LAKE BROWNWOOD
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey of Lake Brownwood during the period April 21 - April 24, 1997. The purpose of the survey was to determine the capacity of the lake at the conservation pool elevation. From this information, future surveys will be able to determine the location and rates of sediment deposition in the conservation pool over time. Survey results are presented in the following pages in both graphical and tabular form. All elevations presented in this report will be reported in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29) unless noted otherwise. The conservation pool elevation for Lake Brownwood is 1425.0 feet. From a survey conducted in 1940, the lakes original surface area was estimated at 7,298 acres and the storage volume was estimated at 149,925 acre-feet of water. The 1940 survey was based on a combination of field surveying and a 1927 U. S. Geological Survey topographic map with 20 foot contours.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

Lake Brownwood and Lake Brownwood Dam are owned and operated by the Brown County Water Improvement District No. 1. The reservoir is located at the confluence of Pecan Bayou and Jim Ned Creek in Brown County, eight miles north of Brownwood, TX (See Figure 1.). Records indicate the drainage area is approximately 1,535 square miles. At the conservation pool elevation, the lake has approximately 68 miles of shoreline and is 13.5 miles long. The widest point of the reservoir, located two and one-quarter miles upstream of the dam on Jim Ned Creek, is approximately one and one-half miles.

The State Board of Water Engineers issued Permit No. 1036 to the Brown County Water Improvement District No. 1 on December 3, 1929. Certificate of Adjudication No. 14-2454 was issued by the Texas Water Commission on June 1, 1983. The certificate authorized the Brown County Water Improvement District No. 1 to maintain an existing dam on Pecan Bayou and impound therein, not to exceed 114,000 acre-feet of water. The owner was authorized to divert, not to exceed 15,996 acre-feet of water per annum and use not to exceed 12,797 acre-feet of water annually for municipal purposes. Additionally, the owner was granted the right to divert, not to exceed, 5,004 acre-feet of water per annum and use not to exceed 4,003 acre-feet of water annually for industrial purposes. The certificate also authorizes the owner to divert, not to exceed, 8,712 acre-feet of water per annum and use not to exceed 6,970 acre-feet of water per annum to irrigate a maximum of 7,891 acres of land within the boundaries of the Brown County Water Improvement District No. 1.

Records indicate the construction for the project began in 1930. Flood waters filled the reservoir in 1932 but were released in order to complete the construction of the dam. The project was completed in 1933 and deliberate impoundment began in July of that same year. D. W. Ross was the design engineer for the original project.

The original dam consisted of an earthfill embankment, 1,580 feet in length, rising to a height of 120 feet with a crest elevation of 1,449.5 feet. In 1982 the embankment was modified and raised to an elevation of 1,470.0 feet. The service spillway is a earth cut channel located approximately 800 feet to the left (north) of the dam. A two feet wide concrete wall serves as a weir and extends 479 feet at elevation 1,425.0 feet. The outlet works consist of three gated outlets, staggered at elevations 1,360.0, 1,380.0 and 1,408.5 feet. All flows that pass through the embankment are discharged through a 42 inch diameter conduit.

HYDROGRAPHIC SURVEYING TECHNOLOGY

The following sections will describe the theory behind Global Positioning System (GPS) technology and its accuracy. Equipment and methodology used to conduct the subject survey and previous hydrographic surveys are also addressed.

GPS Information

The following is a brief and simple description of Global Positioning System (GPS) technology. GPS is a relatively new technology that uses a network of satellites, maintained in precise orbits around the earth, to determine locations on the surface of the earth. GPS receivers continuously monitor the broadcasts from the satellites to determine the position of the receiver. With only one satellite being monitored, the point in question could be located anywhere on a sphere surrounding the satellite with a radius of the distance measured. The observation of two satellites decreases the possible location to a finite number of points on a circle where the two spheres intersect. With a third satellite observation, the unknown location is reduced to two points where all three spheres intersect. One of these points is obviously in error because its location is in space, and it is ignored. Although three satellite measurements can fairly accurately locate a point on the earth, the minimum number of satellites required to determine a three dimensional position within the required accuracy is four. The fourth measurement compensates for any time discrepancies between the clock on board the satellites and the clock within the GPS receiver.

GPS technology was developed in the 1960's by the United States Air Force and the defense establishment. After program funding in the early 1970's, the initial satellite was launched on February 22, 1978. A four year delay in the launching program occurred after the Challenger space shuttle disaster. In 1989, the launch schedule was resumed. Full operational capability was reached on April 27, 1995 when the NAVSTAR (NAVigation System with Time And Ranging) satellite constellation was composed of 24 Block II satellites. Initial operational capability, a full constellation of 24 satellites, in a combination of Block I (prototype) and Block II satellites, was achieved December 8, 1993. The NAVSTAR satellites provide data based on the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to NAD '83.

The United States Department of Defense (DOD) is currently responsible for implementing and maintaining the satellite constellation. In an attempt to discourage the use of these survey units as a guidance tool by hostile forces, the DOD has implemented means of false signal projection called Selective Availability (S/A). Positions determined by a single receiver when S/A is active result in errors to the actual position of up to 100 meters. These errors can be reduced to centimeters by performing a static survey with two GPS receivers, one of which is set over a point with known coordinates. The errors induced by S/A are time-constant. By monitoring the movements of the satellites over time (one to three hours), the errors can be minimized during post processing of the collected data and the unknown position computed accurately.

Differential GPS (DGPS) can determine positions of moving objects in real-time or "on-the-fly." In the early stages of this program, one GPS receiver was set up over a benchmark with known coordinates established by the hydrographic survey crew. This receiver remained stationary during the survey and monitored the movements of the satellites overhead. Position corrections were determined and transmitted via a radio link once per second to a second GPS receiver located on the moving boat. The boat receiver used these corrections, or differences, in combination with the satellite information it received to determine its differential location. The large positional errors experienced by a single receiver when S/A is active are greatly reduced by utilizing DGPS. The reference receiver calculates satellite corrections based on its known fixed position, which results in positional accuracies within three meters for the moving receiver. DGPS was used to determine horizontal position only. Vertical information was supplied by the depth sounder.

The need for setting up a stationary shore receiver for current surveys has been eliminated with the development of fee-based reference position networks. These networks use a small network of GPS receivers to create differential corrections for a large network of transmitting stations, Wide Area Differential GPS (WADGPS). The TWDB receives this service from ACCQPOINT, a WADGPS correction network over a FM radio broadcast. A small radio receiver purchased from ACCQPOINT, collects positional correction information from the closest broadcast station and provides the data to the GPS receiver on board the hydrographic surveying boat to allow the position to be differentially corrected.

Equipment and Methodology

The equipment used in the performance of the hydrographic survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Johnson outboard motors. Installed within the enclosed cabin are an Innerspace Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, a Trimble Navigation, Inc. 4000SE GPS receiver, an ACCQPOINT FM receiver, and an on-board 486 computer. Power was provided by a water-cooled generator through an in-line uninterruptible power supply. Reference to brand names does not imply endorsement by the TWDB.

The GPS equipment, survey vessel, and depth sounder combine together to provide an efficient hydrographic survey system. As the boat travels across the lake surface, the depth sounder gathers approximately ten readings of the lake bottom each second. The depth readings are stored on the survey vessel's on-board computer along with the corrected positional data generated by the boat's GPS receiver. The daily data files collected are downloaded from the computer and brought to the office for editing after the survey is completed. During editing, bad 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 daily recorded lake elevation on the day the survey was performed. Accurate estimates of the lake volume can be quickly determined by building a 3-D model of the reservoir from the collected data. The level of accuracy is equivalent to or better than previous methods used to determine lake volumes, some of which are discussed below.

Previous Survey Procedures

Originally, reservoir surveys were conducted with a rope stretched across the reservoir along pre-determined range lines. A small boat would manually pole the depth at selected intervals along the rope. Over time, aircraft cable replaced the rope and electronic depth sounders replaced the pole. The boat was hooked to the cable, and depths were again recorded at selected intervals. This method, used mainly by the Soil Conservation Service, worked well for small reservoirs.

Larger bodies of water required more involved means to accomplish the survey, mainly due to increased size. Cables could not be stretched across the body of water, so surveying instruments were utilized to determine the path of the boat. Monumentation was set for the end points of each line so the same lines could be used on subsequent surveys. Prior to a survey, each end point had to be located (and sometimes reestablished) in the field and vegetation cleared so that line of sight could be maintained. One surveyor monitored the path of the boat and issued commands via radio to insure that it remained on line while a second surveyor determined depth measurement locations by turning angles. Since it took a major effort to determine each of the points along the line, the depth readings were spaced quite a distance apart. Another major cost was the land surveying required prior to the reservoir survey to locate the range line monuments and clear vegetation.

