

POSSUM KINGDOM LAKE  
HYDROGRAPHIC SURVEY REPORT

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# **POSSUM KINGDOM LAKE HYDROGRAPHIC SURVEY REPORT**

## **INTRODUCTION**

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Possum Kingdom Lake in June, 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 reported 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 information from the latest sedimentation survey performed by URS/Forrest and Cotton, Inc. Consulting Engineers (1974). At the normal pool elevation of 1,000.00 feet, they reported a surface area of 17,700 acres and a capacity of 570,243 acre-feet.

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

Possum Kingdom Lake and associated Morris Sheppard Dam are owned and operated by the Brazos River Authority. The facility is located on the Brazos River, 11 miles southwest of Graford and 18 miles northwest of Mineral Wells. The 310 miles of shoreline are located in Palo Pinto, Stephens, Young and Jack Counties. Dam construction commenced May 29, 1938. The structure was completed and deliberate impoundment of water began March 21, 1941. Hydroelectric power was generated for the first time on April 17, 1941, and water was discharged over the spillway for the first time on May 5th of the same year. The general contractors for the construction of Morris Sheppard Dam were C. F. Lytle and A. L. Johnson. Estimated cost of the facility was \$7,000,000.

Permit #1262 (Application #1351) was issued May 9, 1938 by the Board of Water

Engineers to the Brazos River Conservation and Reclamation District. It granted the permittee the right to construct a dam in and across the bed of the Brazos River and to impound, divert, appropriate, and use an amount not to exceed 1,500,000 acre-feet of water per annum for the purpose of domestic, municipal, industrial, mining, power generation, recreation and irrigation. Storage capacity was not to exceed 750,000 acre-feet of water. Permit #1262 was later amended February 9, 1987. Records indicate the Brazos River Authority (formerly Brazos River Conservation and Reclamation District) had a priority right to use not to exceed 230,750 acre-feet of water per annum for municipal, industrial, irrigation and mining purposes. The amendment to Permit # 1262 authorized an interbasin transfer to the Trinity River Basin of up to 5,240 acre-feet of water per annum of the municipal authorization. Certificate of Adjudication #12-5155 was issued to the Brazos River Authority on December 17, 1987. The owner was authorized to maintain an existing dam (Morris Sheppard) and reservoir (Possum Kingdom Lake) and impound therein not to exceed 724,739 acre-feet of water. The owner was authorized a priority right to divert and use not to exceed 230,750 acre-feet of water per annum for municipal, industrial, irrigation and mining purposes. For system operation purposes, the owner was authorized to exceed the priority right and to annually divert and use from Possum Kingdom Lake not to exceed 175,000 acre-feet of the municipal authorization of which amount not more than 5,240 acre-feet of water of the municipal authorization may be transferred to the Trinity River Basin for municipal use by the Authority's service area customers; 250,000 acre-feet of water for industrial purposes; 250,000 acre-feet for irrigation purposes and 49,800 acre-feet of water for mining purposes. All diversions and use of waters from Possum Kingdom Lake in excess of 230,750 acre-feet of water in one calendar year would be charged against the sum of the amounts designated as priority rights in the other reservoirs included in the System Operation Order. The owner was also authorized to use the impounded waters of Possum Kingdom Lake for non-consumptive recreation purposes. A non-priority right was authorized to the owner for non-consumptive use of water released from or flowing out of the lake for Hydroelectric power generation. Certificate of Adjudication #5167 (issued December 14, 1987) states the owner 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. This water is to be released from Possum Kingdom Lake (Certificate of Adjudication # 5155) and other reservoirs owned and operated by the Brazos River Authority.

Morris Sheppard Dam consists of a reinforced concrete, Ambursen-type, massive buttress with a flat-slab deck, a section of nine roof-weir gates, two bulkhead sections and an earthen dike. The total length is 2,740 feet with a maximum height of 189 feet at elevation 1,024 feet. The spillway consists of nine roof-weir type gates 73 feet 8 inches wide by 13 feet high with top of gate elevation 1,000.0 feet. Flood-control releases are made from one or more of these gates. They have a total discharge capacity of 550,000 cubic feet per second (cfs) at elevation 1,000.0 feet. There are two 12-foot-diameter penstocks with gates and control tower for water supply to the turbines in the powerhouse. The turbine operation provides regulated releases. When turbines are not operating, necessary low-flow releases are controlled by two 30 inch by 24 inch gates that discharge water into the outlet conduit through the face of the dam. The power facility consists of two 11,250 kw generating units.

Records indicate the original capacity of Possum Kingdom Lake at normal pool elevation of 1,000.0 feet was 724,739 acre-feet with a surface area of 19,800 acres. These records were based on 1935-1938 topographic surveys. A sediment survey performed by URS/Forrest and Cotton Inc. in 1974 revised the volume at the same elevation to 570,243 acre-feet with a surface area of 17,700. acres. The 1974 survey reported an average lake width of one mile with a maximum width of 3.5 miles. The length of the lake was estimated at 65 miles. Depths were reported to be more than 100 feet near the dam.

The drainage area for Possum Kingdom Lake is estimated at 23,596 square miles, of which 9,566 square miles is probably noncontributing. Major tributaries include Rock Creek, Deep Elm Creek, Connor Creek, Cedar Creek, Caddo Creek and Bluff Creek.

## **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 early 1970's, the initial satellite was launched on February 22, 1978. A four year delay in the launching program occurred after the Challenger space shuttle disaster. In 1989, the launch schedule was resumed. Full operational capability 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 Possum Kingdom Lake. 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 Possum Kingdom Lake 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 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 strung across the body of water, 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 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 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 Possum Kingdom Lake 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 point, stamped TWDB #13 was chosen due to the close proximity to the reservoir, the unobstructed view of the reservoir, and the security of the area.

A static survey using two Trimble 4000SE GPS receivers was performed to obtain coordinates for TWDB #13 on June 6, 1994. Prior to the field survey, staff researched locations of known first-order benchmarks and requested Brazos River Authority employees to physically locate the associated monuments prior to arrival. The monument chosen to provide horizontal control was a United States Geological Survey first-order monument named CADD0 located approximately 1 mile northwest of Caddo, Tx. The coordinates for the monument are published as Latitude  $32^{\circ} 43' 32.18423''$ N and Longitude  $98^{\circ} 41' 11.24644''$ W. Staff positioned a GPS receiver over this monument and positioned a second receiver over the TWDB #13 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 #13.

