VOLUMETRIC SURVEY OF LAKE PALESTINE

JUNE 2003 SURVEY

Prepared by the:

TEXAS WATER DEVELOPMENT BOARD

September 2005
Texas Water Development Board

Prepared for:

Deep East Texas Council of Governments

In cooperation with the

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

This report was prepared by staff of the Surface Water Availability Section:

Barney Austin, Ph.D.

Duane Thomas
Randall Burns
Marc Sansom
Heidi Moltz

Published and Distributed
by the
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711-3231

EXECUTIVE OVERVIEW

The Texas Water Development Board entered into a contract with the United States Army Corps of Engineers, Fort Worth District and the Deep East Texas Council of Governments to perform a volumetric survey of Lake Palestine. The goal of the study was to produce updated elevation-area and elevation-volume tables using current GPS, acoustical depth sounder and GIS technology.

Records indicate the top of the conservation pool (cpe) for Lake Palestine is at elevation 345.0 feet (ft) above mean sea level. A lake boundary was digitized from digital orthophoto quadrangle images (DOQ). Depth and positional data were collected along a layout of transects or pre-plotted navigation lines spaced approximately 500 feet apart using commercially available software.

Data were collected at Lake Palestine during the period from June 3 to June 24, 2003. The water levels were in the range of 345.01 ft to 345.64 ft. Approximately 196,000 data points were collected over 450 miles of transects.

The results of the current (2003) survey indicate the lake encompasses 22,656 surface acres and contains a volume of 373,202 ac-ft at cpe 345.0 ft. A 1989 study by Turner Collie & Braden Inc. indicated Lake Palestine had 23,833 surface acres and a volume of 361,600 ac-ft. This is an increase of 11,603 ac-ft or approximately a 3.2% gain in volume in 2003. The increase in volume may be due to the different methodologies used in the studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

LAKE PALESTINE

VOLUMETRIC SURVEY REPORT

INTRODUCTION

Staff of the Surface Water Availability Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Lake Palestine during the period from June 3 to June 24, 2003. The purpose of the survey was to determine the current volume of the lake at the conservation pool elevation (cpe) 345.0 feet. Survey results are presented in the following pages in both graphical and tabular form.

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gauge at Lake Palestine. The datum for this gauge is reported as mean sea level (msl). Thus, elevations are reported here in feet (ft) above msl. Volume and area calculations in this report are referenced to water levels provided by the USGS gauge: USGS 08031400 Lk. Palestine nr Frankston, TX.[1]

Lake Palestine is located on the Neches River (Neches River Basin) in Anderson, Cherokee, Henderson, and Smith Counties, 4 miles east of Frankston, TX (Figure 1). At the top of cpe 345.0 ft above msl, the lake has approximately 170 miles of shoreline. Records indicate the drainage area is approximately 839 square miles.[2]

LAKE HISTORY AND GENERAL INFORMATION

Lake Palestine and Blackburn Crossing Dam were originally authorized under Permit No. 1832 (Application No. 1975) by the State Board of Water Engineers to the Upper Neches River Authority on July 12, 1956[3]. Authorization was granted to construct a dam in three stages. The first stage of the process was the planning stage. The second stage was constructing the dam and creating a reservoir of 30,500 acre-feet (ac-ft) capacity. The third stage involved enlarging the dam; therefore, increasing the reservoir to a total capacity of 410,000 ac-ft. Currently, the Upper Neches River Municipal Water Authority (UNRMWA) operates Lake Palestine under the authority granted to them in Certificate of Adjudication No. 06-3254B[4]. Permission was given to operate a dam and existing reservoir known as Lake Palestine and to impound therein not to exceed 411,840 ac-ft. UNRMWA is authorized to operate Lake Palestine and an impoundment created by a downstream diversion dam as one system. The owner may use and not exceed a total 238,110 ac-ft per annum from the system. For more information about the uses, diversion locations, priorities, special conditions, time limitations and points of return please refer to the Certificate of Adjudication 06-3254B that is on record with the Texas Commission on Environmental Quality.

Construction for Blackburn Crossing Dam started May 30, 1960 and was completed June 13, 1962. The original design for Lake Palestine was to operate at cpe 317.0 ft and to contain 30,500 ac-ft with a surface area of 4,000 acres. The enlargement of the dam began September 26, 1969 and was completed on March 3, 1971.

Original design estimates for the area-capacity curves for Lake Palestine were obtained from 10-foot contour interval topographic maps[5]. These estimates were based on calculations by Forrest and Cotton, Inc. and show Lake Palestine originally containing 411,840 ac-ft and having a surface area of 25,560 acres at cpe 345.0 ft.

In November 1989, a report on sedimentation of Lake Palestine was published by Turner Collie & Braden Inc.[5] for the City of Dallas Water Utilities. The 1989 estimates show Lake Palestine having a total capacity of 361,600 ac-ft and a surface area of 23,833 acres at cpe 345.0 ft.

The following table for Blackburn Crossing Dam and Lake Palestine is based on information furnished by the Upper Neches River Municipal Water Authority[2] and results of the TWDB 2003 survey.

Table 1. Blackburn Crossing Dam and Lake Palestine Pertinent Data

Owner

Upper Neches River Municipal Water Authority

Operator

Upper Neches River Municipal Water Authority

Design Engineer

Forrest and Cotton, Inc.

General Contractor (for enlargement)

Wm. A. Smith Construction Co., Inc.

Location

On the Neches River in Cherokee and Anderson Counties, 4 miles east of Frankston, TX. The lake extends into Smith and Henderson Counties.

Purpose

Municipal, industrial, irrigation and domestic use

Drainage Area

839 square miles

Dam

Type:	Earthfill
Length (including spillway):	5,720 ft
Maximum Height:	75 ft
Crest Elevation:	364.0 ft

Spillway (Emergency)

Type:	Concrete weir
Length:	500 ft
Crest elevation:	345.0 ft
Control:	None

Outlet Works (Service Spillway)

Location:	Near the center of the dam
Type:	Gated concrete tower
Discharge:	Conduit, 8.5-ft. diameter
Invert of conduit:	298.0 ft
Control:	Two 5 by 7 ft gates

Low-Flow Outlet

Type:	2 pipes, 36-inch diameter from tower
Control:	Valves operated from tower
Discharge:	To outlet conduit
Lowest slide gate invert (elev.):	309.5 ft
Other slide gate invert (elev.):	312.5 ft, 322.5 ft. and 332.5 ft

The following information was obtained from the TWDB 2003 volumetric survey.

Feature	**Elevation (Above msl)**	**Capacity (Acre-feet)**	**Area (Acres)**
Top of Conservation Pool (Volume or Total Storage)	345.0	373,202	22,656
Conservation Pool (Between elev. 345.0 ft – 309.5 ft)	N/A	370,908	N/A
Inactive Pool below Low-Flow Invert	309.5	2,295	759

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the latest volumetric survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin (Hydro-survey boat), equipped with twin 90-Horsepower Honda outboard motors. (Reference to brand names throughout this report does not imply endorsement by TWDB). Installed within the enclosed cabin are a Coastal Oceanographics' Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal and an on-board PC. A water-cooled 4.5 kW generator provides electrical power through an in-line uninterruptible power supply.

For the areas on the lake that were harder to navigate, a 20-foot aluminum shallow-draft flat bottom SeaArk craft (River-runner) with cabin and equipped with one 100-horsepower Yamaha outboard motor was used. The portable data collection equipment on-board the boat included a Knudsen 320 B/P Echosounder (depth sounder), a Trimble Navigation, Inc. AG132

GPS receiver with Omnistar differential GPS correction signal and a laptop computer.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the pre-plotted transect lines, the depth sounder takes approximately ten readings of the lake bottom each second. The depth readings are stored on the computer along with the positional data generated by the boat's GPS receiver. The data files collected are downloaded from the computer and brought to the office for editing after the survey is completed. During editing, poor-quality data is removed or corrected, multiple data points are averaged to one data point per second, and the average depths are converted to elevation readings based on the water-level elevation recorded at the time the data was collected. Accurate estimates of the lake volume can be quickly determined by building a 3-D Triangular Irregular Network (TIN) model of the lake from the collected data.

PRE-SURVEY PROCEDURES

The lake's boundary was digitized using Environmental Systems Research Institute's (ESRI) ArcView from digital orthophoto quadrangle images (DOQ). The DOQ's are produced by VARGIS of Texas LLC for the TEXAS Orthoimagery Program (TOP). The DOQ products produced for the Department of Information Resources and the GIS Planning Council under the Texas Orthoimagery Program reside in the public domain. More information can be obtained on the Internet at http://www.tnris.state.tx.us/DigitalData/doqs.htm. The lake's boundary was created by digitizing the BROWNSBORO SE, CHANDLER SW, MOORE STATION SE & NE, SALINE BAY NW, SW & SE and BERRYVILLE (all quadrants), TEXAS DOQ's. Records indicate the lake-level elevations at the time the DOQ's were photographed on January 19, 23 & 25, 1995 were 345.94ft, 345.98ft & 345.98ft above msl respectively. The lake and island boundaries were given an elevation of 346.0 ft and TWDB Staff utilized these boundary conditions in modeling Lake Palestine for this report.

The DOQ graphic boundary file was transformed from UTM Zone 15 datum to NAD '83, using Environmental Systems Research Institute's (ESRI) Arc/Info PROJECT command with the NADCOM (standard conversion method within the United States) parameters.

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using HYPACK software. The survey design required the use of approximately 530 survey lines placed perpendicular to the original creek channel and tributaries along the length of the lake.

SURVEY PROCEDURES

The following procedures were followed during the volumetric survey of Lake Palestine performed by the TWDB. Information regarding equipment calibration and operation, the field survey, and data processing is presented.

Equipment Calibration and Operation

Prior to collecting data each day on-board the Hydro-survey boat, the depth sounder was calibrated with the Innerspace 443 Velocity Profiler, an instrument used to measure the variation in the speed of sound at different depths in the water column. The average speed of sound through the entire water column below the boat was determined by averaging local speed-of-sound measurements collected through the water column. The velocity profiler probe was first placed in the water to acclimate it. The probe was next raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again to the surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed was computed by the velocity profiler. This average speed of sound was entered into the ITI449 depth sounder, which then provided the depth of the lake bottom. The depth was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly.

On-board the River-runner boat, the Knudsen depth sounder was calibrated using the DIGIBAR-Pro Profiling Sound Velocimeter by Odom Hydrographic Systems. Basically, the steps to determine the speed of sound are the same as those used for the Innerspace 443 Velocity Profiler. The probe was first placed in the water to acclimate it, then raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again to the surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed was computed by the velocimeter. The speed of sound was then entered into the bar check feature in the Knudsen software program. The depth was then checked manually with a stadia (survey) rod or weighted measuring tape to ensure that the depth sounder was properly calibrated and operating correctly.

The speed of sound in the water column ranged from 4,900 feet per second to 4,933 feet per second during the Lake Palestine survey. 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 $\pm$0.2 ft. An additional estimated error of $\pm$0.3 ft arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$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. Further information on these calculations is presented in Appendix G.

During the survey, the horizontal mask setting on the onboard GPS receiver 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. An internal alarm sounds if PDOP rises above seven 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 Omnistar receiver. The reservoir's initialization file used by the HYPACK data collection program was set up to convert the collected Differential GPS positions to state-plane coordinates on the fly.

Field Survey

The water levels remained above cpe during the survey, ranging from 345.01 ft to 345.64 ft. Overall, the survey crew had good weather conditions with 3 days of weather related delays. Upon arriving at Lake Palestine, TWDB staff met with personnel from the UNRMWA. After discussing the logistics for the survey, the crew began data collection the following day.

The design layout for collecting data at Lake Palestine required pre-plotting transects (range lines) that were perpendicular to the river and contributing creek channels. These transects had an average spacing of 500 ft. While collecting data, the boat operator would steer the boat on course (with GPS navigation) starting from one shore and heading to the opposite shore. The data collector would monitor the data display and depth sounder to make sure the latitude; longitude and depth (x,y,z) values were being logged. Adjustments could be made if the instruments were receiving bad data at that time. The depth sounder and GPS equipment records 10 data points every second. These points are averaged to one data point per second for generating the model. The distance between data points depended on the speed of the boat. The maximum distance between data points during the survey of Lake Palestine was approximately 30 ft.

Approximately 196,000 data points were collected over the 457 miles traveled during the data collection phase of Lake Palestine. These points were stored digitally on the boat's computer in 610 data files. Random data were collected in those areas where the crew was not able to stay on course due to obstructions. Figure 2 shows the actual location of all data points collected.

Data Processing

The collected data were downloaded from diskettes onto TWDB's network computers. Tape backups were made for future reference as needed. To process the data, the EDIT routine in the HYPACK Program was run on each raw data file. Data points such as depth spikes, erroneous depths caused by vegetation interference or data with missing depth or positional information were deleted from the files. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. After all changes had been made to the raw data files, the edited files were saved and then combined into a single X, Y, Z data file, to be used with the GIS software to develop a model of the lake bottom elevation.

The resulting data file was imported into Environmental System Research Institute’s (ESRI) Arc/Info Workstation GIS software. This software was used to convert the data to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the lake's bottom surface using Arc/Info's TIN software module. The module generates a triangulated irregular network (TIN) from the data points and the boundary file using a method known as Delauney's criteria for triangulation. A triangle is formed between three non-uniformly spaced points, including all points along the boundary. If there is another point within the triangle, additional triangles are created until all points lie on the vertex of a triangle. All of the data points are used in this method. The generated network of three-dimensional triangular planes represents the bottom surface. With this representation of the bottom, the software then calculates elevations along the triangle surface plane by determining the elevation along each leg of the triangle. The lake area and volume can be determined from the triangulated irregular network created using this method of interpolation.

Volumes and areas were calculated from the TIN for the entire lake at one-tenth of a foot interval from the lowest elevation to the contour used for the lake boundary during the 2003 survey. From elevation 290.5 ft to 346.0 ft, the surface areas and volumes of the lake were computed using Arc/Info software. The computed lake 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.

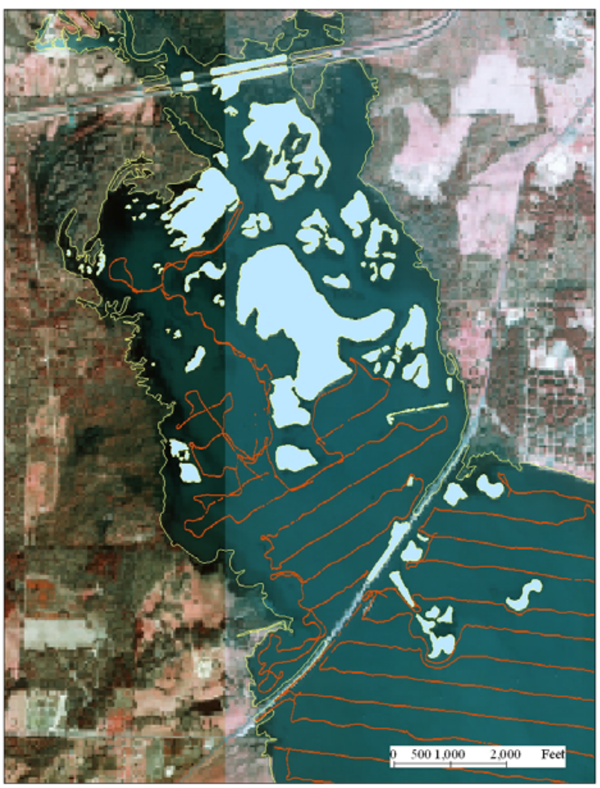


Figure 3. Data collection pattern in upper reaches of Lake Palestine.

The lack of data points around islands in the upper reaches of the reservoir produces jumps or spikes in the area calculations at the elevation they occur. This is a disadvantage in the otherwise flexible Delauney's interpolation routine, and as a result the area calculations near elevation 343 ft begin to decrease below what would be expected based on the total surface area of the digitized boundary. Staff compensated for this, by uniformly distributing the known area from the digitized boundary between elevations 342.8 ft and 346.0 ft. The elevation-area graph in Appendix D displays both the calculated area and interpolated area.

Other products developed from the model include a shaded relief map (Figure 4) and a shaded depth range map (Figure 5). To develop these maps, the TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command. Linear filtration algorithms were applied to the DTM to produce smooth cartographic contours. The resulting contour map of the bottom surface at 5-ft intervals is presented in Figure 6. Finally, the cross-section endpoints are in Appendix E and the corresponding cross-section plots are in Appendix F.

RESULTS

Results from the 2003 TWDB survey indicate Lake Palestine encompasses 22,656 surface acres and contains a total volume of 373,202 ac-ft at cpe 345.0 ft. The lake boundary (shoreline miles) was calculated to be 170 miles at elevation 346 ft and was derived from the digitized boundary from the DOQ's. The deepest point physically measured during the survey was a depth of 54.49 ft corresponding to elevation 290.51 ft and was located approximately 1,500 feet upstream of Blackburn Crossing Dam.

SUMMARY AND COMPARISONS

The original estimates indicated Lake Palestine contained 411,844 ac-ft and had a surface area of 25,560 acres. The results of a 1989 survey showed Lake Palestine having a total capacity of 361,600 ac-ft and an area of 23,833 surface acres.

TWDB staff performed a volumetric survey of Lake Palestine during the period of June 3 through 24, 2003. The 2003 survey utilized a differential global positioning system, depth sounder and geographical information system technology to create a digital model of the lake's bathymetry.

At conservation pool elevation 345.0 ft, the current survey measured 22,656 surface acres, and a total volume at cpe is 373,202 ac-ft. The inactive pool or dead pool storage, below elevation 309.5 ft, contains 2,294 ac-ft; thus, the conservation storage or capacity found in this survey is 370,908 ac-ft. Lake Palestine has gained 11,602 ac-ft or 3.2 percent in total volume since 1989. It is recommended that another survey utilizing similar methods be performed in five to ten years or after major flood events to monitor changes to the lake's capacity.

Comparisons between the 1971 original design, the 1989 sediment survey and the 2003 TWDB volumetric survey are presented in Table 2.

