# VOLUMETRIC SURVEY OF WHITE RIVER LAKE

**Prepared for:**

**White River**
**Municipal Water Authority**

**Prepared by:**

**The Texas Water Development Board**

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# Texas Water Development Board

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## INTRODUCTION

Staff of the Hydrologic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey on White River Lake in October, 1992. Additional data were collected in the upper reaches of the lake in March, 1993. 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.

## HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

White River Lake, owned by White River Municipal Water Authority, is located in Crosby County approximately 16 miles southeast of Crosbyton, Texas (See Figure 1). White River Dam is located on the White River, a tributary of the Salt Fork of the Brazos River. Dam construction was completed in 1963, and White River Lake began impounding water in October of that year.

Application No. 2101 was filed with the State of Texas Board of Water Engineers on September 22, 1958 by White River Municipal Water District to appropriate 7,000 acre-feet of water annually by impounding 33,160 acre-feet of water. Allocation of the 7,000 acre-feet was as follows: 4,000 acre-feet municipal use for the cities of Post, Spur, Ralls, and Crosbyton; 1,000 acre-feet for industrial use; and 2,000 acre-feet for mining use. Permit No. 1920 was granted on November 3, 1958.

On November 21, 1960, Application No. 2175 was submitted to amend Permit No. 1920 to authorize a new dam site approximately 3,500 feet downstream of the original location, to increase the impounding capacity from 33,160 acre-feet to 38,232 acre-feet, to approve the location of the diversion point, and to authorize a change in date of commencement and completion of work. Permit No. 1920-A was granted on December 28, 1960. There was no change in the water use allocation. Upon completion of construction, the capacity of the lake was calculated to be 38,650 acre-feet. Of this total, 650 acre-feet was dead storage, which resulted in 38,000 acre-feet of conservation storage. The surface area at capacity was calculated to be 1,808 acres at elevation 2,369.0 feet above mean sea level, based on the National Geodetic Vertical Datum of 1929 (NGVD '29). All elevations presented in this report are reported in NGVD '29 unless noted otherwise.

Application No. 2101-B was filed on May 28, 1971 to amend Permit No. 1920, as amended, to raise the service spillway an additional three and one-half feet to an elevation of 2,372.5 feet. This increased the authorized impounding capacity by 6,665 acre-feet for a total capacity of 44,897 acre-feet.

Certificate of Adjudication No. 12-3693 was issued on February 20, 1985 and authorized the impoundment not to exceed 44,897 acre-feet of water. The owner was also authorized to divert the following: 4,000 acre-feet for municipal purposes and 2,000 acre-feet for mining purposes.

White River Dam was constructed as a rolled-earth structure approximately 3,300 feet long and 84 feet high. The elevation of the top of the dam is 2,395.0 feet. Record information indicates the conservation storage to be 44,300 acre-feet with a surface area of 2,020 acres at elevation 2372.2 feet. The service spillway is a concrete rectangular drop-inlet structure with an uncontrolled crest at elevation 2372.2 feet. The service outlet is a rectangular-shaped tower located to the north of the emergency spillway with an overflow elevation of 2,391.5 feet. Three gate-controlled openings are located in the tower at elevations 2,356.0 feet, 2,340.0 feet and 2,323.0 feet. A 48-inch pipe extends from the lowest inlet 80 feet out into the lake.

## HYDROGRAPHIC SURVEYING TECHNOLOGY

### 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 monitor the broadcasts from the satellites over time 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. Additional satellite readings would also produce a possible location on a sphere surrounding that satellite with a radius of the distance measured. The observation of two satellites from an unknown point 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 first put into use on February 22, 1978, when the first satellite was launched. The NAVSTAR (NAVigation System with Time And Ranging) satellite constellation will consist of 24 satellites when fully implemented. At the time of the survey, 21 satellites of the constellation were fully functional. The United States Department of Defense (DOD) is 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 (1 to 3 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 White River 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. Positional accuracies can be produced within 3 meters for the moving receiver. DGPS was used to determine horizontal position only. Vertical information was supplied by the depth sounder.

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 other methods previously used to determine lake volumes.

TWDB staff verified the horizontal accuracy of the DGPS used in the White River survey to within the specified accuracy of three meters. 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 was set up over another known USGS first order monument. Based on the differentially-corrected coordinates received and the published coordinates for these points, the results compared within 2.8 meters.

