VOLUMETRIC SURVEY OF SAM RAYBURN RESERVOIR

Prepared for:

Deep East Texas Council of Governments

In cooperation with the

U. S. Army Corps of Engineers, Fort Worth District

Prepared by:
Texas Water Development Board

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

Barney Austin, Ph.D.
Duane Thomas
Randall Burns
Tim Osting
Tony Connell
Holly Weyant

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EXECUTIVE SUMMARY

The Texas Water Development Board (TWDB), Deep East Texas Council of Governments (DETGOG), and United States Army Corps of Engineers (USACE), Fort Worth District, entered into Memorandum of Agreement R044801061 in March of 2004 to survey the capacity of Sam Rayburn Reservoir at the top of the power pool elevation. The purpose of the survey was to update the elevation-area and elevation-volume tables using current GPS, acoustical depth sounder, and GIS technology. Staff from the TWDB Surface Water Resources Division performed the survey during the period of March 15 through April 28, 2004.

The results of the 2004 survey indicate the reservoir encompasses 112,590 surface acres and contains a total of 2,876,033 acre-feet of water at power pool elevation (164.4 ft). In 1971, an USACE resurvey calculated Sam Rayburn Reservoir to encompass 114,500 surface acres with a total volume of 2,898,500 acre-feet. A comparison of the current survey with the 1971 resurvey indicates a 1.7% reduction in surface area and a 0.8% reduction in total volume at the power pool elevation in 2004. However, a portion of this change may be attributed to the difference in computational methodologies between the 1971 and 2004 surveys. The figures presented in this report represent the best estimates of current reservoir capacity and area that can be obtained using current technology and resources.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

RESERVOIR HISTORY AND GENERAL INFORMATION

Sam Rayburn is one of the four reservoirs authorized for the Neches-Angelina Rivers Basin by the River and Harbor Act of 1945 (Public Law 14, 79th Congress, 1st Session) [1] in accordance with the plan outlined in Senate Document 98 (76th Congress, 1st Session), and modified by the River and Harbor Act of 1948 (Public Law 858, 80th Congress, 2nd Session). In 1955, Congress appropriated the first construction funds for this site, originally known as McGee Bend Dam and Reservoir, for its proximity to McGee Bend on the river. In 1963, by special resolution of the 88th Congress, the name was changed to Sam Rayburn to honor the late House Speaker, who was a champion of soil and water conservation.[1, 2]

Construction of Sam Rayburn Dam and Reservoir began in September of 1956 and deliberate impoundment began in March of 1965. Commercial power generation with one unit began July 1, 1966. Nearly 1,000,000 visitors were reported to have visited that year.[2, 3] A second power-generating unit came online on May 1, 1968, and by 1981 annual visitation to the reservoir had reached nearly 2,500,000. The Sam Rayburn Project, including the dam, appurtenant structures, and surrounding shoreline, is owned by the U.S. Government, and operated by the U.S. Army Corps of Engineers (USACE), Fort Worth District. The facility provides for flood control, hydroelectric power generation, and conservation of water for municipal, industrial, agricultural, and recreational uses.[1]

As one of the four reservoirs planned for the Neches-Angelina River Basin, this project was constructed pending contributions from local interests. The Lower Neches Valley Authority (LNVA) contributed $5,000,000 ($2,000,000 towards the construction of B.A. Steinhagen Lake and $3,000,000 for Sam Rayburn Reservoir). Public Law 80-858 permits the sponsoring agency (LNVA) to withdraw water from B.A. Steinhagen Lake not to exceed 820,000 ac-ft, at a rate not to exceed 2,000 cubic-feet per second (cfs), for its own use. A contract with LNVA, approved by the Secretary of the Army on January 22, 1957, enforces these provisions. In October of 1981, the estimated project cost was $68,315,000.[1]

In August 1986, Certificate of Adjudication No. 06-4411 was issued by The Texas Water Commission (presently the Texas Commission on Environmental Quality (TCEQ), formerly the Texas Natural Resource Conservation Commission), upholding Public Law 80-858 and granting the LNVA the water rights to Sam Rayburn Reservoir. The current authorization[4], in part, permits the LNVA to store water in Sam Rayburn Reservoir for later use within the LNVA service area. The complete certificate is on file in the Records Division of the TCEQ.

The authorization permits LNVA to divert and use not to exceed 50,000 ac-ft of water per annum for municipal purposes, 660,000 ac-ft per annum for industrial purposes, and 110,000 ac-ft per annum for irrigation purposes from Sam Rayburn Reservoir and B.A. Steinhagen Lake. In addition, the City of Lufkin contracts for 2.98 percent of the conservation storage between elevations 164.4 ft and 149.0 ft of Sam Rayburn Reservoir. The contract cost the City of Lufkin an estimated $525,600, in addition to a portion of the annual operation and maintenance costs.[1]

Table 1 summarizes information for Sam Rayburn Dam and Reservoir based on information furnished by the USACE. Figure 1 shows the general vicinity of Sam Rayburn Reservoir.

Table 1. Pertinent Data for Sam Rayburn Dam and Reservoir

Owner of Sam Rayburn Dam and Facilities
United States of America

Operator of Sam Rayburn Dam and Facilities
U. S. Army Corps of Engineers, Fort Worth District

Engineer
U. S. Army Corps of Engineers (Design)

General Contractor
Paul Hardeman, Inc., Stanton, California

Location of Dam
River mile 25.2 on the Angelina River, in the Neches River Basin, 10 miles northwest of Jasper, Jasper County, Texas.

Drainage Area
3,449 square miles

Dam

Type	Rolled earth filled
Length (total)	17,870 ft
Maximum Height	120 ft (above stream bed)[5]
Top Width	42 ft

Table 1. (continued) Pertinent Data for Sam Rayburn Dam and Reservoir

Spillway (modified 1994-96) [6]

Type	Labyrinth weir with chute and stilling basin
Length	640 ft, uncontrolled
Crest elevation	176.0 ft
Control	None

Outlet Works

Type	Two gated conduits
Size	10 ft by 20 ft by 180 ft
Control	Two tractor-type gates (plus one emergency tractor type gate)
Invert Elevation	105.0 ft

Reservoir Data (Based on TWDB 2004 volumetric survey)

Feature	Elevation (ft above msl)	Capacity (Acre-feet)	Area (Acres)
Top of Flood Control Pool	173.0	N/A	N/A
Top of Power Pool	164.4	2,876,033	112,590
Top of Power Head and Sediment Reserve	149.0	1,460,990	72,013

Figure 1
Vinicity Map Sam Rayburn Reservoir
Source: United States Army Corps of Engineers, Lake Manager, Jasper, Texas

VOLUMETRIC SURVEY OF SAM RAYBURN RESERVOIR

Introduction

The Texas Water Development Board (TWDB), Deep East Texas Council of Governments (DETCOG), and United States Army Corps of Engineers (USACE), Fort Worth District, entered into Memorandum of Agreement R044801061 in March of 2004 to survey the capacity of Sam Rayburn Reservoir at the top of the power pool elevation. The purpose of the survey was to update the elevation-area and elevation-volume tables using current GPS, acoustical depth sounder, and GIS technology. Staff, from the TWDB Surface Water Resources Division, conducted the survey during the period of March 15 through April 28, 2004. Additionally, the TWDB compared cross-sections from the 2004 survey to the original Sediment Range Lines established in 1961 by the USACE, and established new range lines in the Attoyac and Ayish Bayous to facilitate future tracking of sedimentation in these areas.

Bathymetric Survey

Records[1] indicate the power pool elevation for Sam Rayburn is 164.4 ft. During the survey, the water levels varied between elevations 165.64 ft and 167.83 ft. The survey team used two boats equipped with a depth sounder, velocity profiler, and integrated Differential Global Positioning System (DGPS) equipment to navigate along pre-planned range lines spaced approximately 500 feet apart in a perpendicular fashion to the original stream channel. The survey design incorporated approximately 1,730 survey range lines. While navigating along these range lines, the survey team traveled more than 2,200 miles collecting over 720,000 data points. Figure 2 shows actual data collected during the TWDB survey.

Prior to collecting data each day, the depth sounders are calibrated using velocity profilers[7]. These instruments measure the speed of sound through the water column at one-foot intervals and calculate an average speed of sound to be entered into the depth

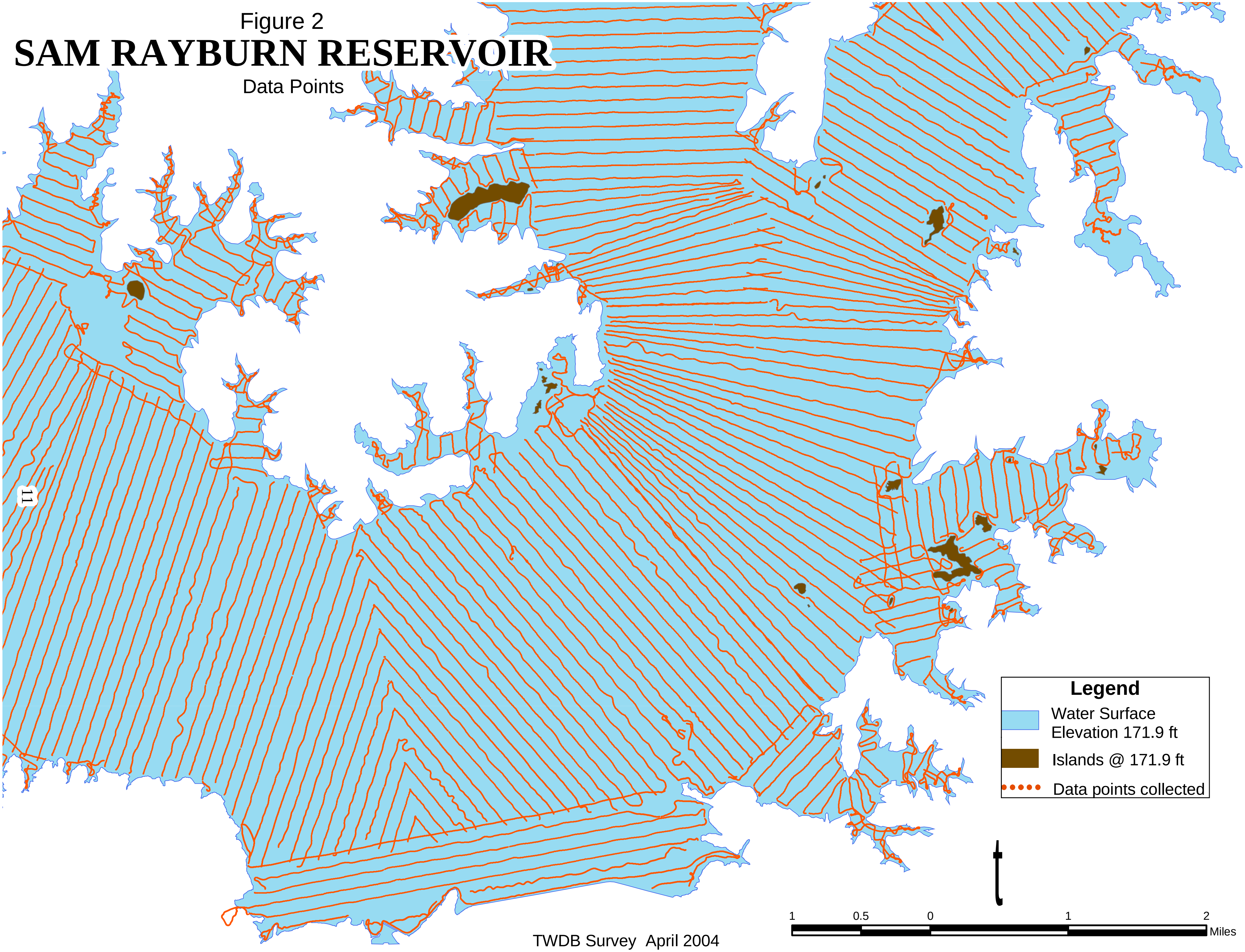


Figure 2
SAM RAYBURN RESERVOIR
Data Points
11
Legend
Water Surface Elevation 171.9 ft
Islands @ 171.9 ft
Data points collected
1
0.5
0
1
2
Miles
TWDB Survey April 2004

sounder. The survey team then verifies the depth sounder calibration using a weighted measuring tape or stadia rod.

During the TWDB survey, the speed of sound varied between 4,888 and 4,809 feet per second. Based on the measured speed of sound for various depths and the average speed of sound calculated for the entire water column, the depth sounder is accurate to within ±0.2 ft. An additional estimated error of ±0.3 ft arises from variation in boat inclination. These two factors combine to give an overall accuracy of ±0.5 ft for any instantaneous reading. These errors tend to be fairly minimal over the entire survey, since some errors are positive and some are negative, canceling each other out.[8]

In February of 2004, four pressure transducers were installed around the reservoir to monitor variations in the water surface elevation during data collection. A more detailed discussion of the transducers and the results of their monitoring are presented in Appendix G. TWDB staff also met with USACE personnel to discuss the data collection process and collect relevant historical information.

The GPS receiver's horizontal mask setting was set to 10 degrees and the PDOP (Position Dilution of Precision) limit was set to seven to maximize the accuracy of the horizontal positioning. If the PDOP rises above seven, an internal alarm sounds to advise the field crew that the horizontal position has degraded to an unacceptable level. Further positional accuracy is obtained through differential corrections using the internal Omnistar receiver.[9] The HYPACK MAX[10] surveying software converts the differential GPS positions to state-plane coordinates instantaneously.

Datum

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gauge at Sam Rayburn Dam. The datum for this gauge is reported as mean sea level (msl), thus elevations reported here are in feet (ft) above msl. Volume and area calculations in this report are referenced to water levels provided by the USACE gauge: USGS 08039300 Sam Rayburn Reservoir, near Jasper, TX.[6]

Survey Results

The results of the TWDB 2004 Survey indicate Sam Rayburn Reservoir has a volume of 2,876,033 acre-feet and encompasses 112,590 acres at power pool elevation. When compared to data from an U.S. Army Corps of Engineers 1971 Resurvey[3], Sam Rayburn Reservoir has experienced a 1.7% reduction in overall surface area and a 0.8% reduction in total volume at the power pool elevation. The volume between the top of the power pool (164.4 ft) and the top of the power head or sediment reserve (149.0 ft) decreased by 31,458 ac-ft, or 2.2%. However, the sediment reserve volume below elevation 149.0 ft increased approximately 8,970 ac-ft or 0.6% and most likely can be attributed to better measurement techniques. The results of the TWDB 2004 survey of Sam Rayburn Reservoir are presented on the following page in Table 2, along with results from an USACE 1971 resurvey.

Due to the methodological differences in computing the area and volume, direct comparisons of the TWDB 2004 survey with prior surveys of Sam Rayburn Reservoir are not recommended and are presented here for informational purposes only.[11] The TWDB considers the 2004 survey to be a significant improvement over previous methods and recommends that the same methodology be used to resurvey the reservoir in 5 to 10 years.

Table 2. Sam Rayburn Reservoir Data

Feature	Elevation (ft above msl)	2004 Capacity (Acre-Feet)	1971 Capacity[1, 3] (Acre-Feet)	2004 Surface Area (Acres)	1971 Surface Area (Acres)
Top of Flood Control Pool	173.0	N/A	3,997,600	N/A	142,710
Top of Power Pool*	164.0	2,831,129	2,852,585	111,984	113,410
(Volume or Total Storage)	164.4	2,876,033	2,898,500	112,590	114,500
Incremental Power Pool Elevation					
Top of Flood Control Pool to Top of Power Pool	173.0 ft – 164.0 ft	N/A	1,145,040	N/A	N/A
Top of Power Pool to Top of Power Head	164.0 ft – 149.0 ft	1,370,139	1,400,565	N/A	N/A
Top of Power Pool to Top of Power Head	164.4 ft – 149.0 ft	1,415,042	1,446,500**	N/A	N/A
Top of Power Head & Sediment Reserve	149.0 ft	1,460,990	1,452,020	72,013	74,040

*Original records reported the top of Power Pool Elevation at 164.0 ft. While, the power pool elevation was raised to 164.4 ft in 1969 the 1971 resurvey report still referred to elevation 164.0 ft as top of power pool. Both elevations are presented here for comparision.[12]

** Value interpolated from Reservoir Pertinent Data Sheet[1]

DATA PROCESSING

Reservoir Boundary

Prior to surveying Sam Rayburn, a lake boundary was established by digitizing a line at the land water interface visible in aerial photography, or digital orthophoto quadrangle images (DOQs) using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software. The DOQs were photographed over multiple days in 1995 and 1996 and 2004. Consequently, the reservoir water surface elevation varies significantly from 156.6 ft to 167.28 ft. over the range of images. Using this information, a line was digitized from the land water interface in each photo and labeled according to the water surface elevation of that day. These lines were then input as a soft line, with a known elevation, into the model. An upper boundary, necessary for modeling the reservoir, was established using the 1:24,000 scale 180-ft contour from digital hypsography. By contrast the DOQs have a scale of 1:12,000. Using the 2004 DOQs[13], nearly 590 miles of the shoreline were assigned elevation 167.28 ft (Figure 3) with an additional 95 miles of shoreline assigned elevation 162.67 ft . Due to the age of the 1995-96 DOQs only a small portion of the reservoir was defined using them at elevation 156.6 ft.

