VOLUMETRIC SURVEY OF LAKE CROOK

Prepared for:

City of Paris

In cooperation with the

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

Prepared by: Texas Water Development Board

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EXECUTIVE OVERVIEW

The Texas Water Development Board entered into a contract with the United States Army Corps of Engineers, Fort Worth District and the City of Paris (Texas) to perform a volumetric survey of Lake Crook. 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 for Lake Crook is at elevation 476.0 feet (ft) above mean sea level. A lake boundary was digitized from a digital orthophoto quadrangle image (DOQ). Depth and positional data was collected along a layout of transects or pre-plotted navigation lines spaced approximately 500 feet using commercially available software.

Data were collected at Lake Crook on June 9 and 10, 2003. The water levels remained fairly constant at 475.5 ft. More than 14,000 data points were collected over 32 miles of transects.

Post-processing the data included removing any depth spikes and erroneous depths caused by vegetation interference. All the edited files were combined into an X, Y, and Z (latitude, longitude and elevation) file and imported into a GIS software package. The digitized boundary file and point file were then used to create a Digital Terrain Model (DTM) of the lake's bottom surface using a Triangulated Irregular Network (TIN) software module. Volumes and areas were calculated from the TIN for the entire lake at one-tenth foot intervals from the lowest elevation to the contour used for the lake boundary.

The results of the current survey indicate the lake encompasses 1,060 surface acres and contains a total of 9,210 ac-ft at conservation pool elevation 476.0 ft. Compared to the latest Soil Conservation Service survey (1956), Lake Crook had 1,226 surface acres and a total volume of 9,960 ac-ft. This is a reduction of 750 ac-ft or less than 10% loss in volume in 47 years.

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INTRODUCTION

Staff of the Surface Water Availability Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Lake Crook during the period of June 9 and 10, 2003. The purpose of the survey was to determine the current volume of the lake at the conservation pool elevation. 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 Crook. 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 USACE gauge: USGS 07335600 Lk. Crook nr Paris, TX.[1] (a list of references is located on page 10).

Lake Crook is located on Pine Creek, a tributary of the Red River (Red River Basin). The facility is five miles north of Paris, TX in Lamar County (Figure 1). At the top of conservation pool elevation (cpe) 476.0 ft above msl, the lake has approximately 12 miles of shoreline. Records indicate the drainage area is approximately 52 square miles.[2]

LAKE HISTORY AND GENERAL INFORMATION

Lake Crook and Crook Dam were originally authorized under Permit No. 646 (Application No. 679) by the State Board of Water Engineers to the City of Paris on February 26, 1923. Permission was granted to construct a dam and impound to use 12,000 acre–feet of water (ac-ft) for municipal purposes[3]. The City of Paris currently has authorization under Certificate of Adjudication No. 02-4943 issued June 7, 1987 by the Texas Water Commission to maintain an existing reservoir on Pine Creek in Lamar County known as Lake Crook[4]. The City has the right to impound, not to exceed, 11,011 ac-ft. The owner is authorized to divert and use not to exceed 12,000 ac-ft per annum for municipal purposes.

The original design for Lake Crook[2], at cpe 476.0 ft, indicates a surface area of 1,226 acres and the initial volume was 11,487 ac-ft.

The following table for Crook Dam and Lake Crook is based on information furnished by the City of Paris and results of the TWDB 2003 survey[3].

Table 1. Crook Dam and Lake Crook Pertinent Data

Owner

City of Paris

Operator

City of Paris Water Utilities Department

Design Engineer

John W. Cooke

General Contractor

Denison and Burcher and McGuire and Cavander

Location

On Pine Creek (Red River Basin) in Lamar County, five miles north of Paris, TX.

Purpose

Municipal water supply

Drainage Area

52 square miles

Dam

Type:	Earthfill with protective concrete slab on the upstream face
Length (total):	3,100 ft
Maximum Height:	38 ft
Crest Elevation:	484.0 ft

Spillway

Type:	Concrete weir
Length:	300 ft
Crest elevation:	476.0 ft
Control:	None

Outlet Works

Type:	One conduit
Size:	18-inch diameter
Control:	Valve-controlled
Type:	Low-flow releases

The following information was obtained from the TWDB 2003 Volumetric Survey of Lake Crook:

Feature	**Elevation (Above msl)**	**Capacity (Acre-feet)**	**Area (Acres)**
Top of Conservation Pool (Volume or Total Storage)	476.0	9,210	1,060
Conservation Pool (Between elev. 476.0 ft – 456.8 ft)	N/A	9,195	N/A
Inactive Pool below Spillway Sill	456.8	15	15

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the latest volumetric survey consisted of 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 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 a digital orthophoto quadrangle image (DOQ). VARGIS of Texas LLC produced the DOQ 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 PARIS NW, TEXAS DOQ. There are no records of the lake's elevation at the time the DOQ was photographed on February 2, 1995. For the purpose of this report the lake boundary digitized from the DOQ was given an elevation of 476.0 ft (spillway crest elevation). This assumption was base on the fact that the spillway appears to be engaged in the photograph.

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 parameters, which is a standard method within the United States.

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 41 survey lines placed perpendicular to the original creek channel and its tributaries.

SURVEY PROCEDURES

The following procedures were followed during the volumetric survey of Lake Crook 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 River-runner boat, the Knudsen depth sounder was calibrated using the DIGIBAR-Pro Profiling Sound Velocimeter by Odem Hydrographic Systems. The probe was first placed in the water to acclimate it, 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 4,890 feet per second to 4,908 feet per second during the Lake Crook 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 lake'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

TWDB staff collected data at Lake Crook on June 9 and 10, 2003. The water levels remained fairly constant at 475.5 ft. The survey crew experienced excellent weather conditions with no weather related delays. Upon arriving at Lake Crook, TWDB staff met with personnel from the City of Paris' Utility Department. After discussing the logistics for the survey, the crew began data collection that day.

The design layout for collecting data at Lake Crook required pre-plotting transects (range lines) that were perpendicular to the old 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 depends on the speed of the boat. The maximum distance between data points during the resurvey of Lake Crook was approximately 20 ft.

Over 14,000 data points were collected over the 32 miles traveled during the data collection phase of Lake Crook. These points were stored digitally on the boat's computer in 54 data files. Data were collected in those areas where the crew was not able to stay on course due to obstructions. In addition, five lines were driven parallel to the old river channel of the lake. 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. CD 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 spillway crest elevation of 476.0 ft. From elevation 452.5 ft to 476.0 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.

Other products developed from the model include a shaded relief map (Figure 3) and a shaded depth range map (Figure 4). 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 1-ft intervals is presented in Figure 5. Finally, eight cross-sections were drawn through the TIN for inspection. 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 Crook encompasses 1,060 surface acres and contains a total volume of 9,210 ac-ft at cpe 476.0 ft. The lake boundary was calculated to consist of approximately 13 shoreline miles and was derived by digitizing the boundary visible in the DOQ. The deepest point physically measured during the survey was 23.5 ft corresponding to elevation 452.5 ft above msl and was located approximately 600 ft upstream of Crook Dam.

SUMMARY AND COMPARISONS

Crook Dam[3] was completed in 1923 and deliberate impoundment of Lake Crook began the same year. Original design information was based on a U. S. Soil Conservation Service (SCS) survey. Records indicate that Lake Crook had a total surface area of 1,291 acres and a volume of 11,487 ac-ft at cpe 476.0 ft.

In a 1936 survey[2], the SCS determined the volume had been reduced to 10,755 ac-ft at cpe 476.0 ft. A (SCS) survey in 1956 found the volume had been reduced to 9,960 ac-ft.

TWDB staff performed a volumetric survey of Lake Crook on June 9 and 10, 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 476.0 ft, the current survey measured 1,060 surface acres, for a reduction of 166 surface acres from when the lake was first impounded. The 2003 TWDB survey results indicate that the total volume at the cpe is 9,210 ac-ft. The inactive pool or dead pool storage, below elevation 456.8 ft, contains 15 ac-ft; thus, the conservation storage or capacity found in this survey is 9,195 ac-ft. Lake Crook has lost 2,277 ac-ft or 20% of its volume since 1923. 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 1923 original design, the 1936 and 1956 Soil Conservation Service surveys and the 2003 TWDB volumetric survey are presented in Table 2.