## Equipment

The equipment used in the hydrographic survey of White River 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 Depth Sounder and 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 is supported by a dot matrix printer and a B-size plotter. Power is provided by a water-cooled generator through an in-line uninterruptible power supply. References 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 30 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.

## Survey Methods

A shore station site was selected at the southwest corner of the lake on a concrete pad near the inlet pumps. This location was chosen because of its close proximity to the lake, the unobstructed view of the lake, and security of the fenced-in area. A brass cap marked TWDB #003 was embedded into the southeast corner of the pad to serve as a benchmark for the survey.

A static survey using the two Trimble 4000SE GPS receivers was performed to obtain coordinates for TWDB #003. One GPS receiver was positioned over a USGS first-order monument named MUD, located approximately five miles east of the lake. MUD was established in 1964 by the U. S. Coast & Geodetic Service. Satellite data were gathered from this station for almost two hours, with up to seven satellites visible to the receiver. During the same time period, data were gathered from the second receiver positioned over TWDB #003.

Once data collection ended, the data were retrieved from the two receivers using Trimble Trimvec software, and processed to determine coordinates for the shore station benchmark. The NAVSTAR satellites use the World Geodetic System (WGS '84) datum. The WGS' 84 coordinates for TWDB #003 were determined to be North latitude 33°27'26.73477", West longitude 101°05'25.05898", and ellipsoid height of 701.625 meters. The approximate NGVD '29 elevation is 2394.6 feet. Those coordinates were then entered into the shore station receiver located over TWDB #003 to fix its location and allow calculation and broadcasting of corrections through the radio and modem to the roving receiver located on the boat.

The reservoir's surface area was determined by digitizing the lake boundary from 1962 USGS quad sheets that were photo-revised in 1981. Intergraph Microstation CADD software was used to digitize the boundary in the North American Datum of 1927 (NAD '27) used for this map. The boundary was then transformed to the North American Datum of 1983 (NAD '83) using Microstation Projection Manager. NAD '83, a flat projected representation of the curved earth surface, was chosen to calculate areas and volumes. The data points obtained by DGPS were also transformed from WGS '84 to NAD '83.

The survey layout was pre-planned, using approximately 40 survey lines at a spacing of 500 feet. Figure 2 presents 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 33,000 data points. Depths were transformed to elevations based on a water surface elevation of 2369.7 feet for the October survey, and 2369.0 for the March survey. The data points were used to create a digital terrain model (DTM) of the lake's bottom surface using Microstation Terrain Modeler, also a product of the Intergraph Corporation. The product uses Delauney's criteria for triangulation to produce a DTM, or a numerical representation of the actual bottom surface. From this dry lake bottom representation, the Modeler product calculates the surface area and volume of the entire lake at the specified elevations. Figure 3 is a graphical representation of a grided version of the three-dimensional DTM. Areas that were too shallow for data collection or obstructed by vegetation were estimated by the Modeler product, using a straight-line interpolation. The difference between the estimated volumes and the actual volume is believed to be minor because the shallow areas do not contain significant amounts of water. Figure 4 presents a two-dimensional version of the same map, using bands of color increasing in intensity from shallow to deep water.

The DTM was then smoothed and linear smoothing algorithms were applied to the smoothed model to produce smooth contours. The following smoothing options were chosen for this model: Douglas-Peucker option with a tolerance of 0 feet, to eliminate redundant points, and Round Corners with a delta of 50 feet. Figure 5 presents a contour map and typical cross sections of the lake.

## DATA

White River Lake is a wishbone-shaped lake approximately sixteen thousand (16,000) feet in length. The deepest portions of the lake are found within the area immediately adjacent to the dam. The cross sections reflect relatively flat bottoms with fairly steep side slopes throughout the lake (Figure 5). Substantial aquatic vegetation was encountered in the shallow, upper reaches of the lake. The vegetation caused difficulty in obtaining a good reading of the bottom with the depth sounder during the October trip. During the return trip in March, more data were gathered with the depth sounder where the vegetation had died back. Additional data 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.

White River Lake was estimated by this survey to encompass 1642 acres and to contain a volume of 31,846 acre-feet at the normal pool elevation of 2,372.2 feet. The reservoir volume table is presented in Appendix A, and the area table in Appendix B. An elevation-area-volume graph is presented in Appendix C. Since the surface elevation of the lake on the survey dates ranged from 2369.0 to 2369.7 feet, lake volumes above that elevation are estimated, based on a straight-line interpolation from the last data points collected to the normal pool elevation lake boundary as digitized. The positional data collected in the field corresponds with the boundary obtained from the photo-revised USGS map. The Board does not represent the boundary, as depicted in this report, to be a detailed actual boundary. It is an approximation of the actual boundary used to compute the volume and area within the upper elevations.