Once data collection ended, staff process the data on the boat's computer. 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 #13 were determined to be North latitude  $32^{\circ} 52' 51.83176''$ , West longitude  $98^{\circ} 28' 42.09806''$ , and ellipsoid height of 382.9254 meters. The approximate NGVD '29 elevation is 1,352.41 feet. These coordinates were entered into the shore station receiver located over TWDB #13 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 six USGS quad sheets. The names of the quad sheets are as follows: Fortune Bend, Texas, (Provisional Edition) 1984; Costello Island, Tx., (Provisional) 1984; Cove Creek, Tx., 1967 (Photorevised 1981); Brad, Tx., 1967 (Photoinspected 1979); Ross Mountain, Tx., 1967 (Photorevised 1981) and Graham, Tx. (Photorevised 1981). AutoCad software was used to digitize the 1,000.0 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 to represent the area surveyed and to insure that all data points gathered were within the boundary. The resulting acreage at the normal pool elevation was thereby estimated to be 17,624 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 700 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 167,480 data points.

TWDB staff verified the horizontal accuracy of the DGPS used in the Possum Kingdom Lake 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  $0^{\circ}$ , to acquire information on the rising satellites. A horizontal mask of  $10^{\circ}$  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 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 ranged from 998.97 to 999.29 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 determined to be insignificant on Possum Kingdom Lake. 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 resulting three-dimensional triangular plane surface representation, .

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 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 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 ten foot intervals are presented in Figure 6.

## DATA

Staff of the TWDB collected hydrographic data on Possum Kingdom Lake during the period June 8-21, 1994. The survey crew noticed major relief along the perimeter of the lake between Morris Sheppard Dam and Sandy Beach. Deep channel cuts were observed on the depth charts with tall limestone cliffs bordering the water's edge. From Costello Island downstream to the dam, the lake was characterized by numerous coves and tributaries. The topography upstream of Costello Island represented more of a gentle sloping floodplain. The widest point of the lake

was located in this area. Some of the range lines driven by the survey crew were over 10,000 feet long. The survey crew isolated areas of silt and vegetation developing between Costello Island and Sandy Island. A major sediment deposit was at Carter Bend near the confluence of Rock Creek. Several other islands or silt deposits have developed or have expanded in size. As the survey crew collected data upstream of Waco Bend, the deeper water channel narrowed and the crew had to resort to collecting random data in a zig-zagging manner instead of parallel range lines. Over 250 miles of parallel range lines were driven in the nine days it took to collect the field data.

Results of this survey indicate that Possum Kingdom Lake now encompasses around 17,624 surface acres and contains a volume of 556,220 acre-feet at the normal pool elevation of 1,000.0 feet. The lowest elevation encountered during the field survey was 894.09 feet, or 106 feet of depth and was found about 300 feet from the dam, and about 275 feet from the north shoreline. The computed 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 maps in the deep water depth areas. 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 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 2.5 percent less than the 1974 previous record information for the lake. The original low flow outlet at elevation 874.8 feet has silted in and has been closed. The low flow outlet invert elevation is now considered to be at elevation 911.5 feet. The dead storage at this elevation is calculated to be 4,402 acre-feet. Therefore, the conservation storage capacity is calculated to be 551,818 acre-feet.

## SUMMARY

Previously, a sedimentation survey performed in 1974 by URS\Forrest and Cotton Inc. found that Possum Kingdom Lake had lost  <sup>$724,739 - 570,243 = 154,496$</sup>  154,496 acre-feet, or 21.0 percent of its capacity due to sedimentation in the 33 years that had passed since completion of the reservoir. This equates to an estimated loss of 4,681.7 acre-feet per year during the 33 year period.

In June 1994, a second survey was performed by the Texas Water Development Board's Hydrographic Survey Program. The purpose of the survey was to determine the current storage volume of Possum Kingdom Lake 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 1,000.0 feet was 556,220 acre-feet. The conservation storage capacity was calculated to be 551,818 acre-feet.  <sup>$570,243 - 556,220 = 14,023$</sup>  The estimated reduction in storage capacity, compared to the 1974 survey information, was 14,023 acre-feet, or 2.5 percent. This equates to an estimated loss of 701.15 acre-feet per year during the last 20 years. There could be many different factors as to why the current sedimentation rate is different than the rate reported by the previous survey. Repeating the 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 current sedimentation rates and the storage loss due to sedimentation occurring in Possum Kingdom Lake.

## CALCULATION OF DEPTH SOUNDER ACCURACY

For the water column from 2 to 60 feet:  $V = 4799$  fps Assumed  $V_{10} = 4785$  fps