Additionally, the USACE field office in Jasper, Texas provided high resolution photography taken while the reservoir was at elevation 163.6 ft and contours at various elevations collected with portable GPS units. The USACE data sets were useful in refining the boundary elevations near the federal parks located around the reservoir. Further refinements to the input elevations were made by manipulating the DOQ imagery's color bands to enhance the water. This technique allowed for better definition of the land water interface in heavily vegetated areas.

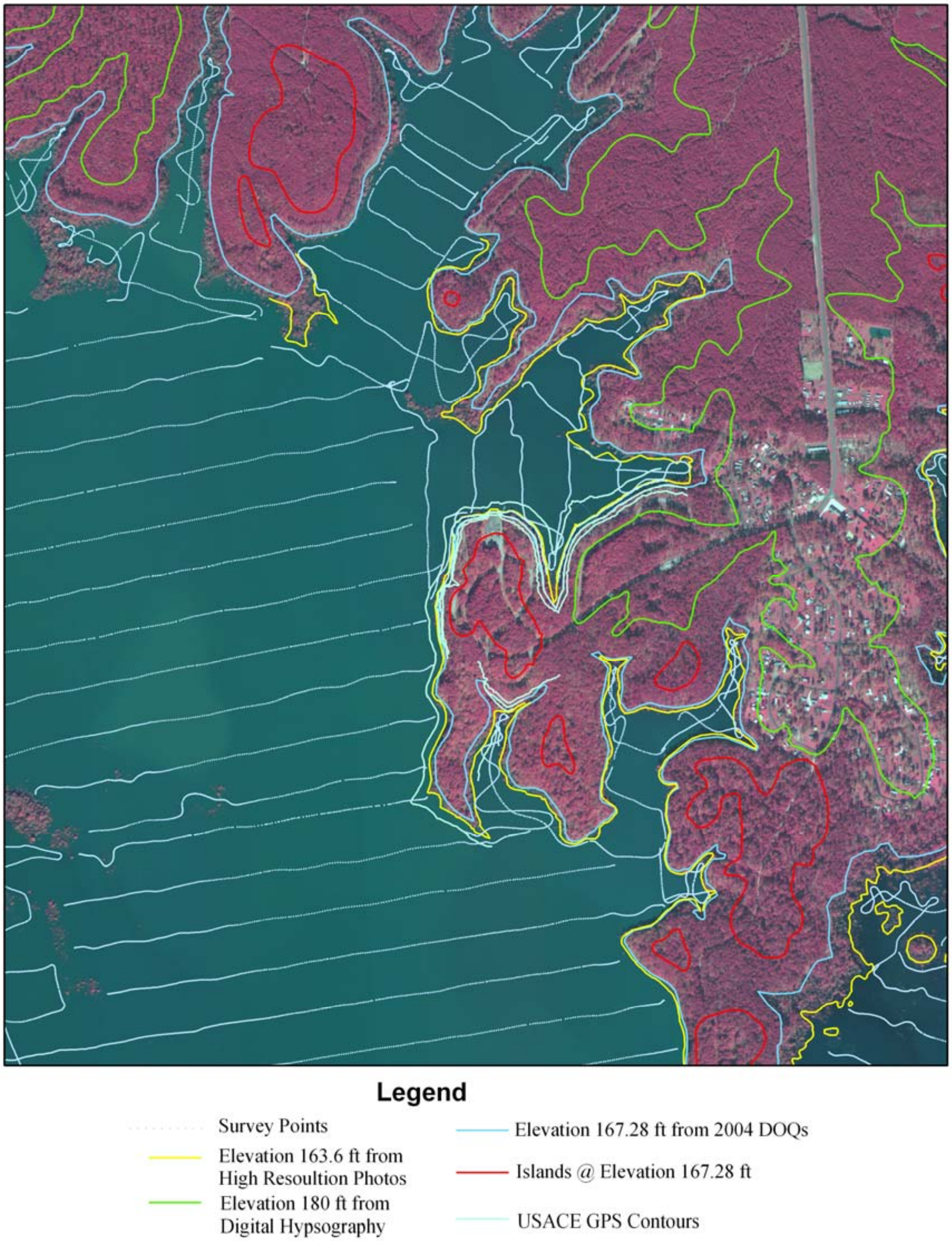


Figure 3. Boundary input parameters are established for the TIN model. Nearly 590 miles of shoreline were digitized and assigned elevation 167.28 ft. The heavy vegetation and canopy coverage precludes locating the exact land water interface in many locations. Team members used several data sets and image enhancing techniques to estimate the boundary in these areas.

TIN Model

Upon completion of data collection, the raw data files are edited in HYPACK MAX to remove any anomalies. The water surface elevations for each respective day are then applied and the depths are converted to corresponding elevations. Measurements from the four pressure transducers (Appendix G) installed around the reservoir were evaluated and it was determined that no further adjustments to the survey data were necessary. The resulting X, Y, Z file is imported into ESRI's ArcInfo Workstation GIS 9.1 software, and converted to a MASS points file. Using ArcInfo's TIN module,[14] the MASS points, boundary file, and line files representing various elevations in the lake corresponding to the land water interface in the aerial photos, are used to create a Triangulated Irregular Network (TIN) model of the reservoir bottom surface.

The TIN model uses Delauney's criteria for triangulation to place a triangle between three non-uniformly spaced points, including the boundary.[14] Using Arc/Info software, volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals, from elevation 82.9 ft to elevation 164.4 ft. The area and volume calculations have been stopped at conservation pool elevation despite generating the TIN Model to elevation 180 ft. A higher degree of estimation and hence greater margin of error in the calculations would be expected at elevations above 164.4 ft, due to the lack of data above that elevation, and the scale difference between the 180 ft upper boundary and the contours (soft lines) digitized from aerial photos.

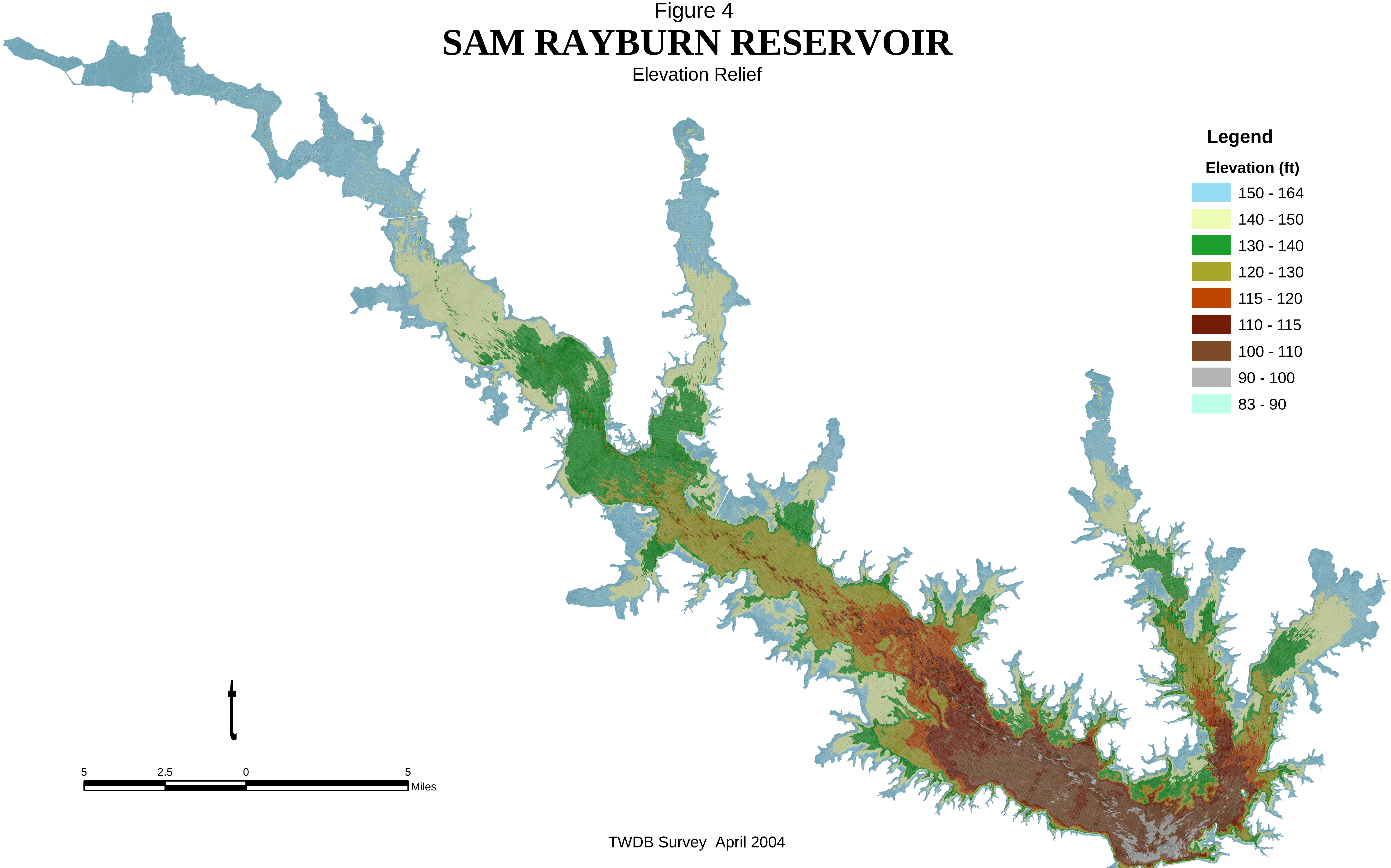
The computed reservoir volume table is presented in Appendix A and the area table in Appendix B. An elevation-volume graph and an elevation-area graph are presented in Appendix C and Appendix D, respectively.

Figures 4 and 5, on the following pages, depict the bottom relief of the reservoir in elevations and depth ranges throughout the reservoir. To develop these maps, ranges for elevations where designated throughout the TIN and assigned corresponding colors.

Figure 4

SAM RAYBURN RESERVOIR

Elevation Relief

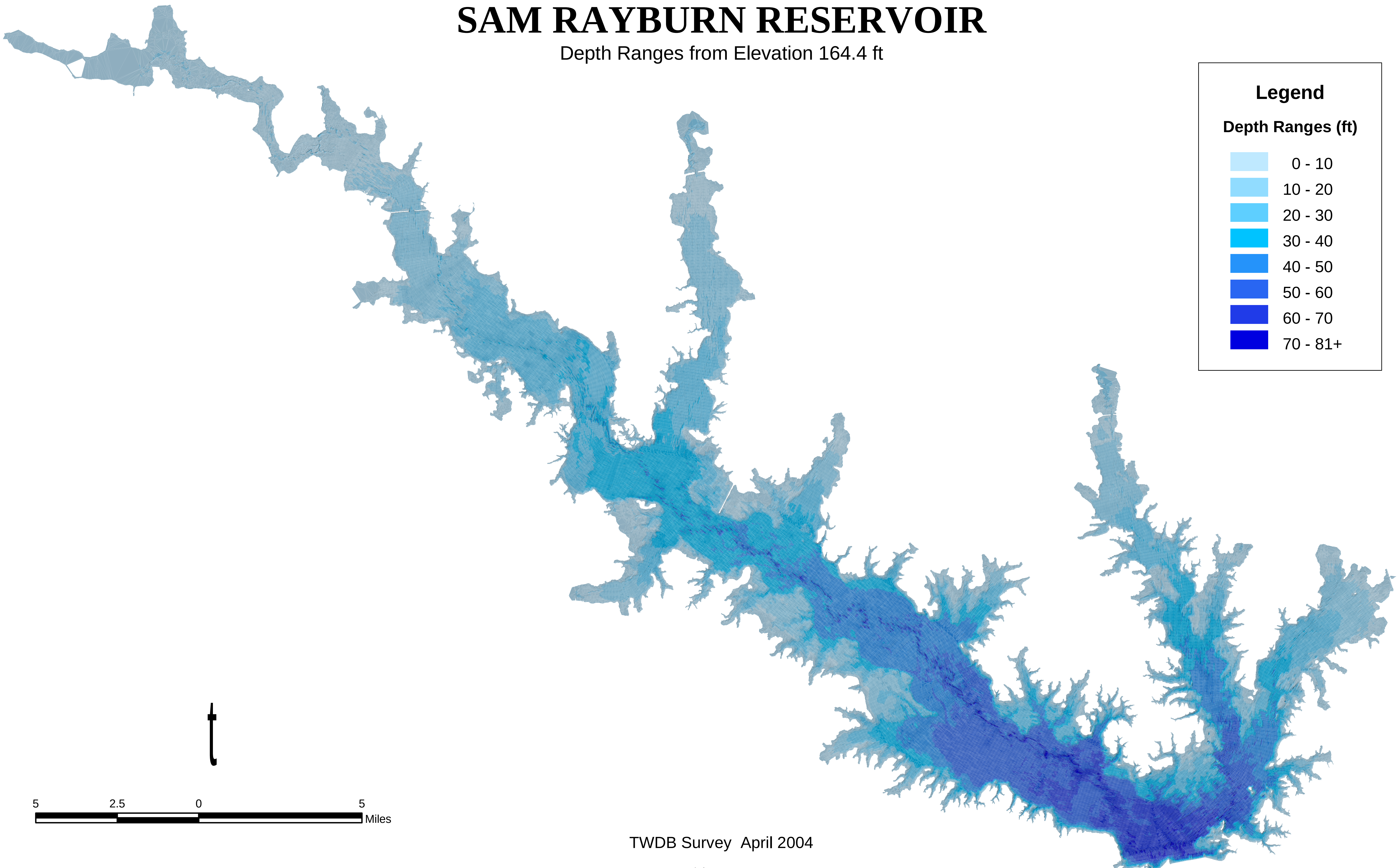


TWDB Survey April 2004

Figure 5

SAM RAYBURN RESERVOIR

Depth Ranges from Elevation 164.4 ft



TWDB Survey April 2004

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Figure 9 (rear pocket), a 5-ft interval contour map, was also developed from this TIN. The TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command in ArcInfo. Linear filtration algorithms were applied to the resultant Digital Terrain Model to produce smooth cartographic contours.

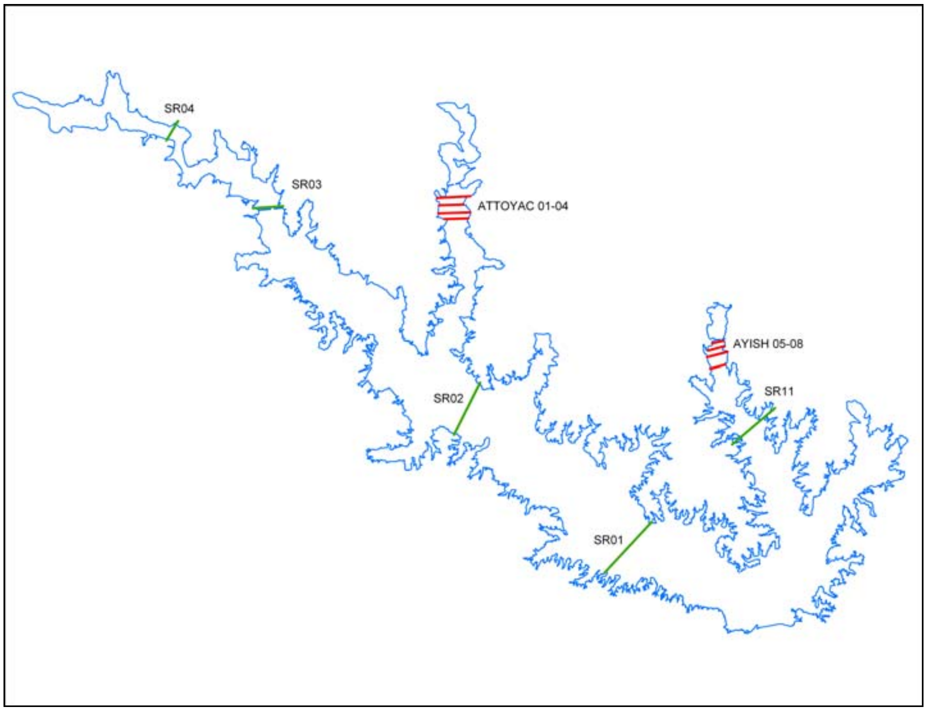
Finally, five cross-sections were produced from the TIN with positions corresponding to sediment ranges presented in the 1971 USACE Resurvey of Sam Rayburn Reservoir report. Eight additional cross-sections in the Attoyac and Ayish Bayous, for monitoring deltaic formations, were also extrapolated from this TIN and are presented in Appendix F, with end point coordinates for all sediment range lines listed in Appendix G.