The storage volume calculated by this survey is approximately twenty-nine percent less than the previous record information for the lake. The estimated surface area at normal pool elevation is almost nineteen percent less than the previous record information of 2020 acres. The original intention behind Permit 2101-B was to raise the lake level by five feet. The permit was approved for three and one-half feet. It is possible that the area figure was not corrected for the as-built elevation. The difference may also be a result of the improved methodology over the years used to calculate the volumes and surface areas. In addition, poor topographic maps at the time the record information was determined may have resulted in an over-estimate of the actual lake volume and surface area.

## SUMMARY

When the lake was constructed in 1963, the elevation of the river bed was recorded as 2,317 feet. The lowest elevation encountered during this survey was 2,324.6 feet, or 47.6 feet of depth. Therefore, sediment appears to have entirely filled the lower 7.6 feet of the lake. The estimated reduction in storage capacity is 13,141 acre-feet, or twenty-nine percent less than that previously conceived on the permit. It is assumed that the reduction in estimated storage is due to both a combination of siltation, 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.

The useable amount of water available to the Water Authority is dependent on the current lowest usable intake. Water authority staff verified that the lowest intake is not currently in use and has been boarded up due to problems with siltation. Therefore, the lowest usable intake is at elevation 2340.0 feet, and dead storage space below this outlet is estimated at 1,966 acre-feet. The resulting effective conservation storage volume for White River Lake is therefore estimated to be 29,880 acre-feet.

