VOLUMETRIC SURVEY
OF
SOMERVILLE LAKE

Prepared for:

BRAZOS RIVER AUTHORITY

Prepared by:

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INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Somerville Lake during the period October 24 thru November 2, 1995. The purpose of the survey was to determine the capacity of the lake at the conservation 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 1959, the U. S. Army Corps of Engineers calculated the initial surface area of Somerville Lake at the conservation pool elevation of 238.0 feet to be 11,460 acres with a corresponding initial capacity of 160,100 acre-feet.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

Somerville Lake is located on Yegua Creek in Burleson, Lee, and Washington Counties, approximately 15 miles northwest of Brenham, 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). 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. The lake is located downstream of the confluence of the Middle Yegua and East Yegua Creeks. Other major contributing tributaries are Cedar, Nails and Big Creeks. Inflows to the lake originate over a 1,007 square mile drainage area. At the conservation capacity pool elevation of 238.0 feet, the lake is approximately 11 miles long and 3.5 miles wide at its widest point near the dam. The shoreline at this elevation is approximately 59.57 miles long.

Under the Flood Control Act (September 3, 1954) the U. S. Congress authorized the construction of Somerville Lake for flood control, water supply and other multi-purpose uses. The Secretary of the Army approved a contract on May 10, 1962 authorizing the Brazos River Authority to purchase the water rights in the conservation pool of Somerville Lake. Certificate of Adjudication #12-5164 was issued by the Texas Water Commission on December 14, 1987 to the Brazos River Authority (BRA) to impound 160,110 acre-feet of water at elevation 238.0 in an existing reservoir known as Somerville Lake. The owner was authorized a priority right to divert and use not to exceed 48,000 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 Somerville Lake not to exceed 49,500 acre-feet of water for municipal purposes; 50,000 acre-feet of water for industrial purposes, 50,000 for irrigation purposes and 500 acre-feet of water for mining purposes. Any diversions and use of water from Somerville Lake in excess of 48,000 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 Somerville Lake for non-consumptive recreation purposes. Certificate of Adjudication #12-5167 (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 Somerville Lake and other reservoirs owned and operated by the Brazos River Authority.

Construction of the dam commenced on June 4, 1962. Deliberate impoundment of water began January 3, 1967 and the facility was completed October 27, 1967. The project was designed by the COE and the general contractor was Clement Brothers Company, Inc. of Hickory, N.C. The estimated project cost was $21,700,000.

Somerville Dam is composed of a 20,210 foot rolled earthfill embankment, a 1,250 foot uncontrolled spillway, and a 4,715 foot dike. The dam rises from the natural streambed to a maximum height of 80 feet, or elevation 280.0 feet. Located near the right (south) end of the dam, the uncontrolled spillway is a 1,250 feet long ogee weir with a crest elevation of 258 feet. The spillway, at the maximum design flood stage eleveation of 274.5 feet, has a discharge capacity of 286,000 cubic feet per second (cfs) . The outlet works are composed of a 10-foot-diameter concrete conduit with an invert elevation of 206.0 feet. Discharges into the conduit are controlled by two 5-foot wide by 10-foot high tractor-type 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 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 conservation pool boundary from USGS quad sheets. The name of the quad sheets are as follows: Somerville, TX. 1971 (Photorevised 1988), Flag Pond, TX. 1971 (Photorevised 1988) and Dime Box, TX. 1959 (Photorevised 1989). 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 223 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 Somerville Lake 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 U. S. Geological Survey first-order monument named "LYONS" located one mile west of Lyons, TX. The coordinates for the monument are published as Latitude 30° 23' 3.66272"N and Longitude 96° 34' 37.33586"W.

On August 29, 1995, TWDB staff performed a static survey to determine the WGS'84 coordinates for the control point to be used during the survey. An existing U. S. Army Corps of Engineer's surveyor's brass cap, set flush in concrete and located on the service walk to the inlet tower, was chosen for the control point. Stamped on the brass cap was "105.0 O/S LEFT" 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 the control point were determined to be North latitude 30° 19' 9.83957" and West longitude 96° 31' 25.43253".

Using the newly determined coordinates, a shore station was set up 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 Somerville

Lake 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 Somerville Lake 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 Somerville Lake, the speed of sound in the water column varied daily between 4864 and 4874 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 Somerville Lake during the period of October 24 thru November 2, 1995. Approximately 102,710 data points were collected over the 181.53 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 213 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.