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Aug 29 1994

POSSUM KINGDOM LAKE JUNE 1994 SURVEY

ELEV. FEET	VOLUME IN ACRE-FEET									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
893										
894										
895								1	1	1
896	1	1	1	2	2	2	2	3	3	4
897	5	6	7	8	10	12	14	16	19	21
898	24	27	31	35	39	44	49	54	60	66
899	72	78	85	92	100	108	117	126	136	146
900	157	168	179	191	203	216	229	242	255	269
901	283	297	312	327	343	358	375	391	408	425
902	442	460	478	496	515	534	554	574	594	615
903	637	658	681	704	727	751	775	800	825	851
904	877	904	931	958	986	1014	1043	1072	1101	1131
905	1161	1191	1222	1253	1285	1318	1351	1386	1421	1457
906	1493	1530	1567	1605	1644	1683	1723	1763	1804	1845
907	1887	1929	1972	2016	2060	2105	2150	2196	2243	2290
908	2337	2386	2435	2485	2535	2587	2638	2691	2744	2797
909	2852	2906	2962	3018	3075	3132	3190	3249	3308	3368
910	3428	3489	3550	3612	3675	3738	3802	3866	3931	3997
911	4063	4130	4197	4265	4333	4402	4472	4542	4613	4684
912	4756	4829	4902	4975	5049	5123	5198	5274	5350	5427
913	5504	5582	5660	5739	5818	5898	5979	6060	6141	6223
914	6306	6389	6473	6557	6642	6727	6813	6899	6986	7074
915	7162	7250	7339	7429	7519	7609	7700	7791	7883	7975
916	8068	8162	8256	8350	8446	8542	8638	8736	8834	8932
917	9032	9131	9232	9333	9435	9538	9641	9744	9849	9953
918	10059	10164	10271	10378	10485	10593	10702	10812	10922	11032
919	11143	11254	11367	11479	11593	11706	11820	11935	12051	12167
920	12283	12400	12518	12636	12754	12873	12993	13114	13234	13356
921	13477	13600	13723	13846	13970	14094	14219	14345	14471	14598
922	14725	14853	14981	15110	15240	15370	15500	15631	15763	15895
923	16028	16162	16296	16430	16566	16701	16838	16975	17112	17250
924	17389	17528	17668	17808	17949	18091	18234	18377	18521	18665
925	18811	18957	19105	19254	19404	19556	19710	19866	20023	20181
926	20341	20501	20664	20827	20992	21157	21324	21492	21660	21830
927	22000	22172	22345	22519	22693	22869	23046	23224	23404	23584
928	23766	23948	24132	24317	24503	24689	24877	25066	25256	25446
929	25638	25831	26025	26219	26415	26612	26810	27008	27208	27409
930	27610	27812	28016	28220	28425	28631	28838	29046	29255	29466
931	29677	29889	30102	30317	30532	30748	30965	31183	31402	31622
932	31843	32065	32288	32512	32737	32963	33190	33419	33648	33879
933	34110	34342	34576	34810	35045	35281	35518	35756	35994	36234
934	36475	36717	36959	37203	37447	37692	37939	38186	38434	38683
935	38933	39184	39436	39689	39944	40199	40455	40712	40970	41229
936	41490	41751	42013	42277	42541	42807	43073	43340	43609	43878
937	44149	44421	44693	44967	45242	45518	45795	46074	46354	46635
938	46917	47201	47486	47772	48059	48347	48637	48928	49220	49514
939	49809	50105	50403	50702	51002	51304	51606	51910	52215	52522
940	52830	53139	53449	53761	54074	54388	54703	55019	55336	55655
941	55975	56296	56618	56941	57265	57591	57918	58246	58575	58906

## POSSUM KINGDOM LAKE JUNE 1994 SURVEY

ELEV. FEET	VOLUME IN ACRE-FEET									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
942	59238	59571	59905	60240	60577	60914	61253	61592	61933	62276
943	62619	62963	63309	63656	64004	64353	64703	65054	65407	65761
944	66115	66471	66828	67187	67546	67907	68268	68631	68996	69361
945	69728	70096	70465	70835	71207	71580	71954	72329	72706	73084
946	73463	73844	74226	74609	74993	75379	75766	76155	76544	76935
947	77328	77721	78116	78512	78909	79307	79707	80108	80510	80914
948	81318	81724	82131	82539	82949	83360	83772	84185	84600	85016
949	85433	85851	86271	86692	87114	87537	87962	88388	88815	89244
950	89673	90104	90537	90970	91405	91841	92278	92717	93157	93599
951	94041	94485	94931	95378	95826	96276	96727	97179	97633	98088
952	98544	99002	99461	99921	100380	100850	101310	101780	102240	102710
953	103180	103650	104120	104600	105070	105550	106030	106510	106990	107470
954	107950	108440	108920	109410	109900	110390	110880	111370	111860	112360
955	112860	113350	113850	114350	114850	115360	115860	116370	116880	117380
956	117890	118410	118920	119430	119950	120460	120980	121500	122020	122550
957	123070	123590	124120	124650	125180	125710	126240	126770	127310	127840
958	128380	128920	129460	130000	130550	131090	131640	132190	132730	133290
959	133840	134390	134950	135510	136060	136620	137180	137750	138310	138880
960	139440	140010	140580	141150	141730	142300	142880	143450	144030	144610
961	145190	145780	146360	146950	147530	148120	148710	149300	149890	150490
962	151080	151680	152280	152880	153490	154090	154690	155300	155910	156520
963	157130	157750	158360	158980	159600	160220	160840	161470	162090	162720
964	163350	163980	164610	165240	165880	166510	167150	167790	168430	169080
965	169720	170370	171010	171660	172320	172970	173620	174280	174940	175600
966	176260	176920	177590	178260	178930	179600	180270	180940	181620	182300
967	182980	183660	184340	185030	185710	186400	187090	187790	188480	189180
968	189880	190580	191280	191980	192690	193400	194100	194810	195530	196240
969	196960	197670	198390	199110	199840	200560	201290	202010	202740	203470
970	204210	204940	205680	206420	207160	207900	208650	209390	210140	210890
971	211640	212400	213160	213910	214670	215440	216200	216970	217740	218510
972	219280	220060	220830	221610	222400	223180	223970	224760	225550	226340
973	227130	227930	228730	229530	230330	231140	231950	232760	233570	234390
974	235200	236020	236850	237670	238500	239320	240160	240990	241830	242660
975	243510	244350	245190	246040	246890	247750	248600	249460	250320	251180
976	252040	252910	253780	254650	255520	256400	257280	258160	259050	259940
977	260830	261720	262610	263510	264410	265320	266220	267130	268040	268960
978	269870	270790	271710	272640	273570	274490	275430	276360	277300	278240
979	279190	280130	281080	282030	282990	283950	284910	285880	286850	287820
980	288800	289780	290760	291740	292730	293720	294720	295720	296720	297720
981	298730	299740	300750	301770	302780	303810	304830	305860	306890	307930
982	308970	310010	311060	312100	313160	314210	315270	316330	317390	318460
983	319530	320600	321680	322760	323840	324930	326020	327110	328210	329310
984	330410	331520	332620	333740	334850	335970	337090	338210	339340	340470
985	341600	342740	343880	345020	346170	347310	348460	349620	350780	351940
986	353100	354260	355430	356600	357770	358950	360130	361310	362500	363690
987	364880	366070	367270	368470	369670	370880	372090	373300	374520	375740
988	376960	378180	379410	380640	381880	383120	384360	385610	386850	388110
989	389370	390630	391890	393160	394430	395710	396990	398270	399560	400850
990	402150	403450	404750	406060	407370	408680	410000	411330	412650	413990
991	415320	416670	418010	419360	420720	422080	423450	424830	426210	427590

## POSSUM KINGDOM LAKE JUNE 1994 SURVEY

ELEV. FEET	VOLUME IN ACRE-FEET									ELEVATION INCREMENT IS ONE TENTH FOOT										
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9										
992	428990	430380	431790	433190	434610	436030	437450	438880	440320	441770										
993	443220	444670	446140	447600	449080	450550	452040	453530	455020	456520										
994	458030	459540	461060	462580	464100	465640	467170	468710	470260	471810										
995	473370	474930	476500	478070	479640	481220	482810	484400	485990	487590										
996	489190	490800	492410	494030	495650	497270	498890	500530	502160	503790										
997	505430	507080	508720	510370	512030	513680	515340	517010	518680	520350										
998	522020	523700	525380	527060	528750	530440	532140	533840	535540	537240										
999	538950	540660	542380	544100	545820	547540	549270	551000	552740	554480										
1,000	556220																			

