VOLUMETRIC SURVEY
OF
LAKE NACOGDOCHES

Prepared for:

City of Nacogdoches

Prepared by:

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Texas Water Development Board

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INTRODUCTION

Staff of the Hydrographic Survey Program of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Lake Nacogdoches in March, 1994. 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 documented in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29) unless noted otherwise. The results will be compared to the original volumetric estimates when the dam and reservoir were built. At normal pool elevation (279.0 feet), records indicate a surface area of 2,210 acres with a capacity of 42,318 acre-feet.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

Lake Nacogdoches and associated Loco Dam are owned by the City of Nacogdoches and are located on Bayou Loco, a tributary of the Angelina River, a tributary of the Neches River. The facility is in Nacogdoches County approximately 10 miles west of Nacogdoches, Tx.. Dam construction commenced in June of 1975. Deliberate impoundment occured on May 4, 1976. Freese, Nichols and Endress Consulting Engineers of Fort Worth, Tx. designed the facility. Talon Construction Company of Addison, Tx. was the general contractor.

The dam's structure is a rolled earthin embankment, approximately 4,350 feet in length and 50 feet tall above the natural streambed. The service spillway is a concrete "Morning Glory" designed drop inlet. The 25 foot diameter crest is at elevation 279.0 ft. msl. The emergency spillway (earthin cut channel) is located at the west end of the embankment and is approximately

500 feet wide with a crest elevation of 286.0 feet msl. The outlet works consist of three valved controlled gates housed in a concrete tower near the service spillway drop inlet. The gates are 3 feet by 3 feet and are at elevation 235.9, 252.8 and 269.7 feet. Records indicate the drainage area for Lake Nacogdoches is 89.2 square miles

The Texas Water Commission issued Water Rights Permit #2560 (Application #2783) to the City of Nacogdoches on May 6, 1970 authorizing the impoundment of 41,140 acre-feet of water and the use, not to exceed 22,000 acre-feet of water per annum for municipal purposes. It also granted the permitee to use the impounded waters for recreational purposes. A change in the capacity computations for the reservoir required an admendment to the permit that was issued June 28, 1977. The revised calculations showed, and the amended permit authorized, the impoundment of 42,318 acre-feet of water. Certificate of Adjudication #4864 was issued February 19, 1987. It granted the same impoundment and uses as Permit #2560A. An amendment to Certificate of Adjudication #4864 was issued on June 17, 1988. It increased the rate of diversion from 6.22 cfs (2,800 gpm) to 62.2 cfs (28,000 gpm).

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 1960's by the United States Air Force and the defense establishment. After program funding in the eary 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 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 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" and was used during the survey of Lake Nacogdoches. 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

The equipment used in the hydrographic survey of Lake Nacogdoches 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.

As the boat traveled across the lake surface, the depth sounder gathered approximately ten readings of the lake bottom each second. The depth readings were averaged over the one-second interval and stored with the positional data to an on-board computer. After the survey, the average depths were corrected to elevation using the daily lake elevation. The set of data points logged during the survey were used to calculate the lake volume. Accurate estimates of the lake volume can be quickly determined using these methods, to produce an affordable survey. 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 strung across the reservoir along pre-determined range lines. A small boat was used to 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 strung across the reservoir so surveying instruments were utilized to determine the path of the boat. Monumentation was set for each end point 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 reading 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 it's 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 hard to detect after the fact. 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 again 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.

Survey Methods

The first task of the Hydrographic Survey field staff after arriving at Lake Nacogdoches was to establish a horizontal position reference control point. Figure 3 shows the location of the control point established for the survey. The location for the benchmark, stamped TWDB #12, was chosen due to the close proximity to the reservoir and the security of the area.

A static survey using two Trimble 4000SE GPS receivers was performed to obtain coordinates for TWDB #12 on March 23, 1994. Prior to the field survey, staff researched locations of known first-order benchmarks and requested City of Nacogdoches employees to physically locate the associated monuments prior to arrival. The monument chosen to provide horizontal control was a City of Nacogdoches Horizonal Control Monument (first-order) stamped "MON-34". The coordinates for this monument were established in 1992 and are published as

Latitude 31° 34' 58.01893"N and Longitude 094° 43' 14.78918"W and ellipsoid height of 55.30508 meters. Staff positioned a GPS receiver over this monument and positioned a second receiver over the TWDB #12 control point. Satellite data, with up to six satellites visible to the receiver, were gathered for approximately one hour at both locations in order to determine the coordinates of TWDB #12.

The data was retrieved and processed from both receivers, using Trimble Trimvec software, to determine coordinates for the shore station benchmark. The NAVSTAR satellites use the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to NAD '83. The WGS' 84 coordinates for TWDB #12 were determined to be North latitude 31° 37' 02.89", West longitude 094° 48' 55.89", and ellipsoid height of -10.97 meters. The approximate NGVD '29 elevation is 441.06 feet. These coordinates were entered into the shore station receiver located over TWDB #12 to fix its location and allow calculation and broadcasting of corrections through the radio and modem to the roving receiver located on the boat during the survey.

The reservoir's surface area was determined prior to the survey by digitizing the lake boundary from two USGS quad sheets. The name of the quad sheets are LAKE NACOGDOCHES SOUTH, TX. (1983) and LAKE NACOGDOCHES NORTH, TX. (1983). AutoCad software was used to digitize an estimate of the 279.0 contour based on the North American Datum of 1927 (NAD '27) used for these maps. The graphic boundary was then transformed from NAD '27 to NAD '83 using Environmental Systems Research Institutes's (ESRI) Arc/Info project command with the NADCOM parameters, to get the boundary into a more recent datum compatible with the positions received from the satellites. The area of the boundary shape was the same in both datum. All of the collected data and the calculations performed after the survey were done in the NAD '83 datum, a flat projected representation of the curved earth surface. NAD '27 is also a flat projection, but the two datum have a slightly different point of origin, and distinctly different state plane false northing and false easting coordinate to be able to distinguish coordinate points between the two datum.