Electronic positioning systems were the next improvement. If triangulation could determine the boat location by electronic means, then the boat could take continuous depth soundings. A set of microwave transmitters positioned around the lake at known coordinates would allow the boat to receive data and calculate its position. Line of site was required, and the configuration of the transmitters had to be such that the boat remained within the angles of 30 and 150 degrees in respect to the shore stations. The maximum range of most of these systems was about 20 miles. Each shore station had to be accurately located by survey, and the location monumented for future use. Any errors in the land surveying resulted in significant errors that were difficult to detect. Large reservoirs required multiple shore stations and a crew to move the shore stations to the next location as the survey progressed. Land surveying was still a major cost.

Another method used mainly prior to construction utilized aerial photography to generate elevation contours which could then be used to calculate the volume of the reservoir. Fairly accurate results could be obtained, although the vertical accuracy of the aerial topography was generally one-half of the contour interval or ± five feet for a ten-foot contour interval. This method could be quite costly and was only applicable in areas that were not inundated.

PRE-SURVEY PROCEDURES

The reservoir's surface area was determined prior to the survey by digitizing with AutoCad software the lake's pool boundary (elevation 1425.0) from USGS quad sheets. The name of the quad sheets are as follows: BYRDS, TX (1987), THRIFTY, TX (1977), OWENS, TX (1978), and LAKE BROWNWOOD, TX (1987). The graphic boundary file created was then transformed into the proper datum, from NAD '27 datum to NAD '83, using Environmental Systems Research Institutes's

(ESRI) Arc/Info project command with the NADCOM parameters. The area of the lake boundary was checked to verify that the area was the same in both datums.

The survey layout was designed by placing survey track lines at 500 foot intervals across the lake. The survey design for this lake required approximately 349 survey lines to be placed along the length of the lake. Survey setup files were created using Coastal Oceangraphics, Inc. Hypack software for each group of track lines that represented a specific section of the lake. The setup files were copied onto diskettes for use during the field survey.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

At the beginning of each surveying day, the depth sounder was calibrated with the Innerspace Velocity Profiler. The Velocity Profiler calculates an average speed of sound through the water column of interest for a designated draft value of the boat (draft is the vertical distance that the boat penetrates the water surface). The draft of the boat was previously determined to average 1.2 ft. The velocity profiler probe is placed in the water to moisten and acclimate the probe. The probe is then raised to the water surface where the depth is zeroed. The probe is lowered on a cable to just below the maximum depth set for the water column, and then raised to the surface. The unit displays an average speed of sound for a given water depth and draft, which is entered into the depth sounder. The depth value on the depth sounder was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly. During the survey of Lake Brownwood, the speed of sound in the water column varied daily between 4800 and 4850 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, plus an estimated error of ± 0.3 feet due to the plane of the boat for a total accuracy of ± 0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some are positive readings and some are negative readings. Further information on these calculations is presented in Appendix A.

During the survey, the onboard GPS receiver was set to a horizontal mask of 10° and a PDOP (Position Dilution of Precision) limit of 7 to maximize the accuracy of horizontal positions. An internal alarm sounds if the PDOP rises above seven to advise 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 setup to convert the collected DGPS positions on-the-fly to state plane coordinates. Both sets of coordinates were then stored in the survey data file.

Field Survey

Data was collected on Lake Brownwood during the period April 21 through April 24, 1997. Approximately 95,526 data points were collected over the 148 miles traveled along the pre-planned survey lines and the random data-collection lines. These points were stored digitally on the boat's computer in 394 data files. Data were not collected in areas of shallow water (depths less than 3.0 feet) or with significant obstructions unless these areas represented a large amount of water. Some random data lines were also collected, perpendicular to the survey layout, by the field crew during the survey. More intensive data were also collected around various shallow features noted by lake patrol staff on a map of the lake. Figure 2 shows the actual location of all data collection points.

TWDB staff noted that the majority of the lake was void of submerged trees and aquatic vegetation. The bathemetry of the lake was very typical of a high velocity, river cut gorge. One side of the lake was normally very rugged, rocky, and steep; while the other side had a more gentle slope. At times, creek channels could be distinguished on the depth sounder's analog charts. There were also various shallow water areas, delineated with marker buoys by the lake patrol, in which more intensive data was collected to clearly define the hazards.

Data collection in the headwaters was discontinued when the boat could no longer make transects across the lake due to shallow water, islands, and extensive deposits of silt. Deep water could still be found in the narrow river channel. The collected data were 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 each day for future processing.

Data Processing

The collected data were down-loaded from diskettes onto the TWDB's computer network. 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 or data with missing depth or positional information were deleted from the file. The depth information collected every 0.1 seconds was averaged to get one reading for each second of data collection. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water surface held steady at 1425.2 feet. After all changes had been made to the raw data file, the edited file was saved with a different extension. After all the files were edited, the edited files were combined into a single data file, representative of the lake, to be used with the GIS software to develop a model of the lake's bottom surface.

The resulting DOS data file was imported into the UNIX operating system used to run Environmental System Research Institutes's (ESRI) Arc/Info GIS software and converted to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the reservoir's bottom surface using Arc/Info's TIN module. The module builds an irregular triangulated network from the data points and the boundary file. This software uses 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 preserved for use in determining the solution of the model by using this method. The generated network of three-dimensional triangular planes represents the actual bottom surface. Once the triangulated irregular network (TIN) is formed, the software then calculates elevations along the triangle surface plane by solving the equations for elevation along each leg of the triangle. Information for the entire reservoir area can be determined from the triangulated irregular network created using this method of interpolation.

If data points were collected outside the boundary file, the boundary was modified to include the data points. The boundary file in areas of significant sedimentation was also down-sized as deemed necessary based on the data points and the observations of the field crew. The resulting boundary shape was used to develop each of the map presentations of the lake in this report.

There were still some areas where volume and area values could not be calculated by interpolation because of a lack of information along the 1425.0 contour line of the reservoir. "Flat triangles" were drawn at these locations. Arc/Info does not use flat triangle areas in the volume or contouring features of the model. These areas were determined to be insignificant on Lake Brownwood. Therefore no additional points were required for interpolation and contouring of the entire lake surface. Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals. The area of lake computed from the TIN, was calculated to be 6,587 surface acres. The computed area was 711 surface acres less than originally calculated in 1940. The computed reservoir volume table is presented in Appendix B and the area table in Appendix C. An elevation-area-volume graph is presented in Appendix D.

Other presentations developed from the model include a shaded relief map and a shaded depth range map. 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. Using the POLYSHADE command, colors were assigned to the range of elevations represented by the polygons that varied from navy to yellow. The lower elevation was assigned the color of navy, and the 1425.0 lake elevation was assigned the color of yellow. Different color shades were assigned to the different depths in between. Figure 3 presents the resulting depth shaded representation of the lake. Figure 4 presents a similar version of the same map, using bands of color for selected depth intervals. The color increases in intensity from the shallow contour bands to the deep water bands.

Linear filtration algorithms were then applied to the DTM smooth cartographic contours versus using the sharp engineered contours. The resulting contour map of the bottom surface at two-foot intervals is presented in Figure 5.

RESULTS

Results from the 1997 TWDB survey indicate Lake Brownwood encompasses 6,587 surface acres and contains a volume of 131,429 acre-feet at the conservation pool elevation of 1425.0 feet. The shoreline at this elevation was calculated to be 68.3 miles. The deepest point of the lake, elevation 1357.9 or 67.1 feet of depth, was located approximately 355 feet upstream from the center of the dam. There is no dead storage in the lake, therefore the conservation storage capacity of the lake is 131,430 acre-feet.

SUMMARY

Lake Brownwood was formed in 1933. Initial storage calculations estimated the volume at the conservation pool elevation of 1425.0 feet to be 149,925 acre-feet with a surface area of 7,298 acres.

Numerous sediment surveys have been performed since the lake was built. The latest survey was performed by the Soil Conservation Service in 1959. Results from the survey indicated that the surface area of the lake remained unchanged, and the storage volume had decreased to 143,400 acre-feet.

During the period of April 21 - 24, 1997, a hydrographic survey of Lake Brownwood was performed by the Texas Water Development Board's Hydrographic Survey Program. The 1997 survey used technological advances such as differential global positioning system and geographical information system technology to build a model of the reservoir's bathemetry. These advances allowed a survey to be performed quickly and to collect significantly more data of the bathemetry of Lake Brownwood than previous survey methods. Results indicate that the lake's capacity at the conservation pool elevation of 1425.0 feet was 131,429 acre-feet and the area was 6,587 acres.

The estimated reduction in storage capacity at the conservation pool elevation of 1425.0 feet between 1940 and 1959 was 6,525 acre-feet or 343.4 acre-feet per year. The average annual deposition rate of sediment in the conservation pool of the reservoir can be estimated at 0.22 acre-feet per square mile of drainage area. From 1959 to 1997, the estimated reduction in storage capacity was 11,971 acre-feet or 315.0 acre-feet per year. The average annual deposition rate of sediment in the conservation pool of the reservoir can be estimated at 0.205 acre-feet per square mile of drainage area. (It should be noted that these values are only mathematical estimates made from the available information.)