Table 2. Area and Capacity Comparisons for Lake Palestine

FEATURE	Original Design	Sediment Survey	TWDB Current Survey
Year	1971	1989	2003
Area (acres)	25,560	23,833	22,656
Volume (ac-ft)	411,844	361,600	373,202

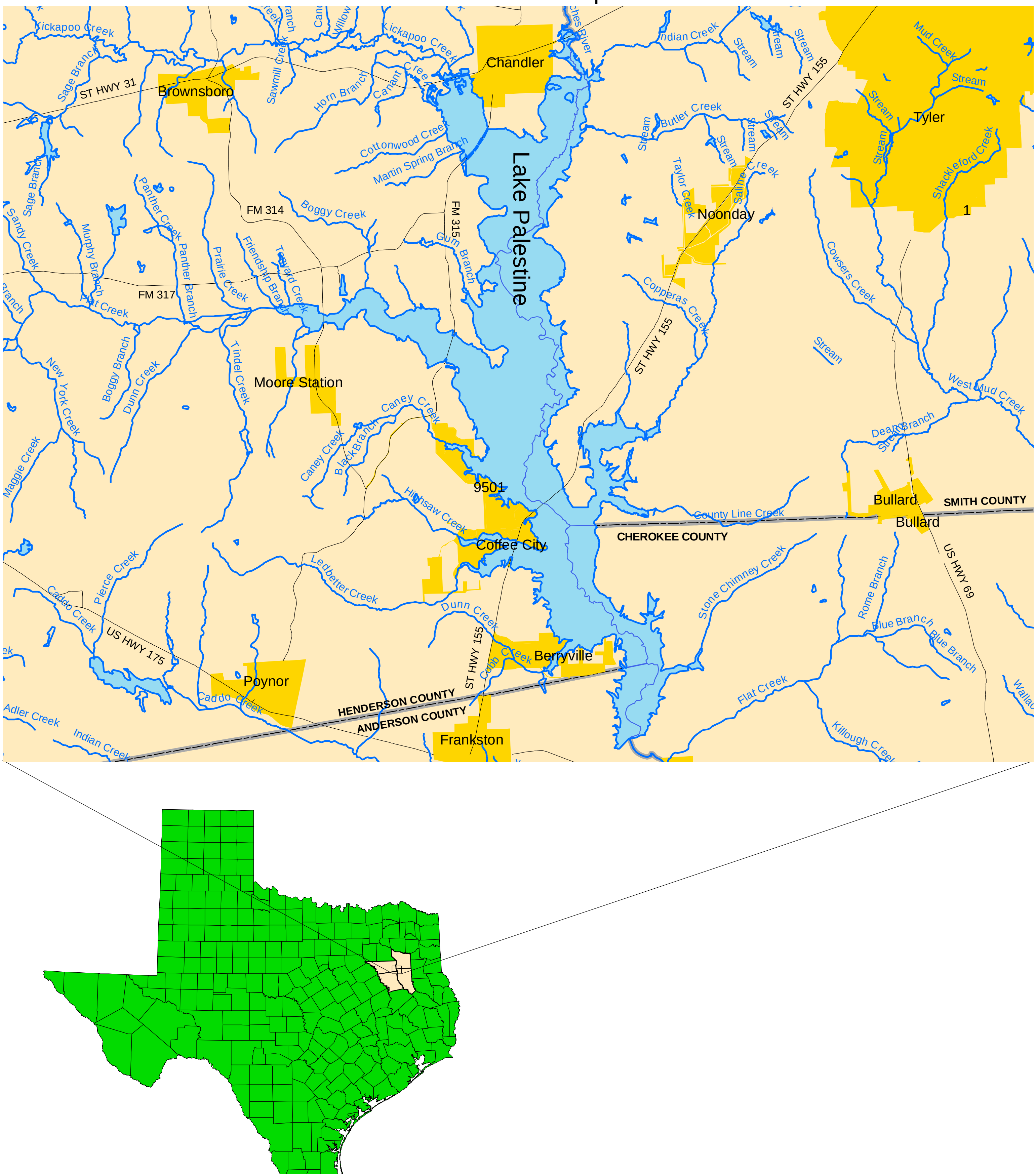
REFERENCES

1. United States Geological Survey, <http://waterdata.usgs.gov/tx/nwis/uv/?site_no=08031400&PARAmeter_cd=72020,00054>, January 2004.
2. Texas Water Development Board. 1973. Report 126 Part I. "Engineering Data on DAMS AND RESERVOIRS IN TEXAS"
3. Texas Water Development Board. 1966. Report 48. "Dams and Lakes in Texas, Historical and Descriptive Information"
4. Texas Water Commission. 1987. Certificate of Adjudication 06-3254B
5. Turner Collie & Braden Inc. 1989. "REPORT ON SEDIMENTATION LAKE LEWISVILLE, LAKE RAY HUBBARD, LAKE PALESTINE"