Sediment Range Lines

In 1961, the USACE established 14 sedimentation range lines and 9 degradation range lines to monitor sedimentation in the reservoir. The USACE resurveyed those lines in 1971, with the stated purpose of confirming "the sedimentation line profiles and to observe any changes which may have occurred."[3] In 1971, the USACE calculated the sediment production rate to be 0.083 ac-ft per square mile, or approximately 288 ac-ft of sediment deposition per year within the reservoir. With a sediment storage capacity of 1,452,000 ac-ft, the USACE concluded that sediment deposition would not be of concern for many years.

In 1995, the TWDB performed a reconnaissance survey on six of the original 1961 sediment range lines. Cross-sectional plots for five of these range lines are plotted in Appendix F using the 1971, 1995, and 2004 data. Their locations are shown on the next page in Figure 6 along with locations for eight range lines developed for this report. Inspection of the original five range line plots appears to indicate sediment deposition is not posing a significant problem in the areas of the following sediment range lines: SR01 through SR04, and SR11.

Figure 6. Location of historical and TWDB sediment range lines.



The TWDB has designated eight additional sediment range lines for Sam Rayburn Reservoir, four in the Attoyac Bayou and four in the Ayish Bayou, to monitor sediment deposition and progression of deltaic formations visible in the 1995-96 DOQs. Figures 7 and 8 on the following pages show the location of the TWDB range lines imposed on the 1995 aerial photos.

Figure 7. Location of TWDB sediment range lines in the Attoyac Bayou: Attoyac-01 through Attoyac-04. The 1995-1996 DOQs encompassing the Ayish and Attoyac arms of Sam Rayburn were photographed while the water surface elevation was near 156.5 ft.

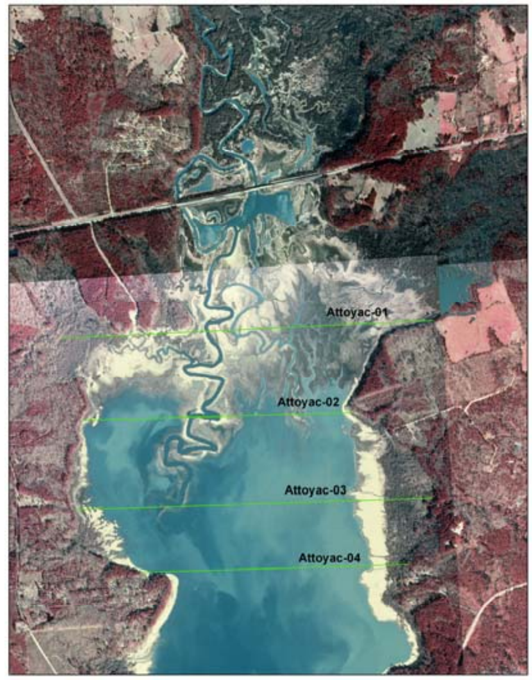
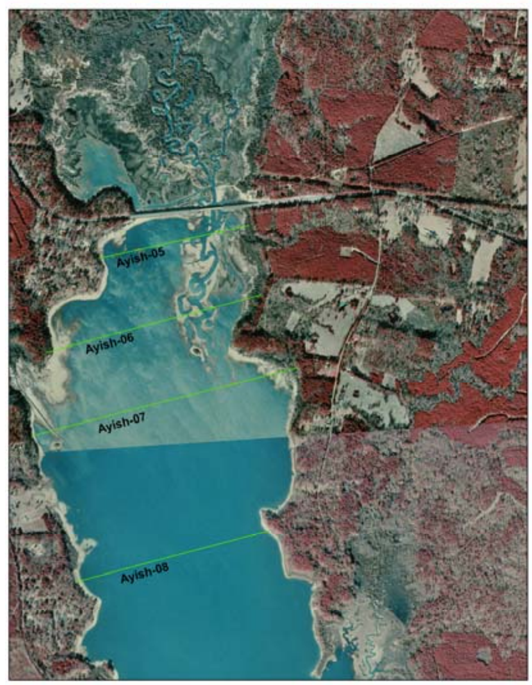


Figure 8. The northern reaches of Aysish Bayou showing the location of TWDB sediment range lines Ayish-05 through Ayish-08.



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Appendix A

Sam Rayburn Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — APRIL 2004 SURVEY

Power Pool Elevation 164.4 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
80									0	0
81	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0
85	0	0	0	0	1	1	1	1	1	1
86	1	2	2	2	2	3	3	3	4	4
87	5	5	6	7	8	9	9	11	12	13
88	14	16	17	19	21	23	25	27	30	32
89	35	38	41	45	48	52	56	60	64	69
90	74	79	84	89	95	101	107	114	120	127
91	135	142	150	158	166	175	184	194	203	214
92	224	235	246	258	270	282	295	308	322	336
93	350	365	381	397	413	430	448	466	484	503
94	523	544	565	587	609	633	657	682	708	735
95	763	792	822	853	884	917	951	986	1,022	1,060
96	1,099	1,139	1,180	1,223	1,268	1,314	1,362	1,412	1,463	1,517
97	1,572	1,629	1,688	1,749	1,812	1,877	1,944	2,014	2,085	2,159
98	2,235	2,313	2,394	2,477	2,563	2,651	2,741	2,834	2,930	3,029
99	3,131	3,236	3,344	3,456	3,571	3,689	3,812	3,937	4,067	4,201
100	4,338	4,480	4,627	4,777	4,932	5,092	5,257	5,426	5,601	5,780
101	5,965	6,154	6,349	6,550	6,756	6,969	7,187	7,413	7,645	7,884
102	8,130	8,383	8,643	8,910	9,184	9,465	9,753	10,048	10,350	10,660
103	10,977	11,301	11,633	11,972	12,318	12,673	13,034	13,404	13,781	14,166
104	14,558	14,959	15,368	15,786	16,212	16,648	17,092	17,545	18,007	18,477
105	18,956	19,444	19,941	20,446	20,961	21,484	22,017	22,559	23,110	23,670
106	24,239	24,818	25,406	26,003	26,610	27,226	27,851	28,486	29,130	29,783
107	30,445	31,116	31,795	32,484	33,181	33,888	34,604	35,328	36,062	36,805
108	37,559	38,322	39,095	39,878	40,670	41,472	42,285	43,107	43,940	44,783
109	45,636	46,500	47,375	48,260	49,157	50,064	50,982	51,910	52,848	53,796
110	54,754	55,722	56,700	57,688	58,686	59,694	60,712	61,740	62,778	63,826
111	64,884	65,953	67,032	68,122	69,222	70,333	71,455	72,587	73,731	74,886
112	76,052	77,230	78,418	79,618	80,828	82,049	83,280	84,521	85,772	87,032
113	88,303	89,583	90,873	92,172	93,481	94,799	96,126	97,462	98,809	100,164
114	101,530	102,905	104,289	105,683	107,086	108,499	109,921	111,353	112,794	114,245
115	115,705	117,175	118,654	120,142	121,641	123,148	124,665	126,192	127,728	129,274
116	130,830	132,396	133,973	135,559	137,156	138,763	140,381	142,009	143,648	145,297
117	146,958	148,630	150,313	152,007	153,713	155,430	157,160	158,900	160,653	162,418
118	164,195	165,983	167,783	169,596	171,420	173,256	175,104	176,966	178,840	180,726
119	182,625	184,537	186,460	188,396	190,345	192,306	194,280	196,268	198,269	200,283
120	202,311	204,352	206,407	208,474	210,555	212,648	214,754	216,873	219,005	221,149
121	223,307	225,477	227,659	229,855	232,063	234,283	236,517	238,764	241,024	243,296
122	245,581	247,880	250,191	252,516	254,855	257,207	259,572	261,951	264,345	266,752
123	269,173	271,608	274,057	276,521	278,999	281,491	283,996	286,516	289,050	291,598
124	294,159	296,735	299,324	301,927	304,543	307,172	309,815	312,471	315,140	317,823
125	320,519	323,229	325,953	328,691	331,444	334,211	336,992	339,788	342,599	345,423
126	348,263	351,117	353,987	356,872	359,772	362,687	365,618	368,564	371,526	374,503
127	377,495	380,502	383,524	386,560	389,612	392,677	395,757	398,851	401,959	405,081
128	408,217	411,367	414,531	417,710	420,903	424,110	427,333	430,569	433,821	437,087
129	440,368	443,664	446,974	450,299	453,639	456,994	460,364	463,749	467,150	470,565
130	473,996	477,442	480,904	484,381	487,874	491,382	494,905	498,443	501,997	505,566
131	509,151	512,752	516,367	519,999	523,645	527,308	530,986	534,680	538,390	542,115
132	545,856	549,613	553,386	557,175	560,981	564,803	568,641	572,494	576,365	580,252
133	584,155	588,076	592,014	595,969	599,941	603,931	607,939	611,964	616,008	620,068
134	624,147	628,243	632,357	636,489	640,639	644,807	648,994	653,197	657,420	661,661

Appendix A (continued)

Sam Rayburn Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — APRIL 2004 SURVEY

Power Pool Elevation 164.4 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
135	665,922	670,202	674,500	678,816	683,151	687,505	691,877	696,268	700,678	705,105
136	709,552	714,017	718,501	723,005	727,527	732,069	736,631	741,211	745,812	750,431
137	755,070	759,728	764,404	769,101	773,816	778,552	783,307	788,082	792,877	797,691
138	802,526	807,381	812,255	817,149	822,062	826,996	831,950	836,921	841,913	846,924
139	851,955	857,006	862,076	867,168	872,280	877,413	882,566	887,739	892,934	898,148
140	903,384	908,641	913,919	919,218	924,537	929,877	935,238	940,618	946,021	951,443
141	956,888	962,353	967,837	973,344	978,870	984,419	989,988	995,576	1,001,186	1,006,816
142	1,012,467	1,018,138	1,023,830	1,029,544	1,035,278	1,041,034	1,046,812	1,052,610	1,058,430	1,064,270
143	1,070,132	1,076,014	1,081,916	1,087,838	1,093,780	1,099,744	1,105,728	1,111,731	1,117,755	1,123,797
144	1,129,860	1,135,944	1,142,046	1,148,169	1,154,312	1,160,478	1,166,664	1,172,872	1,179,102	1,185,353
145	1,191,627	1,197,923	1,204,240	1,210,580	1,216,940	1,223,324	1,229,730	1,236,157	1,242,607	1,249,078
146	1,255,572	1,262,088	1,268,625	1,275,185	1,281,767	1,288,372	1,294,999	1,301,648	1,308,321	1,315,016
147	1,321,734	1,328,475	1,335,238	1,342,025	1,348,834	1,355,667	1,362,523	1,369,401	1,376,304	1,383,229
148	1,390,179	1,397,152	1,404,148	1,411,170	1,418,214	1,425,283	1,432,377	1,439,494	1,446,636	1,453,800
149	1,460,990	1,468,204	1,475,440	1,482,700	1,489,983	1,497,291	1,504,621	1,511,974	1,519,351	1,526,750
150	1,534,174	1,541,621	1,549,091	1,556,587	1,564,104	1,571,646	1,579,212	1,586,800	1,594,413	1,602,048
151	1,609,707	1,617,389	1,625,094	1,632,824	1,640,576	1,648,352	1,656,152	1,663,974	1,671,821	1,679,690
152	1,687,584	1,695,501	1,703,440	1,711,403	1,719,388	1,727,397	1,735,429	1,743,482	1,751,559	1,759,656
153	1,767,777	1,775,919	1,784,081	1,792,267	1,800,473	1,808,703	1,816,956	1,825,230	1,833,528	1,841,849
154	1,850,194	1,858,564	1,866,955	1,875,373	1,883,813	1,892,279	1,900,770	1,909,285	1,917,828	1,926,396
155	1,934,993	1,943,616	1,952,265	1,960,943	1,969,646	1,978,378	1,987,137	1,995,923	2,004,738	2,013,580
156	2,022,452	2,031,352	2,040,280	2,049,239	2,058,226	2,067,246	2,076,297	2,085,385	2,094,508	2,103,662
157	2,112,851	2,122,072	2,131,326	2,140,615	2,149,937	2,159,295	2,168,688	2,178,115	2,187,580	2,197,079
158	2,206,615	2,216,188	2,225,794	2,235,438	2,245,116	2,254,831	2,264,579	2,274,360	2,284,175	2,294,021
159	2,303,903	2,313,820	2,323,760	2,333,724	2,343,710	2,353,742	2,363,797	2,373,898	2,383,999	2,394,123
160	2,404,293	2,414,486	2,424,701	2,434,940	2,445,202	2,455,487	2,465,794	2,476,125	2,486,478	2,496,855
161	2,507,254	2,517,654	2,528,099	2,538,567	2,549,036	2,559,550	2,570,064	2,580,601	2,591,162	2,601,745
162	2,612,328	2,622,957	2,633,586	2,644,238	2,654,913	2,665,611	2,676,331	2,687,144	2,698,118	2,709,091
163	2,720,087	2,731,107	2,742,149	2,753,191	2,764,256	2,775,344	2,786,455	2,797,589	2,808,747	2,819,927
164	2,831,129	2,842,333	2,853,535	2,864,784	2,876,033					

Appendix B

Sam Rayburn Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD APRIL 2004 SURVEY

Power Pool Elevation 164.4 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
80									0	0
81	0	0	0	0	0	0	0	0	0	0
82	0	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0	0
84	0	0	0	0	0	0	0	0	0	0
85	0	1	1	1	1	1	1	1	1	2
86	2	2	2	3	3	3	4	4	5	5
87	6	6	7	8	8	9	10	11	12	13
88	14	15	16	18	19	20	22	23	25	27
89	29	31	33	34	36	38	40	43	45	47
90	49	51	54	56	58	61	63	66	68	71
91	74	77	80	83	86	89	92	96	99	103
92	107	110	114	118	122	126	130	134	139	143
93	148	153	157	162	167	172	178	183	189	195
94	201	208	215	223	231	239	247	256	265	275
95	284	293	303	313	323	333	345	356	369	381
96	394	408	423	439	455	471	488	505	523	542
97	561	580	600	620	641	662	683	705	727	749
98	772	795	818	842	867	893	919	946	974	1,003
99	1,034	1,065	1,098	1,133	1,168	1,204	1,240	1,278	1,316	1,356
100	1,397	1,440	1,485	1,529	1,575	1,623	1,671	1,719	1,768	1,819
101	1,871	1,922	1,977	2,034	2,094	2,156	2,221	2,288	2,357	2,426
102	2,495	2,564	2,634	2,705	2,774	2,845	2,915	2,986	3,059	3,131
103	3,205	3,279	3,354	3,429	3,505	3,580	3,656	3,733	3,810	3,887
104	3,967	4,049	4,134	4,220	4,307	4,396	4,485	4,575	4,663	4,750
105	4,836	4,922	5,010	5,099	5,189	5,280	5,371	5,464	5,556	5,649
106	5,741	5,833	5,926	6,020	6,114	6,208	6,302	6,393	6,484	6,575
107	6,663	6,752	6,841	6,931	7,020	7,111	7,201	7,292	7,386	7,483
108	7,582	7,682	7,778	7,875	7,973	8,073	8,174	8,275	8,376	8,481
109	8,586	8,693	8,803	8,913	9,021	9,126	9,230	9,331	9,430	9,528
110	9,628	9,729	9,830	9,931	10,030	10,131	10,230	10,329	10,430	10,531
111	10,634	10,738	10,843	10,949	11,057	11,165	11,272	11,382	11,493	11,606
112	11,718	11,830	11,942	12,050	12,154	12,258	12,359	12,460	12,559	12,657
113	12,754	12,850	12,945	13,039	13,132	13,225	13,319	13,414	13,509	13,606
114	13,702	13,797	13,891	13,986	14,080	14,175	14,270	14,365	14,460	14,554
115	14,649	14,742	14,838	14,935	15,029	15,123	15,218	15,314	15,411	15,510
116	15,612	15,713	15,815	15,917	16,018	16,123	16,228	16,335	16,442	16,552
117	16,663	16,774	16,887	17,000	17,115	17,232	17,350	17,468	17,589	17,709
118	17,826	17,943	18,060	18,180	18,301	18,424	18,549	18,675	18,802	18,929
119	19,053	19,175	19,298	19,422	19,548	19,679	19,811	19,943	20,076	20,210
120	20,345	20,478	20,609	20,740	20,870	20,998	21,125	21,253	21,382	21,510
121	21,637	21,764	21,889	22,015	22,143	22,273	22,403	22,533	22,660	22,789
122	22,918	23,050	23,183	23,317	23,451	23,586	23,724	23,862	24,001	24,141
123	24,282	24,423	24,565	24,707	24,848	24,989	25,129	25,268	25,408	25,547
124	25,686	25,824	25,961	26,094	26,227	26,359	26,493	26,627	26,761	26,895
125	27,030	27,168	27,310	27,453	27,599	27,743	27,887	28,030	28,175	28,321
126	28,469	28,619	28,772	28,925	29,078	29,233	29,386	29,540	29,692	29,845
127	29,995	30,145	30,292	30,439	30,585	30,729	30,870	31,009	31,149	31,289
128	31,430	31,572	31,714	31,857	32,002	32,148	32,297	32,443	32,589	32,736
129	32,883	33,029	33,175	33,325	33,476	33,626	33,776	33,926	34,078	34,232
130	34,386	34,541	34,696	34,849	35,001	35,155	35,308	35,462	35,614	35,770
131	35,926	36,080	36,236	36,392	36,547	36,703	36,862	37,019	37,175	37,331
132	37,489	37,648	37,812	37,975	38,136	38,299	38,459	38,622	38,786	38,951
133	39,120	39,292	39,464	39,637	39,813	39,988	40,166	40,344	40,520	40,694
134	40,872	41,052	41,231	41,411	41,592	41,771	41,950	42,133	42,321	42,513