It is difficult to compare the original design information, the 1959 survey, and the TWDB survey performed because little is known about the previous surveys, the amount of data collected, and the method used to process the collected data. However, the TWDB considers the 1997 survey to be a significant improvement over previous survey procedures and recommends that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage capacity.

CALCULATION OF DEPTH SOUNDER ACCURACY

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

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

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):

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

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR VOLUME TABLE

Aug 12 1997

LAKE BROWNWOOD APRIL 1997 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,358										
1,359				1	1	1	1	1	1	2
1,360	2	2	2	2	3	3	3	3	4	4
1,361	4	5	5	5	5	6	6	7	7	7
1,362	8	8	9	9	10	10	11	11	12	13
1,363	13	14	15	16	17	17	18	19	20	21
1,364	23	24	25	26	28	29	30	32	34	35
1,365	37	38	40	42	44	46	48	50	52	54
1,366	56	58	61	63	65	68	70	73	75	78
1,367	81	84	86	89	92	95	99	102	105	108
1,368	112	115	119	122	126	130	134	138	142	146
1,369	150	154	159	163	168	172	177	182	187	192
1,370	197	202	208	213	219	225	230	236	242	248
1,371	254	261	267	274	280	287	294	301	308	315
1,372	323	330	338	346	353	361	369	378	386	394
1,373	403	411	420	429	438	447	456	466	475	485
1,374	495	505	515	525	535	545	556	567	577	588
1,375	600	611	622	634	646	657	669	682	694	707
1,376	719	732	745	758	772	785	799	813	827	841
1,377	856	871	885	901	916	931	947	963	979	996
1,378	1012	1029	1047	1064	1082	1100	1118	1137	1156	1175
1,379	1194	1214	1234	1255	1276	1297	1318	1340	1362	1385
1,380	1408	1431	1455	1479	1503	1527	1552	1578	1604	1630
1,381	1657	1684	1712	1740	1769	1798	1827	1857	1888	1918
1,382	1950	1982	2014	2047	2081	2115	2149	2185	2220	2257
1,383	2294	2331	2370	2409	2448	2489	2530	2572	2614	2658
1,384	2702	2748	2794	2842	2890	2939	2989	3040	3092	3145
1,385	3199	3253	3308	3364	3421	3479	3537	3597	3657	3718
1,386	3779	3842	3905	3970	4035	4101	4168	4236	4304	4374
1,387	4444	4516	4588	4661	4736	4811	4887	4965	5043	5123
1,388	5203	5285	5367	5452	5537	5623	5711	5800	5890	5981
1,389	6073	6166	6261	6357	6453	6551	6651	6751	6853	6956
1,390	7061	7166	7273	7382	7491	7601	7713	7826	7940	8056
1,391	8172	8290	8409	8529	8650	8773	8896	9021	9147	9274
1,392	9402	9531	9662	9793	9926	10059	10194	10330	10467	10604
1,393	10743	10883	11024	11167	11310	11455	11601	11748	11896	12045
1,394	12195	12347	12499	12653	12808	12964	13120	13278	13437	13597
1,395	13757	13919	14082	14246	14411	14577	14745	14913	15083	15254
1,396	15426	15599	15773	15948	16125	16302	16480	16660	16840	17022
1,397	17204	17388	17572	17759	17946	18135	18324	18516	18708	18902
1,398	19097	19294	19492	19691	19892	20095	20298	20504	20711	20919
1,399	21128	21339	21552	21767	21984	22202	22422	22644	22868	23093
1,400	23320	23548	23779	24012	24246	24483	24722	24963	25206	25451
1,401	25698	25946	26196	26447	26700	26954	27209	27466	27724	27983
1,402	28243	28504	28767	29031	29296	29562	29829	30098	30368	30639
1,403	30911	31185	31460	31736	32014	32293	32573	32855	33139	33424
1,404	33710	33999	34289	34580	34874	35168	35465	35763	36063	36365
1,405	36668	36972	37279	37587	37897	38209	38522	38838	39156	39474
1,406	39795	40118	40442	40769	41097	41427	41758	42092	42427	42764

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ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,407	43103	43444	43786	44131	44476	44824	45173	45524	45876	46230
1,408	46586	46943	47302	47663	48026	48390	48755	49122	49491	49861
1,409	50233	50606	50980	51357	51734	52113	52494	52876	53260	53645
1,410	54032	54419	54809	55200	55592	55986	56381	56777	57175	57574
1,411	57975	58377	58781	59187	59594	60002	60412	60823	61236	61650
1,412	62066	62483	62901	63321	63742	64164	64588	65013	65440	65868
1,413	66298	66729	67161	67596	68031	68468	68906	69346	69788	70230
1,414	70674	71119	71566	72015	72465	72916	73369	73824	74281	74739
1,415	75198	75660	76124	76590	77058	77528	77999	78473	78949	79427
1,416	79906	80388	80872	81358	81846	82335	82827	83321	83817	84315
1,417	84814	85316	85820	86326	86834	87344	87856	88370	88888	89407
1,418	89928	90452	90978	91507	92039	92572	93108	93646	94187	94730
1,419	95275	95823	96373	96926	97481	98038	98598	99160	99724	100290
1,420	100858	101428	102000	102575	103150	103728	104307	104889	105472	106057
1,421	106644	107233	107823	108417	109011	109606	110204	110802	111403	112005
1,422	112609	113213	113820	114429	115038	115649	116262	116876	117492	118109
1,423	118728	119348	119970	120594	121219	121845	122473	123103	123735	124367
1,424	125001	125637	126274	126914	127554	128196	128839	129484	130131	130779
1,425	131429									