FIGURE 1

# WHITE RIVER LAKE

LOCATION MAP

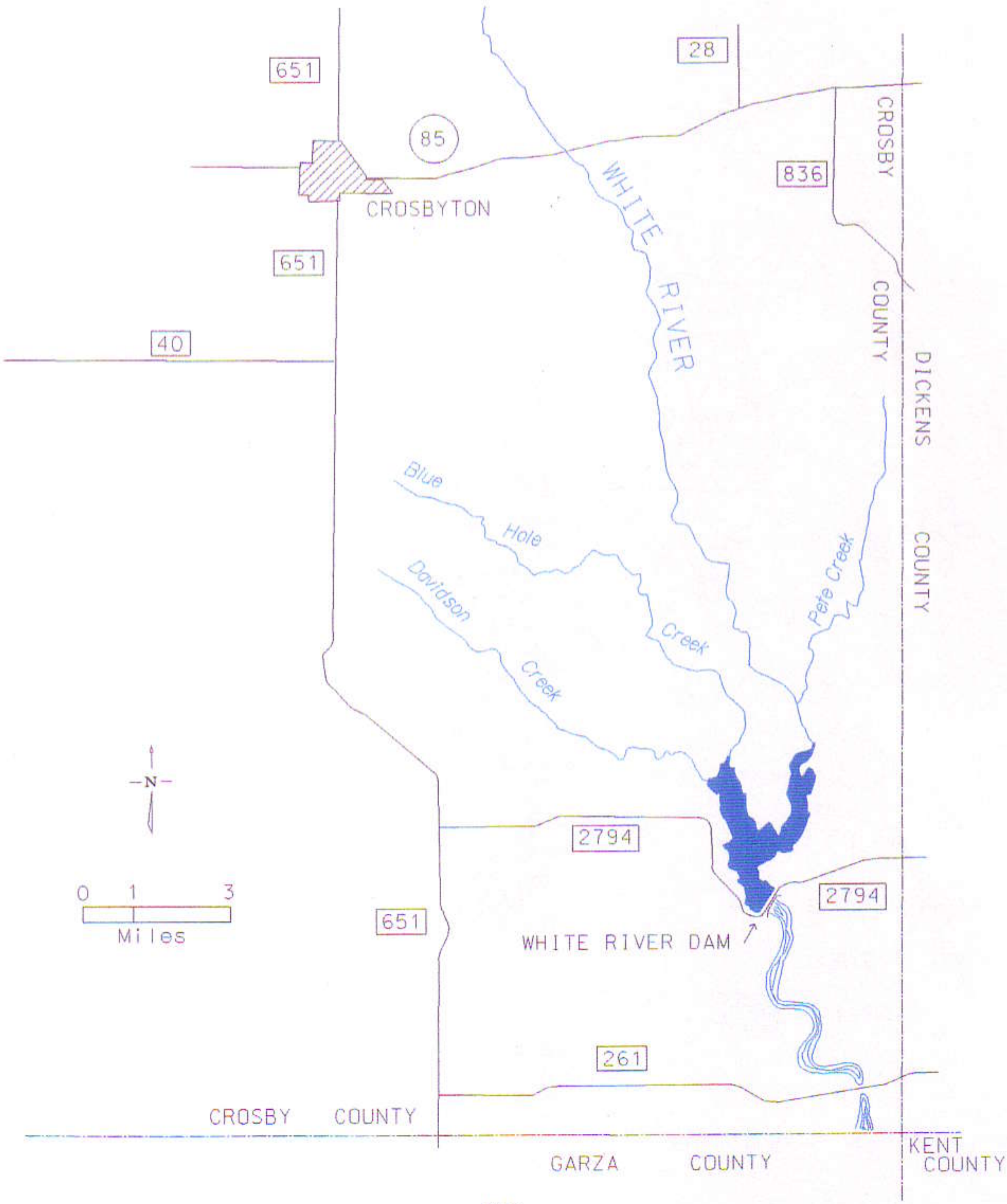

FIGURE 2

# WHITE RIVER LAKE

LOCATION OF SURVEY DATA

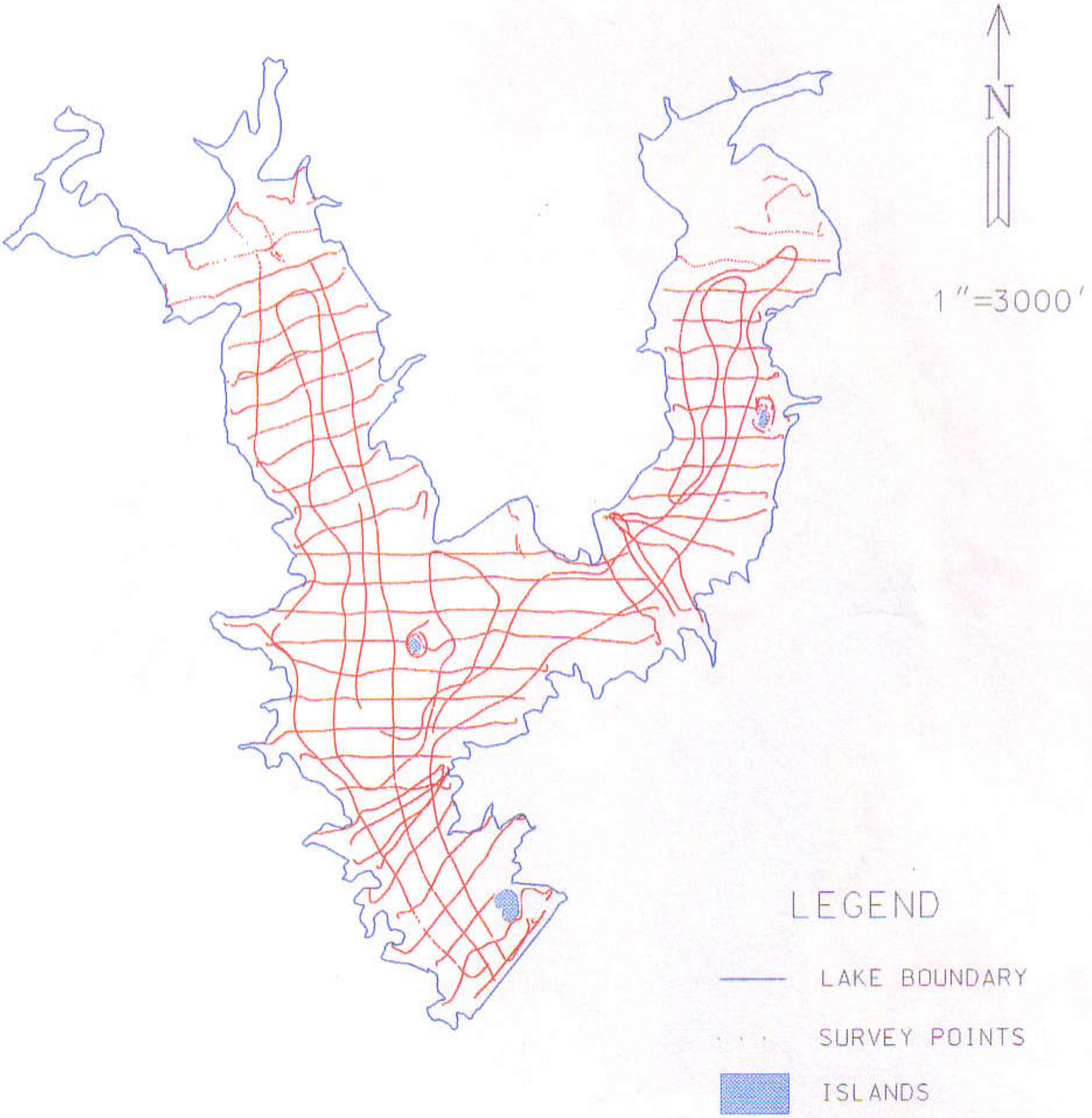


