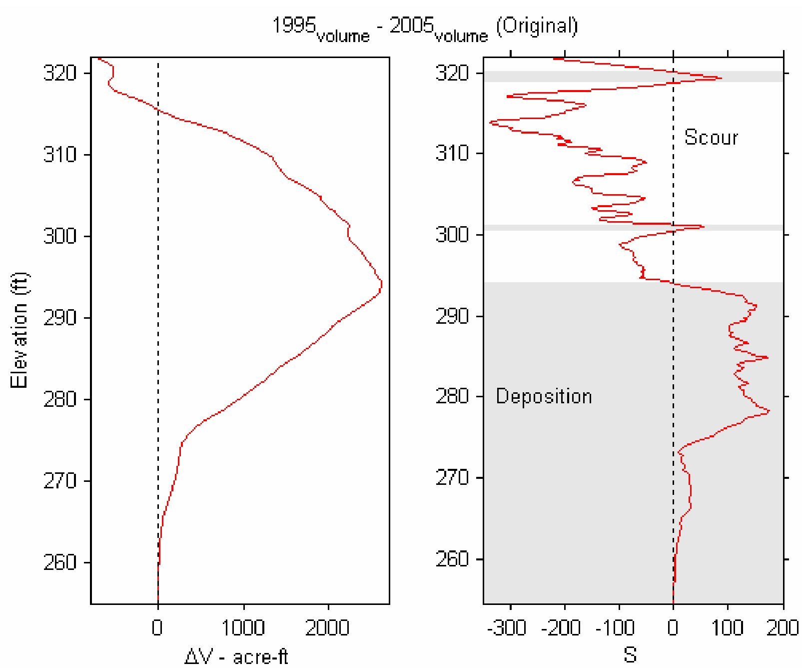


Figure 3 – Cedar Creek Data vs. Elevation comparison from the original 1995 and 2005 survey reports: Left) Volume change (ΔV) ,Right) Sedimentation (S)

Data Editing

The goal of the data re-editing process was to determine if the deposition & scour evident in Figure 3 was actually due to sedimentation processes within the reservoir or whether it was an artifact of the data collection/data editing processes used in generating the original survey reports. For this analysis, data from the 1995 and 2005 surveys were edited manually (through detailed inspections of the TIN models derived from each dataset) and automatically using the HydroEdit program. For this comparison, all TIN models were created using the 2005 reservoir boundary.

Shallow Water Editing

Before editing the raw data from each survey, the "Shallow-Area Problem" (SAP) fix was applied to each dataset. The SAP fix (Furnans, 2006) estimates the water column depths in areas between the reservoir boundary and the closest raw data survey points to the boundary (Figure 4). This fix eliminates artificial "jumps" in the area vs elevation relationship (Figure 4a) near conservation pool elevations that occur due to the method of TIN generation used in the ArcGIS 3D Analyst package. With this SAP fix, bathymetric contours are extended up into the non-surveyed portions of the reservoir, and likely present a more realistic representation of the actual (unknown) bathymetry in these areas (Figure 5). The effect is to smooth the area vs. elevation relationship for elevations nearest to the conservation pool elevation, and the reservoir volume also increases.

