VOLUMETRIC SURVEY OF LAKE TEXANA

Prepared for:

Lavaca-Navidad River Authority

In cooperation with the

United States Army Corps of Engineers

Prepared by
Texas Water Development Board

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INTRODUCTION

Staff from the Surface Water Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Lake Texana during the period of August 9 – 23, 2000. Supplementary data was collected on November 28, 2000. The primary purpose of this survey was to determine the current volume of the lake at conservation pool elevation. Results from this survey will serve as a basis for comparison to future surveys to allow the location and rates of sediment deposition to be determined. Survey results are presented here 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 gage at Lake Texana (08164525 Lake Texana near Edna, Texas). The datum for this gage is reported as mean sea level (msl) (USGS, 1999). Elevations are reported in this report according to the same datum, in feet above mean sea level (msl). Volume and area calculations in this report are referenced to water levels provided by the USGS gage.

The original design data for Lake Texana shows the surface area at conservation pool elevation, 44.0 feet, to be 9,934 acres and the total storage volume to be 165,918 acre-feet of water (U.S. Department of Interior, Bureau of Reclamation, 1992). The Bureau of Reclamation conducted a sediment survey of Lake Texana in 1991. At that time, the surface area at conservation pool elevation was found to be 10,134 acres, and the total volume was 163,506 acre-feet of water (U.S. Department of Interior, Bureau of Reclamation, 1992). The elevation given for the top of the dead pool was given as 15.0 feet.

This report compares the 2000 survey results with the original design information and the 1991 survey results.

LAKE HISTORY AND GENERAL INFORMATION

Historical information for Lake Texana was obtained from several publications (U.S. Department of the Interior 1980, U.S. Department of the Interior 1981, Blanton and Ferrari 1992). The Lavaca-Navidad River Authority, Texas Water Development Board, and Bureau of Reclamation cooperatively financed, designed, and constructed what was originally known as the Palmetto Bend Project (Lake Texana and Palmetto Bend Dam). Historically, the Lavaca-Navidad River Authority has maintained and operated the Lake Texana facilities and associated Palmetto Bend Dam.

Water Rights Permit #2776 granted the Lavaca-Navidad River Authority (LNRA) and the Texas Water Development Board (TWDB) the right to construct a dam on the Navidad River and impound water known as Stage 1 Dam and Reservoir (Palmetto Bend Dam and Lake Texana). Certificate of Adjudication #16-2095 was issued July 3, 1981, and reestablished the owner's right to impound up to 170,300 acre-feet of water on the Navidad River. Both LNRA and TWDB were authorized to divert and to use the impounded water for municipal and industrial purposes. The impounded water was also to be used for recreational purposes. The certificate of adjudication was amended several times in the following years. In general, the amendments made changes to the allowable diversions and interbasin transfers, and provided for environmental fresh water flow releases to maintain the Lavaca-Matagorda Bay and Estuary System.

One item noted under the special conditions of the Certificate of Adjudication #16-2095 that relates to this study is the requirement that the water rights holders establish sediment range lines. The purpose of the range lines was to establish a sedimentation base line when the reservoir was first built and to allow determination of sediment loading with subsequent surveys. During the original design of Lake Texana, approximately 61 sediment range lines were established and the end points of these lines were monumented. In 1991 the Bureau of Reclamation performed a sediment survey and collected data along 25 of the 61 pre-established sediment range lines. The cross sections were then overlaid and comparisons of the sediment load were made. A revised area-capacity table was developed from the 1991 sediment survey.

Lake Texana is located on the Navidad River (Lavaca River Basin) in Jackson County, seven miles southeast of Edna (Figure 1), Texas and approximately five miles upstream of the confluence with the Lavaca River. At conservation pool elevation (44 feet msl) the reservoir extends approximately 18 miles upstream into the Navidad River valley. At this same elevation, Lake Texana extends eight miles upstream along Sandy Creek and 13 miles along Mustang Creek. Records indicate that the drainage area is approximately 1,404 square miles. At conservation pool elevation, the lake has approximately 126 miles of shoreline. Lake Texana was designed as a major municipal and industrial water supply reservoir. There was no provision for flood storage in the design of the dam. Floodwaters are passed through the facility and downstream during major flood events.

Construction for Lake Texana and Palmetto Bend Dam started in 1976 and was completed in 1980. Deliberate impoundment began in May of 1980. The design engineer for the project was the Bureau of Reclamation (U.S. Department of the Interior, 1981) and the general contractor was Holloway Construction.

Engineering designs (U.S. Department of the Interior, 1980) show Palmetto Bend Dam and appurtenant structures to consist of a rolled-earthfill embankment approximately one mile in length, with a maximum height of 58 feet and a crest elevation of 55.0 feet msl. Farm-to-Market Road 3131 runs along the 42-foot wide section on the dam's crest and spillway. Soil cement was placed on the upstream slope of the dam to protect from wave action and erosion. Bermuda grass covers the downstream slope of the dam. A drainage ditch system is located downstream of the dam and dikes to divert the run-off from the structure and surrounding areas. The length of the dam and dikes inclusive is approximately eight miles.

The service spillway is a 464-foot wide concrete structure. The structure consists of twelve bays that are controlled by 22.5-foot high by 35-foot wide radial gates. The gated structure is designed to release a maximum of 190,000 cubic-feet of water per second. A concrete stilling basin is located at the downstream toe of the service spillway. On the upstream side of the spillway, located at each abutment are dual level outlet works that are designed to deliver water for municipal and industrial purposes. The intake structure consist of two gates, each 48-inch by 60-inch, that pass water through two conduits to terminal structures. From here water is distributed through 60-inch diameter pipes.

A concrete intake structure provides for downstream releases. This structure includes multi-level intakes with one 8-foot by 8-foot gate and two 4-foot by 4-foot gates. The invert elevation of the lowest gate is at elevation 4.0 feet. All discharges that are released through the intake structure flow through an 8-foot by 8-foot conduit from the intake tower to the dam. The conduit increases in size to 8 feet by 10 feet from the dam to the downstream stilling basin. The maximum designed release through this structure is 1,800 cubic feet of water per second.

SURVEY EQUIPMENT

The equipment used to perform the volumetric survey consists of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Honda outboard motors. (Reference to brand names throughout this report does not imply endorsement by TWDB). The on-board electronic surveying equipment includes a Coastal Oceanographics, Inc. Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, Trimble Navigation, Inc. 4000SE GPS receiver, an OmniSTAR receiver, and a 486 computer. A water-cooled generator provides electrical power through an in-line uninterruptible power supply. In shallow areas and where navigational hazards (stumps) were present, a 20-foot aluminum shallow-draft flat bottom SeaArk craft with cabin equipped with one 115-horsepower Evinrude outboard motor was used. The portable data collection equipment on-board the shallow-draft boat included a Knudsen 320 B/P Echosounder (depth sounder), a Trimble Navigation, Inc. 4000SE GPS receiver, an OmniSTAR receiver, and a 486 laptop computer.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. The depth sounder acquires approximately ten bottom readings each second as the boat traverses the lake. The depth readings are stored on the laptop computer along with the corrected positional data generated by the boat's GPS receiver. The data files are downloaded from the computer each day and returned 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 get one data point per second, and average depths are converted to elevation readings based on the lake elevation recorded on the day the survey was performed. Accurate estimates of the lake volume can be quickly determined by building a 3-dimensional numerical model of the lake from the collected data.

PRE-SURVEY PROCEDURES

The reservoir's boundary was digitized using Environmental Systems Research Institute's (ESRI) Arcview from digital orthophoto quadrangle images (DOQ's). The DOQ's were 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 map boundary was created from the Ganado, Manson, and Louise, Texas DOQ's. The lake elevations at the time the DOQs were photographed were 43.78 feet (02/20/1995) for the Ganado and Manson DOQ's and 43.45 feet (01/24/1996) for the Louise DOQ. The DOQ graphic boundary files were transformed from UTM Zone 14 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 Coastal Oceanographics, Inc. HyPack software. The survey design required the use of approximately 421 survey lines along the length of the lake.

SURVEY PROCEDURES

Equipment Calibration and Operation

Each day prior to surveying the depth sounder was calibrated with the Innerspace 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 in the water column beneath 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 moisten and acclimate the probe. The probe was next raised to the water surface where the depth was zeroed. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised 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 the shallow draft boat the depth sounder was calibrated using the bar check feature in the Knudsen software program. This was performed by adjusting the speed of sound setting on the Knudsen echosounder until the displayed depth matched the manually measured depth. The manual measurement was obtained using a stadia (survey) rod.

While surveying Lake Texana, the speed of sound in the water column ranged from 4,880 feet per second to 4,955 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 $\pm$0.2 feet. An additional estimated error of $\pm$0.3 feet arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some readings are positive and some are negative. Further information on these calculations is presented in Appendix G.

During the survey, the horizontal mask setting on the on-board GPS receiver was set to 10°, and the PDOP (Position Dilution of Precision) limit was set to 7 to maximize the accuracy of the horizontal positioning. An internal alarm sounds if PDOP rises above seven to alert the field crew that the horizontal position has degraded to an unacceptable level. The lake's initialization file used by the Hypack data collection program was set up to convert the collected DGPS positions to state-plane coordinates on the fly.

Field Survey

TWDB staff collected data on Lake Texana for approximately eleven days during the period of August 9 - 23, 2000, again on November 28, 2000, and finally on January 24, 2001. Lake elevations dropped continuously from 42.25 feet msl on August 9, 2000, to 41.65 feet msl on August 23, 2000. Weather conditions during this period varied dramatically. At times conditions were hot with temperatures in the upper 90's, little or no wind, and a glass-smooth lake-surface. At other times, squalls formed from the east and south of the lake and generated strong winds, heavy lightning, and white caps on the lake. Data collection was suspended during these times until the storms passed.

The survey crew collected data along the entire perimeter of the lake and in those areas that had navigational obstructions using the shallow draft boat. The crew also used this boat to collect data in the upper reaches of the Navidad River, Sandy Creek, and Mustang Creek. Some inundated areas of the lake were too shallow or too overgrown with water hyacinths to allow data to be collected. These areas included Mustang Creek upstream of Highway 172 and the area upstream of U. S. Highway 59 known as the "Jungle". The larger boat was later used in the survey to collect data in the open (clear of obstructions) waters. During the August survey, data was collected on 351 of the 421 pre-plotted survey transects in the lake. Where possible, random data was collected in areas that were too restricted to drive the pre-plotted lines. Due to navigational obstructions and low lake-levels, the crew was only able to collect data along 20 of the original 34 sediment range lines.

TWDB staff returned to Lake Texana on November 28, 2000 to collect supplementary data on Mustang Creek upstream of Highway 172. The lake elevation at this time was 44.15 feet msl. Approximately 13 miles of data were collected on 40 pre-plotted lines that the crew could not access in August due to the water hyacinth. This data was then edited and added to the original data set collected in

August by TWDB. Over the entire survey, approximately 139,200 data points were collected over the 260 miles traveled. These points, shown in Figure 2, were stored digitally on the boat's computer in 623 data files.

The purpose of the January 24'th trip was to collect data in an area locally known as “Alligator Hole”, located in the northwest arm of the lake formed by the Navidad River. The lake was at elevation 44.15 feet msl at this time. Several random individual data points were collected in the deeper sections at this site.

The Navidad River flows in a north to south direction with Palmetto Bend Dam being located at the south end of the lake basin. TWDB staff observed the terrain surrounding the lake to have characteristics typical of the Coastal Plains. The topography to the east of the reservoir was generally flat while there was some elevation rise on the western shoreline. Mixed soil of sandy loam and clay was observed along the shoreline. Bank erosion was most prominent along the western shore near Brackenridge Plantation Recreation Area and Lake Texana State Park.

The majority of the land surrounding the lake perimeter is owned by the LNRA and is leased for cattle grazing or agricultural purposes. In the upper reaches of the Navidad River, Sandy and Mustang Creeks, the land surrounding the reaches was undeveloped. Only a few residences were observed near the perimeter of the lake. Lake Texana State Park is located approximately midway upstream of the dam and along the west bank of the lake. LNRA has preserved, developed, and maintained Brackenridge Plantation Recreation Area and Mustang Wilderness Campground. They have also established and maintain nine boat ramps around the lake. U.S. Highway 59 spans Lake Texana in the upper reaches of the basin while State Highway 111 crosses the lake midway between Highway 59 and Palmetto Bend Dam.

While performing the survey the field crew noted on the depth sounder chart that the lake bathymetry was fairly regular (no major drops or rises in the bathymetry) in the main basin of the lake between Highway 111 and Highway 59. Shallower depths were noted along the shoreline while deeper depths were observed when the boat crossed the old channel. A defined channel (thalweg) for the Navidad

River was still evident in the main basin of the lake. As the basin widened between Highway 111 and Palmetto Bend Dam, the old river channel began to meander in an east to west direction.

All collected data was stored in individual data files for each pre-plotted range line or random data collection event. These files were downloaded to diskettes at the end of the day for subsequent processing.

Data Processing

The collected data was downloaded from diskettes onto TWDB's computer network. Tape backups were made for future reference. To process the data, the EDIT routine in the Hypack Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from each file. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the August survey, the water surface varied from elevation 42.25 to 41.65 feet msl according to elevation data provided by USGS elevation gage (08164525 Lake Texana near Edna, Texas). The water surface elevation was 44.15 on November 28, 2000 when supplementary data was collected on Mustang Creek. After all corrections were applied to the raw data file, the edited file was saved with a different extension. The edited files were combined into a single (x, y, z) data file which was used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was downloaded to a Sun ULTRA 10 workstation running the UNIX operating system. Environmental System Research Institute's (ESRI) Arc/Info GIS 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 actual 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 presented in Appendix A and surface areas in Appendix B were calculated below elevation 44.0 feet msl from the TIN using Arc/Info software. Volumes above 44.0 feet in Appendix A are based on data obtained during the 1991 survey. Incremental increases in volume above 44.0 feet found in the 1991 survey were added to the volume at 44.0 feet found in the present survey. The areas presented in Appendix B above 44.0 feet were also obtained from the 1991 survey.

Other products developed from the model include a shaded elevation range 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 elevation contour map of the bottom surface at two-foot intervals is presented in Figure 5. Finally, 20 cross-sections, shown on the map in Figure 5, are presented in the plots in Appendix E and the corresponding coordinates are shown in Appendix F.

RESULTS

Results from the 2000 TWDB survey indicate that Lake Texana encompasses 9,727 surface acres and contains a total volume of 161,085 acre-feet at the conservation pool elevation of 44.0 feet msl (gage datum). Dead pool storage, the volume below elevation 15.0 feet msl is 7,839 acre-feet. Thus, the conservation storage (total volume - dead storage) for Lake Texana is 153,246 acre-feet. The shoreline at conservation pool elevation was calculated to be approximately 126 miles. The deepest point of the lake, at elevation -18.9 msl and corresponding to a depth of 62.9 feet, was located approximately 773 feet upstream from the Palmetto Bend Dam in the old streambed.