APPENDIX C - RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD  
RESERVOIR AREA TABLE

Aug 29 1994

POSSUM KINGDOM LAKE JUNE 1994 SURVEY

ELEV. FEET	AREA IN ACRES									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
893										
894										
895					1	1	1	1	1	1
896	2	2	2	2	2	3	4	5	6	8
897	9	11	12	15	17	19	21	23	25	28
898	30	33	38	41	44	48	51	55	58	61
899	64	66	70	75	79	84	88	94	100	105
900	109	113	117	120	123	126	129	132	136	139
901	143	146	150	153	156	159	162	166	169	172
902	175	179	182	186	189	193	197	203	208	212
903	217	221	226	230	235	240	245	250	255	260
904	264	268	273	276	280	284	287	291	295	299
905	303	307	312	317	323	330	339	348	355	361
906	366	372	377	383	388	394	399	405	411	416
907	422	427	433	438	444	450	457	462	468	473
908	480	487	495	503	509	515	521	527	533	539
909	545	552	559	565	571	577	583	588	594	599
910	605	612	617	623	628	634	640	647	653	659
911	665	671	676	682	688	694	700	705	711	716
912	721	726	731	736	742	748	753	759	764	770
913	775	780	786	791	796	801	807	813	818	824
914	830	835	840	845	850	856	861	867	872	878
915	883	887	892	896	901	906	910	915	920	926
916	932	938	944	950	957	963	970	977	983	989
917	995	1002	1009	1016	1022	1028	1034	1040	1045	1050
918	1055	1061	1066	1072	1079	1085	1091	1096	1101	1106
919	1112	1119	1125	1130	1135	1140	1145	1151	1156	1161
920	1167	1173	1178	1184	1189	1195	1200	1205	1210	1215
921	1220	1226	1231	1237	1242	1248	1253	1259	1264	1270
922	1276	1281	1286	1292	1297	1303	1309	1314	1320	1326
923	1332	1338	1343	1349	1355	1360	1366	1372	1377	1383
924	1389	1395	1402	1408	1415	1422	1429	1436	1443	1450
925	1459	1469	1482	1496	1513	1532	1547	1562	1576	1590
926	1603	1616	1627	1639	1651	1662	1672	1682	1691	1701
927	1712	1723	1732	1743	1753	1764	1775	1787	1799	1810
928	1821	1832	1843	1853	1863	1873	1883	1893	1903	1912
929	1922	1932	1943	1953	1963	1972	1982	1991	2001	2010
930	2019	2028	2037	2046	2056	2066	2076	2087	2097	2107
931	2118	2128	2137	2147	2157	2167	2176	2185	2194	2203
932	2213	2224	2235	2246	2257	2268	2278	2288	2298	2309
933	2319	2328	2337	2346	2355	2364	2374	2383	2393	2403
934	2412	2422	2431	2440	2449	2457	2466	2476	2485	2495
935	2506	2517	2527	2537	2547	2556	2567	2577	2587	2598
936	2608	2618	2629	2639	2649	2659	2669	2680	2690	2700
937	2711	2721	2732	2743	2755	2767	2780	2793	2805	2817
938	2829	2842	2854	2866	2879	2891	2904	2917	2930	2943
939	2957	2970	2982	2995	3008	3020	3033	3046	3059	3072
940	3085	3097	3110	3122	3134	3146	3157	3169	3180	3192
941	3203	3214	3226	3237	3249	3263	3276	3289	3300	3312