While collecting data, TWDB staff observed the lake bottom to be fairly uniform upstream of the dam in the main reservoir area yet the creek channels could still be distingushed on the analog charts as the boat crossed the channels. Overall, Somerville Lake was fairly free of stumps and fallen trees. The crew did encounter several sand bars and a large area of silt in the upper reaches of Yegua Creek near Flag Pond. Personal observations by one crew member regarding his visits to the lake 25 years ago, are that the islands near Welch Park have pretty much eroded away.

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 237.57 to 238.01 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 conservation pool elevation of the lake. This was calculated as 11,456 acres for Somerville Lake. 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 conservation 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. Approximately 2,367 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 conservation 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

Results from the 1995 survey indicate Somerville Lake now encompasses 11,456 surface acres and contains a volume of 155,062 acre-feet at the conservation pool elevation of 238.0 feet. The shoreline at this elevation was calculated to be 59.57 miles. The lowest elevation encountered was around elevation 203.17 feet, or 34.83 feet of depth and was found near the dam.

The storage volume calculated by the 1995 survey is approximately 3.15 percent less than the previous record information for the lake. The lowest gated outlet invert elevation is at elevation 206.0 feet. There is no storage volume in the lake at this elevation. Therefore, the conservation storage capacity for the lake is 155,062 acre-feet.

SUMMARY

Somerville Lake was authorized by the Federal Flood Control Act approved September 3, 1954 and the Public Works Appropriation Act of 1958. Construction of the dam commenced on

June 4, 1962. Deliberate impoundment of water began January 3, 1967. Initial storage calculations estimated the volume of the lake at the conservation pool elevation of 238.0 feet to be 160,100 acre-feet with surface area of 11,460 acres.

During the period October 24 and November 2, 1995, a hydrographic survey of Somerville Lake 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 Somerville Lake than previous survey methods. Results from the survey indicate that the lake's capacity at the conservation pool elevation of 238.0 feet was 155,062 acre-feet. The estimated reduction in storage capacity, if compared to the original volume in 1967 was 5,038 acre-feet, or 3.15 percent. This equates to an estimated loss of 179.93 acre-feet per year during the 28 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 0.1787 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 Somerville Lake.

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):

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

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR VOLUME TABLE

Jan 30 1996

SOMERVILLE LAKE NOVEMBER 1995 SURVEY

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
208									1	1
209	2	4	7	11	15	21	29	39	53	70
210	91	116	147	182	222	266	313	363	417	473
211	533	597	663	731	802	877	954	1035	1119	1207
212	1297	1390	1486	1584	1684	1786	1891	1998	2107	2220
213	2335	2454	2576	2702	2832	2965	3102	3244	3390	3540
214	3694	3851	4012	4176	4343	4516	4693	4875	5061	5253
215	5450	5651	5856	6067	6283	6505	6733	6966	7204	7447
216	7693	7944	8199	8457	8719	8986	9256	9530	9808	10091
217	10377	10668	10962	11261	11564	11871	12183	12499	12819	13143
218	13471	13803	14138	14476	14818	15164	15512	15865	16220	16579
219	16941	17306	17675	18046	18421	18799	19180	19564	19951	20341
220	20734	21130	21529	21932	22337	22746	23158	23572	23989	24409
221	24833	25259	25688	26120	26555	26992	27433	27878	28325	28776
222	29230	29687	30148	30612	31080	31552	32028	32508	32993	33482
223	33977	34477	34982	35494	36014	36541	37073	37610	38153	38700
224	39252	39809	40370	40937	41508	42085	42667	43253	43843	44438
225	45038	45641	46249	46861	47476	48096	48719	49345	49976	50609
226	51247	51888	52532	53180	53831	54486	55144	55806	56471	57140
227	57813	58490	59171	59856	60544	61235	61930	62628	63330	64036
228	64745	65457	66172	66891	67613	68338	69066	69797	70532	71269
229	72010	72755	73502	74252	75005	75762	76521	77283	78047	78815
230	79587	80362	81141	81924	82712	83505	84303	85105	85912	86723
231	87539	88360	89185	90016	90852	91692	92536	93385	94238	95096
232	95957	96822	97691	98563	99440	100320	101204	102091	102982	103877
233	104775	105677	106582	107490	108403	109319	110238	111161	112088	113019
234	113954	114893	115835	116781	117732	118686	119646	120610	121579	122553
235	123535	124521	125511	126504	127501	128502	129507	130516	131529	132545
236	133566	134593	135624	136658	137696	138739	139785	140836	141891	142951
237	144015	145087	146165	147251	148343	149443	150554	151671	152795	153925
238	155062									