SUMMARY AND COMPARISONS

Lake Texana was initially impounded in 1980. Storage calculations in 1980 (U.S. Department of the Interior, 1992) reported the volume at conservation pool elevation 44.0 feet msl to be 165,918 acre-feet with a surface area of 9,934 acres. The dead pool below elevation 15.0 feet msl was reported as

8,034 acre-feet, giving a conservation storage of 157,884 acre-feet.

In 1991 the Bureau of Reclamation performed a sedimentation survey of Lake Texana. Storage calculations in 1991 (U.S. Department of the Interior, 1992) reported the volume at conservation pool elevation 44.0 feet msl to be 163,506 acre-feet with a surface area of 10,134 acres. The dead pool below elevation 15.0 feet msl was reported as 7,963 acre-feet, and thus the conservation storage was 155,543 acre-feet.

In August 2000, TWDB staff completed a volumetric survey of Lake Texana utilizing differential global positioning system and geographical information system technologies to create a digital model of the lake's bathymetry. Results indicate that the lake's volume at the conservation pool elevation of 44.0 feet msl is 161,085 acre-feet, with a corresponding area of 9,727 acres. The dead pool below elevation 15.0 feet was found to be 7,839 acre-feet, and thus the conservation storage found in this survey is 153,246 acre-feet.

Comparing the original design data with results from the current survey (Table 1), the surface area at conservation pool elevation 44.0 feet msl decreased by 207 surface acres. The reduction in volume at conservation pool elevation is 4,833 acre-feet (-2.9%) or 242 acre-feet/year (since 1980). The average annual deposition rate of sediment in the lake can be estimated at 0.17 acre-feet/square mile of drainage area.

Comparing the findings from the 1991 sediment survey and the current survey, the surface area at conservation pool elevation 44.0 feet msl decreased by 407 surface acres. The reduction in volume at conservation pool elevation is 2,421 acre-feet (-1.5%) or 269 acre-feet/year (since 1991). The average annual deposition rate of sediment in the lake can be estimated at 0.19 acre-feet/square mile of drainage area.

Based on the amount of data collected and the improved methods and technology used in the current survey, the current data set is considered to be an improvement over previous survey procedures. It is recommended that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage volume.

Table 1. Area and volume comparisons at elevation 44.0 feet msl.

Year	1980	1991	2000
Area (acres)	9,934	10,134	9,727
Volume (acre-feet)	165,918	163,506	161,085

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Appendix A

Lake Texana

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — August 2000 SURVEY

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

ELEVATION in Feet	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0
-18	0	0	0	0	0	0	0	0	0	0
-17	0	0	0	0	0	0	0	0	0	0
-16	0	0	0	0	0	0	0	0	0	0
-15	0	0	0	0	0	0	0	0	0	0
-14	0	0	0	0	0	0	0	0	0	0
-13	0	0	0	0	0	0	0	1	1	1
-12	1	1	1	1	1	1	1	1	1	1
-11	1	1	1	1	1	1	1	2	2	2
-10	2	2	2	2	2	2	2	2	3	3
-9	3	3	3	3	3	3	4	4	4	4
-8	4	4	4	5	5	5	5	5	6	6
-7	6	6	6	7	7	7	7	7	8	8
-6	8	8	9	9	9	10	10	10	11	11
-5	11	12	12	12	13	13	13	14	14	15
-4	15	15	16	16	17	17	18	18	19	20
-3	20	21	21	22	23	24	24	25	26	27
-2	27	28	29	30	31	32	33	34	35	37
-1	38	39	40	42	43	45	46	48	49	51
0	52	54	56	58	60	62	64	66	68	70

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	70	73	75	77	80	83	85	88	91	94
1	97	100	103	107	110	114	117	121	125	129
2	133	137	142	146	151	155	160	165	170	175
3	181	186	192	198	204	210	216	223	229	236
4	243	250	257	265	272	280	288	297	305	314
5	323	332	341	351	361	371	381	392	403	414
6	426	438	450	463	476	490	504	518	533	549
7	565	582	600	618	638	658	679	701	724	749
8	775	802	831	861	892	925	960	997	1035	1076
9	1118	1161	1207	1254	1304	1355	1409	1465	1522	1583
10	1645	1710	1776	1845	1916	1990	2066	2145	2227	2311
11	2398	2488	2579	2673	2770	2868	2969	3073	3179	3287
12	3398	3510	3626	3743	3863	3986	4111	4238	4368	4500
13	4634	4771	4909	5051	5195	5341	5490	5641	5795	5951
14	6110	6271	6435	6601	6770	6942	7116	7293	7472	7654
15	7839	8026	8216	8409	8604	8801	9001	9204	9409	9617
16	9827	10040	10256	10474	10694	10918	11143	11372	11603	11836
17	12072	12310	12550	12793	13039	13286	13536	13788	14042	14299
18	14558	14819	15083	15349	15617	15888	16160	16435	16711	16990
19	17271	17555	17840	18128	18417	18709	19003	19298	19596	19895
20	20197	20500	20806	21113	21423	21734	22048	22364	22682	23002
21	23324	23647	23973	24300	24630	24960	25293	25627	25964	26302
22	26642	26984	27328	27674	28022	28372	28724	29077	29432	29789
23	30149	30510	30873	31239	31607	31977	32349	32724	33100	33479
24	33860	34243	34628	35016	35406	35798	36192	36589	36988	37389
25	37792	38197	38604	39014	39425	39839	40254	40672	41092	41514
26	41937	42363	42791	43220	43652	44086	44521	44959	45399	45840
27	46284	46729	47177	47626	48077	48530	48984	49441	49900	50360
28	50823	51287	51754	52223	52694	53168	53644	54123	54603	55087
29	55573	56061	56553	57046	57543	58042	58543	59048	59554	60064
30	60576	61090	61607	62127	62649	63174	63701	64231	64764	65299
31	65836	66376	66919	67465	68013	68564	69117	69672	70230	70791
32	71353	71918	72485	73054	73626	74199	74776	75355	75936	76519
33	77105	77693	78283	78876	79471	80070	80670	81274	81882	82492
34	83106	83723	84343	84966	85593	86224	86858	87496	88137	88782
35	89431	90082	90737	91396	92057	92722	93391	94062	94737	95415

Appendix A (continued)

Lake Texana

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — August 2000 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
36	96096	96780	97467	98157	98850	99546	100246	100949	101656	102366
37	103080	103796	104517	105241	105968	106699	107433	108171	108912	109657
38	110405	111156	111911	112670	113432	114197	114966	115739	116515	117295
39	118078	118865	119655	120448	121245	122045	122849	123656	124467	125280
40	126098	126918	127743	128570	129400	130232	131068	131905	132746	133588
41	134434	135282	136132	136986	137841	138700	139562	140426	141293	142163
42	143036	143911	144790	145671	146555	147442	148332	149224	150120	151018
43	151919	152823	153730	154639	155551	156467	157385	158306	159229	160156
44	161085									
45	161085*									
47	194678*									
50	237224*									

*Reservoir volumes based on 1991 survey

Appendix B

Lake Texana

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — August 2000 SURVEY

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0
-18	0									
-17	0	0	0	0	0	0	0	0	0	0
-16	0	0	0	0	0	0	0	0	0	0
-15	0	0	0	0	0	0	0	0	0	0
-14	0	0	0	0	0	0	0	0	0	0
-13	0	0	0	0	0	0	0	0	0	0
-12	0	0	0	0	0	0	0	1	1	1
-11	1	1	1	1	1	1	1	1	1	1
-10	1	1	1	1	1	1	1	1	1	1
-9	1	1	1	1	1	1	1	1	1	2
-8	2	2	2	2	2	2	2	2	2	2
-7	2	2	2	2	2	2	2	2	2	3
-6	3	3	3	3	3	3	3	3	3	3
-5	3	3	4	4	4	4	4	4	4	4
-4	4	5	5	5	5	5	5	6	6	6
-3	6	6	7	7	7	7	7	8	8	8
-2	9	9	9	10	10	10	11	11	11	12
-1	12	13	13	14	14	15	15	16	16	17
0	17	18	18	19	19	20	21	21	22	23

	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	23	24	24	25	26	27	28	28	29	30
1	31	32	33	34	35	36	37	38	39	40
2	42	43	44	45	46	48	49	50	52	53
3	54	56	57	59	60	62	64	65	67	69
4	70	72	74	76	78	80	82	84	86	88
5	90	93	95	98	100	103	106	109	112	115
6	118	122	125	129	133	138	143	148	154	159
7	166	172	180	188	197	207	217	228	239	252
8	266	279	293	308	323	340	357	375	394	411
9	429	447	466	484	504	524	546	568	591	613
10	634	656	678	701	724	750	776	803	830	857
11	881	904	928	952	976	999	1023	1047	1070	1094
12	1117	1141	1165	1189	1213	1238	1262	1285	1308	1331
13	1354	1377	1400	1426	1451	1476	1500	1525	1550	1575
14	1600	1626	1651	1677	1702	1728	1754	1780	1807	1834
15	1861	1886	1912	1937	1963	1988	2014	2040	2065	2090
16	2116	2142	2168	2194	2220	2245	2270	2296	2321	2346
17	2370	2393	2417	2441	2464	2486	2509	2532	2555	2578
18	2601	2625	2649	2671	2693	2715	2735	2756	2778	2800
19	2822	2843	2865	2886	2907	2927	2946	2965	2985	3005
20	3025	3045	3065	3086	3106	3127	3148	3169	3189	3209
21	3228	3246	3265	3283	3300	3318	3335	3353	3372	3392
22	3413	3432	3451	3470	3488	3506	3525	3543	3562	3582
23	3602	3623	3645	3668	3690	3712	3734	3756	3777	3799
24	3820	3842	3863	3886	3909	3932	3955	3978	4000	4021
25	4042	4063	4083	4104	4124	4145	4166	4187	4208	4227
26	4247	4267	4287	4307	4327	4347	4367	4387	4406	4426
27	4444	4464	4483	4501	4519	4538	4556	4576	4596	4616
28	4636	4657	4679	4701	4725	4748	4773	4797	4822	4847
29	4873	4899	4925	4951	4976	5002	5029	5056	5081	5106
30	5132	5158	5184	5210	5236	5261	5286	5311	5337	5362

Appendix B (continued)

Lake Texana

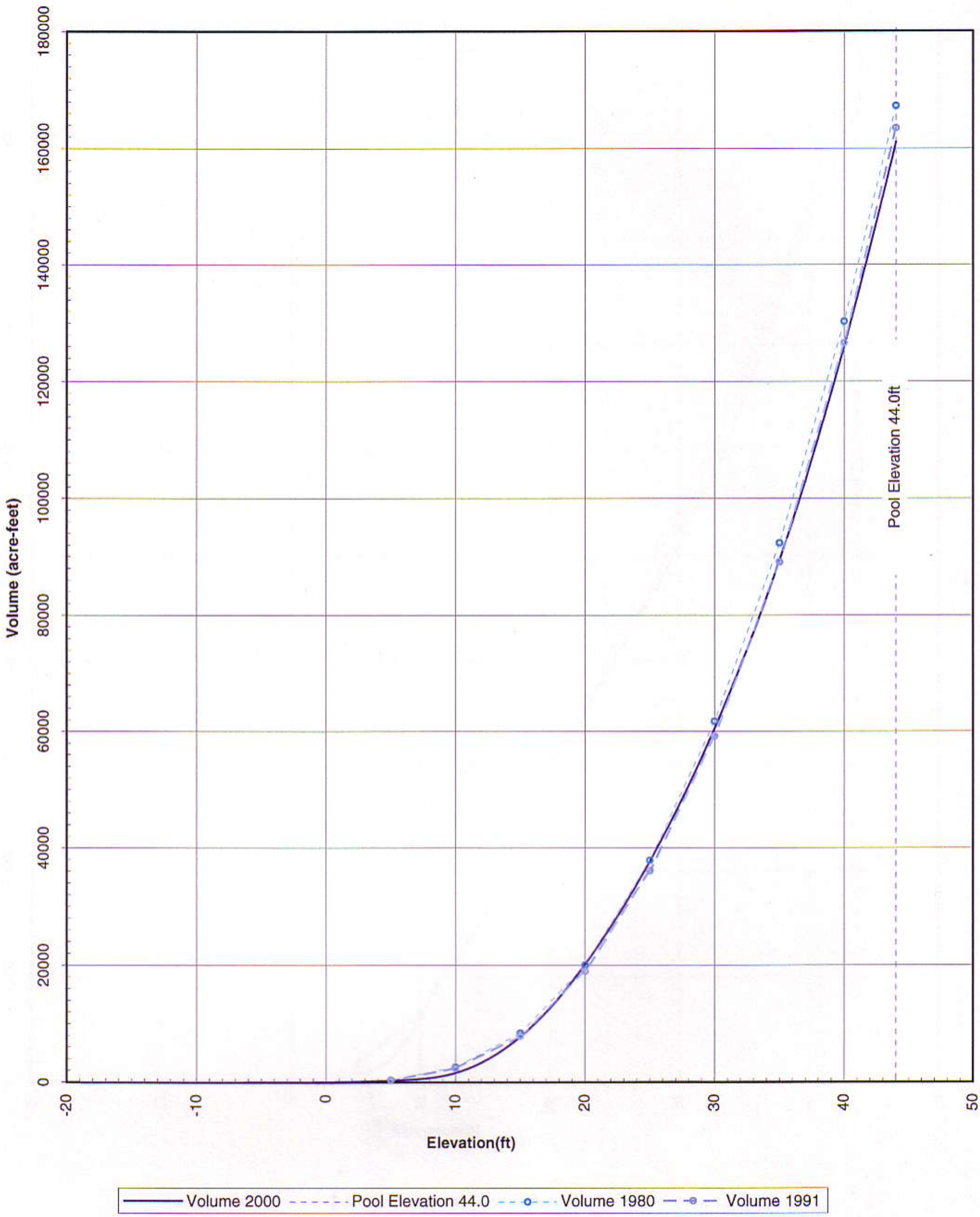
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — August 2000 SURVEY