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FIGURE 3

# WHITE RIVER LAKE

3-DIMENSIONAL BOTTOM SURFACE

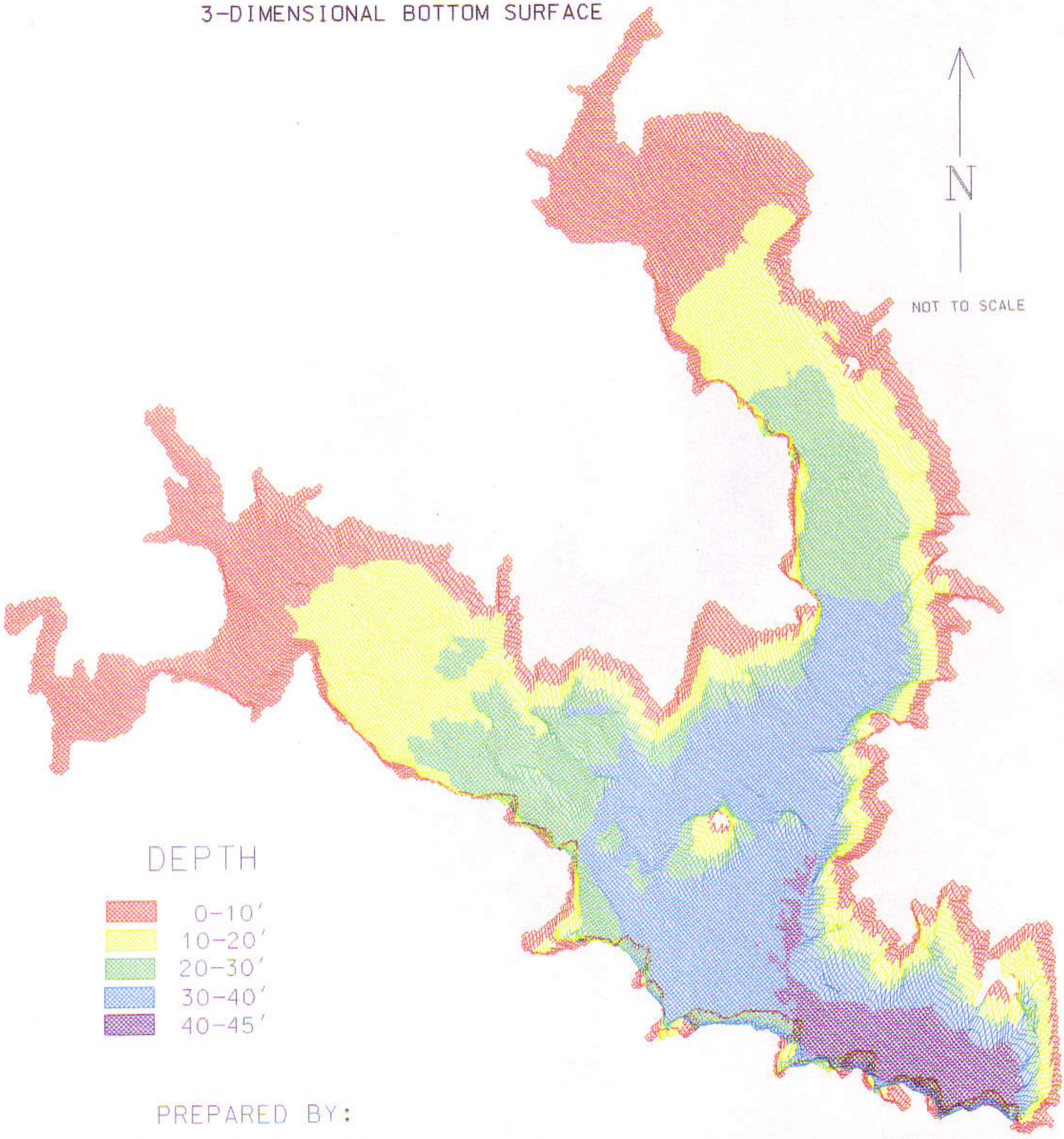