## RESERVOIR AREA TABLE

page 2

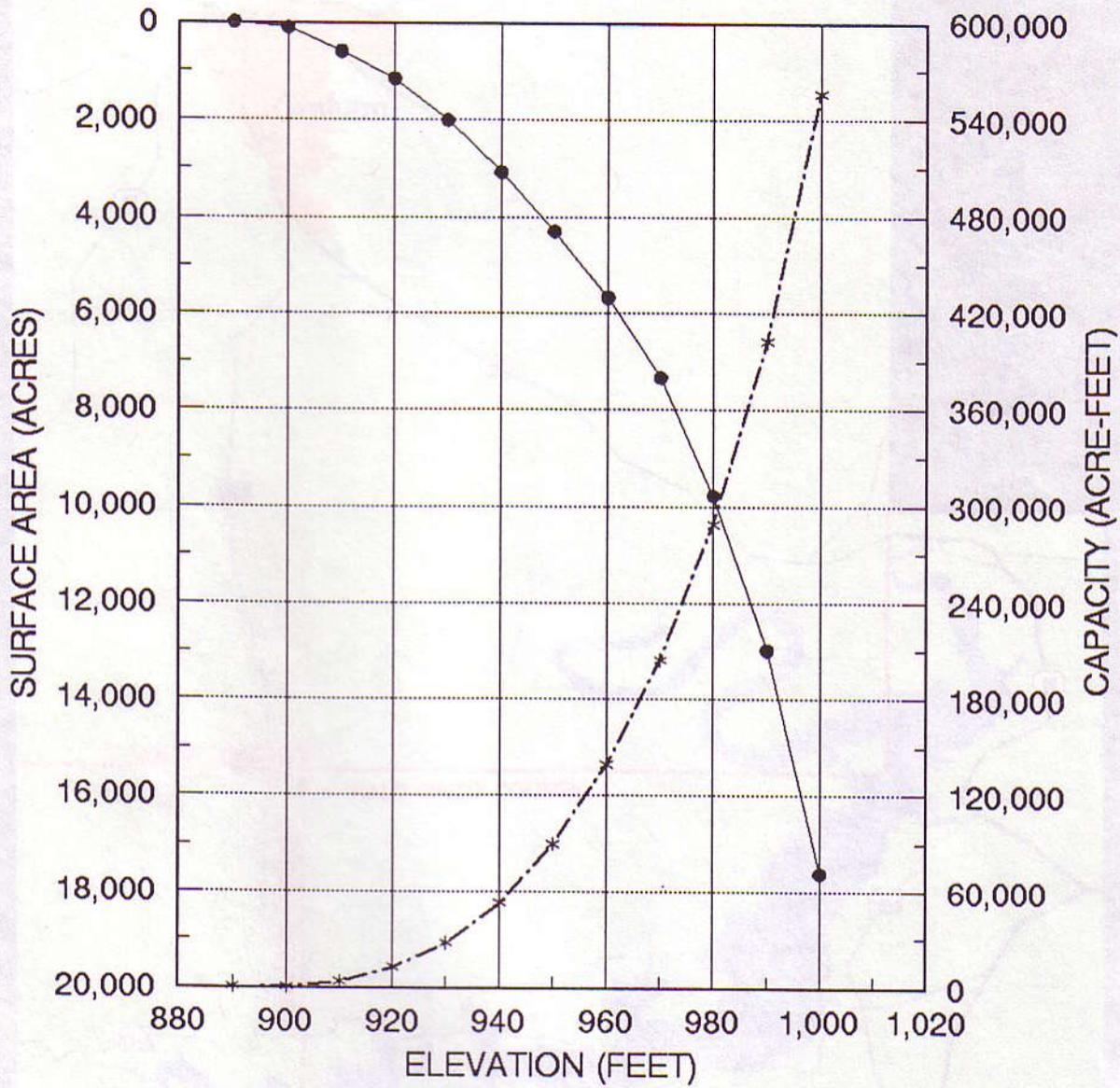
POSSUM KINGDOM LAKE JUNE 1994 SURVEY

ELEV. FEET	AREA IN ACRES									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
942	3324	3335	3347	3358	3369	3380	3392	3404	3416	3428
943	3439	3451	3462	3474	3485	3496	3508	3519	3530	3542
944	3554	3565	3577	3589	3600	3612	3624	3636	3649	3661
945	3674	3685	3697	3710	3722	3734	3747	3760	3773	3786
946	3799	3812	3825	3838	3852	3865	3878	3891	3904	3917
947	3929	3942	3954	3966	3978	3990	4002	4015	4028	4040
948	4053	4065	4078	4090	4102	4115	4127	4139	4152	4165
949	4178	4191	4203	4216	4228	4240	4253	4265	4278	4291
950	4303	4316	4329	4341	4354	4367	4381	4394	4407	4420
951	4434	4448	4462	4476	4490	4503	4517	4530	4543	4557
952	4570	4583	4596	4609	4622	4636	4649	4662	4676	4689
953	4703	4717	4732	4746	4760	4773	4787	4800	4813	4826
954	4839	4852	4864	4877	4890	4902	4915	4928	4942	4955
955	4969	4982	4997	5011	5025	5039	5053	5066	5080	5093
956	5107	5120	5134	5147	5160	5174	5188	5202	5215	5230
957	5243	5257	5270	5284	5298	5311	5325	5339	5353	5367
958	5382	5396	5413	5429	5443	5458	5473	5489	5503	5518
959	5533	5548	5562	5577	5592	5606	5621	5635	5650	5664
960	5678	5692	5707	5721	5735	5749	5763	5777	5791	5805
961	5819	5833	5847	5861	5875	5890	5905	5921	5937	5952
962	5968	5984	6000	6017	6033	6049	6065	6082	6099	6115
963	6132	6148	6164	6180	6196	6212	6228	6245	6261	6277
964	6293	6309	6325	6342	6358	6375	6391	6406	6422	6438
965	6454	6472	6489	6506	6524	6541	6558	6575	6592	6608
966	6626	6644	6661	6679	6698	6715	6733	6752	6770	6788
967	6807	6826	6845	6864	6883	6903	6921	6939	6957	6975
968	6992	7010	7027	7044	7062	7079	7096	7113	7130	7147
969	7164	7182	7200	7217	7235	7252	7270	7287	7305	7323
970	7341	7360	7379	7398	7418	7438	7457	7476	7495	7513
971	7532	7552	7572	7593	7614	7636	7659	7680	7701	7723
972	7744	7765	7787	7808	7830	7852	7874	7895	7915	7936
973	7958	7980	8003	8026	8048	8071	8093	8115	8138	8160
974	8183	8207	8231	8255	8279	8303	8326	8349	8373	8396
975	8420	8444	8466	8489	8513	8537	8560	8584	8608	8632
976	8656	8681	8705	8730	8756	8782	8809	8835	8862	8889
977	8915	8941	8968	8994	9020	9046	9072	9098	9125	9151
978	9177	9204	9230	9257	9284	9311	9338	9367	9395	9424
979	9453	9483	9513	9544	9577	9614	9648	9681	9712	9744
980	9776	9807	9837	9868	9899	9929	9959	9990	10020	10051
981	10081	10112	10144	10176	10209	10242	10275	10308	10340	10372
982	10405	10436	10468	10499	10530	10563	10594	10626	10658	10689
983	10720	10752	10784	10817	10849	10880	10912	10943	10974	11005
984	11036	11067	11100	11132	11163	11194	11225	11256	11287	11317
985	11347	11377	11406	11435	11464	11493	11522	11551	11580	11608
986	11637	11665	11694	11723	11752	11780	11809	11839	11868	11897
987	11927	11958	11988	12018	12048	12079	12110	12141	12172	12204
988	12235	12268	12300	12335	12371	12407	12444	12481	12517	12554
989	12591	12629	12668	12706	12743	12781	12820	12859	12897	12936
990	12975	13013	13052	13091	13130	13170	13212	13256	13301	13348
991	13396	13446	13495	13544	13597	13654	13712	13771	13833	13892

## POSSUM KINGDOM LAKE JUNE 1994 SURVEY

ELEV. FEET	AREA IN ACRES					ELEVATION INCREMENT IS ONE TENTH FOOT				
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
992	13947	14001	14057	14112	14168	14227	14288	14351	14413	14473
993	14531	14588	14645	14701	14757	14812	14867	14923	14978	15032
994	15085	15137	15189	15239	15290	15341	15391	15441	15491	15540
995	15588	15637	15685	15734	15782	15828	15873	15919	15965	16010
996	16052	16095	16134	16170	16205	16240	16275	16310	16345	16380
997	16415	16450	16484	16519	16554	16588	16623	16657	16692	16726
998	16760	16794	16829	16863	16897	16931	16965	16999	17032	17066
999	17100	17134	17167	17201	17234	17268	17301	17335	17368	17401
1,000	17624									

