VOLUMETRIC SURVEY
OF
MILLER'S CREEK RESERVOIR

Prepared for:

NORTH CENTRAL TEXAS
MUNICIPAL WATER AUTHORITY

Prepared by:

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TABLE OF CONTENTS

INTRODUCTION 1

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR 1

HYDROGRAPHIC SURVEYING TECHNOLOGY 2
GPS Information 2
Equipment 4
Survey Methods 5

DATA 7

SUMMARY 8

LIST OF FIGURES

FIGURE 1 - LOCATION MAP 9
FIGURE 2 - LOCATION OF SURVEY DATA 10
FIGURE 3 - 3-D BOTTOM SURFACE 11
FIGURE 4 - DEPTH RANGES 12
FIGURE 5 - 2-D CONTOUR MAP 13

LIST OF APPENDICES

APPENDIX A - RESERVOIR VOLUME TABLE A-1
APPENDIX B - RESERVOIR AREA TABLE B-1
APPENDIX C - AREA-ELEVATION-CAPACITY TABLE C-1

MILLER'S CREEK RESERVOIR
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrologic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Millers Creek Reservoir 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

Millers Creek Reservoir, owned by North Central Texas Municipal Water Authority and the Texas Water Development Board, is located in Baylor and Throckmorton counties approximately 13 miles east southeast of Munday, Texas (See Figure 1). Millers Creek Dam is located on Millers Creek, a tributary of the Brazos River. Dam construction was completed in 1974. It was not until late 1978 that the North Central Texas Municipal Water Authority was able to supply its users with water. Due to heavy rains in the watershed, the reservoir filled within 24 hours on August 4, 1978.

Application No. 2910 was filed with the Board of Water Engineers on April 13, 1961 by North Central Texas Municipal Water Authority to appropriate 6,050 acre-feet of water annually by impounding 25,520 acre-feet of water. The following maximum allocations were established: 3,500 acre-feet for municipal use; 1,000 acre-feet for industrial use; and 500 acre-feet for mining purposes. Permit No. 1995 was granted October 3, 1961.

An amendment to Permit No. 1995 was issued by the Texas Water Commission on April 6, 1983, authorizing the owners to increase the capacity of the reservoir from 25,520 acre-feet to 30,696 acre-feet of water. This was achieved by raising the service spillway crest three feet to an elevation to 1334.0 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.

Certificate of Adjudication No. 3444 was issued on February 20, 1985 and authorized the impoundment of not to exceed 30,696 acre-feet of water. The owners were also authorized to divert the following: 3,500 acre-feet for municipal purposes, 1,000 acre-feet for industrial purposes and 500 acre-feet for mining purposes.

Millers Creek Dam was constructed as an earthfill structure approximately 9,250 feet in length and 75 feet high, with an upper elevation of 1,355.0 feet. Record information indicates the conservation storage to be 30,696 acre-feet with a surface area of 2,350 acres at elevation 1334.0 feet. The service spillway is a concrete rectangular-shaped drop-inlet structure with an uncontrolled crest at elevation 1334.54 feet. The low-flow outlet is an 18 inch diameter concrete encased pipe at elevation 1,305.0 feet. The emergency spillway, located at the west end of the dam, is an uncontrolled earthen channel with a 3,000 foot crest length at elevation 1,340.0 feet.

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 Miller's Creek Reservoir. 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 Miller's Creek 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 Miller's Creek Reservoir 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

The Hydrographic Survey crew set a benchmark in November of 1992 that would serve as control for the shore station site. A brass cap marked TWDB #002 was embedded into the curb and gutter of the water treatment plant driveway approximately seventy feet southeast of the concrete storage tank. This location was chosen because of its close proximity to the lake, the unobstructed view of the lake, and security of the area.

A static survey using the two Trimble 4000SE GPS receivers was performed to obtain coordinates for TWDB #002. One GPS receiver was positioned over a USGS first-order monument named COUNTY, located approximately twenty miles west of the lake. COUNTY was established in 1974. Satellite data were gathered from this station for approximately an hour and a half, with up to seven satellites visible to the receiver. During the same time period, data were gathered from the second receiver positioned over TWDB #002.

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 #002 were determined to be North latitude 33° 24' 46.65", West longitude 99° 24' 05.12", and ellipsoid height of 383.6567 meters. The approximate NGVD '29 elevation is 1353.2 feet. Those coordinates were then entered into the shore station receiver located over TWDB #002 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 revised in 1981 from 1979 aerial photographs. Intergraph Microstation CADD software was used to determine the boundary based on the North American Datum of 1927 (NAD '27) used for this map. The original boundary prior to the 1983 permit revision (elevation 1,331.0 feet) was digitized along with the 1,340.0 contour. The information 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. Once in NAD '83, the Microstation Terrain Modeler product was used to determine the boundary at elevation 1334.54 feet. The resulting shape was modified slightly to match information gathered in the field, resulting in 2,268 acres at the normal pool elevation.