TEXAS WATER DEVELOPMENT BOARD

RESERVOIR AREA TABLE

Aug 12 1997

LAKE BROWNWOOD APRIL 1997 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

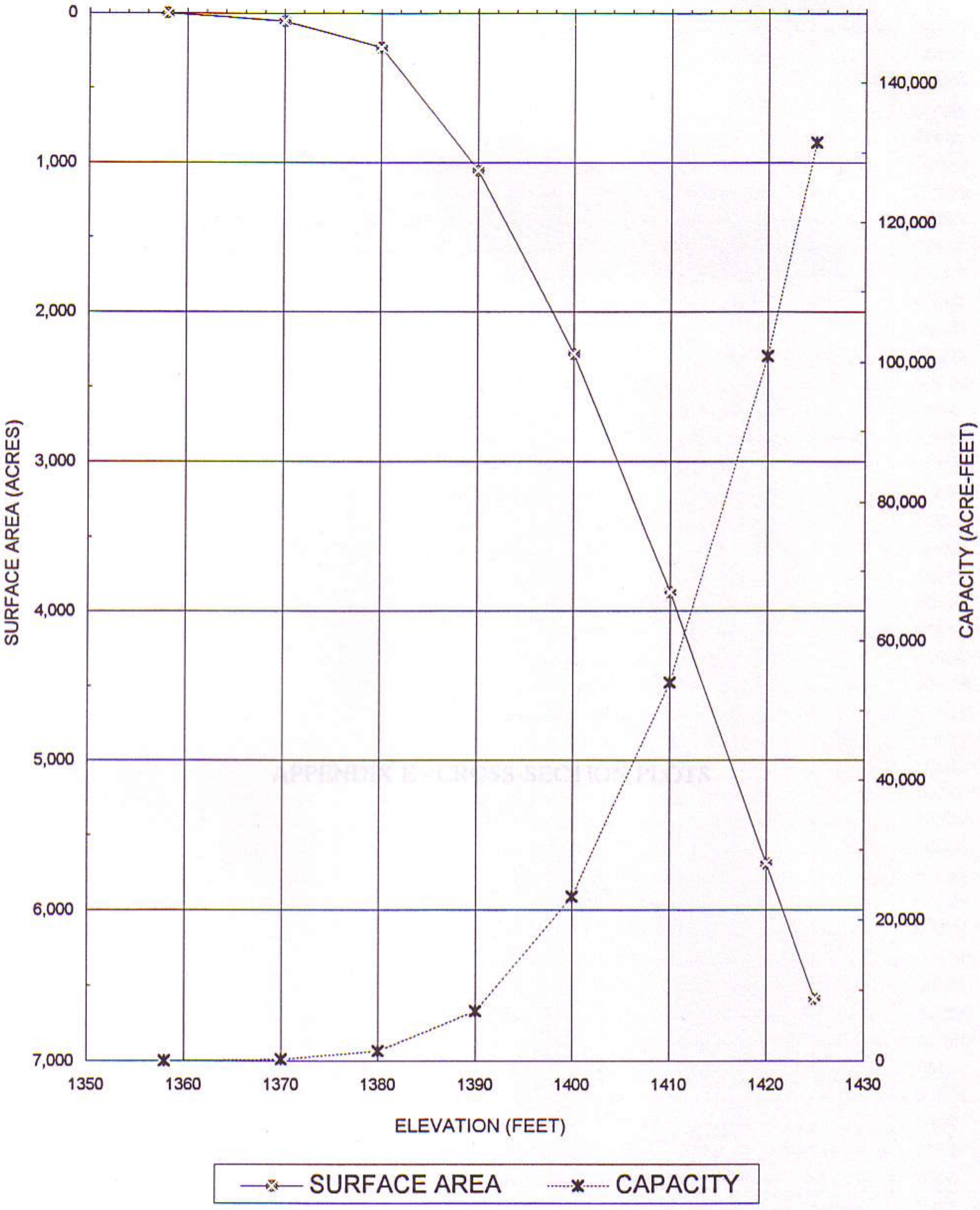
ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,358									1	1
1,359	1	1	1	1	1	1	2	2	2	2
1,360	2	2	2	2	2	3	3	3	3	3
1,361	3	3	3	3	3	3	3	4	4	4
1,362	4	5	5	5	5	6	6	6	7	7
1,363	7	8	8	8	9	9	10	10	10	11
1,364	11	12	13	13	14	14	15	15	16	16
1,365	17	17	18	18	19	19	20	20	21	21
1,366	22	23	23	24	24	25	25	26	26	27
1,367	28	28	29	30	30	31	32	32	33	34
1,368	34	35	36	36	37	38	39	40	41	42
1,369	42	43	44	45	46	47	48	49	50	51
1,370	52	53	54	55	56	57	58	59	60	61
1,371	63	64	65	66	67	68	69	71	72	73
1,372	74	75	77	78	79	80	81	82	84	85
1,373	86	87	88	89	91	92	93	94	96	97
1,374	98	99	101	102	103	105	106	107	109	110
1,375	112	113	115	116	118	120	121	123	125	126
1,376	128	130	131	133	135	137	138	140	142	144
1,377	146	148	150	152	154	156	159	161	163	166
1,378	168	171	173	176	179	182	184	187	190	194
1,379	197	200	203	207	210	213	217	220	223	227
1,380	230	234	237	241	245	249	252	257	261	265
1,381	270	275	279	284	288	293	298	302	307	312
1,382	317	322	327	332	338	343	349	354	360	367
1,383	373	380	386	393	400	407	415	423	431	440
1,384	449	459	468	478	488	498	507	515	523	531
1,385	539	548	556	565	574	581	589	597	604	613
1,386	621	630	639	648	656	665	674	682	691	700
1,387	709	719	729	738	748	758	768	778	789	799
1,388	810	823	835	847	859	871	883	894	905	916
1,389	928	939	950	962	974	986	1000	1013	1026	1038
1,390	1051	1063	1075	1087	1099	1111	1124	1136	1149	1161
1,391	1173	1184	1195	1206	1216	1228	1242	1254	1265	1276
1,392	1287	1299	1309	1320	1331	1341	1352	1362	1373	1383
1,393	1395	1406	1418	1430	1441	1452	1463	1474	1486	1498
1,394	1510	1521	1532	1542	1552	1562	1572	1582	1592	1602
1,395	1613	1623	1634	1646	1656	1668	1680	1691	1702	1714
1,396	1725	1736	1748	1759	1769	1779	1789	1799	1808	1819
1,397	1830	1842	1855	1867	1880	1893	1906	1919	1932	1945
1,398	1959	1973	1987	2002	2017	2031	2046	2060	2074	2089
1,399	2104	2120	2137	2159	2176	2193	2209	2226	2243	2260
1,400	2278	2297	2316	2336	2357	2377	2399	2422	2442	2460
1,401	2476	2491	2505	2520	2533	2546	2559	2572	2584	2596
1,402	2608	2620	2632	2644	2656	2668	2680	2692	2705	2717
1,403	2730	2743	2756	2769	2783	2797	2813	2828	2843	2859
1,404	2875	2891	2908	2924	2941	2958	2975	2991	3006	3022
1,405	3038	3055	3073	3090	3109	3130	3146	3164	3182	3199
1,406	3217	3235	3254	3274	3291	3308	3326	3344	3362	3381

RESERVOIR AREA TABLE

LAKE BROWNWOOD APRIL 1997 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

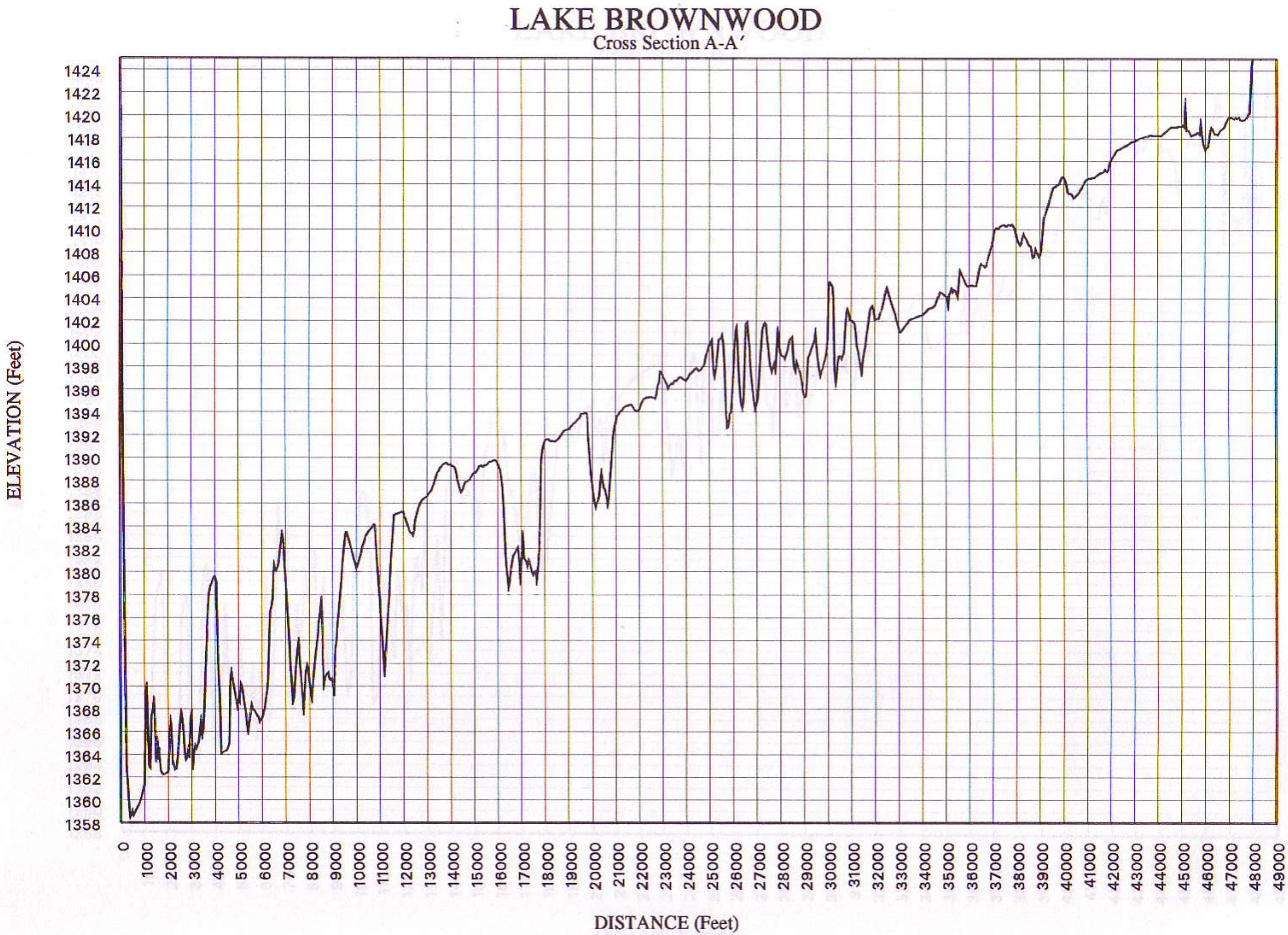
ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,407	3399	3416	3432	3449	3466	3483	3500	3516	3532	3549
1,408	3566	3583	3600	3616	3632	3647	3663	3678	3694	3709
1,409	3724	3739	3754	3768	3784	3799	3815	3829	3844	3859
1,410	3873	3887	3901	3915	3929	3944	3958	3972	3986	4000
1,411	4015	4031	4047	4062	4077	4092	4107	4121	4135	4148
1,412	4162	4175	4189	4203	4217	4232	4247	4261	4275	4289
1,413	4303	4318	4333	4348	4362	4377	4391	4405	4419	4433
1,414	4448	4462	4476	4491	4507	4523	4539	4556	4573	4590
1,415	4609	4629	4649	4669	4688	4708	4727	4747	4767	4787
1,416	4807	4827	4848	4868	4888	4909	4929	4949	4968	4987
1,417	5007	5027	5047	5068	5090	5111	5134	5157	5181	5204
1,418	5227	5250	5275	5303	5326	5349	5371	5394	5417	5440
1,419	5463	5488	5514	5539	5563	5587	5609	5631	5651	5672
1,420	5692	5711	5730	5749	5767	5786	5805	5823	5842	5861
1,421	5880	5898	5916	5933	5951	5966	5982	5997	6012	6027
1,422	6043	6058	6073	6089	6104	6119	6135	6150	6166	6181
1,423	6196	6217	6236	6256	6275	6295	6314	6334	6353	6373
1,424	6392	6412	6431	6451	6470	6490	6509	6529	6548	6568
1,425	6587									