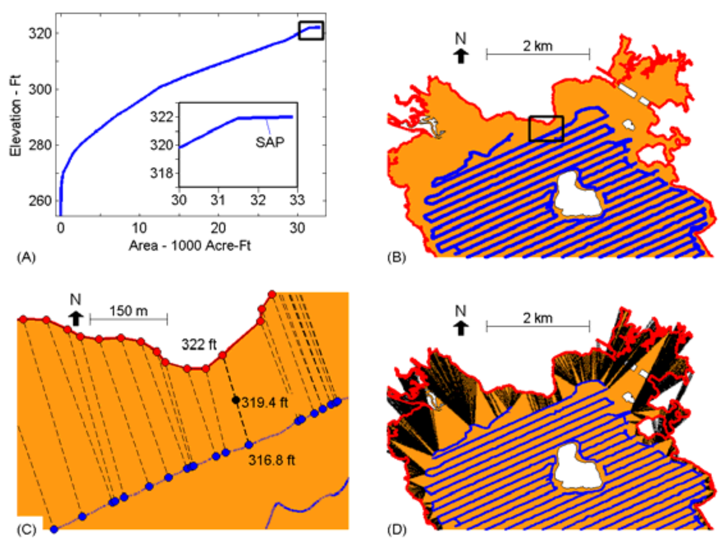


Figure 4 - Shallow Area Problem (SAP) for Cedar Creek Reservoir, TX. A) Elevation-Area graph with artificial area "jump," B) Map with sounding points (blue), C) Close-up of boxed area in B), showing elevation interpolation along connecting lines (black) between boundary (red) and sounding points (blue), D) Lake map with sounding points (blue) and interpolated points (black). Data shown from 2005 survey. Figure reproduced from Furnans (2006b).

It should be noted that Figure 5 is reproduced from Figure 5 in Furnans (2006b) where it was used in comparing results obtained when manually editing the 2005 survey data and when using the automated editing routines in the HydroEdit program (Furnans, 2006a). Data reported in the original 2005 volume and area tables were computed from data edited within the HydroEdit program but without the SAP fix applied.

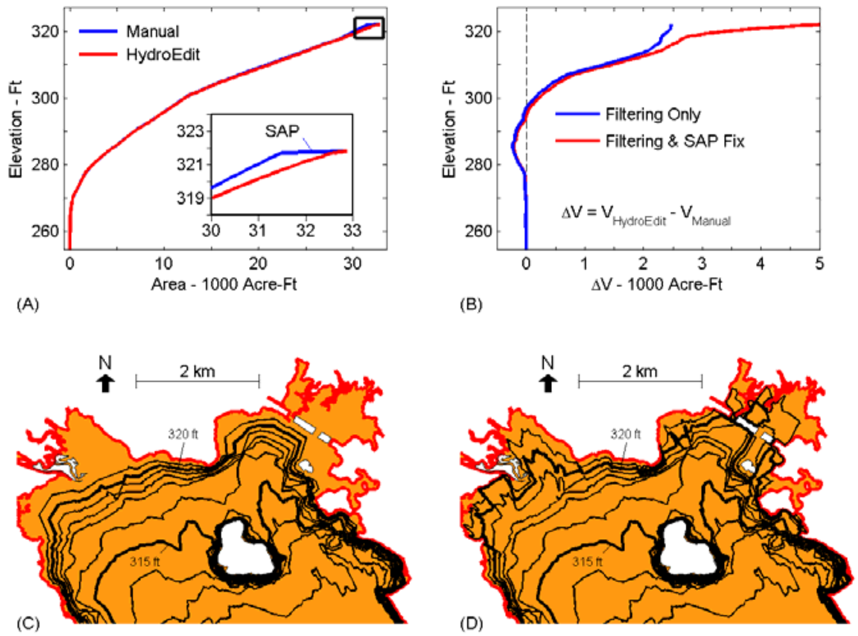


Figure 5 – Solution of the Shallow Area Problem (SAP) for Cedar Creek Reservoir, TX. A) Elevation-Area graph without the "artificial jump," B) Volume increases over manual editing results using HydroEdit filtering and SAP solution, C) Bathymetry contours for manually edited data, showing lack of depth in upper reaches of reservoir, D) Bathymetry contours for HydroEdit filtered data with the SAP solution, showing estimated depths in upper reservoir reaches. Contours shown at 1-ft intervals with the lake boundary (red) at elevation 322 ft. Data shown is from the 2005 survey. Figure reproduced from Furnans (2006b).

Deep Water Re-Editing

After implementing the SAP fix to both the 1995 and 2005 datasets, deep-water re-editing was performed to eliminate "bad" data which was not properly edited when the raw data from each survey was first edited. The editing process uses comparisons of the bathymetry generated from each survey dataset to identify possible locations of "bad" sounding data points. For this discussion, a "bad" sounding data point is a data point collected by the hydrosurvey crew (and not interpolated in the SAP fix) that produces unexpected and/or abrupt changes in the reservoir bathymetry derived from the dataset containing the "bad" point.

