VOLUMETRIC SURVEY
OF
LAKE GEORGETOWN

Prepared for:

BRAZOS RIVER AUTHORITY

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This report was prepared by the Hydrographic Survey group:

Scot Sullivan, P.E.
Duane Thomas
Wayne Elliott
Steve Segura
Marc Robichaud
For more information, please call (512) 936-0848

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LAKE GEORGETOWN
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Lake Georgetown during the period April-May, 1995. The purpose of the survey was to determine the capacity of the lake at the normal pool elevation and to establish baseline information for future surveys. From this information, future surveys will be able to determine sediment deposition locations and rates 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. Based on U. S. Geological topographic maps dated 1962, the U. S. Army Corps of Engineers calculated the initial surface area of Lake Georgetown at the normal pool elevation of 791.0 feet to be 1,310 acres with a corresponding initial capacity of 37,080 acre-feet.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

Lake Georgetown is located on the North Fork of the San Gabriel River in Williamson County, three and one half miles west of Georgetown, TX. The lake and dam facility are owned by the United States Government, and maintained and operated by the U. S. Army Corps of Engineers, Fort Worth District (COE). Inflows to the lake originate over a 247 square mile drainage area. The lake, at the conservation capacity pool elevation of 791.0 feet, is approximately 6.5 miles long and approximately 2/3 of a mile wide at its widest point near the dam.

Originally, Water Rights Permit #2367 was granted by the Texas Water Rights

Commission to the Brazos River Authority (BRA) on July 16, 1968 allowing use and storage of 37,100 acre-feet of water in Lake Georgetown in space contracted with the United States of America, between elevation 699 feet and 791. Various modifications to the original permit have occurred, resulting in the current authorization as follows. Certificate of Adjudication #5162 was issued by the Texas Water Commission December 14, 1987 to the BRA to impound 37,100 acre-feet of water in an existing reservoir on the North Fork San Gabriel River. The owner was authorized a priority right to divert and use not to exceed 13,610 acre-feet of water per annum for municipal, industrial irrigation and mining purposes. For the purposes of the system operation, the BRA was authorized to exceed the priority right and annually divert and use from Lake Georgetown not to exceed 16,500 acre-feet of water for municipal purposes; 4,100 acre-feet of water for irrigation purposes; 16,400 acre-feet of water for industrial purposes and 100 acre-feet of water for mining purposes. Any diversions and use of water from Lake Georgetown in excess of 13,610 acre-feet of water in one calendar year would be charged against the sum of the amounts designated as priority rights in other reservoirs included in the System Operation Order. Owner was also authorized to use the water impounded in Lake Georgetown for non-consumptive recreation purposes. Certificate of Adjudication #5167 (issued December 14, 1987) states the BRA is authorized to divert and use not exceed, 30,000 acre-feet of water for municipal purposes and 170,000 acre-feet of water for industrial purposes, to be used in the San Jacinto-Brazos Coastal Basin. These waters are to be released from Lake Georgetown and other reservoirs owned and operated by the Brazos River Authority.

Construction of the existing dam commenced on January 26, 1976. Deliberate impoundment of water began March 3, 1980 and the facility was completed July 22nd of the same year. The project was designed by the COE and the general contractors were as follows: the Dahlstrom Corporation for the initial embankment, the Zackry Corporation for the outlet works, and J.D. Abrams for the completion work to the entire structure. The estimated project cost was $18,504,000.

North San Gabriel Dam is a rolled earthfill structure with a length of 6,929 feet rising 162 feet above the natural streambed to an elevation of 861.0 feet. Located near the right end of the dam, the uncontrolled spillway is a 1000.0 foot long broad-crested weir at elevation 834.0 feet with a discharge capacity of 280,000 cubic feet per second (cfs) at the maximum design flood stage of 856.0 feet. The outlet works are composed of a 11-foot-diameter concrete conduit with an invert elevation of 720.0 feet. Discharges are controlled by two 5-foot wide by 11 foot high hydraulically operated slide gates.

HYDROGRAPHIC SURVEYING TECHNOLOGY

The following sections will describe the equipment and methodology used to conduct this hydrographic survey. Some of the theory behind Global Positioning System (GPS) technology and its accuracy are also addressed.

GPS Information

The following is a brief and simple description of Global Positioning System (GPS) technology. GPS is a 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 1960s by the United States Air Force and the defense establishment. After program funding in the early 1970s, 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 will be reached when the NAVSTAR (NAVigation System with Time And Ranging) satellite constellation is composed of 24 Block II satellites. At the time of the survey, the system had achieved initial operational capability. A full constellation of 24 satellites, in a combination of Block I (prototype) and Block II satellites, was fully functional. 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." 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.

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, a Motorola Radius radio with an Advanced Electronic Applications, Inc. packet modem, and an on-board computer. The computer was supported by a dot matrix printer and a B-size plotter. 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 shore station included a second Trimble 4000SE GPS receiver, Motorola Radius radio and Advanced Electronic Applications, Inc. packet modem, and an omni-directional antenna mounted on a modular aluminum tower to a total height of 40 feet. The combination of this equipment provided a data link with a reported range of 25 miles over level to rolling terrain that does not require that line-of-sight be maintained with the survey vessel in most conditions, thereby reducing the time required to conduct the survey.

The GPS equipment, survey vessel, and depthsounder 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 togethered 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 $\pm$ 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 normal pool boundary from two USGS quad sheets. The names of the quad sheets are as follows: Georgetown, TX 1982; and Leander NE, TX 1962 (Photo-revised 1976). 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 75 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 CONTROL SETUP

The first task of the Hydrographic Survey field staff after arriving at Lake Georgetown was to establish a horizontal reference control point. Figure 3 shows the location of the control point established. This location was chosen due to the close proximity to the reservoir and the security of the area.

