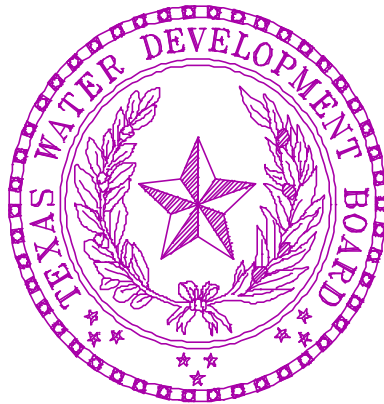


# **VOLUMETRIC SURVEY OF LAKE CYPRESS SPRINGS**

**Prepared for:**

**FRANKLIN COUNTY  
WATER DISTRICT**



**Prepared by:**

**The Texas Water Development Board**

March 10, 2003

# Texas Water Development Board

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# **LAKE CYPRESS SPRINGS HYDROGRAPHIC SURVEY REPORT**

## **INTRODUCTION**

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey of Lake Cypress Springs during the period of April 20 – 22, 1998. 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 the elevation is noted otherwise. The conservation pool elevation for Lake Cypress Springs is 378.0 feet. The original design information estimates the original surface area at this elevation to be 3,400 acres and the storage volume to be 72,800 acre-feet of water.

## **HISTORY AND GENERAL INFORMATION OF THE RESERVOIR**

Franklin County Water District owns the water rights to Lake Cypress Springs and operates and maintains associated Franklin County Dam. The lake is located on Big Cypress Creek in Franklin County, eight miles southeast of Mount Vernon, Texas (see Figure 1). Records indicate the drainage area is approximately 75 square miles. At the conservation pool elevation, the lake has approximately 44.5 miles of shoreline and is 7 miles long. The widest point of the reservoir is approximately 2.51 miles (located 2.5 miles upstream of the dam).

Water Rights Permit No. 2231 (Application 2423) was issued to Franklin County Water District on November 10, 1966 and authorized the construction of a dam to impound 72,800 acre-feet of water. The owner was granted the right to divert and use not to exceed 1,000 acre-feet of water for municipal purposes. The permit was amended several times in the following years. The Texas Water Commission issued Certificate of Adjudication No. 04-4560 on October 13, 1986. The

certificate authorizes Franklin County Water District to maintain an existing dam and reservoir on Cypress Creek (Lake Cypress Springs) and to impound, not to exceed, 72,800 acre-feet of water. The owner was authorized to divert and use not to exceed 9,300 acre-feet of water per year for municipal purposes of which 5,000 acre-feet of water could be diverted into the Sabine River Basin and 2,185 acre-feet of water could be diverted into the Sulphur River Basin. Authorization was granted to use not to exceed 5,940 acre-feet of water per annum for industrial purposes and to use not to exceed 60 acre-feet of water per annum for irrigation purposes. The impounded water of Lake Cypress Springs was also authorized for recreational purposes. A "Use" change was amended to Certificate of Adjudication 04-4560 on January 3, 1990. It basically allowed the owner to use not to exceed 5,640 acre-feet of water per annum for industrial purposes and use not to exceed 360 acre-feet of water per annum for irrigation purposes.

Records indicate the construction for Lake Cypress Springs started in July 1968. Deliberate impoundment for Lake Cypress Springs began on July 7, 1970 and the project was officially completed February 15, 1971. The design engineer for the facility was Wisenbaker, Fix, and Associates. The general contractor was Vibig Construction Company. The estimated cost of the dam was \$1,270,000.

Franklin County Dam and appurtenant structures consist of a rolled earth fill embankment, 5,230 feet in length, with a maximum height of 74 feet and a crest elevation that varies from 395.0 feet to 397.0 feet. The service spillway is located near right end of the main embankment. The rectangular shaped drop inlet is uncontrolled. The crest elevation of the 23-feet by 23-feet opening is 378.0 feet. Discharges flow into a 10-feet by 10-feet box conduit. An 18-inch concrete pipe with duplicate valve controls serve as a low-flow outlet. The invert elevation is 329.0. Discharge water flow into the 10-foot square conduit. The emergency spillway, located to the left (north) of the dam, is an earth trench cut through the natural ground. The uncontrolled broad-crested weir is 1,000 feet in length at elevation 385.0 feet.

## **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.

The United States Air Force and the defense establishment developed GPS technology in the 1960's. 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 the 1983 North American Datum (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) is an advance mode of satellite surveying in which positions of moving objects can be determine in real-time or "on-the-fly." This technological breakthrough was the backbone of the development of the TWDB's Hydrographic Survey Program. In the early stages of the 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 another 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. This type of operation can obtain a horizontal positional accuracy of within one meter. In addition, the large positional errors experienced by a single receiver when S/A is active are negated. Since a greater accuracy is needed in the vertical direction, the depth sounder supplies vertical data during a survey. The lake surface during the survey serves as the vertical datum for the readings from the depth sounder.

The need for setting up a stationary shore receiver for current surveys has been eliminated by registration with a fee-based satellite reference position network (OmniSTAR). This service works in a differential mode basically the same way as the shore station, except on a worldwide basis. For a given area in the world, a network of several monitoring sites (with known positions) collect GPS signals from the NAVSTAR network. GPS corrections are computed at each of these sites to correct the GPS signal received to the known coordinates of the site. The corrections from each of the sites within the network are automatically sent via a leased line to a "Network Control Center" where the data corrections are checked and repackaged for up-link to a "Geostationary" L-band satellite. The

“real-time” corrections for the entire given area in the world are then broadcast by the satellite to users of the system in the area covered by the satellite. The OmniSTAR receiver translates the information and supplies it to the on-board Trimble receiver for correction of the boat’s GPS positions. The accuracy of this system in a real-time mode is normally 1 meter or less.

## **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 OmniSTAR receiver, and an on-board 486 computer. A water-cooled generator through an in-line uninterruptible power supply provides electrical power. 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 with 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 remained a major cost with this method.

More recently, aerial photography has been used prior to construction, to generate elevation contours from which 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  $\pm$  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 378.0). The boundary file was created from the following 7.5-minute USGS quadrangle maps: NEW HOPE, TX (1965), and PURLEY, TX (1964). The graphic boundary file created was then transformed into the proper datum, from NAD '27 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 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 129 survey lines to be placed along the length of the lake. Survey setup files were created using Coastal Oceanographics, 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 Cypress Springs 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 Cypress Springs, the speed of sound in the water column varied from 4847 to 4859 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  $\pm 0.3$  feet due to the plane of the boat for a total accuracy of  $\pm 0.5$  feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some are positive 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  $10^\circ$  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 were collected at Lake Cypress Springs during the period of April 20 - 22, 1998. During data collection, the crew had excellent weather with moderate temperatures and mild winds.. Approximately 49,858 data points were collected over the 105 miles traveled along the 129 survey lines run (pre-planned, random, and parallel). These points were stored digitally on the boat's computer in 165 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. Figure 2 shows the actual location of all data collection points.

TWDB staff observed the land surrounding the lake to be generally flat to rolling hills. Along

the north shoreline of the lake, between the dam and County Road 115 the crew observed extensive residential development with bulkheads, piers and boat slips. Several parks were also scattered around the perimeter of the lake. Shoreline erosion due to sloughing of the bank was observed in the areas without any bulkheads. This was a frequent occurrence upstream of County Road 115. The east of the lake around the dam was the widest area of the lake. The lake narrowed as you traveled west from the dam until the lake represented more of a river in the headwaters of Cypress Creek. Cattail Island was the only island observed during the time of this survey.

While performing the survey on the lake, TWDB staff noted on the depth sounder that the bathymetry/contour of the lake bottom reflected the characteristics of the terrain surrounding the lake. A gradual slope was notice as you traveled from the shoreline to the center of the lake. Near the center of the lake, the old creek channel of Cypress Creek was easily distinguished during work in the main body of the lake.

There were only a few areas in the lake that the crew encountered navigational hazards. There were two pump station sites located just east of the Highway 115 bridge. One site located near the north shoreline provides water for the City of Mt. Vernon and Cypress Springs Water Supply Corporation. The second site near the south shoreline provides water to the Cypress Springs Water Supply Corporation and the City of Winnsboro. In addition, sediment deposits and standing vegetation were observed mainly in the upper reaches of Panther Creek and Cypress Creek. The crew was able to collect data in these areas, but at a much slower pace. Data collection in the headwaters was limited when the boat could no longer cross the lake due to shallow water and extensive vegetation.