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

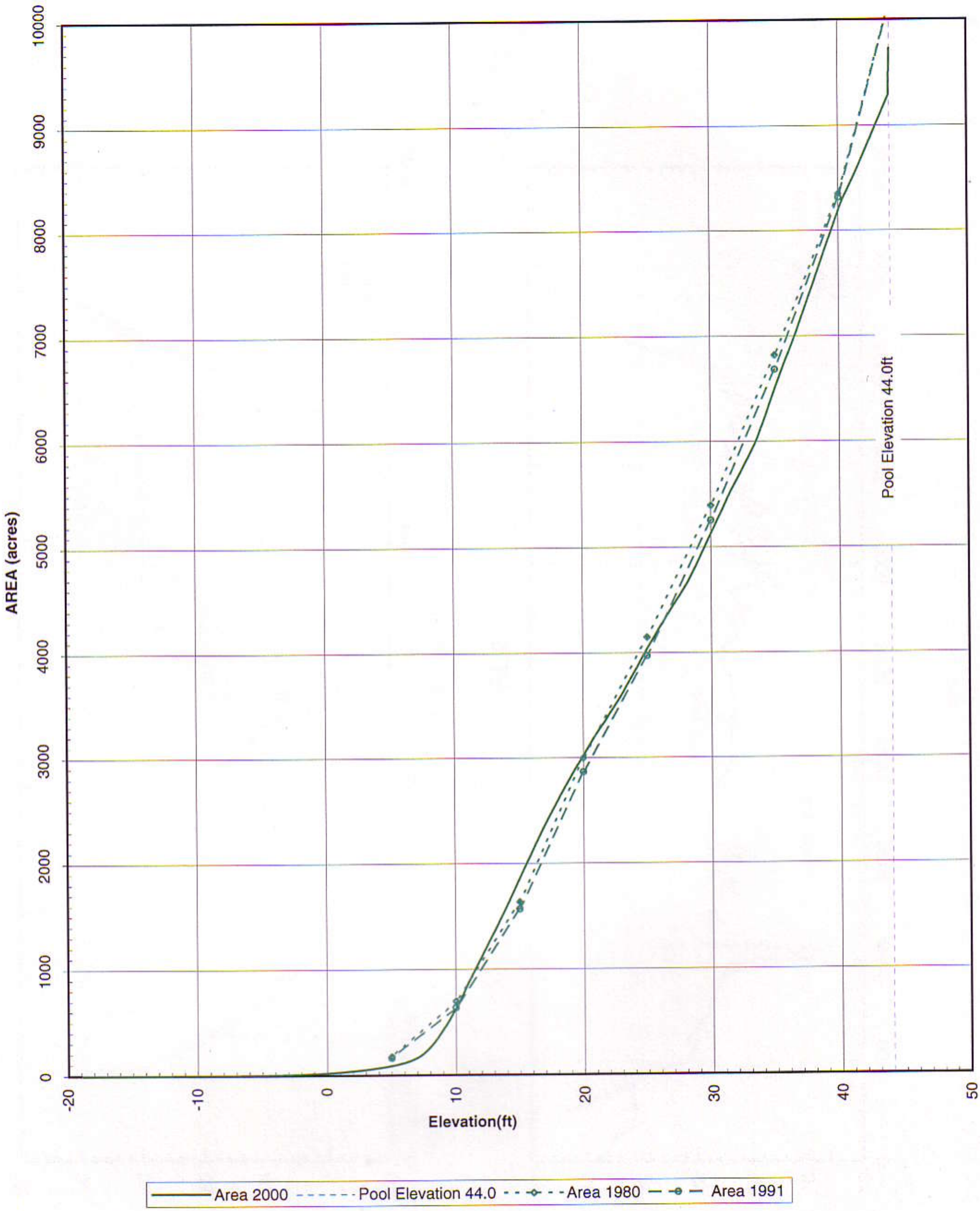
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
31	5389	5416	5443	5469	5495	5519	5544	5567	5591	5613
32	5636	5658	5681	5704	5727	5751	5776	5799	5822	5845
33	5868	5893	5917	5942	5967	5995	6024	6055	6088	6121
34	6154	6186	6218	6252	6287	6324	6361	6396	6431	6466
35	6500	6534	6567	6600	6634	6666	6699	6731	6763	6794
36	6824	6855	6885	6917	6948	6981	7015	7049	7083	7118
37	7152	7186	7221	7256	7291	7325	7360	7395	7430	7464
38	7499	7534	7568	7603	7638	7673	7709	7744	7780	7815
39	7849	7884	7917	7951	7986	8020	8055	8088	8122	8156
40	8190	8228	8257	8286	8313	8340	8365	8391	8416	8441
41	8467	8492	8517	8542	8567	8593	8618	8643	8669	8694
42	8719	8745	8770	8795	8821	8846	8872	8897	8923	8948
43	8974	9000	9025	9051	9076	9102	9128	9153	9179	9205
44	9727									
45	10589*									
47	12642*									
50	15722*									

*Reservoir areas from 1991 survey



Lake Texana
August 2000
Prepared by: TWDB

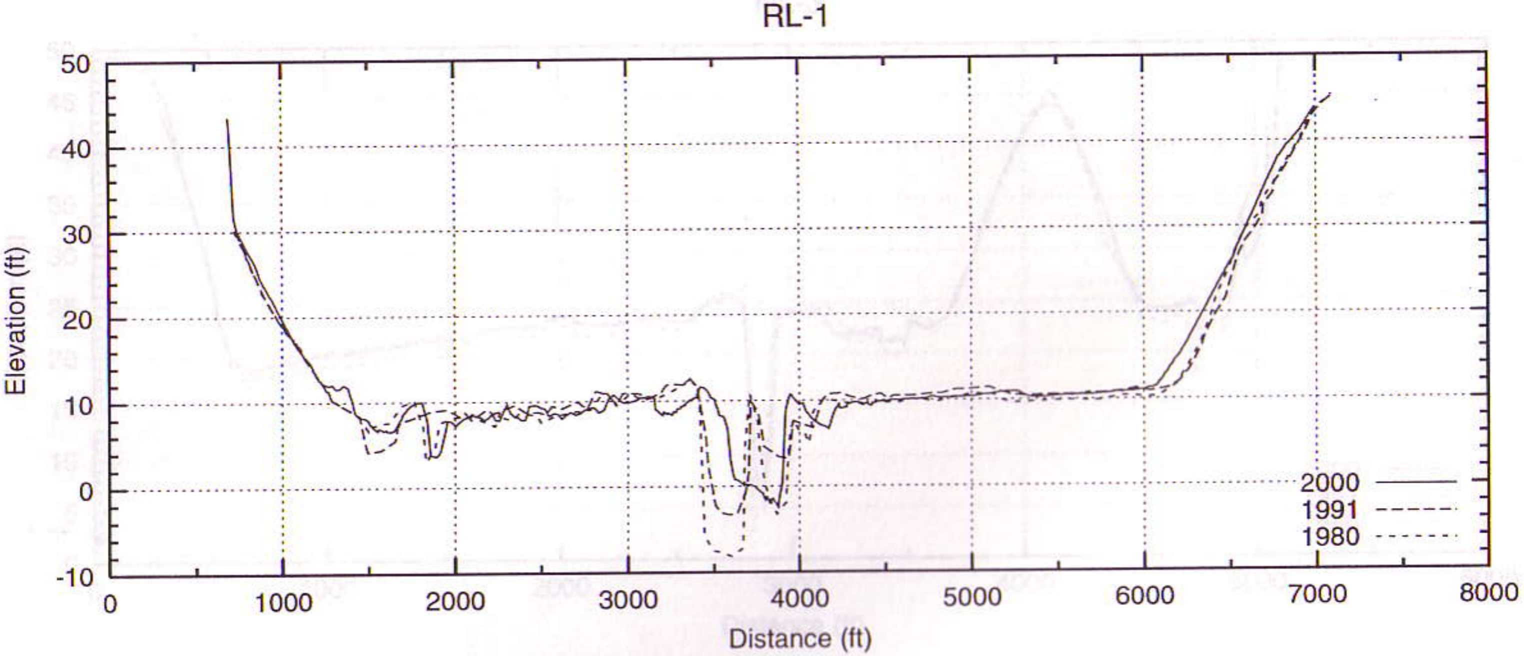
Appendix C Elevation vs. Volume

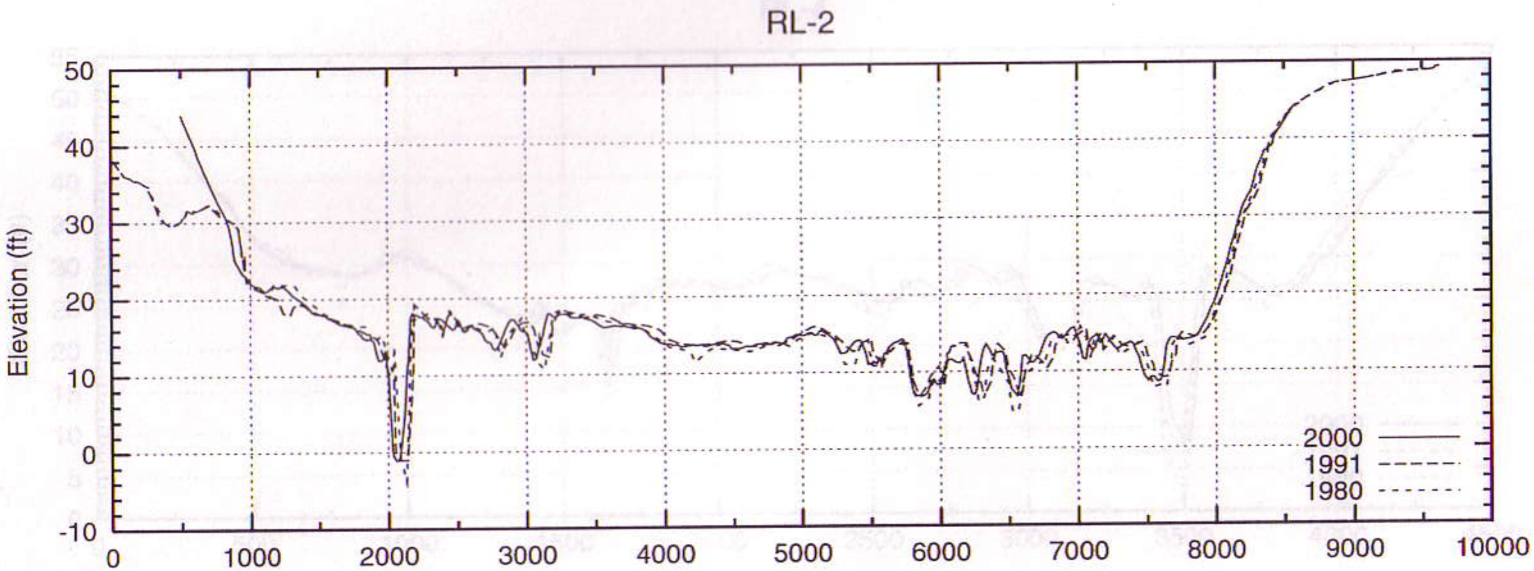


Lake Texana
August 2000
Prepared by: TWDB

Appendix D Elevation vs. Area

Lake Texana

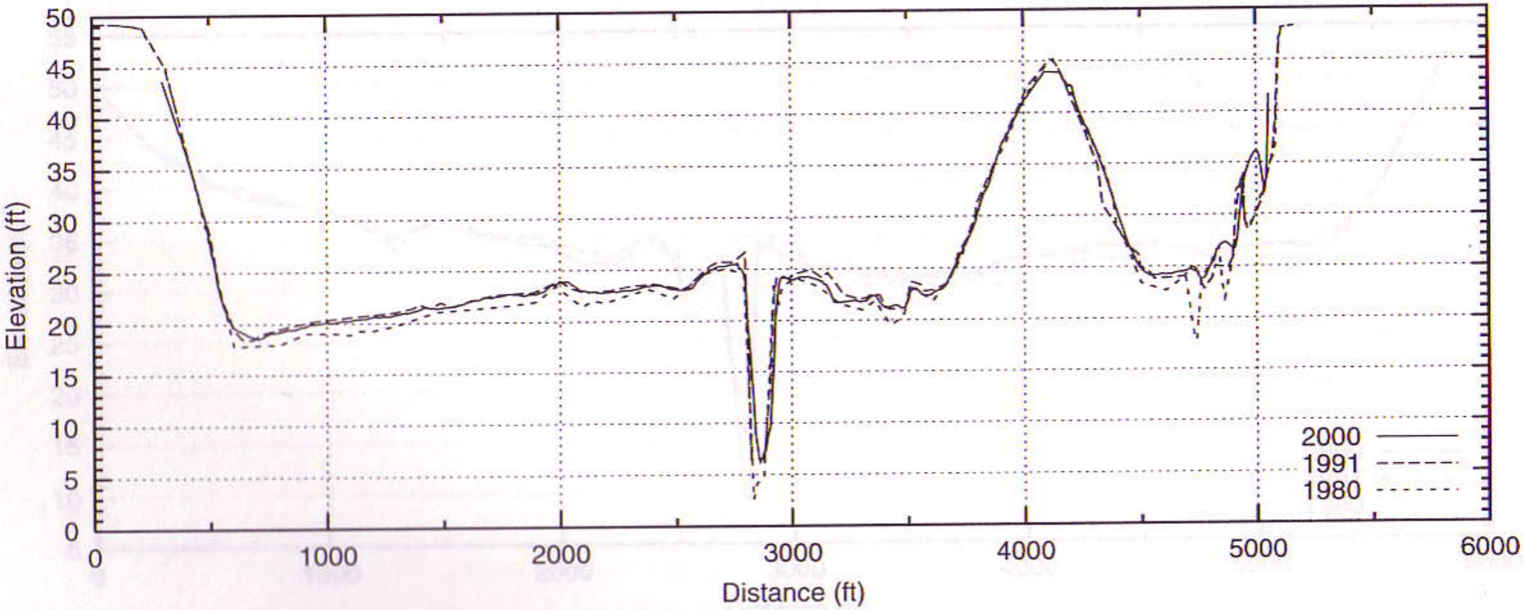




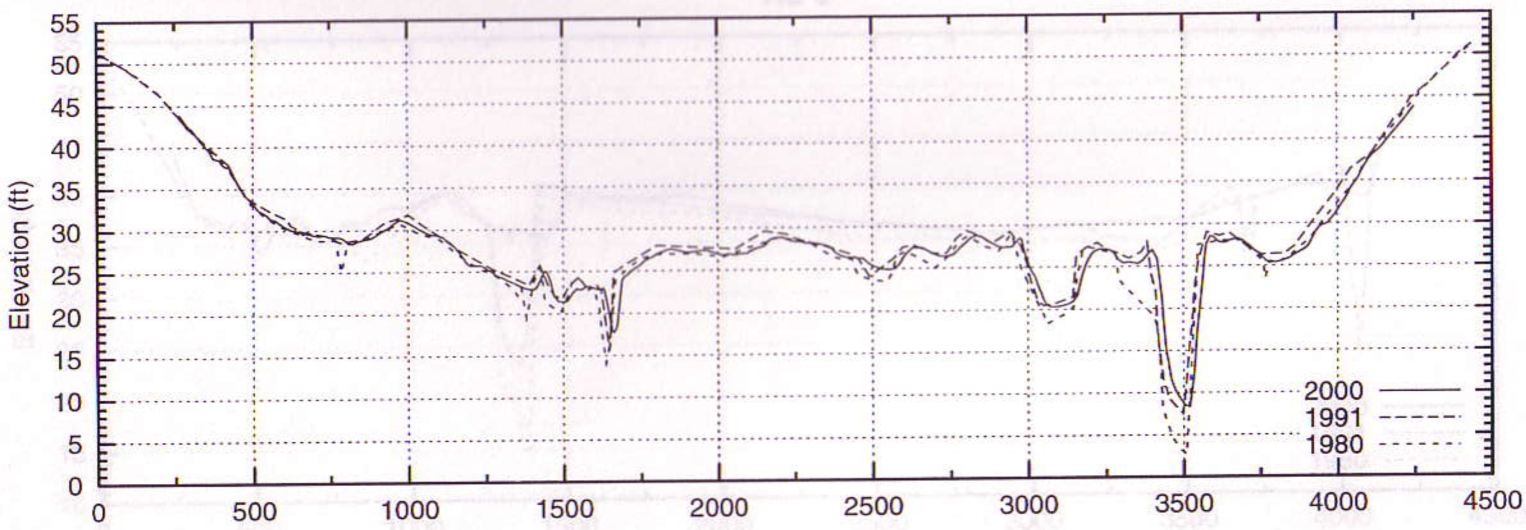
Distance (ft)