Prior to the field survey, TWDB staff had researched locations of known first-order benchmarks and requested Brazos River Authority employees to physically locate the associated monuments. Of the monuments found, the one chosen to provide horizontal control for the survey was a Texas Department of Transportation first-order monument located at the Travis-Williamson County line on Miester Road . The coordinates for the monument are published as Latitude 30° 29' 06.58687"N and Longitude 97° 37' 39.28247"W.

On April 25, 1995, TWDB staff performed a static survey to determine the WGS'84 coordinates of the lake survey control point. The control point used for the shore station was a TWDB surveyor's cap identification number 018 set flush to the ground in concrete and located in a fenced area that was once used for an evaporation station. The GPS receivers were set up over each point and satellite data were gathered for approximately one hour, with up to six satellites visible at the same time to the receivers.

Once data collection ended, the data were retrieved and processed from both receivers, using Trimble Trimvec software, to determine the coordinates for the control point. The WGS' 84 coordinates for TWDB #018 were determined to be North latitude 30° 40' 39.68437" and West longitude 97° 43' 04.73210".

Using the newly determined coordinates, a shore station was set up at TWDB #018 to provide DGPS control during the survey. The coordinates from the static survey were entered into the GPS receiver located over the control point to fix its location. Data received during the survey could then be corrected and broadcast to the GPS receiver on the moving boat during the survey.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

During the survey, the GPS receivers were operated in the following DGPS modes. The reference station receiver was set to a horizontal mask of 0°, to acquire information on the rising satellites. A horizontal mask of 10° was used on the roving receiver for the purpose of calculating better horizontal positions. A PDOP (Position Dilution of Precision) limit of 7 was set for both receivers. The DGPS positions are known to be within acceptable limits of horizontal accuracy when the PDOP is seven (7) or less. 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.

Prior to the survey, TWDB staff verified the horizontal accuracy of the DGPS used during the Lake Georgetown survey to be within the specified accuracy of three meters by the following procedure. The shore station was set up over a known United States Geological Service (USGS) first order monument and placed in differential mode. The second receiver, directly connected to the boat with its interface computer, was placed over another known USGS first order monument and data was collected for 60 minutes in the same manner as during a survey. Based on the differentially-corrected coordinates obtained and the published coordinates for both monuments, the resulting positions fell within a three-meter radius of the actual known monument position.

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 Georgetown, the speed of sound in the water column varied daily between 4860 and 4873 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 plus readings and some are minus readings. Further information on these calculations is presented in Appendix A.

Field Survey

Data was collected on Lake Georgetown during the period of April 25-27, and May 23, 1995. Approximately 23,038 data points were collected over the 22.4 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 107 data files. Data were not collected in areas of shallow water (depths less than 3.0 ft.) or with significant obstructions unless these areas represented a large amount of water. Random data points were collected, when determined necessary by the field crew, by manually poling the depth and entering the depth value into the data file. As each point was entered, the DGPS horizontal position was stored automatically with each return keystroke on the computer. The boat was moving slowly during this period so positions stored were within the stated accuracy of $\pm$ 3 meters to the point poled. Figure 2 shows the actual location of the data collection points.

The collected data were stored in individual data files for each pre-plotted range line or random data collection events. 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. The diskettes were then stored in a secured, safe location 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 ranged daily from 791.11 to 791.23 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. The latitude and longitude coordinates of each point were then converted to decimal degrees by a UNIX awk command. The awk command manipulates the data file format into a MASS points format for use by the GIS software. The graphic boundary file previously digitized was also imported.

The boundary and MASS points files were graphically edited using the Arc/Edit module. The MASS points file was converted into a point coverage and plotted along with the boundary file. If data points were collected outside the boundary file, the boundary was modified to include the data points. Also, the boundary near the edges of the lake in areas of significant sedimentation was down-sized to reflect the observations of the field crew. The resulting boundary shape was considered to be the acreage at the normal pool elevation of the lake. This was calculated as 1,297 acres for Lake Georgetown. The Board does not represent the boundary, as depicted in this report, to be a detailed actual boundary. Instead, it is a graphical approximation of the actual boundary used solely to compute the volume and area of the lake. The boundary does not represent the true land versus water boundary of the lake. An aerial topographic map of the upper four feet of the lake or an aerial photo taken when the lake is at the normal pool elevation would more closely define the present boundary. However, the minimal increase in accuracy does not appear to offset the cost of those services at this time.

The edited MASS points and modified boundary file were 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.

There were some areas where values could not be calculated by interpolation because of a lack of information along the boundary 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 Georgetown. Therefore no additional points were required for interpolation and contouring of the entire lake surface. The TIN product calculated the surface area and volume of the entire reservoir at one-tenth of a foot intervals from the three-dimensional triangular plane surface representation. 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 the shaded relief map, the three-dimensional triangular surface was modified by a GRIDSHADE command. Colors were assigned to different elevation values of the grid. Using the command COLORRAMP, a set of colors that varied from navy to yellow was created. The lower elevation was assigned the color of navy, and the lake normal pool elevation was assigned the color of yellow. Different color shades were assigned to the different depths in between. Figure 4 presents the resulting depth shaded representation of the lake. Figure 5 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.

The DTM was then smoothed and linear smoothing algorithms were applied to the smoothed model to produce smoother contours. The resulting contour map of the bottom surface at ten-foot intervals is presented in Figure 6.