After the survey, the resulting shape was modified slightly to insure that all data points gathered were within the boundary. The resulting acreage at the normal pool elevation was thereby estimated to be 2,212 acres, or about equal to the recorded surface acreage of 2,210 acres. An aerial topo 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 survey layout was pre-planned, using approximately 80 survey lines at a spacing of 500 feet. Innerspace Technology Inc. software was utilized for navigation and to integrate and store positional data along with depths. In areas where vegetation or obstructions prevented the boat from traveling the planned line, random data were collected wherever the boat could maneuver. Additional random data were collected lengthwise in the reservoir. Data points were entered into the data set utilizing the DGPS horizontal position and manually poling the depth in shallow areas where the depth was less than the minimum recordable depth of the depth sounder, which is about 3.5 feet. Figure 2 shows the actual location of the data collection sites. Data were not collected in areas that were inaccessible due to shallow water or obstructions. The data set included approximately 30,342 data points.

TWDB staff verified the horizontal accuracy of the DGPS used in the Lake Nacogdoches survey to be within the specified accuracy of three meters prior to the survey. 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 set to receive and process the corrections. 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.

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 better satellite geometry and thus 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 the maximum entered by the user, to advise the field crew that the horizontal position has degraded to an unacceptable level.

The depth sounder measures depth by measuring the time between the transmission of the sound pulse and the reception of its echo. The depth sounder was calibrated with the Innerspace Velocity Profiler typically once per day, unless the maximum depth varied by more than twenty feet. The velocity profiler calculates an average speed of sound through the water column of interest (typically set at a range of two feet below the surface to about ten feet above the maximum encountered depth), and the draft value or distance from the transducer to the surface. The velocity profiler probe is placed in the water to wet the transducers, then raised to the water surface where the depth is zeroed. The probe is then lowered on a cable to just below the maximum depth set for the water column, and then raised to the surface. The unit reads out an average speed of sound for the water column and the draft measurement, which are then entered into the depth sounder. The speed of sound can vary based on temperature, turbidity, density, or other factors. 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. Manual poling of depths within shallow areas agreed with the depth obtained by the depth sounder typically within $\pm$ 0.3 feet, and since the boat is moving much slower, the plane of the boat has much less effect.

Analog charts were printed for each survey line as the data were collected. The gate mark, which is a known distance above the actual depth that was recorded in the data file, was also printed on the chart. Each analog chart was analyzed, and where the gate mark indicated that the recorded depth was other than the bottom profile, depths in the corresponding data files were modified accordingly. The depth sounder was set to record bad depth readings as 0. During post-processing, all points with a zero depth were deleted.

Each of the resulting data points collected consisted of a latitude, longitude and depth reading. The depths were transformed to elevations with a simple awk Unix command based on the water surface elevation each day, rounded to the nearest tenth of a foot since the depth sounder reads in tenths of a foot. The water surface remained constant at elevation 279.10 feet during the field survey. The latitude, longitude data set was converted to decimal degrees and loaded into Arc/Info along with the NAD '83 boundary file using the CREATETIN command. The data points and the boundary file were used to create a Digital Terrain Model (DTM) of the reservoir's bottom surface using the Arc\Info TIN module. 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. Areas that were too shallow for data collection or obstructed by vegetation were estimated by the Arc/Info's TIN product using this method of interpolation.

There were some areas where interpolation could not occur because of a lack of information along the boundary of the reservoir. "Flat triangles" were drawn at these locations. ArcInfo does not use flat triangle areas in the volume or contouring features of the model. These areas were located in the upper reaches of the river and were determined to be insignificant on Lake Nacogdoches. Therefore no additional points were required for interpolation and contouring of the entire lake surface. From this three-dimensional triangular plane surface representation, the TIN product calculated the surface area and volume of the entire reservoir at one-tenth of a foot intervals.

The three-dimensional triangular surface was then shaded 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 intensities of these colors were assigned to the different depths in between.

Figure 4 consists of the resulting depth shaded representation of the lake. Figure 5 presents a similar version of the same map, using bands of color for selected contour 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 following smoothing options were chosen for this model: Douglas-Peucker option with a 1/1000 tolerance level to eliminate any duplicate points, and Round Corners with a maximum delta of 1/1000 of the model's maximum linear size, in an attempt to smooth some of the angularity of the contours. Contours of the bottom surface at two foot intervals are presented in Figure 6. The map has been split into two maps to increase the definition of the contours.

DATA

The main reservoir of Lake Nacogdoches innundates an area from Loco Dam upstream to the confluences of Yellow Bank Bayou, Little Loco Bayou and Big Loco Bayou. Visual observation noted sediment deposits and vegitation occupied the reaches of Big Loco and Little Loco Bayous. Elevation relief along the perimeter of the lake was steep and the folage was mostly large pine trees.

Lake Nacogdoches was estimated by this survey to encompass 2,212 acres and to contain a volume of 39,523 acre-feet at the normal pool elevation of 279.0 feet. The lowest elevation encountered during the field survey was 232.7 feet, or 46.3 feet of depth and was found about 100 yds out from the middle of the dam. The reservoir volume table is presented in Appendix B and the area table in Appendix C. The one-tenth foot intervals are based on actual calculations from the model. An elevation-area-volume graph is presented in Appendix D. No data points were collected in areas where the depth was shallower than two feet because of the draft limitations of the boat. Straight-line interpolation occurs from the last data points collected to the normal pool elevation lake boundary as digitized. The field data collected corresponded well with the boundary data obtained from the USGS map. The Board does not represent the boundary, as depicted in this report, to be a detailed actual boundary. It is a graphical approximation of the actual boundary that was used solely to compute the volume and area of the lake. This boundary does not represent the true land versus water boundary of the lake.