Appendix B (continued)

Sam Rayburn Reservoir

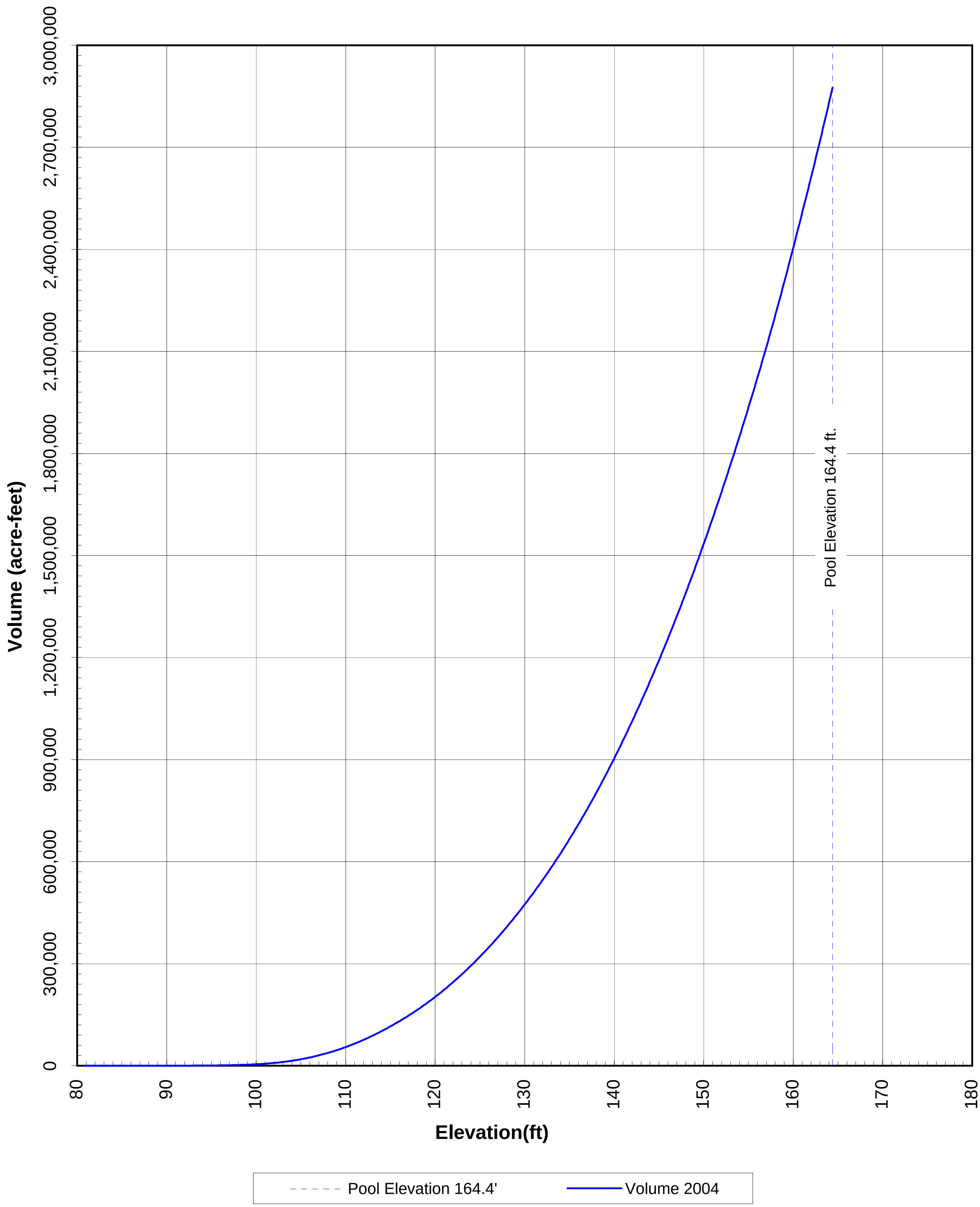
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD APRIL 2004 SURVEY

Power Pool Elevation 164.4 ft

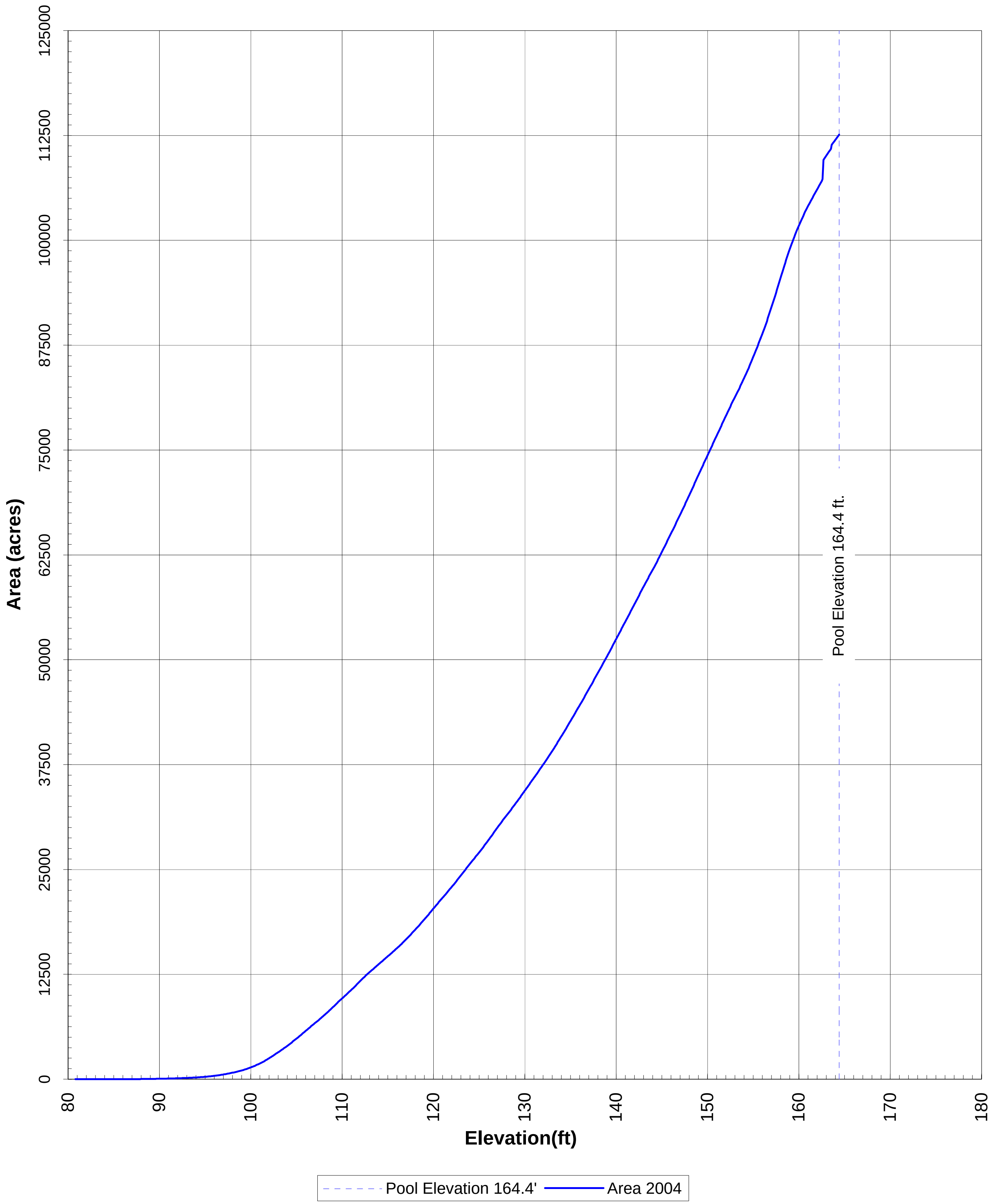
AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
135	42,702	42,888	43,072	43,256	43,442	43,630	43,818	44,003	44,187	44,371
136	44,556	44,745	44,937	45,129	45,322	45,519	45,713	45,907	46,099	46,290
137	46,481	46,673	46,865	47,058	47,254	47,453	47,651	47,850	48,049	48,247
138	48,446	48,643	48,840	49,038	49,237	49,434	49,627	49,821	50,014	50,209
139	50,407	50,606	50,810	51,017	51,224	51,430	51,632	51,837	52,047	52,253
140	52,463	52,674	52,884	53,091	53,296	53,502	53,708	53,916	54,126	54,335
141	54,542	54,749	54,957	55,166	55,375	55,583	55,790	55,994	56,198	56,403
142	56,609	56,817	57,028	57,238	57,451	57,666	57,880	58,092	58,304	58,511
143	58,715	58,920	59,123	59,325	59,529	59,734	59,936	60,135	60,331	60,529
144	60,728	60,930	61,129	61,332	61,542	61,755	61,971	62,189	62,408	62,626
145	62,843	63,065	63,286	63,505	63,722	63,944	64,166	64,384	64,605	64,827
146	65,048	65,267	65,487	65,709	65,933	66,158	66,384	66,611	66,838	67,066
147	67,294	67,522	67,750	67,981	68,210	68,441	68,672	68,905	69,139	69,373
148	69,611	69,850	70,090	70,329	70,567	70,810	71,054	71,295	71,535	71,774
149	72,013	72,248	72,483	72,719	72,953	73,188	73,419	73,649	73,881	74,113
150	74,350	74,590	74,829	75,065	75,300	75,537	75,770	76,004	76,238	76,471
151	76,705	76,938	77,171	77,407	77,643	77,878	78,113	78,347	78,582	78,816
152	79,047	79,278	79,512	79,744	79,973	80,200	80,427	80,651	80,872	81,091
153	81,308	81,524	81,742	81,961	82,182	82,406	82,632	82,863	83,097	83,334
154	83,569	83,807	84,046	84,289	84,532	84,777	85,030	85,291	85,558	85,824
155	86,093	86,365	86,637	86,906	87,175	87,448	87,725	88,005	88,287	88,571
156	88,854	89,143	89,434	89,730	90,036	90,348	90,724	91,056	91,384	91,714
157	92,045	92,378	92,714	93,055	93,399	93,749	94,103	94,460	94,820	95,179
158	95,538	95,897	96,255	96,611	96,966	97,310	97,648	97,980	98,308	98,630
159	98,945	99,252	99,554	99,851	100,139	100,420	100,694	100,965	101,232	101,494
160	101,749	101,998	102,242	102,483	102,724	102,967	103,203	103,432	103,653	103,869
161	104,080	104,286	104,490	104,692	104,893	105,093	105,290	105,488	105,684	105,881
162	106,078	106,276	106,475	106,675	106,876	107,084	107,292	109,591	109,767	109,936
163	110,102	110,266	110,427	110,585	110,742	110,899	111,377	111,529	111,681	111,832
164	111,984	112,135	112,287	112,438	112,590					