RESULTS

Lake Georgetown facility (including all shoreline property) is owned by the Federal Government, and maintained by the U. S. Army Corps of Engineers. Lake Georgetown is basically an on-channel reservoir located on the North San Gabriel River with a few contributing creeks. The Federal Government has restricted any kind of private development at the facility, leaving the lake free of retaining walls, private dock facilities, or other structures. While collecting data during the April-May 1995 survey, TWDB staff observed a well maintained facility. Limestone outcrops were noted on the steep cut side of the lake mostly in the wildlife or undisturbed area while the Corps of Engineers took advantage of the gentle sloping terrain bordering the lake for their parks and camping areas. After traveling approximately six river miles upstream of the dam, the field crew began encountering both standing and submerged trees in the old river channel. Small trees and stumps also occupied many of the coves in the upper reaches making it difficult to maneuver the boat. The old streambed of the San Gabriel River was easily detected on the analog charts of the depth sounder as the boat moved along the preplotted lines.

Results from the 1995 survey indicate Lake Georgetown now encompasses around 1,297 surface acres and contains a volume of 37,010 acre-feet at the normal pool elevation of 791.00 feet. The shoreline at this elevation was calculated to be 21.68 miles. The lowest elevation encountered was around elevation 711.2 feet, or 79.8 feet of depth and was found near the dam.

The storage volume calculated by the 1995 survey is approximately 0.2 percent less than the previous record information for the lake. The lowest gated outlet invert elevation is at elevation 720.0 feet. The dead storage volume at this elevation corresponds to 24 acre-ft. The conservation storage capacity of the lake will not be modified to reflect this storage volume. Therefore, the conservation storage capacity for the lake is 37,010 acre-feet.

SUMMARY

North San Gabriel Dam and Lake Georgetown were authorized by the Federal Flood Control Act approved September 3, 1954 and the Public Works Appropriation Act of 1958. Construction commenced January 26, 1976. Deliberate impoundment began March 3, 1980. Initial storage calculations estimated the volume of the lake at the conservation pool elevation of 791.0 to be 37,080 acre-feet with surface area of 1,310 acres.

During the period April-May 1995, a hydrographic survey of Lake Georgetown was performed by the Texas Water Development Board's Hydrographic Survey Program. The 1995 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 Georgetown than previous survey methods. Results from the survey indicate that the lake's capacity at the normal pool elevation of 791.0 feet was 37,010 acre-feet. The estimated reduction in storage capacity, if compared to the original volume in 1980 was 70 acre-feet, or 0.2 percent. This equates to an estimated loss of 4.67 acre-feet per year during the 15 years between the TWDB's survey and the initial date impoundment began. The annual deposition rate of sediment in the conservation pool can be estimated at 0.022 acre-ft per square mile of drainage area.

It is difficult to compare the original design information and the survey performed by the TWDB because little is know about the procedures and data used in calculating the original storage information. However, the TWDB considers the 1995 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. The second survey will remove any noticeable errors between the original design data and the 1995 survey and will facilitate accurate calculations of sedimentation rates and storage losses presently occurring in Lake Georgetown.

APPENDIX A - DEPTH SOUNDER ACCURACY

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

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

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

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

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

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

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

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

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

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

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

$t_{60} = (60-1.2)/4799$
$= 0.01225$ 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')

APPENDIX B - RESERV.OIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR VOLUME TABLE

LAKE GEORGETOWN MAY 1995 SURVEY

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
713										
714			1	1	1	1	1	1	1	1
715	1	2	2	2	2	2	2	2	3	3
716	3	3	4	4	4	4	5	5	5	6
717	6	6	7	7	7	8	8	9	9	10
718	10	11	11	12	12	13	13	14	15	15
719	16	17	18	18	19	20	21	22	23	24
720	24	25	27	28	29	30	31	32	33	34
721	36	37	38	40	41	43	44	46	47	49
722	50	52	54	55	57	59	60	62	64	66
723	68	70	72	74	76	78	80	82	85	87
724	89	91	94	96	99	101	103	106	109	111
725	114	117	119	122	125	128	131	134	137	140
726	144	147	151	155	159	163	167	171	176	180
727	185	190	195	200	205	210	215	221	226	232
728	237	243	249	255	261	267	273	280	286	293
729	300	307	314	321	328	336	343	351	359	367
730	375	384	393	401	410	419	429	438	448	458
731	468	478	488	498	509	520	531	542	553	564
732	576	587	599	611	623	635	647	659	672	684
733	697	709	722	735	749	762	775	789	802	816
734	830	843	857	872	886	900	914	929	944	959
735	973	988	1004	1019	1034	1050	1066	1081	1097	1113
736	1129	1146	1162	1179	1195	1212	1229	1246	1264	1281
737	1299	1316	1334	1352	1371	1389	1408	1426	1445	1464
738	1483	1503	1522	1542	1561	1581	1601	1622	1642	1663
739	1683	1704	1725	1746	1767	1789	1810	1832	1854	1876
740	1898	1920	1942	1965	1987	2010	2033	2055	2078	2102
741	2125	2148	2172	2195	2219	2243	2267	2291	2315	2339
742	2364	2389	2413	2438	2463	2488	2513	2539	2564	2590
743	2616	2641	2668	2694	2720	2746	2773	2799	2826	2853
744	2880	2907	2935	2962	2990	3018	3046	3074	3102	3130
745	3159	3188	3216	3245	3275	3304	3333	3363	3393	3423
746	3453	3484	3514	3545	3576	3607	3638	3670	3701	3733
747	3765	3797	3829	3861	3894	3926	3959	3992	4025	4058
748	4092	4125	4159	4193	4227	4261	4295	4329	4364	4398
749	4433	4468	4503	4538	4574	4609	4645	4681	4717	4753
750	4789	4826	4862	4899	4936	4973	5010	5047	5085	5122
751	5160	5198	5236	5275	5313	5352	5391	5429	5469	5508
752	5547	5587	5627	5666	5706	5747	5787	5828	5868	5909
753	5950	5991	6032	6073	6115	6157	6198	6240	6282	6325
754	6367	6410	6452	6495	6538	6582	6625	6668	6712	6756
755	6800	6844	6889	6933	6978	7022	7067	7113	7158	7203
756	7249	7295	7340	7386	7433	7479	7526	7572	7619	7666
757	7714	7761	7809	7857	7906	7954	8003	8052	8101	8151
758	8200	8250	8300	8351	8401	8452	8503	8554	8606	8657
759	8709	8761	8813	8865	8918	8971	9024	9077	9130	9184
760	9237	9291	9345	9399	9454	9508	9563	9618	9674	9729
761	9785	9841	9897	9953	10009	10066	10123	10180	10237	10295