Figure 1

LAKE PALESTINE

Location Map

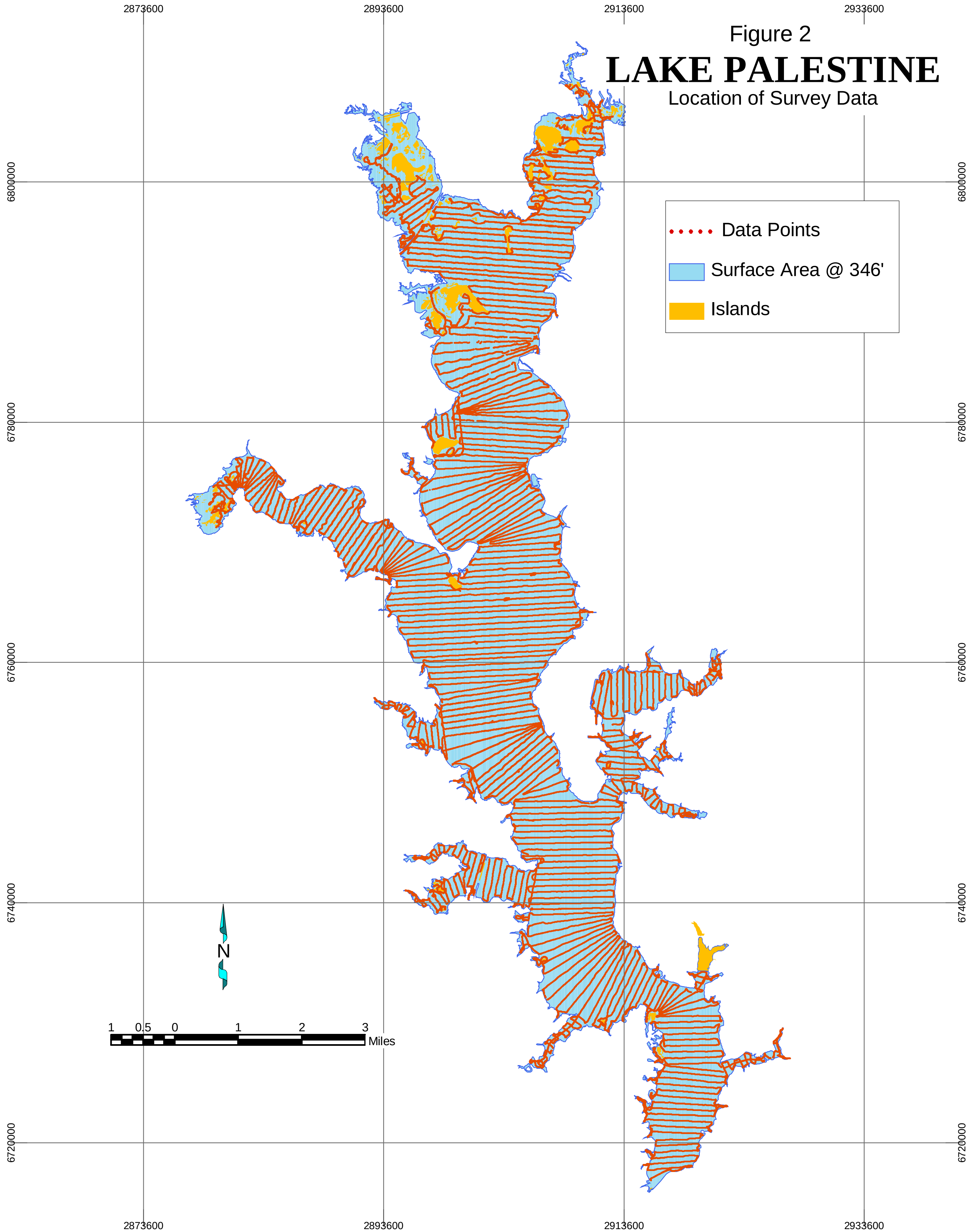


TWDB Survey June 2003

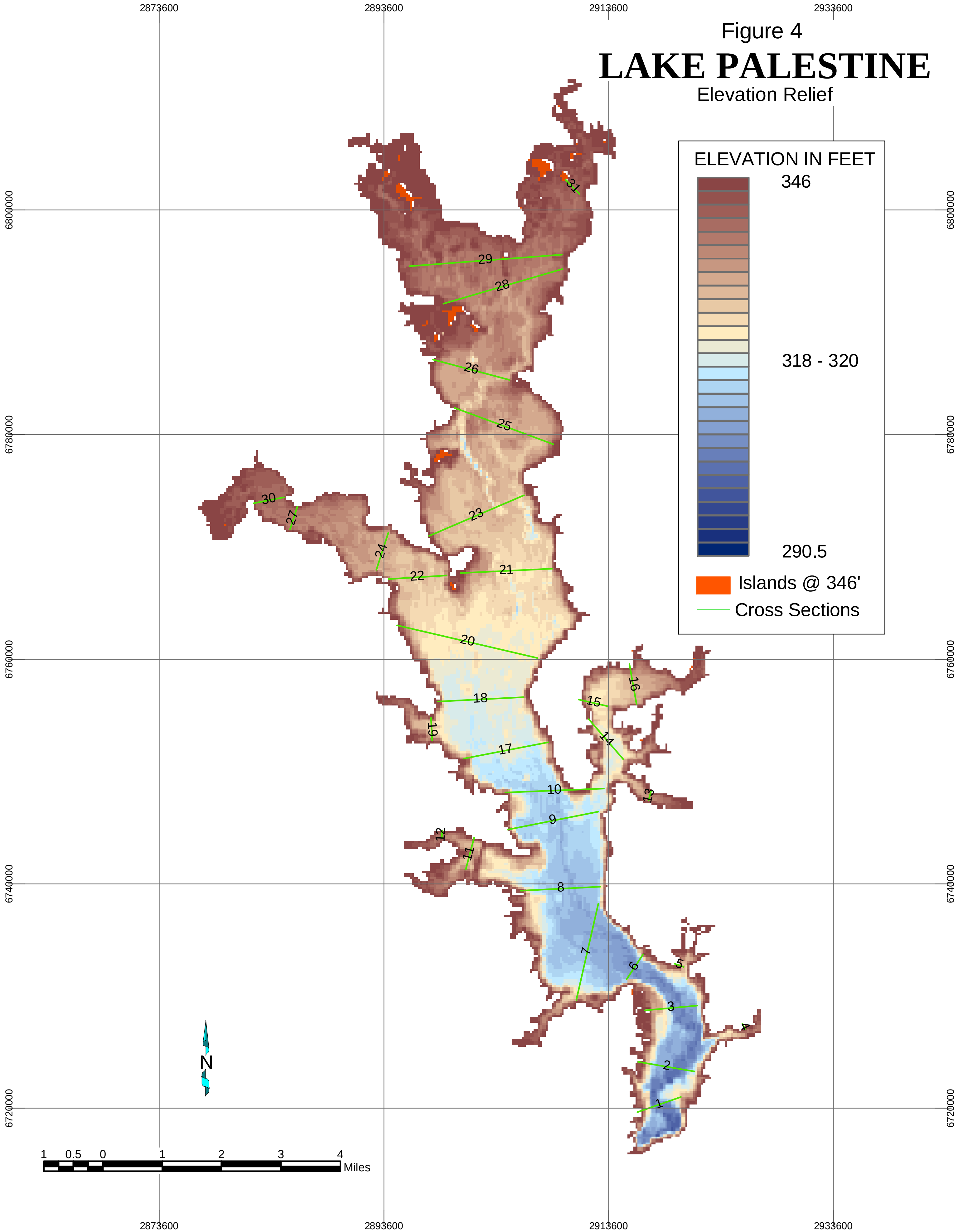
Figure 2

LAKE PALESTINE

Location of Survey Data



TWDB Survey June 2003

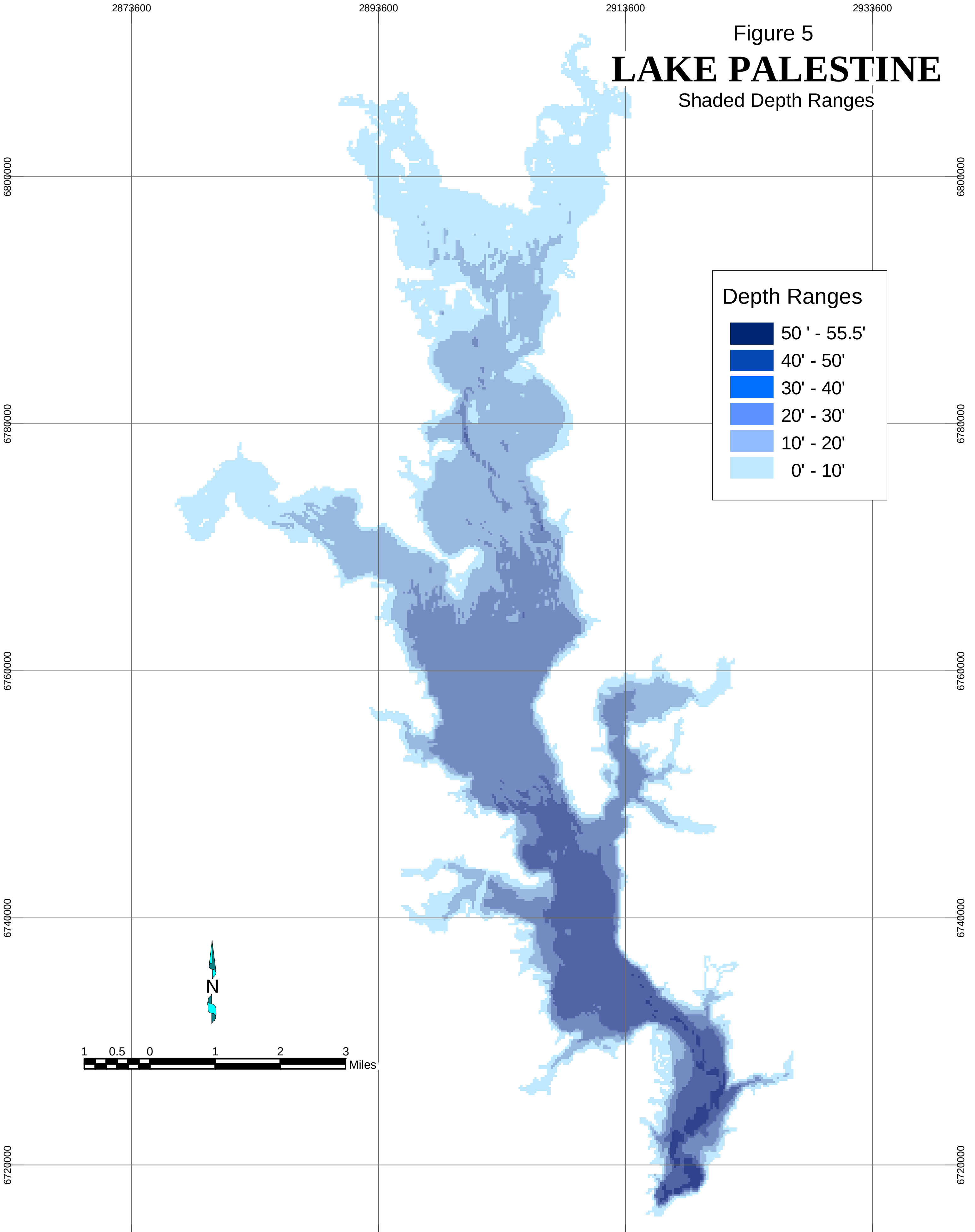


TWDB Survey June 2003

Figure 5

LAKE PALESTINE

Shaded Depth Ranges

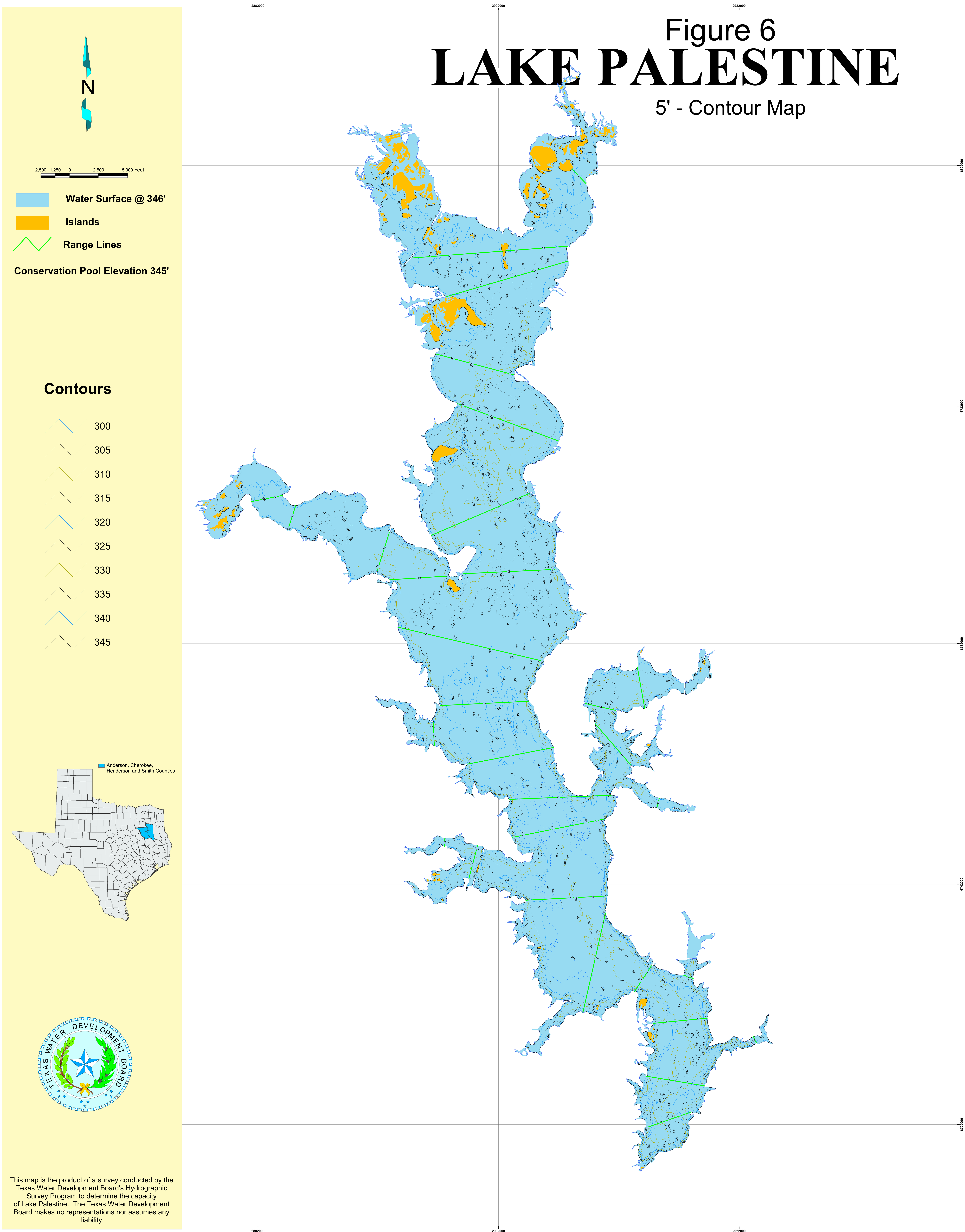


TWDB Survey June 2003

Figure 6

LAKE PALESTINE

5' - Contour Map



TEXAS WATER DEVELOPMENT BOARD JUNE 2003 SURVEY

Appendix A

Lake Palestine

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD JUNE 2003 SURVEY

ELEVATION INCREMENT IS ONE TENTH FOOT VOLUME IN ACRE-FEET CONSERVATION POOL ELEVATION 345.0 ft

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
290						0	0	0	0	0
291	0	0	0	0	0	0	0	0	0	0
292	0	0	0	0	0	0	0	0	0	0
293	0	0	0	0	0	0	0	0	0	0
294	0	0	0	0	0	0	0	0	0	0
295	0	0	0	1	1	1	1	1	1	1
296	1	1	1	1	2	2	2	2	2	2
297	3	3	3	3	4	4	4	4	5	5
298	5	6	6	7	7	7	8	8	9	10
299	10	11	12	12	13	14	15	15	16	17
300	18	20	21	22	23	25	26	28	30	32
301	34	36	38	40	43	45	48	51	54	58
302	61	65	69	74	78	83	88	94	100	106
303	112	119	126	133	141	150	159	168	178	188
304	199	211	223	236	250	264	279	296	312	330
305	349	368	388	409	431	453	477	501	526	552
306	580	608	638	668	699	732	766	801	837	874
307	912	951	992	1,034	1,077	1,121	1,166	1,213	1,260	1,309
308	1,359	1,411	1,463	1,518	1,573	1,631	1,690	1,750	1,812	1,875
309	1,940	2,007	2,076	2,147	2,220	2,295	2,372	2,451	2,532	2,616
310	2,702	2,792	2,884	2,979	3,078	3,180	3,284	3,392	3,503	3,618
311	3,737	3,859	3,985	4,115	4,249	4,387	4,527	4,672	4,819	4,970
312	5,125	5,283	5,444	5,608	5,776	5,948	6,123	6,303	6,486	6,673
313	6,866	7,063	7,265	7,472	7,684	7,902	8,125	8,353	8,586	8,823
314	9,065	9,311	9,561	9,816	10,075	10,339	10,607	10,878	11,154	11,434
315	11,718	12,007	12,300	12,598	12,900	13,206	13,516	13,831	14,149	14,470
316	14,796	15,125	15,458	15,795	16,136	16,480	16,828	17,179	17,534	17,892
317	18,254	18,619	18,988	19,360	19,736	20,115	20,498	20,884	21,274	21,667
318	22,063	22,464	22,868	23,276	23,688	24,104	24,525	24,949	25,378	25,812
319	26,251	26,694	27,143	27,598	28,059	28,526	29,001	29,483	29,974	30,472
320	30,978	31,493	32,015	32,544	33,081	33,625	34,176	34,735	35,301	35,874
321	36,454	37,040	37,634	38,233	38,840	39,452	40,072	40,698	41,331	41,971
322	42,617	43,270	43,929	44,594	45,264	45,941	46,624	47,312	48,006	48,707
323	49,414	50,129	50,850	51,578	52,315	53,058	53,809	54,567	55,332	56,104
324	56,884	57,670	58,464	59,263	60,070	60,883	61,703	62,531	63,364	64,205
325	65,053	65,907	66,768	67,635	68,508	69,388	70,275	71,169	72,068	72,975
326	73,888	74,807	75,734	76,666	77,606	78,552	79,505	80,465	81,432	82,406
327	83,386	84,373	85,366	86,366	87,374	88,388	89,409	90,438	91,474	92,517
328	93,568	94,626	95,691	96,762	97,841	98,927	100,020	101,120	102,227	103,341
329	104,462	105,590	106,725	107,867	109,017	110,173	111,336	112,506	113,683	114,868
330	116,060	117,259	118,466	119,680	120,901	122,129	123,365	124,609	125,860	127,121
331	128,388	129,663	130,947	132,238	133,537	134,843	136,157	137,479	138,808	140,145
332	141,489	142,840	144,199	145,564	146,936	148,315	149,701	151,093	152,491	153,896
333	155,307	156,724	158,148	159,578	161,015	162,458	163,908	165,365	166,828	168,298
334	169,774	171,257	172,746	174,242	175,744	177,253	178,769	180,291	181,819	183,354
335	184,895	186,442	187,995	189,555	191,121	192,695	194,275	195,862	197,455	199,055
336	200,662	202,275	203,894	205,520	207,152	208,791	210,437	212,090	213,748	215,414
337	217,087	218,767	220,454	222,147	223,848	225,556	227,271	228,994	230,723	232,461
338	234,206	235,957	237,718	239,483	241,256	243,035	244,823	246,618	248,418	250,225
339	252,041	253,861	255,689	257,521	259,362	261,210	263,062	264,924	266,791	268,666
340	270,546	272,433	274,330	276,230	278,140	280,055	281,979	283,907	285,845	287,787
341	289,738	291,697	293,662	295,634	297,612	299,598	301,591	303,590	305,595	307,610
342	309,630	311,657	313,691	315,735	317,782	319,839	321,903	323,972	326,049	328,131
343	330,223	332,321	334,426	336,536	338,652	340,776	342,906	345,039	347,179	349,320
344	351,469	353,623	355,778	357,941	360,108	362,277	364,454	366,635	368,820	371,010
345	373,202	375,402	377,606	379,814	382,027	384,245	386,467	388,694	390,925	393,161
346	395,402									

Values above CPE of 345 ft

Appendix B

Lake Palestine

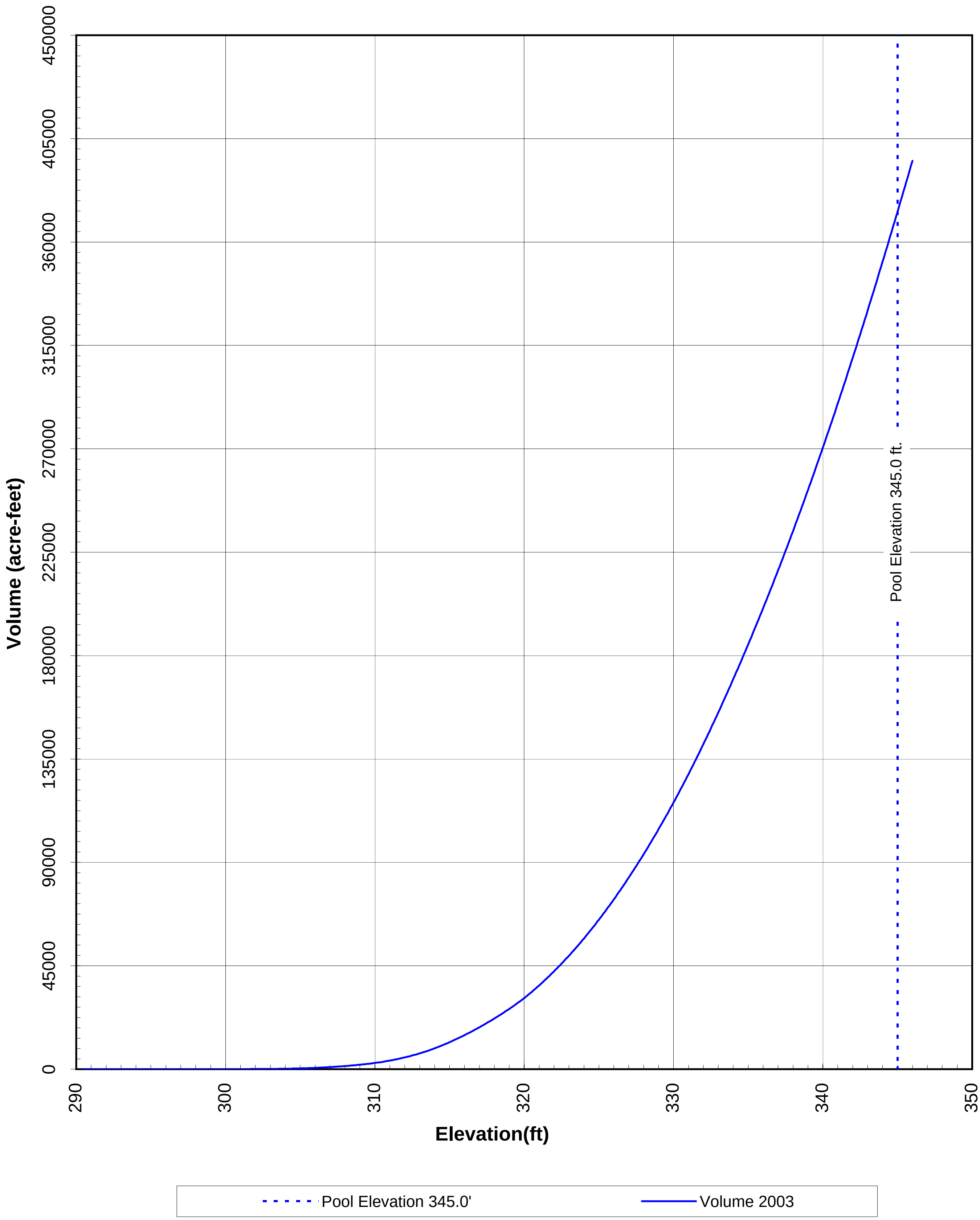
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD | JUNE 2003 SURVEY

ELEVATION INCREMENT IS ONE TENTH FOOT | AREA IN ACRES | Conservation Pool Elevation 345.0 ft

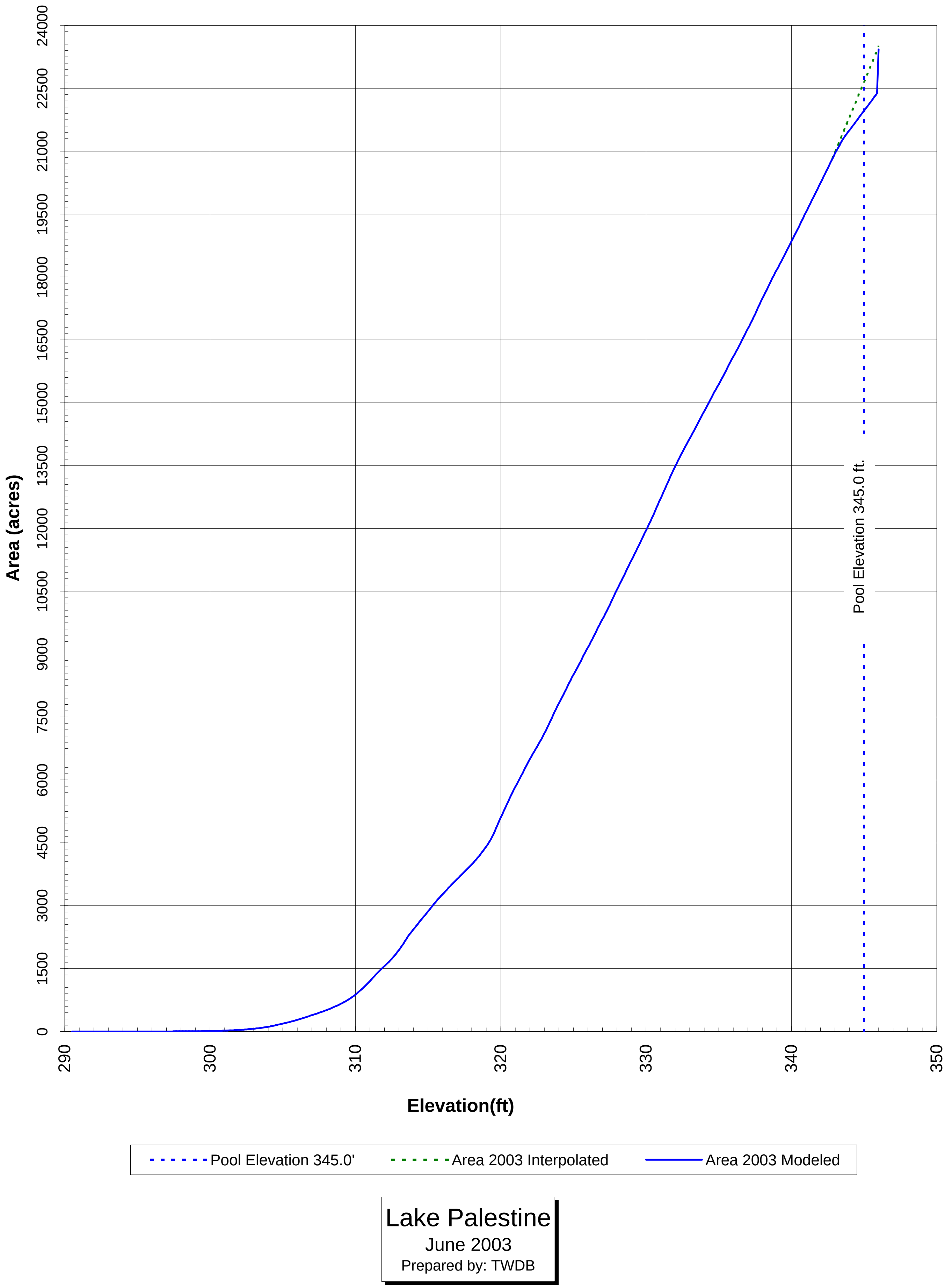
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
290						0	0	0	0	0
291	0	0	0	0	0	0	0	0	0	0
292	0	0	0	0	0	0	0	0	0	0
293	0	0	0	0	0	0	0	0	0	0
294	0	0	0	0	0	0	0	0	0	0
295	0	1	1	1	1	1	1	1	1	1
296	1	1	1	1	1	2	2	2	2	2
297	2	2	2	2	3	3	3	3	3	3
298	4	4	4	4	4	5	5	5	6	6
299	6	7	7	7	8	8	9	9	10	10
300	11	12	12	13	14	15	16	17	18	19
301	20	21	23	24	26	27	29	31	33	35
302	37	40	42	45	47	50	53	56	59	62
303	66	69	73	77	81	86	91	96	101	107
304	113	120	126	133	140	147	157	165	173	182
305	190	197	205	213	221	230	238	247	257	267
306	278	289	299	310	320	332	343	354	365	377
307	389	400	412	424	435	447	459	471	483	495
308	508	521	535	550	565	580	595	611	627	643
309	661	679	698	717	737	759	781	802	826	851
310	878	908	940	970	1,000	1,032	1,063	1,095	1,130	1,166
311	1,204	1,243	1,283	1,320	1,355	1,391	1,425	1,458	1,493	1,527
312	1,562	1,596	1,630	1,663	1,698	1,735	1,772	1,811	1,855	1,900
313	1,946	1,994	2,044	2,095	2,152	2,205	2,256	2,305	2,350	2,394
314	2,439	2,483	2,527	2,571	2,617	2,657	2,696	2,737	2,778	2,820
315	2,865	2,911	2,954	2,997	3,041	3,083	3,124	3,162	3,199	3,237
316	3,274	3,312	3,349	3,387	3,426	3,460	3,495	3,530	3,565	3,599
317	3,634	3,670	3,705	3,741	3,776	3,811	3,844	3,878	3,912	3,947
318	3,985	4,023	4,062	4,102	4,142	4,182	4,225	4,269	4,314	4,360
319	4,411	4,463	4,518	4,578	4,642	4,709	4,783	4,864	4,943	5,023
320	5,106	5,182	5,255	5,331	5,404	5,477	5,551	5,624	5,694	5,765
321	5,833	5,899	5,964	6,031	6,095	6,160	6,228	6,296	6,363	6,431
322	6,496	6,559	6,619	6,680	6,737	6,795	6,854	6,913	6,973	7,038
323	7,109	7,178	7,250	7,324	7,397	7,471	7,547	7,618	7,687	7,760
324	7,830	7,897	7,963	8,033	8,100	8,167	8,238	8,306	8,374	8,446
325	8,511	8,573	8,636	8,702	8,766	8,832	8,902	8,968	9,032	9,098
326	9,162	9,228	9,295	9,360	9,427	9,497	9,568	9,635	9,702	9,769
327	9,835	9,901	9,969	10,036	10,107	10,179	10,251	10,322	10,395	10,471
328	10,543	10,614	10,685	10,753	10,822	10,892	10,964	11,035	11,105	11,175
329	11,244	11,316	11,390	11,459	11,528	11,597	11,666	11,736	11,809	11,883
330	11,956	12,029	12,102	12,173	12,246	12,322	12,398	12,478	12,560	12,637
331	12,714	12,794	12,873	12,950	13,026	13,103	13,179	13,255	13,330	13,403
332	13,475	13,549	13,620	13,689	13,758	13,823	13,886	13,951	14,014	14,078
333	14,143	14,207	14,270	14,334	14,401	14,467	14,533	14,599	14,664	14,729
334	14,795	14,860	14,925	14,991	15,058	15,124	15,188	15,252	15,314	15,375
335	15,438	15,503	15,568	15,632	15,697	15,765	15,834	15,902	15,970	16,035
336	16,099	16,162	16,225	16,290	16,356	16,422	16,491	16,559	16,627	16,694
337	16,763	16,832	16,900	16,971	17,042	17,115	17,189	17,263	17,338	17,412
338	17,485	17,555	17,625	17,695	17,766	17,836	17,907	17,975	18,042	18,108
339	18,174	18,240	18,307	18,373	18,439	18,504	18,571	18,639	18,707	18,776
340	18,846	18,916	18,985	19,054	19,122	19,190	19,259	19,329	19,399	19,471
341	19,543	19,614	19,684	19,754	19,824	19,892	19,960	20,029	20,099	20,169
342	20,241	20,313	20,384	20,457	20,525	20,595	20,666	20,732	20,816	20,866
343	20,983	21,067	21,151	21,234	21,318	21,402	21,485	21,569	21,652	21,456
344	21,820	21,903	21,987	22,071	22,154	22,238	22,322	22,405	22,489	21,920
345	22,656	22,740	22,823	22,907	22,991	23,074	23,158	23,242	23,325	22,383
346	23,492									

Values above CPE of 345 ft



Lake Palestine
June 2003
Prepared by: TWDB

Appendix C Elevation vs. Volume



Appendix D Elevation vs. Area

Appendix E
Lake Palestine

TEXAS WATER DEVELOPMENT BOARD June 2003 SURVEY

Range Line Endpoints
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

Range Line	X	Y
SR 01-L	2,920,040.0	6,721,010.0
SR 01-R	2,916,160.0	6,719,658.5
SR 02-L	2,921,235.5	6,723,299.5
SR 02-R	2,916,233.0	6,724,131.5
SR 03-L	2,921,493.3	6,729,164.5
SR 03-R	2,916,794.5	6,728,710.0
SR 04-L	2,925,759.8	6,727,011.0
SR 04-R	2,925,487.3	6,727,557.0
SR 05-L	2,920,268.3	6,732,593.5
SR 05-R	2,919,442.8	6,732,886.5
SR 06-L	2,916,656.8	6,733,689.5
SR 06-R	2,915,208.8	6,731,481.0
SR 07-L	2,912,675.3	6,738,222.0
SR 07-R	2,910,724.3	6,729,656.0
SR 08-L	2,912,843.3	6,739,752.0
SR 08-R	2,905,787.0	6,739,371.0
SR 09-L	2,912,663.5	6,746,427.5
SR 09-R	2,904,596.0	6,744,811.0
SR 10-L	2,913,179.8	6,748,469.5
SR 10-R	2,904,394.3	6,748,105.5
SR 11-L	2,901,609.3	6,744,112.5
SR 11-R	2,900,860.0	6,741,262.0
SR 12-L	2,898,773.5	6,744,744.5
SR 12-R	2,898,744.3	6,744,023.5
SR-13-L	2,917,133.5	6,747,400.0
SR-13-R	2,917,343.3	6,748,216.0
SR 14-L	2,914,893.5	6,751,058.5
SR 14-R	2,911,801.5	6,754,648.5
SR 15-L	2,913,565.3	6,755,813.5
SR 15-R	2,910,939.3	6,756,413.5
SR 16-L	2,916,079.8	6,755,984.0
SR 16-R	2,915,441.3	6,759,566.0