TEXAS WATER DEVELOPMENT BOARD

RESERVOIR AREA TABLE

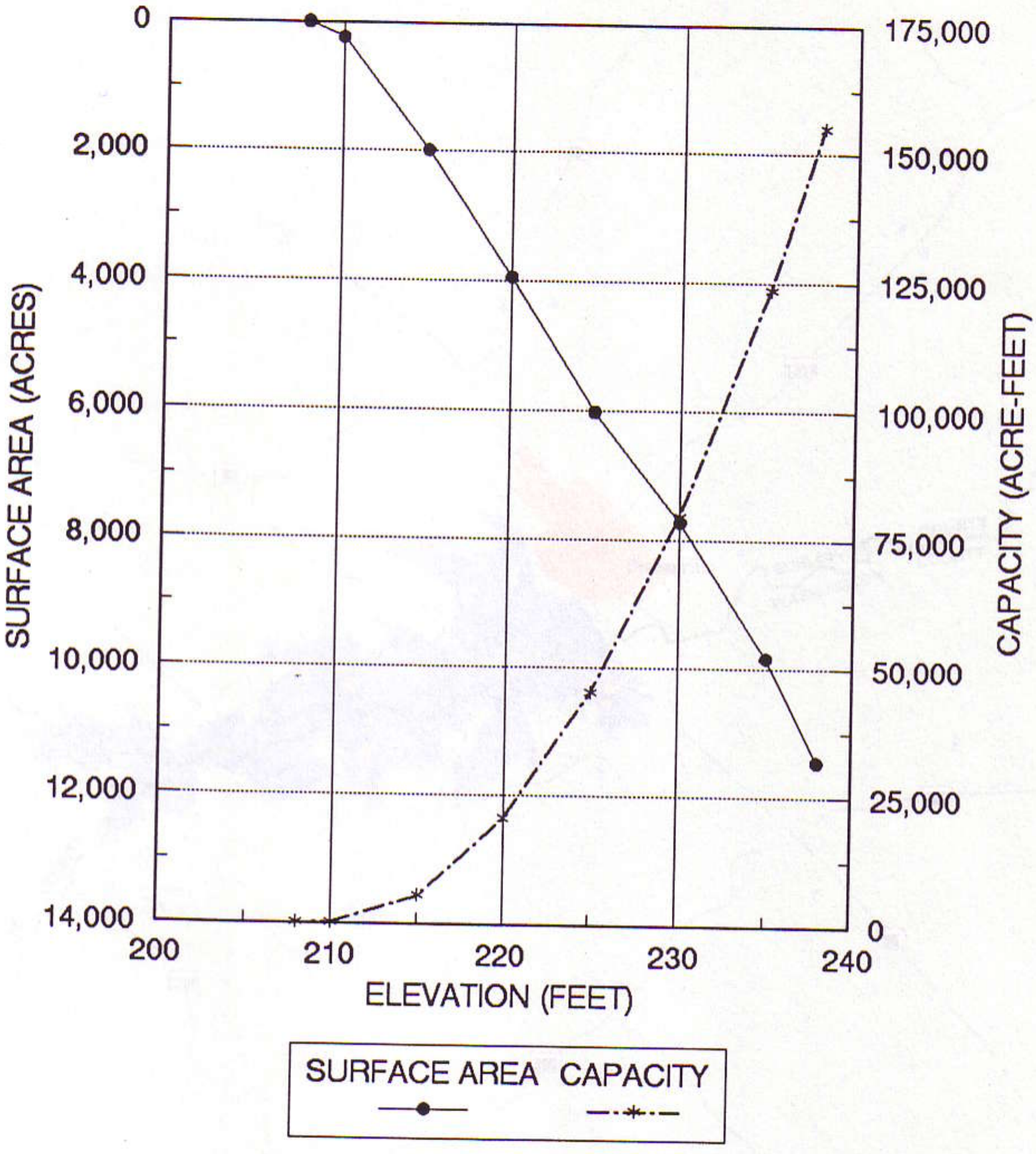
Jan 30 1996

SOMERVILLE LAKE NOVEMBER 1995 SURVEY

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
208							1	2	4	8
209	14	24	32	42	54	67	88	116	151	189
210	234	280	327	374	421	458	488	518	551	585
211	616	645	674	699	727	760	792	824	858	889
212	917	943	969	992	1013	1035	1057	1082	1109	1139
213	1170	1204	1242	1278	1313	1351	1397	1440	1482	1520
214	1557	1588	1621	1657	1698	1746	1797	1843	1891	1941
215	1987	2032	2081	2137	2190	2248	2306	2358	2404	2445
216	2485	2529	2566	2604	2641	2681	2722	2764	2804	2844
217	2885	2924	2966	3009	3052	3093	3137	3182	3223	3261
218	3298	3333	3367	3401	3438	3473	3505	3537	3572	3606
219	3638	3668	3699	3732	3764	3794	3824	3855	3885	3916
220	3947	3977	4008	4040	4071	4100	4129	4159	4188	4217
221	4246	4274	4305	4335	4364	4394	4426	4457	4491	4523
222	4558	4592	4626	4661	4698	4736	4780	4826	4872	4920
223	4971	5024	5086	5160	5233	5293	5348	5400	5449	5496
224	5544	5592	5640	5690	5742	5792	5838	5884	5929	5972
225	6015	6058	6098	6136	6174	6212	6250	6285	6320	6356
226	6391	6426	6461	6495	6529	6564	6600	6636	6673	6711
227	6750	6788	6827	6863	6897	6931	6967	7003	7037	7072
228	7105	7138	7170	7203	7234	7266	7298	7330	7362	7393
229	7425	7457	7487	7518	7548	7577	7605	7634	7664	7696
230	7731	7769	7810	7855	7907	7955	8001	8045	8089	8136
231	8185	8232	8281	8331	8379	8424	8468	8511	8551	8591
232	8631	8670	8708	8745	8783	8820	8857	8893	8928	8963
233	8998	9034	9069	9105	9141	9177	9214	9250	9287	9328
234	9368	9404	9443	9484	9526	9571	9616	9667	9713	9772
235	9842	9879	9916	9953	9991	10029	10068	10108	10147	10188
236	10250	10286	10324	10362	10402	10444	10486	10530	10575	10621
237	10685	10749	10816	10887	10961	11079	11142	11205	11269	11335
238	11456									