Often it was possible to identify bad data based on the reported elevation values. For example, in the 2005 survey data, bad data points usually had elevations ranging from 318.7ft to 319.2ft (these elevations correspond to water depths of approximately 3 ft, which is the depth at which the echosounder was located – thereby suggesting the echosounder calculates a zero-ft water depth below the transducer face). In the 1995 data, a common occurrence was that elevations between successive soundings would drop from approximately 300ft (±0.3ft) to 290ft (±0.3ft) only to return to 300 ft (±0.3ft) values after a short distance. Such a change in recorded elevations is difficult to explain and may indicate an actual dip in reservoir bathymetry. The prevalence of this pattern within the 1995 data, however, suggested the temporary drop to lower elevations (which was found throughout the reservoir) was not physical and was due to some unknown aspect of the data collection process.

Using the simple analysis methodology, comparisons of the volume table and area table data for the original and edited 1995 surveys (Figure 6) show that the 1995 volume at conservation pool elevation increased by nearly 3000 acre-ft. The associated increase in area above elevation 318 is due primarily to the elevation interpolation used in the SAP fix (Figure 6 right). Area and volume tables for the revised 1995 survey data are presented in Appendix C of this report.

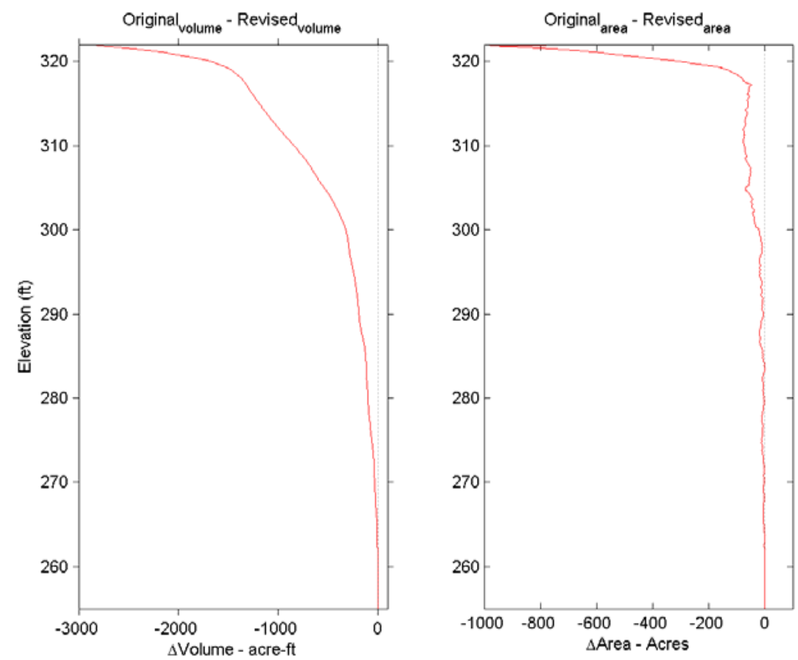


Figure 6 – Comparing the original and edited 1995 TIN models – Left: Volume change vs. Elevation, Right: Area change vs. Elevation. Changes are defined as the original value minus the edited value at each elevation.

Using the simple analysis methodology, comparisons of the volume table and area table data for the original and edited 2005 surveys (Figure 7) show that the 2005 volume at conservation pool elevation increased by over 6000 acre-ft. The associated increase in area above elevation 318 is due primarily to the elevation interpolation used in the SAP fix (Figure 7 right). Area and volume tables for the revised 2005 survey data are presented in Appendix D of this report.