LAKE BROWNWOOD

April 1997 Survey

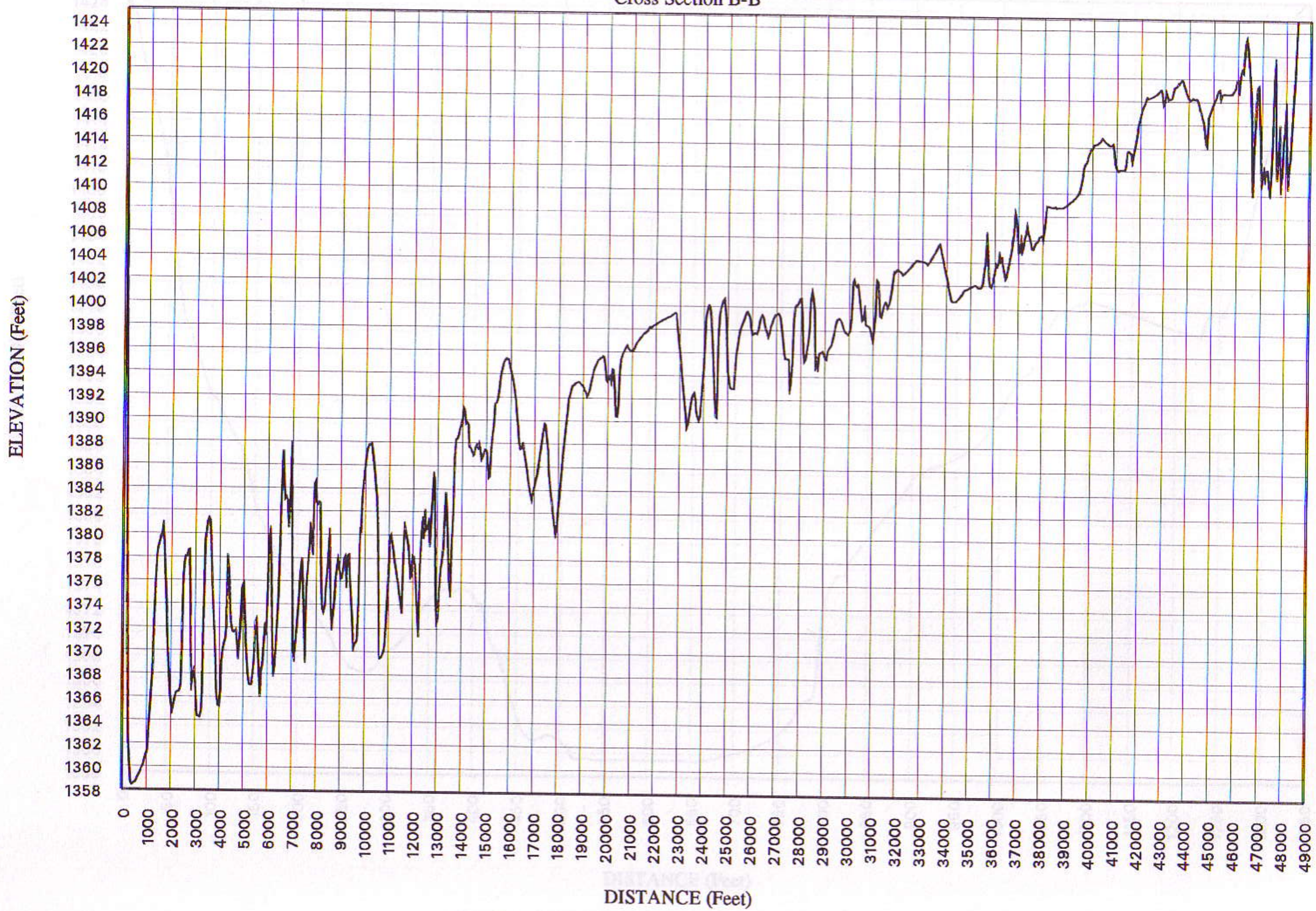
Prepared by: TWDB August 1997



PREPARED BY: TWDB AUGUST 1997

LAKE BROWNWOOD

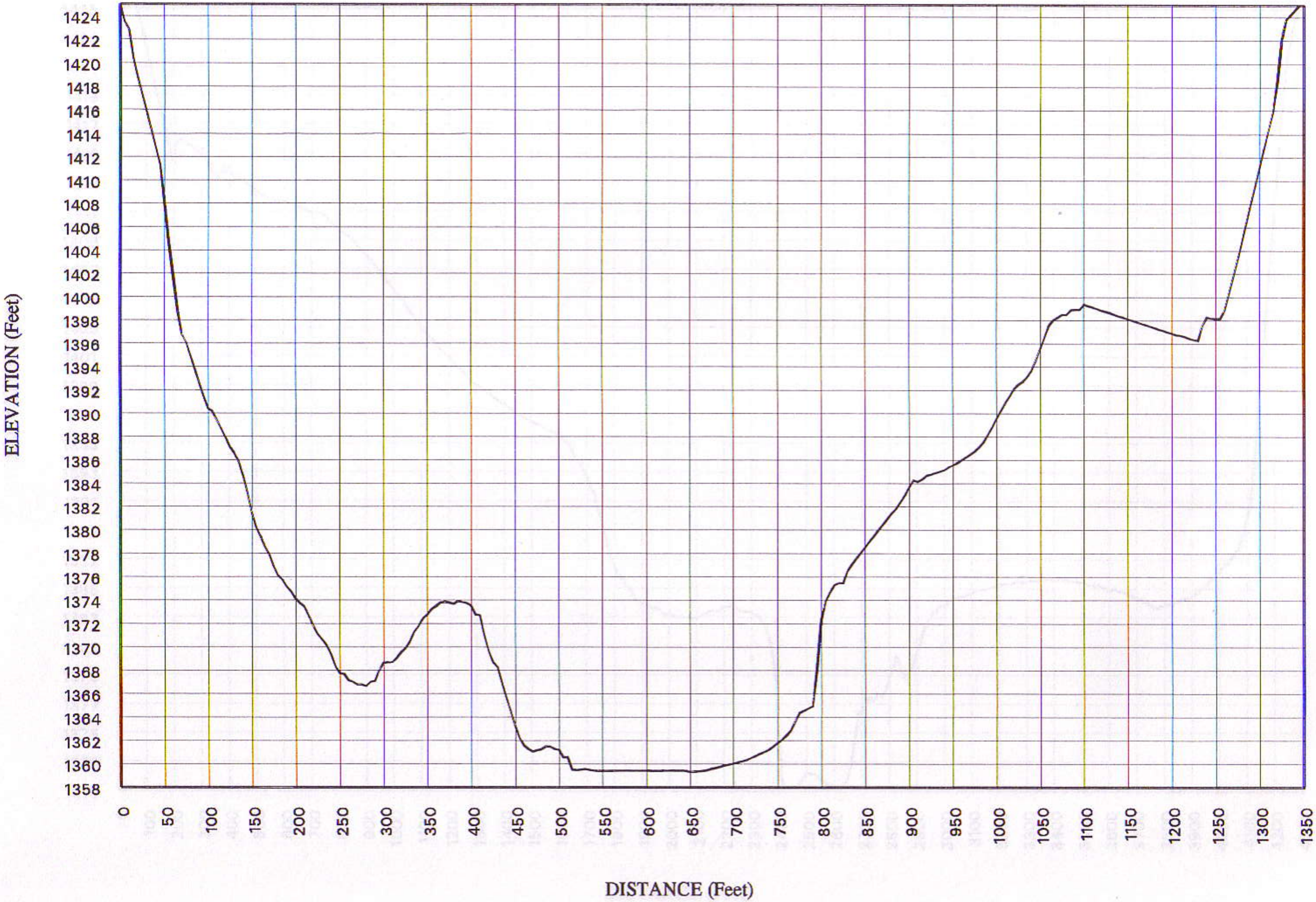
Cross Section B-B′



PREPARED BY: TWDB AUGUST 1997

LAKE BROWNWOOD