Lake Palestine

TEXAS WATER DEVELOPMENT BOARD June 2003 SURVEY

Range Line Endpoints

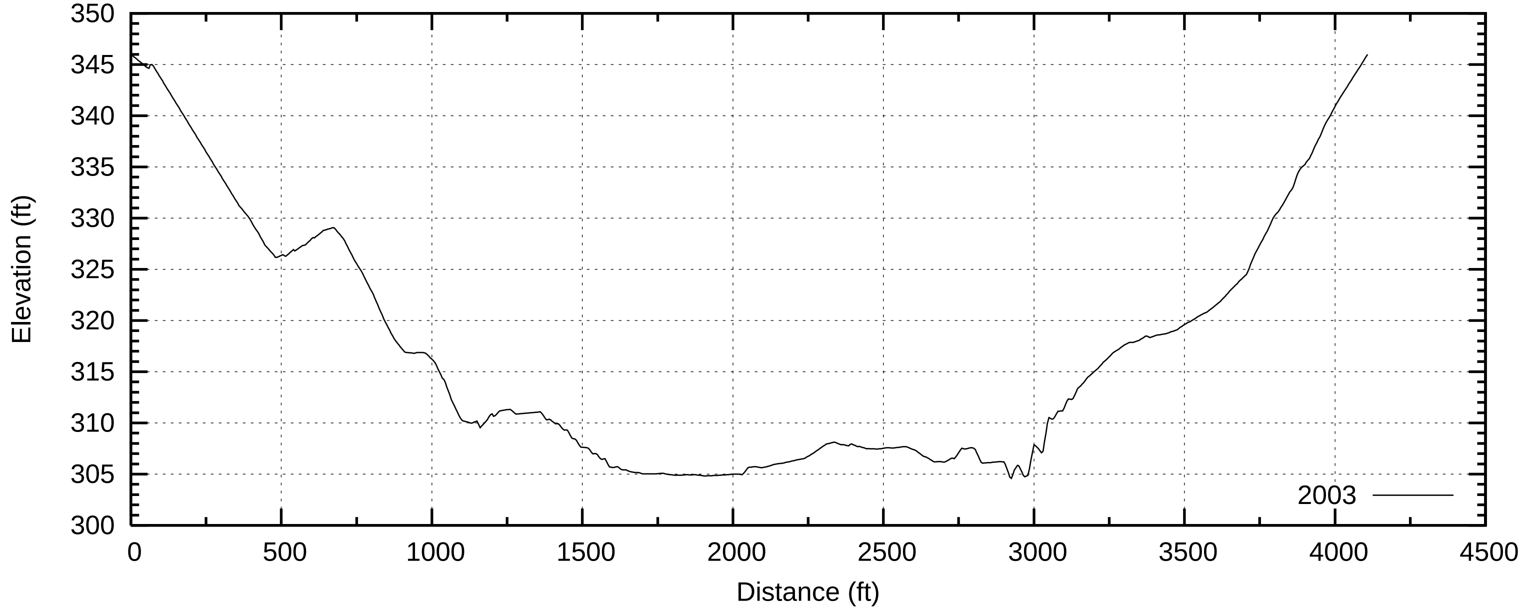
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

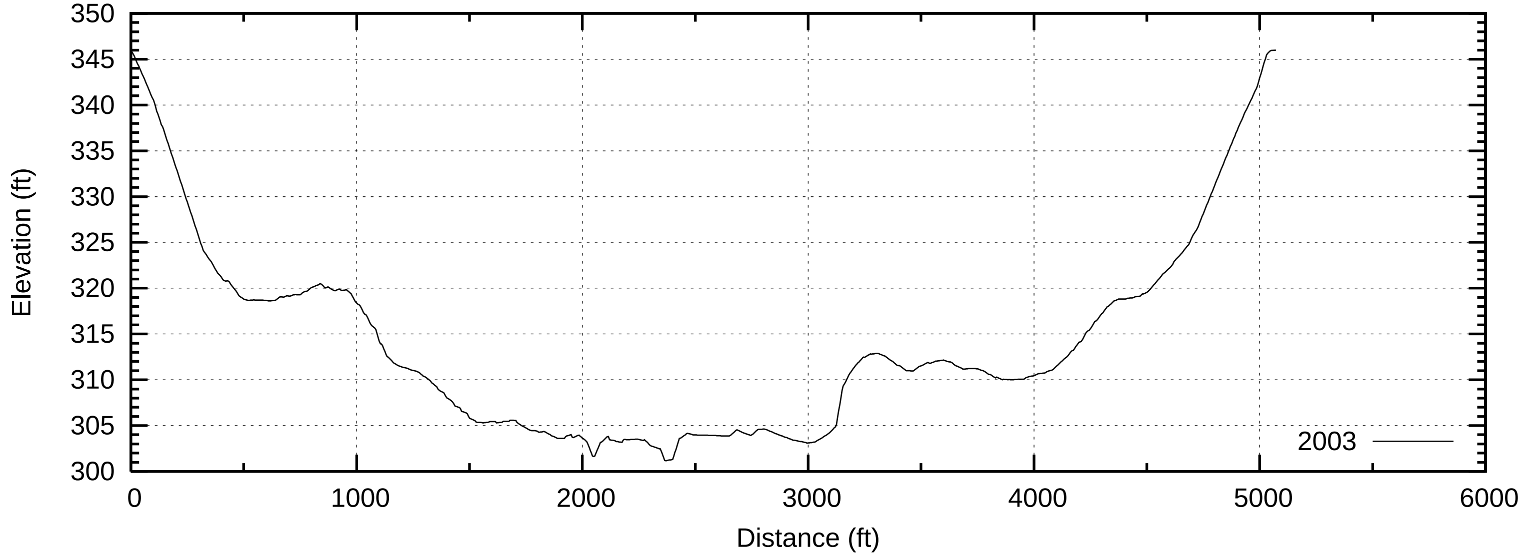
Range Line	X	Y
SR 17-L	2,908,219.3	6,752,607.0
SR 17-R	2,900,689.3	6,751,151.0
SR 18-L	2,906,032.5	6,756,602.0
SR 18-R	2,898,372.5	6,756,234.0
SR 19-L	2,897,766.3	6,754,757.5
SR 19-R	2,897,871.0	6,752,728.0
SR 20-L	2,907,261.5	6,760,084.5
SR 20-R	2,894,771.3	6,763,008.5
SR 21-L	2,908,586.8	6,768,040.5
SR 21-R	2,900,408.8	6,767,650.5
SR 22-L	2,899,152.3	6,767,457.0
SR 22-R	2,894,009.0	6,767,123.0
SR 23-L	2,906,071.5	6,774,597.5
SR 23-R	2,897,611.3	6,770,981.0
SR 24-L	2,893,976.5	6,771,251.5
SR 24-R	2,892,930.0	6,767,932.5
SR 25-L	2,908,647.5	6,779,138.0
SR 25-R	2,899,887.8	6,782,380.0
SR 26-L	2,904,785.5	6,784,868.0
SR 26-R	2,897,975.0	6,786,686.5
SR 27-L	2,885,872.0	6,773,569.5
SR 27-R	2,885,224.8	6,771,570.0
SR 28-L	2,909,466.8	6,794,736.5
SR 28-R	2,898,880.8	6,791,635.0
SR 29-L	2,909,435.5	6,796,018.0
SR 29-R	2,895,868.8	6,794,986.5
SR 30-L	2,884,722.3	6,774,429.0
SR 30-R	2,882,001.0	6,773,890.5
SR 31-L	2,911,000.8	6,801,435.5
SR 31-R	2,909,769.0	6,802,701.5