SOMERVILLE LAKE

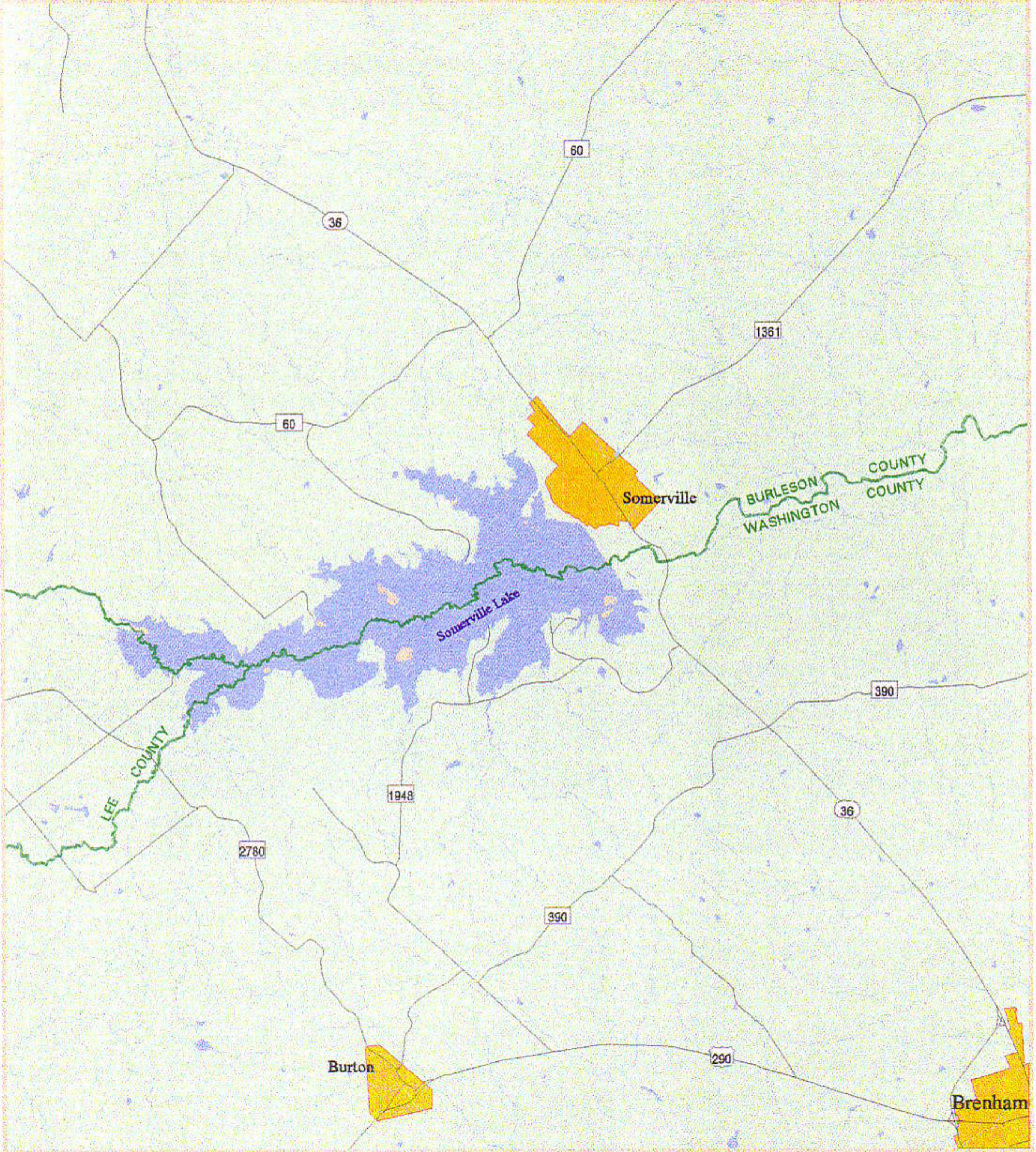
November 1995 SURVEY

Prepared by: TWDB February 1996

FIGURE 1

SOMERVILLE LAKE

Location Map



PREPARED BY: TWDB FEBRUARY 1996

FIGURE 2

