VOLUMETRIC SURVEY OF HUBERT H. MOSS LAKE

Prepared for:

City of Gainesville

Prepared by:
Texas Water Development Board

October 27, 1999

Texas Water Development Board

This report was prepared by staff of the Surface Water Section:

Ruben S. Solis, Ph.D., P.E.
Duane Thomas
Randall Burns
Marc Sansom

Published and Distributed
by the
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711-3231

TABLE OF CONTENTS

INTRODUCTION 1

LAKE HISTORY AND GENERAL INFORMATION 1

VOLUMETRIC SURVEYING TECHNOLOGY 2

PRE-SURVEY PROCEDURES 3

SURVEY PROCEDURES 4

Equipment Calibration and Operation 4
Field Survey 5
Data Processing 6
RESULTS 7

SUMMARY AND COMPARISONS 7

REFERENCES 9

APPENDICES

APPENDIX A - VOLUME TABLE
APPENDIX B - AREA TABLE
APPENDIX C - ELEVATION-AREA- VOLUME GRAPH
APPENDIX D - CROSS-SECTION PLOTS
APPENDIX E - DEPTH SOUNDER ACCURACY
APPENDIX F - GPS BACKGROUND

LIST OF FIGURES

FIGURE 1 - LOCATION MAP
FIGURE 2 - LOCATION OF SURVEY DATA
FIGURE 3 - SHADED RELIEF
FIGURE 4 - DEPTH CONTOURS
FIGURE 5 - CONTOUR MAP

HUBERT H. MOSS LAKE
VOLUMETRIC SURVEY REPORT

INTRODUCTION

Staff of the Surface Water Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Hubert H. Moss Lake on May 18, 1999. The purpose of the survey was to determine the current volume of the lake at the conservation pool elevation. This survey will establish a basis for comparison to future surveys from which the location and rates of sediment deposition in the conservation pool can be determined. Survey results are presented in the following pages in both graphical and tabular form. All elevations presented in this report are reported in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29) unless otherwise noted. The conservation pool elevation for Hubert H. Moss Lake is 715.0 feet. Original design information (TWDB, 1974; Freese, Nichols, and Endress, 1961) showed the surface area at this elevation to be 1,125 acres and the storage volume to be 23,210 acre-feet.

LAKE HISTORY AND GENERAL INFORMATION

Historical information on Hubert H. Moss Lake was obtained from Texas Water Development Board Report 48 (TWDB, 1967), Report 126, Part I (TWDB, 1974), and the results of the current volumetric survey. The City of Gainesville owns the water rights to Moss Lake, and associated Fish Creek Dam. All releases and other lake operations are the responsibility of the City of Gainesville. The lake is located on Big Fish Creek in Cooke County approximately 10 miles northwest of Gainesville, Texas (see Figure 1). Records indicate the drainage area is approximately 69 square miles. At the conservation pool elevation, the lake has approximately 22.3 miles of shoreline and is 3.1 miles long. The widest point of the reservoir is approximately 2.6 miles and is located about 0.5 miles upstream of the dam.

The Texas Water Commission granted Permit No. 2034 (Application No. 2234) to the City of Gainesville on November 12, 1964. The City of Gainesville was authorized to impound 23,210 acre-feet of water with an annual diversion of 4,500 acre-feet of water for municipal use and 2,500 acre-feet of water for industrial use. The Texas Water Commission later issued Certificate of Adjudication No. 02-4881 on June 7, 1987 to the City of Gainesville. The certificate adjudicated the same water rights for impoundment as stated in Permit No. 2034. The City of Gainesville was authorized to impound 23,210 acre-feet of water in an existing reservoir (Moss Lake) and was authorized to divert and use not to exceed 4,500 acre-feet of water per annum from Moss Lake for municipal purposes.

Construction for the Moss Lake project began on December 8, 1964. Deliberate impoundment of water began in April 1965 and the project was officially completed September 24, 1966. Freese, Nichols and Endress were the project engineers. The general contractors were Buckner Construction Company and Hopple Jordan Construction Company. The estimated project cost was $671,000.00.