Lake Palestine

Rangeline SR01



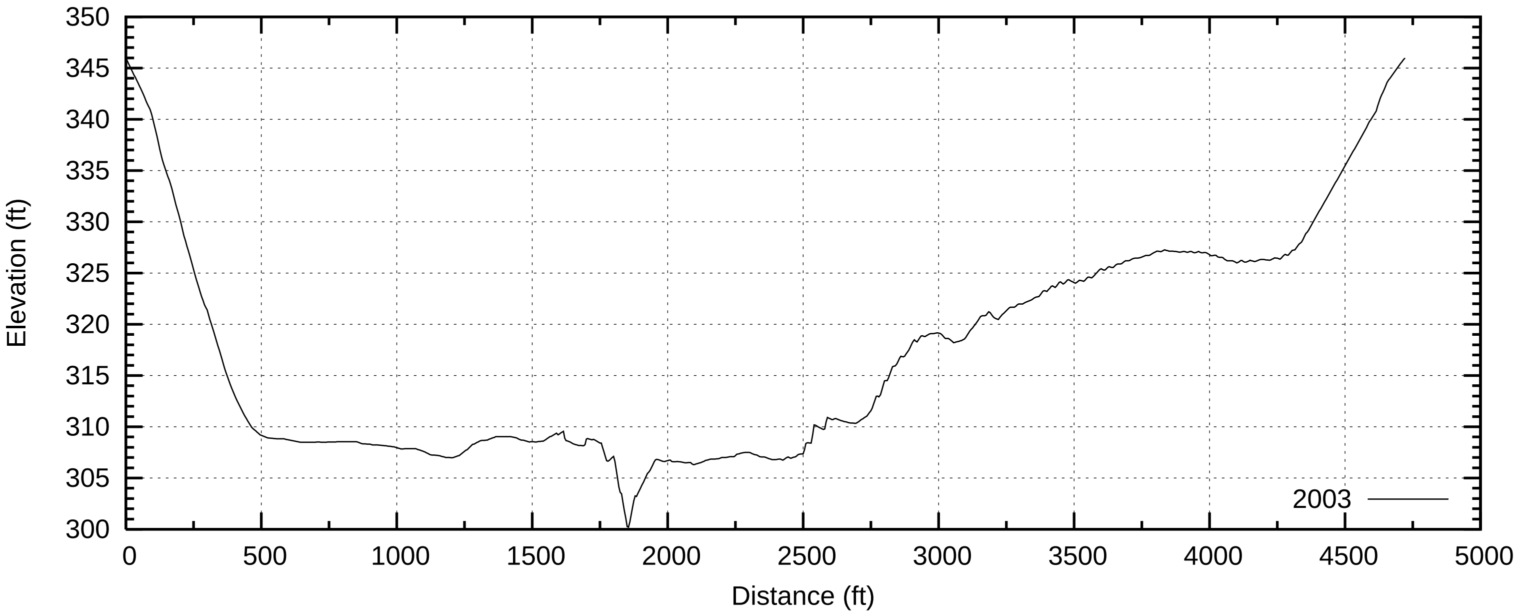
Rangeline SR02



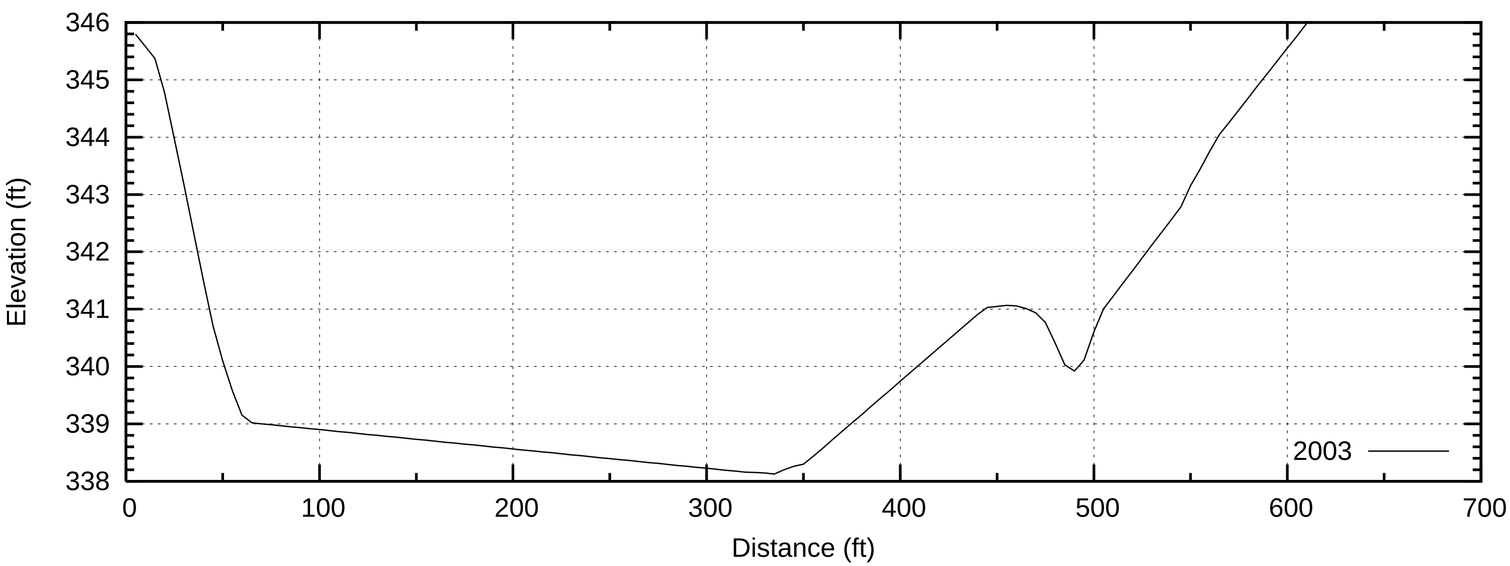
Appendix F

Lake Palestine

Rangeline SR03



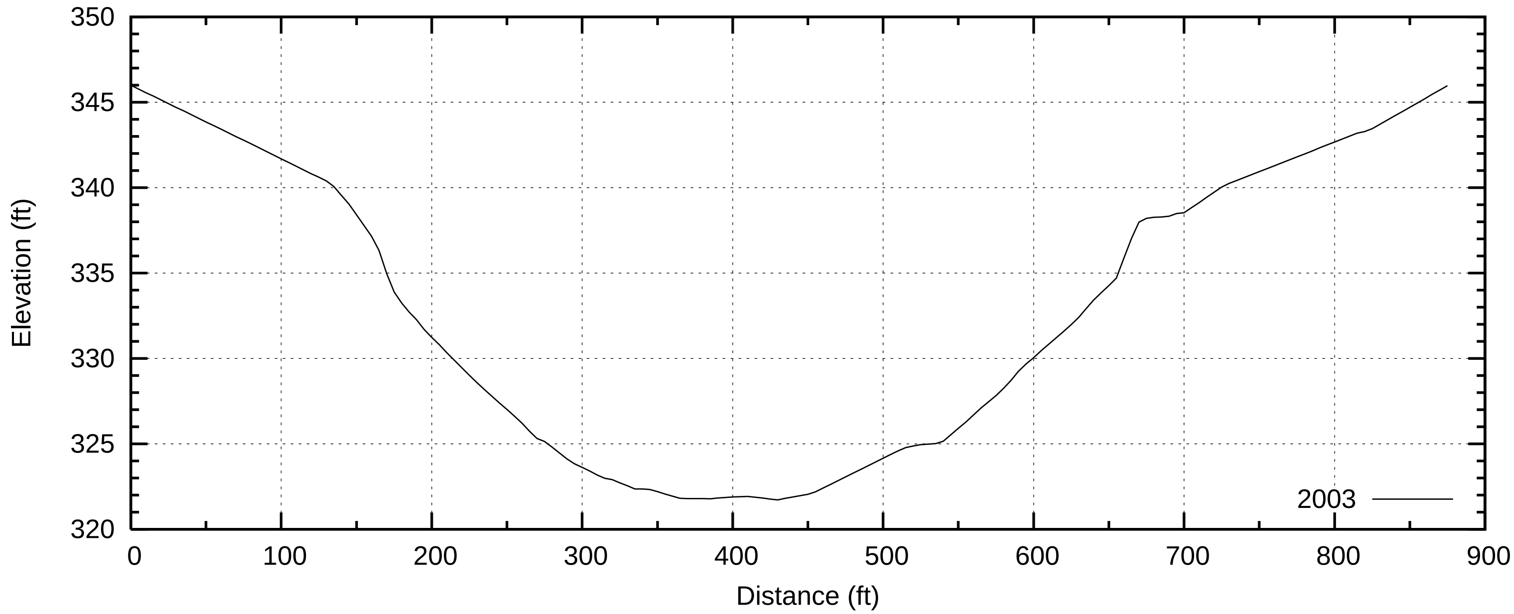
Rangeline SR04



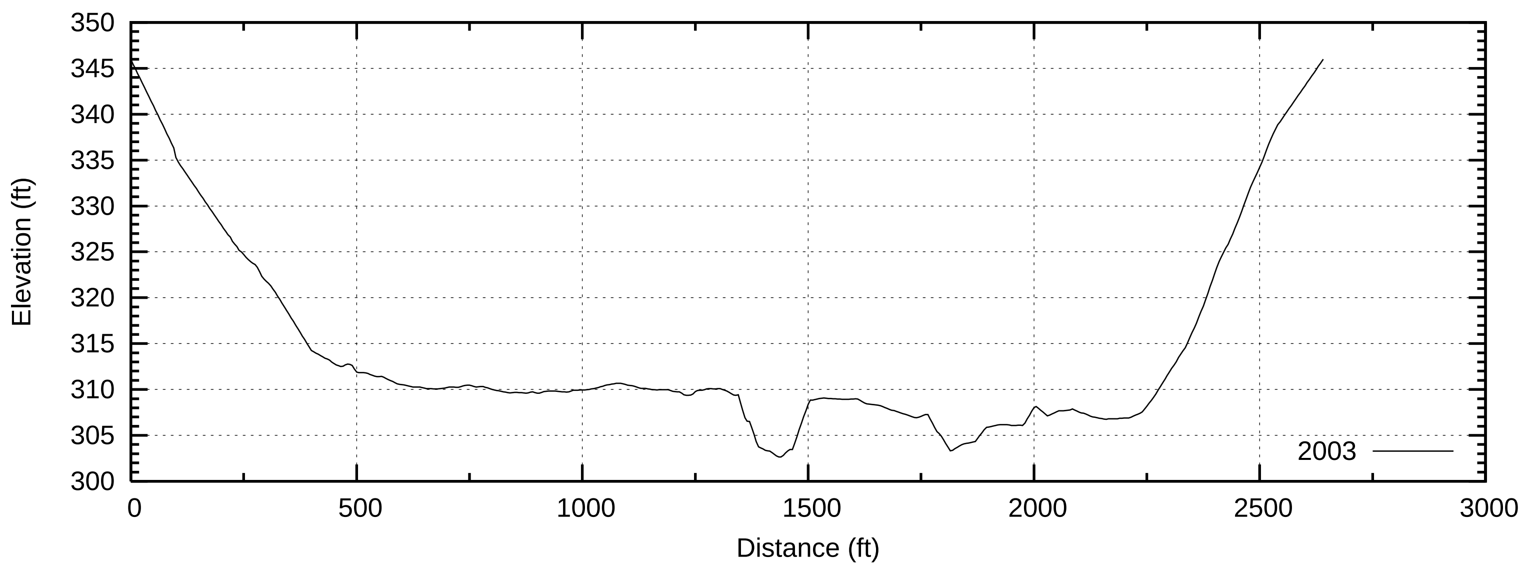
Appendix F

Lake Palestine

Rangeline SR05

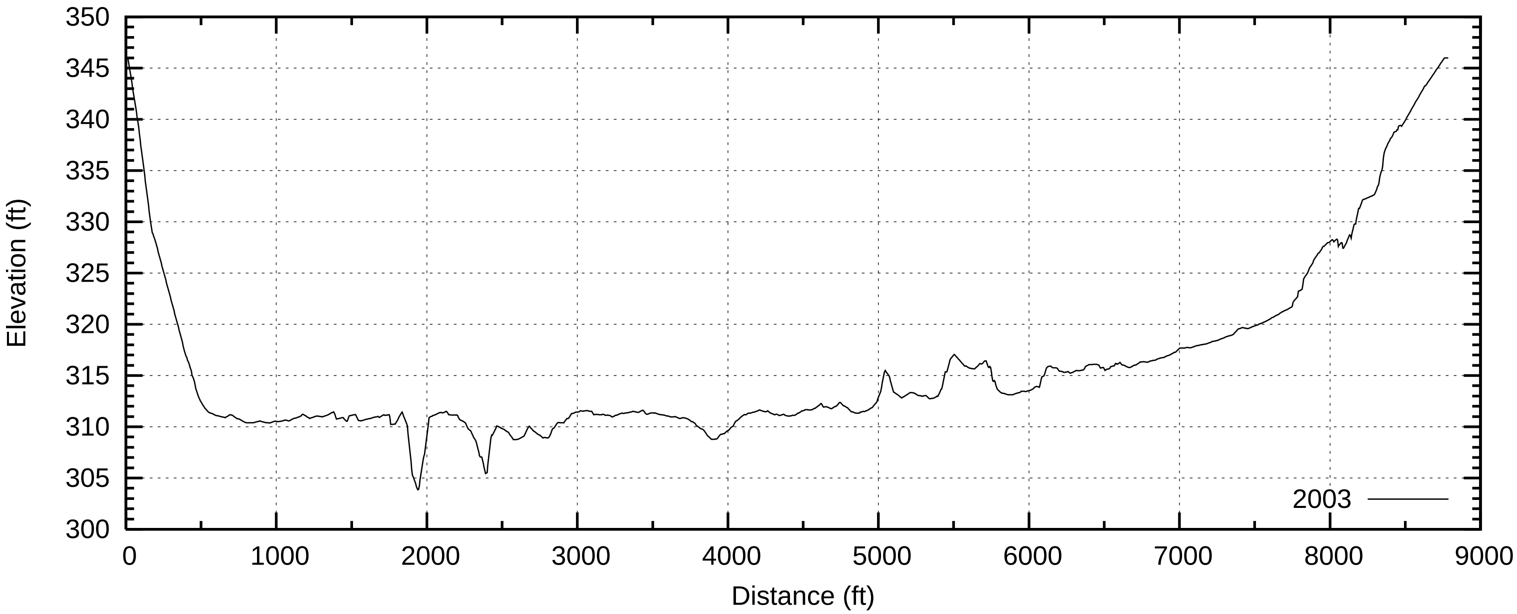


Rangeline SR06

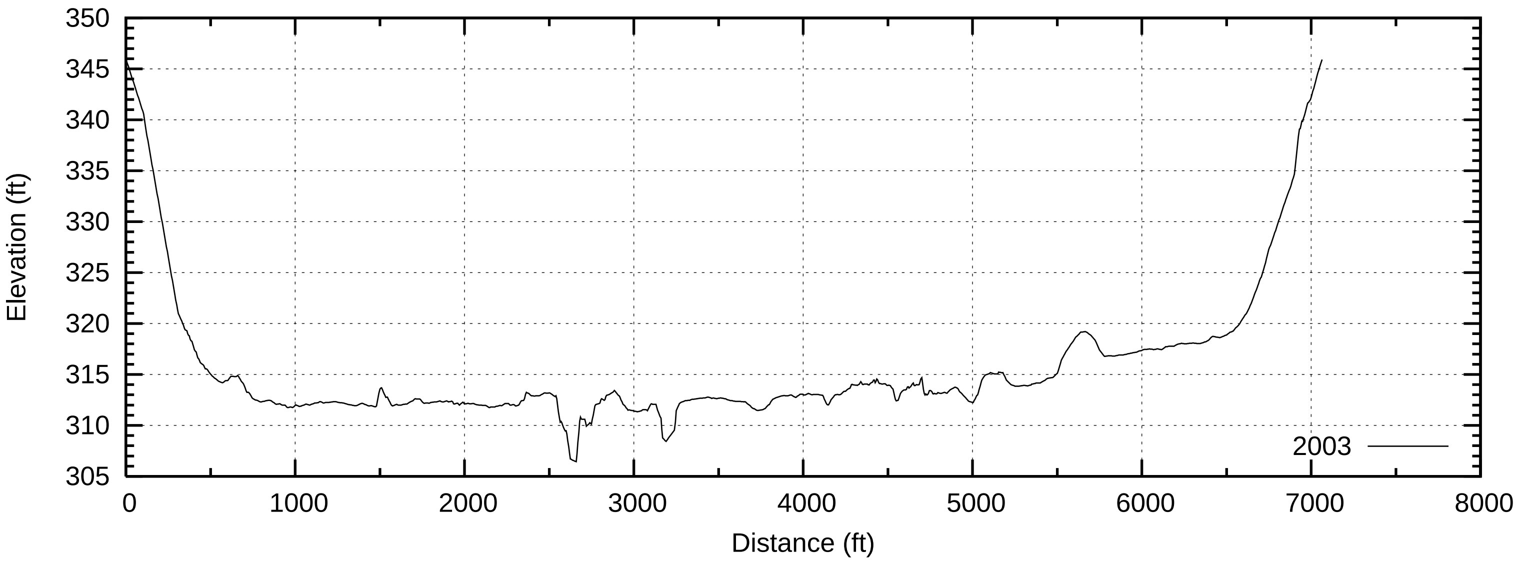


Lake Palestine

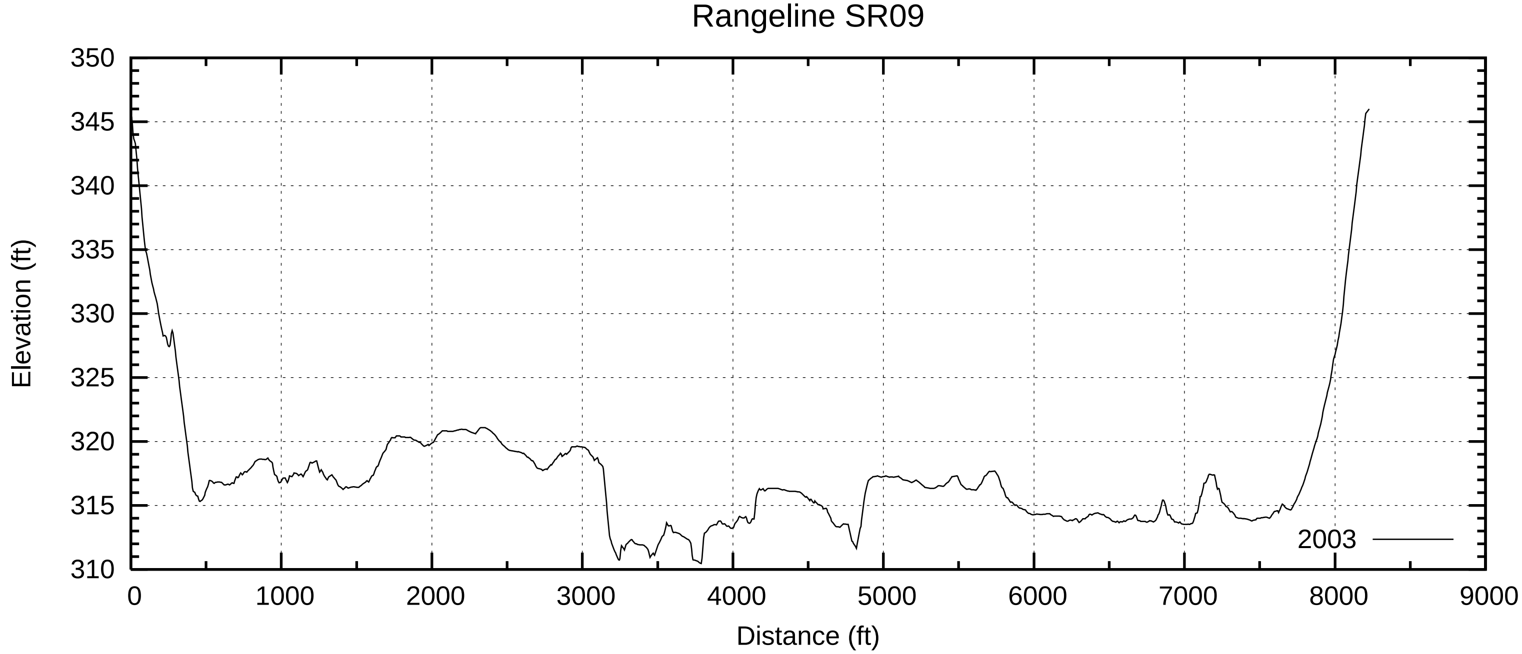
Rangeline SR07

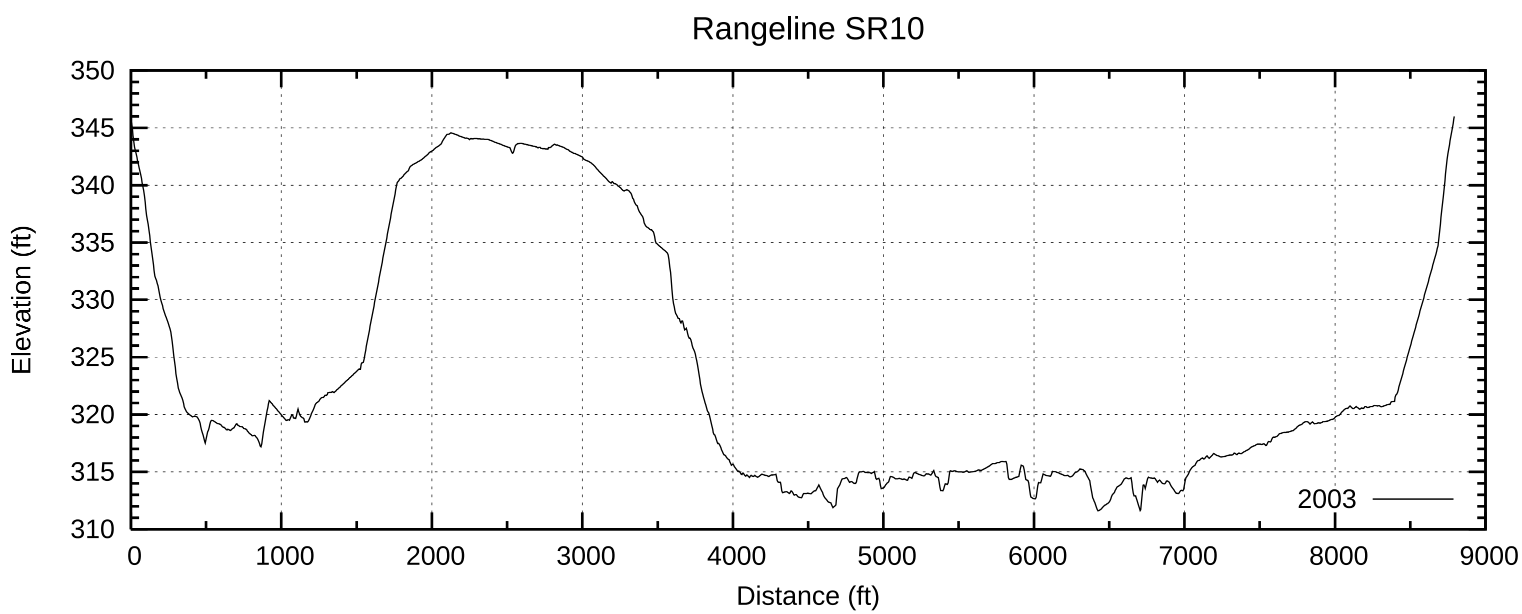