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 downloaded 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 varied between 378.2 and 378.19 feet. After all changes had been made 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, representative of the lake, to be used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was imported into the UNIX operating system used to run Environmental System Research Institute'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 software 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 downsized 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 some areas where volume and area values could not be calculated by interpolation because of a lack of information within 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 for this project, therefore no additional points were needed to allow for interpolation and contouring of the entire lake surface at elevation 378.0. Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals. From elevation 375.0 to elevation 378.0, the surface areas and volumes of the lake were mathematically estimated. This was done by first distributing uniformly across each elevation increment; the surface areas digitized from USGS topographic maps. Volumes were then calculated in a 0.1 foot step method by adding to the existing volume, 0.1 of the existing area, and 0.5 of the difference between the existing area the area for the value being calculated. The computed area of the lake at elevation 378.0 was 3,461 surface acres. The computed area was 61 surface acres more than originally calculated in 1971. 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 378.0 lake elevation was assigned the color of yellow. Different color shades were assigned to the intermediate depths. 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 1998 TWDB survey indicate Lake Cypress Springs encompasses 3,461 surface acres and contains a volume of 67,690 acre-feet at the conservation pool elevation of 378.0 feet. The shoreline at this elevation was calculated to be 44.5 miles. The deepest point of the lake, elevation 325.32 or 52.68 feet of depth, was located approximately 958 feet south southwest from the center of Franklin County Dam. The dead storage volume, or the amount of water below the lowest outlet in the dam, was calculated to be 1 acre-foot based on the low flow outlet invert elevation of 329.0 feet. The conservation storage capacity, or the amount of water between the spillway and the lowest outlet, is therefore the same as the capacity or 67,690 acre-feet.

## **SUMMARY**

Lake Cypress Springs was formed in 1950. Initial storage calculations estimated the volume at the conservation pool elevation of 378.0 feet to be 72,800 acre-feet with a surface area of 3,400 acres.

During the period of April 14 - 15, 1998, a hydrographic survey of Lake Cypress Springs was performed by the Texas Water Development Board's Hydrographic Survey Program. The 1998 survey used technological advances such as differential global positioning system and geographical information system technology to build a model of the reservoir's bathymetry. These advances allowed a survey to be performed quickly and to collect significantly more data of the bathymetry of Lake Cypress Springs than previous survey methods. Results indicate that the lake's capacity at the conservation pool elevation of 378.0 feet was 67,690 acre-feet and the area was 3,461 acres.

The estimated reduction in storage capacity at the conservation pool elevation of 378.0 feet since 1971 was 5,110 acre-feet or 189.26 acre-feet per year. The average annual deposition rate of sediment in the conservation pool of the reservoir can be estimated at 2.523 acre-feet per square mile of drainage area. *(Please note that this is just a mathematical estimate based on the difference between the original design and the current survey. Limited knowledge on actual sedimentation can be determined from one field survey.)*

It is difficult to compare the original design information and the TWDB performed survey because little is known about the original design method, the amount of data collected, and the method used to process the collected data. However, the TWDB considers the 1998 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

$$\begin{aligned}t_{30} &= (30-1.2)/4832 \\ &= 0.00596 \text{ sec.}\end{aligned}$$

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

$$\begin{aligned}t_{45} &= (45-1.2)/4808 \\ &= 0.00911 \text{ sec.}\end{aligned}$$

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

$$\begin{aligned}D_{20} &= [((20-1.2)/4832)(4808)]+1.2 \\ &= 19.9' \quad (-0.1')\end{aligned}$$

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

$$\begin{aligned}D_{30} &= [((30-1.2)/4832)(4808)]+1.2 \\ &= 29.9' \quad (-0.1')\end{aligned}$$

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

$$D_{50} = [((50-1.2)/4799)(4808)]+1.2$$

$$= 50.1' \quad (+0.1')$$

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

$$t_{60} = (60-1.2)/4799$$

$$= 0.01225 \text{ sec.}$$

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

$$D_{10} = [((10-1.2)/4832)(4799)]+1.2$$

$$= 9.9' \quad (-0.1')$$

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

$$D_{30} = [((30-1.2)/4832)(4799)]+1.2$$

$$= 29.8' \quad (-0.2')$$

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

$$D_{45} = [((45-1.2)/4808)(4799)]+1.2$$

$$= 44.9' \quad (-0.1')$$

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

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

$$= 80.2' \quad (+0.2')$$

TEXAS WATER DEVELOPMENT BOARD  
RESERVOIR VOLUME TABLE

Jul 23 1998

Lake Cypress Springs April 1998 Survey

ELEV. FEET	VOLUME IN ACRE-FEET									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
326										
327										
328							1	1	1	1
329	1	1	1	1	2	2	2	3	3	3
330	4	5	5	6	8	9	11	13	16	19
331	22	25	29	34	39	44	50	57	64	71
332	79	87	96	105	115	125	136	148	160	172
333	185	199	213	227	242	258	274	290	306	323
334	340	358	376	394	413	432	451	471	491	512
335	534	556	578	600	623	647	670	694	719	743
336	768	794	819	846	872	899	927	954	983	1011
337	1041	1070	1100	1131	1162	1193	1225	1257	1290	1324
338	1358	1392	1427	1463	1499	1536	1573	1611	1649	1689
339	1729	1769	1811	1853	1896	1939	1983	2028	2073	2119
340	2165	2212	2260	2308	2356	2405	2455	2505	2556	2607
341	2659	2712	2765	2819	2873	2928	2984	3040	3096	3153
342	3211	3270	3329	3388	3448	3509	3570	3632	3694	3757
343	3820	3884	3949	4014	4079	4145	4211	4278	4346	4414
344	4482	4551	4620	4690	4761	4832	4904	4978	5052	5126
345	5202	5278	5355	5433	5511	5590	5670	5750	5831	5913
346	5995	6077	6161	6245	6330	6416	6502	6589	6677	6765
347	6854	6943	7034	7124	7215	7307	7400	7493	7587	7681
348	7776	7872	7969	8066	8164	8262	8361	8461	8561	8662
349	8764	8866	8968	9071	9175	9279	9384	9490	9596	9703
350	9810	9919	10028	10137	10247	10358	10470	10581	10694	10807
351	10921	11035	11150	11265	11381	11498	11615	11733	11852	11971
352	12090	12211	12331	12453	12575	12697	12820	12944	13068	13193
353	13318	13444	13571	13698	13826	13955	14083	14213	14343	14474
354	14605	14737	14870	15003	15137	15271	15406	15542	15678	15815
355	15952	16090	16229	16368	16508	16648	16790	16931	17073	17216
356	17360	17504	17649	17795	17941	18087	18235	18383	18531	18680
357	18830	18980	19131	19283	19435	19587	19740	19894	20048	20203
358	20359	20515	20671	20829	20986	21145	21304	21463	21623	21784
359	21945	22107	22270	22433	22597	22761	22927	23093	23259	23426
360	23594	23762	23931	24101	24271	24442	24614	24786	24958	25132
361	25306	25481	25656	25833	26010	26187	26366	26545	26725	26906
362	27087	27269	27452	27635	27819	28004	28189	28375	28561	28748
363	28936	29124	29313	29503	29693	29884	30076	30268	30461	30655
364	30849	31045	31241	31438	31636	31834	32034	32234	32436	32638
365	32842	33046	33252	33459	33666	33874	34083	34293	34504	34715
366	34928	35141	35355	35570	35787	36004	36221	36440	36660	36880
367	37102	37324	37548	37771	37996	38222	38448	38676	38904	39133
368	39363	39593	39825	40057	40291	40525	40760	40996	41233	41471
369	41709	41949	42189	42430	42673	42916	43160	43405	43650	43897
370	44144	44393	44642	44892	45143	45395	45648	45902	46157	46413
371	46669	46927	47186	47446	47706	47968	48230	48494	48758	49023
372	49290	49557	49826	50095	50366	50637	50910	51183	51458	51733
373	52009	52287	52565	52845	53125	53406	53689	53972	54257	54543
374	54829	55117	55407	55697	55989	56281	56576	56871	57169	57468

Lake Cypress Springs April 1998 Survey

ELEV. FEET	VOLUME IN ACRE-FEET					ELEVATION INCREMENT IS ONE TENTH FOOT				
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
375	57775	58084	58395	58707	59020	59335	59651	59969	60288	60609
376	60932	61255	61581	61907	62236	62565	62897	63229	63564	63899
377	64236	64575	64915	65257	65600	65945	66291	66638	66987	67338
378	67690									