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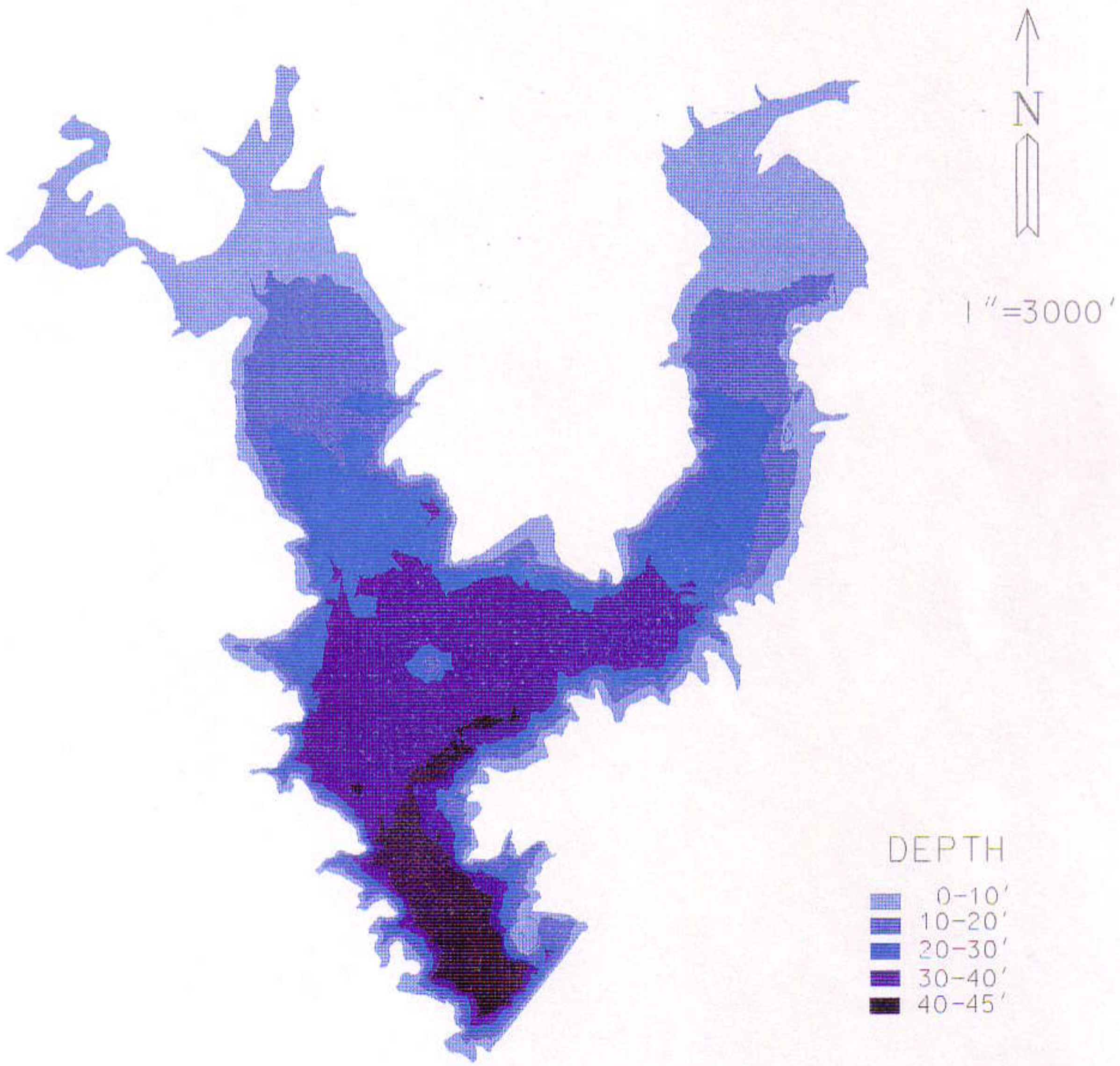
FIGURE 4

# WHITE RIVER LAKE

DEPTH RANGES

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