LAKE GEORGETOWN MAY 1995 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
762	10352	10410	10468	10526	10584	10643	10701	10760	10819	10878
763	10938	10997	11057	11117	11177	11237	11297	11358	11419	11480
764	11541	11603	11664	11726	11788	11851	11913	11976	12039	12102
765	12166	12229	12293	12357	12422	12486	12551	12616	12681	12746
766	12812	12878	12944	13010	13076	13143	13210	13277	13344	13412
767	13480	13548	13616	13685	13754	13824	13893	13963	14033	14104
768	14174	14245	14316	14387	14459	14530	14602	14675	14747	14820
769	14893	14966	15040	15114	15188	15262	15337	15412	15487	15563
770	15638	15714	15791	15867	15944	16021	16098	16176	16254	16332
771	16410	16489	16568	16647	16727	16807	16886	16967	17047	17127
772	17208	17289	17370	17451	17533	17614	17696	17778	17860	17943
773	18026	18109	18192	18275	18359	18442	18526	18610	18695	18779
774	18864	18949	19034	19120	19205	19291	19377	19464	19550	19637
775	19724	19811	19899	19986	20074	20162	20250	20339	20428	20517
776	20606	20696	20785	20875	20966	21056	21147	21238	21329	21421
777	21513	21605	21697	21790	21883	21976	22069	22163	22257	22351
778	22445	22540	22635	22730	22826	22921	23017	23113	23210	23307
779	23404	23501	23599	23696	23794	23893	23991	24090	24189	24289
780	24388	24488	24588	24689	24789	24890	24992	25093	25195	25297
781	25400	25503	25606	25709	25813	25916	26020	26125	26229	26335
782	26440	26545	26651	26757	26863	26970	27077	27184	27292	27400
783	27508	27616	27725	27834	27944	28053	28163	28273	28383	28494
784	28605	28716	28828	28939	29052	29164	29276	29389	29502	29616
785	29729	29843	29957	30072	30186	30301	30417	30532	30648	30764
786	30880	30997	31113	31230	31348	31465	31583	31701	31819	31937
787	32056	32175	32294	32414	32533	32653	32774	32894	33015	33136
788	33257	33379	33500	33622	33745	33867	33990	34113	34236	34360
789	34483	34607	34732	34856	34981	35106	35231	35356	35482	35608
790	35734	35861	35987	36114	36241	36369	36496	36624	36753	36881
791	37010									