Rangeline SR08

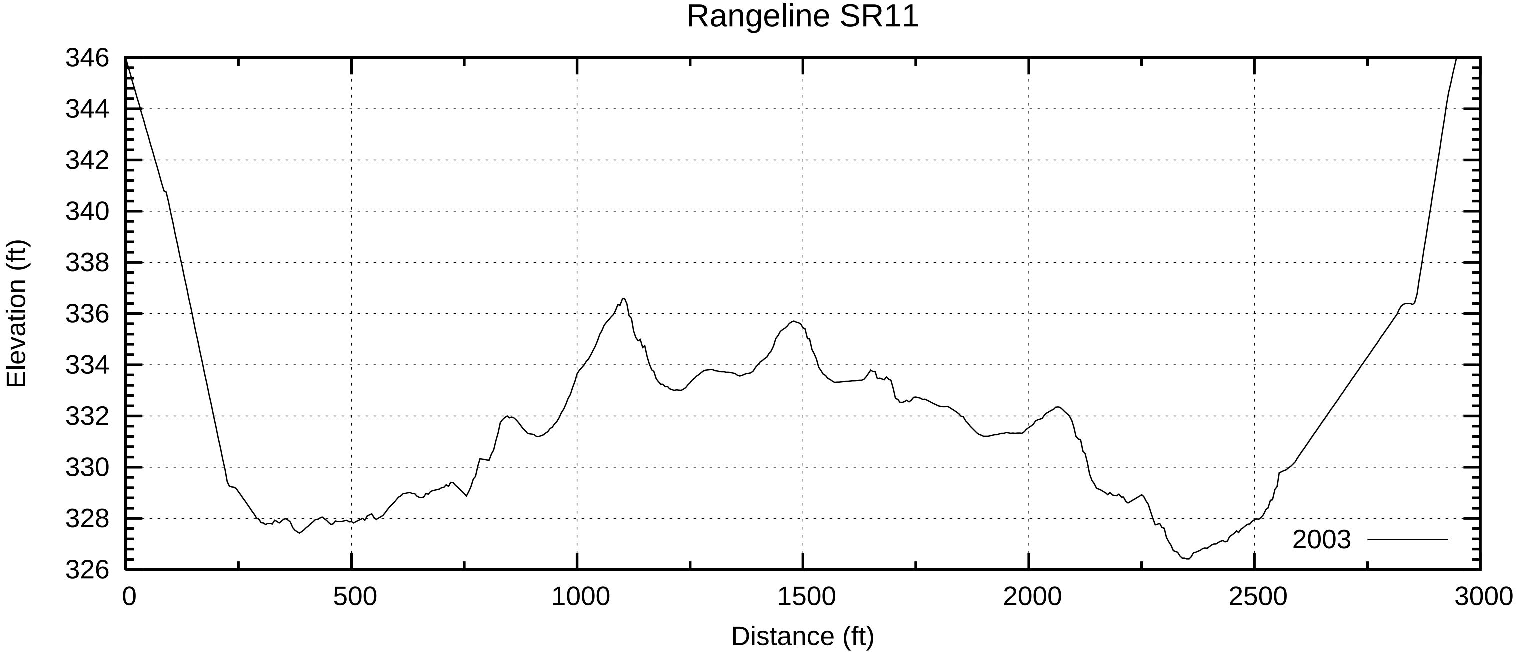


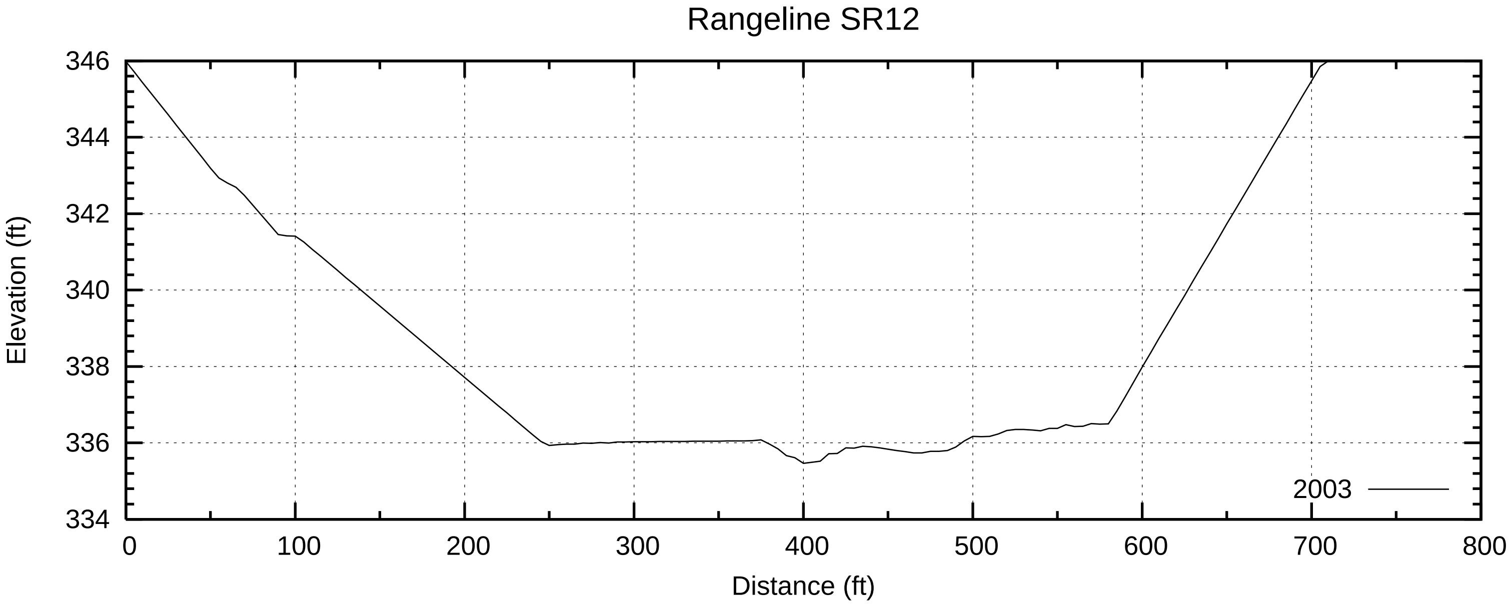
Lake Palestine





Lake Palestine

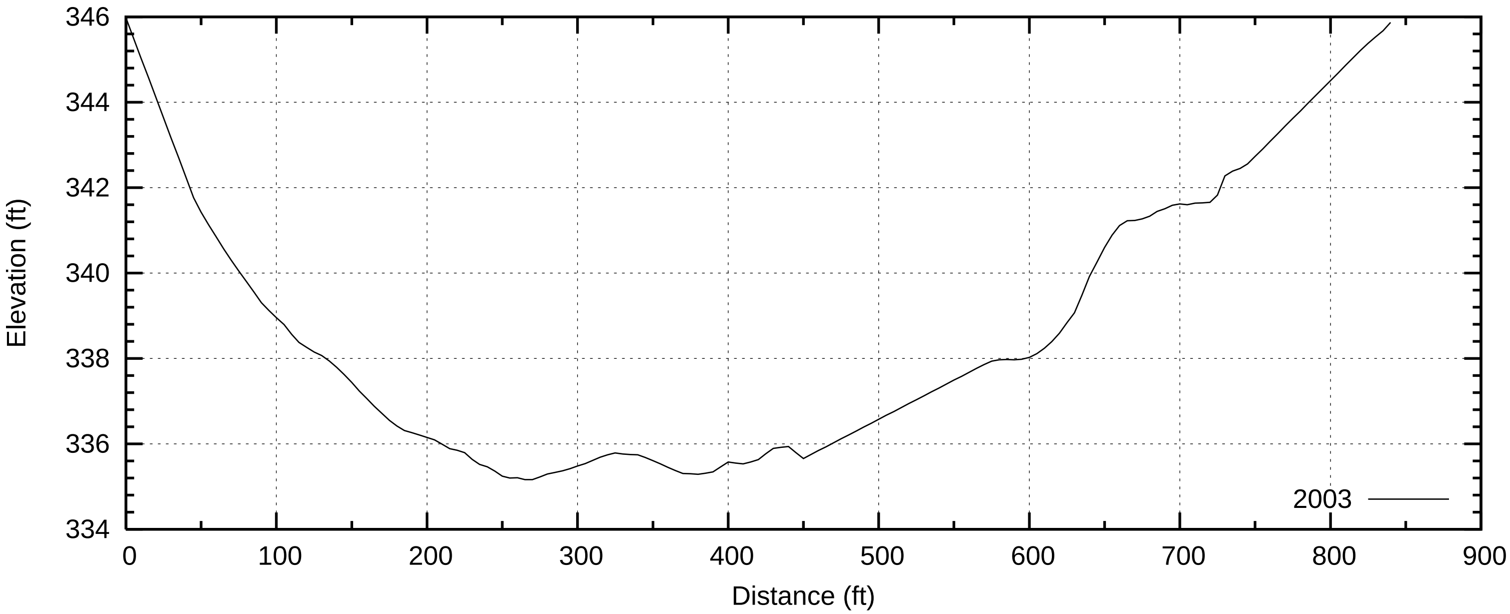




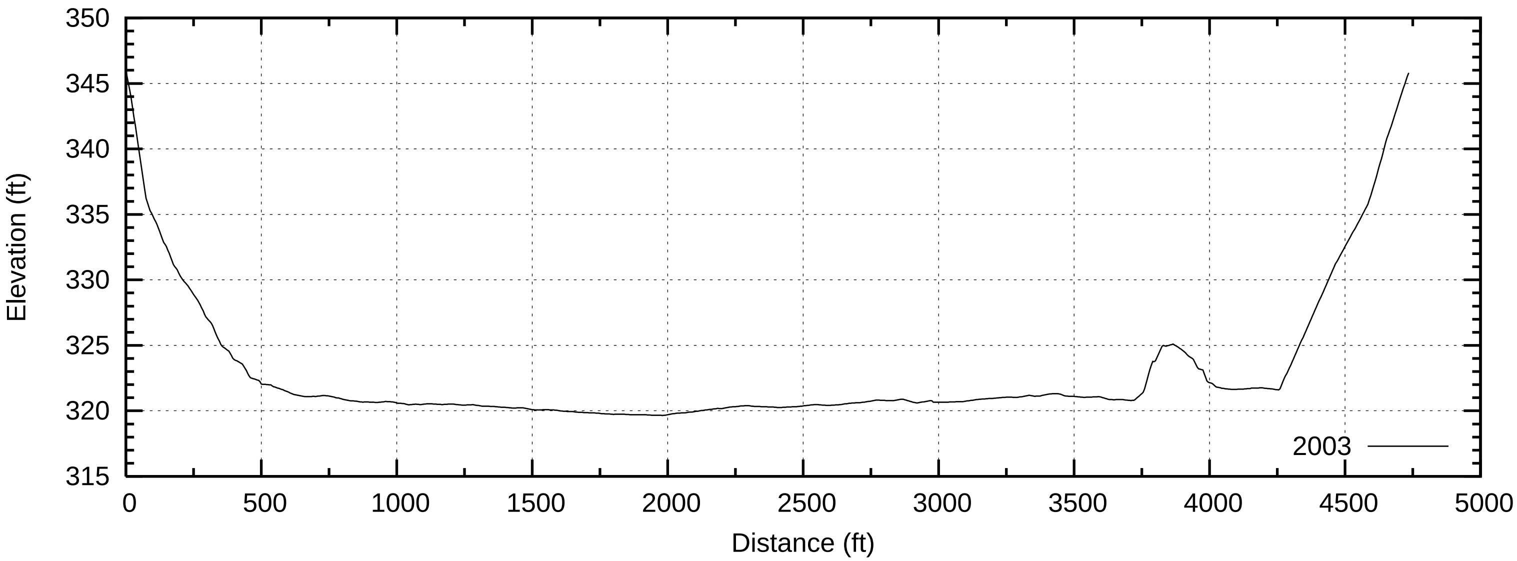
Appendix F

Lake Palestine

Rangeline SR13



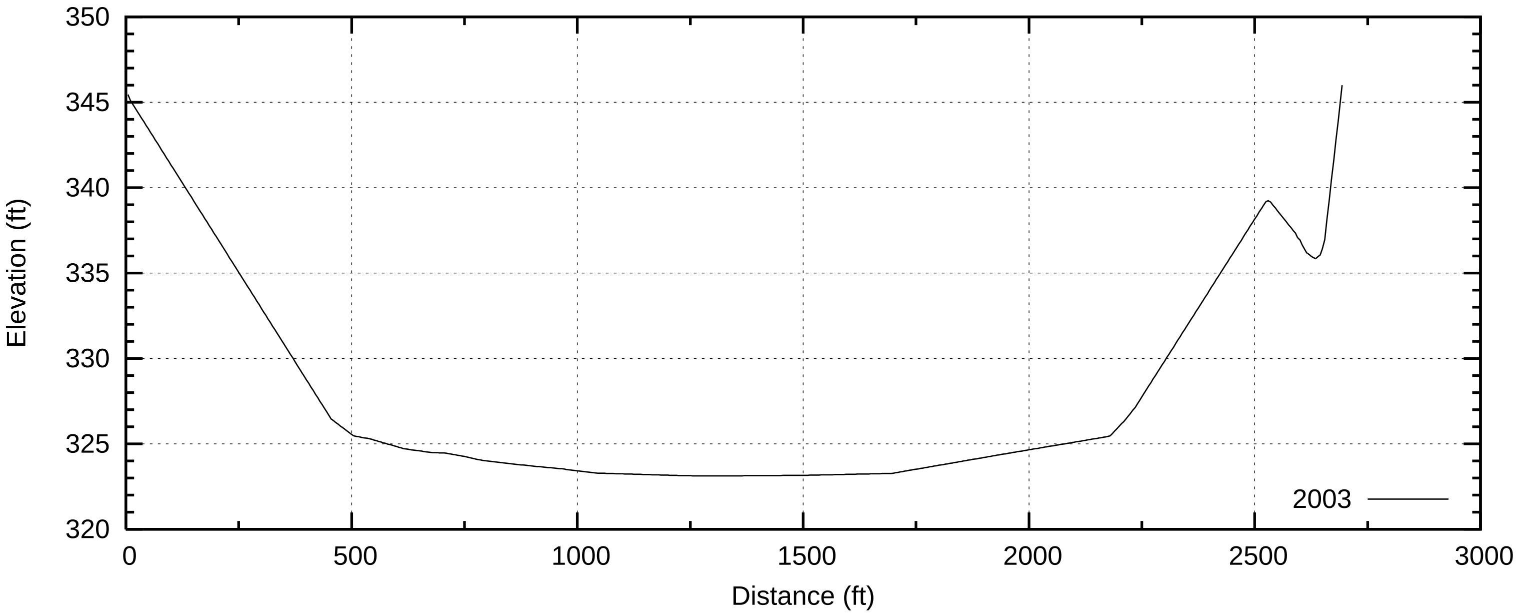
Rangeline SR14



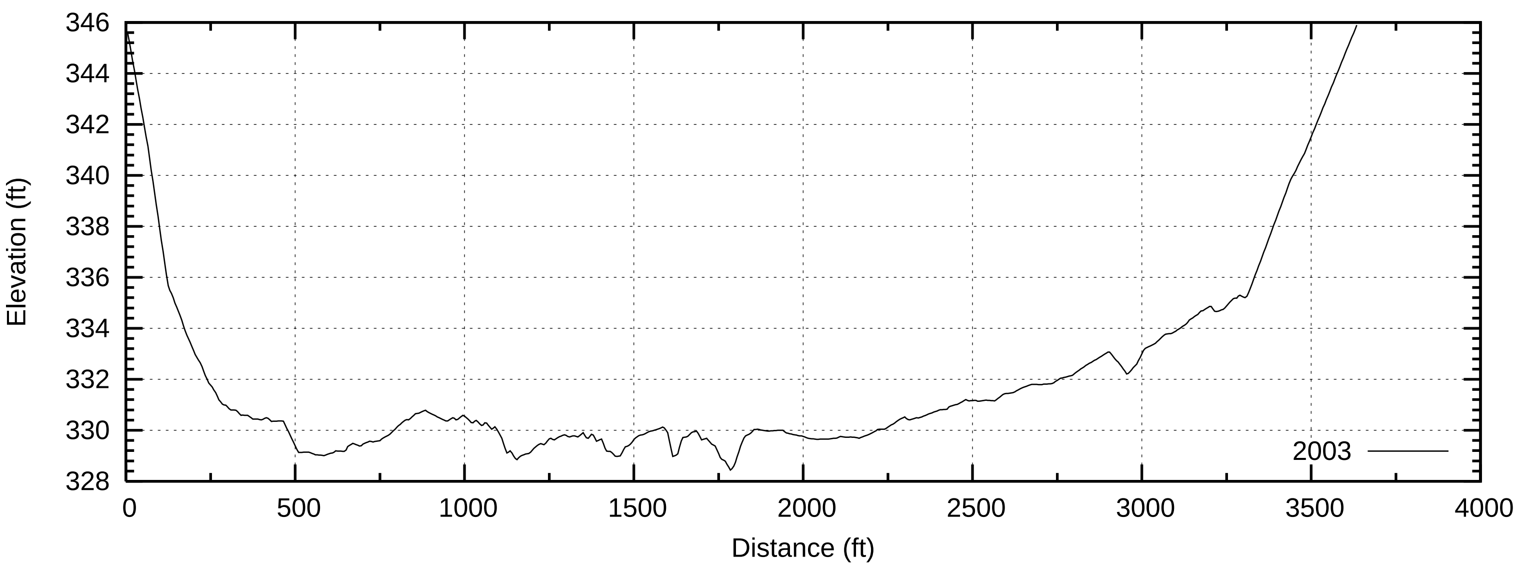
Appendix F

Lake Palestine

Rangeline SR15

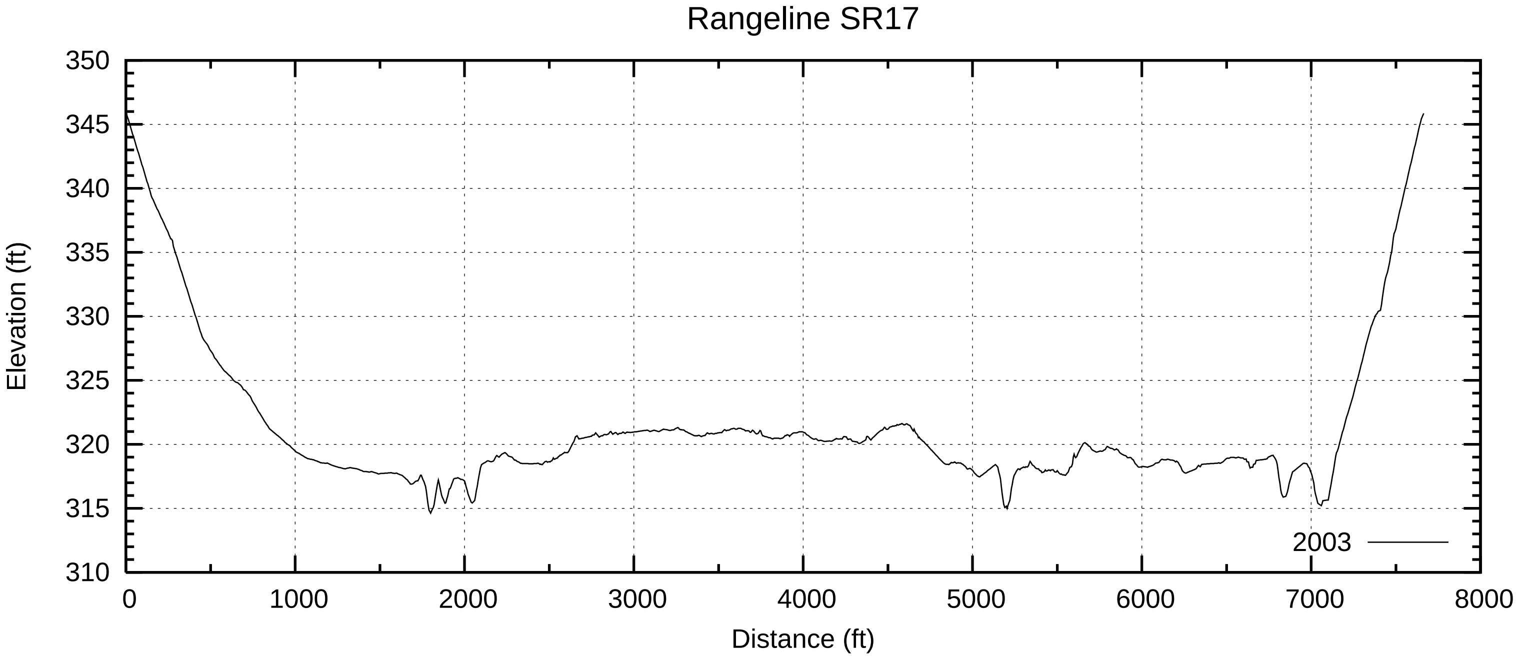


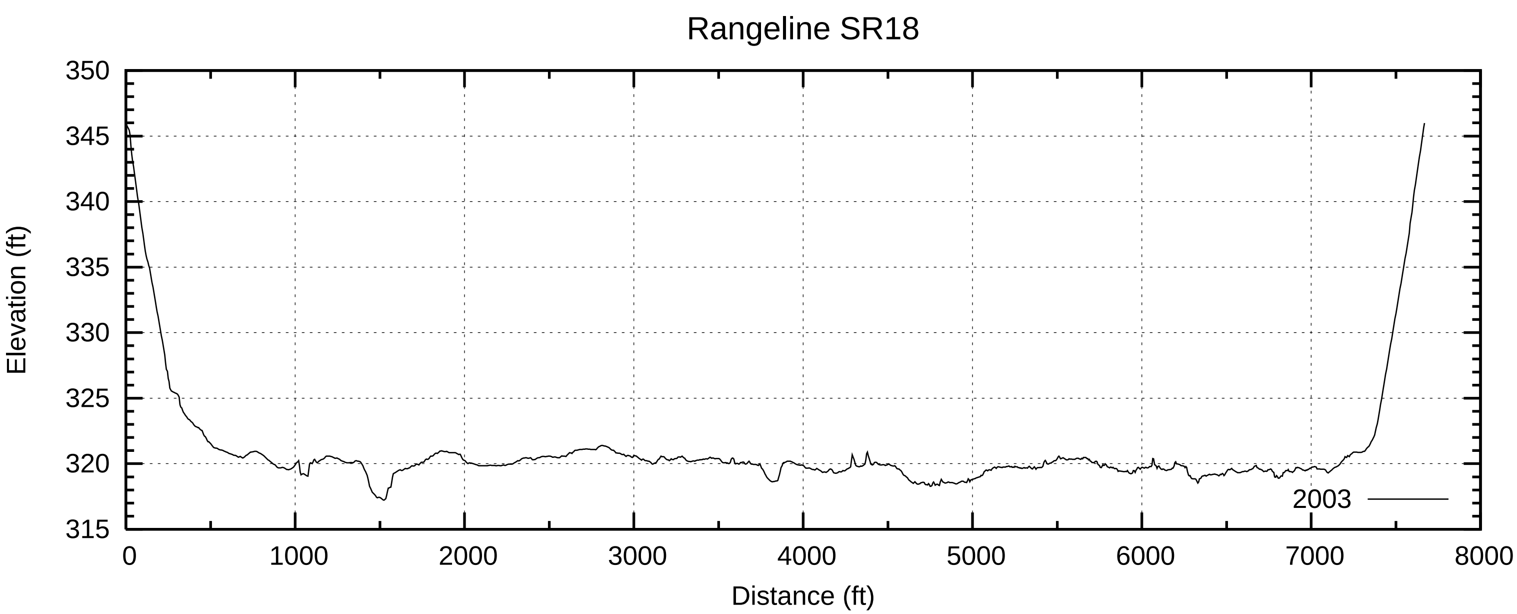
Rangeline SR16