APPENDIX C LAKE CYPRESS SPRINGS AREA TABLE

TEXAS WATER DEVELOPMENT BOARD  
RESERVOIR AREA TABLE

Jul 23 1998

Lake Cypress Springs

April 1998 Survey

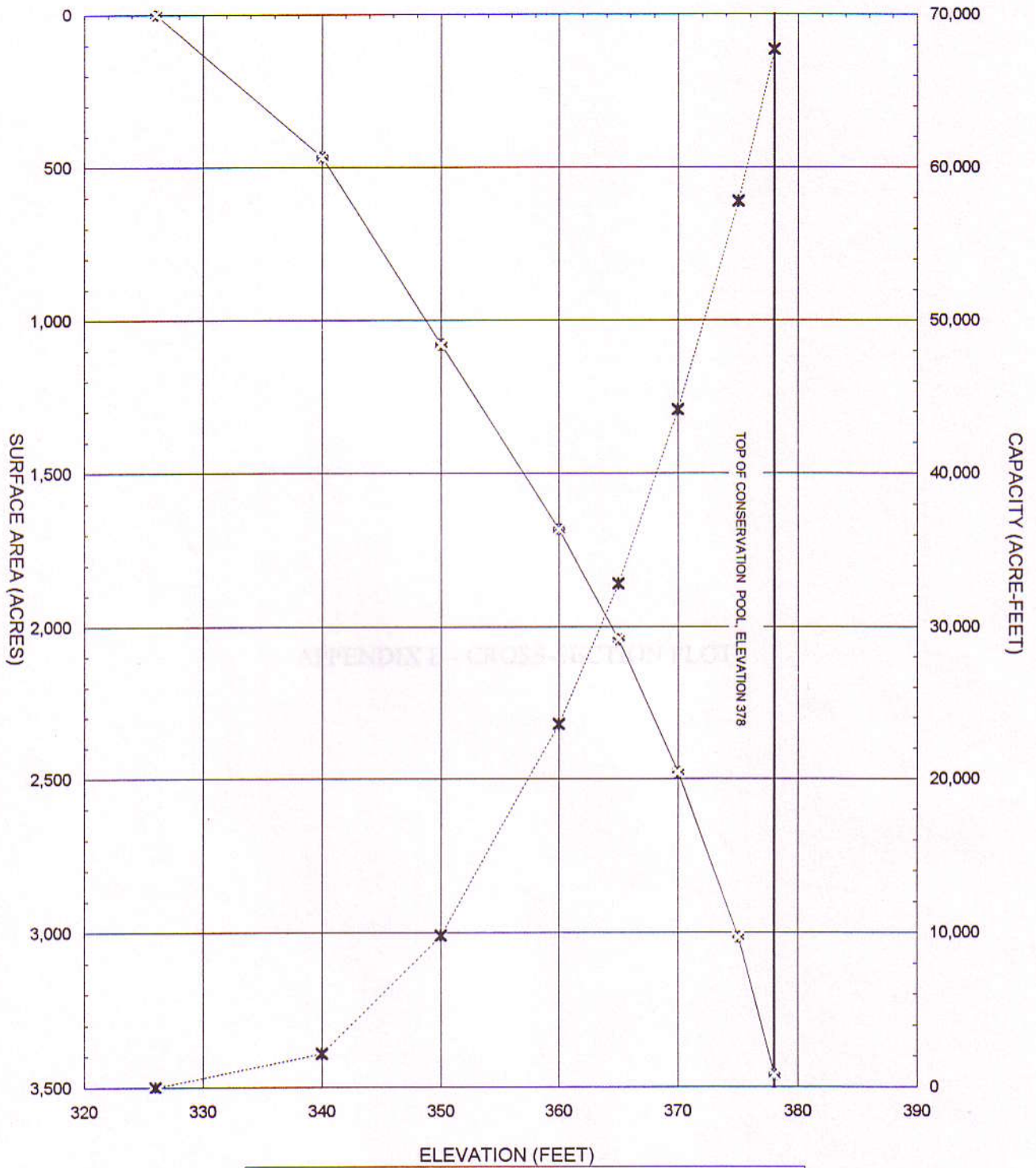
ELEV. FEET	AREA IN ACRES									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
326										
327										
328					1	1	1	1	1	1
329	1	2	2	2	2	3	3	4	4	5
330	6	7	9	12	15	17	20	23	27	30
331	33	37	42	48	53	58	63	67	71	76
332	80	84	89	94	100	106	112	118	123	128
333	133	138	143	148	152	156	160	164	167	170
334	173	177	180	184	188	192	197	202	207	212
335	216	221	224	228	231	234	238	241	245	248
336	252	256	260	264	268	272	276	281	285	290
337	294	299	303	307	312	316	321	326	332	337
338	342	347	353	358	364	370	376	383	389	396
339	403	411	418	425	431	437	443	449	455	461
340	467	472	477	482	488	494	499	505	511	517
341	524	530	535	540	546	551	557	563	569	575
342	581	587	592	598	604	609	615	621	626	631
343	637	642	646	651	656	661	667	672	677	681
344	686	691	696	703	711	719	727	736	743	751
345	758	766	773	780	787	794	800	806	812	818
346	825	831	838	846	853	860	867	874	880	886
347	892	897	903	909	916	922	929	936	942	948
348	954	961	968	975	982	989	995	1001	1006	1012
349	1017	1022	1027	1033	1040	1046	1052	1059	1065	1072
350	1079	1086	1093	1099	1105	1111	1116	1122	1127	1133
351	1139	1145	1152	1158	1164	1170	1176	1182	1188	1194
352	1200	1205	1211	1216	1222	1227	1234	1240	1246	1252
353	1258	1263	1269	1275	1281	1287	1293	1298	1304	1311
354	1317	1323	1329	1335	1341	1347	1353	1359	1365	1371
355	1377	1383	1389	1395	1402	1408	1414	1420	1426	1432
356	1439	1446	1452	1458	1464	1470	1476	1482	1488	1494
357	1500	1506	1512	1518	1523	1528	1534	1539	1546	1552
358	1558	1564	1569	1575	1581	1586	1592	1598	1604	1610
359	1616	1623	1629	1636	1642	1649	1656	1662	1669	1675
360	1681	1687	1693	1699	1705	1712	1718	1724	1731	1737
361	1744	1752	1759	1766	1773	1780	1788	1796	1804	1811
362	1818	1824	1830	1837	1843	1849	1855	1861	1867	1874
363	1880	1887	1893	1899	1906	1912	1919	1927	1934	1942
364	1950	1958	1965	1973	1982	1991	2000	2009	2020	2030
365	2041	2052	2061	2070	2079	2086	2094	2102	2111	2119
366	2128	2138	2147	2157	2166	2175	2183	2192	2201	2211
367	2220	2228	2235	2243	2251	2260	2269	2278	2286	2295
368	2303	2311	2320	2329	2338	2347	2355	2364	2372	2381
369	2390	2400	2409	2418	2427	2436	2445	2453	2462	2470
370	2479	2487	2496	2505	2514	2525	2534	2544	2554	2563
371	2573	2582	2592	2601	2610	2620	2629	2639	2649	2659
372	2669	2679	2689	2700	2710	2720	2730	2740	2749	2759
373	2769	2779	2789	2799	2809	2819	2829	2840	2851	2863
374	2874	2886	2898	2910	2922	2936	2949	2965	2981	3000

Lake Cypress Springs

April 1998 Survey

ELEV. FEET	AREA IN ACRES									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
375	3015	3030	3045	3059	3074	3089	3104	3119	3134	3149
376	3164	3178	3193	3208	3223	3238	3253	3268	3283	3297
377	3312	3327	3342	3357	3372	3387	3402	3416	3431	3446
378	3461									