APPENDIX C - RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR AREA TABLE

LAKE GEORGETOWN MAY 1995 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

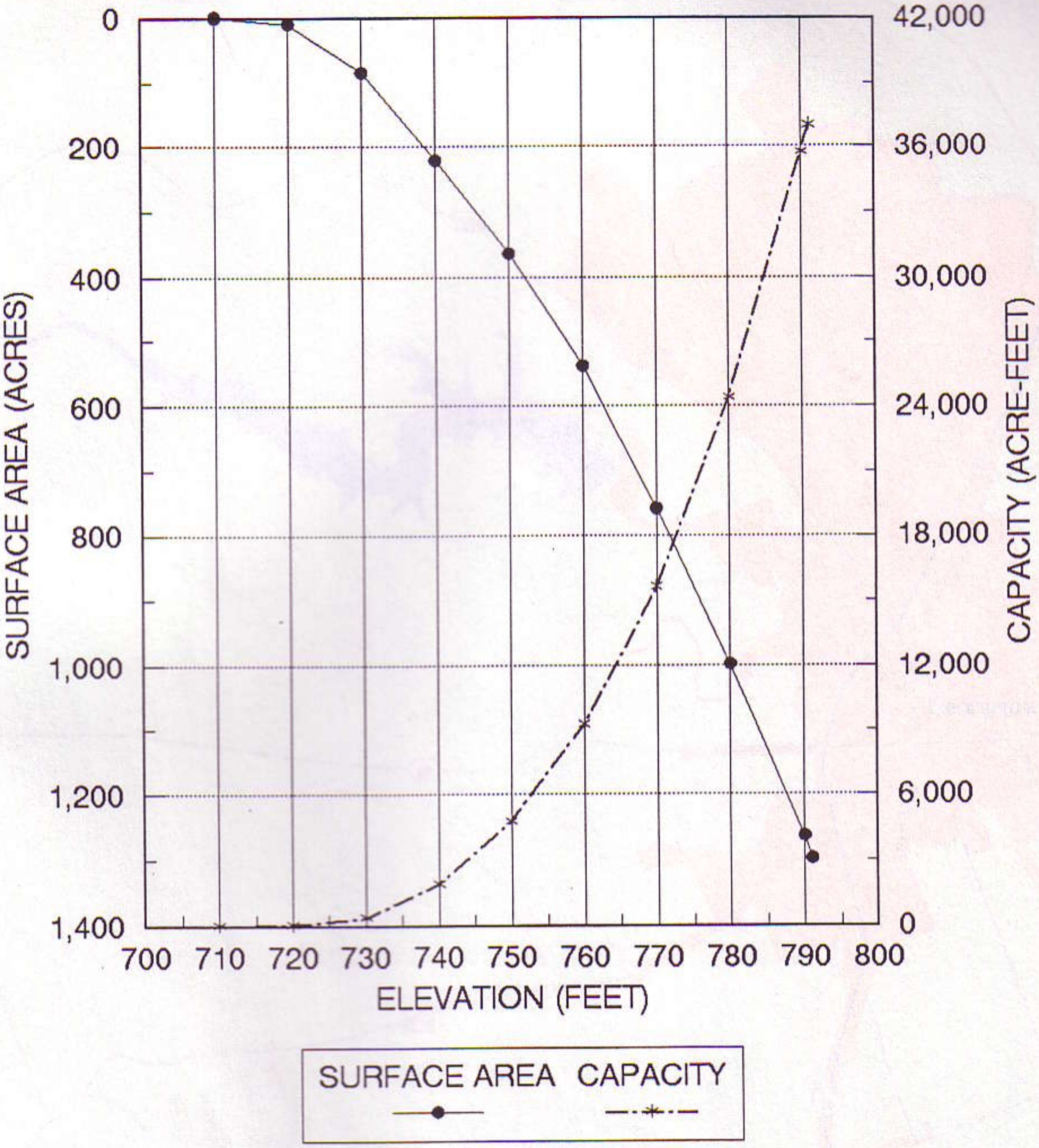
ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
713									1	1
714	1	1	1	1	1	1	1	1	1	1
715	1	1	1	2	2	2	2	2	2	2
716	2	2	2	3	3	3	3	3	3	3
717	3	3	4	4	4	4	4	4	5	5
718	5	5	5	6	6	6	6	6	7	7
719	7	7	8	8	8	8	9	9	9	9
720	10	10	10	11	11	11	12	12	12	13
721	13	13	14	14	14	15	15	15	15	16
722	16	16	17	17	17	18	18	18	19	19
723	19	20	20	20	21	21	21	22	22	23
724	23	23	24	24	24	25	25	26	26	26
725	27	27	28	28	28	29	30	31	32	34
726	35	37	38	39	40	41	42	43	45	46
727	47	48	49	50	51	52	53	54	55	56
728	57	58	59	60	61	62	63	65	66	67
729	68	70	71	72	74	75	77	78	80	82
730	84	86	87	89	91	92	94	95	97	99
731	100	102	104	105	107	108	110	111	112	114
732	115	116	117	119	120	121	122	124	125	126
733	127	128	130	131	132	133	134	135	136	137
734	138	139	140	141	143	144	145	146	147	148
735	150	151	152	153	155	156	157	158	160	161
736	162	164	165	166	168	169	171	172	174	175
737	177	178	180	182	183	185	186	188	189	191
738	192	194	195	197	198	200	201	203	205	206
739	208	209	211	212	213	215	216	217	219	220
740	221	222	223	225	226	227	228	229	231	232
741	233	234	236	237	238	239	240	242	243	244
742	245	247	248	249	250	252	253	254	256	257
743	258	259	261	262	263	265	266	267	269	270
744	271	273	274	276	277	279	280	282	283	285
745	286	288	289	291	293	294	296	298	299	301
746	303	305	307	308	310	312	313	315	317	318
747	320	321	323	324	325	327	328	330	331	333
748	334	336	337	338	340	341	343	344	346	347
749	349	350	352	353	355	356	358	359	360	362
750	363	365	366	368	369	371	372	374	376	377
751	379	381	382	384	385	387	389	390	392	393
752	395	397	398	400	401	403	404	406	407	408
753	410	411	413	414	416	417	419	420	422	423
754	425	426	428	430	431	433	434	436	438	439
755	441	443	444	446	447	449	450	452	453	455
756	457	458	460	461	463	465	466	468	470	472
757	475	477	479	482	484	487	489	491	494	496
758	498	500	502	504	506	509	511	513	515	517
759	519	521	523	524	526	528	530	532	534	536
760	538	540	542	544	545	547	549	551	553	556
761	558	560	562	564	566	567	569	571	573	575

LAKE GEORGETOWN MAY 1995 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
762	577	579	580	582	584	586	587	589	591	592
763	594	596	598	600	602	603	605	607	609	612
764	614	616	618	620	622	624	627	629	631	633
765	636	638	640	642	644	646	648	650	652	654
766	657	659	661	663	665	667	670	673	675	678
767	681	684	687	689	692	695	697	700	702	704
768	707	709	711	714	716	719	721	724	727	729
769	732	735	737	740	743	745	748	751	754	756
770	759	762	764	767	769	772	775	777	780	783
771	786	789	792	794	796	798	800	802	804	806
772	808	810	812	814	816	818	820	822	824	826
773	828	830	832	834	836	838	841	843	845	847
774	849	851	853	855	858	860	862	864	866	869
775	871	873	875	878	880	882	884	887	889	891
776	894	896	899	901	904	907	909	912	914	917
777	919	922	925	927	930	932	935	938	940	943
778	946	948	951	953	956	959	961	964	966	969
779	971	974	977	979	982	984	987	990	992	995
780	998	1000	1003	1006	1009	1012	1015	1017	1020	1023
781	1026	1029	1031	1034	1037	1040	1043	1045	1048	1051
782	1054	1056	1059	1062	1065	1068	1071	1074	1077	1080
783	1083	1086	1089	1092	1095	1097	1100	1103	1105	1108
784	1111	1113	1116	1119	1122	1124	1127	1130	1132	1135
785	1137	1140	1143	1145	1148	1151	1154	1156	1159	1162
786	1164	1166	1169	1171	1174	1176	1178	1181	1183	1186
787	1188	1191	1193	1196	1198	1201	1204	1206	1209	1211
788	1214	1216	1219	1221	1224	1226	1229	1231	1234	1236
789	1238	1241	1243	1246	1248	1251	1253	1256	1258	1261
790	1263	1266	1268	1271	1273	1276	1278	1280	1283	1285
791	1297									