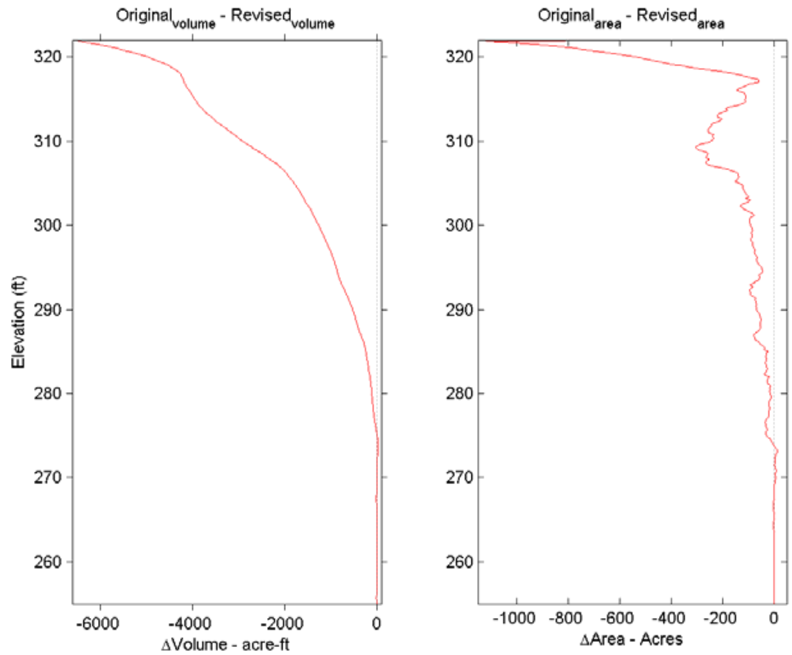


Figure 7 - Comparing the original and edited 2005 TIN models – Left: Volume change vs. Elevation, Right: Area change vs. Elevation. Changes are defined as the original value minus the edited value at each elevation.

Comparing Re-Edited 1995 and 2005 Survey Data

This section presents a comparison of the TIN models generated from the re-edited 1995 and 2005 sounding point datasets. Analyses are presented using the “equal-area analysis method described previously and using visual inspections of each TIN model. The visual inspections were conducted to explain the results of the equal-area analysis and to estimate the significance of the equal-area analysis.

Equal-Area Analysis Results

Results from comparing the re-edited 2005 and 1995 TIN models using the “equal-area” analysis method are presented in Figure 8. In comparison with the ΔV vs. Elevation relationship presented from the original reports (Figure 1), the magnitude of the volume change at elevations below 310 ft has decreased. It is also evident from Figure 8 that reservoir volume at conservation pool elevation increased by over 4000 acre-ft according to the 2005 survey data. This increase is larger than the 800 acre-ft increase suggested from the original 1995 and 2005 survey reports using the simple analysis. Partial explanations for this increase are presented later in this section.

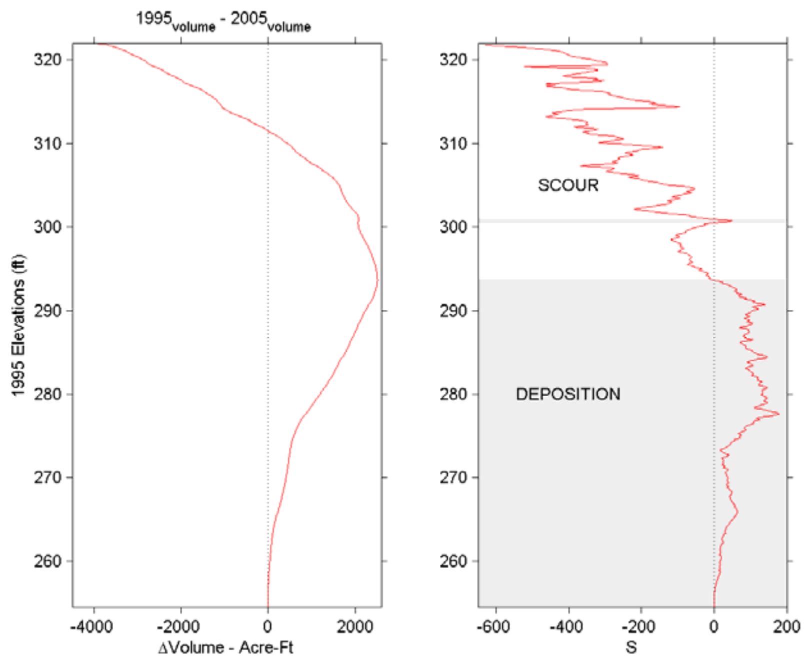


Figure 8 – Comparing re-edited 1995 and 2005 reservoir volumes using the equal-area analysis. Left: volume change vs. elevation, Right: S vs. elevation, showing elevations at which deposition and scour may be occurring.