The storage volume calculated by this survey is approximately 6.6 percent less than the previous record information for the lake. The low flow outlet is at elevation 235.9 feet, resulting in a dead storage of 2 acre-feet. Therefore, the conservation storage for the reservoir is calculated to be 39,521 acre-feet.

SUMMARY

The purpose of the survey was to determine the current storage volume of Lake Nacogdoches utilizing a technologically advanced surveying system consisting of satellite surveying and digital depth sounding equipment, and digital terrain modeling software. Results from the survey indicate that the lake's capacity at the normal pool elevation of 279.0 feet was 39,523 acre-feet. The conservation storage capacity was calculated to be 39,521 acre-feet. The estimated reduction in storage capacity since 1976 when the reservoir was built can be estimated at 2,795 acre-feet or 6.6 percent. This equates to an estimated loss of 155.3 acre-ft per year during the last 18 years.

It is assumed that the reduction in estimated storage capacity is due to both a combination of sedimentation, and improved data and calculation methods. Repeating this survey with the same calculation methodology in five to ten years or after major flood events should remove any noticeable error due to improved calculation techniques and will help isolate the storage loss due to sedimentation.

CALCULATION OF DEPTH SOUNDER ACCURACY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Jun 16 1994

LAKE NACOGDOCHES MARCH 1994 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
232										
233										
234										
235		1	1	1	1	1	1	1	1	2
236	2	2	2	3	3	3	4	4	4	5
237	5	6	6	7	7	8	9	10	10	11
238	12	13	14	16	17	19	21	23	25	28
239	31	34	37	41	45	49	54	58	63	68
240	73	79	85	91	97	104	111	118	125	133
241	141	149	157	166	175	185	194	204	215	225
242	236	248	260	272	285	298	312	326	341	356
243	372	388	404	421	439	457	475	494	514	533
244	554	574	596	618	640	663	686	711	735	760
245	786	812	839	866	894	922	951	980	1009	1039
246	1070	1100	1131	1163	1195	1227	1260	1293	1327	1361
247	1395	1430	1466	1502	1539	1576	1615	1653	1692	1732
248	1772	1812	1853	1894	1936	1978	2020	2064	2107	2151
249	2196	2241	2287	2333	2379	2426	2474	2522	2571	2620
250	2670	2720	2771	2822	2873	2925	2977	3030	3084	3138
251	3192	3247	3302	3358	3415	3472	3530	3588	3646	3705
252	3765	3825	3885	3946	4008	4069	4132	4195	4259	4323
253	4388	4453	4519	4586	4653	4720	4788	4856	4925	4995
254	5065	5136	5207	5278	5350	5423	5496	5570	5644	5718
255	5793	5869	5944	6021	6097	6175	6252	6330	6409	6488
256	6567	6647	6728	6809	6890	6973	7056	7139	7223	7307
257	7392	7478	7564	7651	7738	7826	7914	8002	8092	8181
258	8272	8363	8454	8546	8639	8733	8826	8921	9016	9112
259	9209	9306	9404	9503	9602	9702	9803	9904	10006	10109
260	10212	10315	10419	10524	10629	10735	10842	10949	11057	11165
261	11274	11383	11493	11604	11715	11826	11938	12050	12163	12276
262	12390	12505	12620	12735	12851	12967	13084	13202	13320	13438
263	13557	13677	13797	13918	14039	14161	14283	14405	14528	14652
264	14775	14900	15025	15150	15276	15402	15529	15656	15783	15911
265	16040	16169	16299	16429	16559	16691	16822	16955	17088	17221
266	17355	17489	17624	17759	17895	18031	18168	18305	18443	18581
267	18720	18859	18999	19139	19279	19420	19562	19704	19846	19989
268	20132	20275	20419	20564	20709	20854	21000	21146	21293	21441
269	21589	21737	21886	22035	22185	22335	22486	22637	22788	22940
270	23093	23246	23399	23553	23707	23862	24017	24173	24329	24485
271	24643	24800	24959	25117	25277	25437	25598	25759	25921	26083
272	26247	26411	26576	26742	26909	27076	27245	27415	27585	27756
273	27928	28100	28273	28447	28621	28796	28971	29147	29324	29501
274	29678	29856	30035	30215	30395	30575	30757	30939	31122	31305
275	31489	31674	31860	32046	32233	32420	32609	32798	32988	33179
276	33371	33564	33759	33953	34149	34345	34542	34740	34939	35138
277	35338	35539	35741	35944	36147	36352	36557	36763	36970	37177
278	37386	37596	37806	38017	38229	38443	38657	38872	39088	39305
279	39523									