Appendix F

Lake Palestine

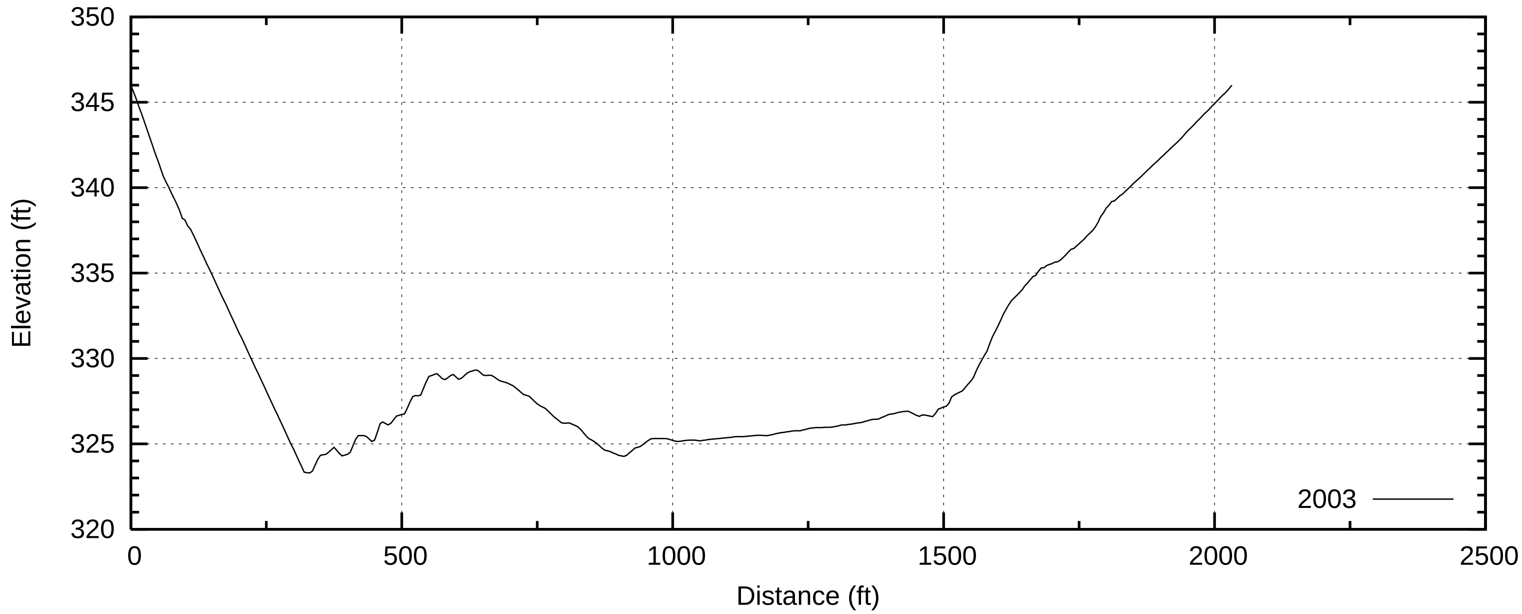




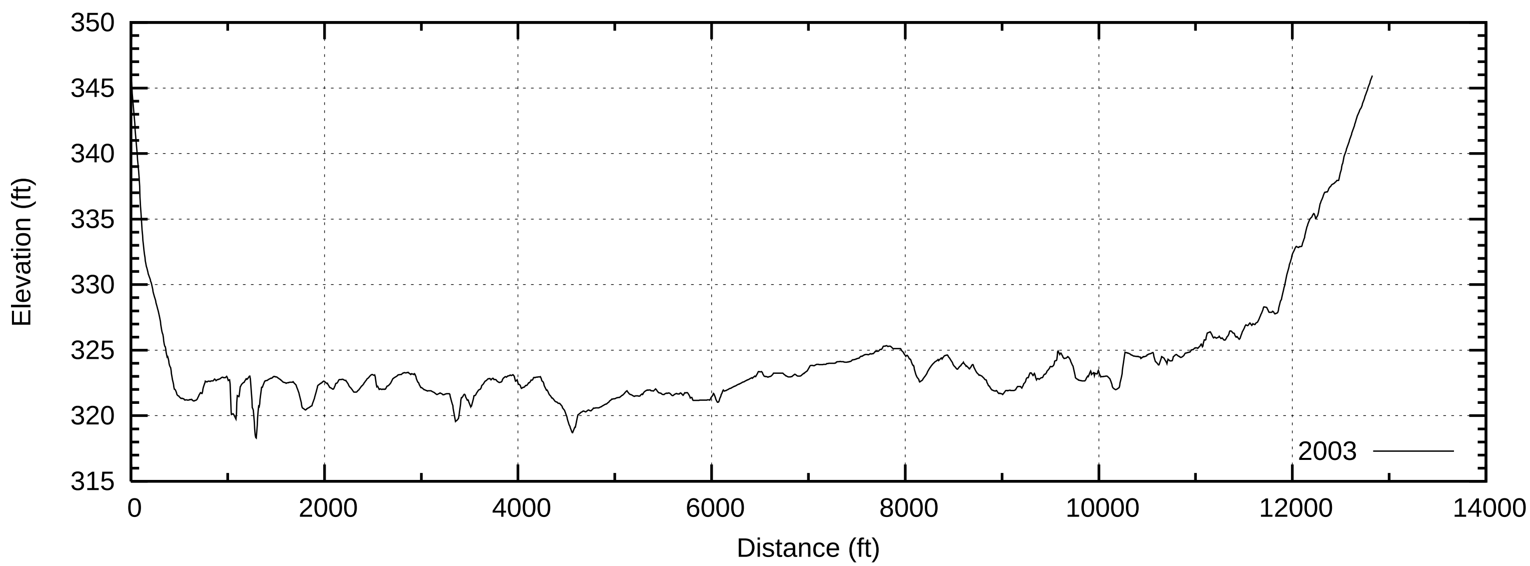
Appendix F

Lake Palestine

Rangeline SR19

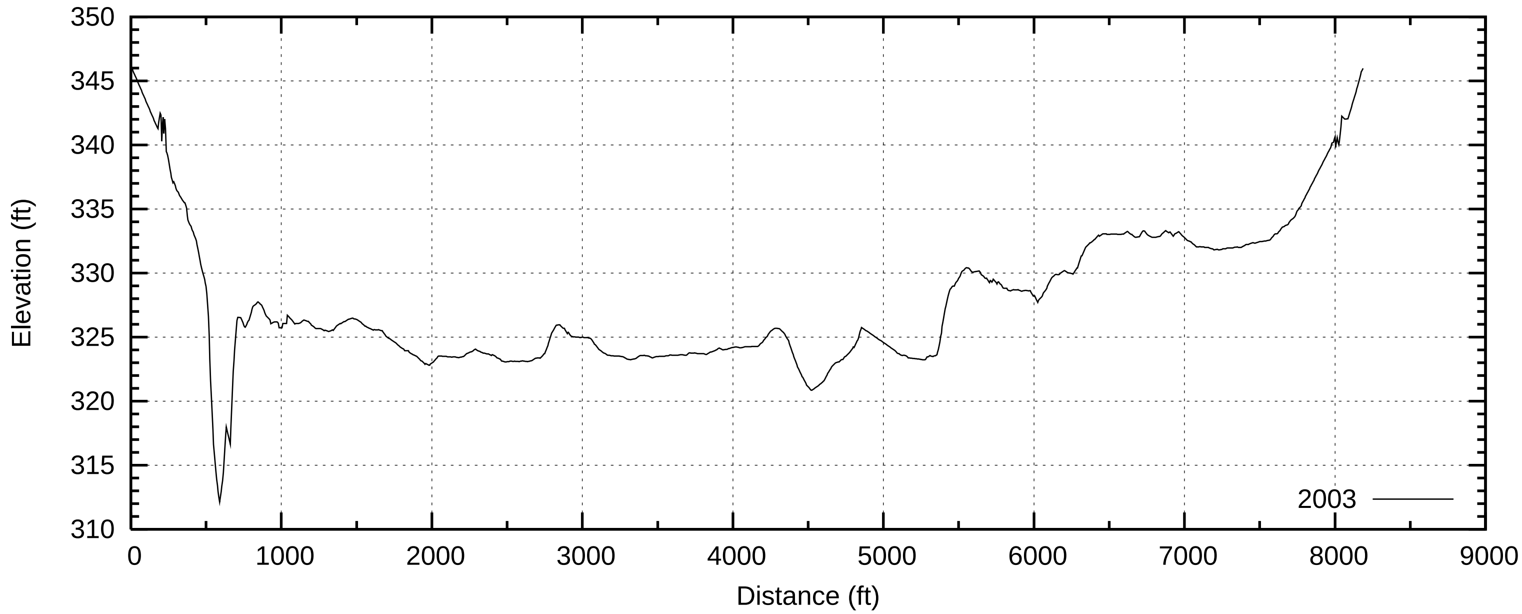


Rangeline SR20

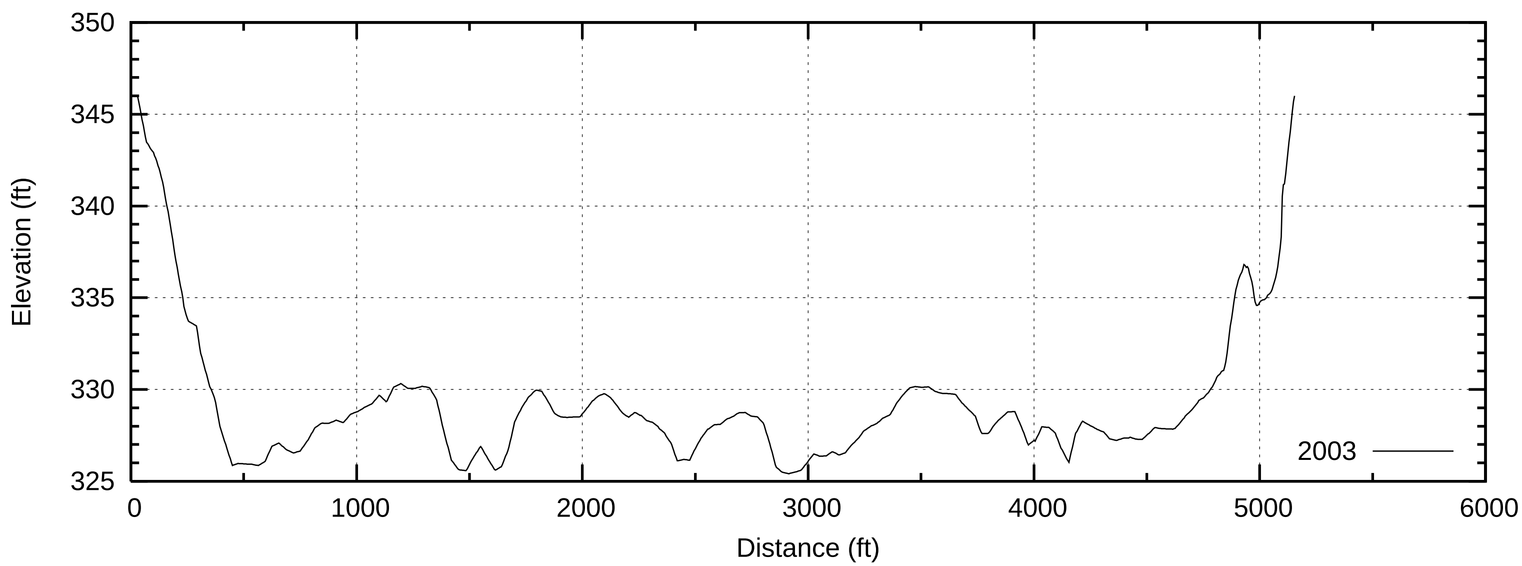


Lake Palestine

Rangeline SR21

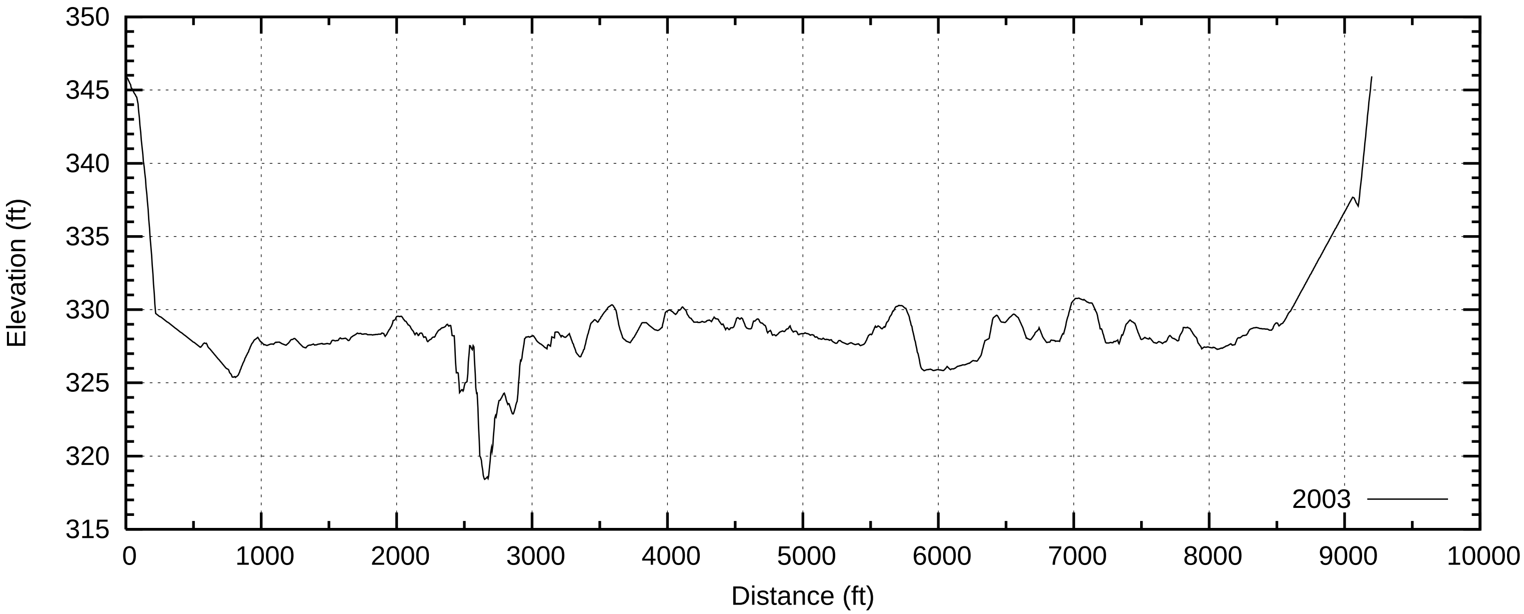


Rangeline SR22

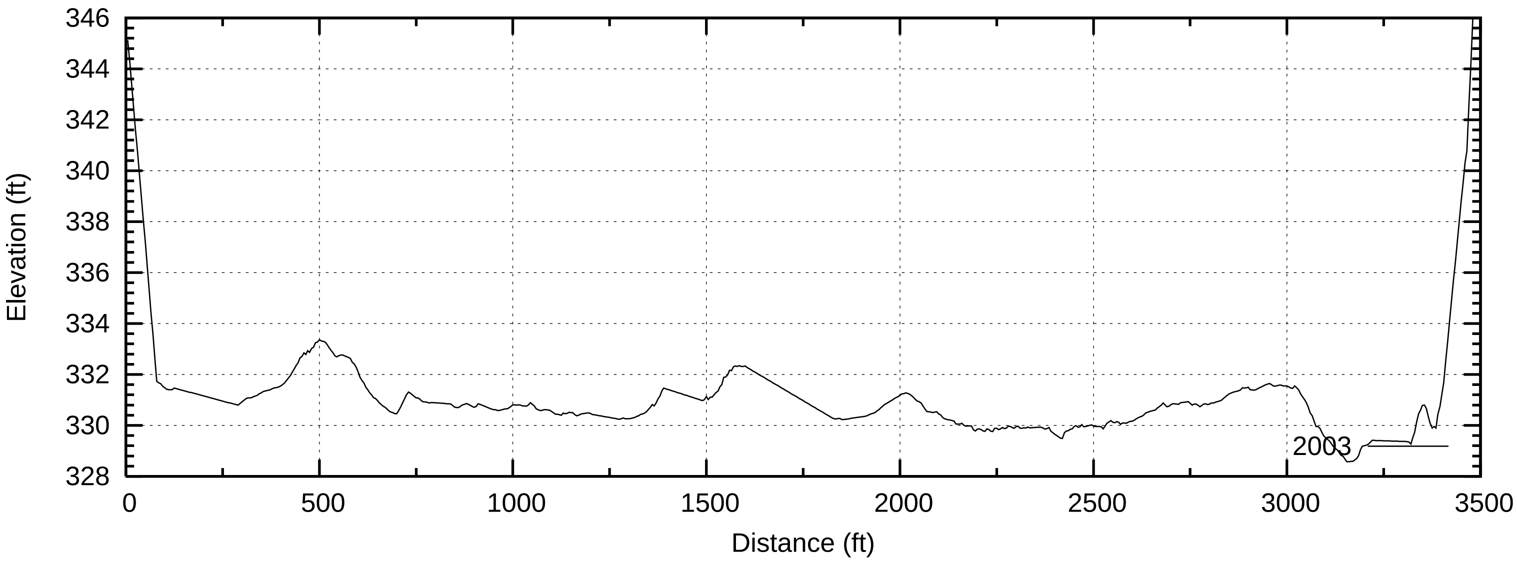


Lake Palestine

Rangeline SR23



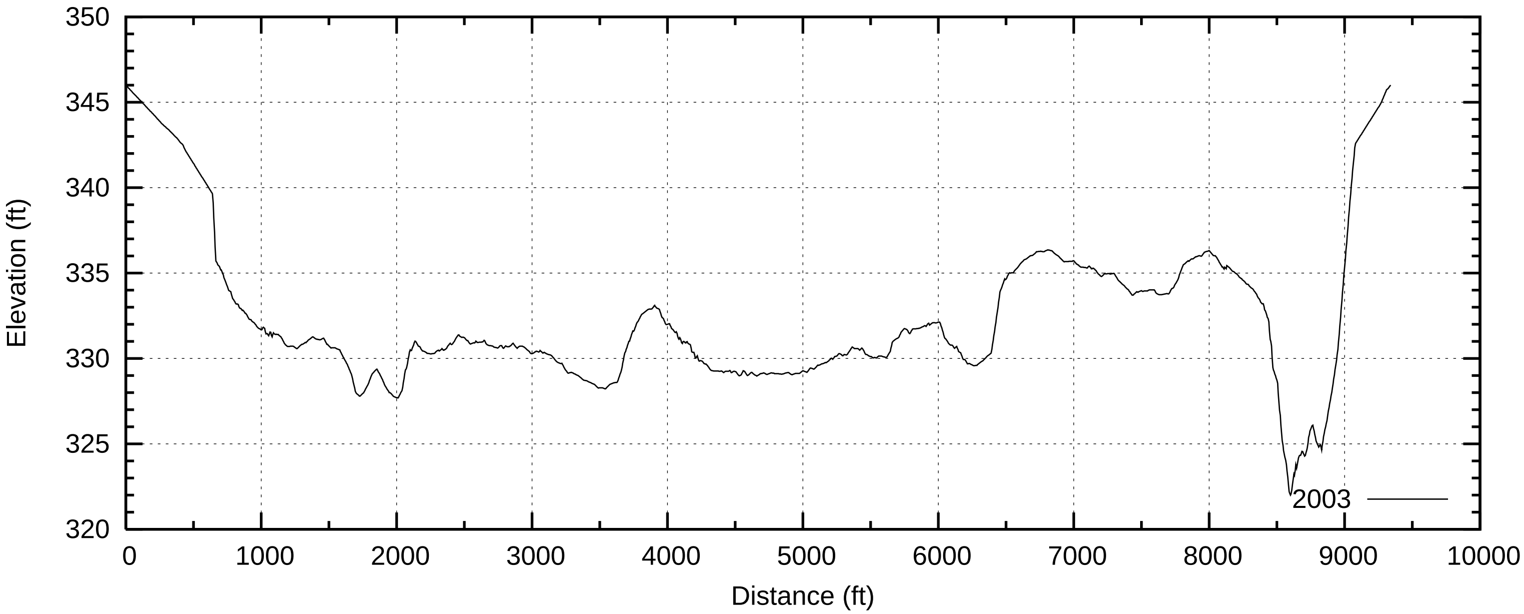
Rangeline SR24



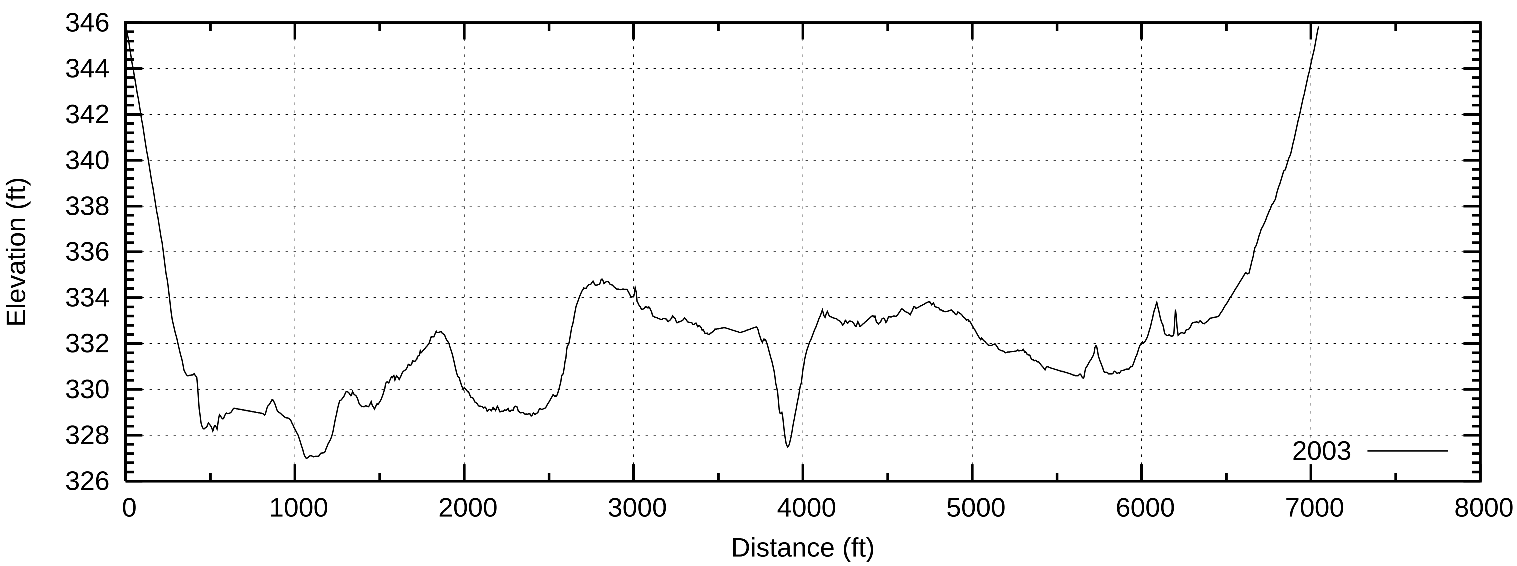