APPENDIX D - AREA-ELEVATION-CAPACITY GRAPH



SURFACE AREA    CAPACITY  
 —●—            -\*- -

**POSSUM KINGDOM LAKE**  
 JUNE 1994 SURVEY  
 Prepared by: TWDB August 1994

# FIGURE 1 POSSUM KINGDOM LAKE

Location Map

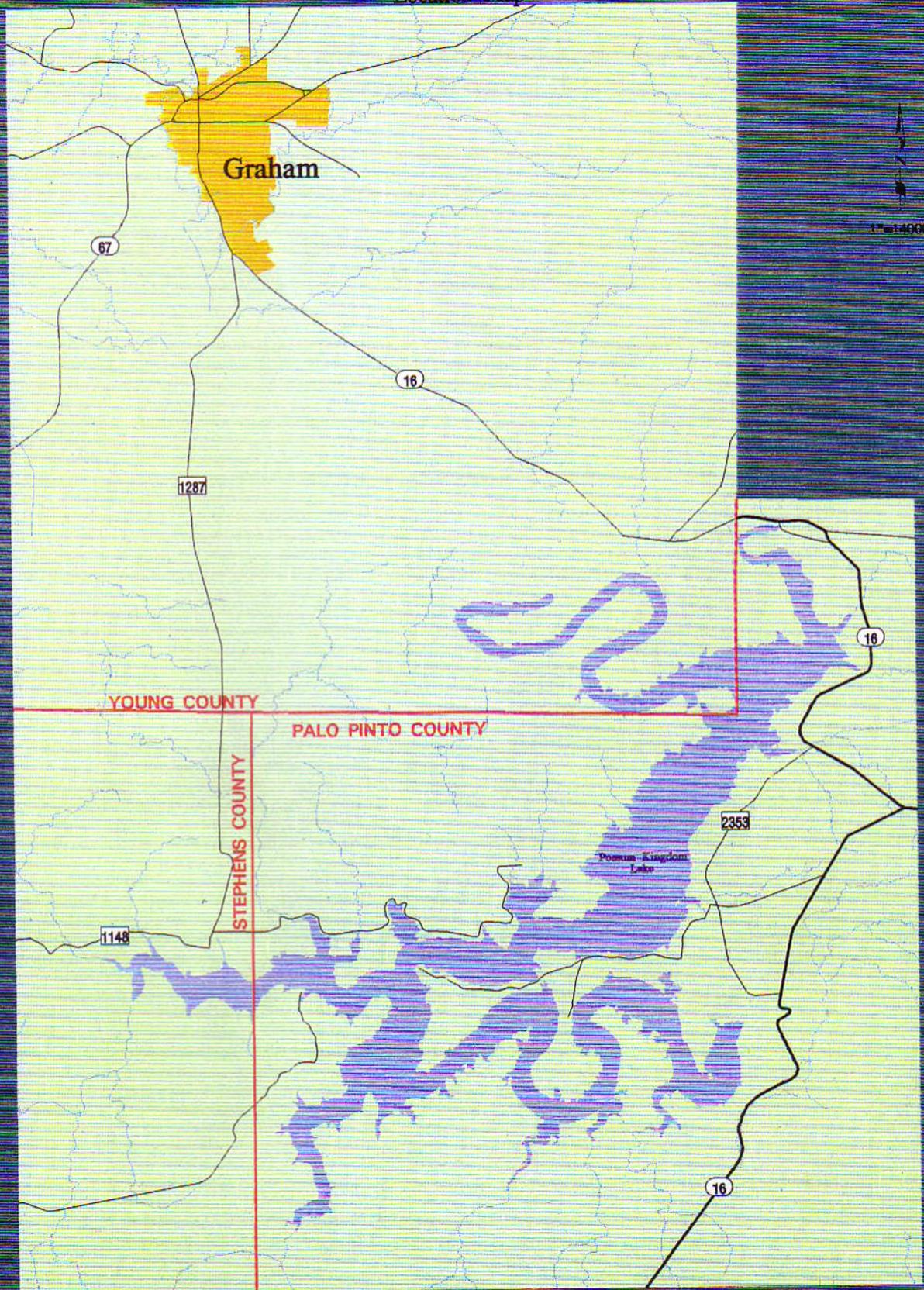
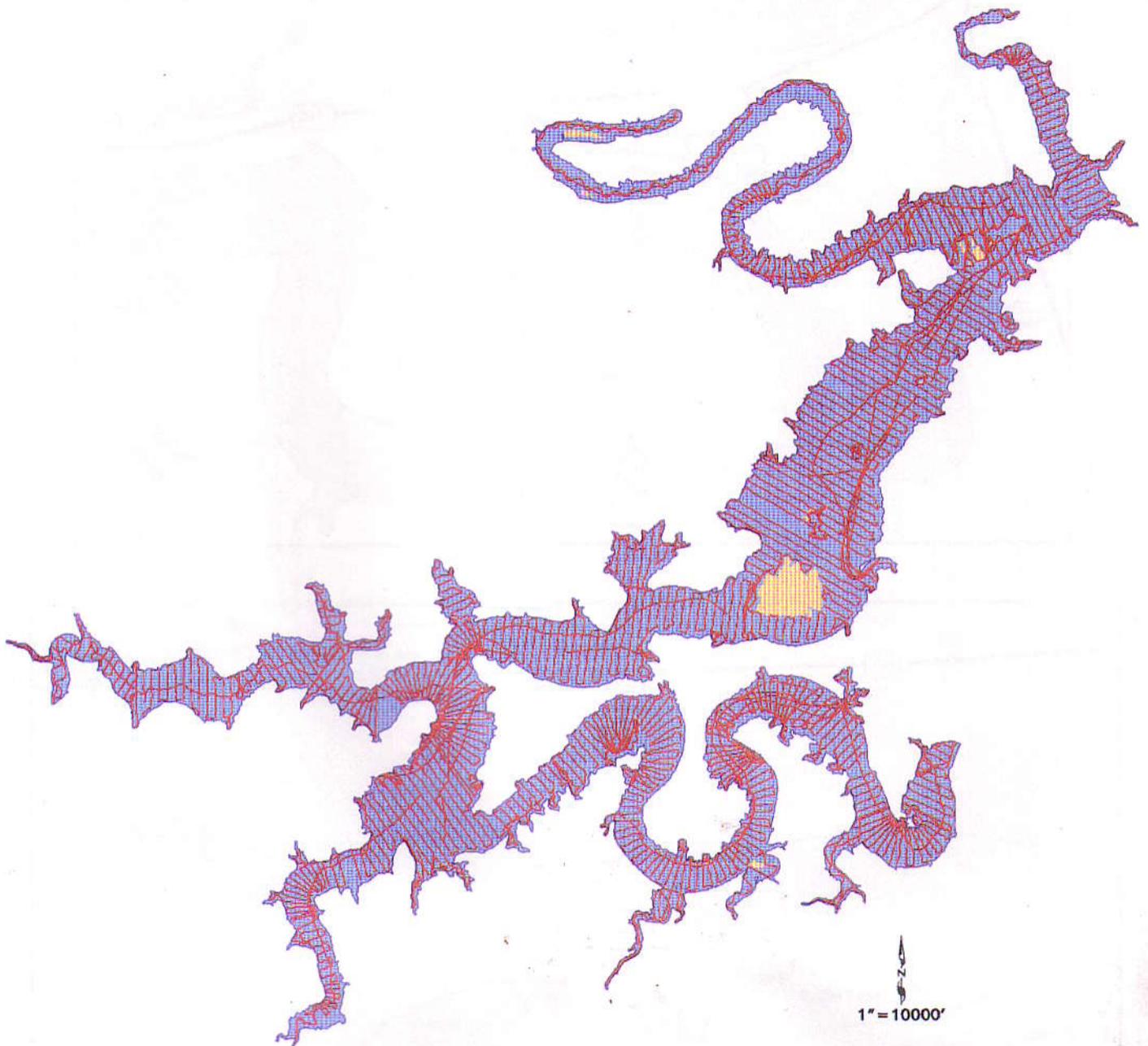