Fish Creek Dam and appurtenant structures consist of an earthfill embankment 1,460 feet in length with a maximum height of 93 feet and a crest width that varies 17 to 40 feet. The top of the embankment's elevation ranges between 740.0 and 741.0 feet. The emergency spillway is an excavated channel cut through natural ground and located to the left (north) of the embankment. The 400 feet broad-crested weir has a crest elevation of 725.0 feet. The discharge channel cuts through hard rock and shale. The service spillway is a concrete structure, morning glory type drop inlet. The 7.0 feet by 7.0 feet crest opening is at elevation 715.0 feet. All flows are discharged downstream of the embankment through a 7.0 feet by 7.0 feet conduit. The outlet works consist of a vertical control inlet tower located approximately 120 feet upstream of the service spillway. A 30-inch steel cylinder steel pipe connects the inlet with the service spillway. The low-flow outlet is a 30-inch culvert type pipe with an invert elevation of 666.0 feet and discharges into the upstream well of the inlet tower. There are two controlled gate openings (3.0 feet by 3.0 feet) in the upper section of the inlet tower. The invert elevations are 684.0 and 702.0 feet. These three openings allow for selected withdrawals at the different elevations.

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used in the performance of the volumetric survey consists of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Johnson outboard motors. (Reference to brand names throughout this report does not imply endorsement by TWDB). Installed within the enclosed cabin are an Innerspace Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, Trimble Navigation, Inc. 4000SE GPS receiver, an OmniSTAR receiver, and an on-board 486 computer. A water-cooled generator provides electrical power through an in-line uninterruptible power supply.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the lake surface, the depth sounder takes approximately ten readings of the lake bottom each second. The depth readings are stored on the survey vessel's on-board computer along with the corrected positional data generated by the boat's GPS receiver. The daily data files collected are downloaded from the computer and brought to the office for editing after the survey is completed. During editing, poor-quality data is removed or corrected, multiple data points are averaged to get one data point per second, and average depths are converted to elevation readings based on the lake elevation recorded on the day the survey was performed. Accurate estimates of the lake volume can be quickly determined by building a 3-D model of the reservoir from the collected data. The level of accuracy is equivalent to or better than previous methods used to determine lake volumes, some of which are discussed in Appendix F.

PRE-SURVEY PROCEDURES

The reservoir's surface area was determined prior to the survey by digitizing the lake's pool boundary (elevation 715.0 feet) with AutoCad software. The boundary was digitized from the following 7.5-minute USGS quadrangle maps: Thackerville, Tex.-Okla. (1968), Muenster East, Tex. (1961) (Photo-revised 1978), Gainesville North, Tex.-Okla. (1960) (Photo-revised 1978) and Marysville, Tex.-Okla. (1968) (Photo-inspected 1978). The graphic boundary file created was then transformed into the proper datum, from NAD '27 datum to NAD '83, using Environmental Systems Research Institute's (ESRI) Arc/Info PROJECT command with the NADCOM (standard conversion method within the United States) parameters. The lake boundary was checked to verify that the area was the same in both datums. This boundary was used in determining the outer lake boundary for subsequent use in calculating the lake's area and volume.

The survey layout was designed with Coastal Oceangraphics, Inc. Hypack software by placing survey track lines at 500-foot intervals across the lake. The survey design for this lake required approximately 71 survey lines to be placed along the length of the lake. The survey layout files were copied onto diskettes for use during the field survey.

SURVEY PROCEDURES

The following procedures were followed during the volumetric survey of Hubert H. Moss Lake performed by the TWDB. Information regarding equipment calibration and operation, the field survey, and data processing is presented.