Lake Texana

RL-3

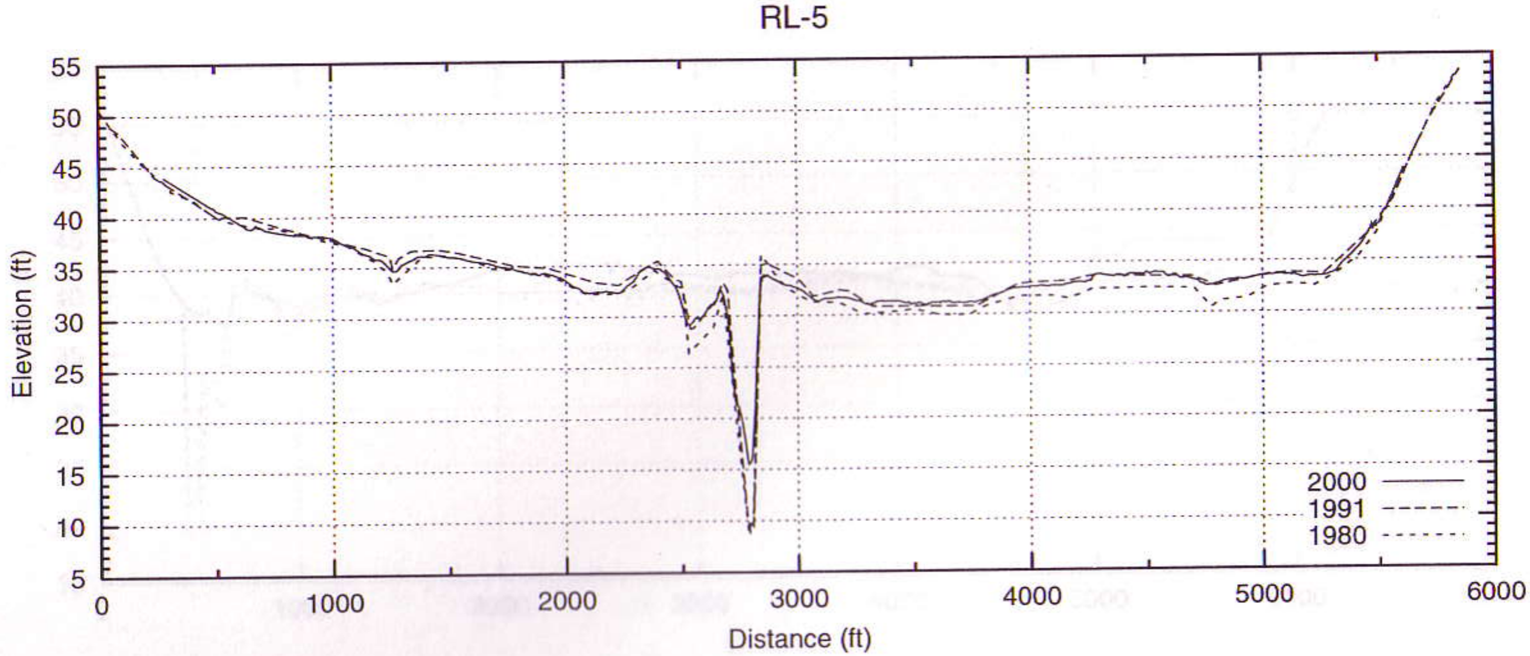


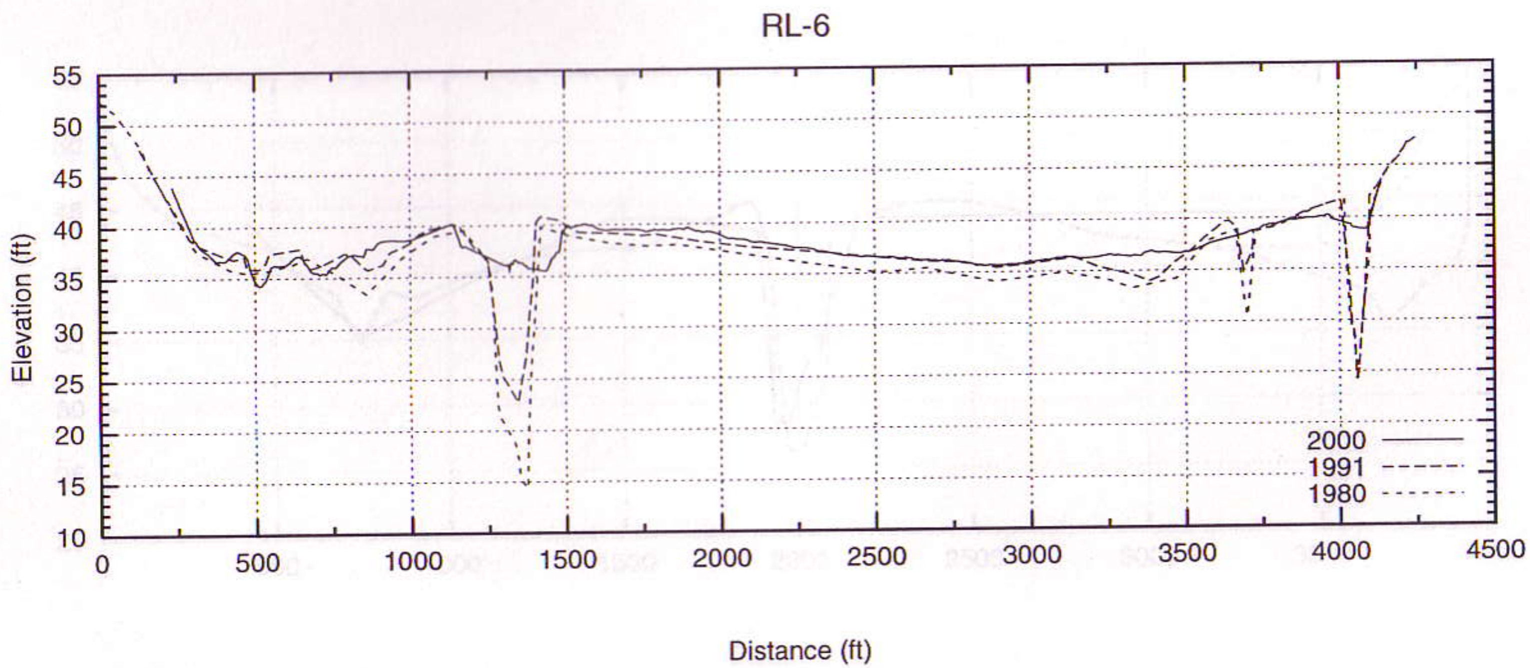
RL-4



Distance (ft)