APPENDIX D - LAKE CYPRESS AREA ELEVATION-CAPACITY GRAPH

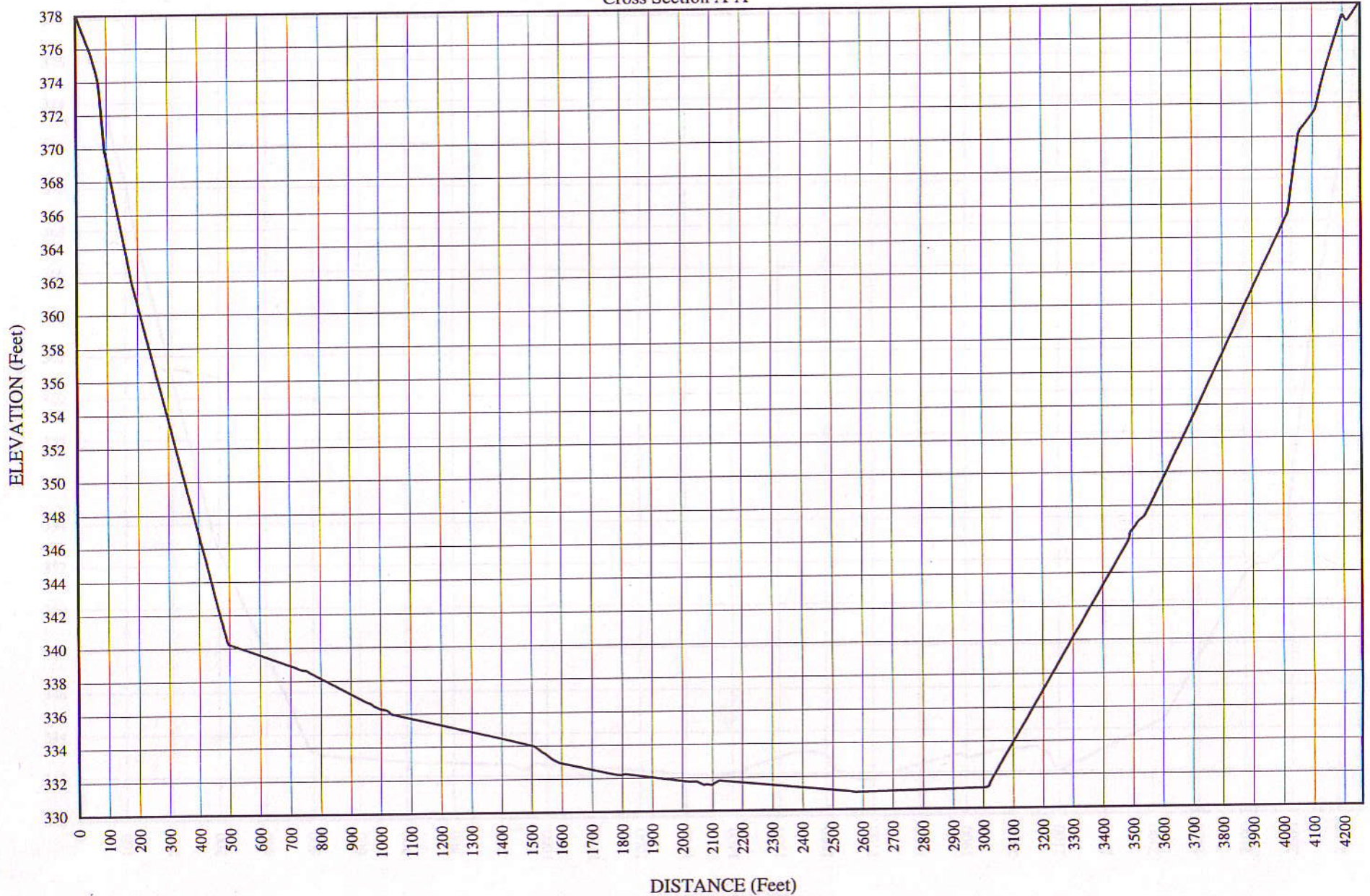


SURFACE AREA      CAPACITY

**LAKE CYPRESS SPRINGS**  
 April 1998 Survey  
 Prepared by: TWDB July 1998

# LAKE CYPRESS SPRINGS

Cross Section A-A'

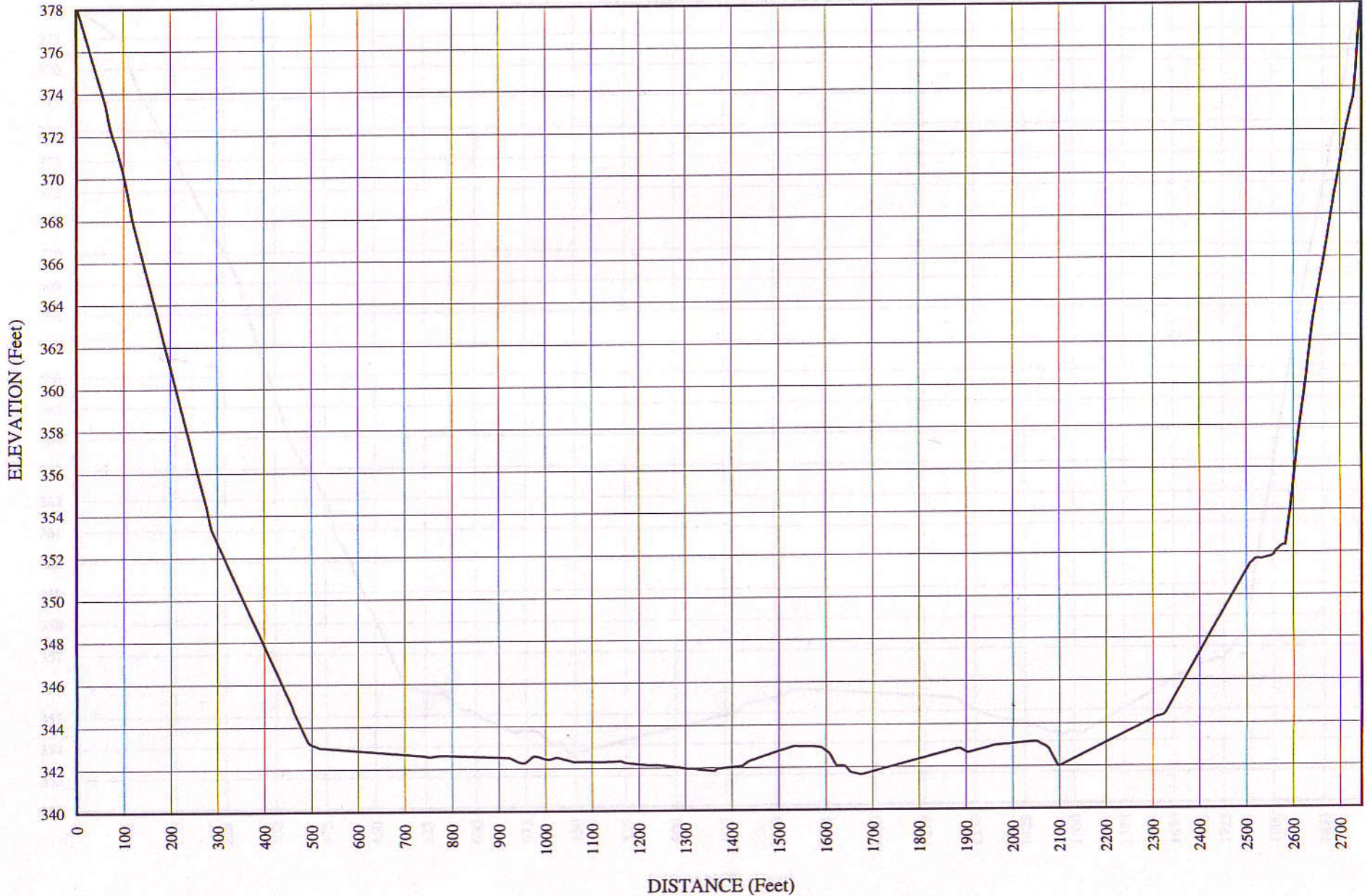


PREPARED BY: TWDB JULY 1998



# LAKE CYPRESS SPRINGS

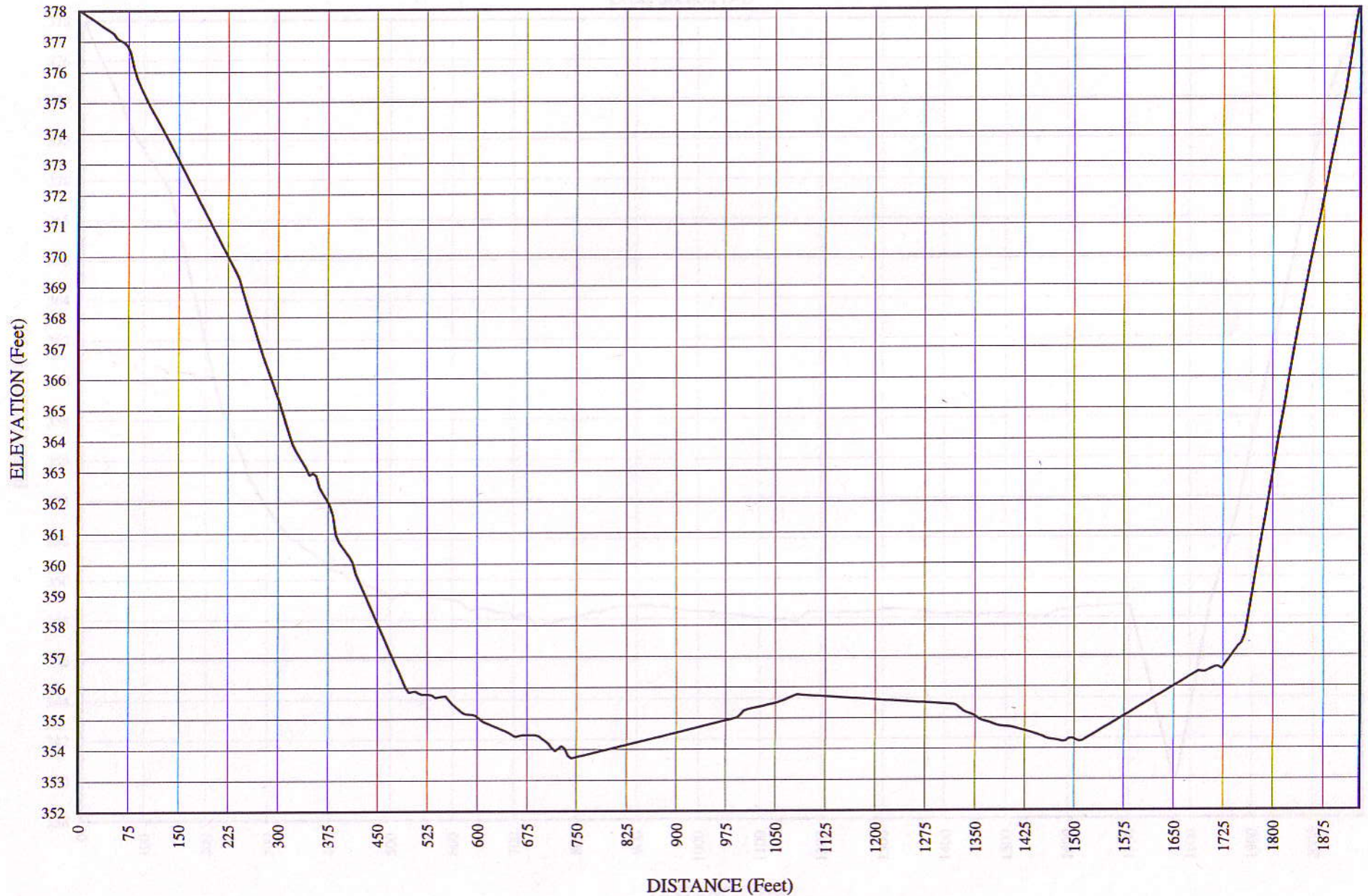
Cross Section B-B'