FIGURE 2

# POSSUM KINGDOM LAKE

Location of Survey Data



EXPLANATION	
	Lake Boundary
	Islands
	Data Points

PREPARED BY: TWDB AUGUST 1994

# FIGURE 3

## POSSUM KINGDOM LAKE

Location of control point # 013.

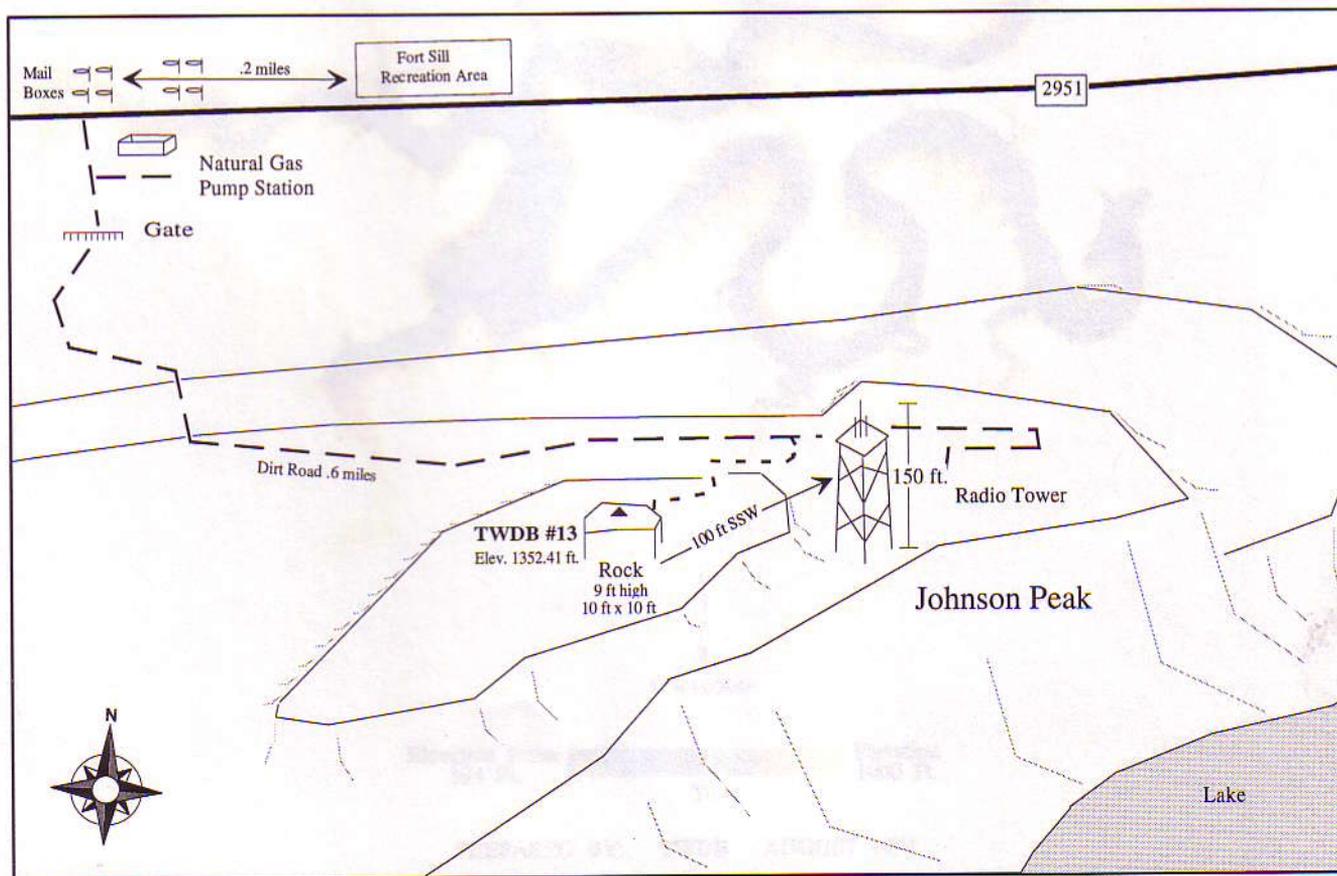
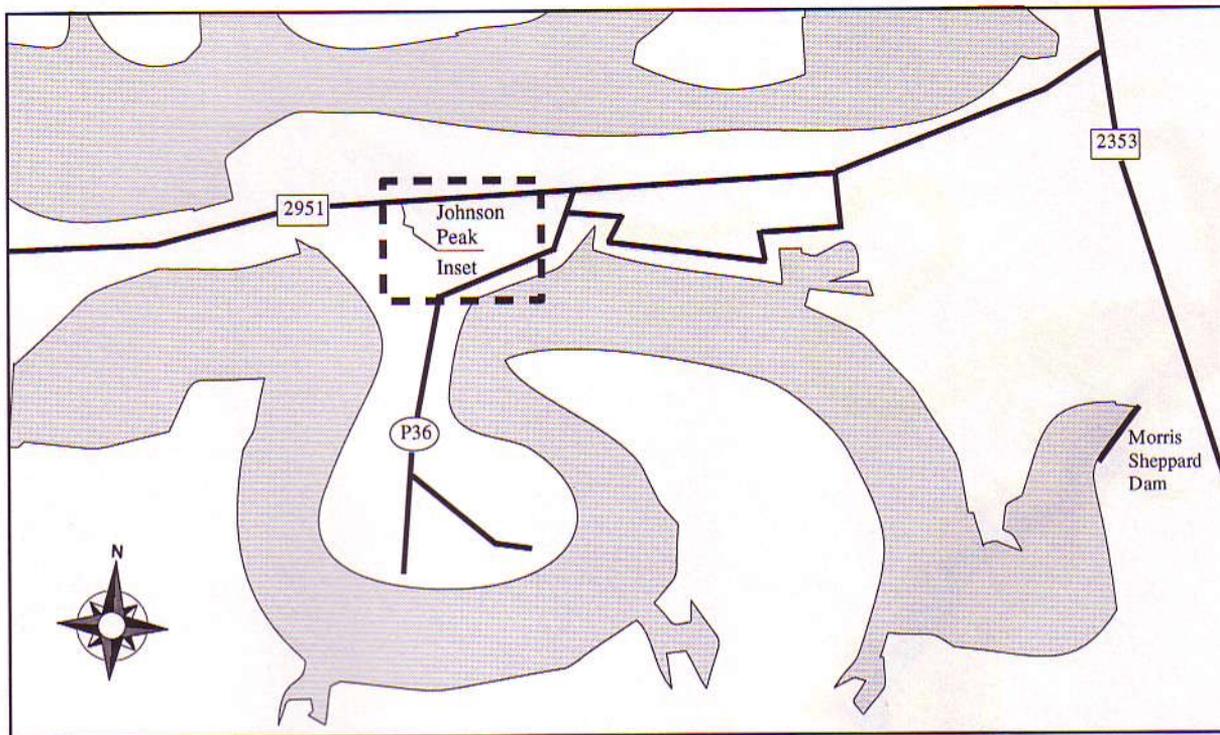
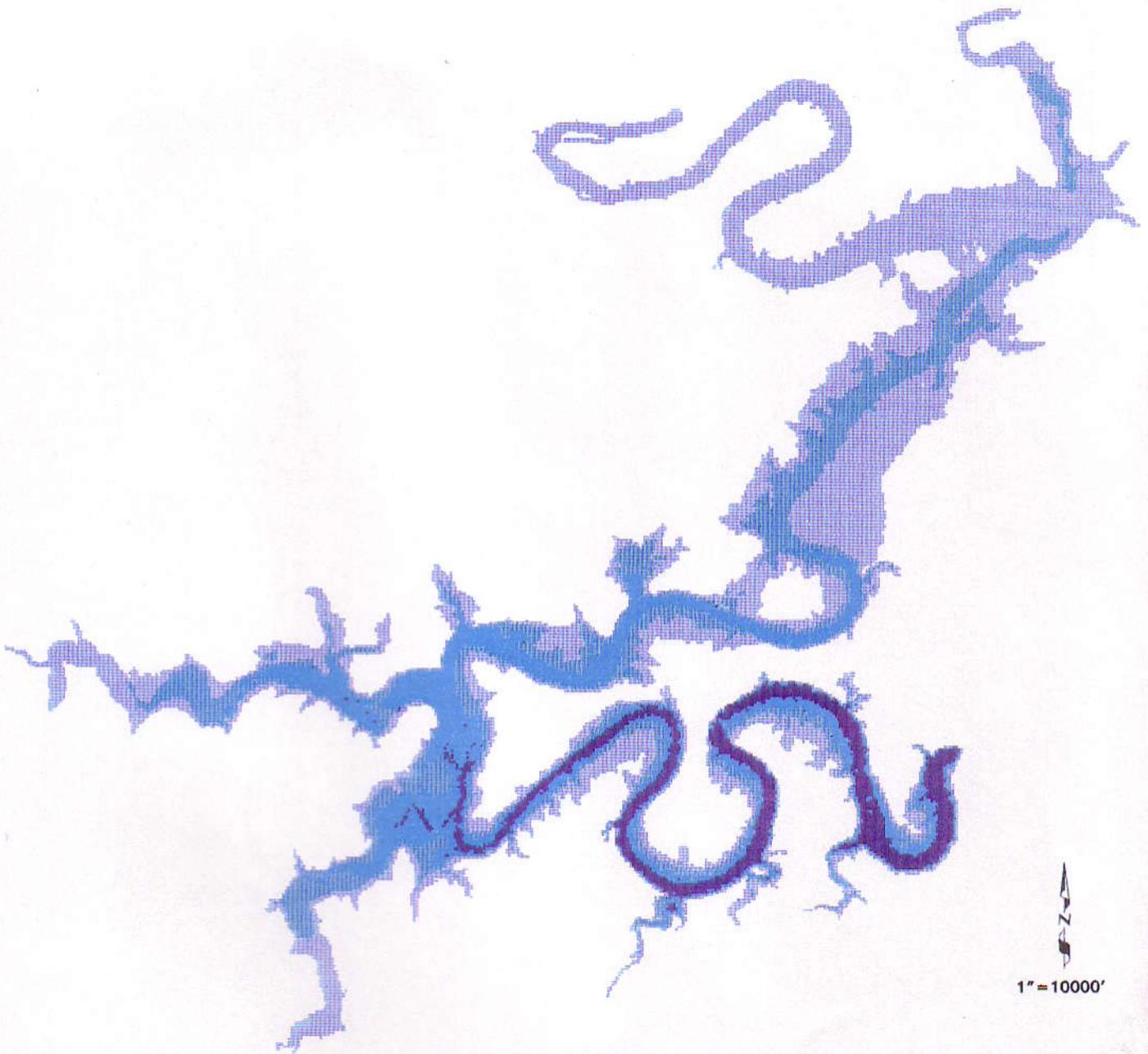




FIGURE 5

# POSSUM KINGDOM LAKE

Depth Ranges



EXPLANATION	
	0 - 30'
	30 - 55'
	55 - 80'
	80 - 105'