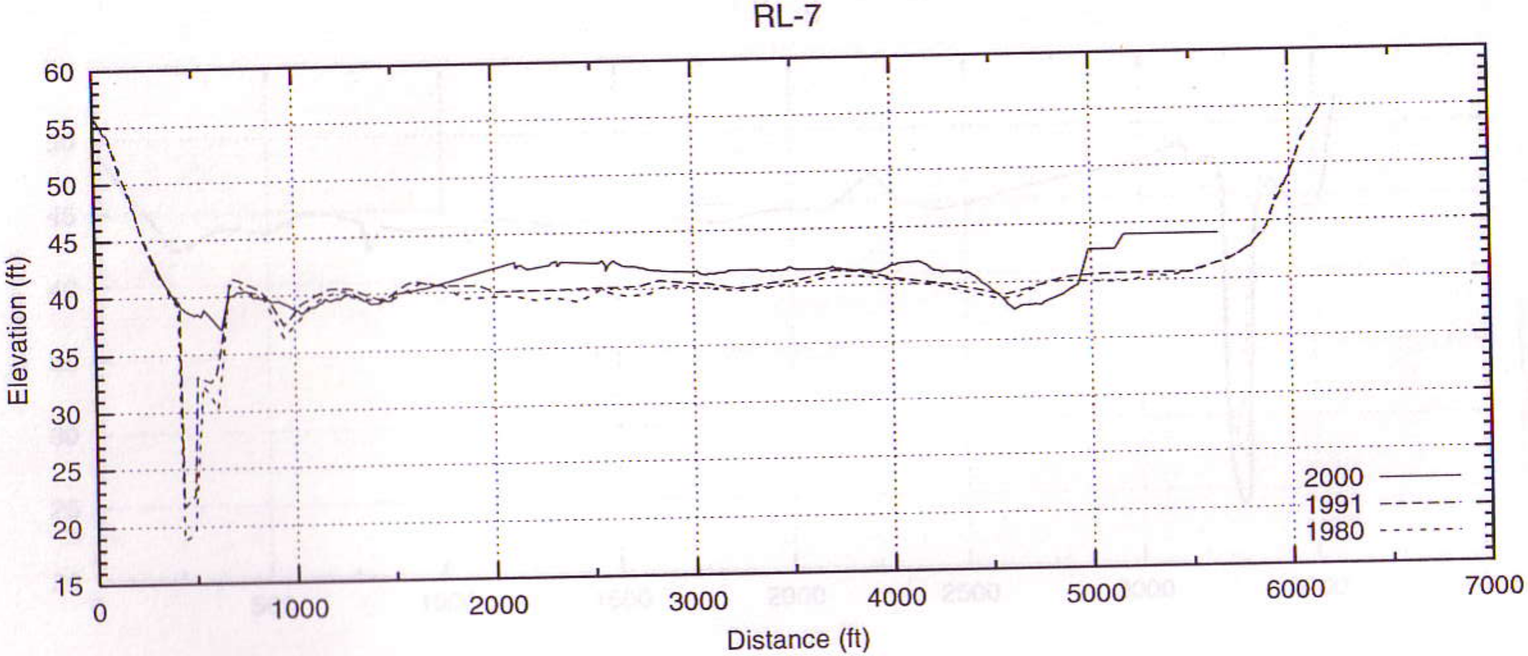
Lake Texana

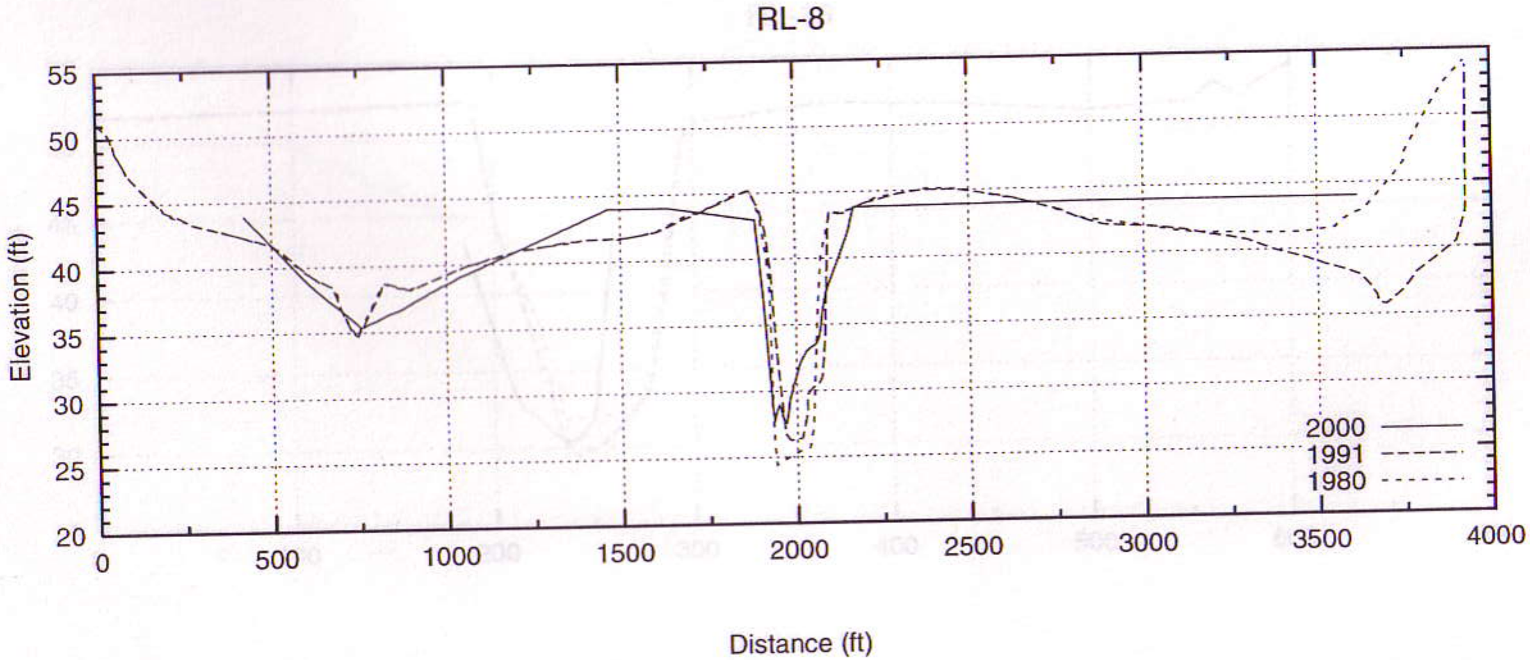




Appendix E

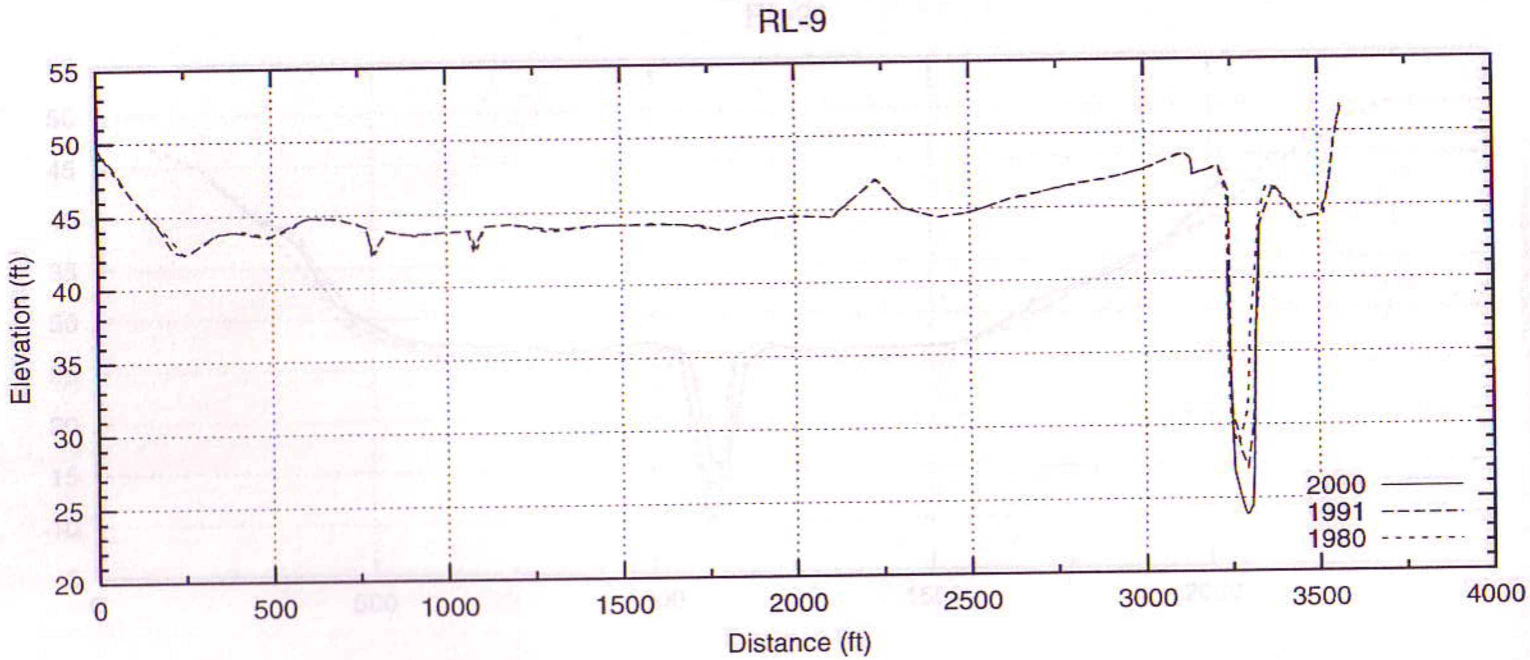
Lake Texana

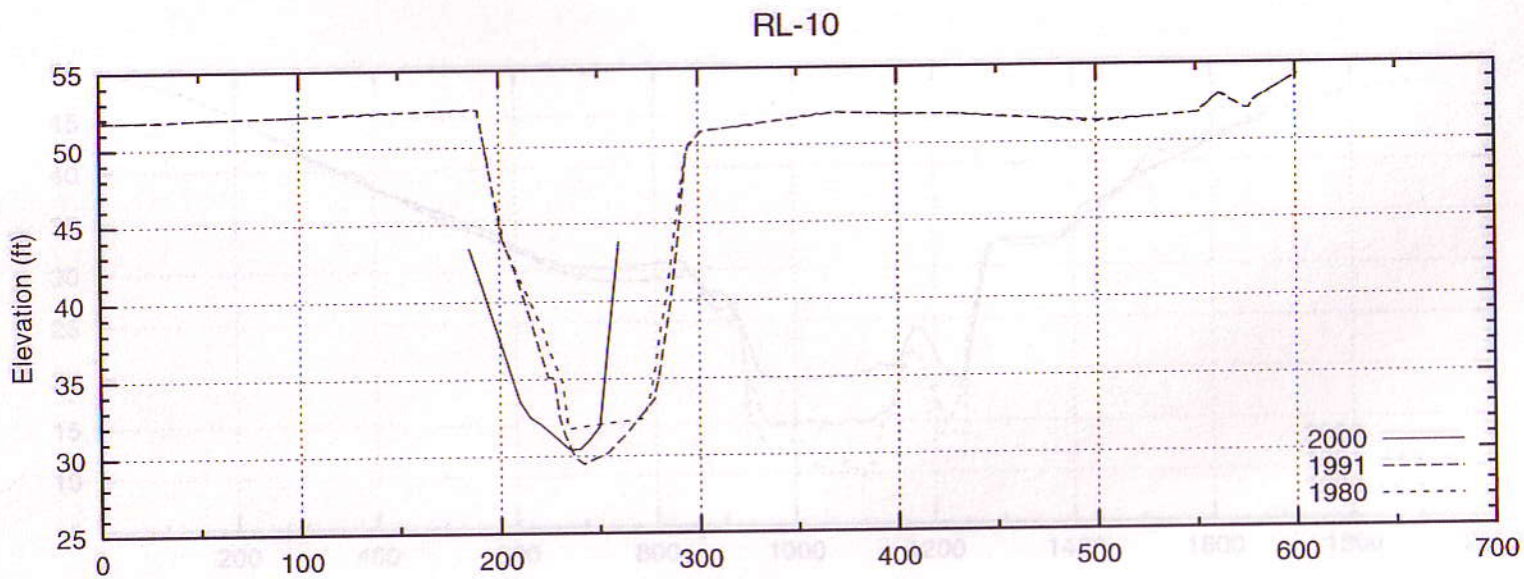




Appendix E

Lake Texana

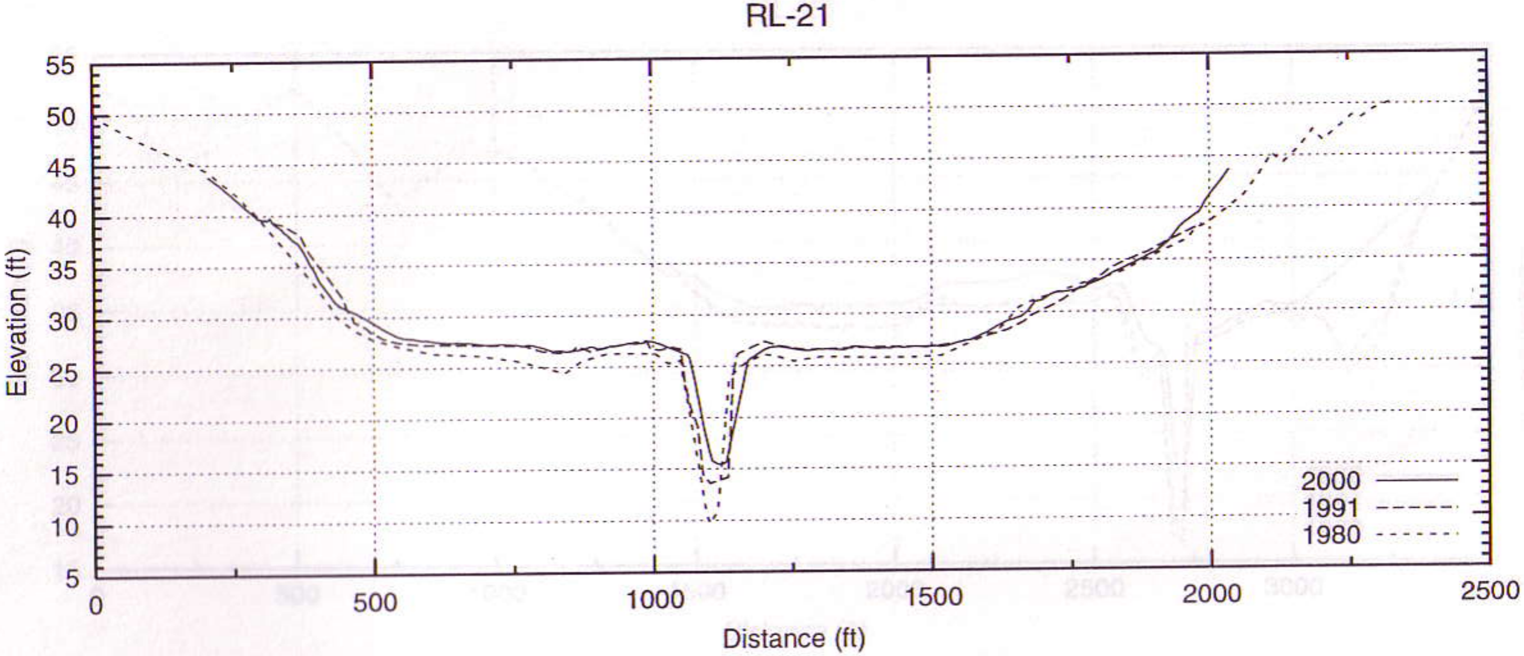




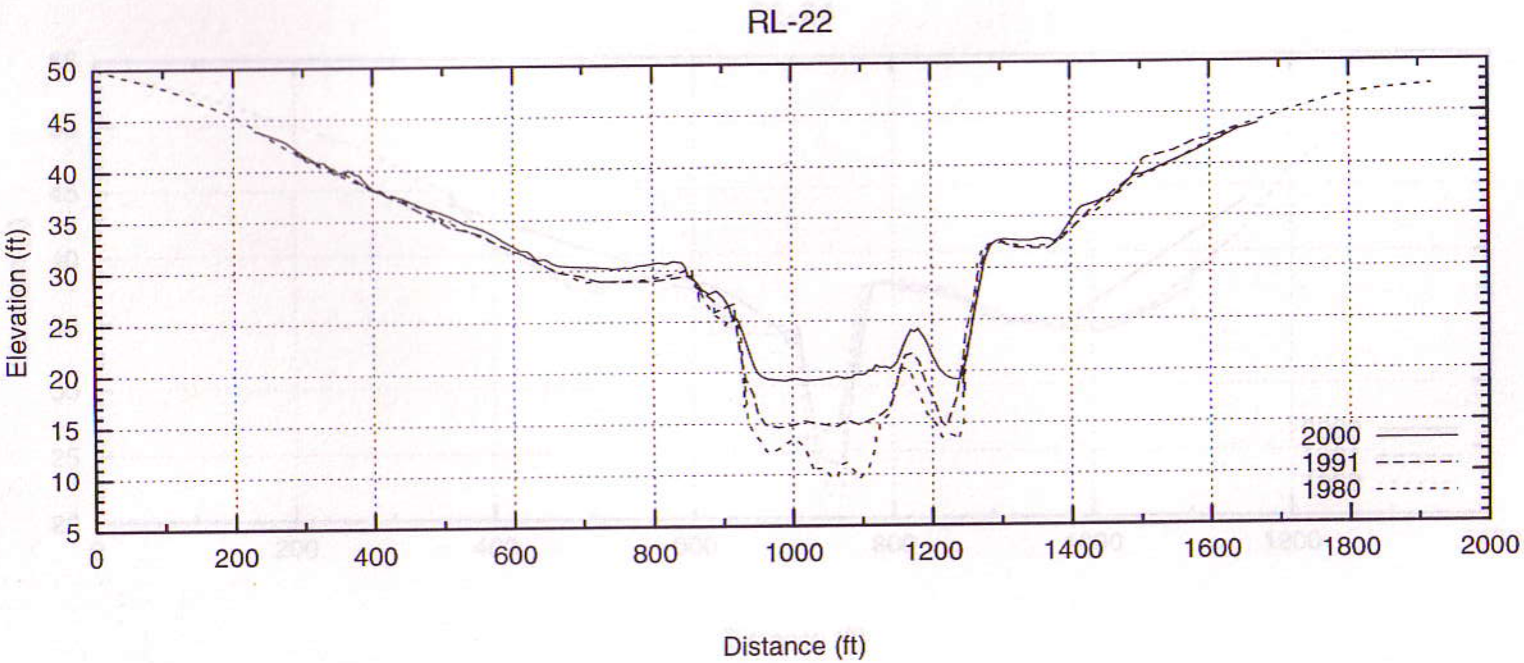
Distance (ft)

Appendix E

Lake Texana



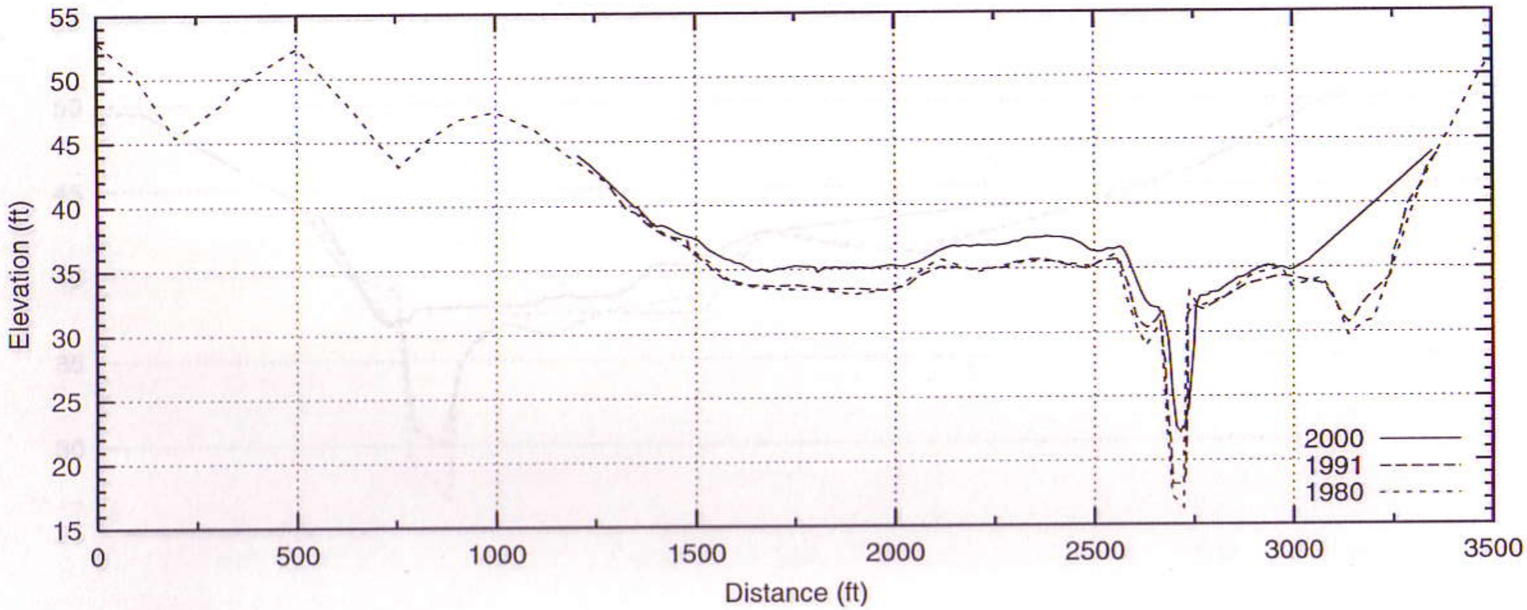
RL-21
Elevation (ft)
Distance (ft)
55
50
45
40
35
30
25
20
15
10
5
0
500
1000
1500
2000
2500
2000
1991
1980