The survey layout was pre-planned, using approximately fifty survey lines at a spacing of 500 feet. Additional random data were collected lengthwise along the lake. 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. 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 17,000 data points.

Depths were transformed to elevations based on a water surface elevation of 1333.3 feet. The data points were used to create a digital terrain model (DTM) of the lake's bottom surface using the Terrain Modeler product. 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 volume 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

Miller's Creek Reservoir is a finger-shaped lake approximately twenty-two thousand (22,000) feet, or just over four miles in length. The deepest portions of the lake are found within the area immediately adjacent to the dam. The cross sections reflect a fairly well defined channel with relatively steep side slopes throughout the lake.

Miller's Creek Reservoir was estimated by this survey to encompass 2268 acres and to contain a volume of 29,171 acre-feet at the normal pool elevation of 1334.54 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 was approximately 1.25 feet low on date of the survey, and the boat can only negotiate in approximately 1.8 feet of water, the upper three feet 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 five percent less than the previous record information for the lake. The estimated surface area at normal pool elevation is within three and one-half percent of the recorded 2,350 acres. The low flow outlet is at elevation 1,305 feet, resulting in dead storage of 1,283 acre-feet. Therefore the conservation storage for the reservoir is calculated to be 27,888 acre-feet.

SUMMARY

The lowest elevation encountered during this survey was 1290.3 feet, or 44.2 feet of depth. The conservation storage was calculated to be 27,888 acre-feet. The estimated reduction in storage capacity is 1,525 acre-feet, or five percent less than that recorded in 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 lowest intake, which is at elevation 1,290.3 feet. Since that is also the lowest elevation encountered in this survey, theoretically there is no dead storage. Should the reservoir experience any significant siltation, it is possible that this inlet could become unusable. The resulting available storage at the next higher inlet, which is at elevation 1,313.0 feet, is 24,955 acre-feet. It is recommended that the lowest inlet be exercised on a regular basis, to delay complete obstruction from siltation.