Table 2. Area and Capacity Comparisons for Lake Crook

FEATURE	Original Design	Soil Conservation Service Survey	Soil Conservation Service Survey	TWDB Current Survey
Year	1923	1936	1956	2003
Area (acres)	1,291	1,227	1,226	1,060
Volume (ac-ft)	11,487	10,755	9,960	9,260

REFERENCES

1. http://waterdata.usgs.gov/tx/nwis/uv/?site_no=07335600&PARAmeter_cd=72020,00054
2. Texas Water Development Board. 1966. Report 48. "Dams and Lakes in Texas, Historical and Descriptive Information"
3. Texas Water Development Board. 1973. Report 126 Part I. "Engineering Data on DAMS AND RESERVOIRS IN TEXAS"
4. Texas Water Commission, 1987, Certificate of Adjudication 02-4943

Appendix A

Lake Crook

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD JUNE 2003 SURVEY

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
452						0	0	0	0	0
453	0	0	0	0	0	0	0	0	0	0
454	0	0	1	1	1	1	1	1	1	2
455	2	2	2	3	3	4	4	5	5	6
456	6	7	8	9	10	11	12	14	15	17
457	18	20	22	24	26	28	30	33	35	38
458	41	44	48	51	55	59	63	67	72	78
459	83	90	97	104	112	121	130	140	150	161
460	172	185	197	211	225	239	255	271	288	306
461	324	343	363	383	404	425	446	468	491	514
462	537	560	584	608	633	658	683	709	735	761
463	788	815	843	871	899	928	957	987	1017	1047
464	1078	1110	1142	1174	1207	1240	1274	1309	1344	1379
465	1415	1451	1487	1524	1562	1600	1638	1677	1716	1756
466	1797	1838	1880	1923	1967	2011	2055	2101	2147	2193
467	2240	2288	2336	2384	2433	2483	2534	2585	2637	2690
468	2743	2796	2851	2905	2961	3016	3072	3129	3186	3244
469	3302	3361	3421	3480	3541	3602	3664	3726	3789	3853
470	3917	3982	4047	4113	4180	4248	4316	4386	4456	4527
471	4599	4671	4745	4819	4895	4971	5048	5126	5205	5284
472	5365	5446	5529	5612	5697	5782	5868	5955	6043	6132
473	6222	6313	6406	6499	6594	6690	6786	6884	6981	7079
474	7177	7275	7374	7473	7573	7673	7773	7874	7974	8076
475	8177	8279	8381	8484	8587	8690	8793	8897	9001	9106
476	9210									

Appendix B

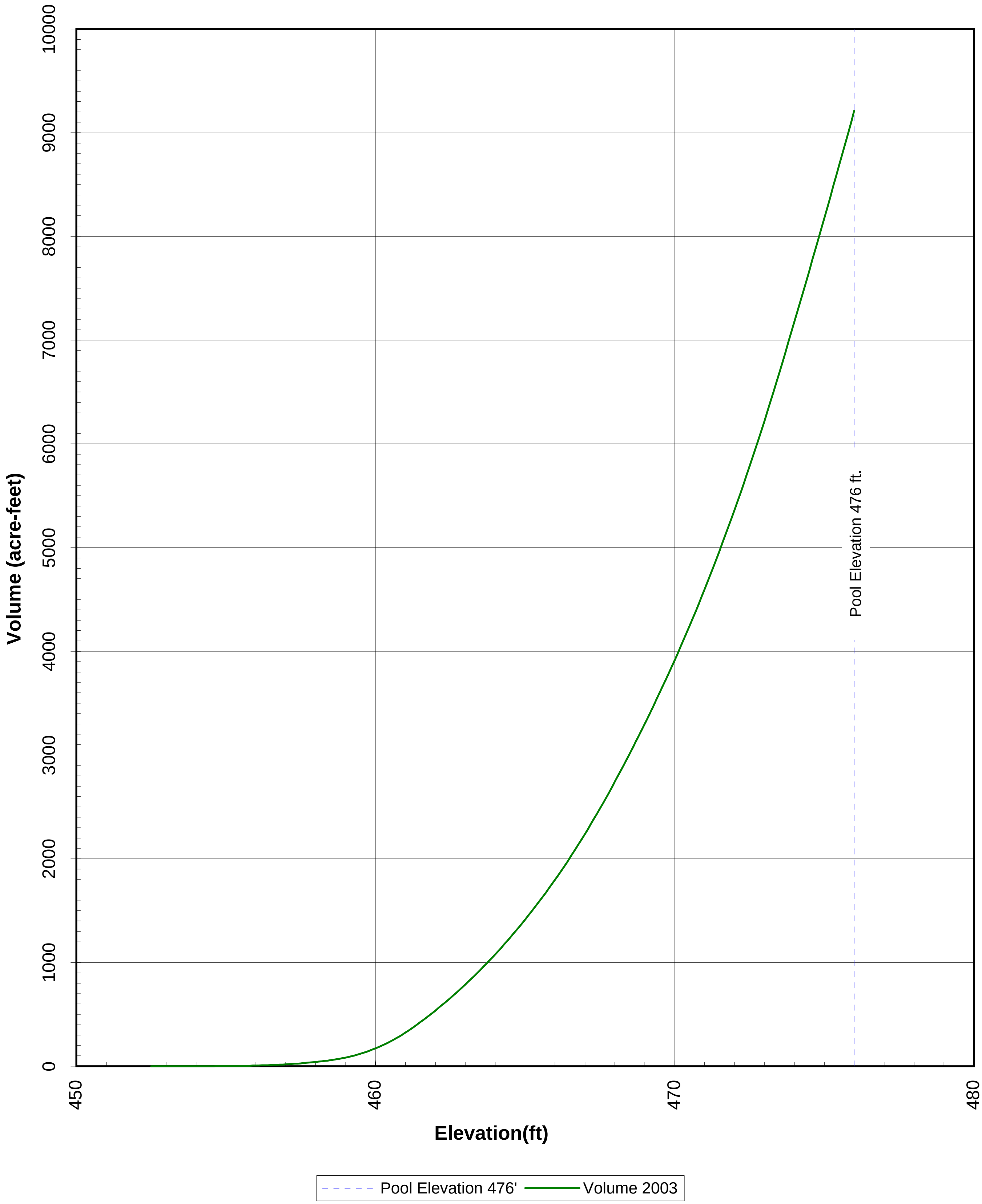
Lake Crook

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD June 2003 SURVEY

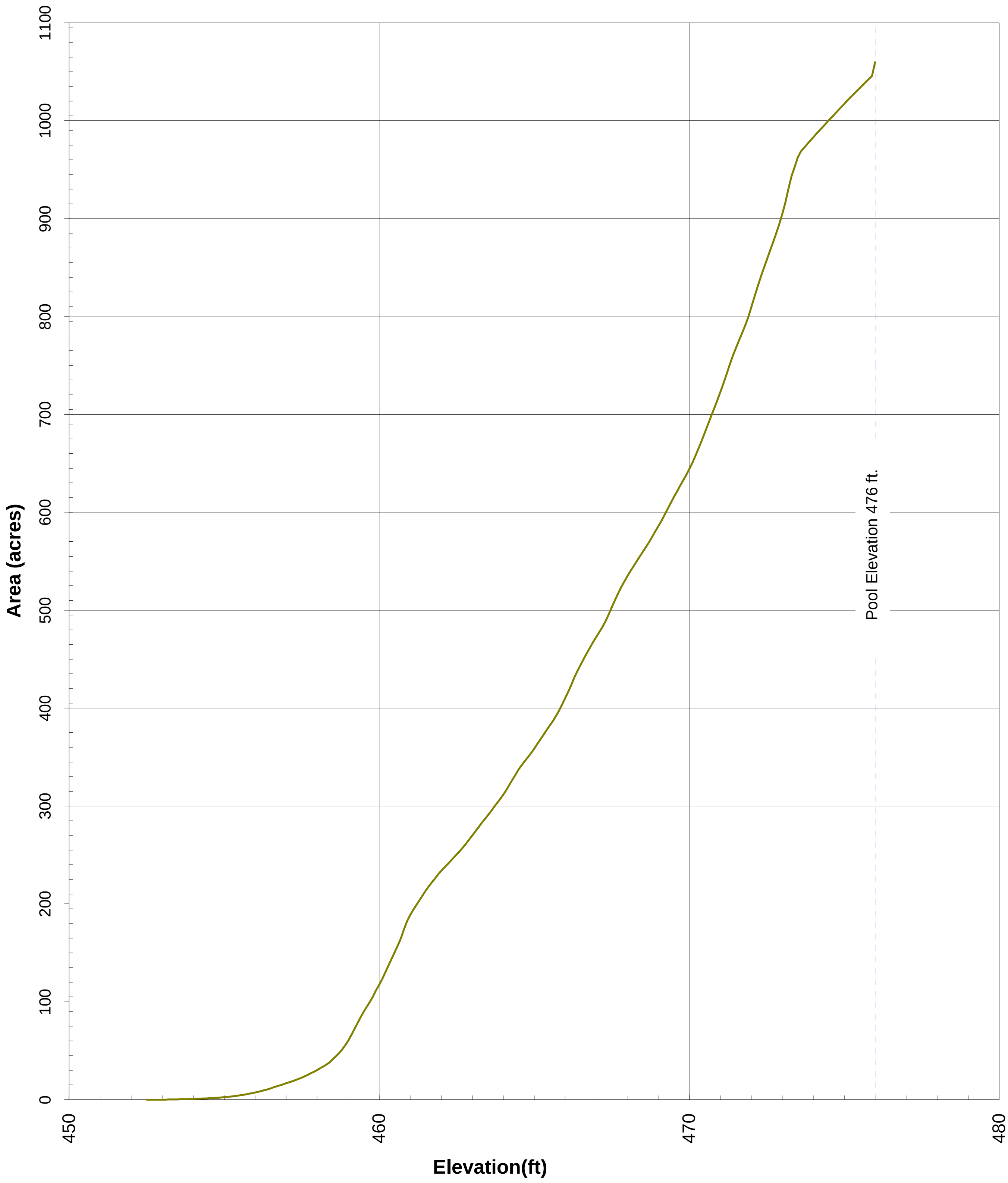
AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
452						0	0	0	0	0
453	0	0	0	0	0	0	0	1	1	1
454	1	1	1	1	1	1	2	2	2	2
455	3	3	3	3	4	4	5	5	6	7
456	7	8	9	10	11	12	13	14	15	16
457	17	18	19	20	21	22	24	25	27	29
458	30	32	34	36	38	41	44	47	51	55
459	60	66	72	78	84	90	95	100	105	112
460	117	123	130	137	144	151	157	165	174	182
461	189	194	199	204	209	214	218	222	226	230
462	234	237	240	244	247	251	254	258	262	266
463	270	274	278	282	286	290	295	299	303	307
464	311	316	322	327	332	337	342	346	350	354
465	359	363	368	372	377	382	386	392	397	403
466	410	417	424	431	438	444	450	456	462	467
467	472	477	483	488	495	503	510	516	523	529
468	534	540	545	550	554	559	564	569	575	580
469	586	591	597	603	609	615	621	627	632	638
470	644	650	658	665	673	681	689	697	706	714
471	723	731	740	750	759	767	775	783	790	799
472	809	820	830	840	849	858	867	876	885	894
473	905	917	931	943	953	962	969	972	976	980
474	983	987	990	994	997	1000	1004	1007	1011	1014
475	1017	1020	1024	1027	1030	1033	1036	1040	1043	1046
476	1060									