PREPARED BY: TWDB JULY 1998

# LAKE CYPRESS SPRINGS

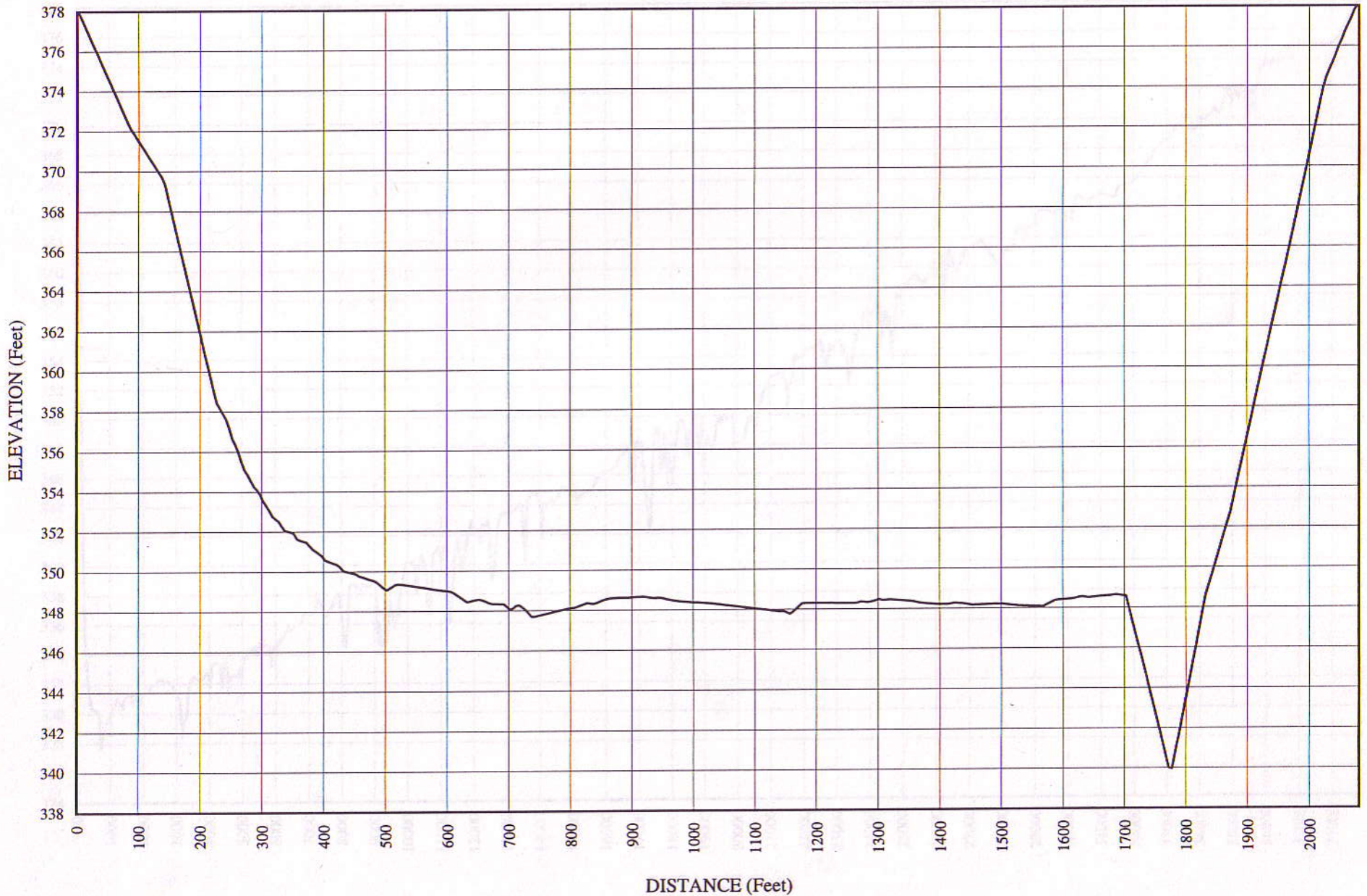
Cross Section C-C'



PREPARED BY: TWDB JULY 1998

# LAKE CYPRESS SPRINGS

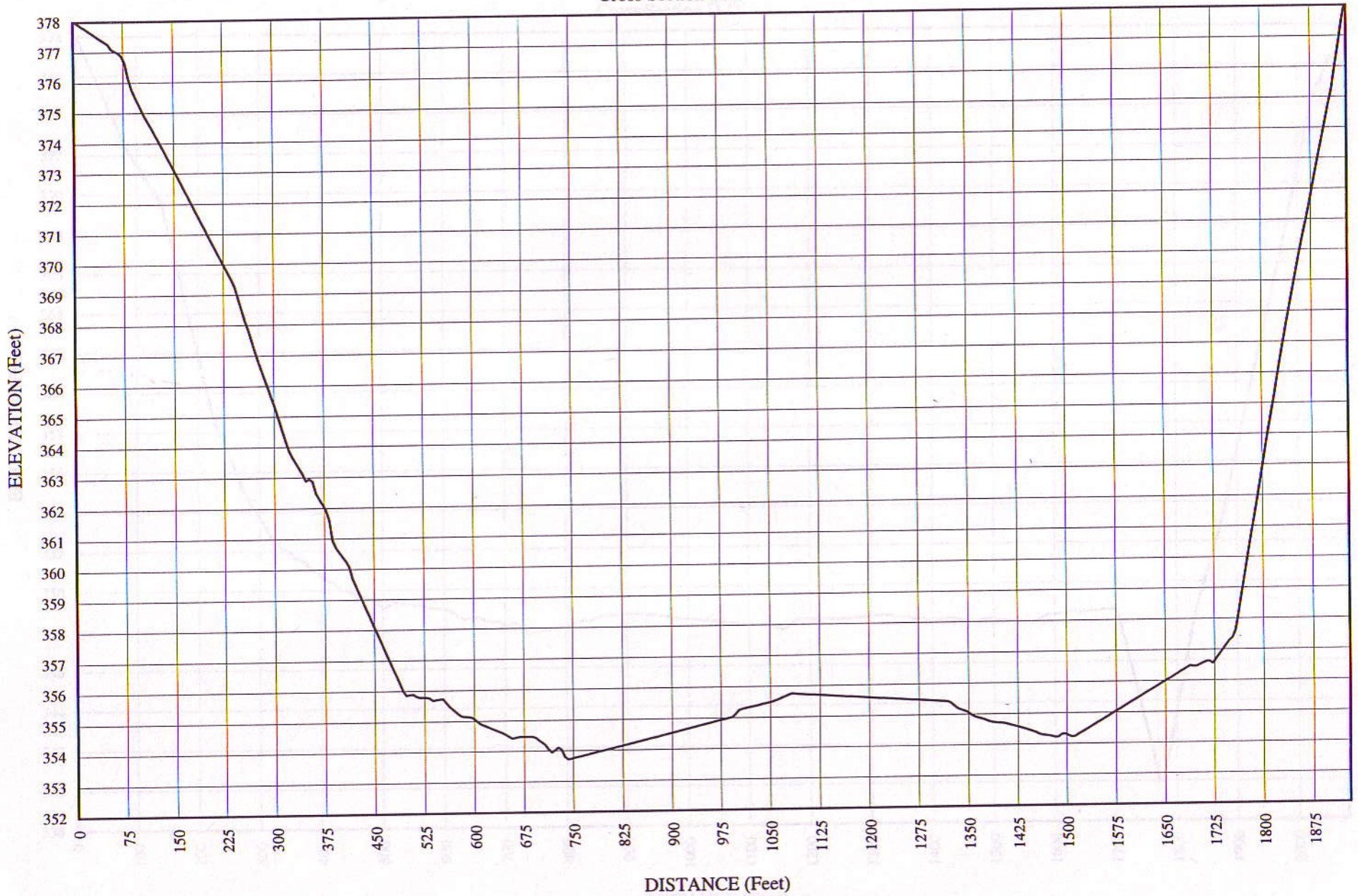
Cross Section D-D'