APPENDIX D - AREA-ELEVATION-CAPACITY GRAPH



LAKE GEORGETOWN

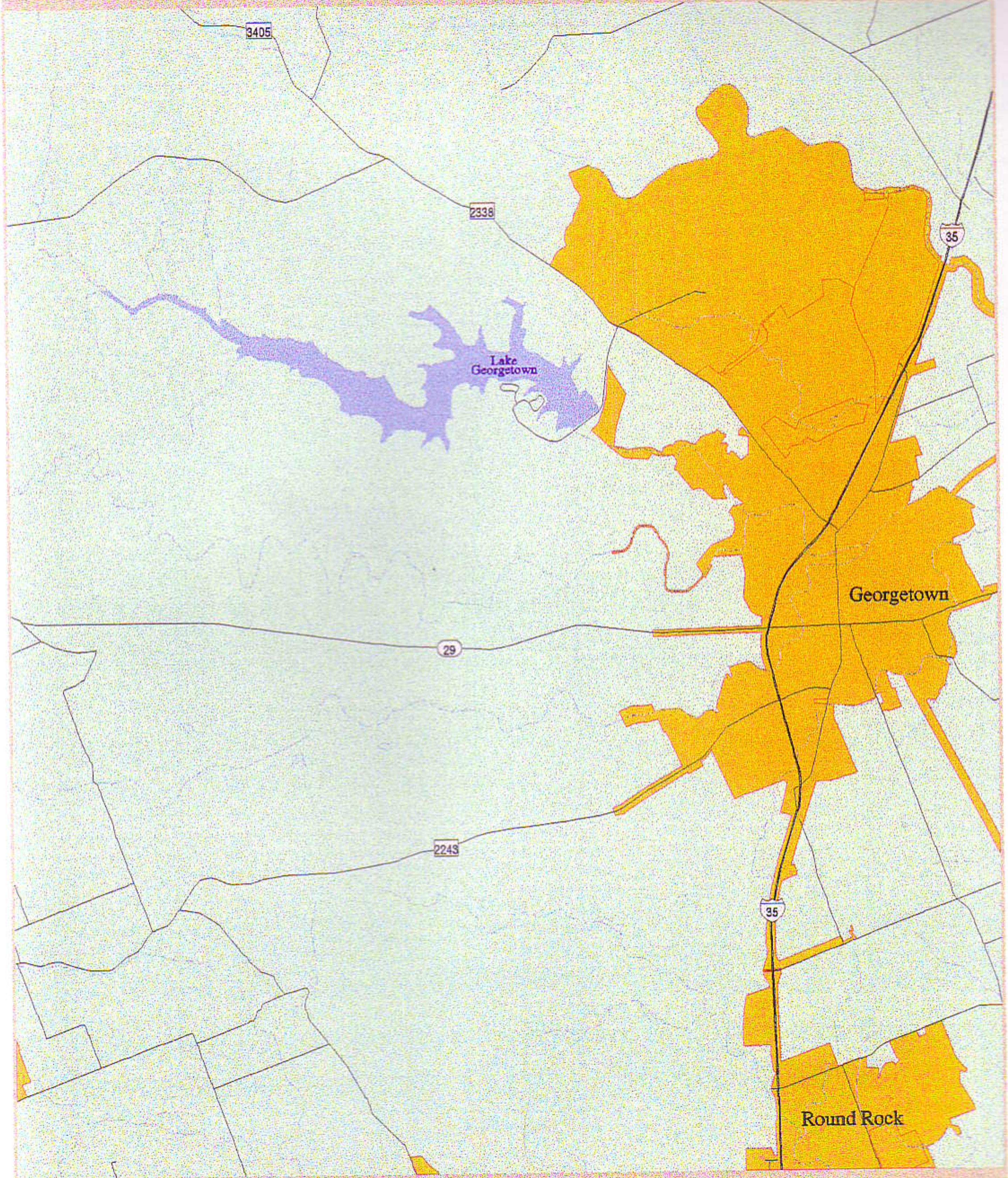
MAY 1995 SURVEY

Prepared by: TWDB August 1995

FIGURE 1

LAKE GEORGETOWN

Location Map

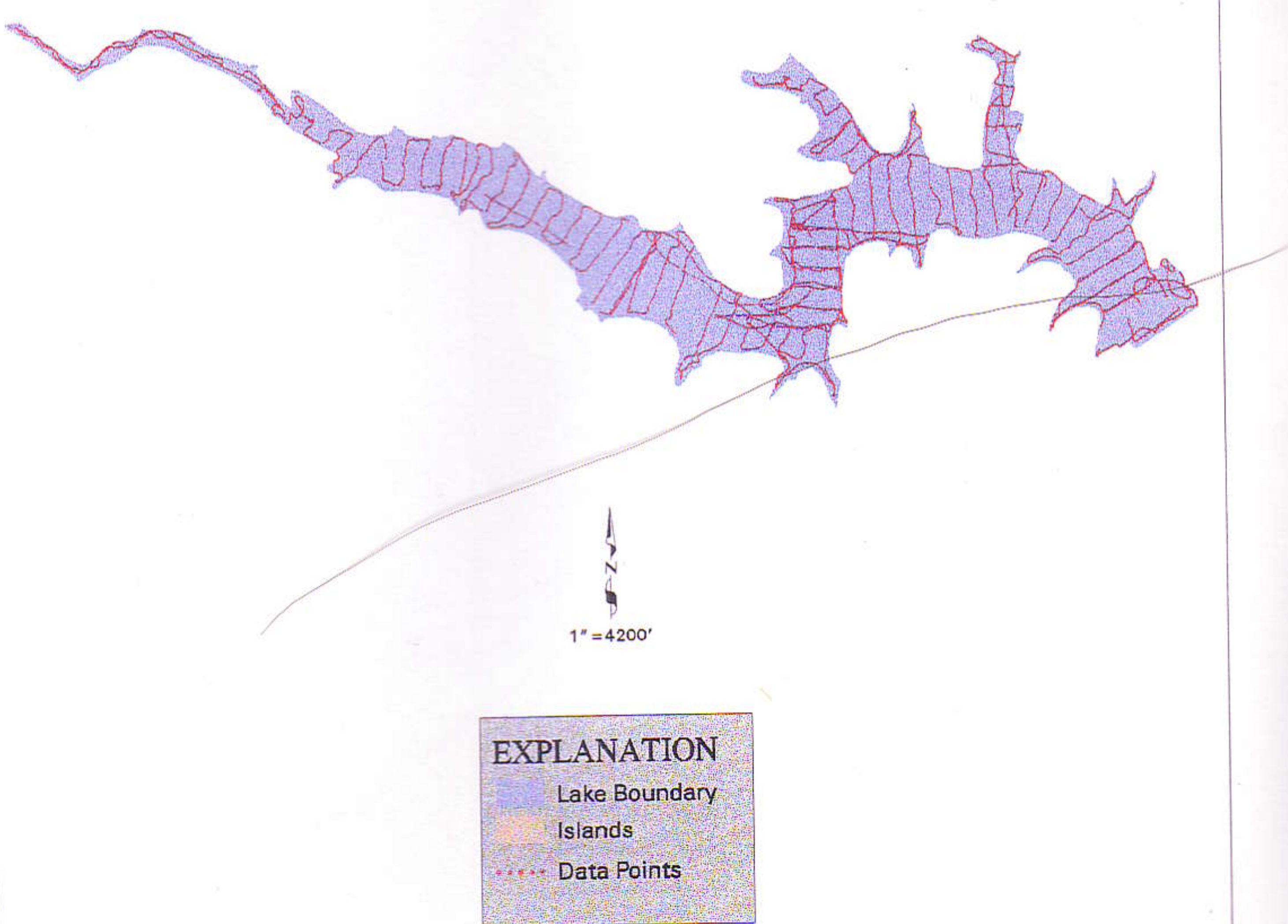


PREPARED BY: TWDB SEPTEMBER 1995