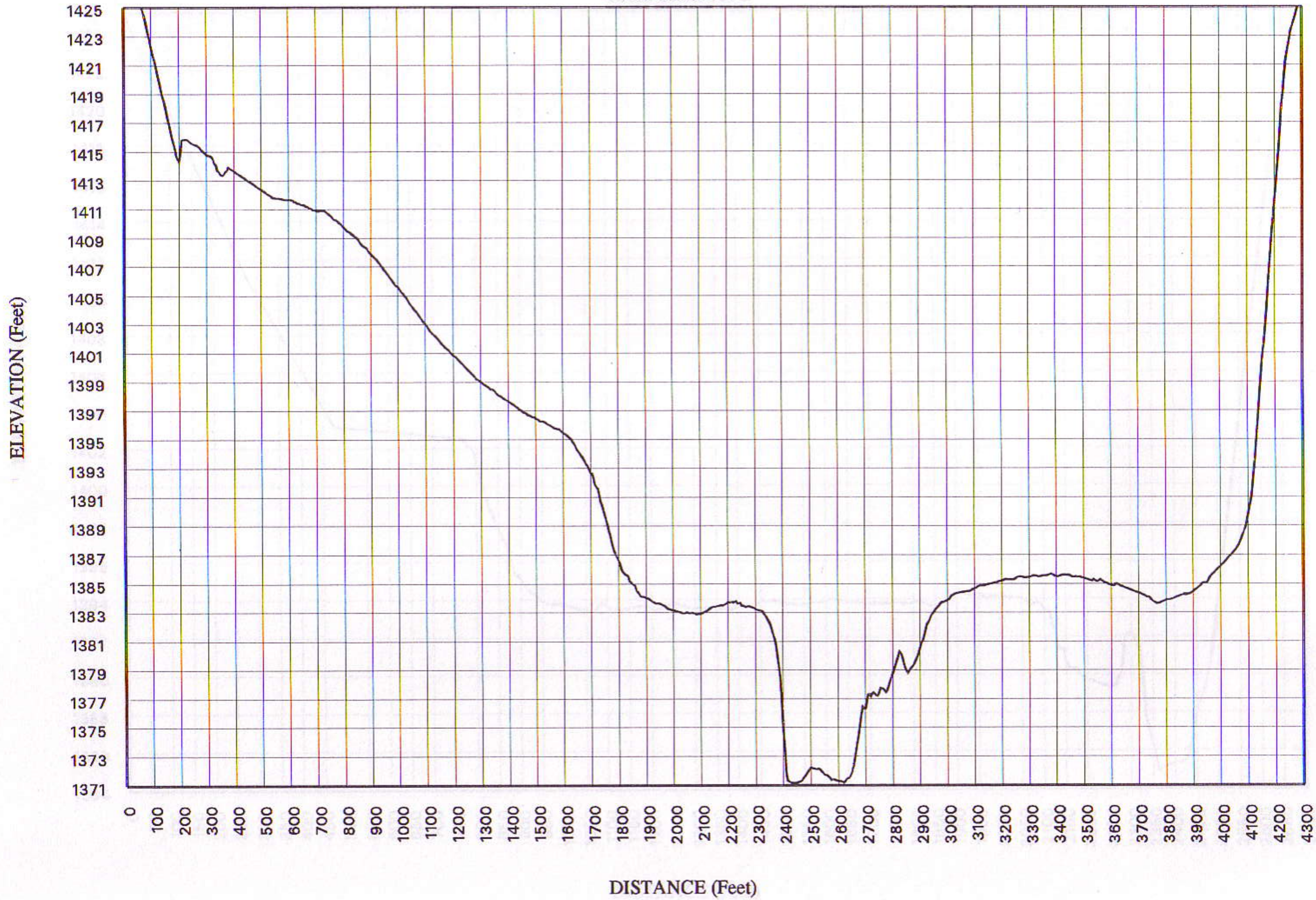
Cross Section C-C′



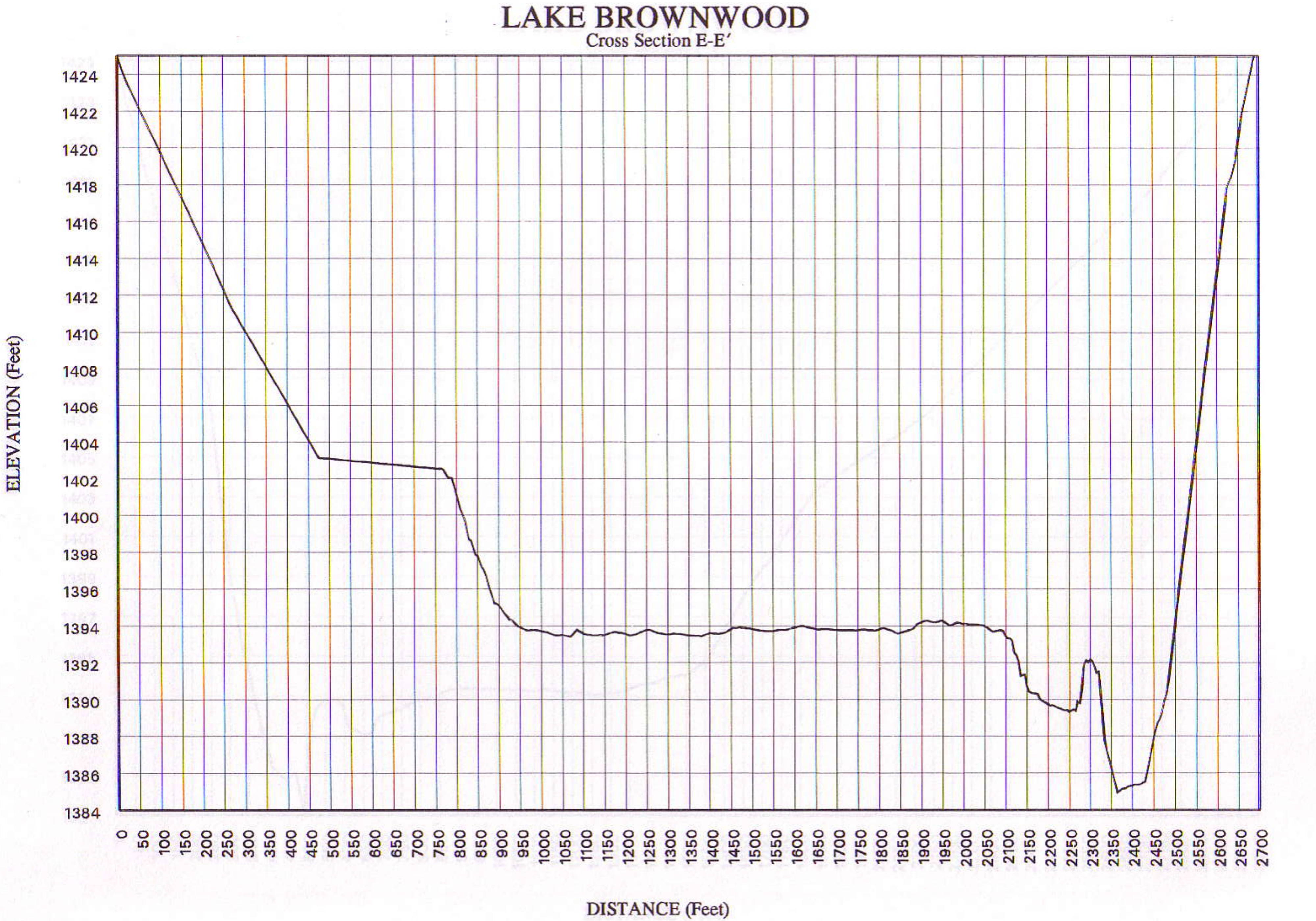
PREPARED BY: TWDB AUGUST 1997

LAKE BROWNWOOD

Cross Section D-D′



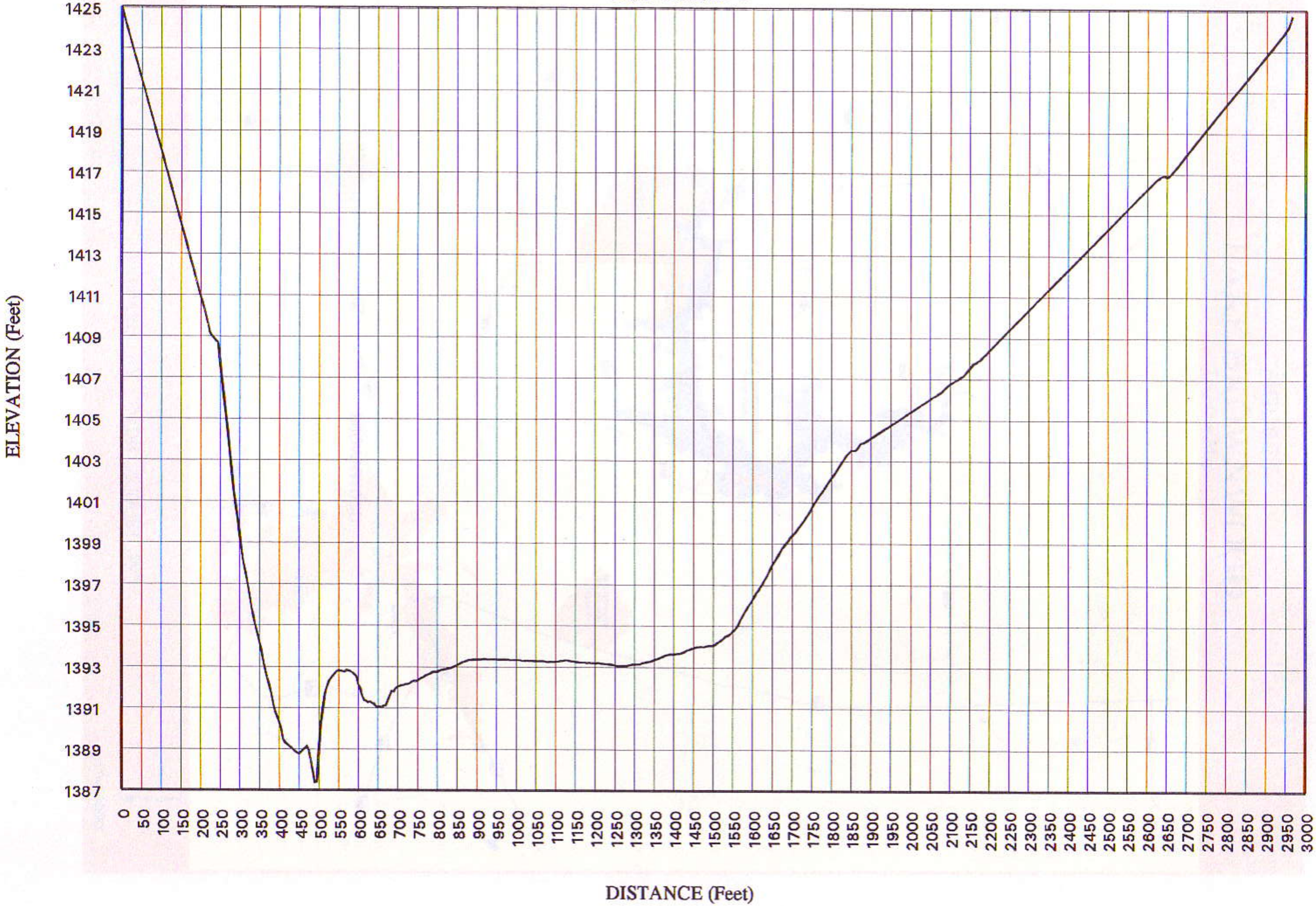
PREPARED BY: TWDB AUGUST 1997



PREPARED BY: TWDB AUGUST 1997