SOMERVILLE LAKE

Location of Survey Data

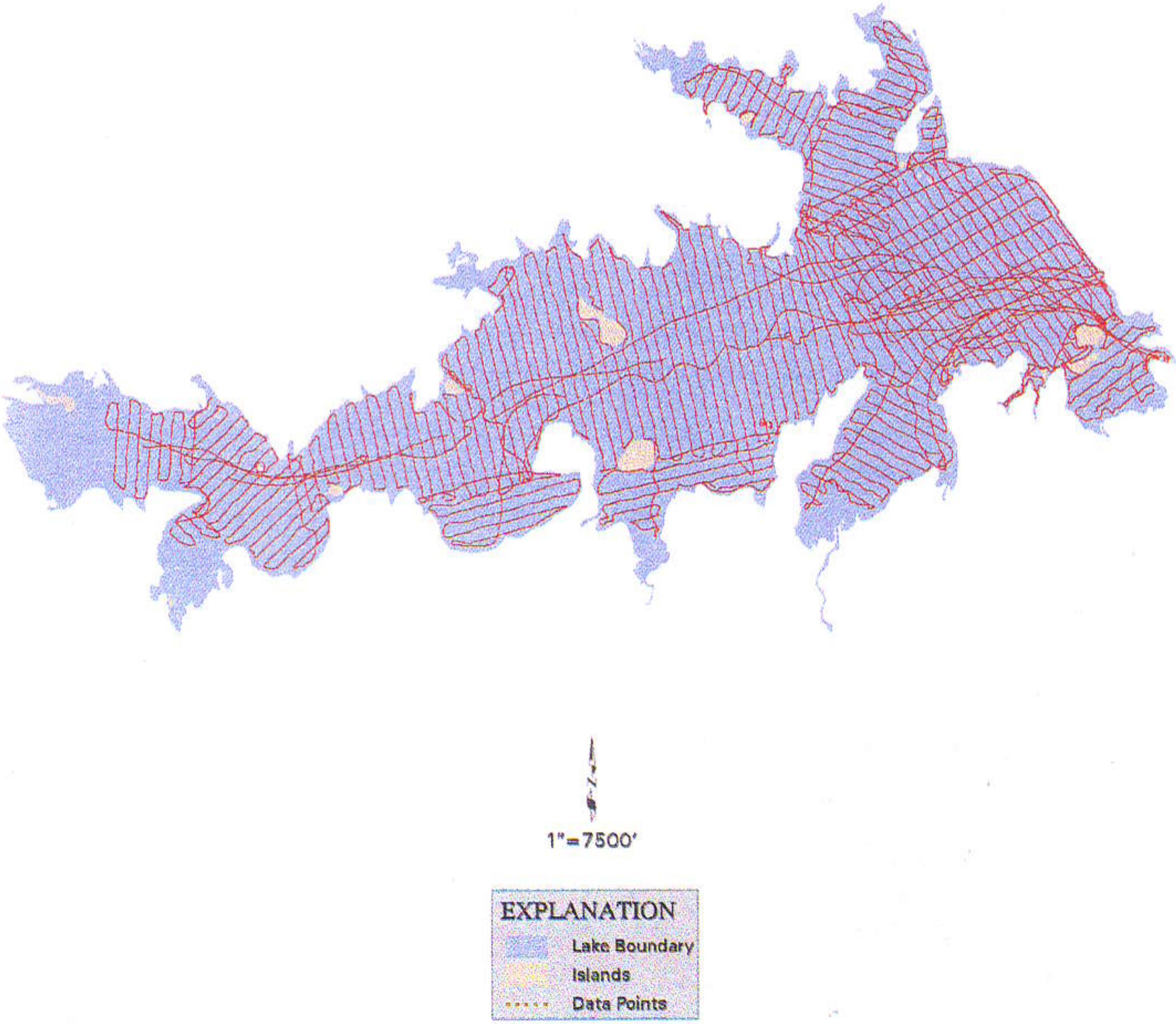


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FIGURE 3

SOMERVILLE LAKE

Location of control Point "105.0 O/S LEFT"