FIGURE 2

LAKE GEORGETOWN

Location of Survey Data

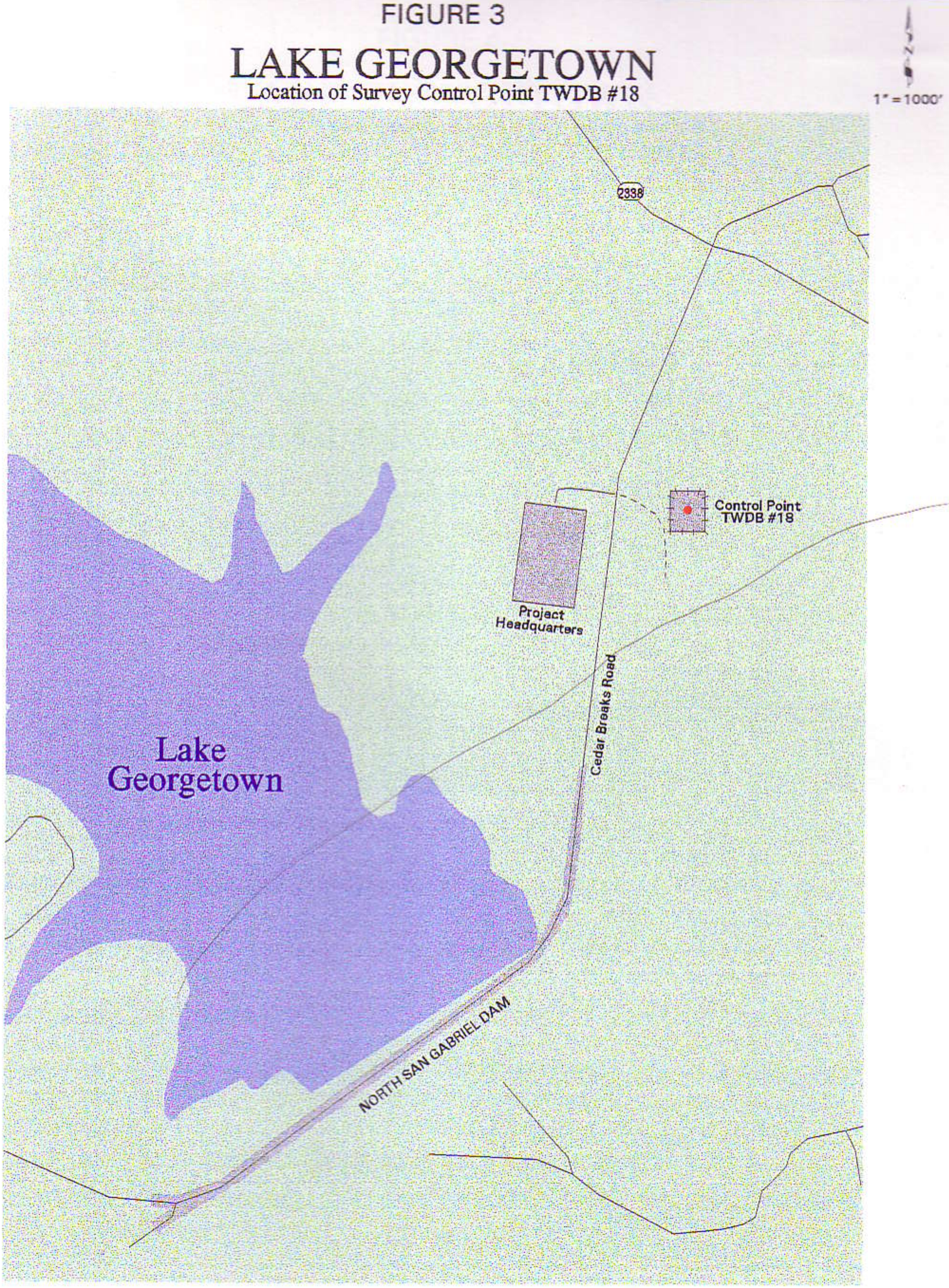


PREPARED BY: TWDB AUGUST 1995

FIGURE 3

LAKE GEORGETOWN

Location of Survey Control Point TWDB #18



PREPARED BY: TWDB SEPTEMBER 1995

FIGURE 4