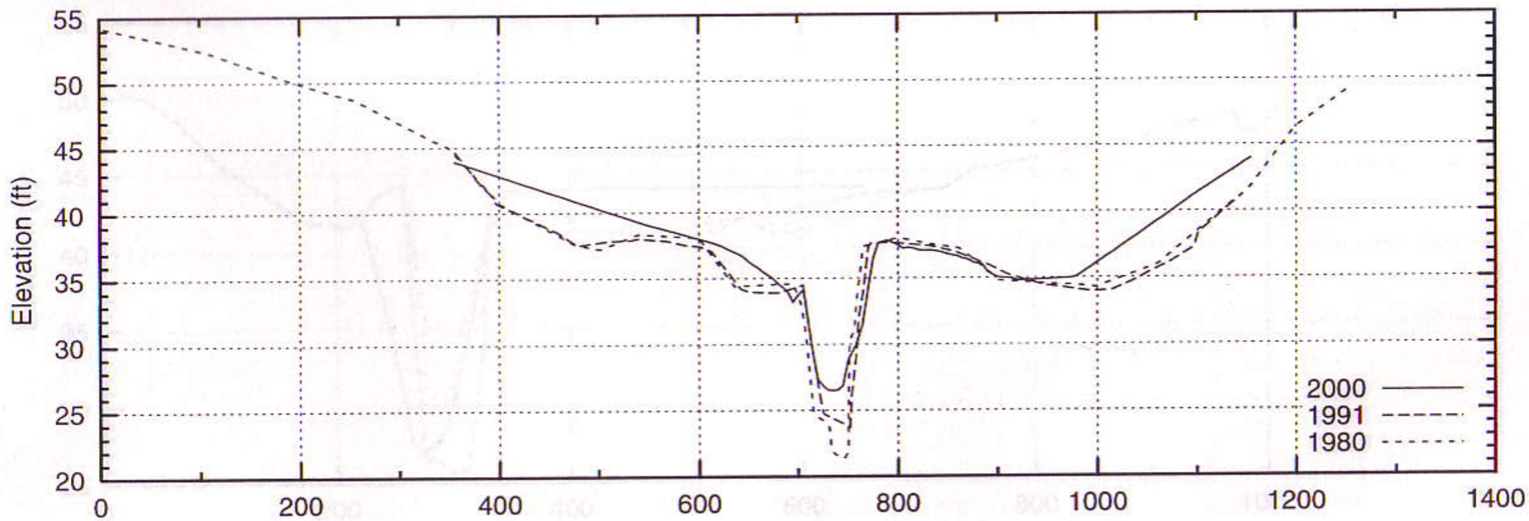
RL-22
Elevation (ft)
50
45
40
35
30
25
20
15
10
5
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2000
1991
1980
Distance (ft)

Lake Texana

RL-23



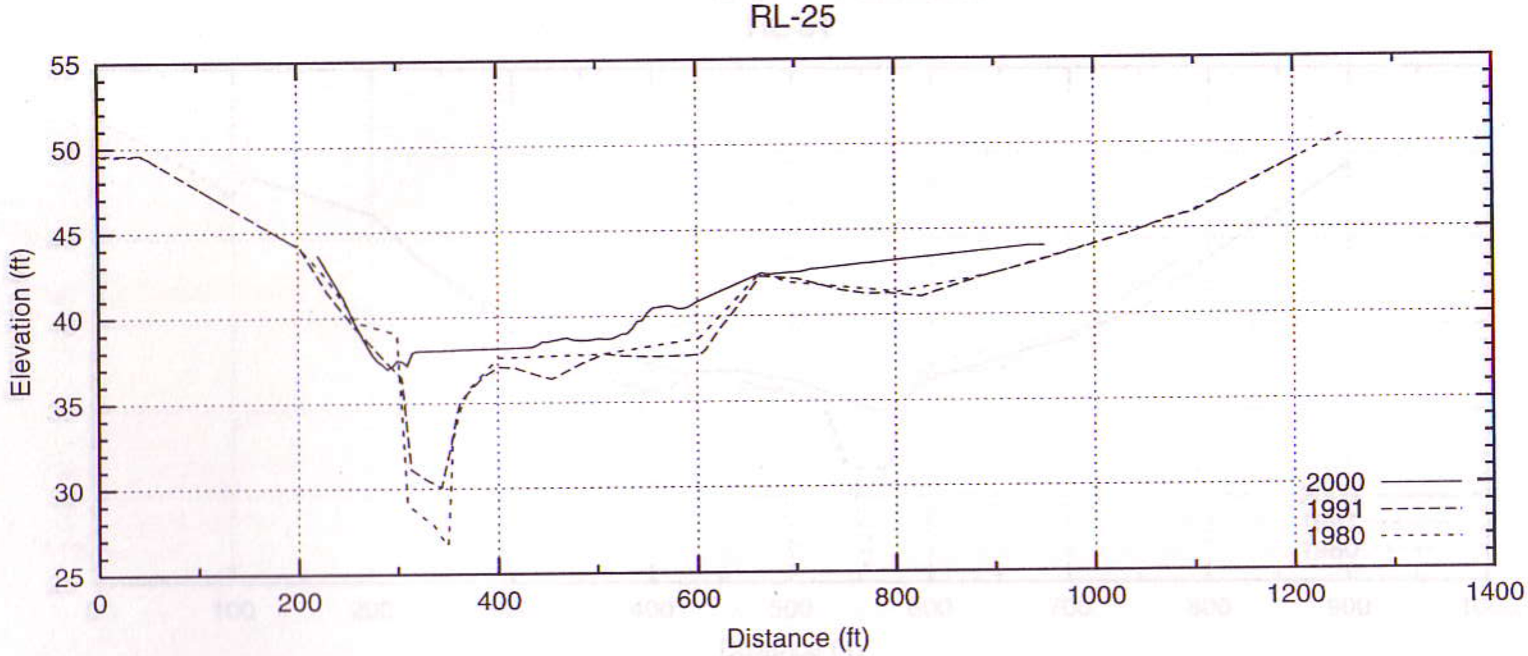
RL-24

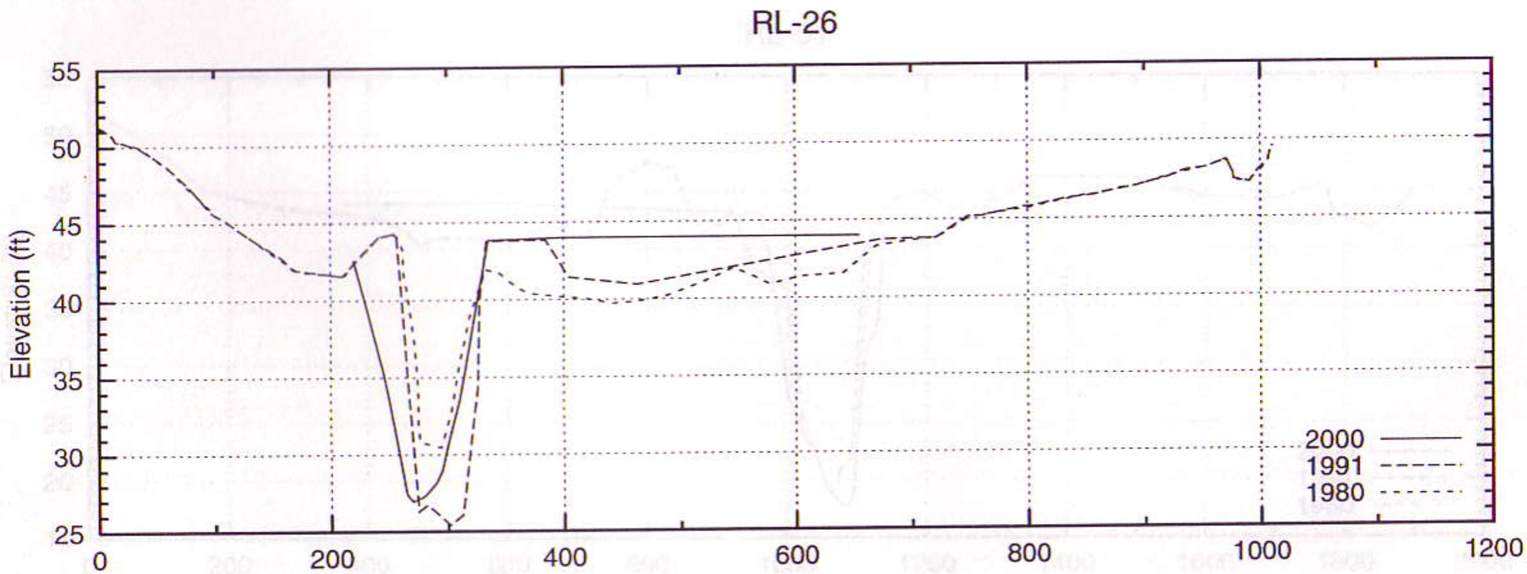


Distance (ft)

Appendix E

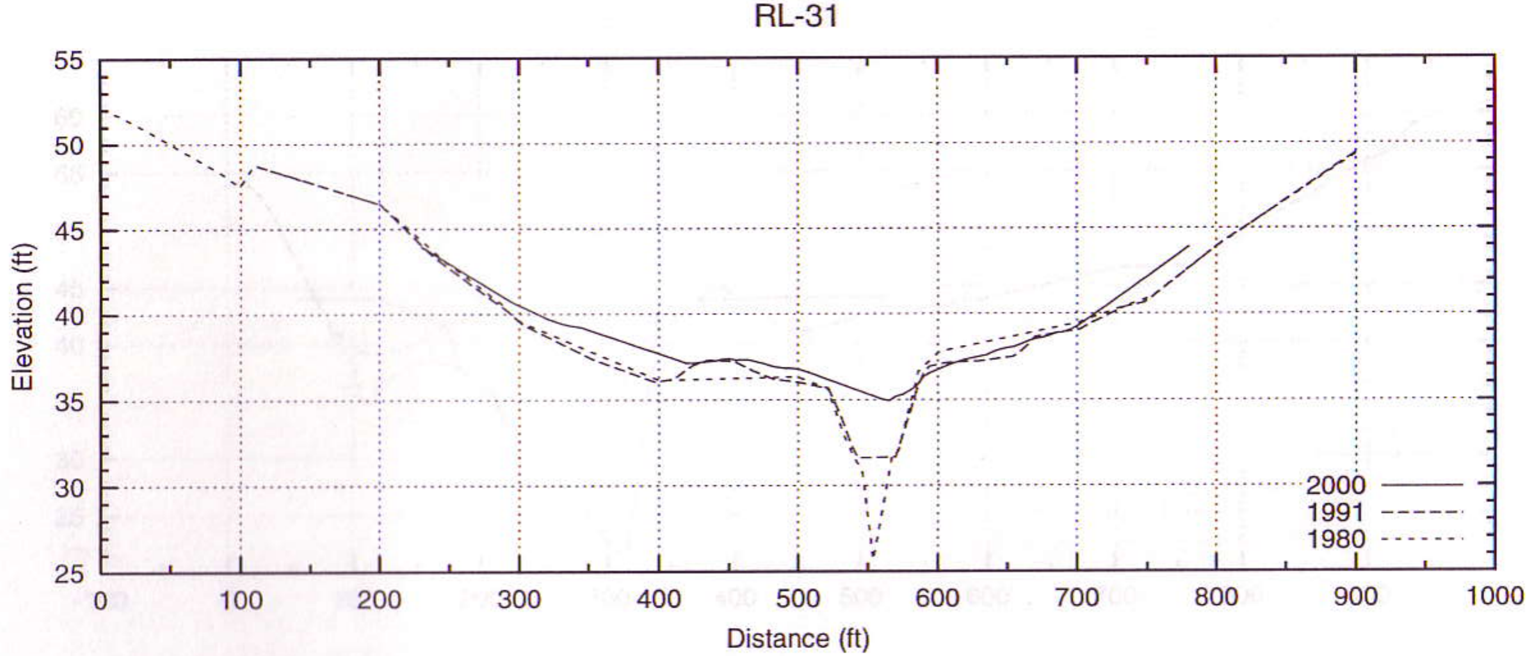
Lake Texana

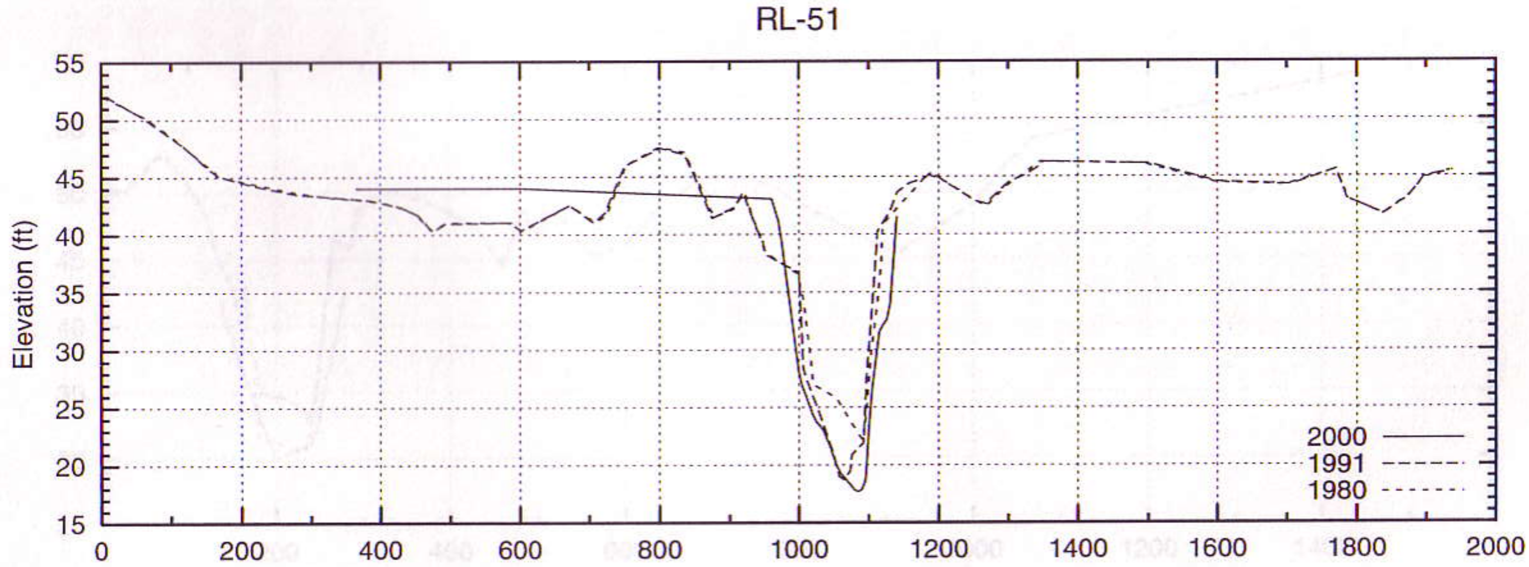




Distance (ft)