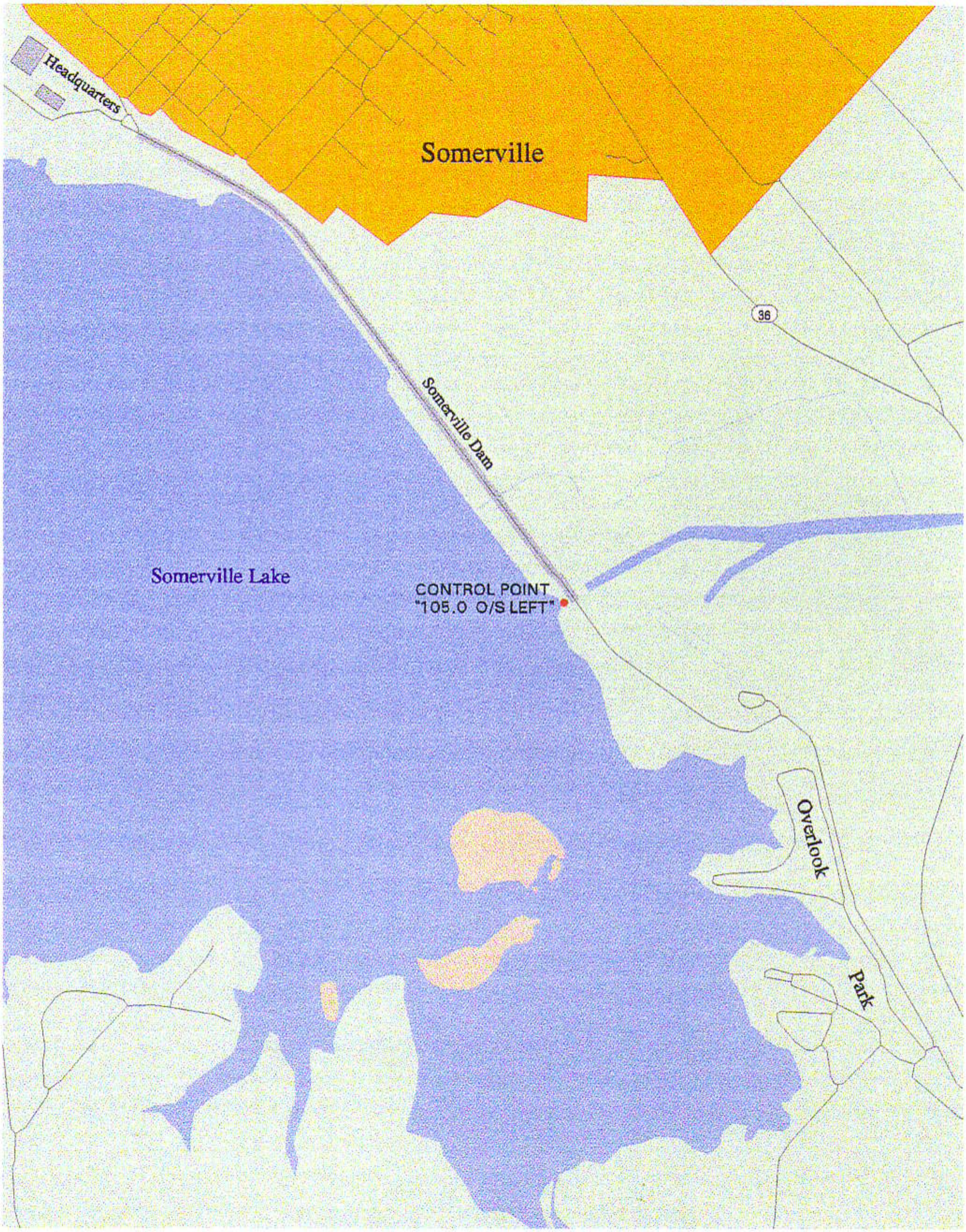

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FIGURE 4

SOMERVILLE LAKE