As shown in the S vs. Elevation plot (Figure 8, right), there is evidence that sediment deposition occurred in areas with elevations (in 1995) below 294 ft and with elevations between 300.4 ft and 301.3 ft. For all other elevations, increases in reservoir volume were found. This result suggests that sedimentation is generally following the expected model for a reservoir, namely sediment is deposited in the deeper reservoir sections, including the main reservoir body and sidearm inlets (Figure 9). Further interpretations of this sedimentation pattern would be speculative without analyzing the time-history of Cedar Creek Reservoir water surface elevations for the period between the 1995 and 2005 surveys. If it is assumed that the areas of scour indicated in Figure 9 is due to improved sampling/TIN model representation of shallow areas (rather than actual scour – see the "Visual Comparisons" section below), then sedimentation rates may be justifiably estimated using the maximum volume change at elevation 294. This maximum change in volume (2512 acre-ft, approximately) corresponds to a sedimentation rate/volumetric loss rate of 251.2 acre-ft per year over the 10-years between reservoir surveys. This loss rate is less than 20% of the 1458 acre-ft/yr loss rate calculated using the original capacity data from 1966 (TWDB, 1973) and the original 1995 survey data (note: using the re-edited 1995 volumes, the loss rate between 1966 and 1995 would be 1358 acre-ft/yr.)

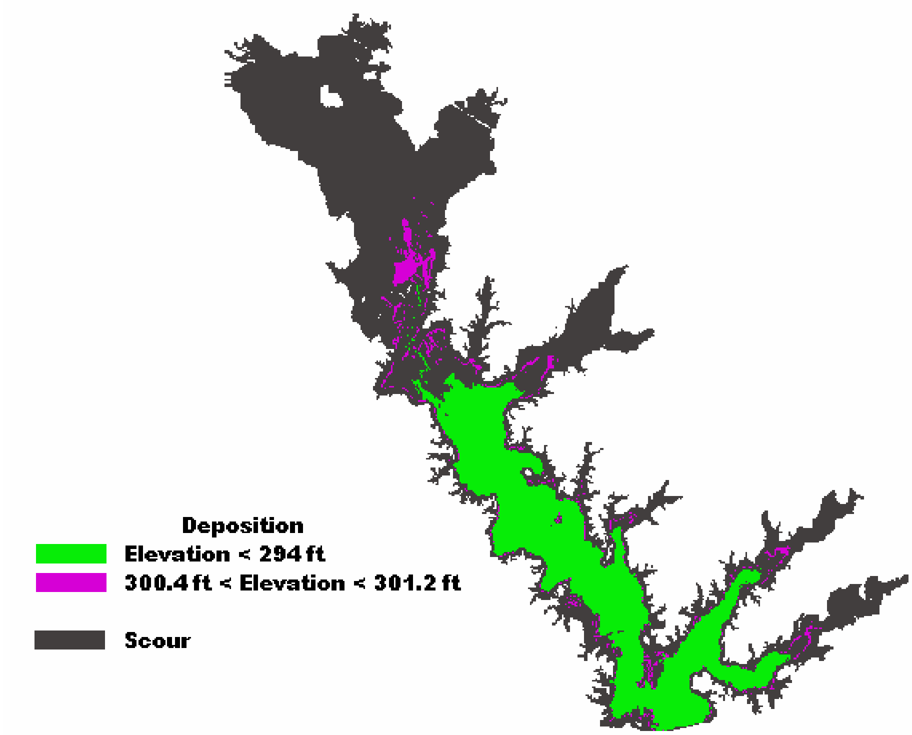


Figure 9 – Cedar Creek Reservoir showing areas of deposition & scour based on 1995 bathymetric elevations and the equal-area analysis presented in Figure 8.