LAKE GEORGETOWN

Shaded Relief

N

1" = 4200'

Elevation From 711 Ft. To Elevation 791 Ft.

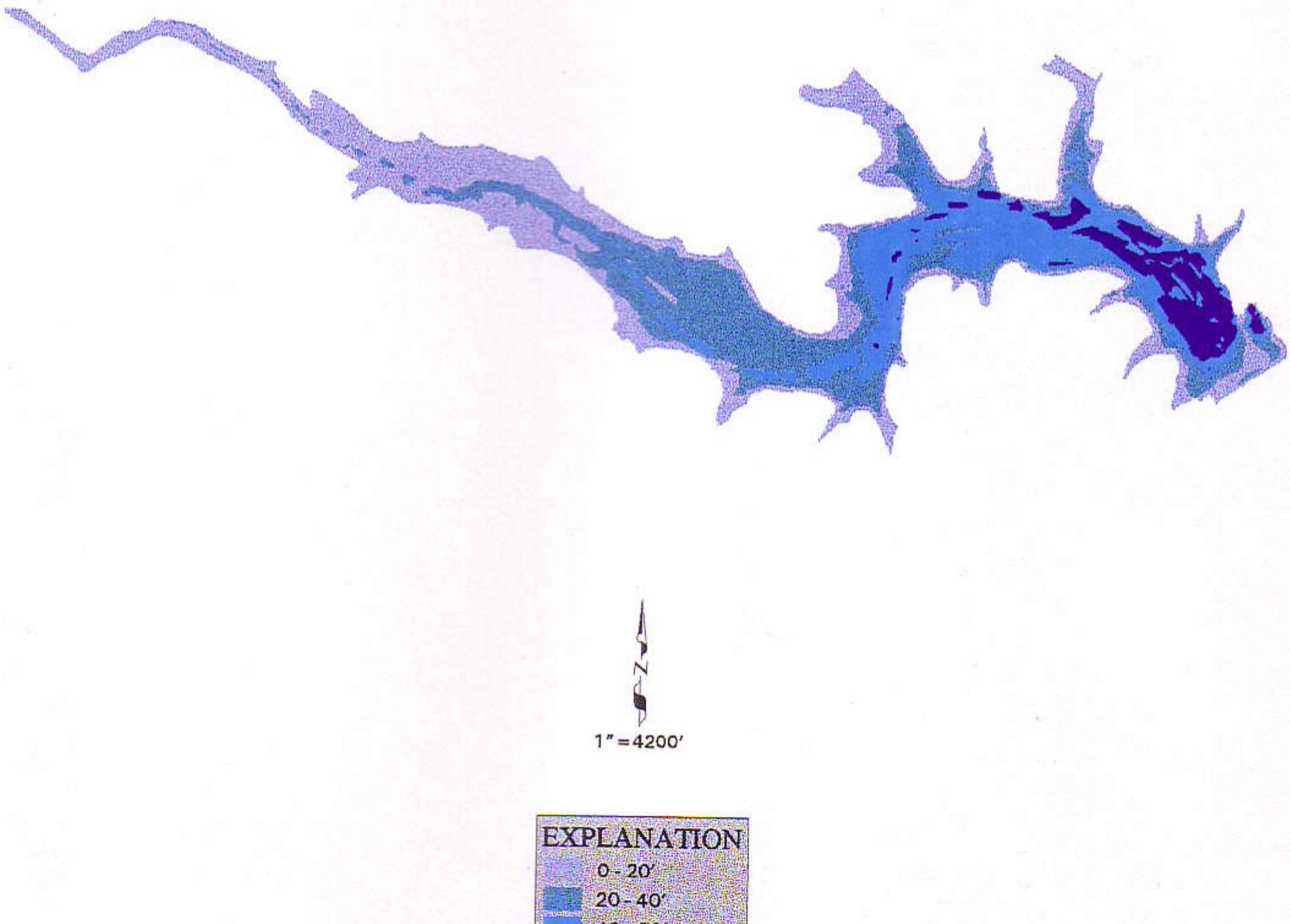
Islands

PREPARED BY: TWDB SEPTEMBER 1995

FIGURE 5

LAKE GEORGETOWN

Depth Ranges



PREPARED BY: TWDB SEPTEMBER 1995