Lake Crook
June 2003
Prepared by: TWDB

Appendix C Elevation vs. Volume



Pool Elevation 476' Area 2003 draft

Lake Crook
June 2003
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Appendix D Elevation vs. Area

Appendix E
Lake Crook

TEXAS WATER DEVELOPMENT BOARD JUNE 2003 SURVEY

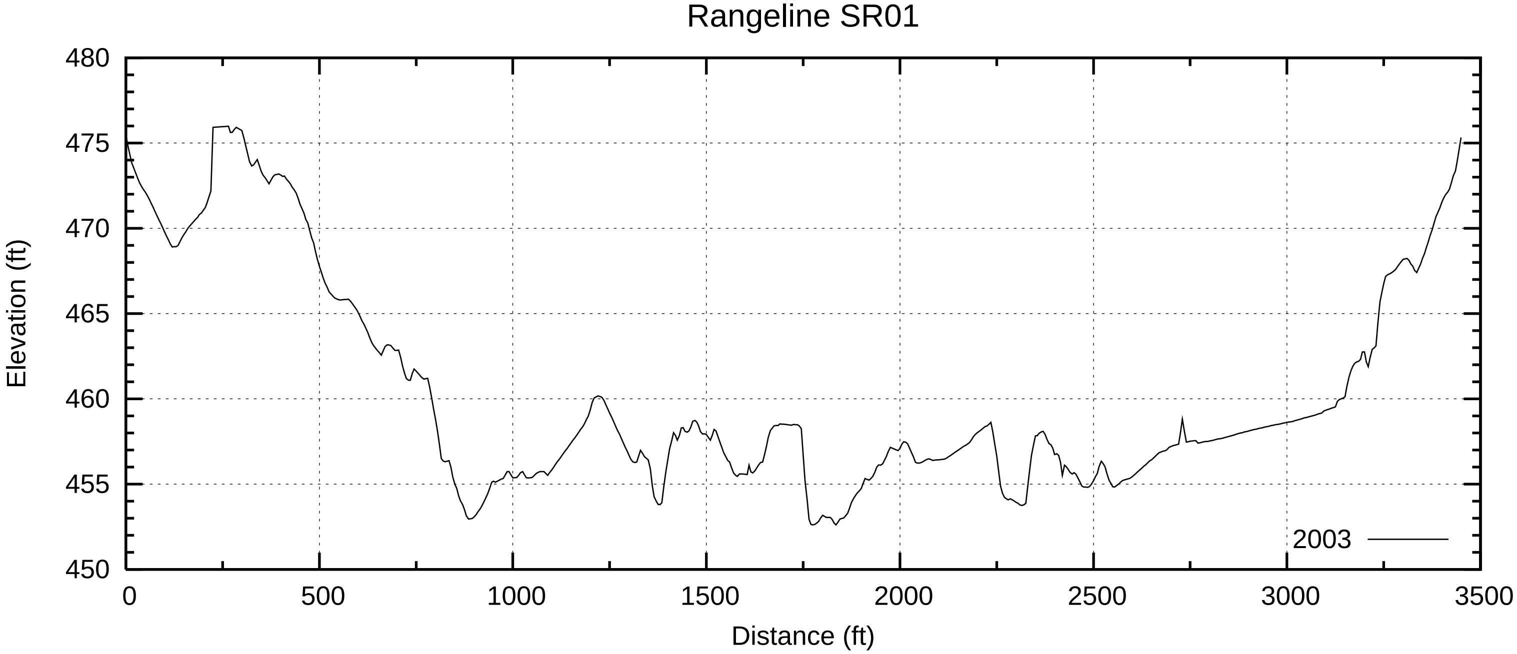
Range Line Endpoints

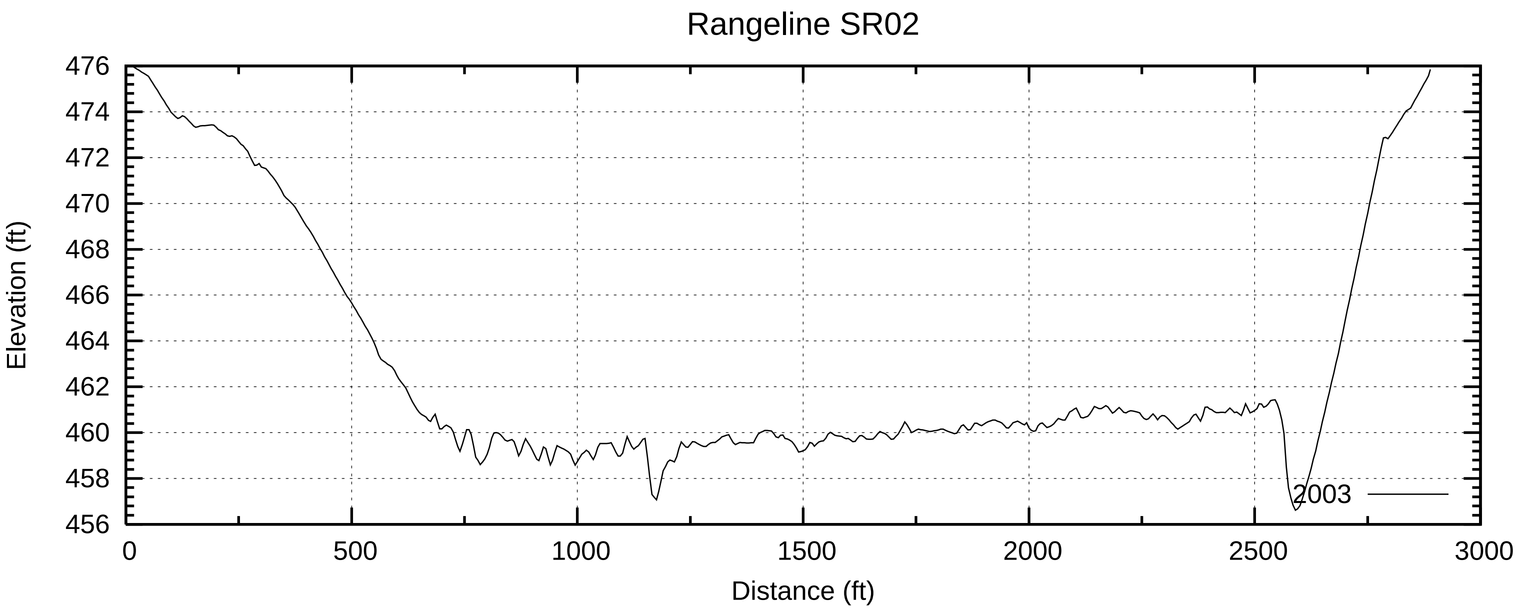
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