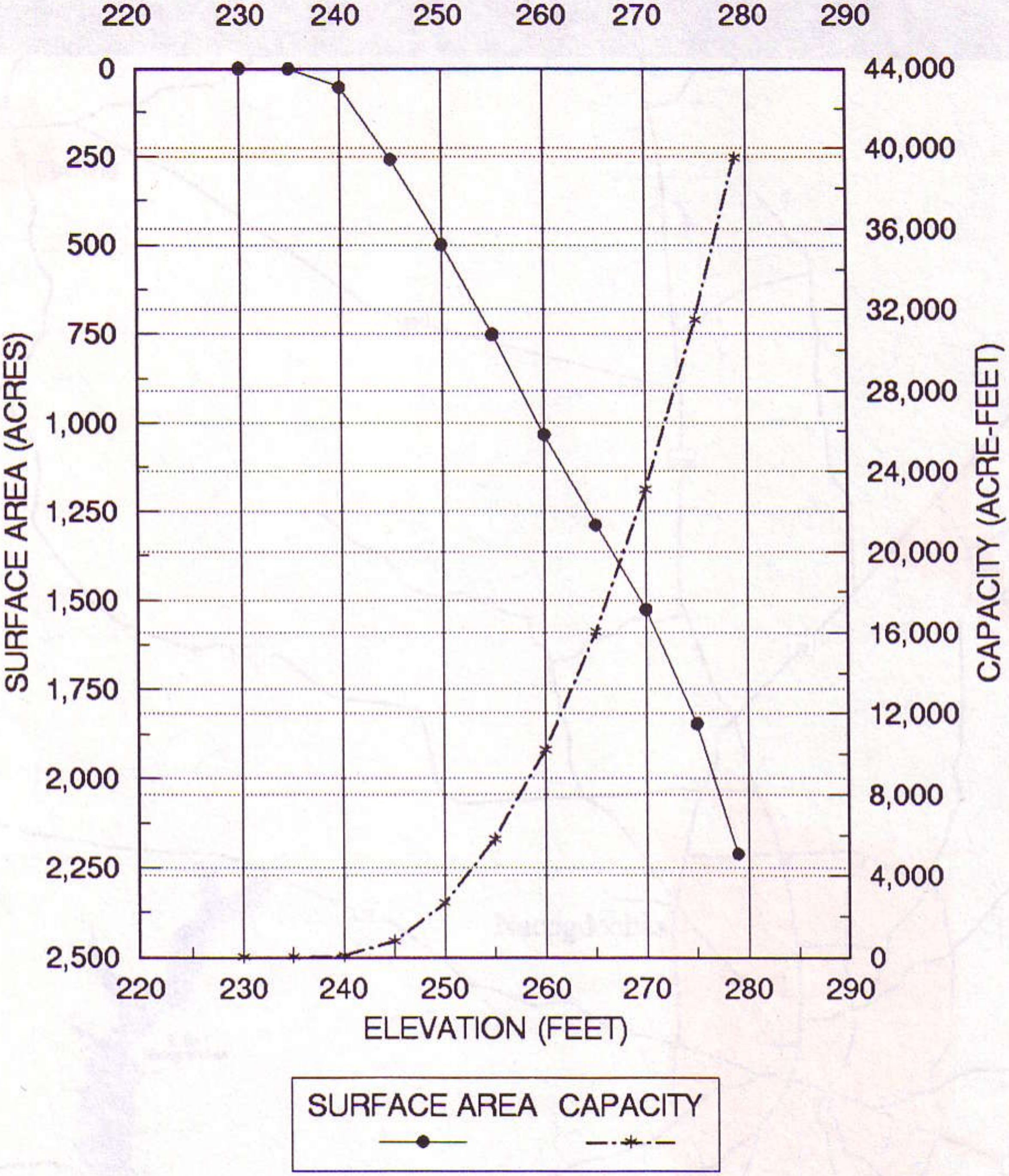
TEXAS WATER DEVELOPMENT BOARD
RESERVOIR AREA TABLE

Jun 16 1994

LAKE NACOGDOCHES MARCH 1994 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
232										
233										
234								1	1	1
235	1	1	1	1	1	1	2	2	2	2
236	2	2	3	3	3	3	4	4	4	4
237	5	5	5	6	6	7	7	8	8	9
238	10	11	12	14	15	18	20	22	25	28
239	30	33	36	38	41	43	46	48	50	52
240	54	57	59	62	64	67	70	72	75	78
241	80	84	87	90	93	95	99	102	105	109
242	113	118	122	126	130	135	139	145	150	154
243	159	163	167	172	177	182	187	191	196	200
244	205	210	216	222	227	232	238	243	248	254
245	259	265	270	275	280	285	289	293	297	301
246	305	309	312	316	321	326	330	335	339	343
247	348	353	359	366	372	378	384	389	393	397
248	401	406	410	414	419	424	428	434	439	444
249	449	453	458	463	469	475	480	485	490	494
250	499	504	508	512	517	522	527	532	537	541
251	546	551	557	563	568	573	578	583	588	593
252	598	602	607	611	616	623	629	634	639	645
253	651	656	661	667	672	677	682	687	693	698
254	703	708	713	718	724	729	734	738	743	747
255	752	756	760	765	770	774	779	783	788	792
256	797	803	808	814	819	825	831	837	842	847
257	853	858	864	869	875	879	884	889	895	901
258	907	913	919	925	930	936	942	949	956	963
259	970	977	983	990	997	1004	1010	1016	1022	1027
260	1033	1039	1045	1050	1057	1063	1069	1075	1081	1086
261	1091	1096	1101	1106	1111	1116	1121	1126	1132	1137
262	1142	1147	1152	1157	1161	1166	1171	1177	1183	1189
263	1194	1199	1204	1208	1213	1218	1223	1227	1232	1237
264	1242	1246	1251	1255	1260	1264	1268	1273	1278	1283
265	1289	1294	1299	1304	1309	1315	1320	1325	1330	1335
266	1340	1345	1350	1355	1360	1365	1370	1375	1380	1385
267	1389	1394	1399	1404	1408	1412	1416	1421	1425	1429
268	1433	1438	1443	1447	1452	1457	1462	1467	1471	1476
269	1481	1486	1491	1496	1500	1504	1509	1513	1517	1522
270	1526	1531	1535	1540	1545	1550	1554	1559	1564	1569
271	1575	1580	1585	1591	1597	1603	1610	1616	1622	1630
272	1638	1646	1655	1664	1673	1682	1691	1700	1707	1714
273	1721	1727	1733	1739	1745	1751	1756	1762	1768	1773
274	1779	1785	1791	1797	1803	1810	1817	1824	1832	1838
275	1845	1852	1859	1866	1873	1879	1887	1896	1906	1917
276	1928	1937	1945	1952	1960	1967	1974	1981	1989	1997
277	2005	2014	2024	2032	2040	2048	2056	2065	2073	2082
278	2090	2099	2108	2118	2127	2137	2146	2156	2166	2176
279	2212									