Sam Rayburn Reservoir
April 2004
Prepared by: TWDB

Appendix C Elevation vs. Volume

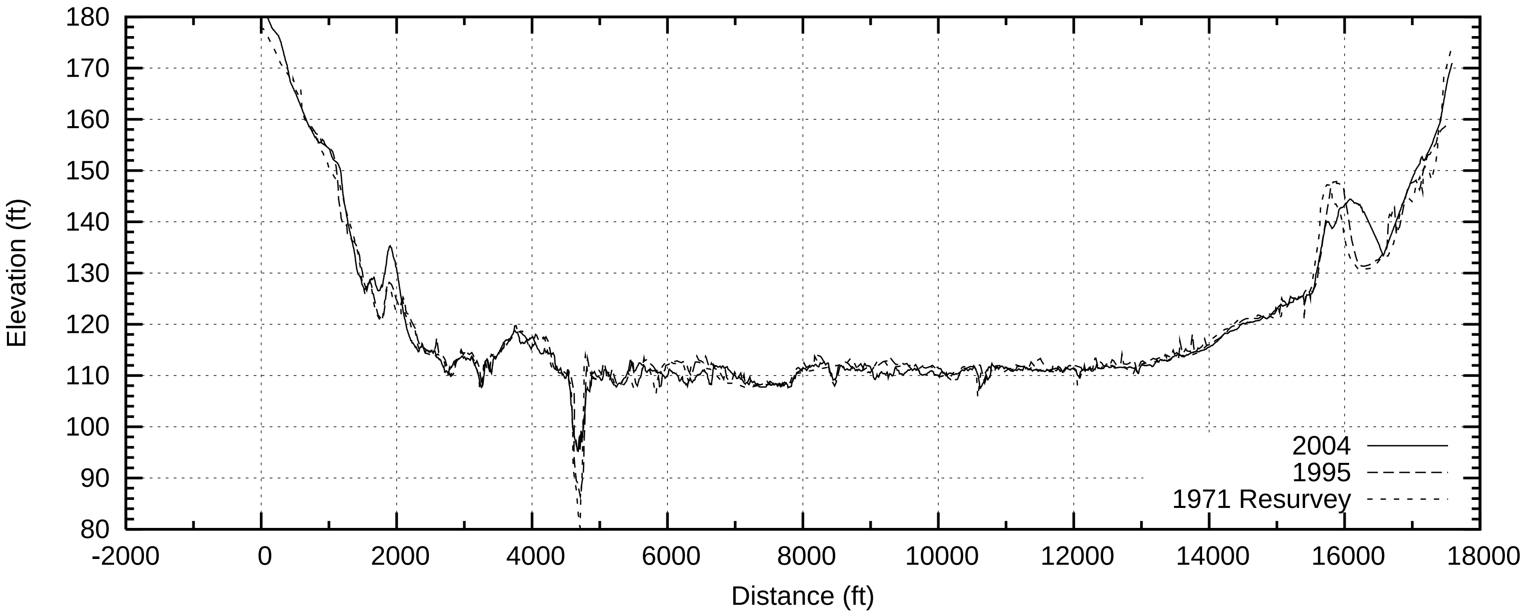


Sam Rayburn Reservoir
April 2004
Prepared by: TWDB

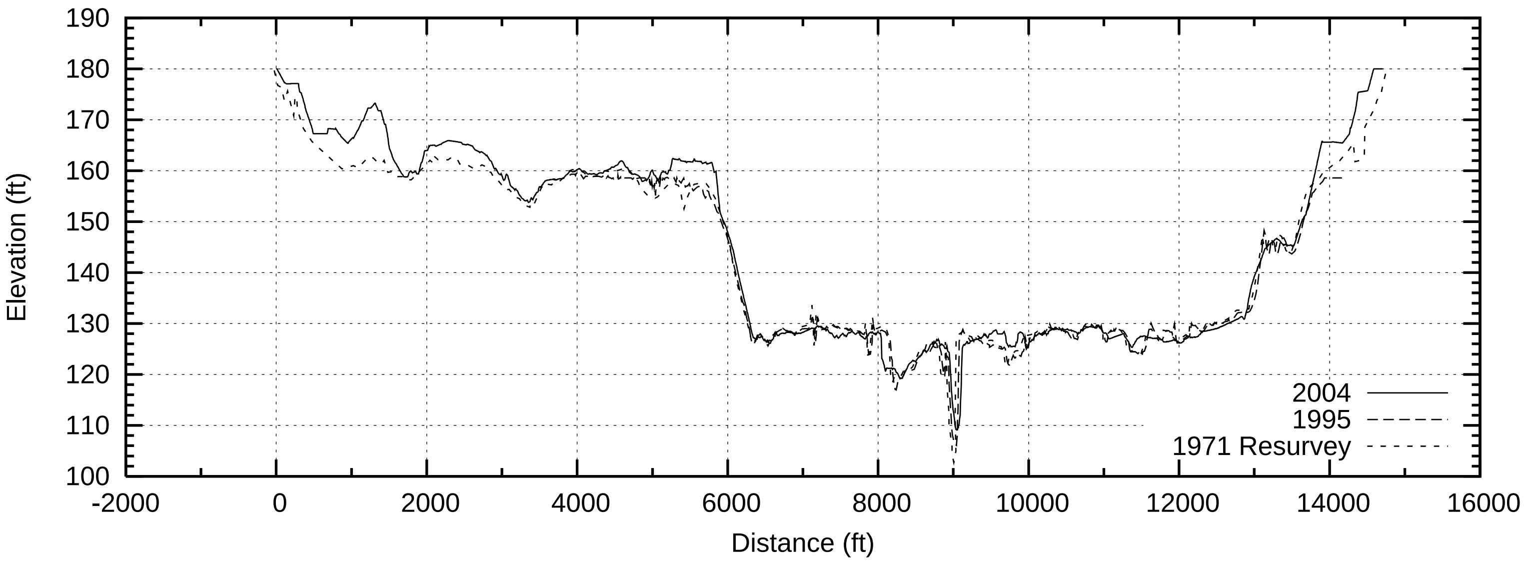
Appendix D Elevation vs. Area

Sam Rayburn Reservoir

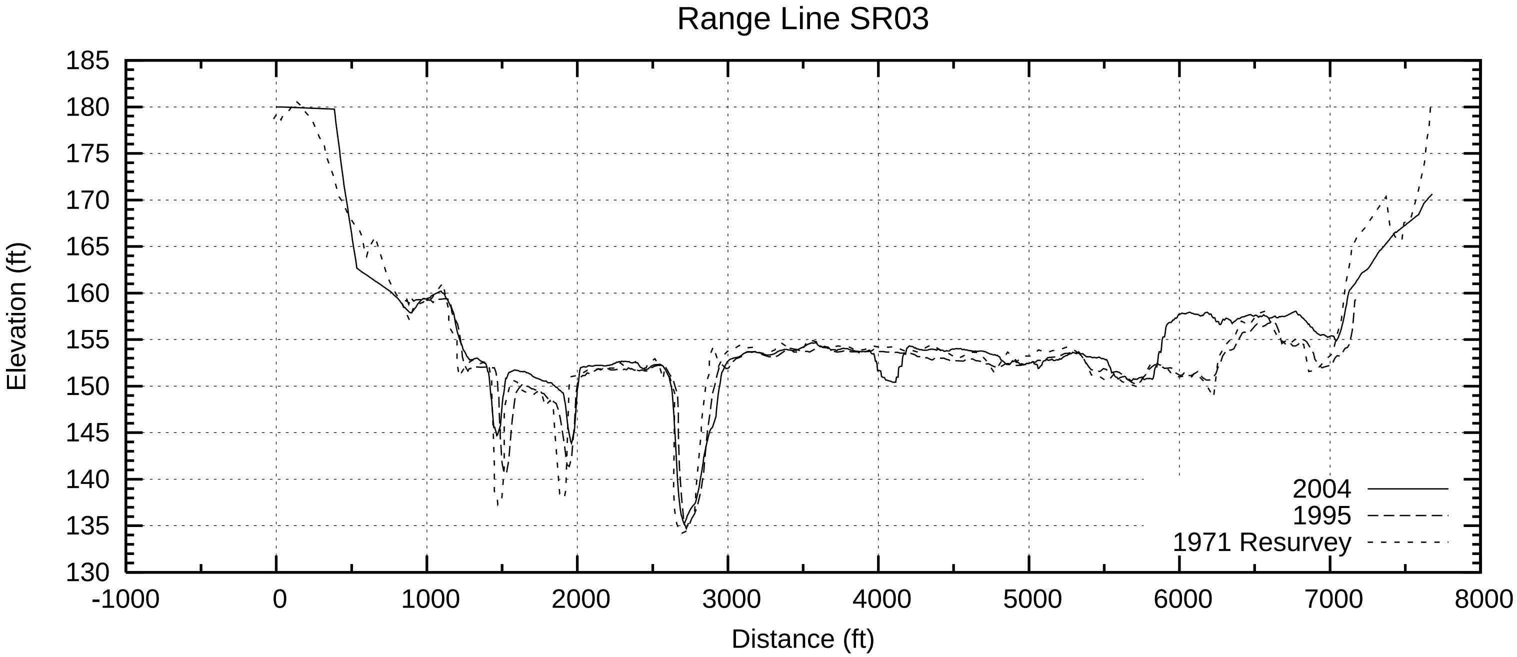
Range Line SR01

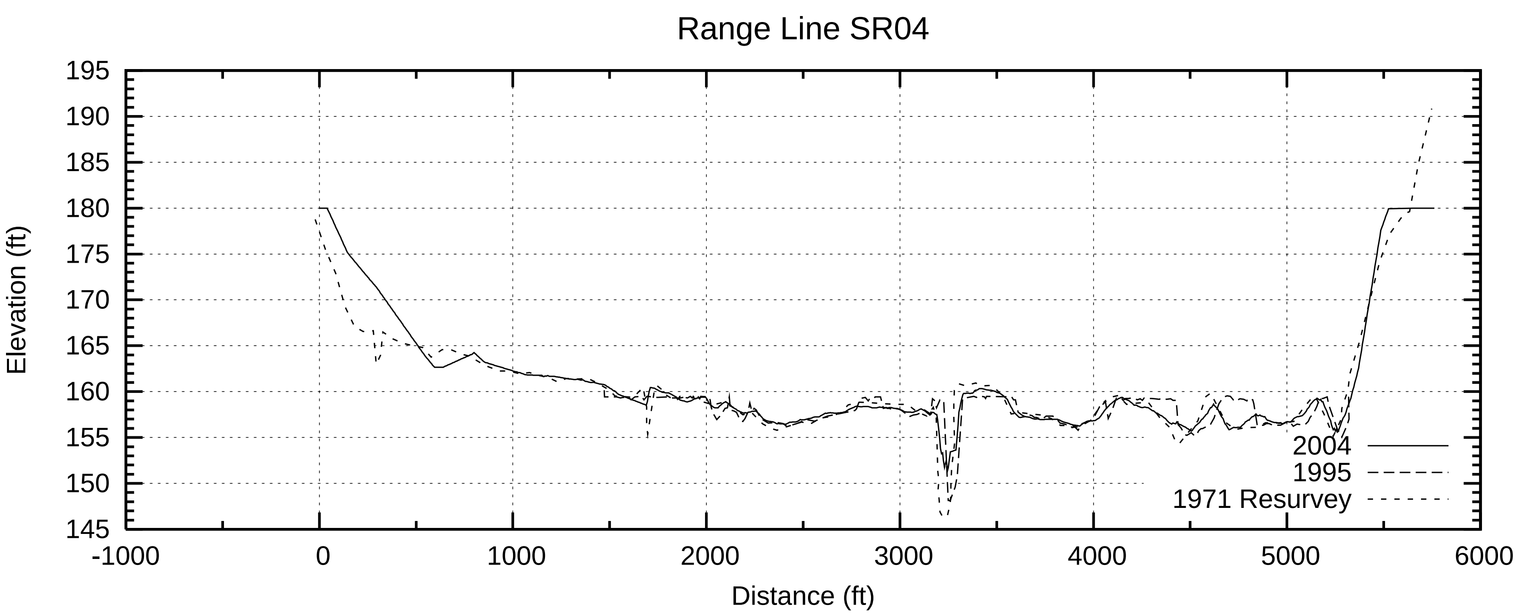


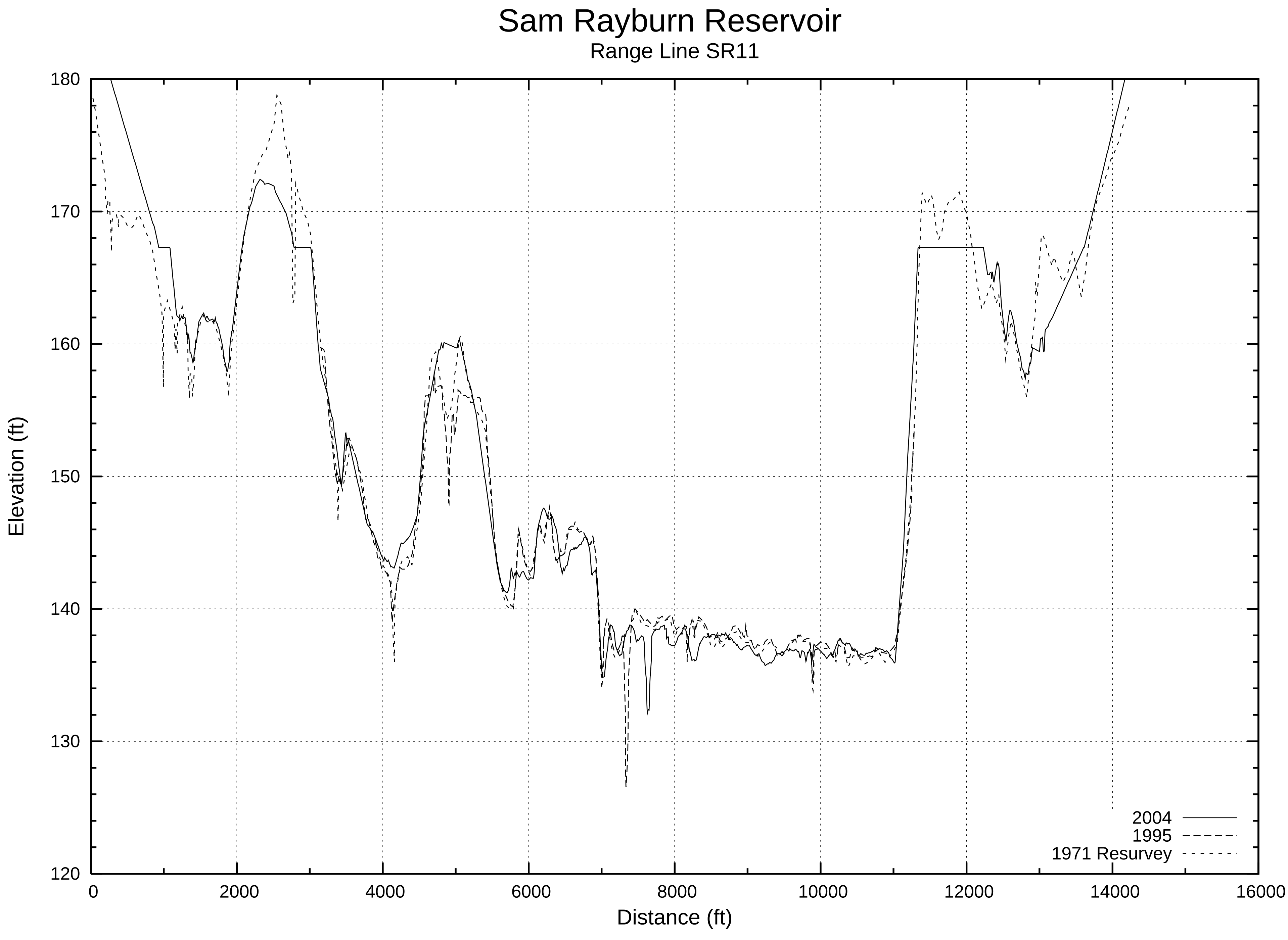
Range Line SR02



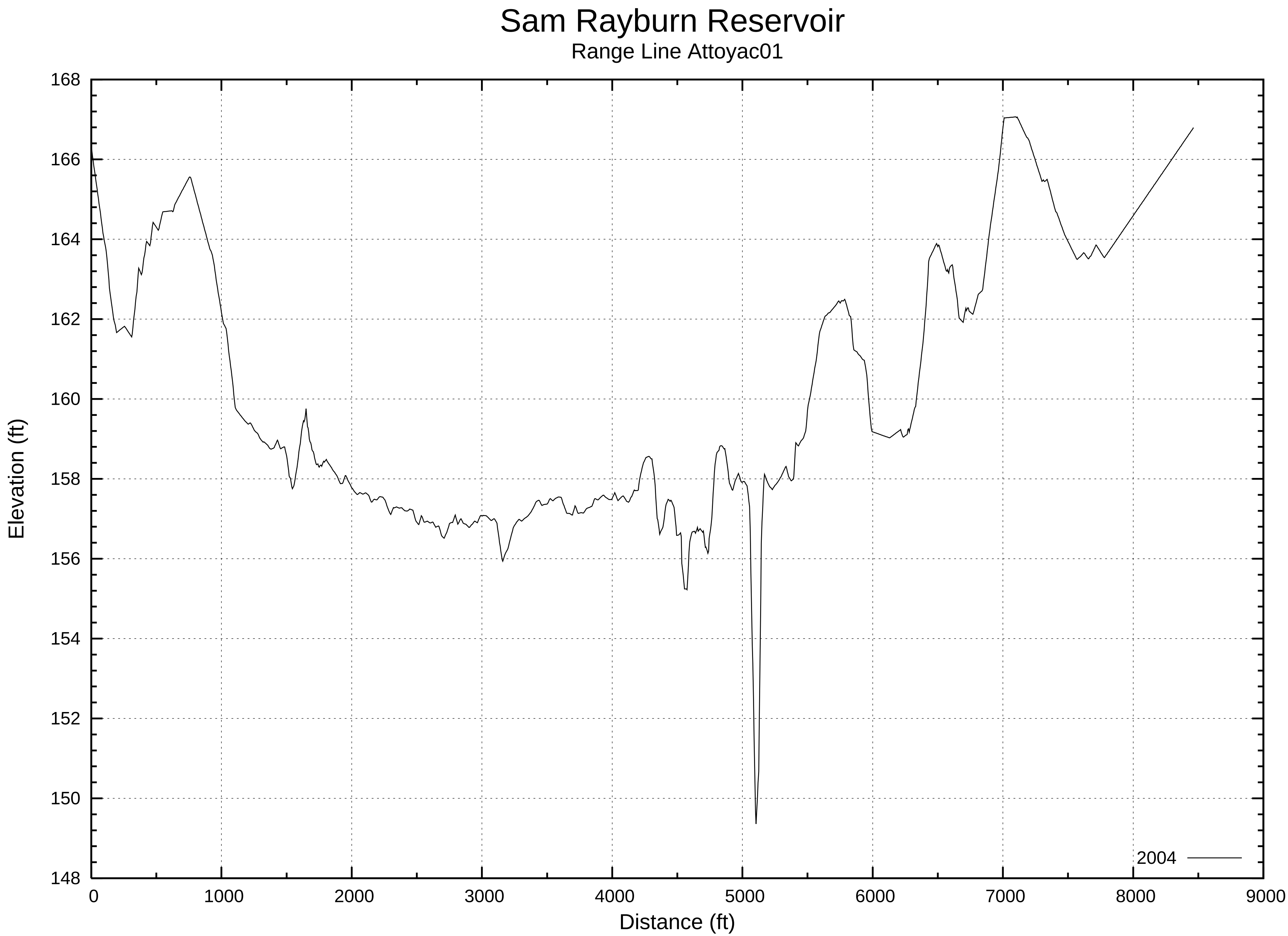
Sam Rayburn Reservoir



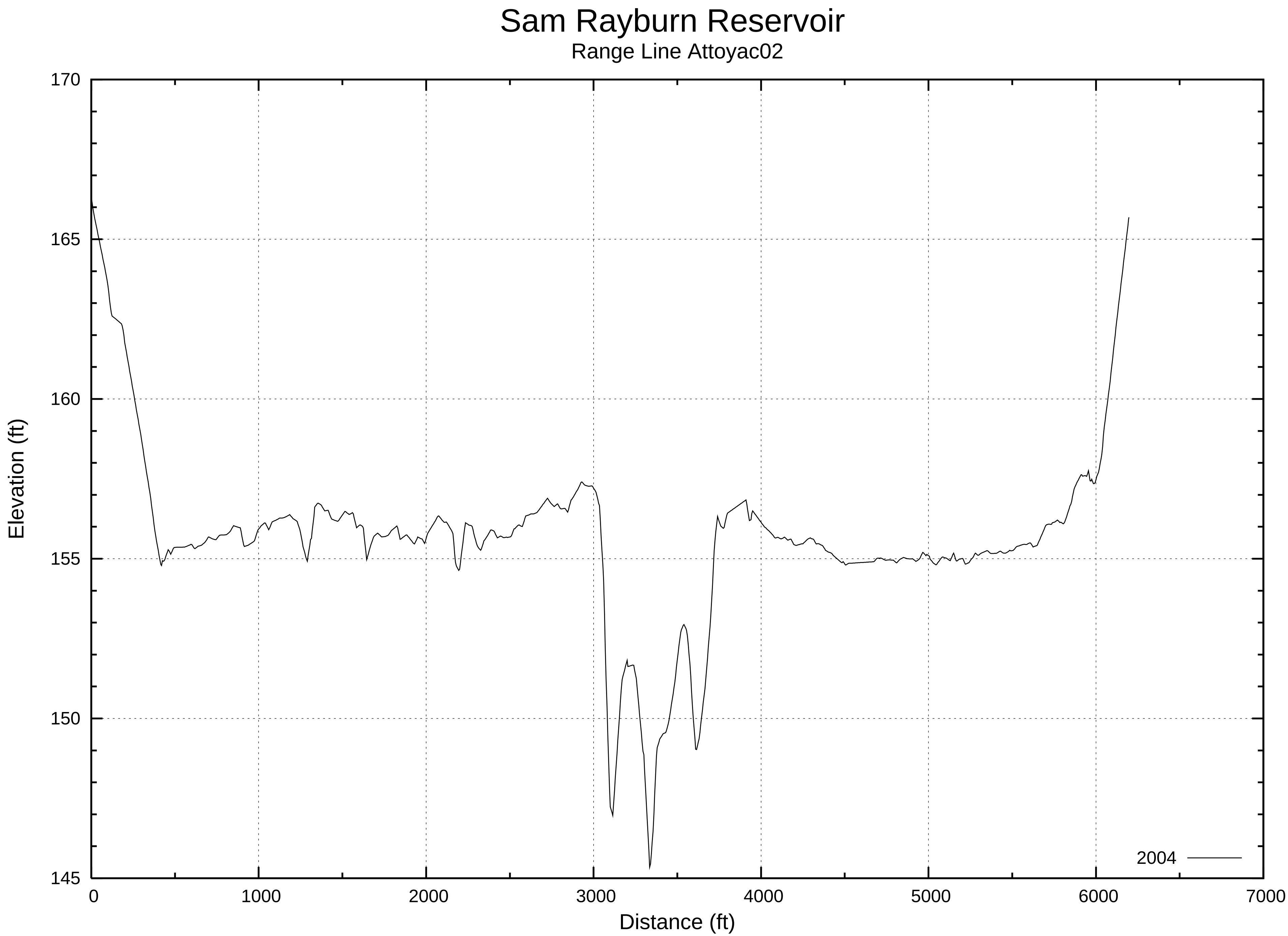


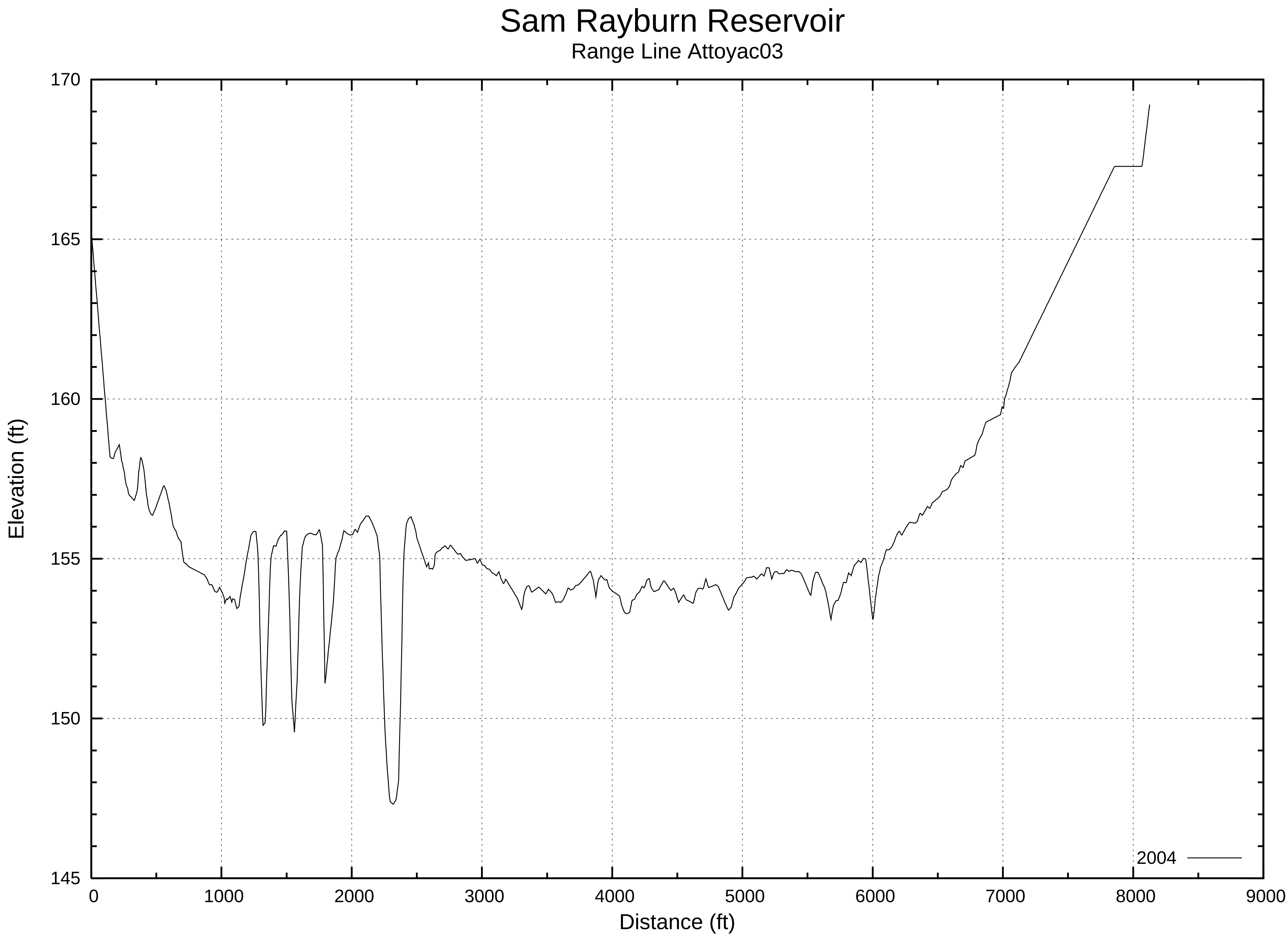