Lake Texana



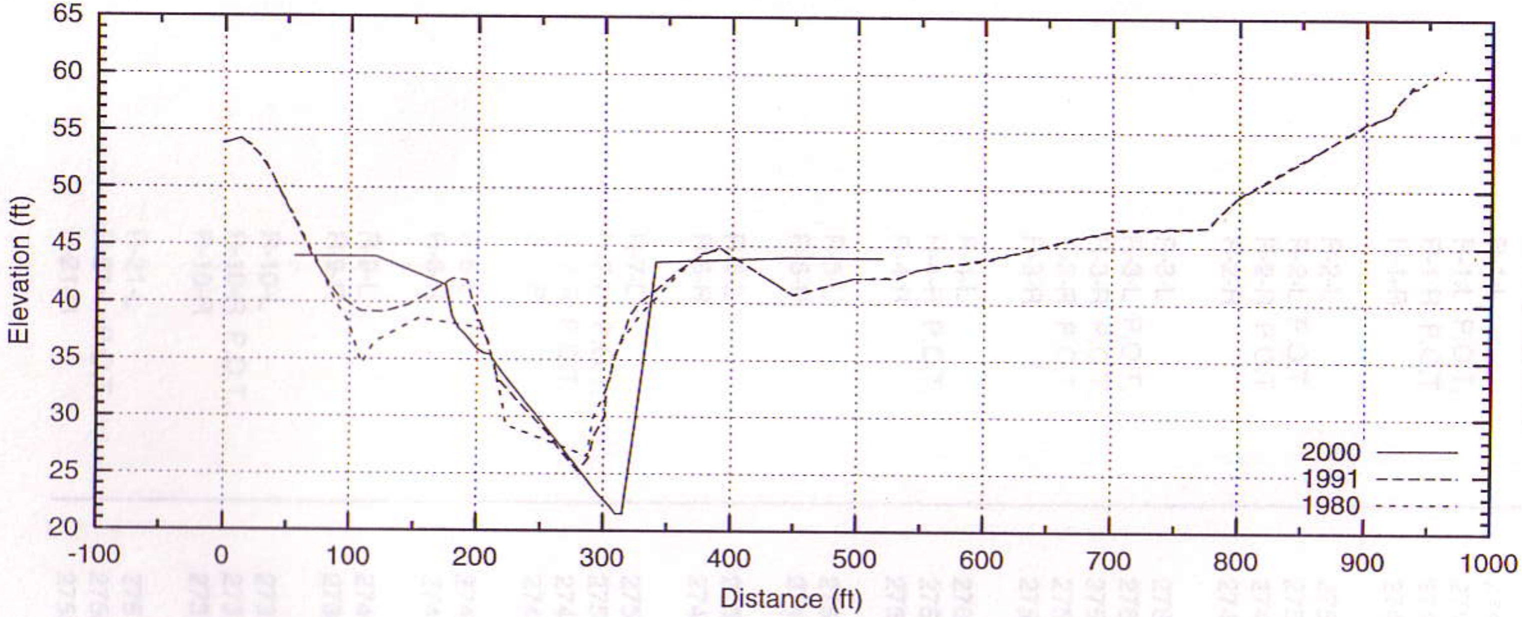


Distance (ft)

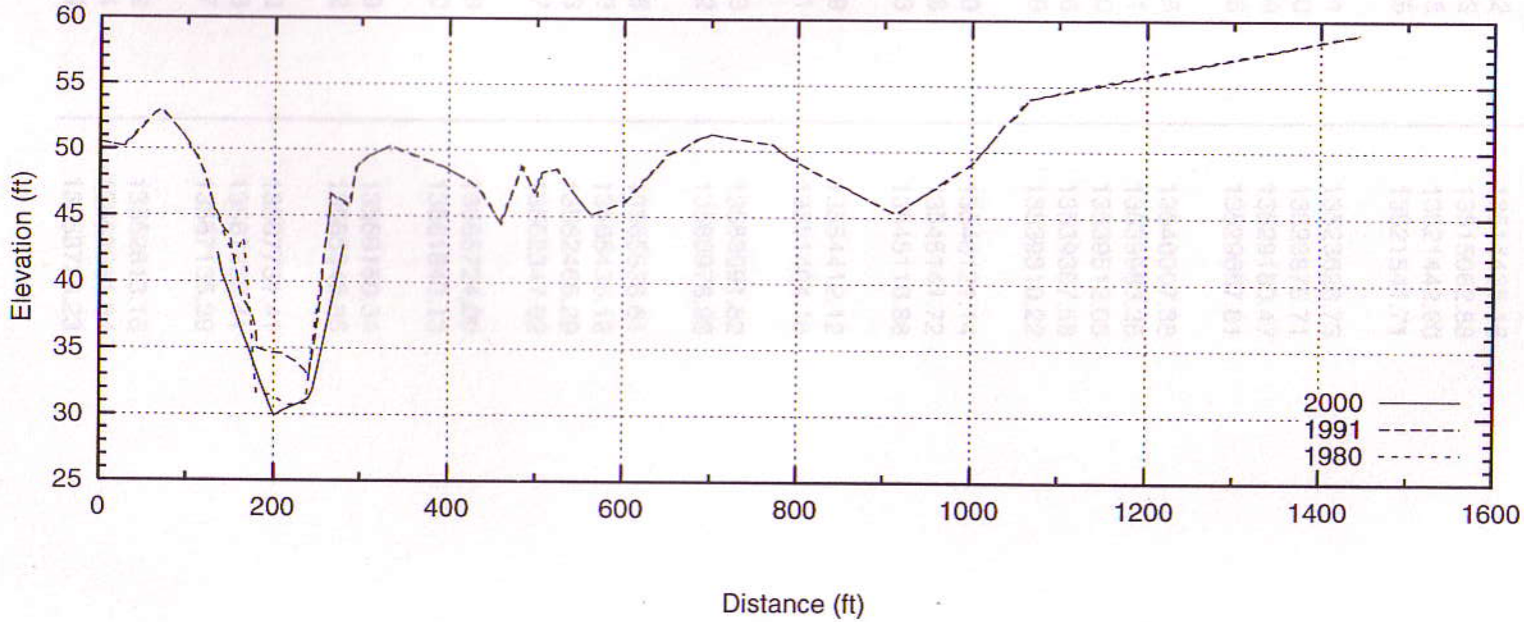
Appendix E

Lake Texana

RL-52



RL-53



Sediment Range Line Number from 1981 report	X-coordinate State Plane NAD 83 (feet)	Y-coordinate State Plane NAD 83 (feet)
R-1-L	2746313.92	13514435.18
R-1-L P.O.T.	2746215.83	13515082.88
R-1-R P.O.T.	2745252.75	13521442.80
R-1-R	2745237.75	13521541.71
R-2-L	2756631.34	13523626.73
R-2-L P.O.T.	2756320.40	13523876.71
R-2-R P.O.T.	2749723.29	13529180.47
R-2-R	2749129.56	13529657.81
R-3-L	2760656.65	13540007.38
R-3-L P.O.T.	2760458.11	13539983.35
R-3-R P.O.T.	2756566.20	13539512.05
R-3-R P.O.T.	2755538.26	13539387.58
R-3-R	2754899.48	13539310.22
R-4-L	2760296.60	13546121.14
R-4-R P.O.T.	2756074.48	13545141.72
R-4-R	2755967.33	13545116.88
R-5-L	2754929.59	13554412.12
R-5-R	2749901.01	13551404.16
R-6-L	2751328.63	13563091.82
R-6-R	2746662.02	13560976.93
R-7-L	2750876.06	13565538.61
R-7-L P.O.T.	2750704.93	13565435.12
R-7-R P.O.T.	2745794.53	13562465.29
R-7-R	2745599.97	13562347.62
R-8-L	2742485.33	13565724.00
R-8-R	2741823.70	13561843.13
R-9-L	2740030.49	13569150.34
R-9-R	2738450.12	13565948.85
R-10-L	2731896.73	13567731.41
R-10-R P.O.T.	2731933.43	13567330.41
R-10-R	2731951.27	13567135.39
R-21-L	2757060.22	13552613.16
R-21-L P.O.T.	2756972.24	13552661.34
R-21-R	2755014.69	13553728.23

Sediment Range Line Number from 1981 report	X-coordinate State Plane NAD 83 (feet)	Y-coordinate State Plane NAD 83 (feet)
R-22-L	2762581.46	13552537.66
R-22-R P.O.T.	2761998.20	13554365.98
R-22-R	2761732.54	13555198.71
R-23-L	2762526.36	13558687.96
R-23-R P.O.T.	2759461.73	13557029.63
R-23-R	2758832.11	13556691.93
R-24-L	2764571.34	13564438.34
R-24-R	2763365.68	13564081.40
R-25-L	2772501.47	13567105.08
R-25-R	2772006.79	13568258.48
R-26-L	2777668.45	13572051.95
R-26-R	2777015.20	13572829.01
R-31-L	2763861.99	13565598.46
R-31-L	2763766.05	13565542.65
R-31-R	2763079.55	13565142.02
R-51-L	2745838.08	13569289.73
R-51-R	2744096.06	13568436.11
R-52-L	2745393.66	13572909.27
R-52-R	2744669.10	13572268.89
R-53-L	2744553.85	13577859.16
R-53-R P.O.T.	2743411.37	13577821.61
R-53-R	2742999.88	13577808.09

APPENDIX G- DEPTH SOUNDER ACCURACY

This example was extracted from the Innerspace Technology, Inc. Operation Manual for the Model 443 Velocity Profiler.

For the following examples, $t_D = (D - d)/V$

Where: t_D = travel time of the sound pulse, in seconds (at depth = D)
D = depth, in feet
d = draft = 1.2 feet
V = speed of sound, in feet per second

To calculate the error of a measurement based on differences in the actual versus average speed of sound, the same equation is used, in this format:

$$D = [t (V)]+d$$

For the water column from 2 to 30 feet: V = 4832 fps

$t_{30} = (30-1.2)/4832$
$= 0.00596$ sec.

For the water column from 2 to 45 feet: V = 4808 fps

$t_{45} = (45-1.2)/4808$
$= 0.00911$ sec.

For a measurement at 20 feet (within the 2 to 30 foot column with V = 4832 fps):

$D_{20} = [((20-1.2)/4832)(4808)]+1.2$
= 19.9' (-0.1')

For a measurement at 30 feet (within the 2 to 30 foot column with V = 4832 fps):

$D_{30} = [((30-1.2)/4832)(4808)]+1.2$
= 29.9' (-0.1')

For a measurement at 50 feet (within the 2 to 60 foot column with V = 4799 fps):

D_{50} = [((50-1.2)/4799)(4808)]+1.2
= 50.1' (+0.1')

For the water column from 2 to 60 feet: V = 4799 fps   Assumed V_{80} = 4785 fps

t_{60} =(60-1.2)/4799
=0.01225 sec.

For a measurement at 10 feet (within the 2 to 30 foot column with V = 4832 fps):

D_{10} = [((10-1.2)/4832)(4799)]+1.2
= 9.9' (-0.1')

For a measurement at 30 feet (within the 2 to 30 foot column with V = 4832 fps):

D_{30} = [((30-1.2)/4832)(4799)]+1.2
= 29.8' (-0.2')

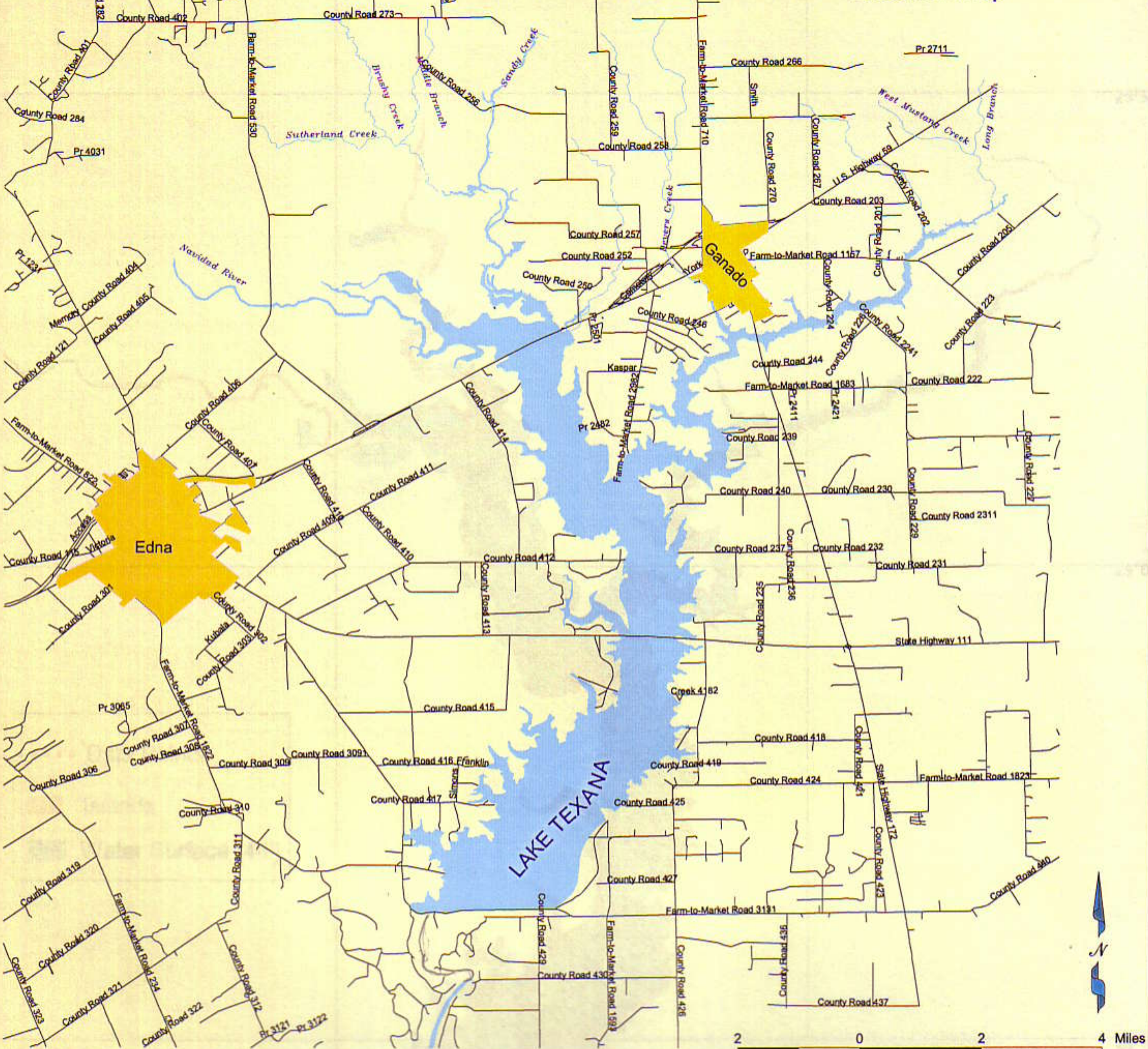
For a measurement at 45 feet (within the 2 to 45 foot column with V = 4808 fps):