PREPARED BY: TWDB JULY 1998

# LAKE CYPRESS SPRINGS

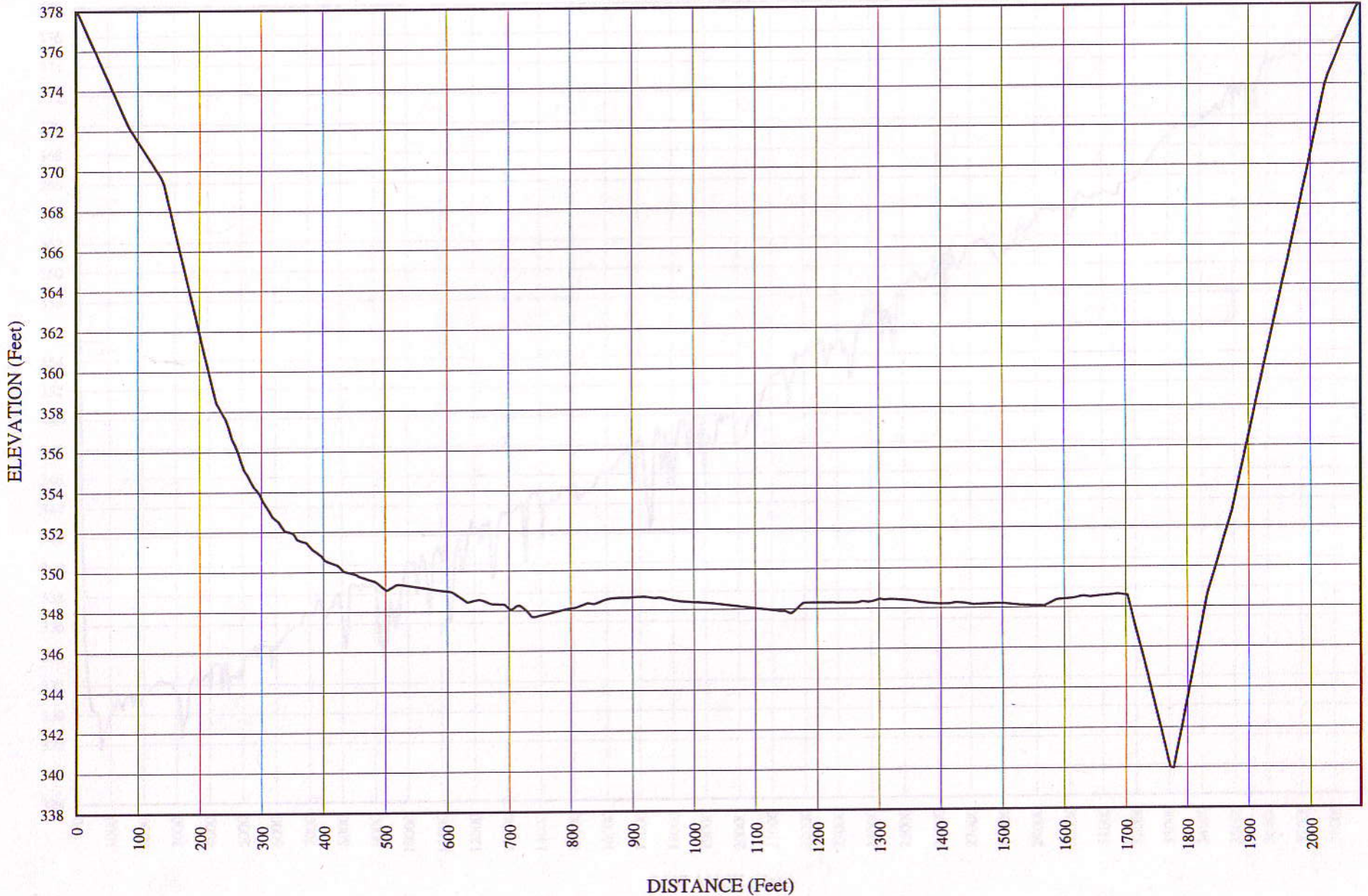
Cross Section C-C'



PREPARED BY: TWDB JULY 1998

# LAKE CYPRESS SPRINGS

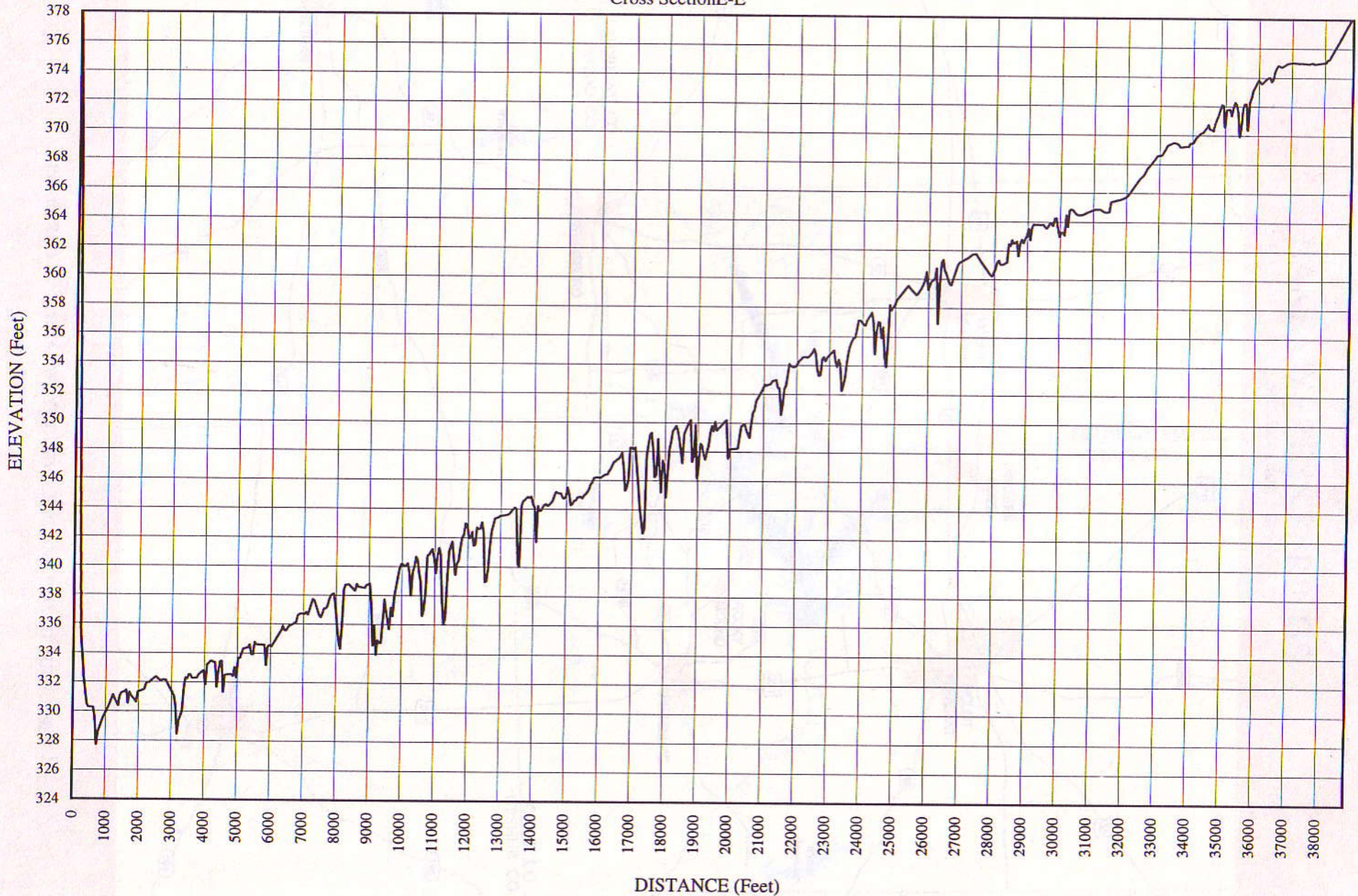
Cross Section D-D'