Sam Rayburn Reservoir
Range Line SR11
Elevation (ft)
180
170
160
150
140
130
120
0
2000
4000
6000
8000
10000
12000
14000
16000
Distance (ft)
2004
1995
1971 Resurvey

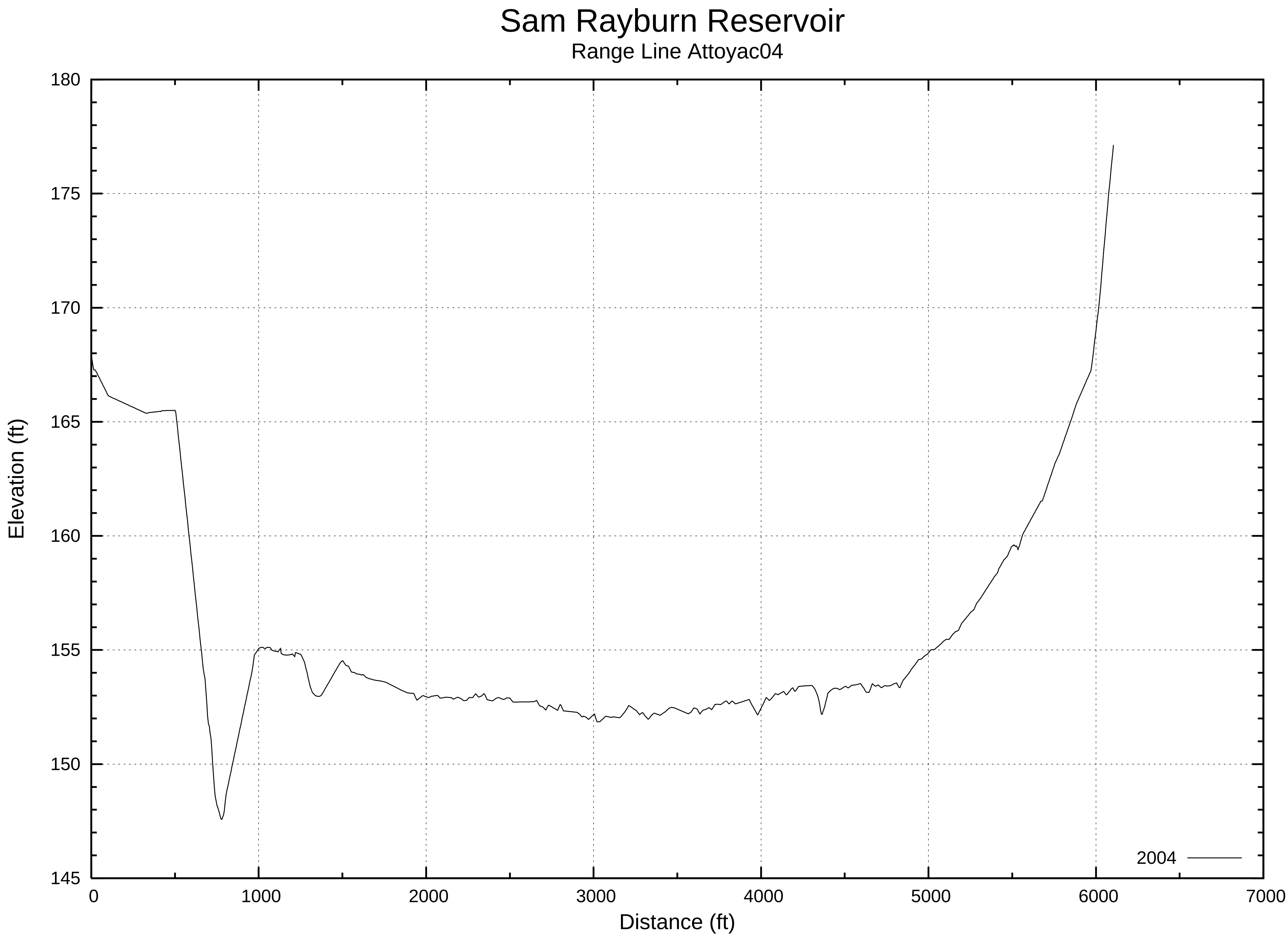


Sam Rayburn Reservoir
Range Line Attoyac01
Elevation (ft)
168
166
164
162
160
158
156
154
152
150
148
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
Distance (ft)
2004

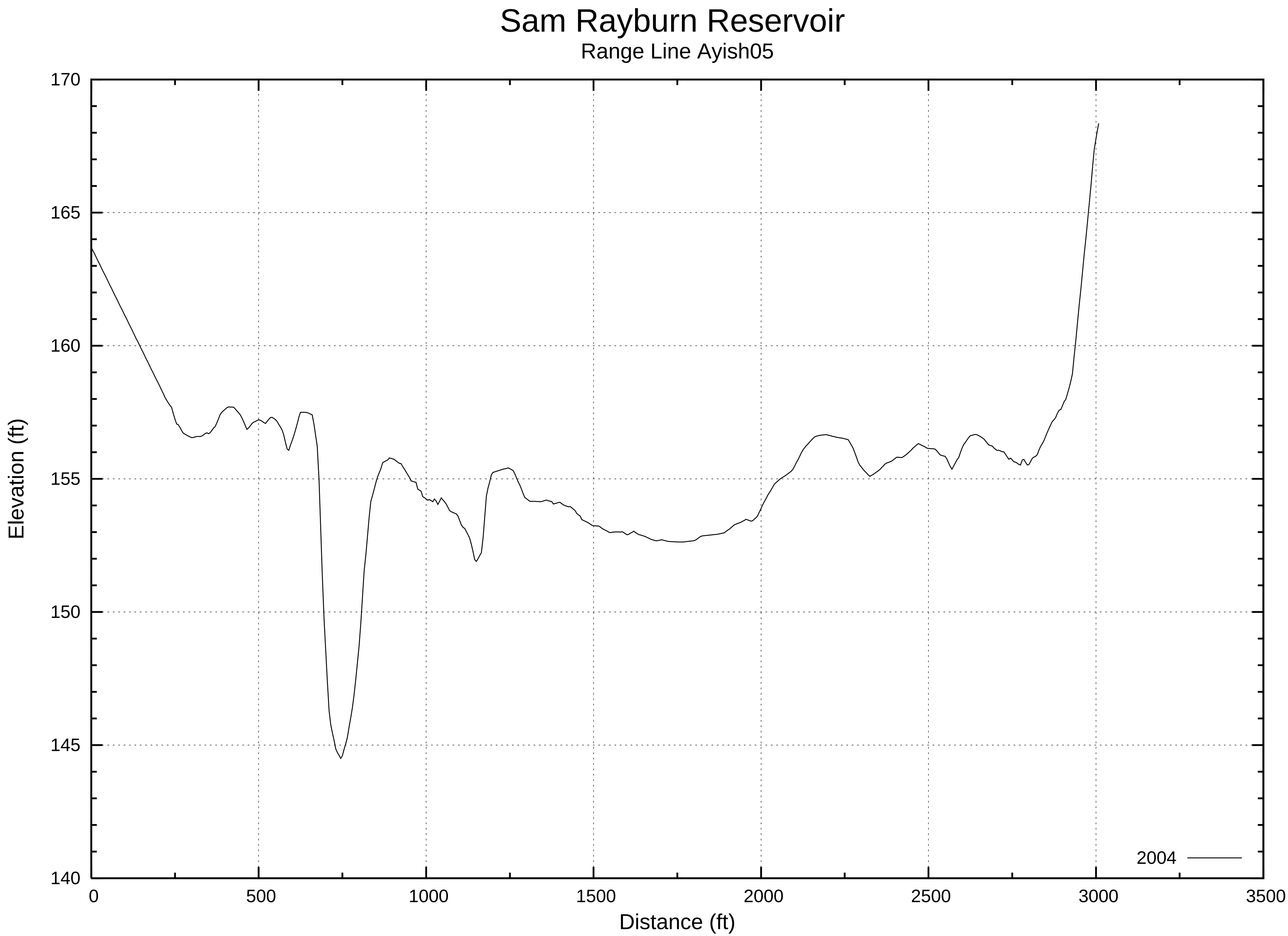

Sam Rayburn Reservoir
Range Line Attoyac02
Elevation (ft)
Distance (ft)
170
165
160
155
150
145
0
1000
2000
3000
4000
5000
6000
7000
2004