Visual Comparisons

To verify the conclusions drawn from the equal-area analysis above, TINs derived from the re-edited survey data were visually analyzed. Figure 10 refutes the assertion that sedimentation occurred uniformly in the deeper portions of the reservoir. As shown in the right portion of Figure 10, most deposition occurred in isolated areas near the dam (at the southern end of the reservoir). It is also evident, however, that adjacent to the areas of greatest deposition were isolated areas of greatest scour (Figure 10, left). It is therefore evident that, for the cumulative area with 1995 bed elevations below 294ft, a net deposition of sediment occurred while individual areas experienced sedimentation or scour. Figure 10 (insets) also indicates that the greatest changes in bathymetry typically occurred near the reservoir boundary where depths are least and where depth interpolation is most affected by the TIN generation process. The insets also indicate the limit of the ArcGIS visual display used to generate this figure – when observed along with the entire reservoir, the area in the insets both appear to be simultaneously uniformly scouring and receiving sediments. Only in the close-up views are the actual differences between the two datasets discernible. This limit makes conclusions difficult to draw based upon Figure 10.

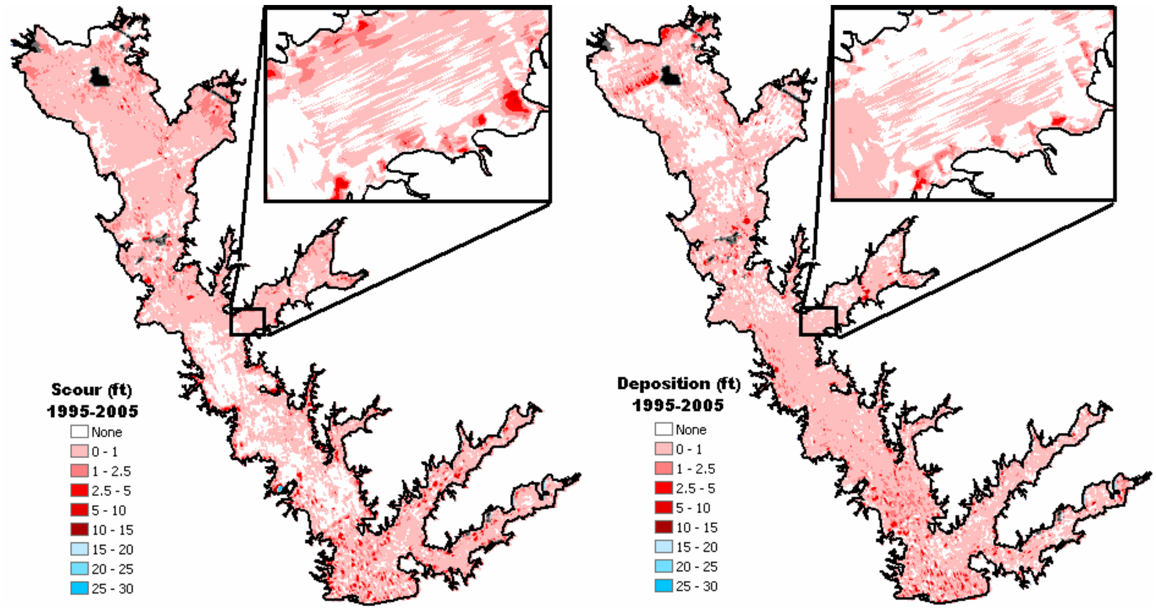


Figure 10 – Changes in Cedar Creek Bed Elevation from 1995-2005 – Left: Scour, Right: Deposition. Based on a raster analysis of the re-edited TIN models using a 10 ft (3.05m) cell size.

Visual comparisons of the TIN models from the re-edited 1995 and 2005 surveys were also made with focus given to the shallow side-arms within Cedar Creek Reservoir. Figure 11 presents a typical conclusion drawn from such comparisons, namely that the method of data collection used in surveying the sidearms in 1995, while considered sufficient at the time of the survey, was actually insufficient to adequately represent the actual bathymetry. As shown in Figure 11a, 1995 soundings (black dots) were often only collected around the perimeter of the sidearm, whereas in 2005 (Figure 11b) greater effort was made to collect bathymetry along the perimeter and through the middle of each sidearm area. The resulting 1995 TIN model contained large, flat, shallow areas (grey) suggesting a low volume of water was present within the sidearm. In contrast, the 2005 TIN model (Figure 11b) suggests bathymetries more representative of a drowned river channel – shallower on the sides with depths increasing downstream and toward the middle of the sidearm. As a result of the difference in data collection methods/survey line layout from the 1995 and 2005 surveys, the 2005 survey found more water in the Cedar Creek sidearms. This is evident in Figure 8 where more volume was found in the 2005 survey at higher elevations, corresponding to the elevations at which the reservoir sidearms would contain the most water.