Range Line	X	Y
Line 01-L	2859794.3	7326010.5
Line 01-R	2859282.3	7322579.5
Line 02-L	2857392.0	7325549.0
Line 02-R	2857691.0	7322675.5
Line 03-L	2854209.3	7323253.5
Line 03-R	2857032.3	7321495.0
Line 04-L	2851940.3	7320963.0
Line 04-R	2855557.5	7318900.0
Line 05-L	2851923.0	7320095.5
Line 05-R	2855604.0	7317774.5
Line 06-L	2850717.5	7319427.0
Line 06-R	2851781.8	7317942.0
Line 07-L	2849491.3	7318479.5
Line 07-R	2850596.0	7317055.5
Line 08-L	2848883.0	7317663.5
Line 08-R	2849795.3	7316406.5
Line 09-L	2852856.3	7316543.5
Line 09-R	2855131.8	7315038.5
Line 10-L	2852055.5	7315246.0
Line 10-R	2853814.0	7314126.0

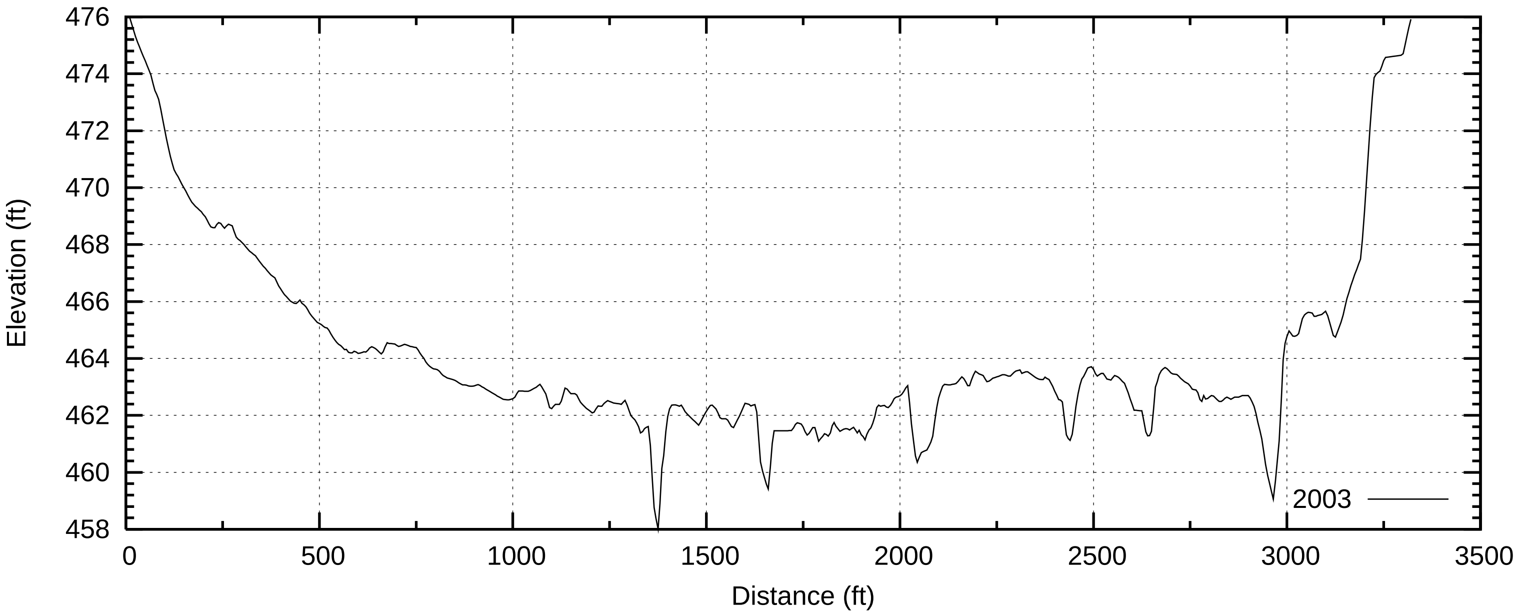
Lake Crook


Rangeline SR01
480
475
470
465
460
455
450
Elevation (ft)
0
500
1000
1500
2000
2500
3000
3500
Distance (ft)
2003


Rangeline SR02
476
474
472
470
468
466
464
462
460
458
456
Elevation (ft)
0
500
1000
1500
2000
2500
3000
Distance (ft)
2003

Lake Crook

Rangeline SR03



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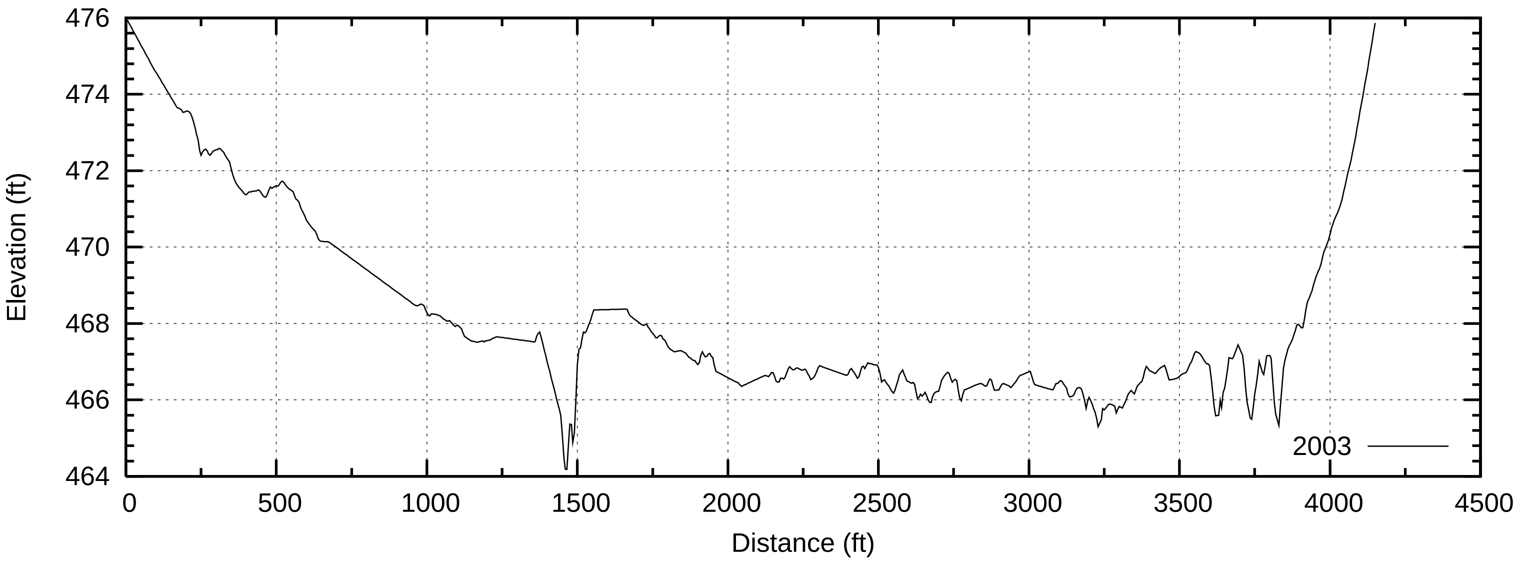

Lake Crook

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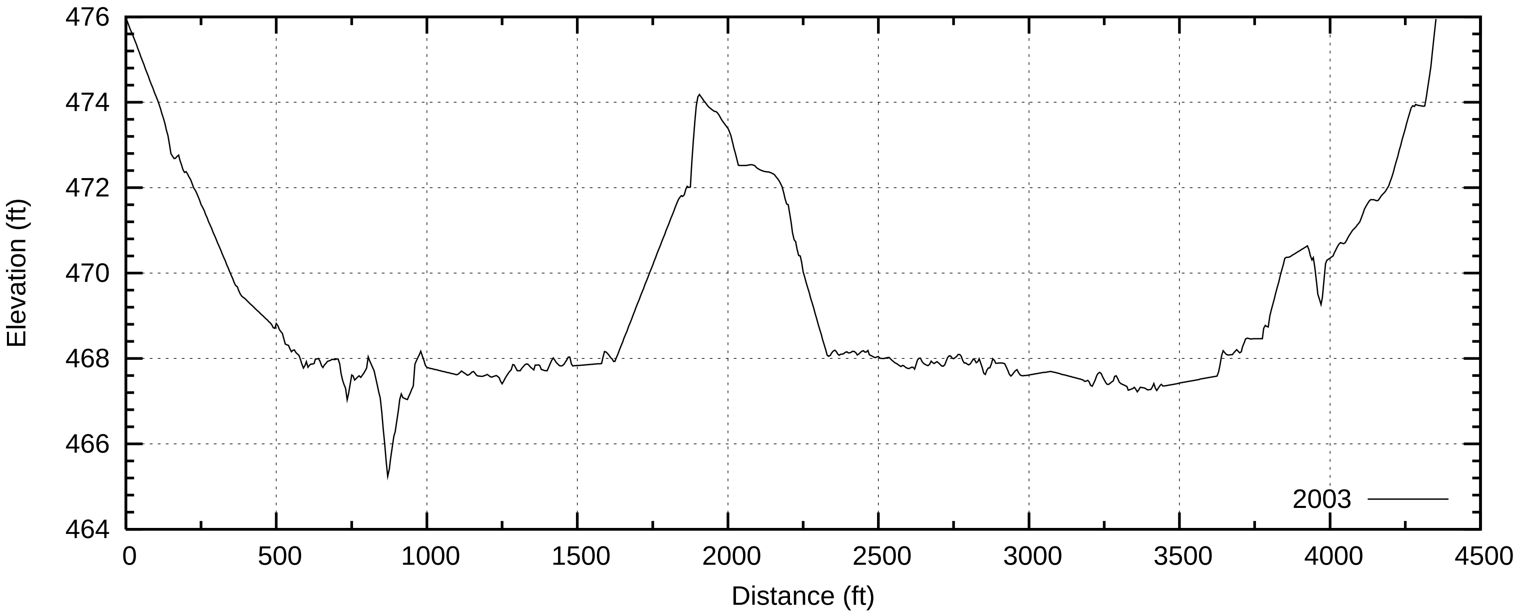