Shaded Relief

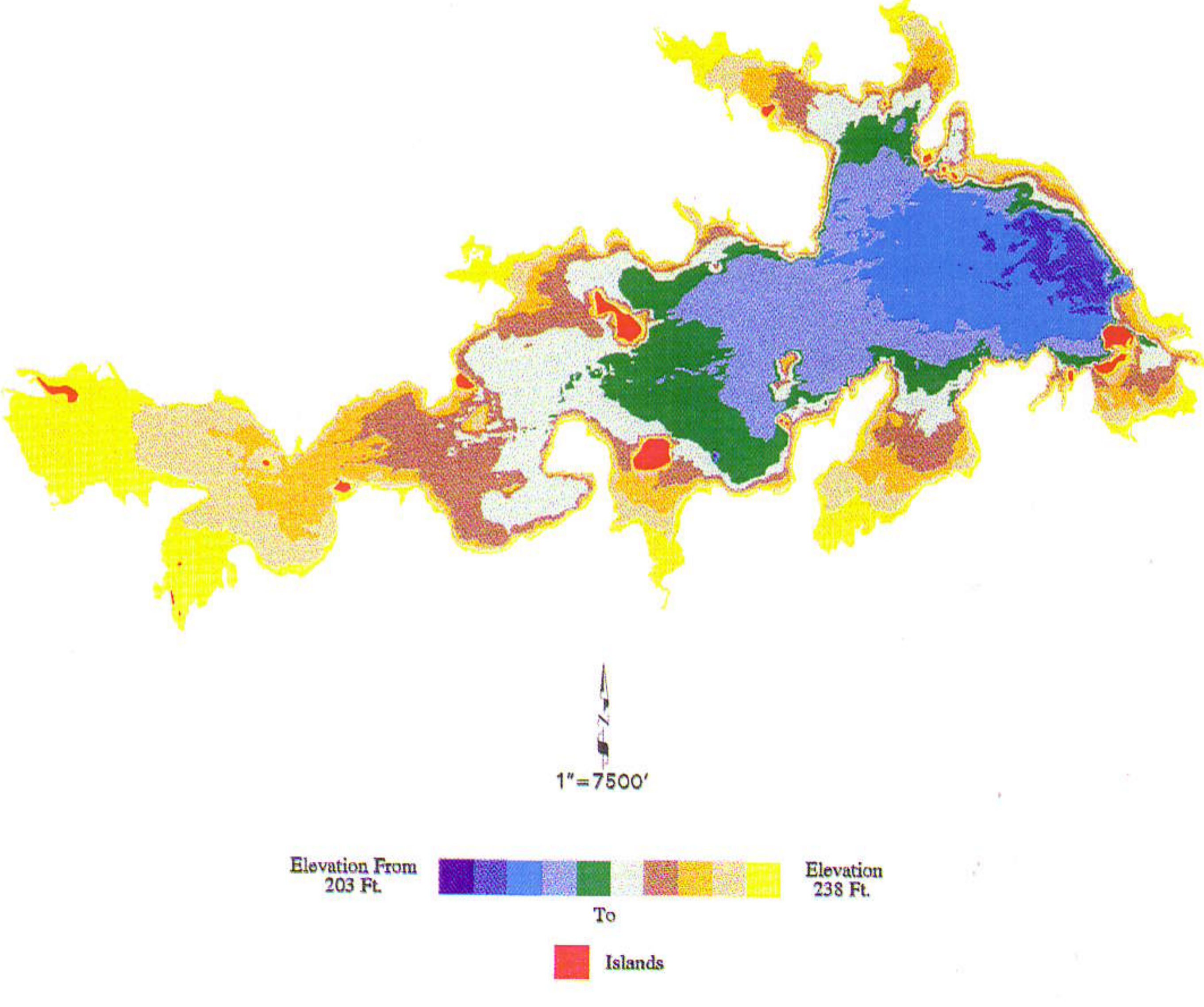

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