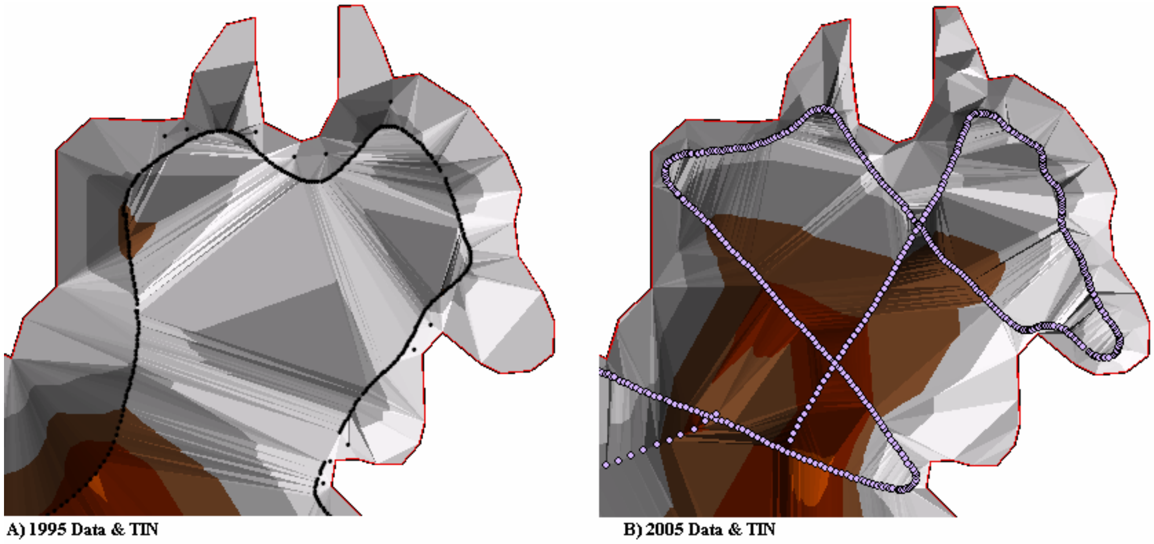


Figure 11 – Data Collection & Tin Generation in Cedar Creek Reservoir Sidearms – A) Sparse data collection & TIN from the 1995 survey, B) Improved data collection & TIN from the 2005 survey. Greater volumes are implicit from the 2005 data.

One final point of consideration in this analysis is that all of the above analyses have considered only the magnitude of the volume differences vs elevation between the two surveys. It is also illustrative to consider these volume differences on a normalized basis, where the volume difference is divided by the reservoir volume at a given elevation and then plotted against elevation (Figure 12). Such an analysis provides insight into the significance of volume differences relative to the expected accuracy of the hydrographic survey. While not officially documented, TWDB estimates of survey error range from 0-3% of the computed volume for any given elevation. Similar estimates were derived in a draft report by Payne and Holly (1997), where they investigated error sources including boat speed/inclination, GPS position accuracy, and wave interference. It is therefore arguable that any differences in volume less than approximately 3% of the surveyed volume may be more reflective of survey error than any sedimentation processes. As indicated in Figure 12, the increase in volume at conservation pool elevation between the 1995 and 2005 surveys amounts to less than a 1% increase, which is well within the error range for TWDB hydrographic surveys. Interestingly, volume changes do not become greater than 3% of the reservoir volume until below approximately elevation 294ft, which is the elevation marking the transition between scour and deposition zones in Figure 8. This provides further evidence of a net deposition of sediment in these areas, although the actual volume of sediment deposited is debatable depending on the accepted level of error within the hydrographic surveys.