LAKE NACOGDOCHES

MARCH 1994 SURVEY

Prepared by: TWDB May 1994

FIGURE 1

LAKE NACOGDOCHES

Location Map

1"=13000'

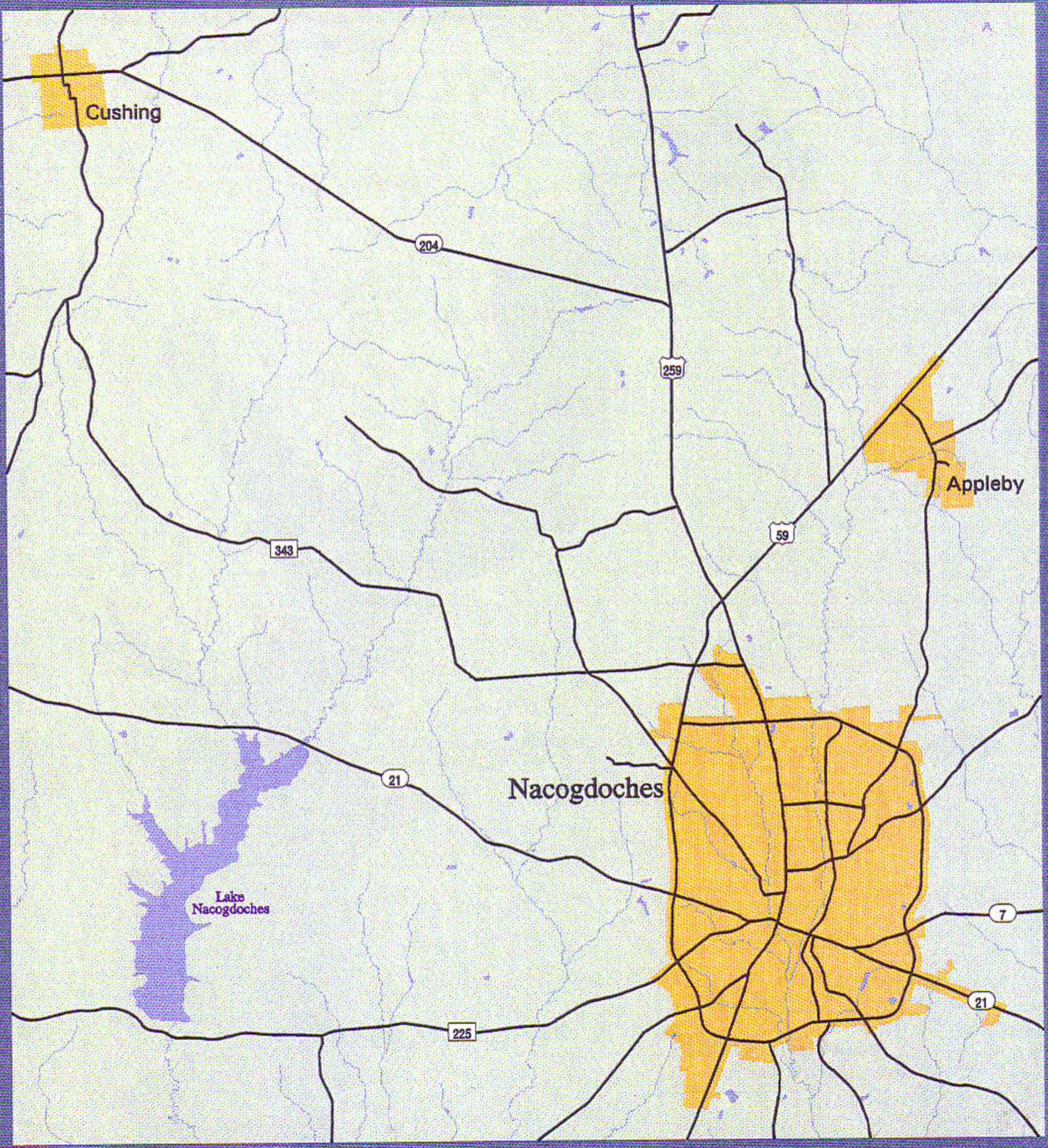
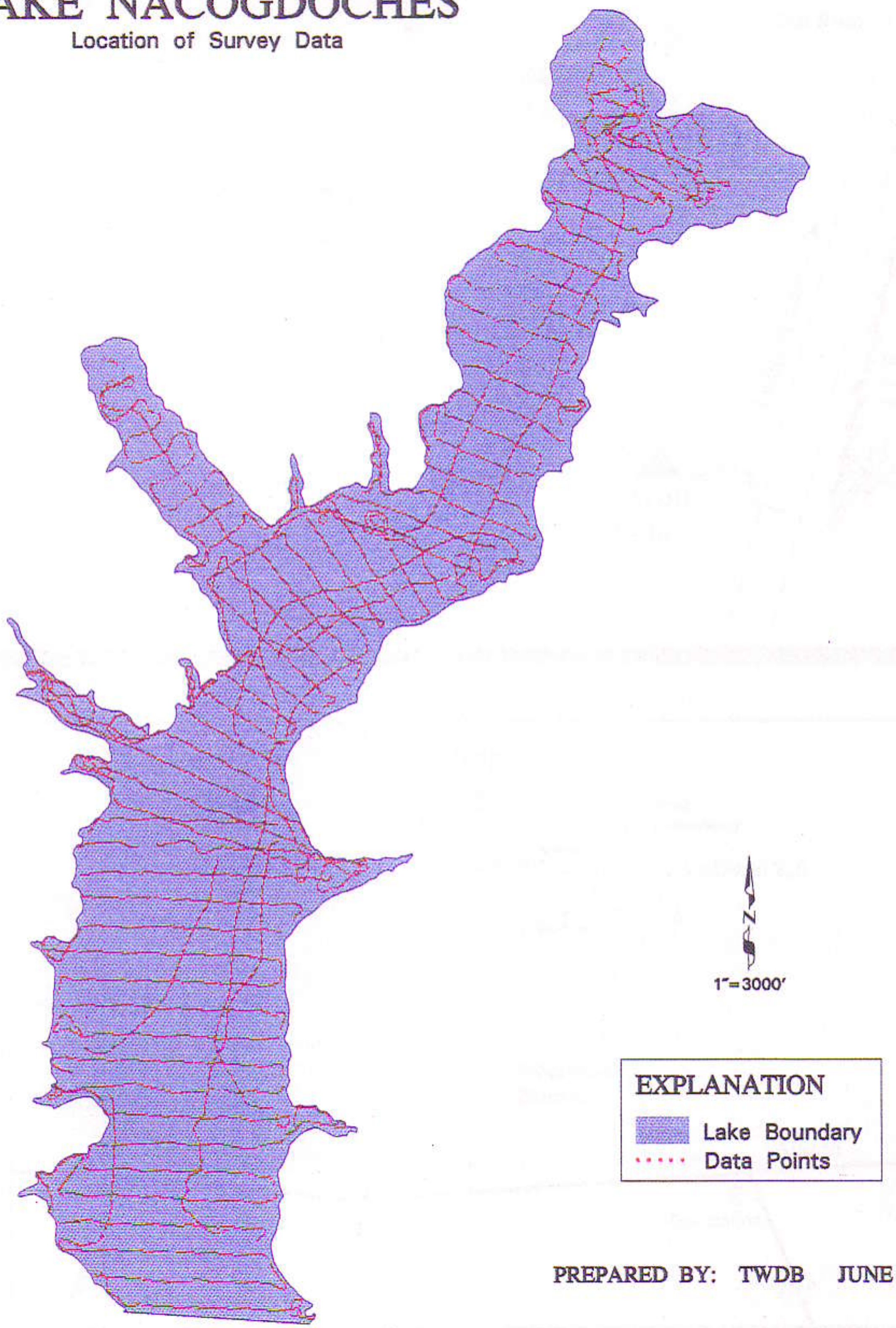