FIGURE 1

MILLER'S CREEK RESERVOIR

LOCATION MAP

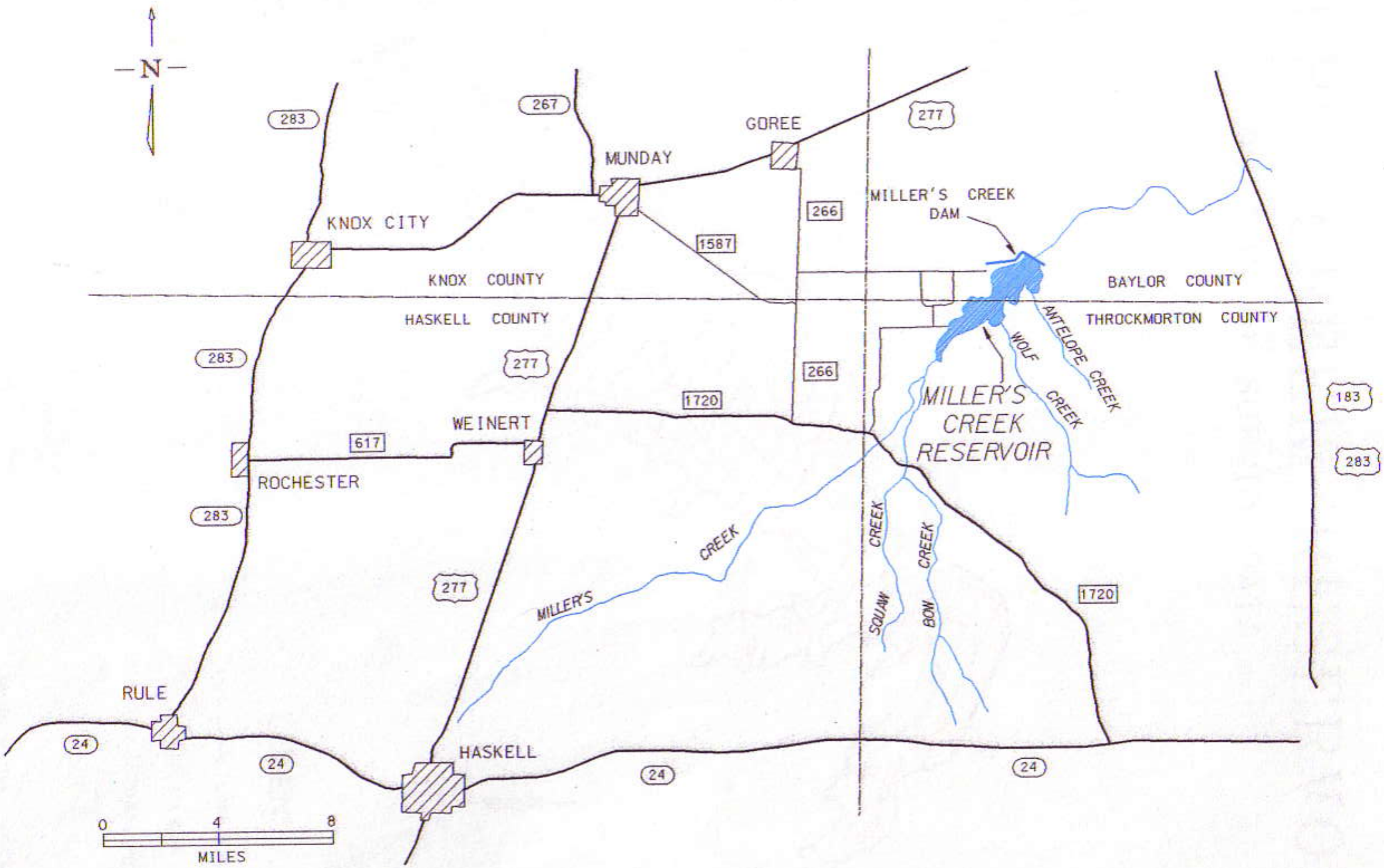

FIGURE 2

MILLER'S CREEK RESERVOIR

LOCATION OF SURVEY DATA

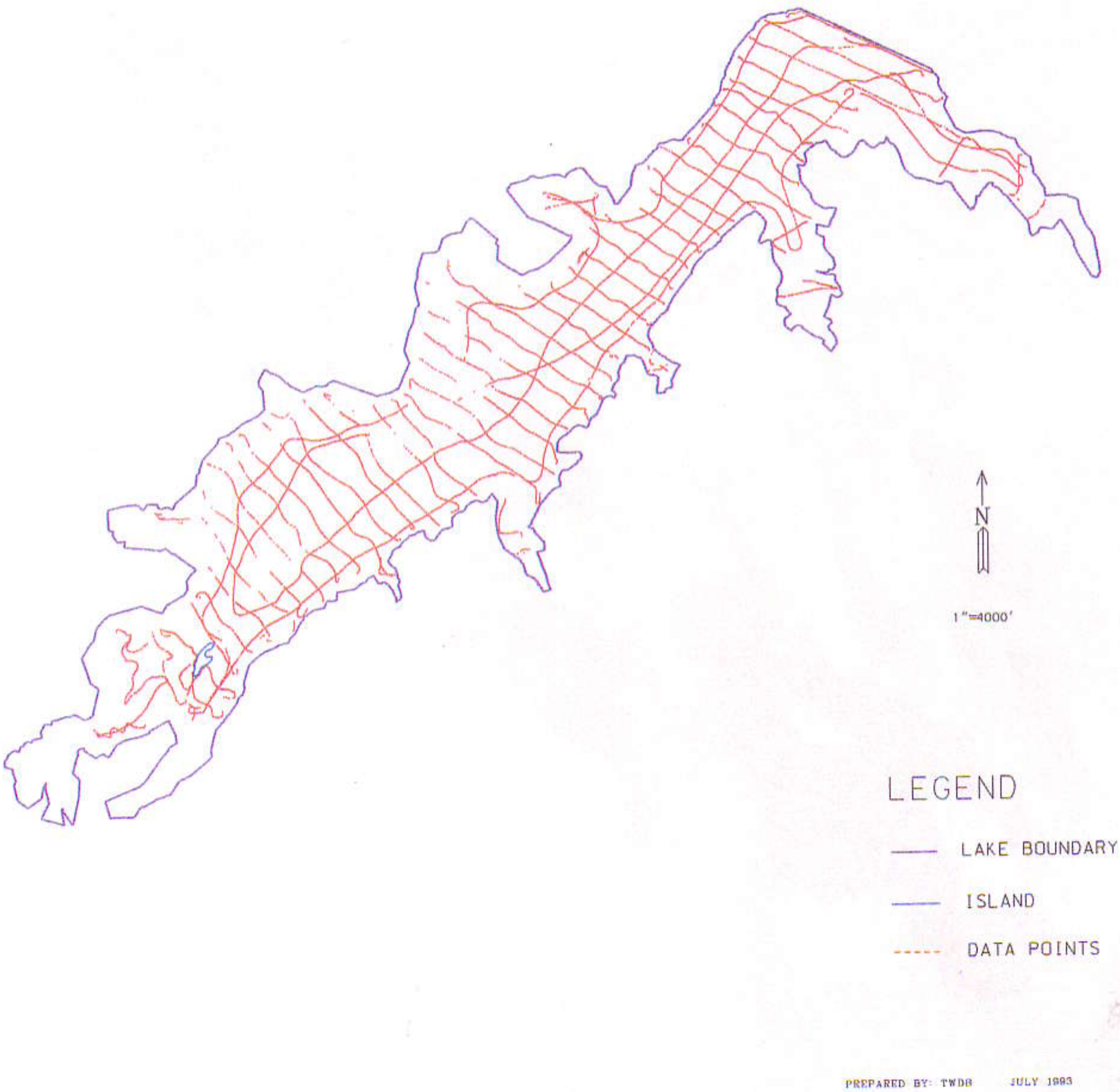