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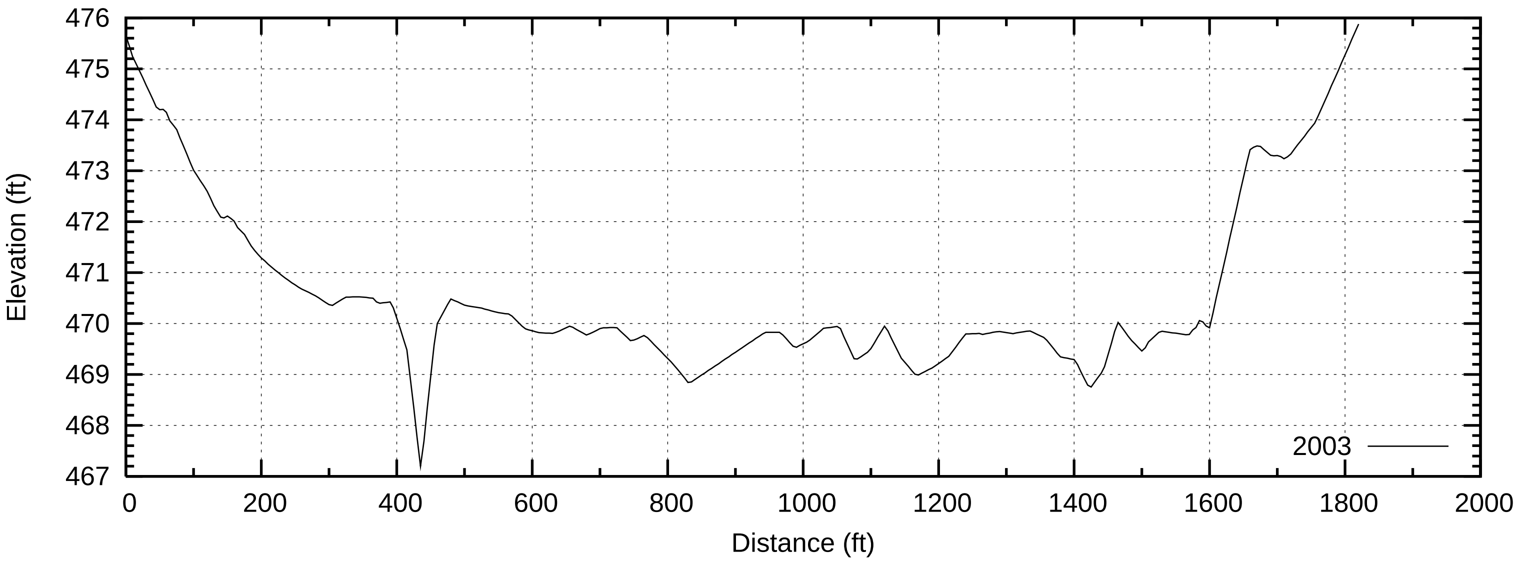
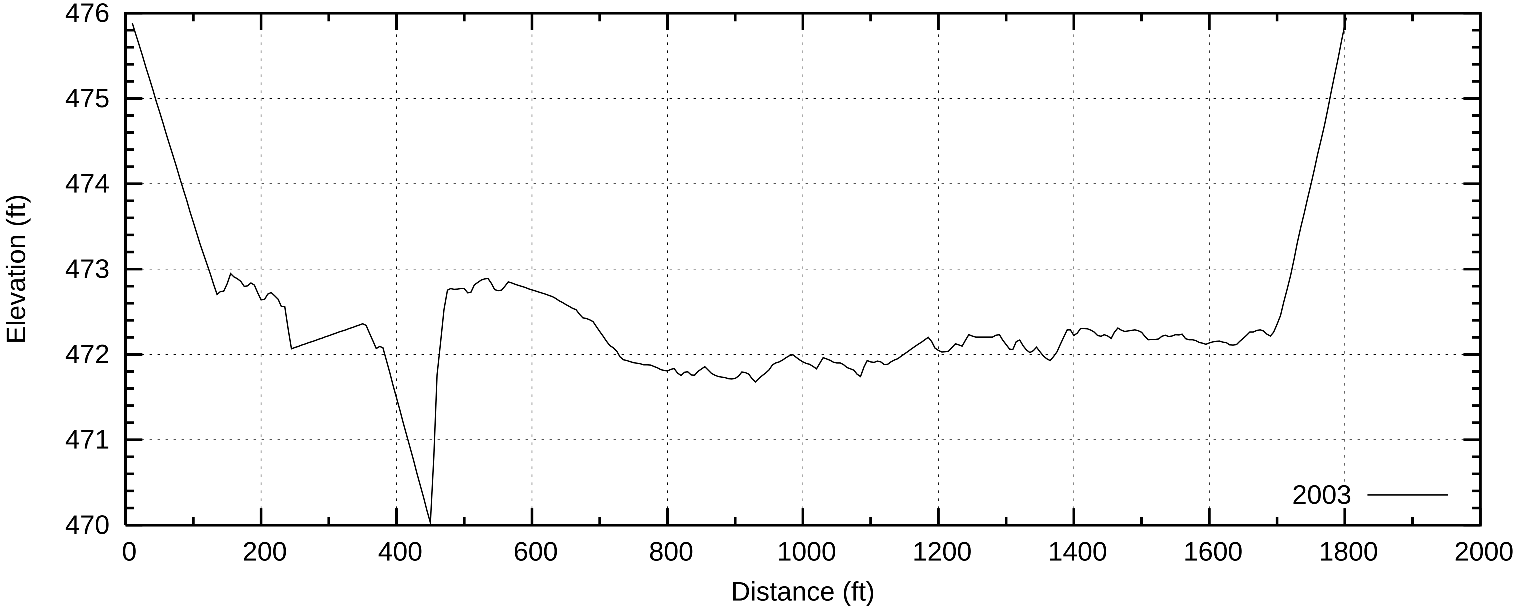