PREPARED BY: TWDB JULY 1998

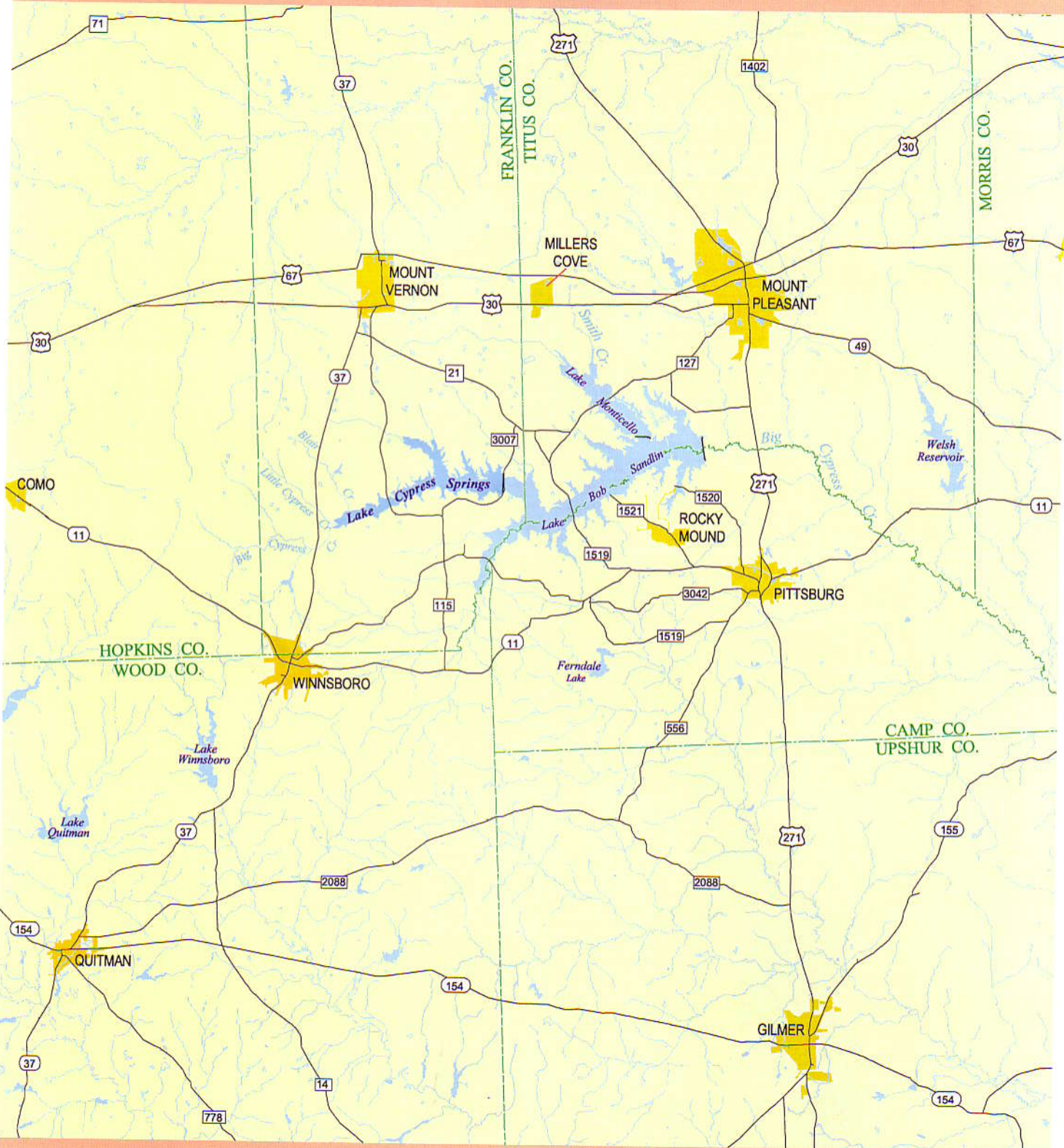
# LAKE CYPRESS SPRINGS

Cross Section E-E'



PREPARED BY: TWDB JULY 1998

FIGURE 1  
LAKE CYPRESS SPRINGS  
Site Location Map

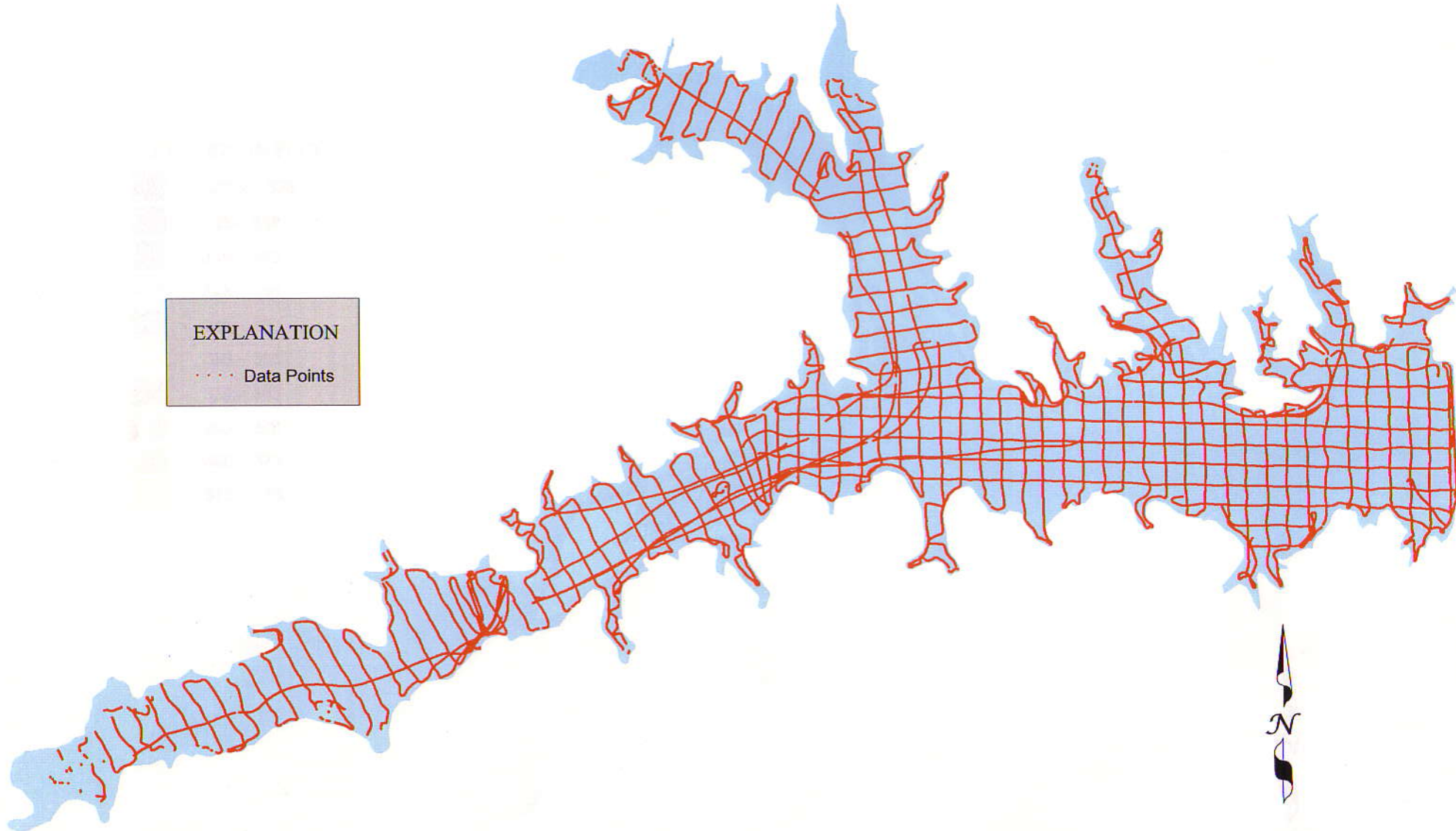


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1" = 9000'