FIGURE 3

MILLER'S CREEK RESERVOIR

3-D BOTTOM SURFACE

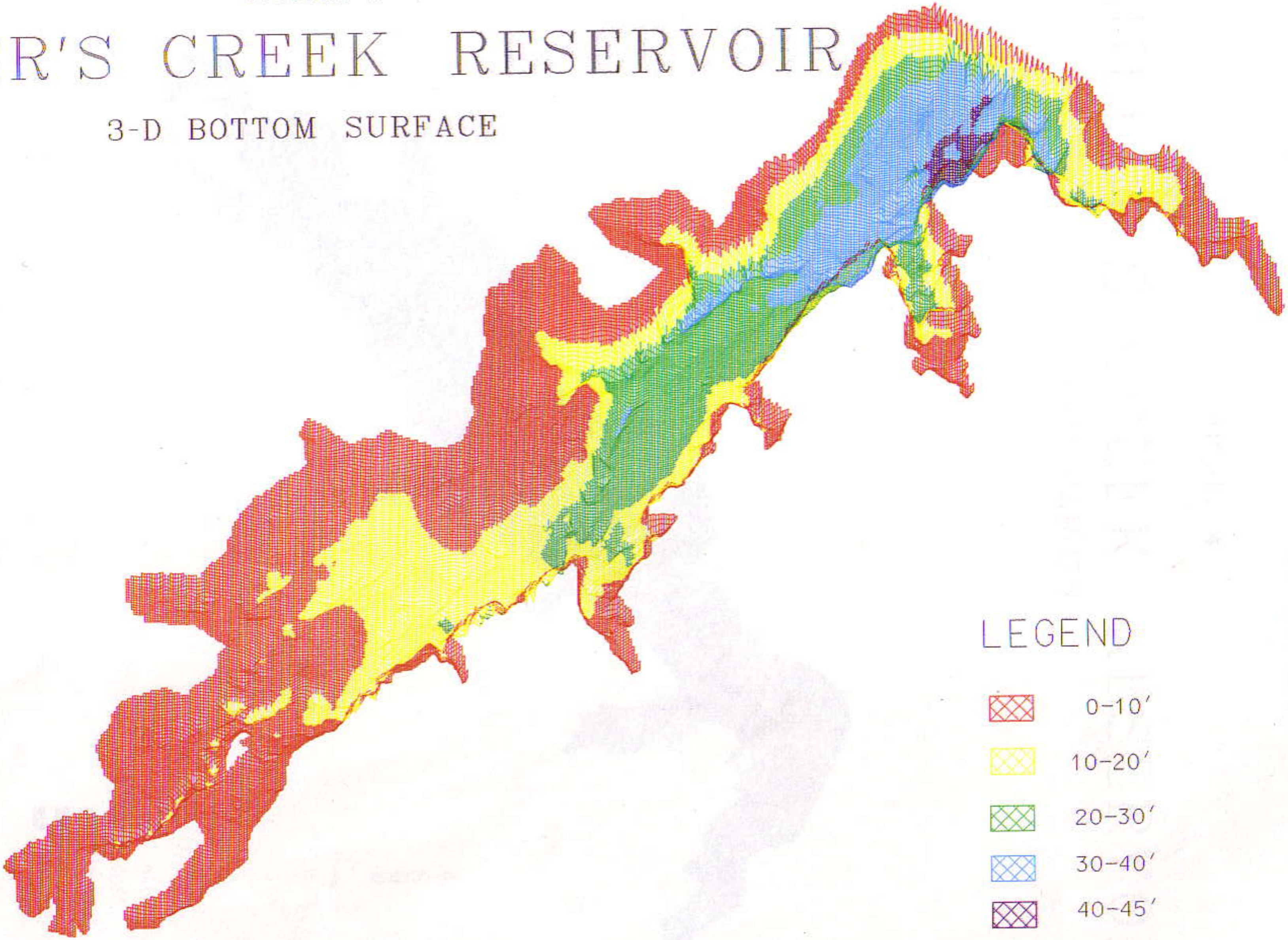

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FIGURE 4

MILLER'S CREEK RESERVOIR

DEPTH RANGES