Appendix F

Lake Crook

Rangeline SR07



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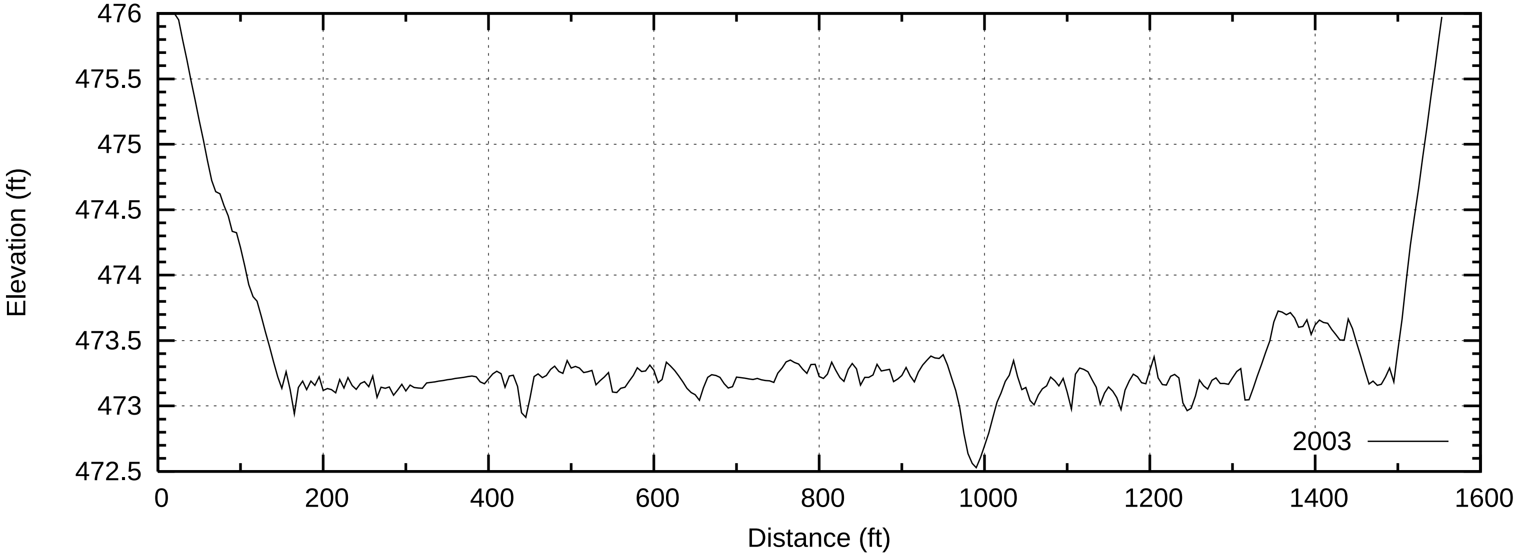
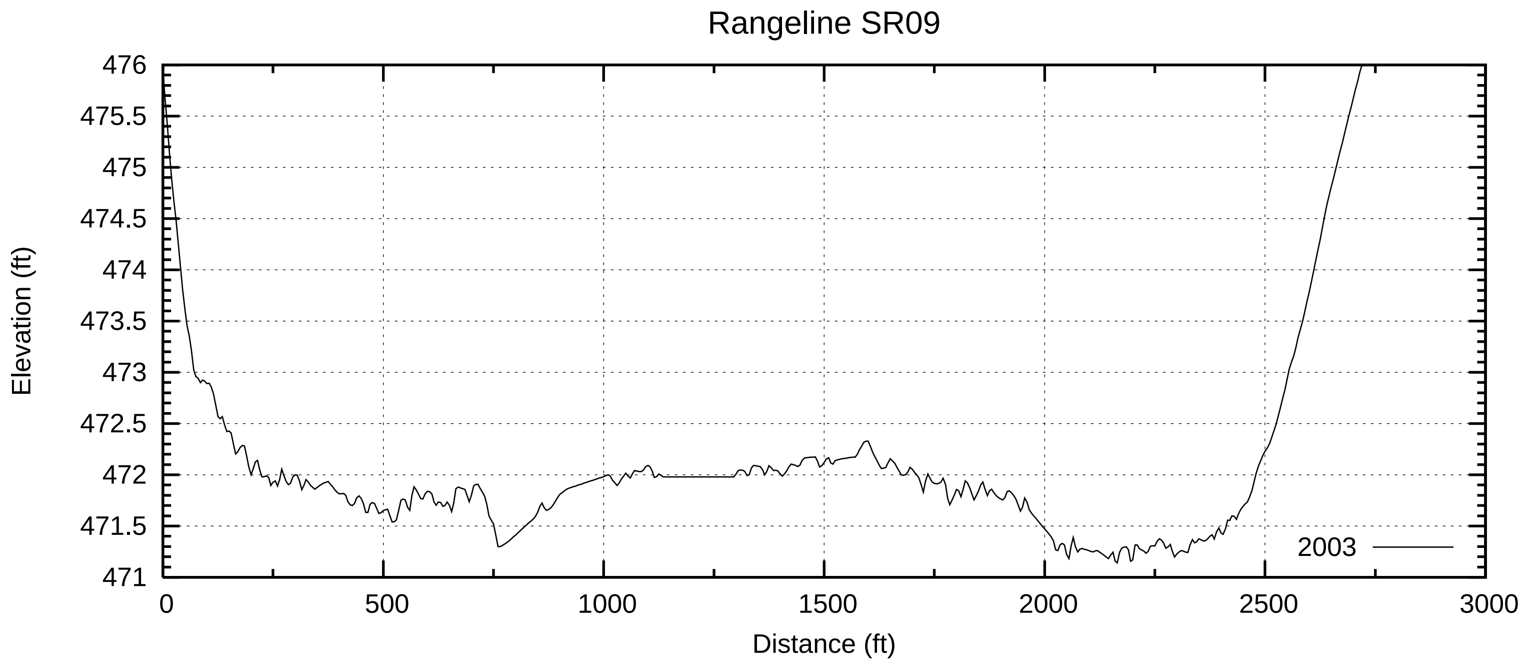
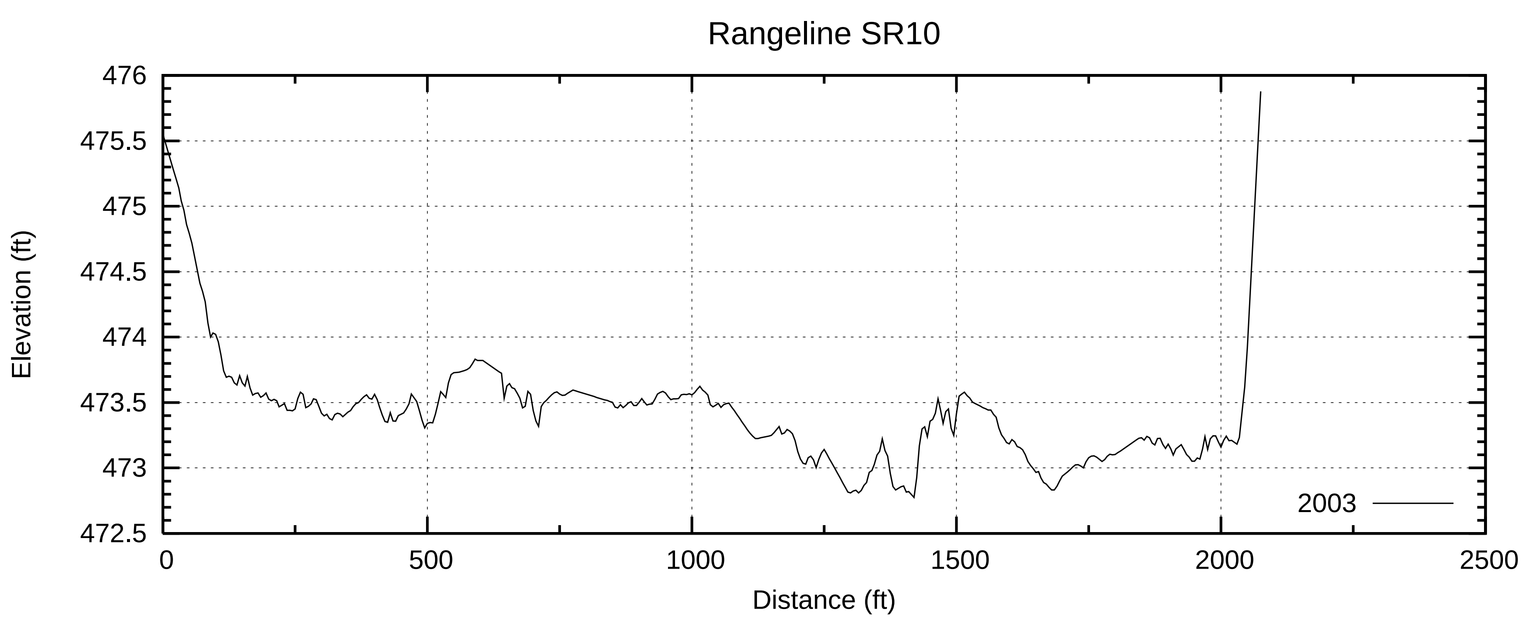