FIGURE 2  
LAKE CYPRESS SPRINGS  
Location of Survey Data



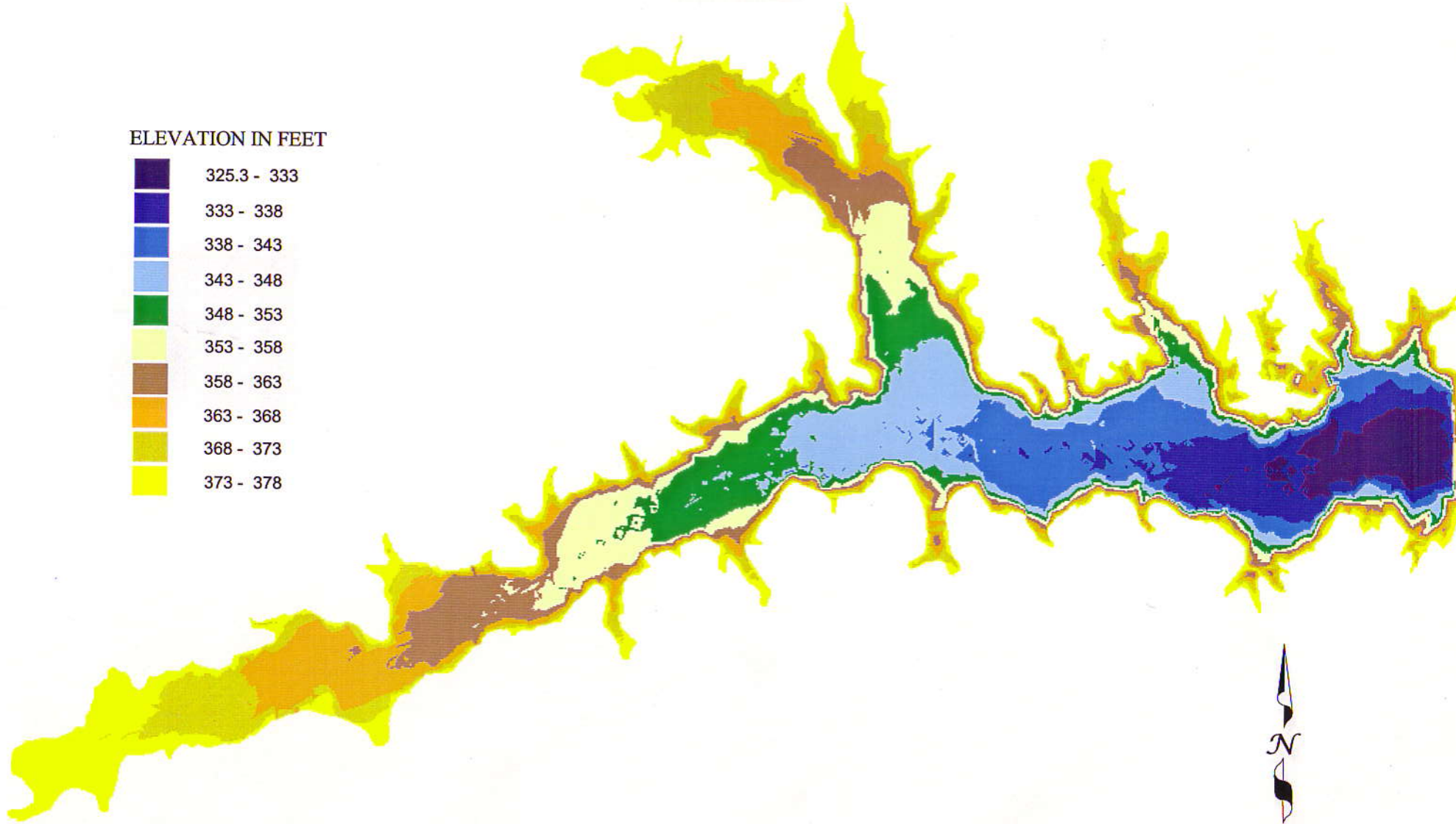
EXPLANATION  
..... Data Points

1" = 2000'



FIGURE 3  
LAKE CYPRESS SPRINGS  
Shaded Relief

ELEVATION IN FEET







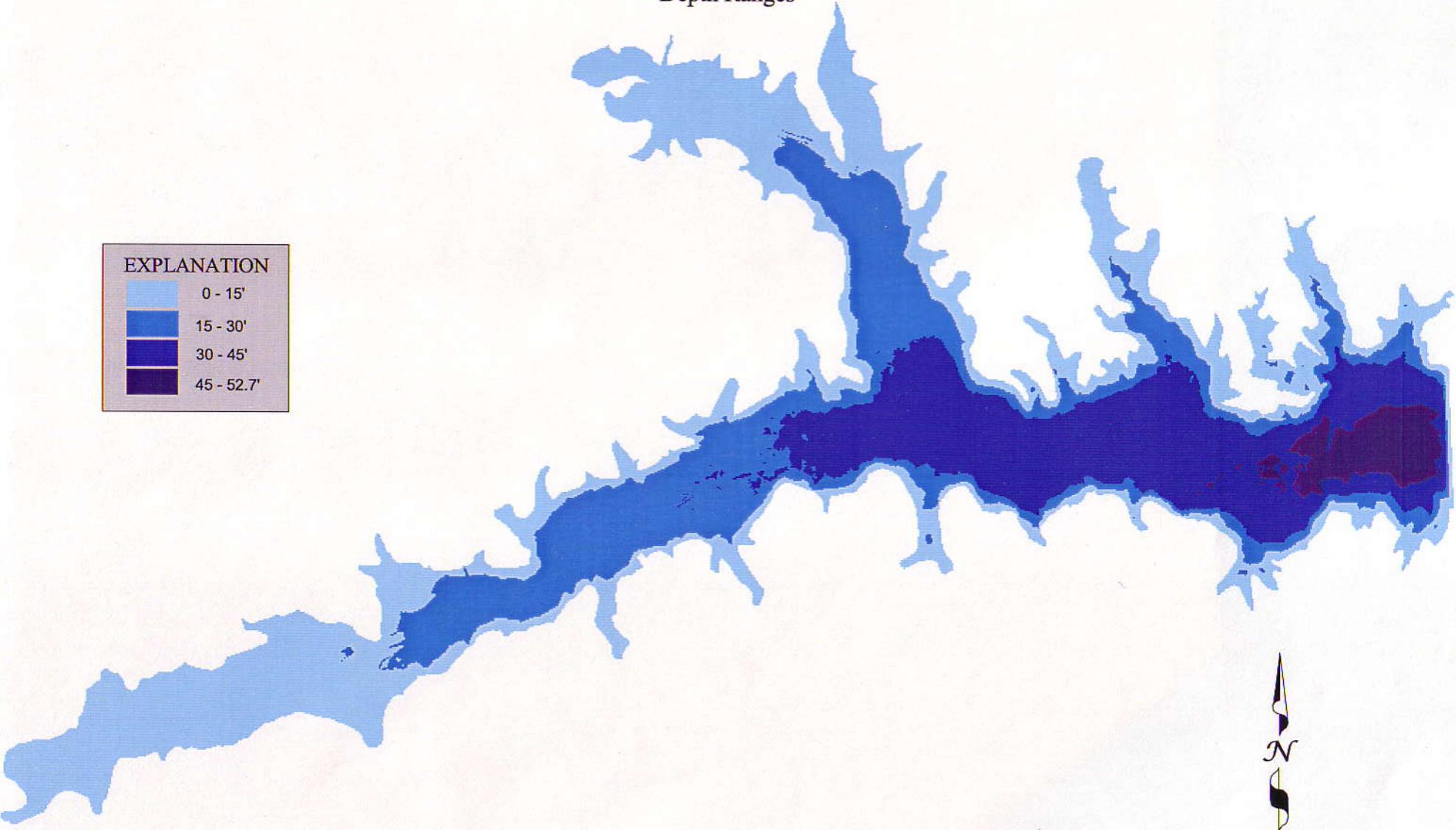
1" = 2000'

PREPARED BY: TEXAS WATER DEVELOPMENT BOARD JULY 1998

FIGURE 4  
LAKE CYPRESS SPRINGS

Depth Ranges

EXPLANATION	
	0 - 15'
	15 - 30'
	30 - 45'
	45 - 52.7'

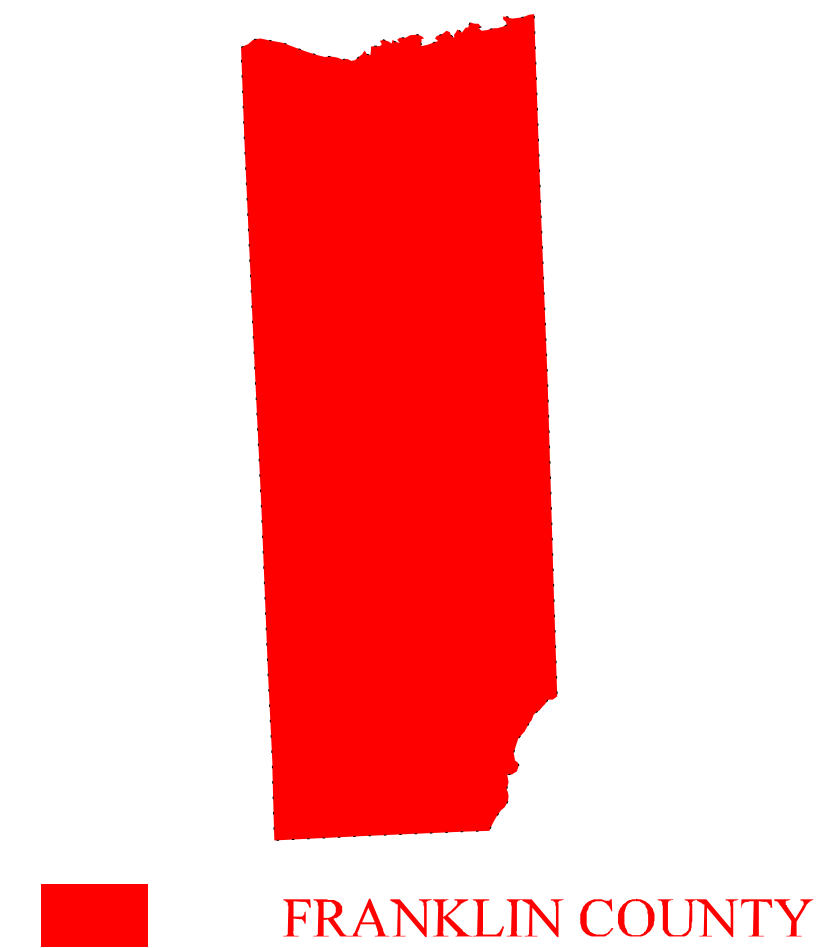


1" = 2000'

# FIGURE 5 LAKE CYPRESS SPRINGS Contour Map



1" = 900'



This map is a product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Lake Cypress Springs. The Texas Water Development Board makes no representations or assumes any liability if this information is used for other purposes such as boating maps.

EXPLANATION	
	2 Foot Contours Lines
	4 Foot Contours Lines
	6 Foot Contours Lines
	8 Foot Contours Lines
	10 Foot Contour Lines
	Normal Pool Elev. 378.0 Feet
	Cross Sections