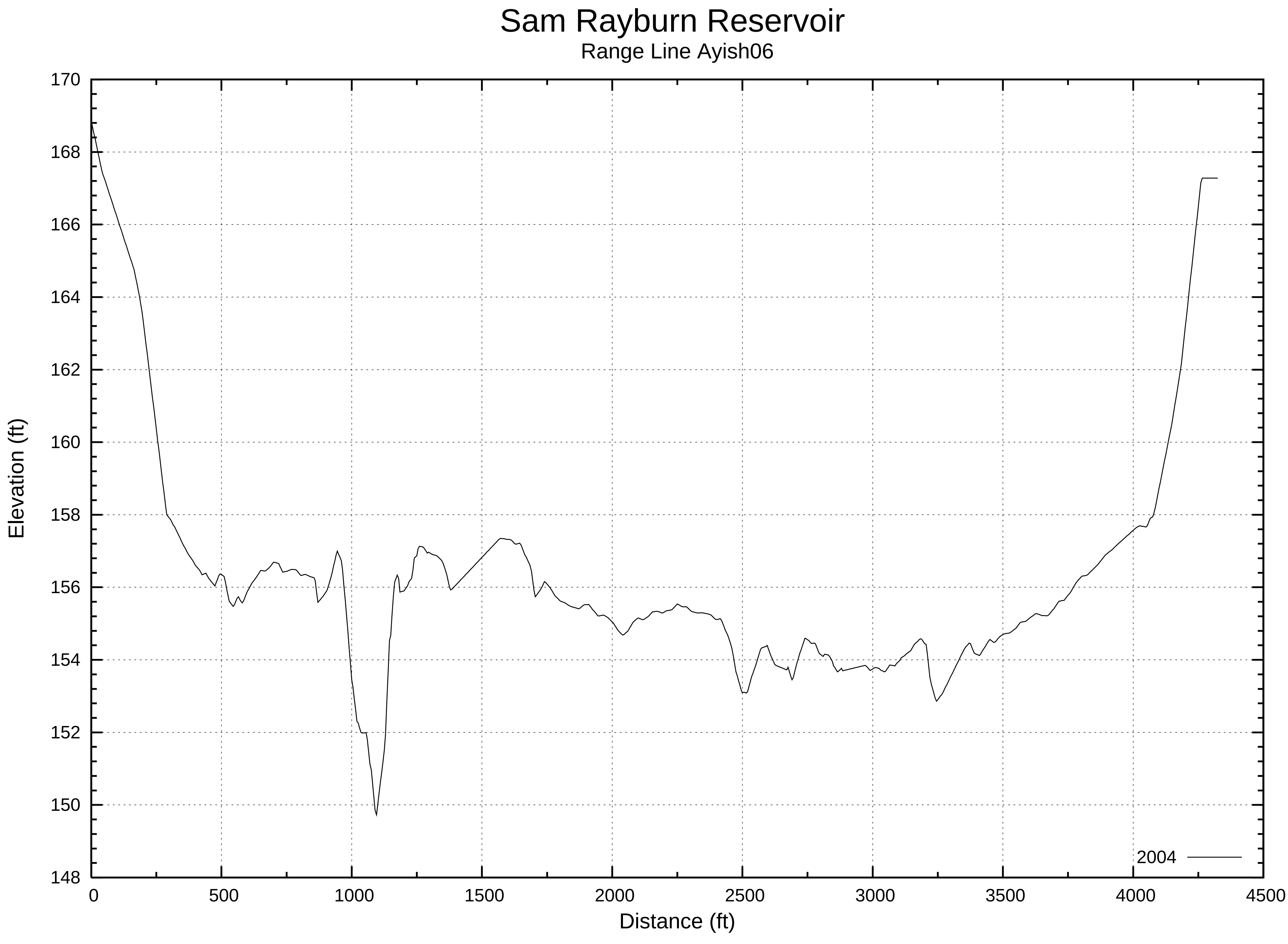
Sam Rayburn Reservoir
Range Line Attoyac03
Elevation (ft)
Distance (ft)
170
165
160
155
150
145
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
2004

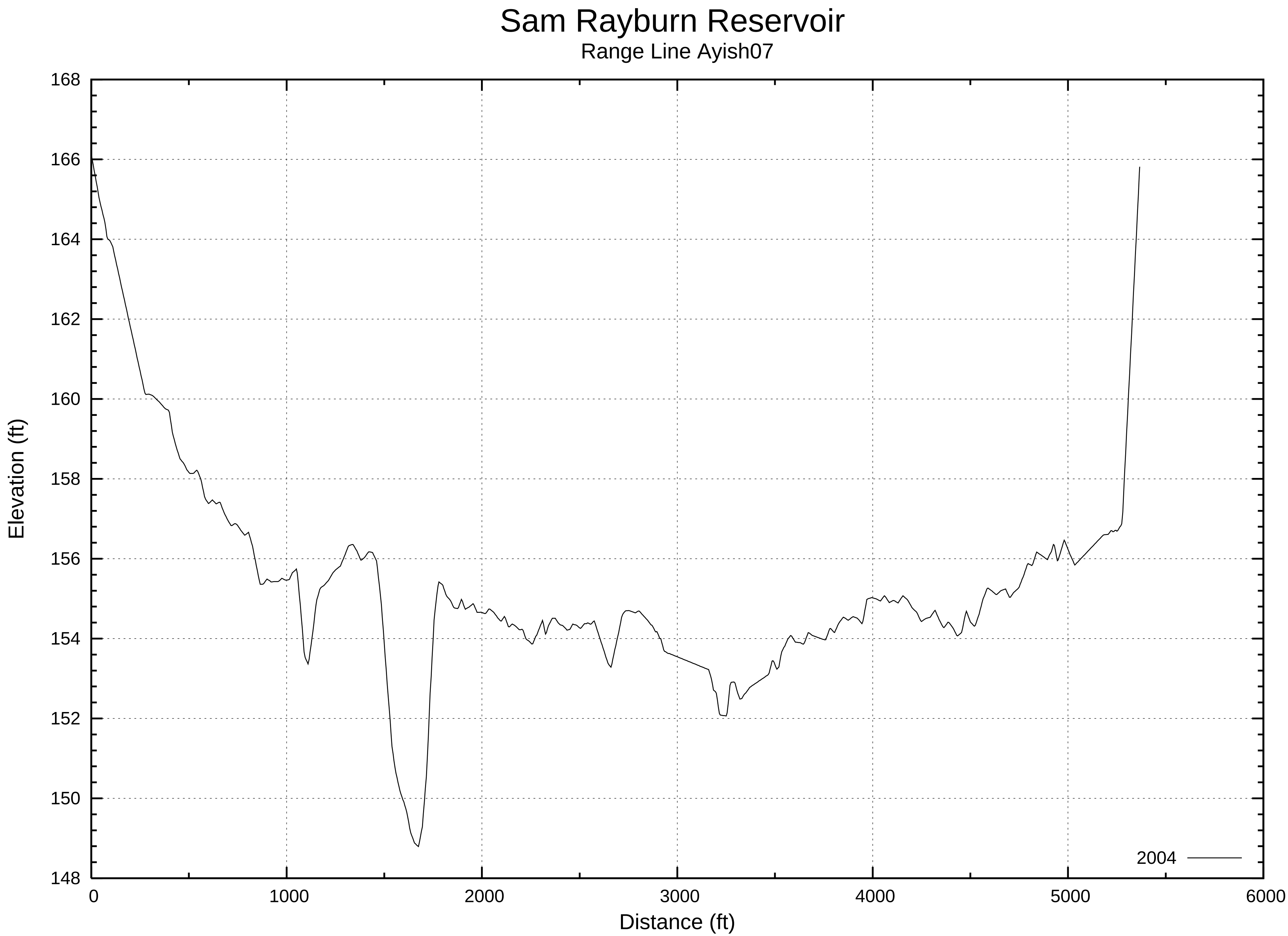

Sam Rayburn Reservoir
Range Line Attoyac04
Elevation (ft)
Distance (ft)
180
175
170
165
160
155
150
145
0
1000
2000
3000
4000
5000
6000
7000
2004

Appendix E

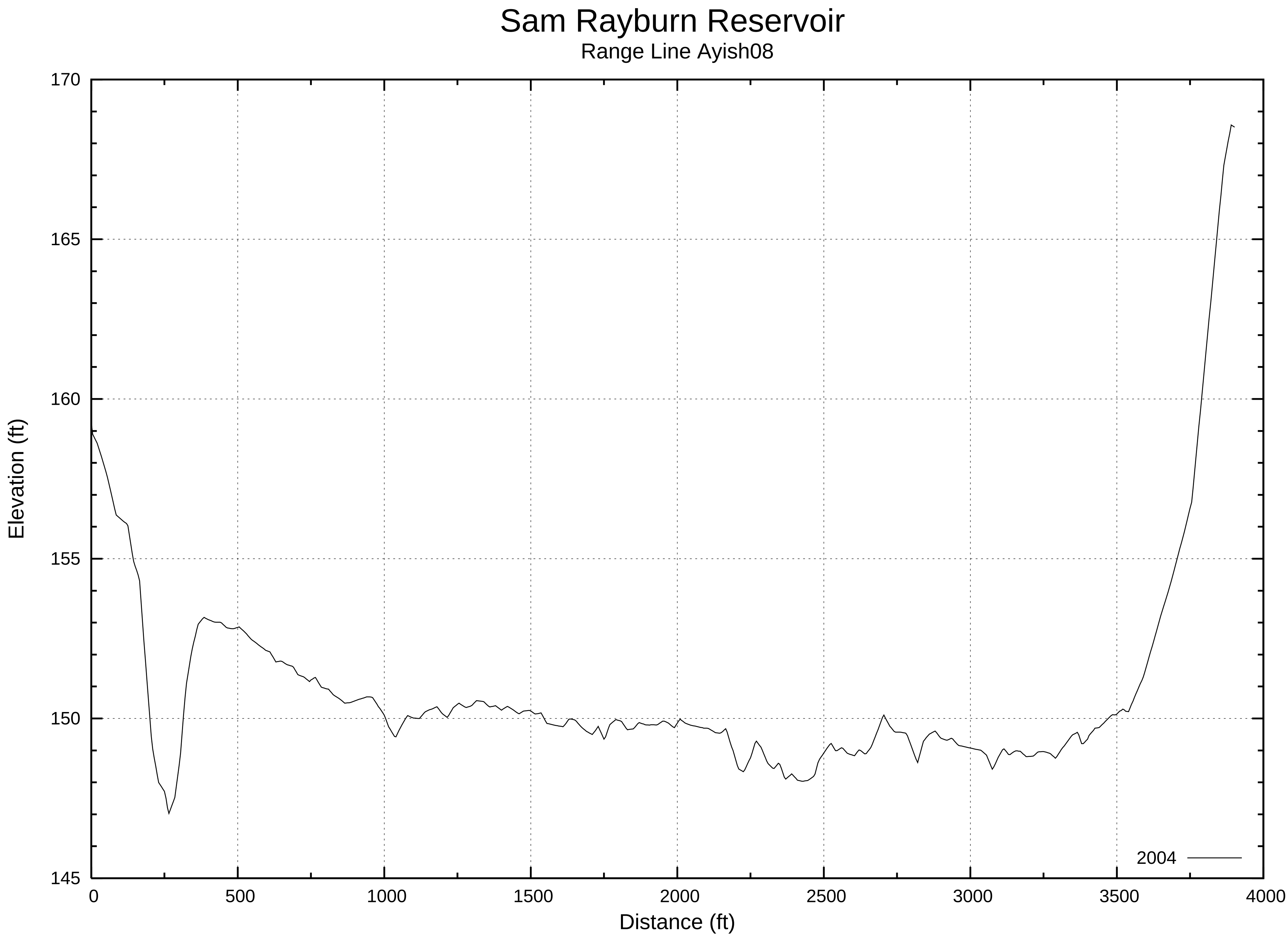


Sam Rayburn Reservoir
Range Line Ayish05
Elevation (ft)
170
165
160
155
150
145
140
0
500
1000
1500
2000
2500
3000
3500
Distance (ft)
2004


Sam Rayburn Reservoir
Range Line Ayish06
Elevation (ft)
170
168
166
164
162
160
158
156
154
152
150
148
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Distance (ft)
2004



Sam Rayburn Reservoir
Range Line Ayish07
Elevation (ft)
Distance (ft)
168
166
164
162
160
158
156
154
152
150
148
0
1000
2000
3000
4000
5000
6000
2004



Sam Rayburn Reservoir
Range Line Ayish08
Elevation (ft)
170
165
160
155
150
145
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (ft)
2004

Appendix E

Appendix F
Sam Rayburn Reservoir

TEXAS WATER DEVELOPMENT BOARD APRIL 2004 SURVEY

Range Line Endpoints
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

Range Line	X	Y
SR 01-L	4,221,263.50	10,432,362.00
SR 01-R	4,209,307.50	10,419,464.00
SR 02-L	4,177,852.00	10,467,571.00
SR 02-R	4,171,222.75	10,454,350.00
SR 03-L	4,128,032.50	10,511,997.00
SR 03-R	4,120,368.00	10,511,520.00
SR 04-L	4,101,468.25	10,533,580.00
SR 04-R	4,098,524.25	10,528,627.00
SR 05-L	4,068,852.50	10,538,190.00
SR 05-R	4,068,341.00	10,534,557.00
SR 06-L	4,051,907.25	10,544,488.00
SR 06-R	4,051,486.50	10,537,224.00
SR 07-L	4,042,648.00	10,540,516.00
SR 07-R	4,041,731.50	10,533,806.00
SR 08-L	4,172,984.75	10,517,996.00
SR 08-R	4,169,368.00	10,517,266.00
SR 09-L	4,175,569.00	10,536,912.00
SR 09-R	4,167,678.50	10,536,387.00
SR 10-L	4,171,573.25	10,550,786.00
SR 10-R	4,171,468.00	10,550,750.00
SR 11-L	4,252,414.00	10,461,115.00
SR 11-R	4,241,568.00	10,451,896.00
SR 12-L	4,239,364.50	10,479,372.00
SR 12-R	4,234,683.50	10,478,967.00
SR-13-L	4,230,759.00	10,499,005.00
SR-13-R	4,229,000.50	10,498,349.00
SR 14-L	4,284,501.00	10,449,421.00
SR 14-R	4,271,970.00	10,454,139.00

Appendix F (continued)

Sam Rayburn Reservoir

Developed by TWDB for future use in investigating deltas in Attoyac and Ayish Bayous

TEXAS WATER DEVELOPMENT BOARD APRIL 2004 SURVEY

Range Line Endpoints

State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

Range Line	X	Y
ATTOYAC-01L	4,175,380.00	10,514,515.00
ATTOYAC-01R	4,166,928.00	10,514,102.00
ATTOYAC-02L	4,173,612.75	10,512,397.00
ATTOYAC-02R	4,167,418.25	10,512,236.00
ATTOYAC-03L	4,167,257.25	10,510,188.00
ATTOYAC-03R	4,175,379.75	10,510,453.00
ATTOYAC-04L	4,168,742.50	10,508,746.00
ATTOYAC-04R	4,174,844.50	10,508,925.00
AYISH-05L	4,239,423.50	10,477,983.00
AYISH-05R	4,236,487.50	10,477,328.00
AYISH-06L	4,239,664.00	10,476,622.00
AYISH-06R	4,235,487.50	10,475,500.00
AYISH-07L	4,240,378.00	10,475,200.00
AYISH-07R	4,235,181.00	10,473,862.00
AYISH-08L	4,239,804.50	10,471,993.00
AYISH-08R	4,236,044.00	10,470,997.00

APPENDIX G - Brief description of water surface elevation data: equipment and methods

Four self-contained water level logging instruments were installed in the upper reaches of Sam Rayburn Reservoir to determine the water surface elevation in the vicinity of each instrument. The instruments were installed to account for significant inflow or wind events that may cause the water surface in the upper reaches to be different than the water surface recorded by the USGS gauge located near the dam. Table 1 describes the location where each logger was installed.

Table 1 – Location of water level logging instrumentation

Bridge that crosses Sam Rayburn Reservoir	Instrument location	Instrument Serial Number
SH 103, Angelina River	Third joint from east abutment, north column	31170
SH 103, Attoyac Bayou	Second joint from east abutment, south column	31168
SH 147	Second joint from east abutment, south column	31164
FM 83, Ayish Bayou	Second joint from east abutment, north column	31169

Each instrument, a Global Water WL-15, consisted of one pressure transducer (vented to the atmosphere), 50 feet of cable and an electronic data logger (Figure 1). The pressure transducer (the thin cylinder on the left in Figure 1) was installed below the water surface, attached to a bridge column and protected inside a perforated 3” PVC pipe. The data logger (the larger cylinder on the right in Figure 1) was installed high above the water surface, attached to a guard rail above the bridge deck.

Water surface elevation at each instrument location was determined indirectly based upon the USGS Sam Rayburn Reservoir nr Jasper, TX, gauge number 08039300. The height of water above each gauge used for this study is shown in Figure 2.

Figure 1 – Photo of water level loggers used for this study.

A simple method was used to determine water surface elevation at each TWDB gauge: for each reading, the height of each TWDB gauge was subtracted from the height of the USGS gauge recorded at the same time. The average difference between each TWDB gauge and the USGS gauge was calculated and was used as an adjustment factor in determining an elevation datum for the TWDB gauge.

Table 2 shows a hypothetical example of the elevation assignment for one TWDB gauge. The difference between the reading at the TWDB gauge and the reading at the USGS gauge was calculated for each record (Figure 3); this was calculated for each data record for the entire period collection (Table 2: column 5 = column 3 minus column 4). The average difference was taken for the entire period (average of all values in column 5). A datum for the TWDB gauge was calculated based upon the datum at the USGS gauge (TWDB datum = USGS datum + average difference). The water surface elevation at the TWDB gauge was calculated (column 6 = TWDB datum + TWDB height). {Note: While not reflected in Figures 2 and 3, additional adjustments were made to the Angelina River data to correct for repositioning of the transducer. Adjustments are reflected in water surface elevations shown in Figures 3 and 4.}

Water surface elevation at each gauge location is shown in Figure 4. Some variation of water surface was evident across the reservoir. To investigate the variation, the difference between the elevation recorded at each gauge and the USGS gauge was calculated (Figure 5). Variation was generally less than one inch (0.083 ft) at all locations; however, differences of up to 0.5 ft were evident during isolated periods. Survey data was not collected during any of those isolated periods therefore, no further adjustments to the survey data were necessary.