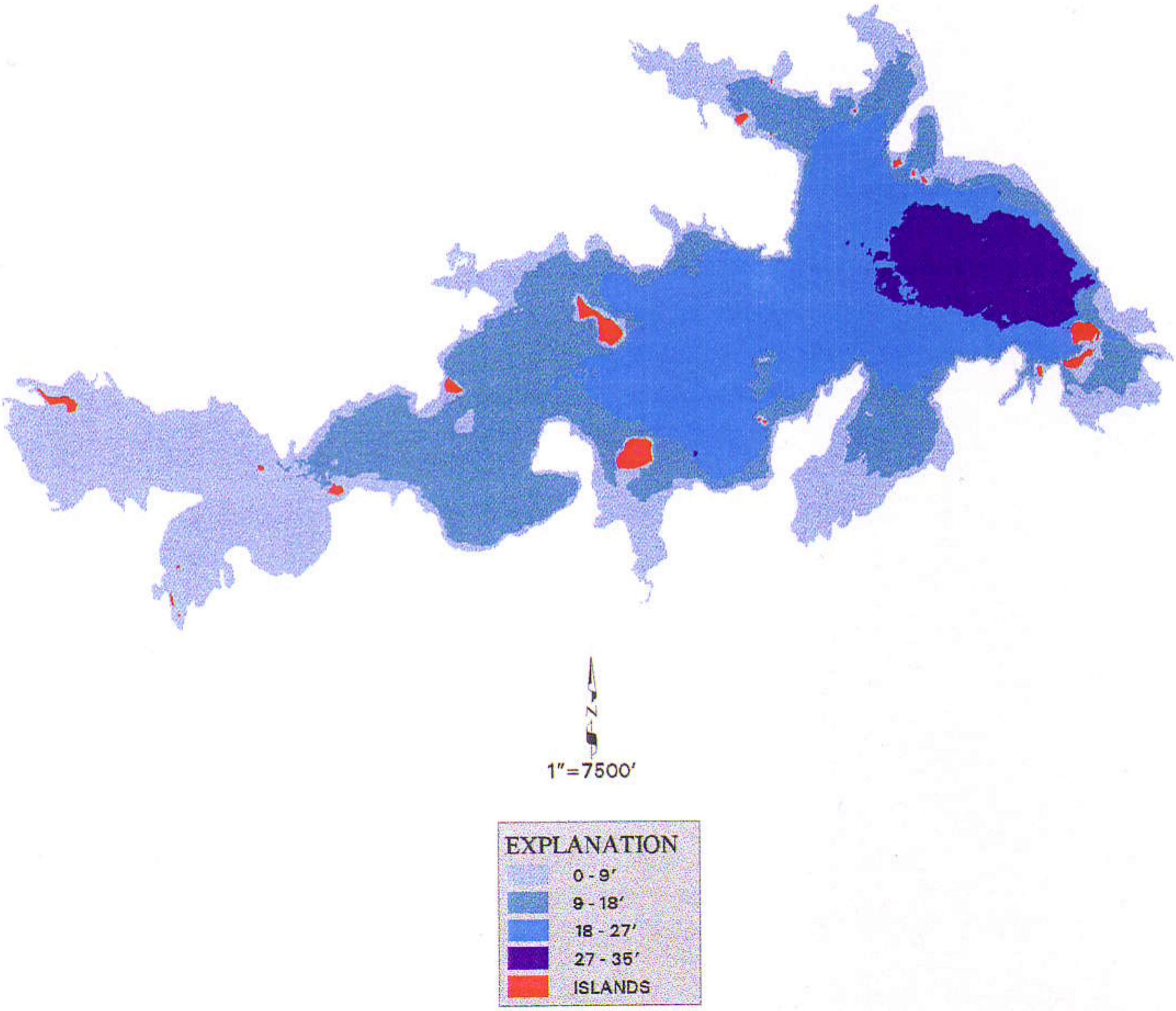
FIGURE 5

SOMERVILLE LAKE

Depth Ranges



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