Appendix F

Lake Crook



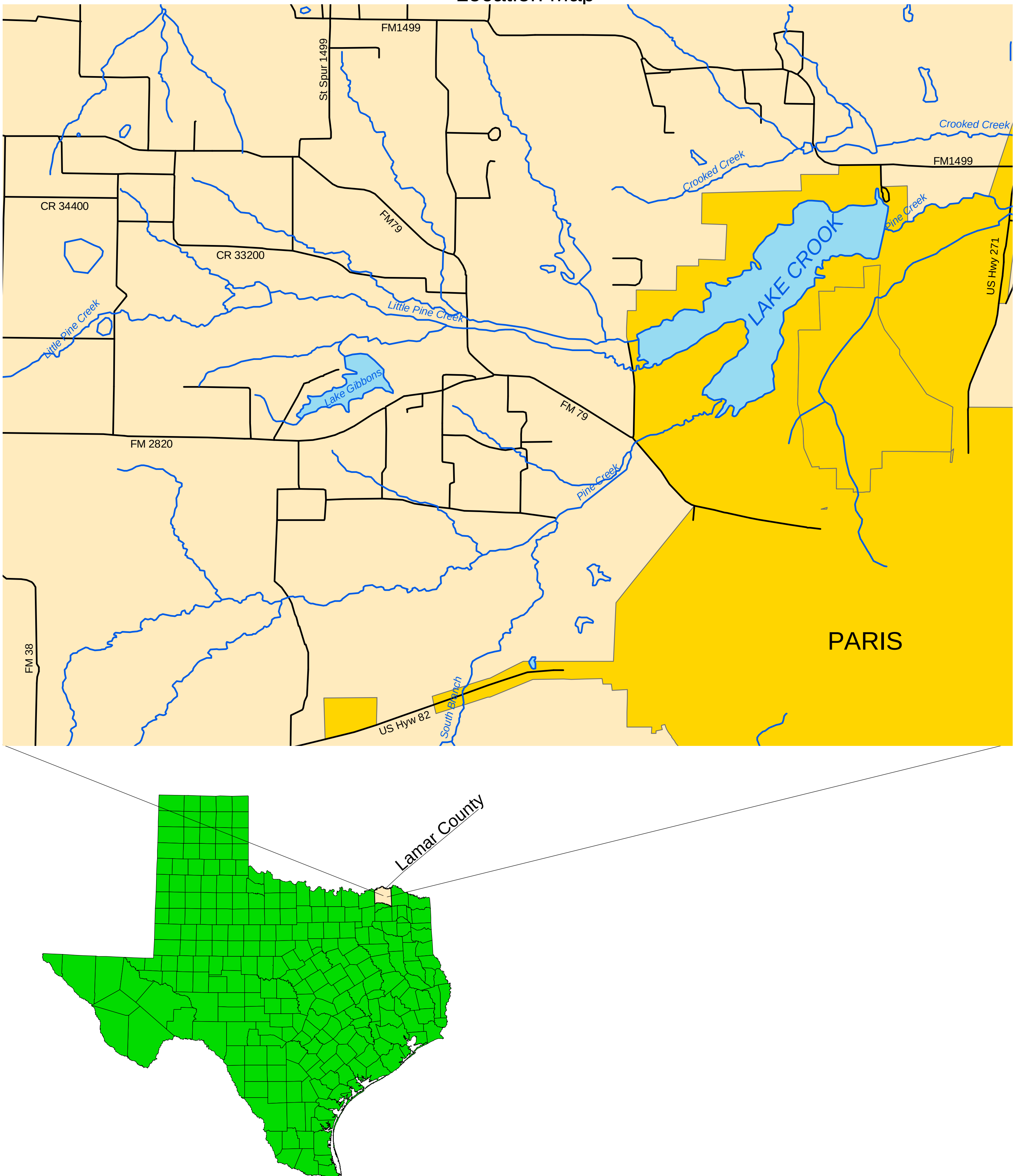


Appendix F

Figure 1

LAKE CROOK

Location Map

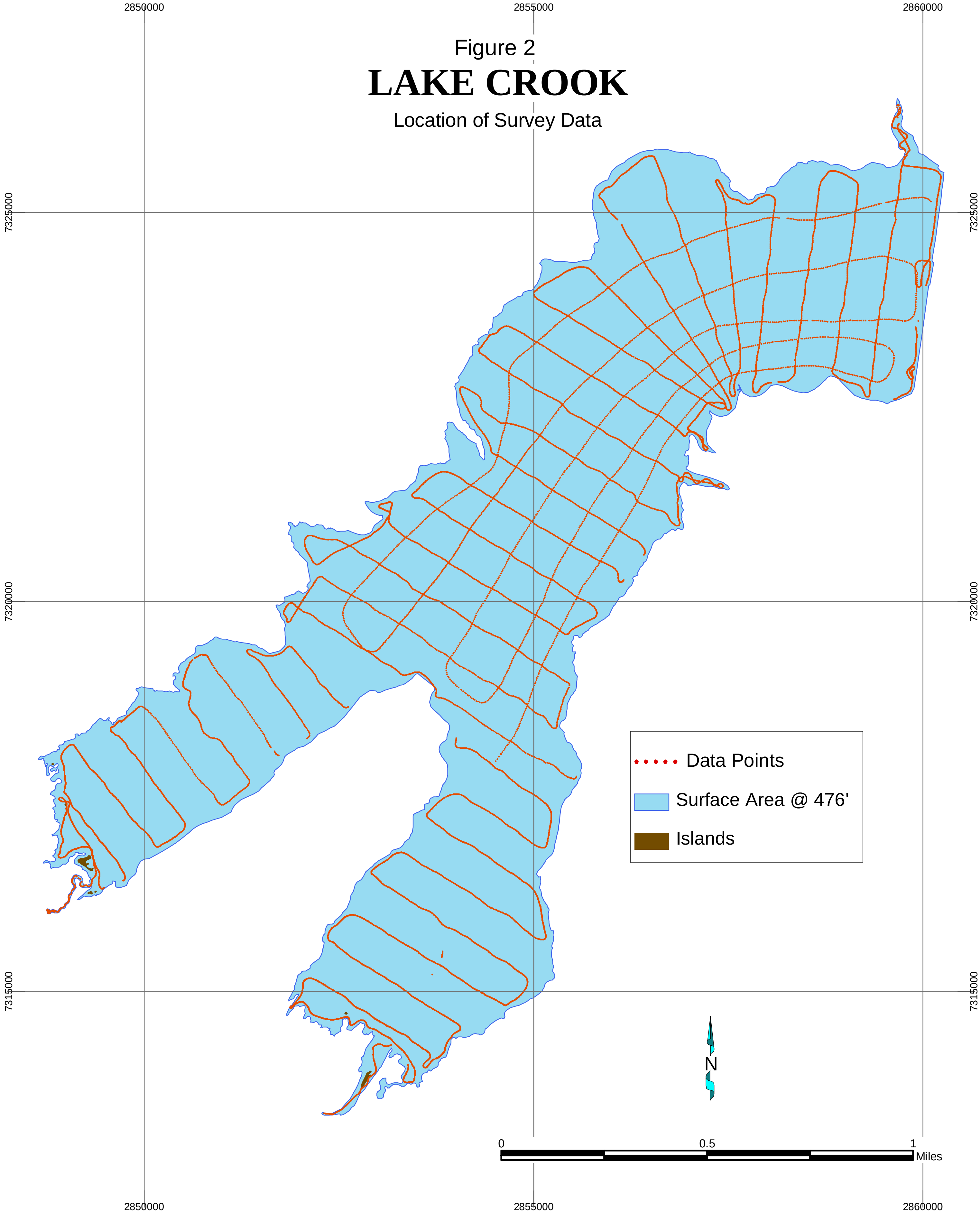


TWDB Survey June 2003

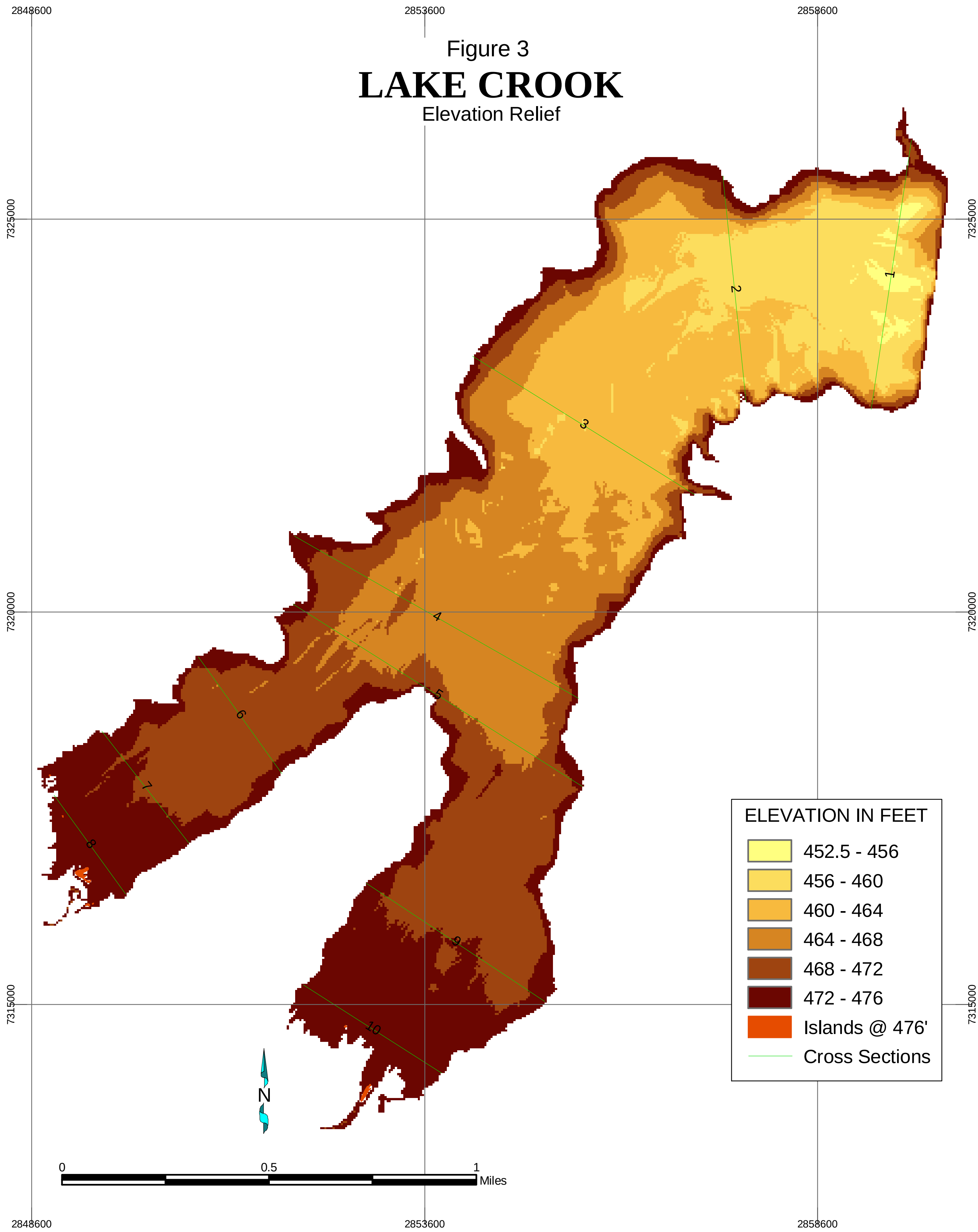
Figure 2

LAKE CROOK

Location of Survey Data



TWDB Survey June 2003



TWDB Survey June 2003

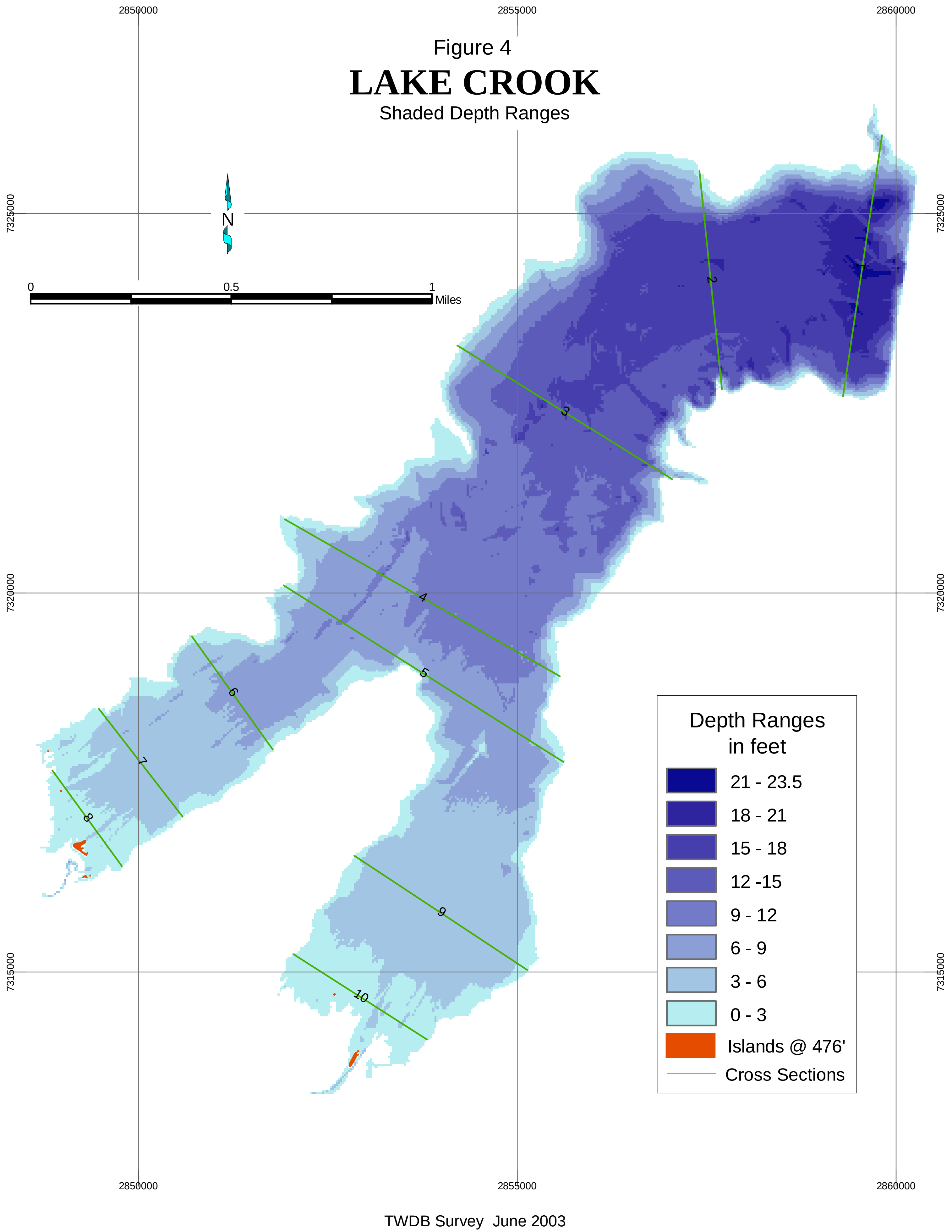