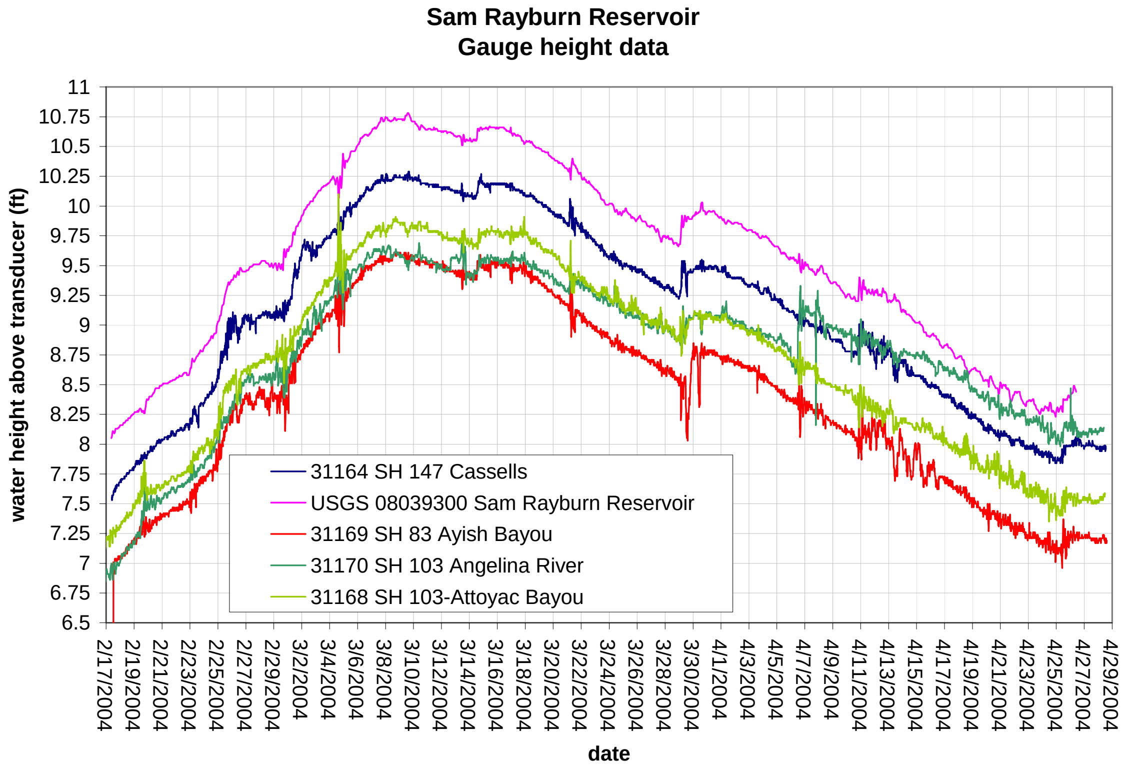


Figure 2 – Water height above gauge datum.

Table 2 – Example of water surface elevation calculations.

1	2	3	4	5	6
Date/time	**USGS water surface elevation**	**USGS gauge height**	**TWDB gauge height**	**Difference (USGS height minus TWDB height)**	**TWDB water surface elevation**
2/17/04 9:00	165.28	8.05	7	1.05	165.38
2/17/04 10:00	165.3	8.07	6.93	1.14	165.31
2/17/04 11:00	165.34	8.11	6.86	1.25	165.24
2/17/04 12:00	165.34	8.11	6.91	1.2	165.29
2/17/04 13:00	165.33	8.1	6.98	1.12	165.36
2/17/04 14:00	165.32	8.09	7	1.09	165.38
2/17/04 15:00	165.33	8.1	6.96	1.14	165.34
2/17/04 16:00	165.36	8.13	6.95	1.18	165.33
2/17/04 17:00	165.36	8.13	6.95	1.18	165.33
2/17/04 18:00	165.36	8.13	6.98	1.15	165.36
2/17/04 19:00	165.36	8.13	7.01	1.12	165.39
USGS datum	**157.23**		**average difference**	**1.15**	**TWDB datum =**
			stdev	0.05	**USGS + 1.15 =**
			median	1.14	**158.38**

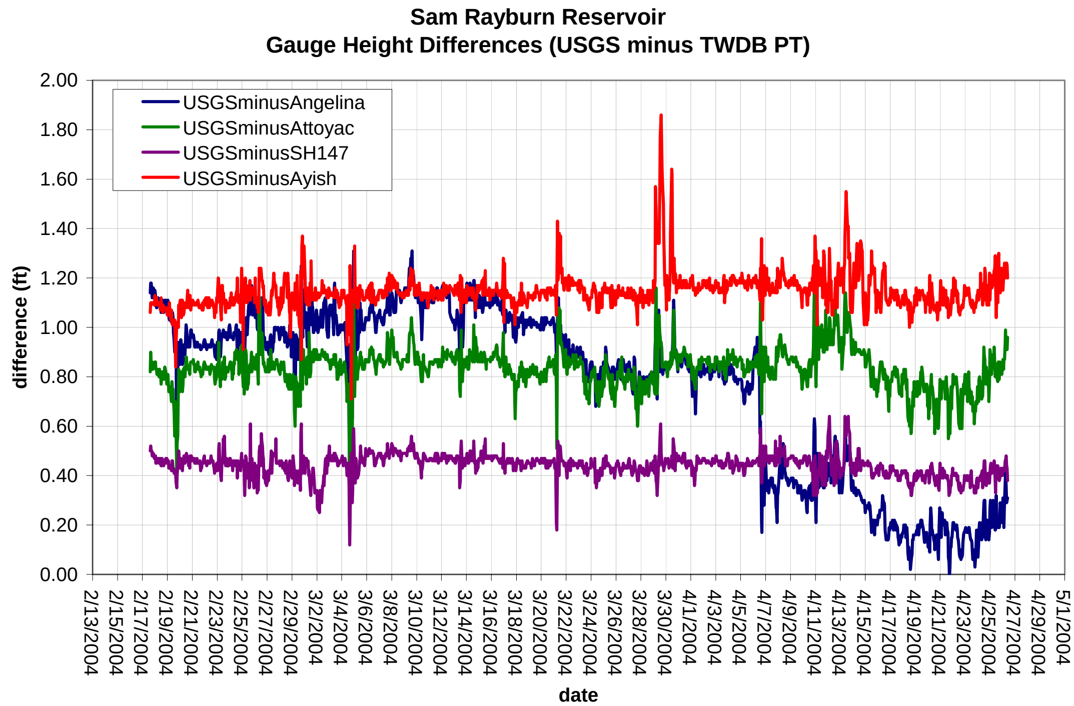


Figure 3 – Difference of water height above each TWDB pressure transducer from water height above USGS Sam Rayburn Reservoir gauge datum.

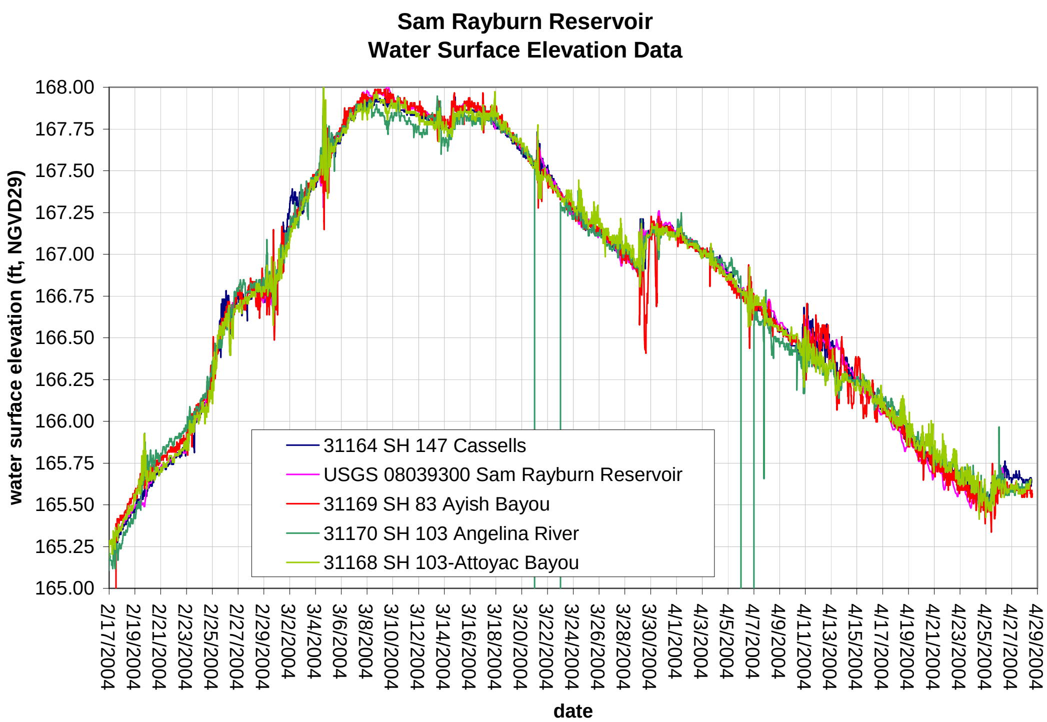


Figure 4 – Water surface elevation at each water level installation.

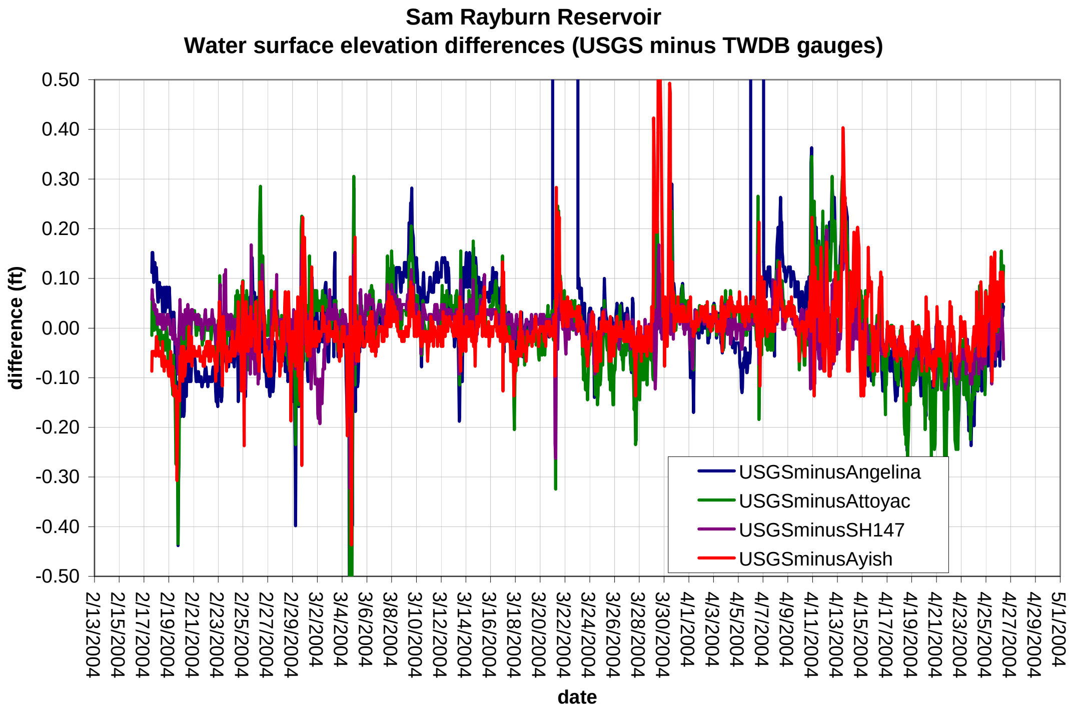
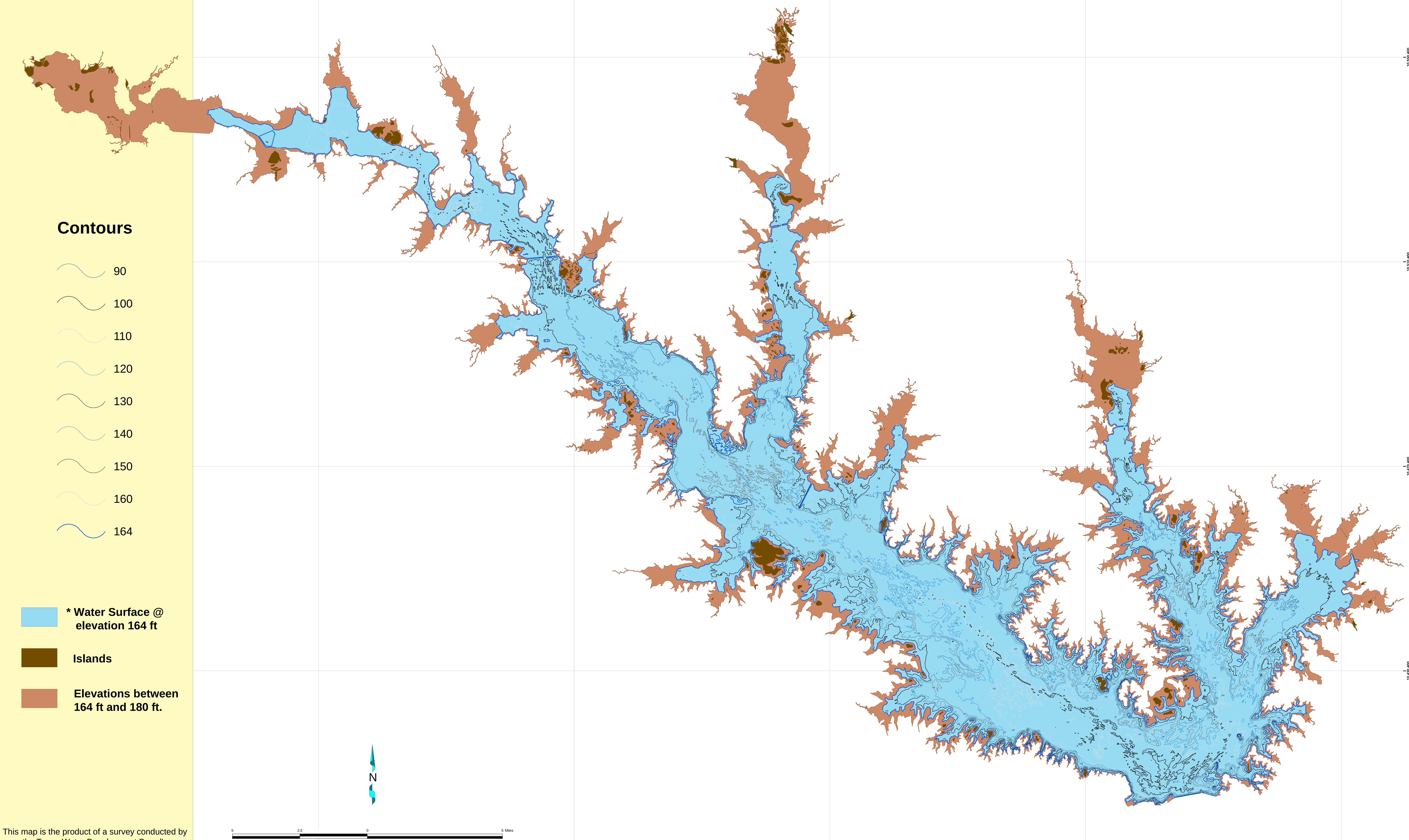


Figure 5 – Difference of water surface elevation at each TWDB installation compared to the USGS Sam Rayburn Reservoir gauge.

Figure 9

SAM RAYBURN RESERVOIR

10' - Contour Map



Contours

- 90
- 100
- 110
- 120
- 130
- 140
- 150
- 160
- 164

*** Water Surface @ elevation 164 ft**

Islands

Elevations between 164 ft and 180 ft.

This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Sam Rayburn Reservoir. The Texas Water Development Board makes no representations or assumes any liability.

* The 164-ft contour represented on this map was derived from a triangular irregular network (TIN) model and is an estimation of the true land water interface.

Prepared by : TEXAS WATER DEVELOPMENT BOARD MARCH 2004