LAKE BROWNWOOD

Cross Section F-F′

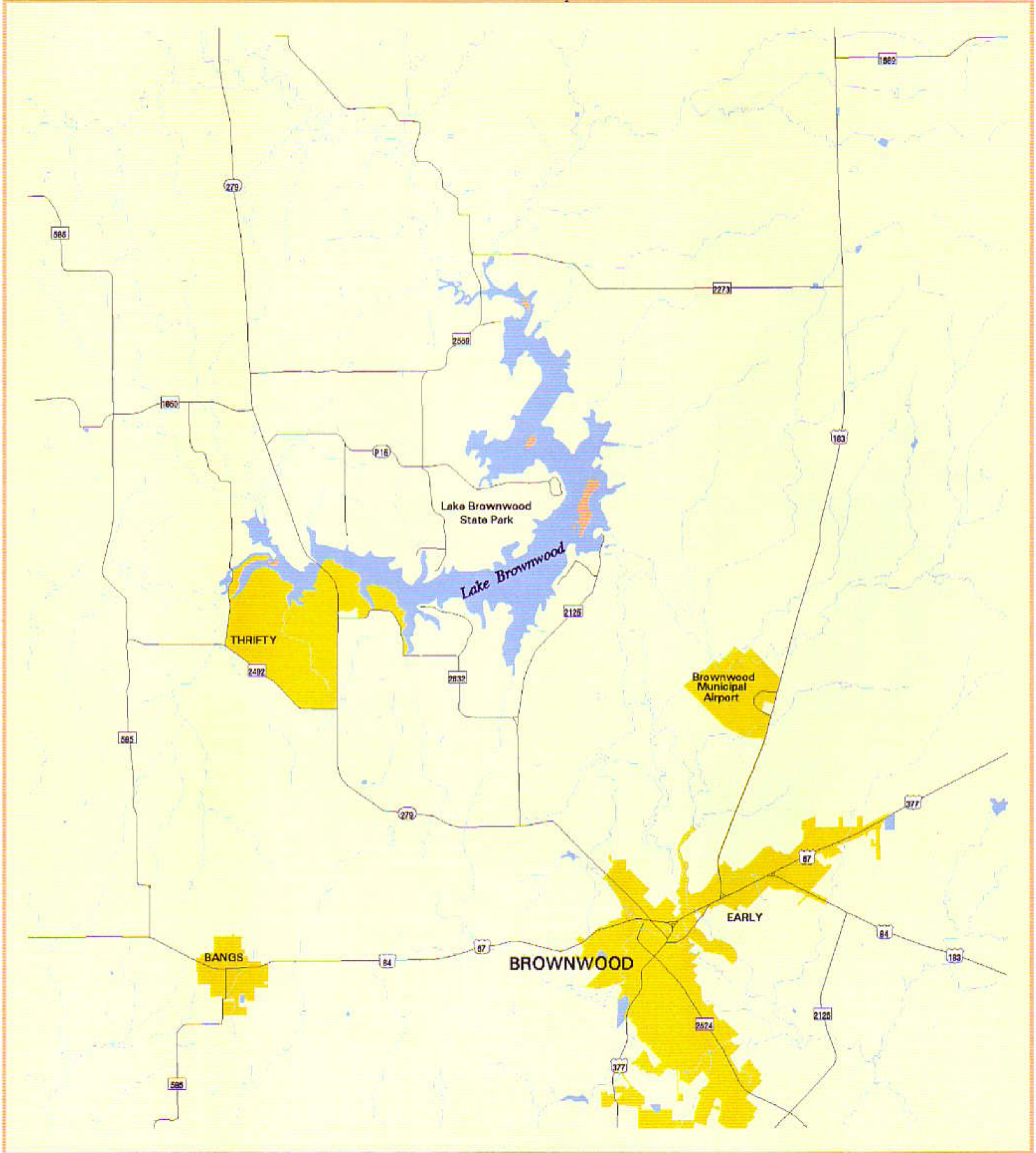


PREPARED BY: TWDB AUGUST 1997

FIGURE 1

LAKE BROWNWOOD

Location Map



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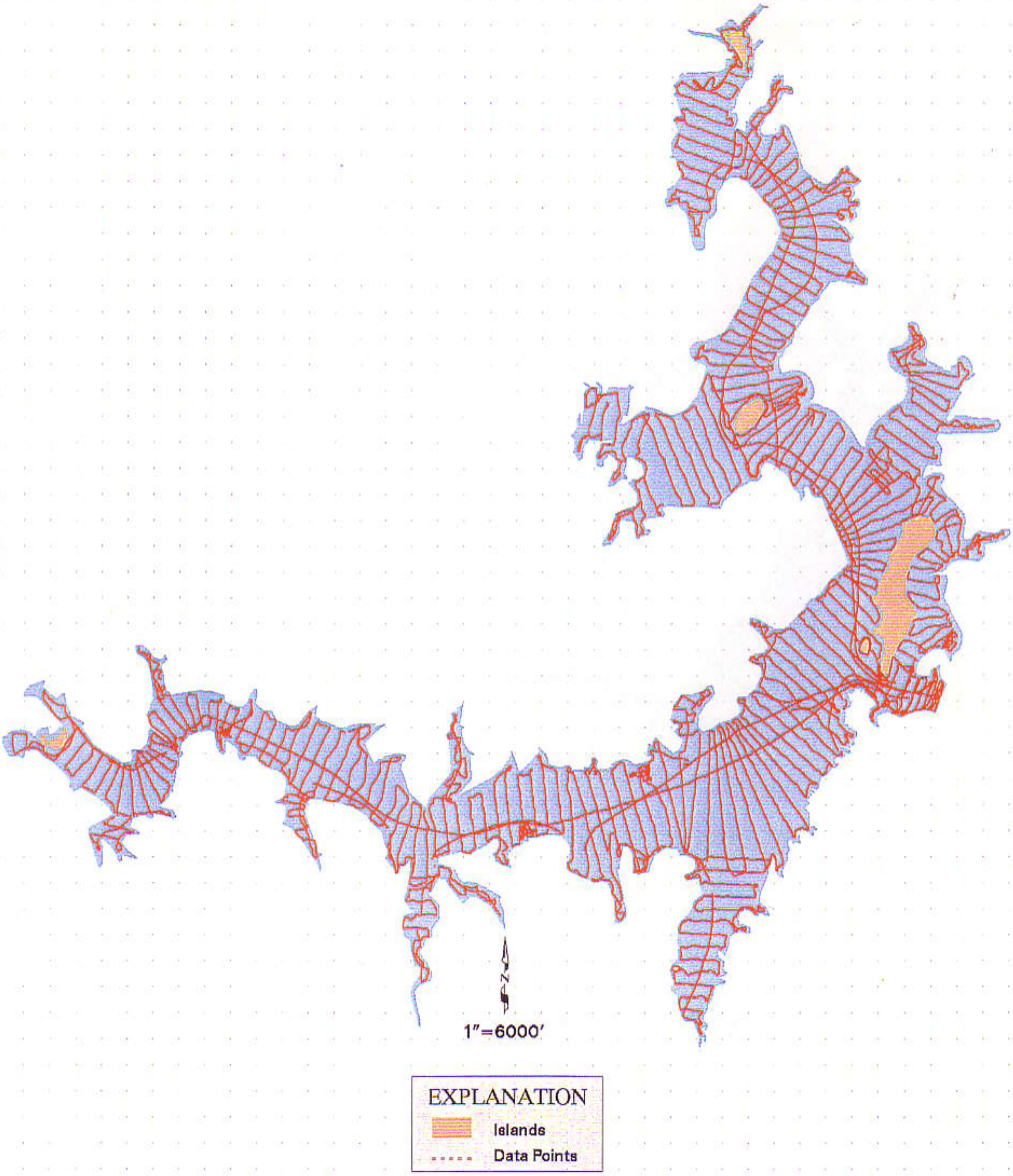
N