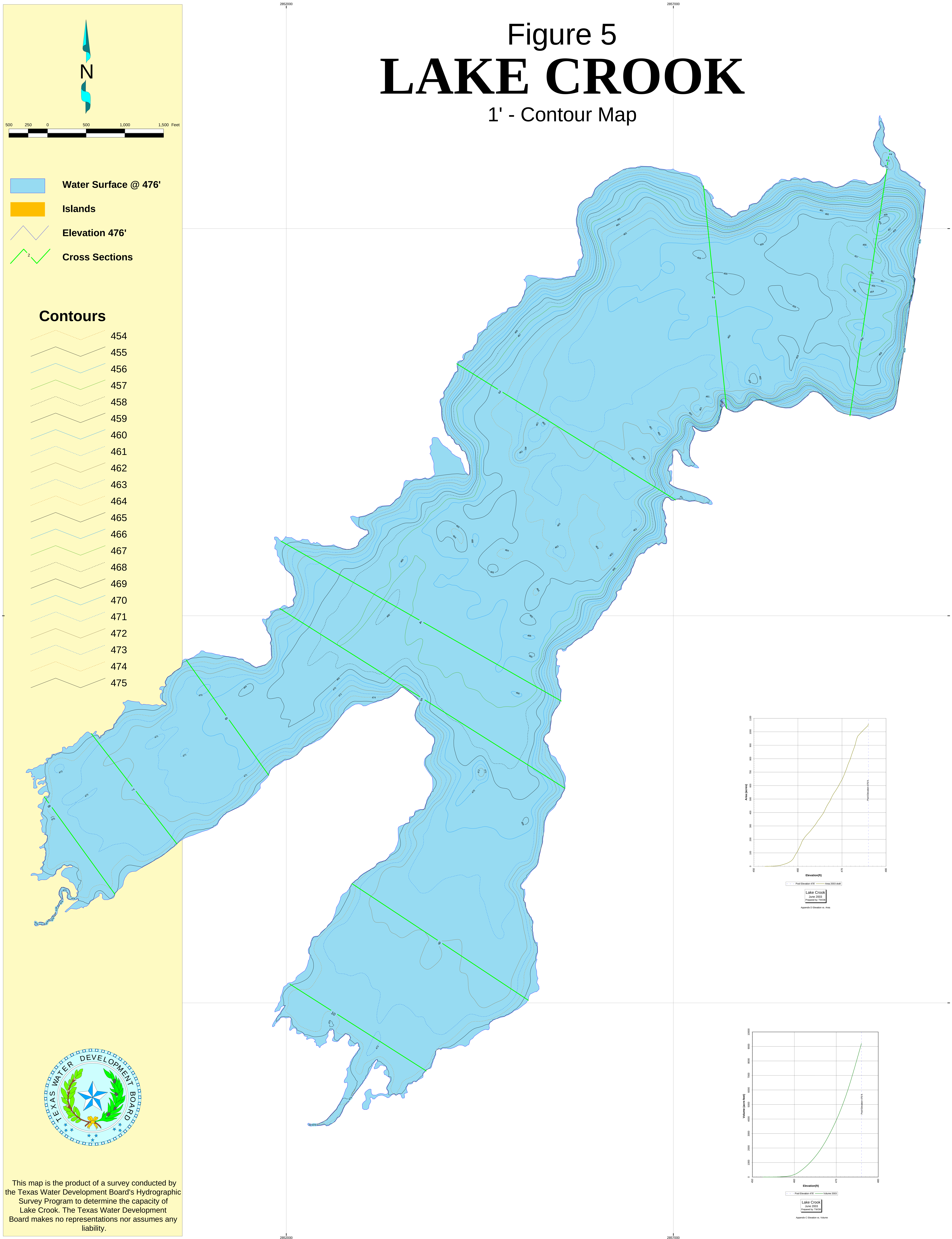


Figure 4
LAKE CROOK
Shaded Depth Ranges
N
0
0.5
1
Miles
2850000
2855000
2860000
7325000
7320000
7315000
1
2
3
4
5
6
7
8
9
10
Depth Ranges
in feet
21 - 23.5
18 - 21
15 - 18
12 -15
9 - 12
6 - 9
3 - 6
0 - 3
Islands @ 476'
Cross Sections
TWDB Survey June 2003

Figure 5
LAKE CROOK
1' - Contour Map



TEXAS WATER DEVELOPMENT BOARD JUNE 2003 SURVEY