Appendix F

Lake Palestine

Rangeline SR25

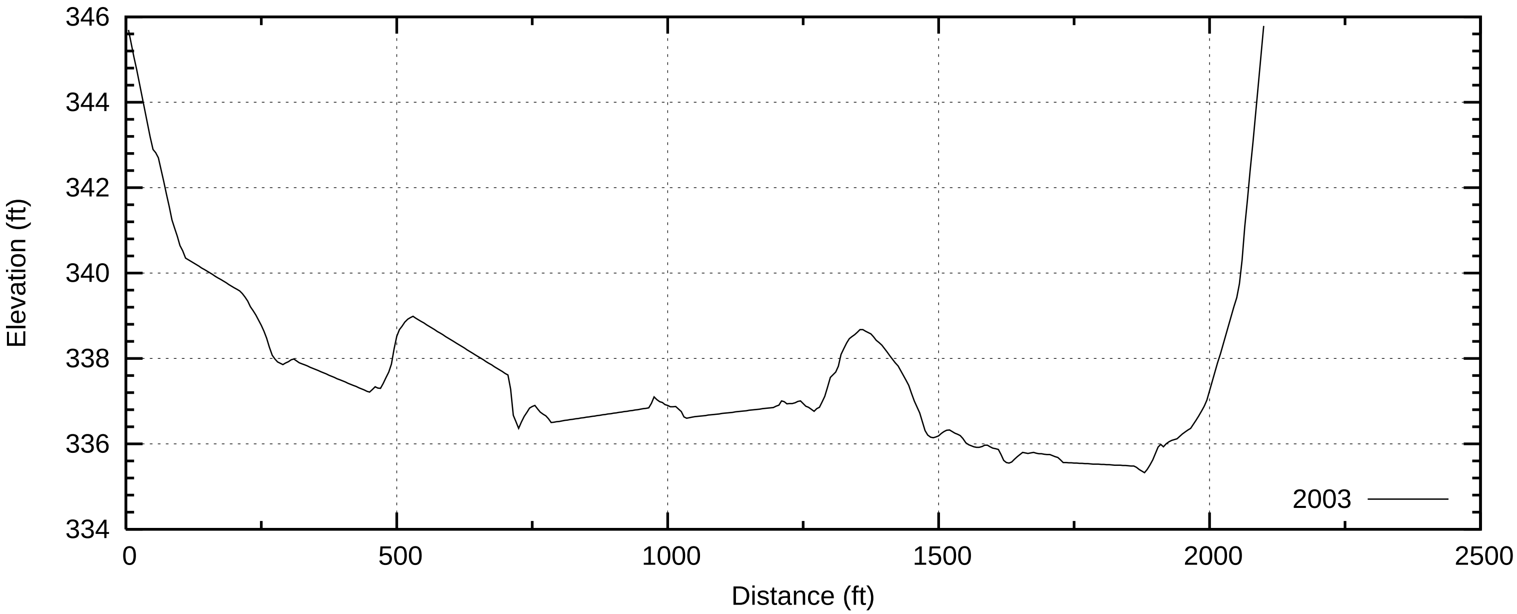


Rangeline SR26

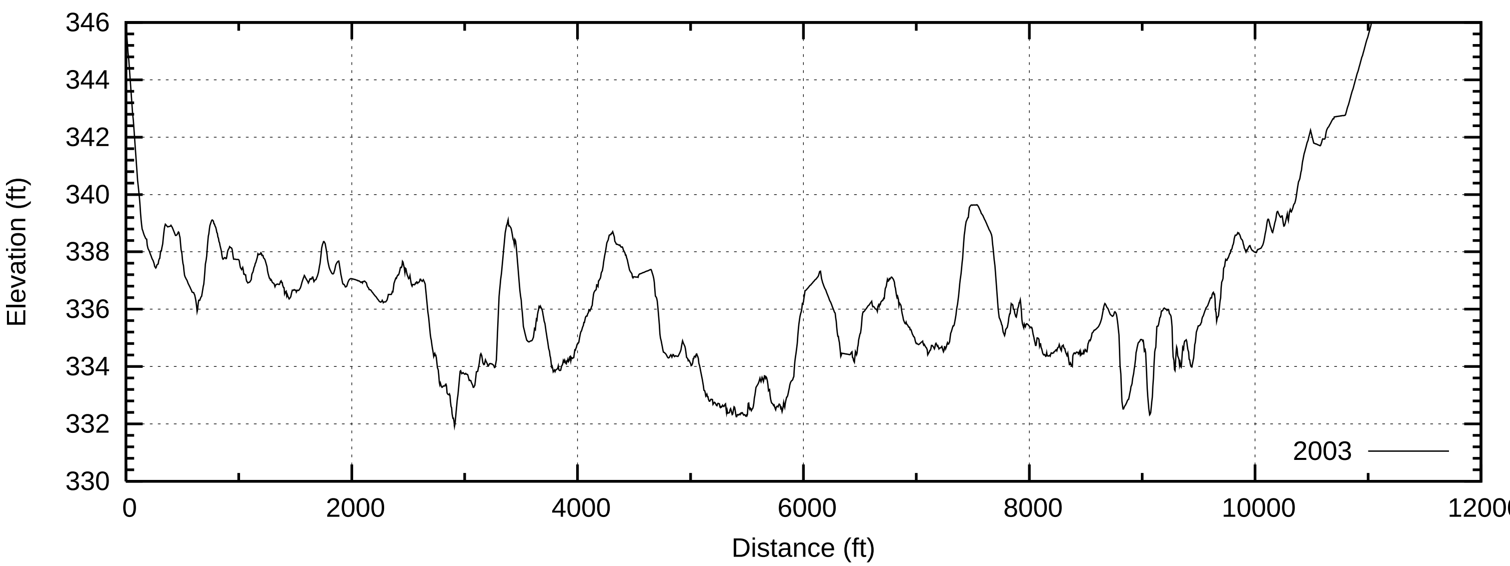


Lake Palestine

Rangeline SR27



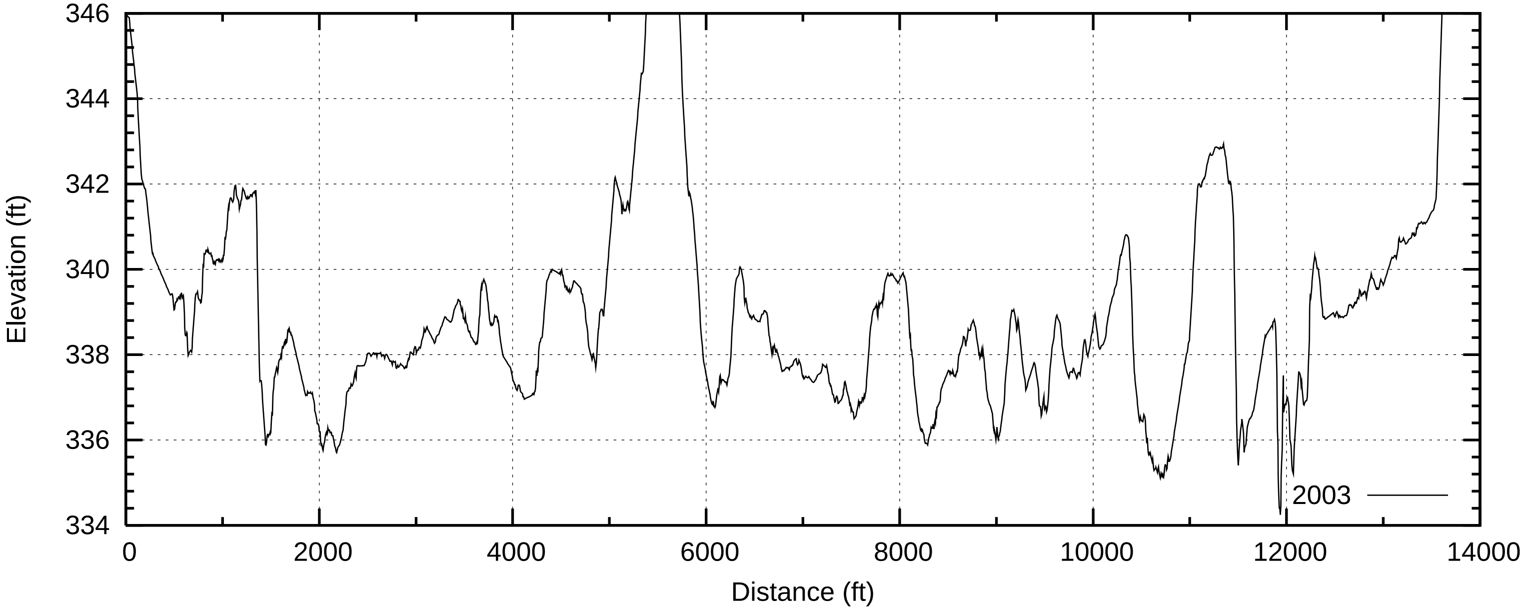
Rangeline SR28



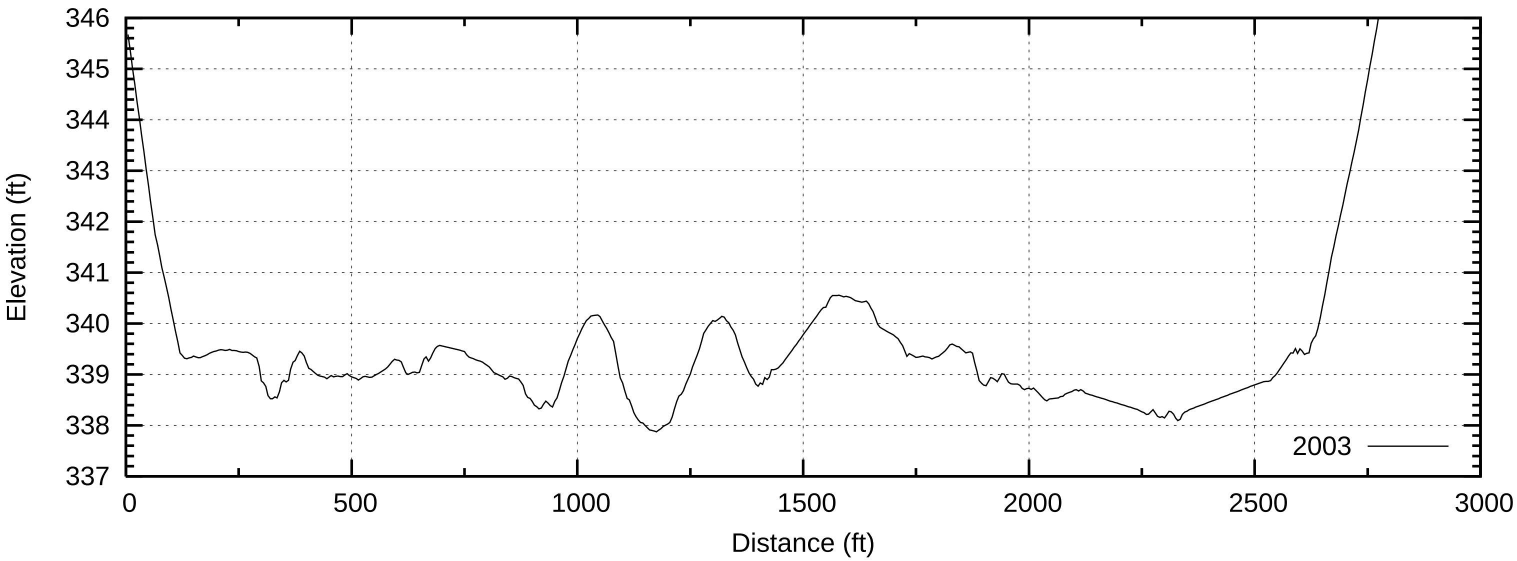
Appendix F

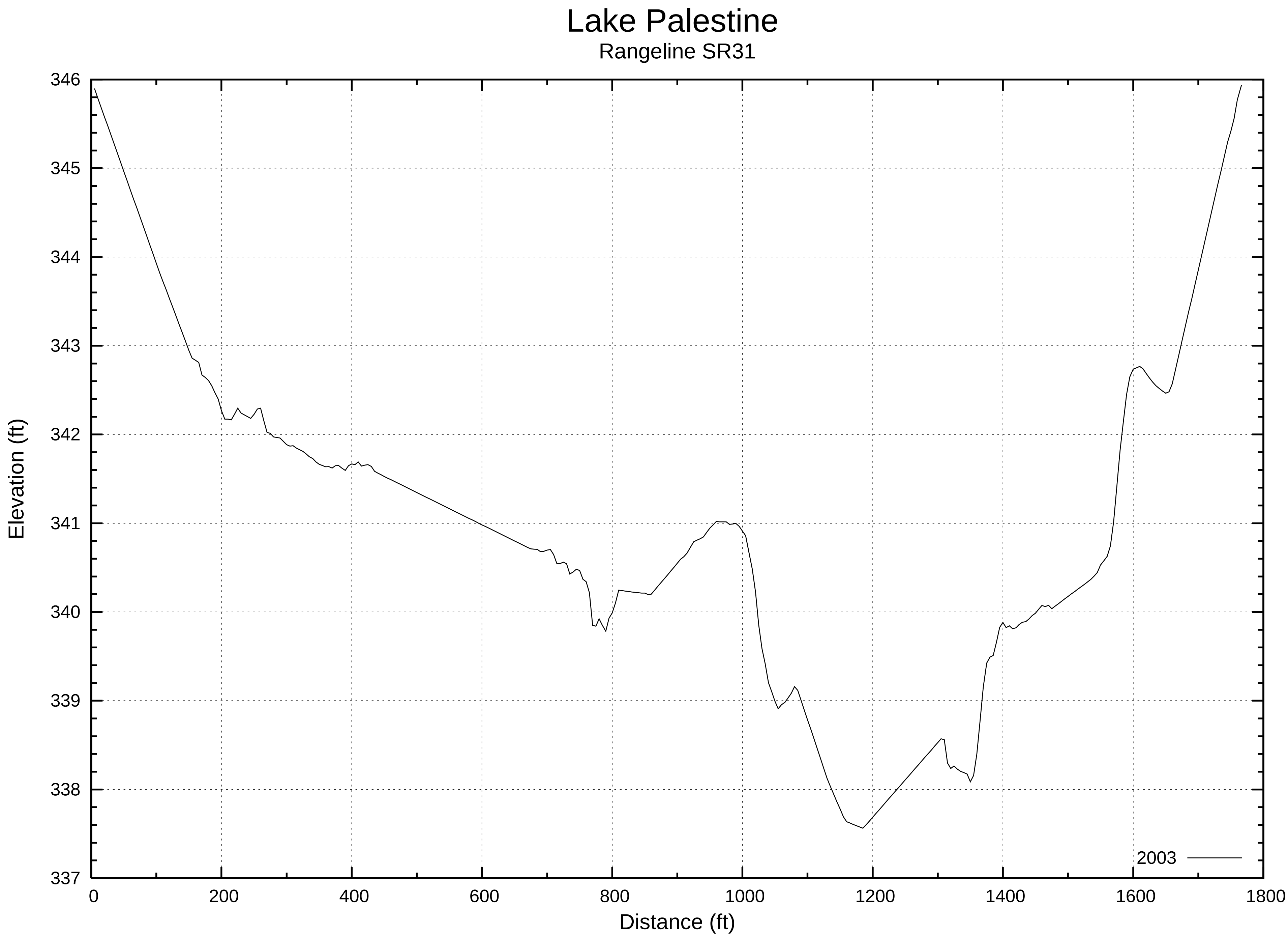
Lake Palestine

Rangeline SR29



Rangeline SR30





Lake Palestine
Rangeline SR31
Elevation (ft)
346
345
344
343
342
341
340
339
338
337
0
200
400
600
800
1000
1200
1400
1600
1800
Distance (ft)
2003