FIGURE 2

LAKE NACOGDOCHES

Location of Survey Data

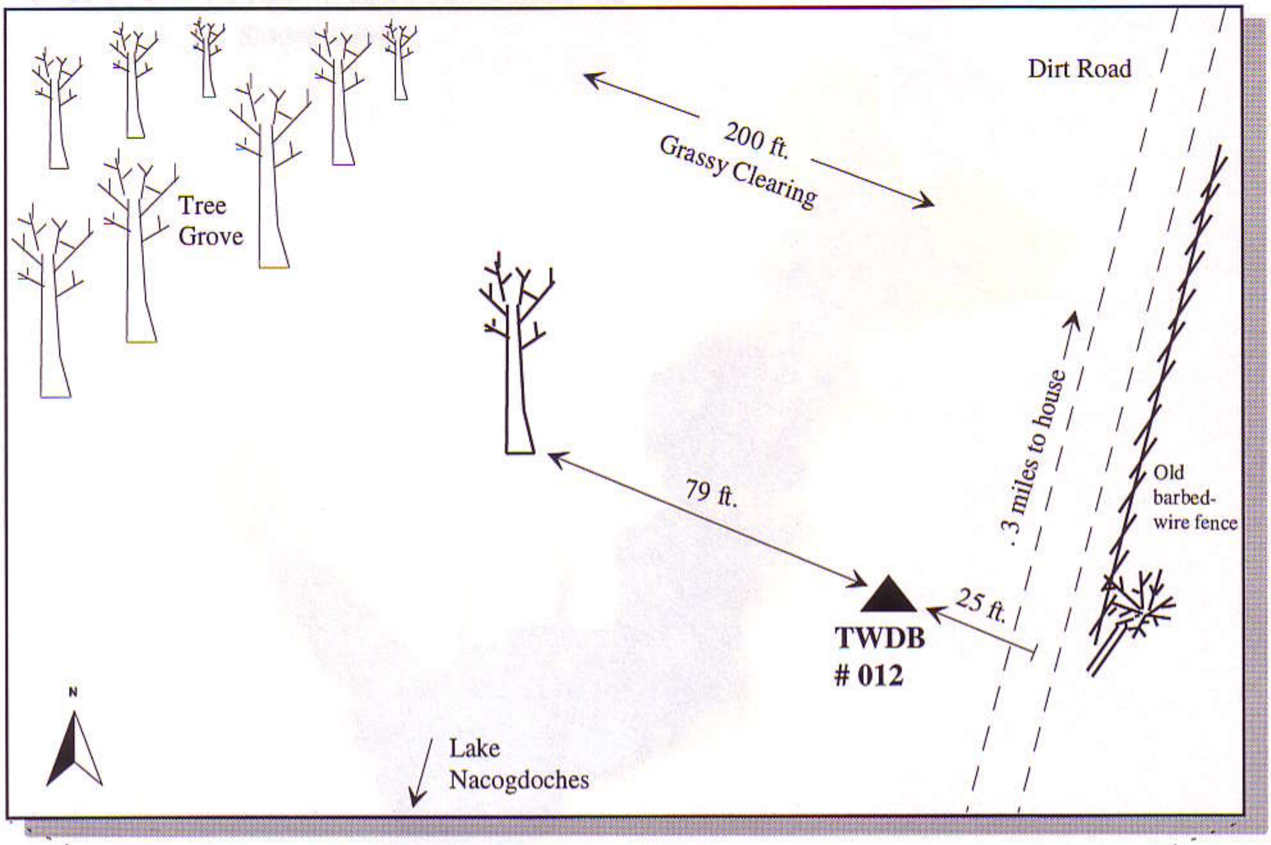


PREPARED BY: TWDB JUNE 1994

FIGURE 3

LAKE NACOGDOCHES

Location of control point # 012.