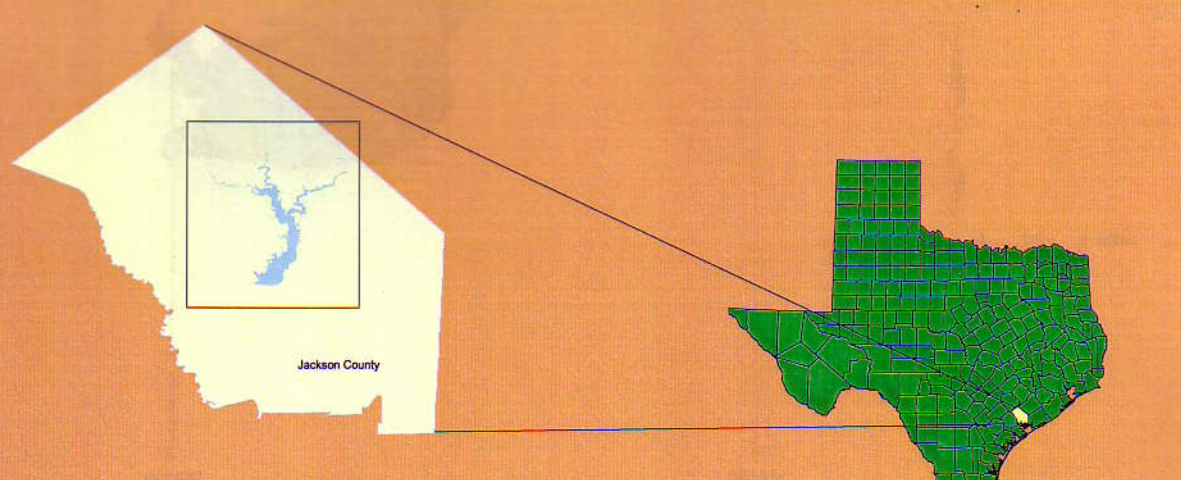
D_{45} = [((45-1.2)/4808)(4799)]+1.2
= 44.9' (-0.1')

For a measurement at 80 feet (outside the 2 to 60 foot column, assumed V = 4785 fps):

D_{80} = [((80-1.2)/4785)(4799)]+1.2
= 80.2' (+0.2')

Figure 1
LAKE TEXANA
Location Map



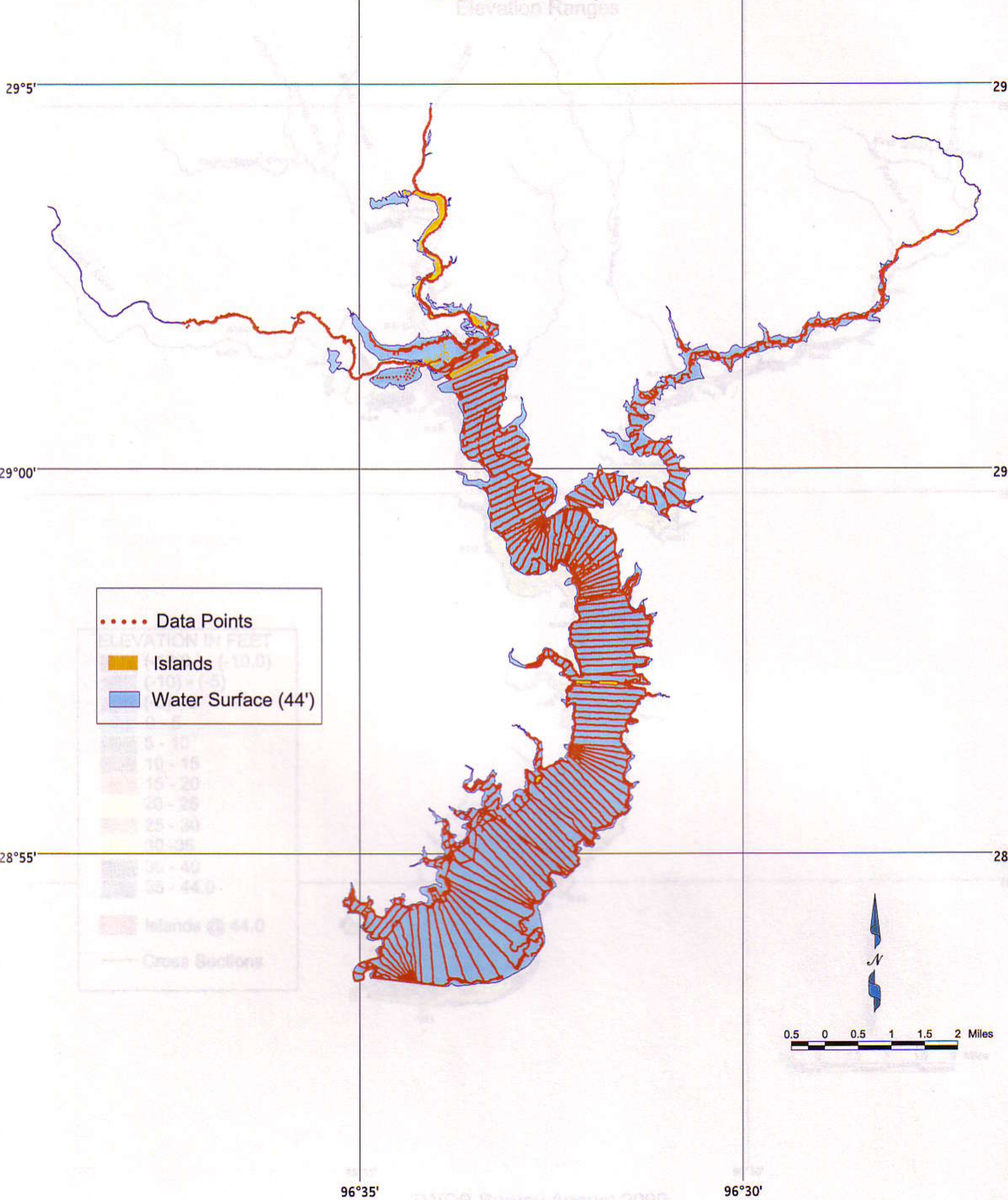


TWDB Survey August 2000

Figure 2

LAKE TEXANA

Location of Survey Data

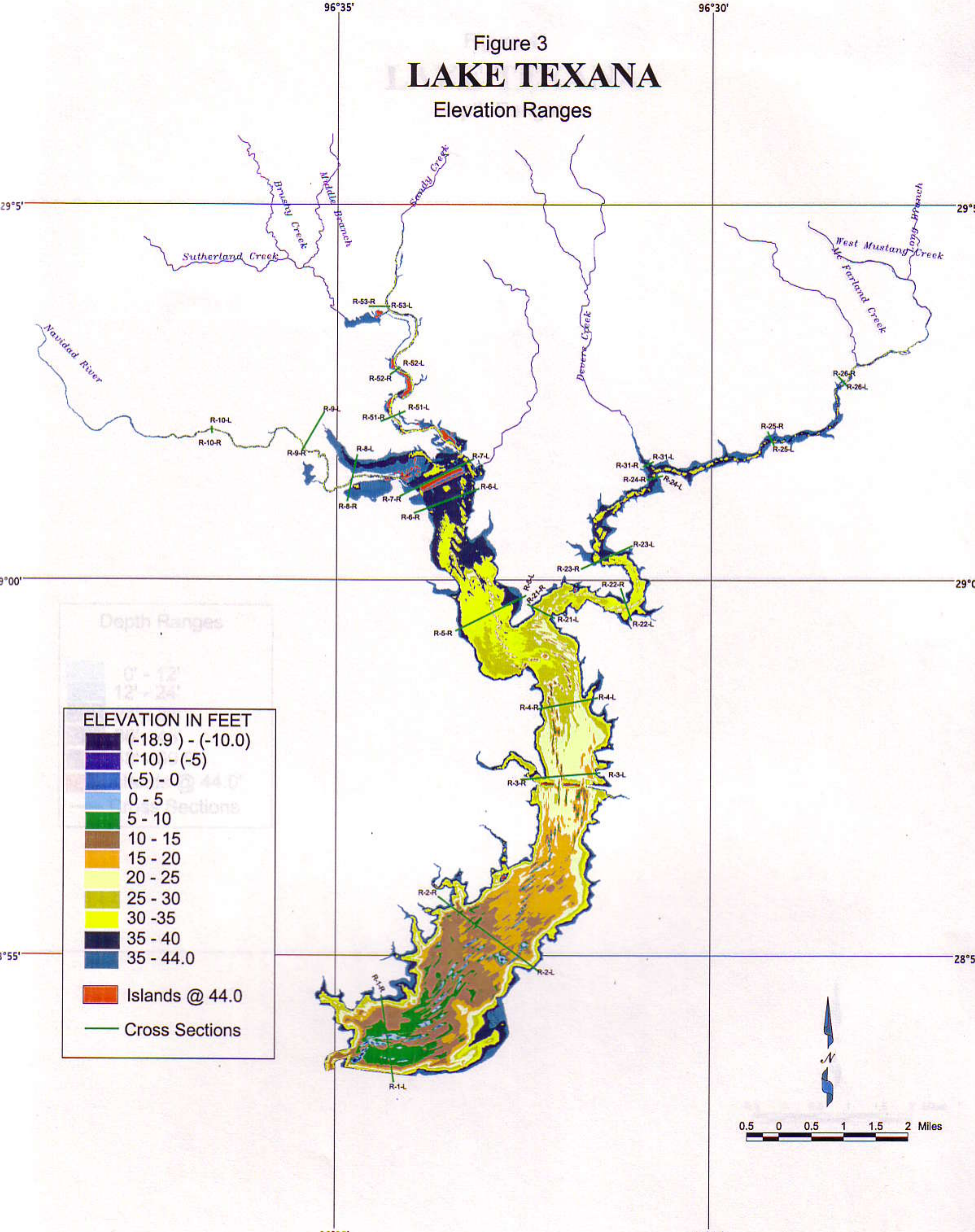


TWDB Survey, August 2000

Figure 3

LAKE TEXANA

Elevation Ranges

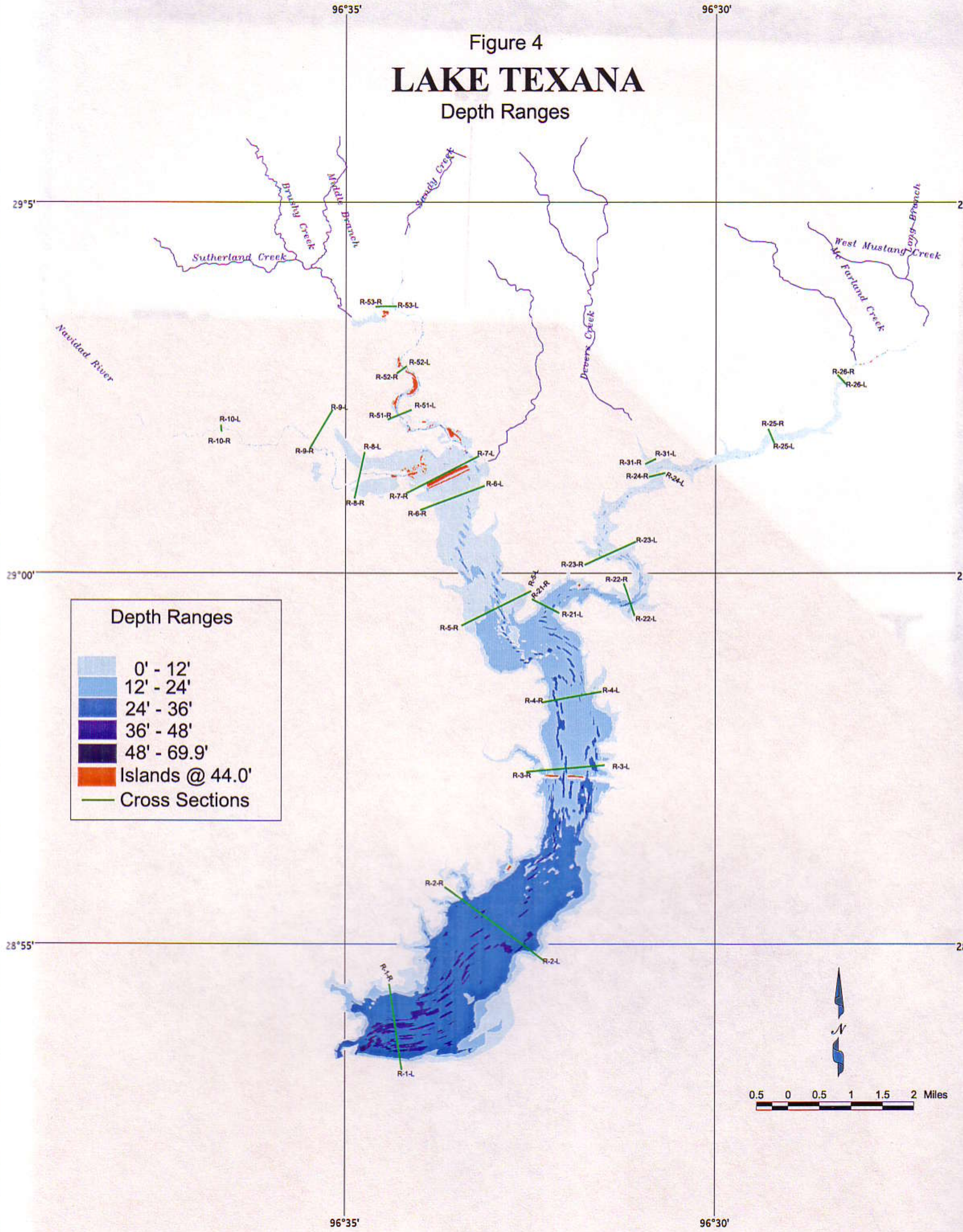


TWDB Survey August 2000

Figure 4

LAKE TEXANA

Depth Ranges



TWDB Survey August 2000