1"=15000'

FIGURE 2

LAKE BROWNWOOD

Location of Survey Data

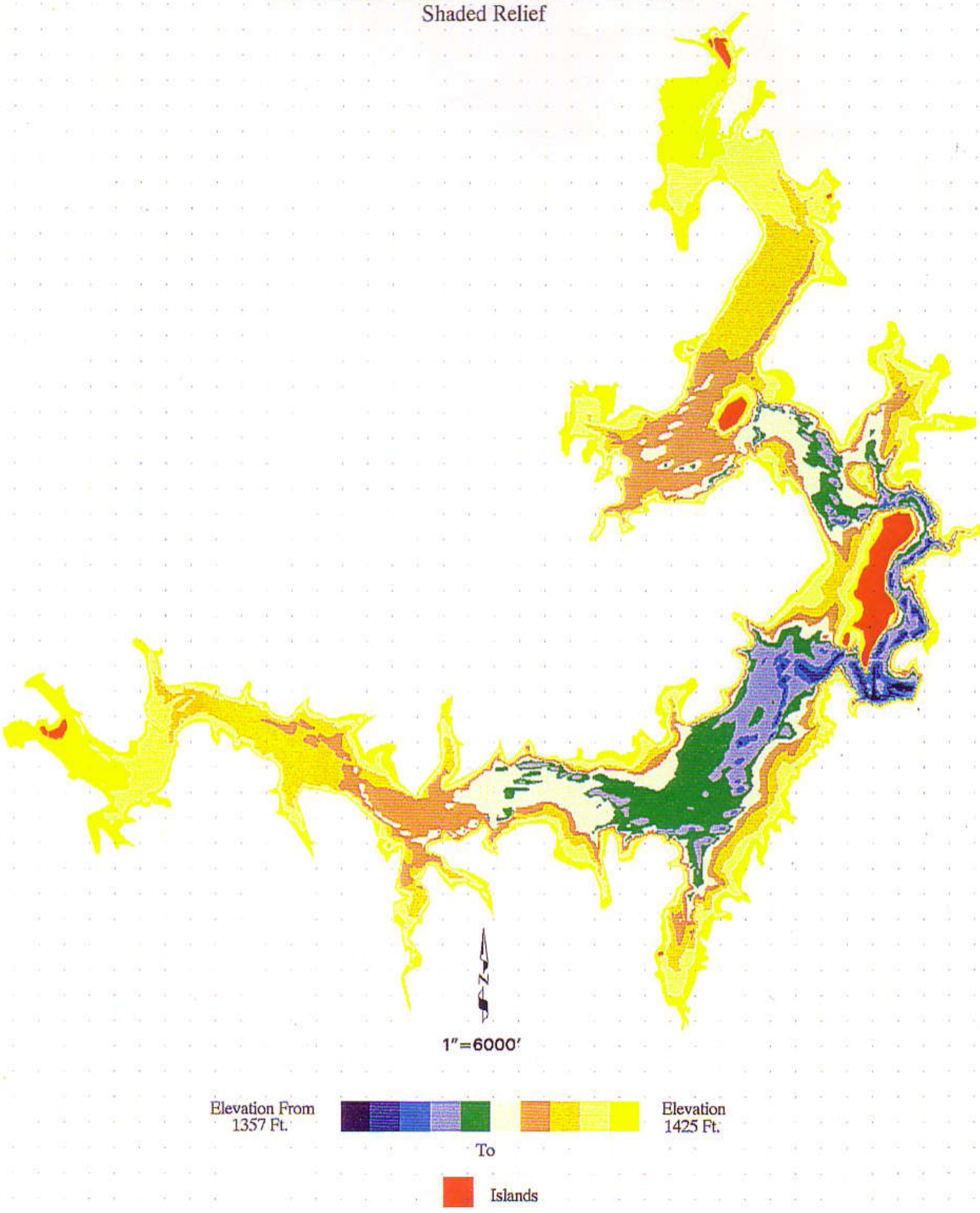


PREPARED BY: TWDB AUGUST 1997

FIGURE 3

LAKE BROWNWOOD

Shaded Relief

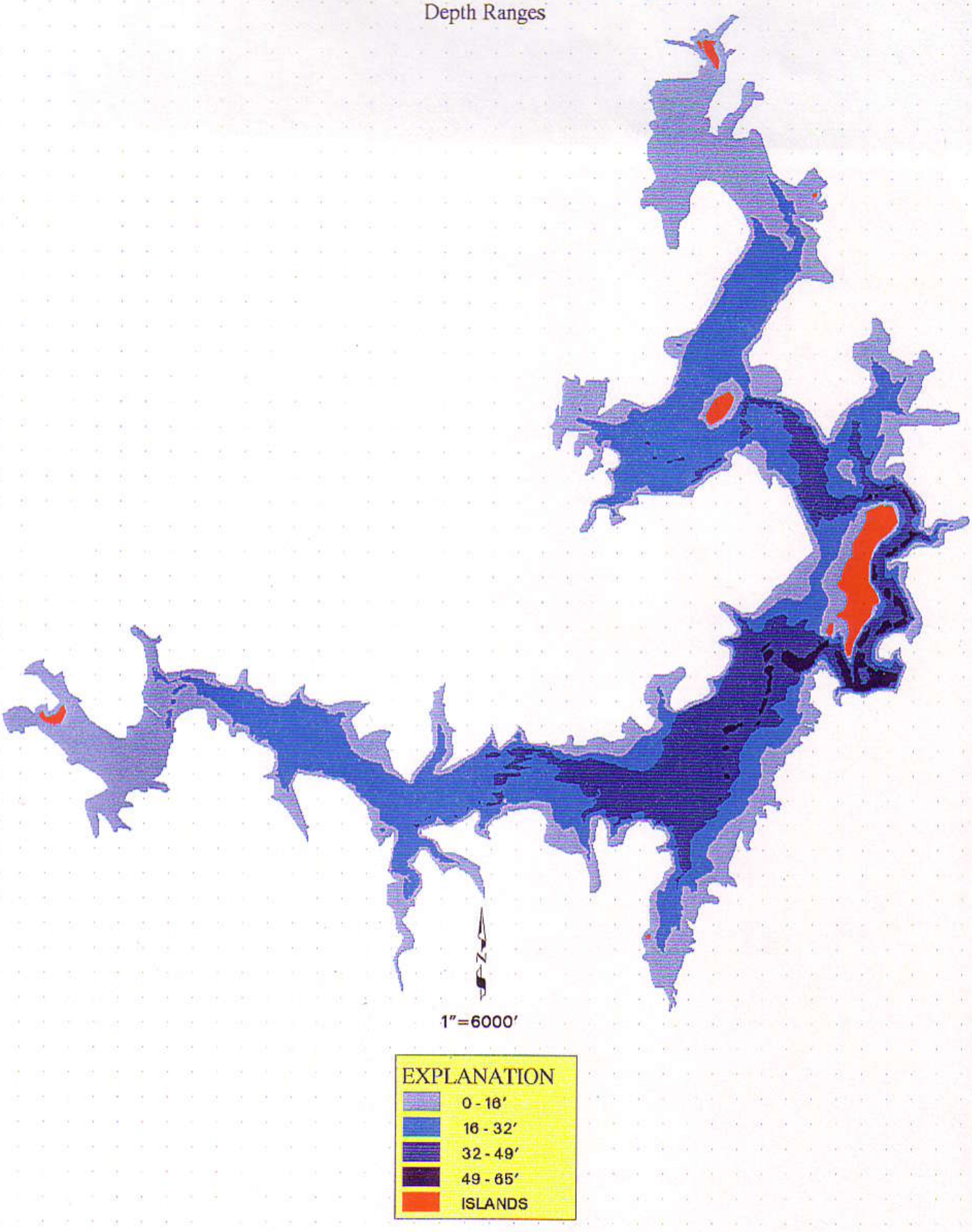


PREPARED BY: TWDB AUGUST 1997

FIGURE 4

LAKE BROWNWOOD

Depth Ranges



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