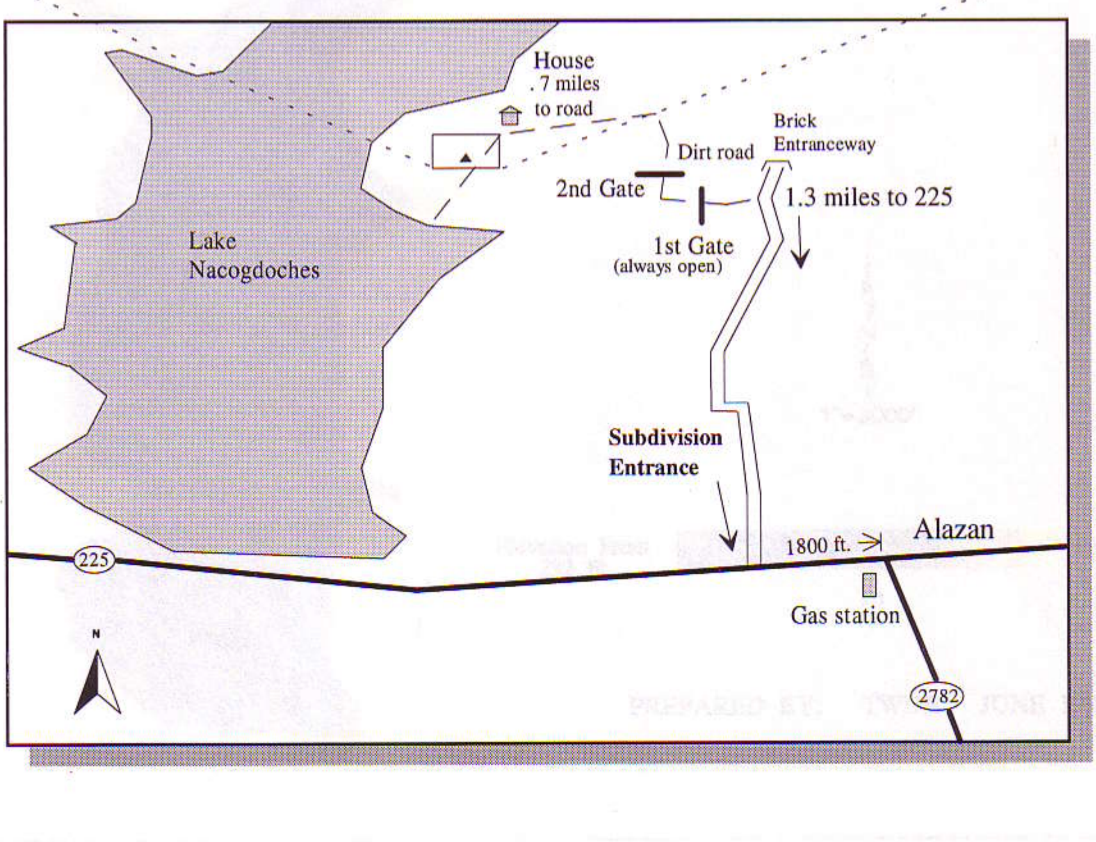


FIGURE 4

LAKE NACOGDOCHES

Shaded Relief

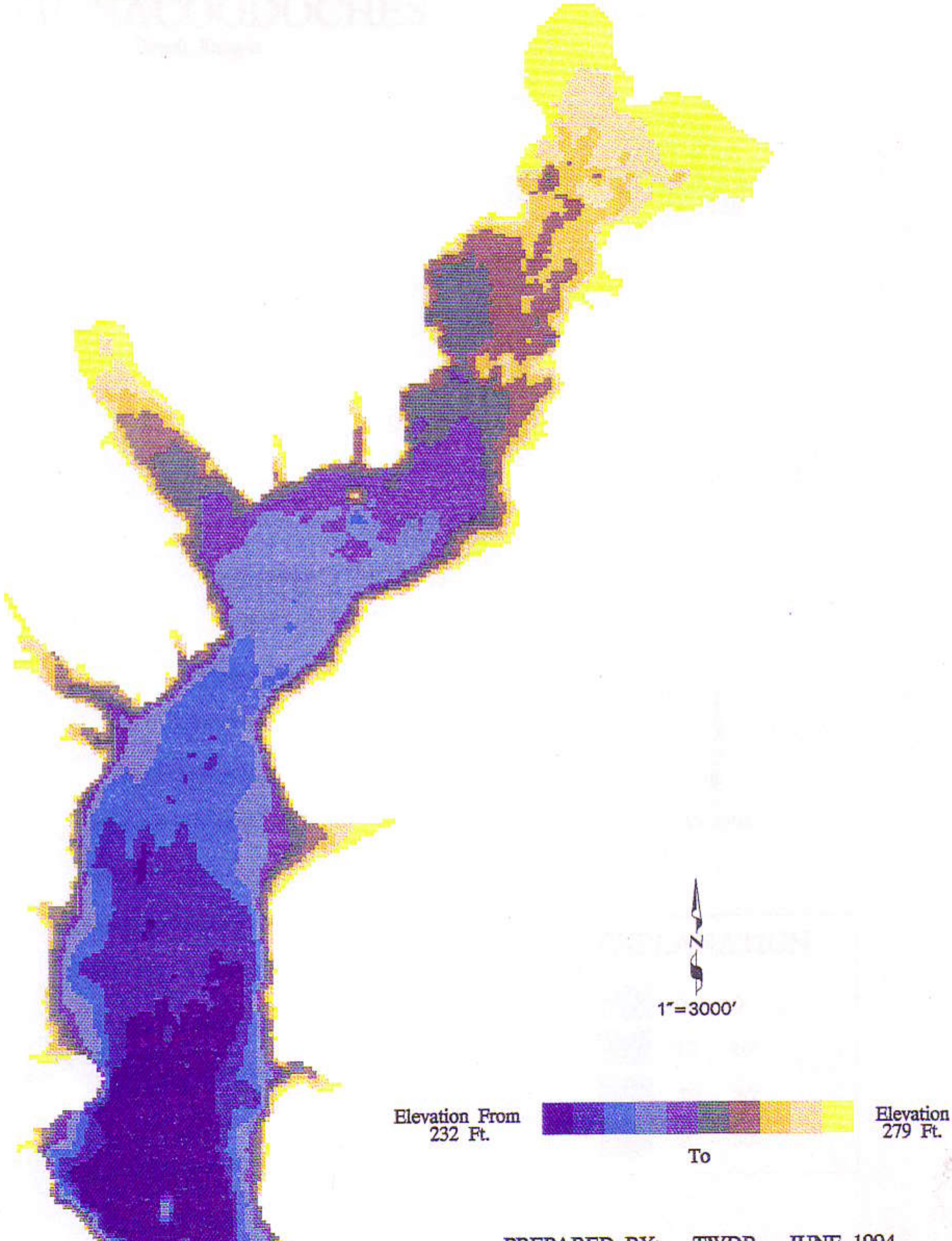


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