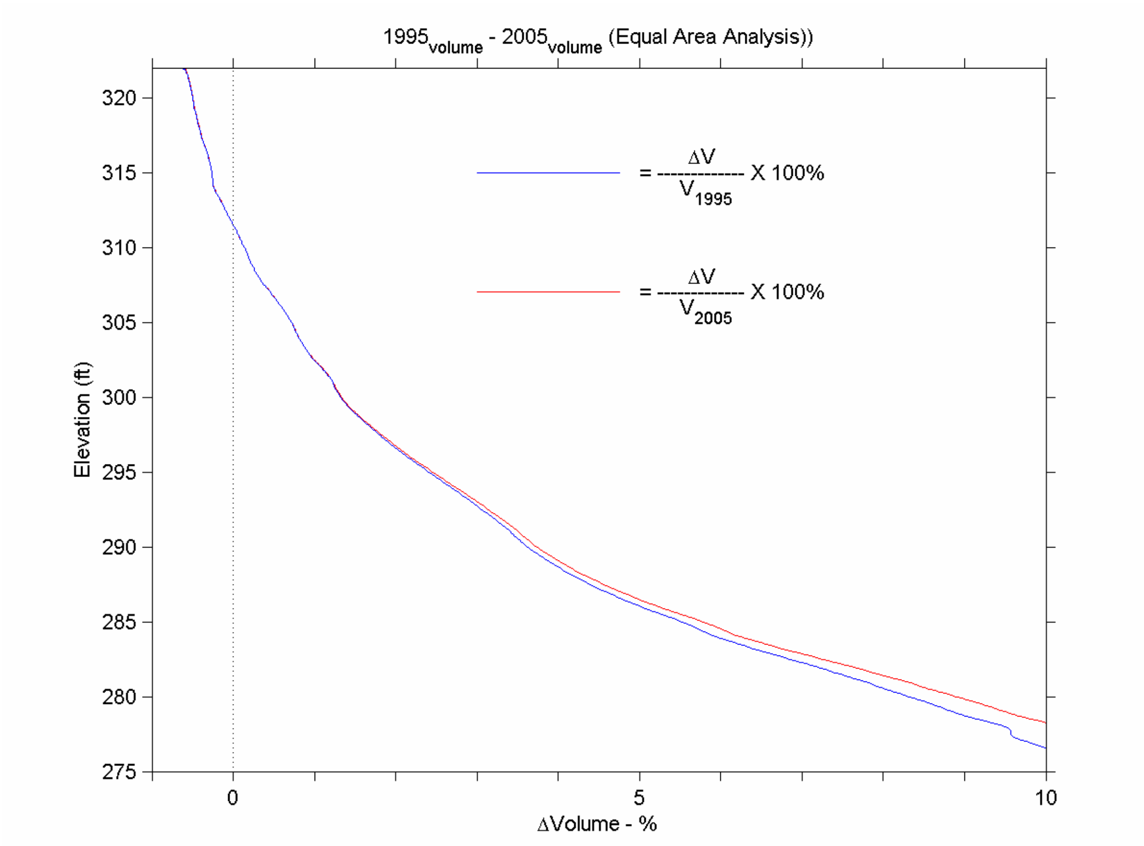


Figure 12 – Normalized ΔV vs. Elevation Relationships between the 1995 and 2005 data (using the equal-area analysis).

Conclusions and Recommendations

Based upon the various analyses of the re-edited 1995 and 2005 survey data, the following conclusions can be made:

1. Sediment deposition is occurring in Cedar Creek reservoir at elevations primarily below 294 ft (as measured in 1995)
2. Sediment deposition is not occurring uniformly, and patterns in the deposition are not readily evident from the data collected
3. Volumetric increases between the 1995 and 2005 surveys are primarily due to differences in the survey data collected in sidearms of Cedar Creek Reservoir.
4. The bathymetry of the sidearms of Cedar Creek reservoir is better represented in the 2005 survey dataset.
5. Comparing volume differences between surveys at given water surface elevations is not a suitable method for determining reservoir sedimentation behavior.
6. Volume changes presented as percentages of reservoir volume provide insight into the significance of the volume change.

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