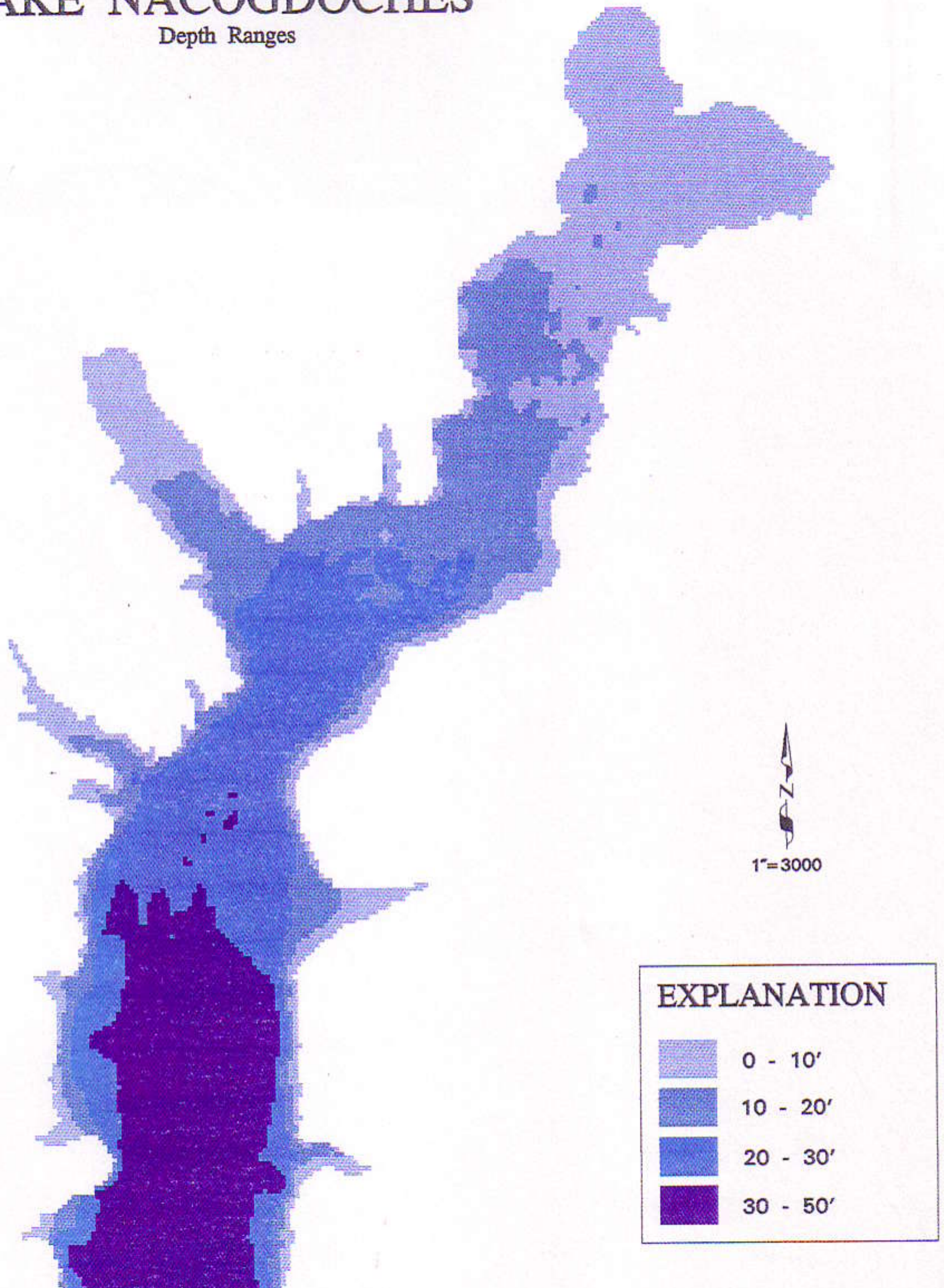
FIGURE 5

LAKE NACOGDOCHES

Depth Ranges



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