Equipment Calibration and Operation

At the beginning of each surveying day, the depth sounder was calibrated with the Innerspace Velocity Profiler, an instrument used to measure the variation in the speed of sound at different depths in the water column. The average speed of sound through the entire water column below the boat was determined by averaging local speed-of-sound measurements collected through the water column. The velocity profiler probe was first placed in the water to moisten and to acclimate the probe. The probe was next raised to the water surface where the depth was zeroed. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised to the surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed was computed by the velocity profiler. This average speed of sound was entered into the ITI449 depth sounder, which then provided the depth of the lake bottom. The depth was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly. During the survey of Hubert H. Moss Lake, the speed of sound in the water column was 4,882 feet per second. Based on the measured speed of sound for various depths and the average speed of sound calculated for the entire water column, the depth sounder is accurate to within ±0.2 feet. An additional estimated error of ±0.3 feet arises from variation in boat inclination. These two factors combine to give an overall accuracy of ±0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some readings are positive and some are negative. Further information on these calculations is presented in Appendix F.

During the survey, the onboard GPS receiver was set to a horizontal mask of 10° and a PDOP (Position Dilution of Precision) limit of 7 to maximize the accuracy of horizontal positions. An internal alarm sounds if the PDOP rises above seven to advise the field crew that the horizontal position has degraded to an unacceptable level. The lake's initialization file used by the Hypack data collection program was set up to convert the collected DGPS positions on-the-fly to state-plane coordinates. Both sets of coordinates were then stored in the survey data file.

Field Survey

Data were collected at Moss Lake on May 18, 1999. Weather conditions were favorable during the data collection phase of the survey. Approximately 25,939 data points were collected over the 27 miles traveled. These points were stored digitally on the boat's computer in 59 data files. Data were not collected in areas of shallow water (depths less than 3.0 feet) or with significant obstructions unless these areas represented a large amount of water. Figure 2 shows the actual location of all data collection points.

TWDB staff observed that the lake's bathymetry had features similar to the topography of the area surrounding the lake. The terrain around the lake was generally flat to rolling hills. The reservoir was mainly located in the flood plain at the confluence of South Fish Creek and North Fish Creek. The flow was in a west to east direction with North Fish Creek feeding into the lake on the north side. In the main body of the lake, the creek channels were easily distinguishable on the depth sounder chart as the boat traveled perpendicular to the shoreline. No major bank erosion was observed along the perimeter of the lake. The crew noted more residential development on the north side of the lake.

Data collection started at the dam and proceeded upstream. The field crew did not encounter any navigational hazards such as submerged trees, stumps or shallow depths until the boat was located in the upper reaches of South Fish Creek and North Fish Creek. Data collection in the headwaters was discontinued when the boat could no longer maneuver due to shallow water and extensive vegetation. Extra data were collected around the outlet works, and at the dam. The collected data were stored in individual data files for each pre-plotted range line or random data collection event. These files were downloaded to diskettes at the end of each day for future processing.

Data Processing

To process the data, the EDIT routine in the Hypack Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from the file. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water surface remained fairly constant at elevation 713.74 feet. After all changes had been made to the raw data file, the edited file was saved with a different extension. The edited files were combined into a single X, Y, Z data file, to be used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was downloaded to a Sun Sparc 20 workstation running the UNIX operating system. Environmental System Research Institute's (ESRI) Arc/Info GIS software was used to convert the data to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the reservoir's bottom surface using Arc/Info's TIN software module. The module generates a triangulated irregular network (TIN) network from the data points and the boundary file using 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 used in this method. The generated network of three-dimensional triangular planes represents the actual bottom surface. With this representation of the bottom, the software then calculates elevations along the triangle surface plane by determining the elevation along each leg of the triangle. The reservoir area and volume can be determined from the triangulated irregular network created using this method of interpolation.

The boundary file was downsized as deemed necessary in significant areas of sedimentation based on the data points collected and the observations of the field crew. The resulting boundary shape was used to develop each of the map presentations of the lake in this report.

Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of foot intervals. From elevation 648.5 to elevation 715.0, the surface areas and volumes of the lake were computed using Arc/Info software. The computed 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. Cross-sections obtained from the TIN model are presented in Appendix D.

Other products developed from the model include a shaded relief map (Figure 3) and a shaded depth range map (Figure 4). To develop these maps, the TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command. Linear filtration algorithms were applied to the DTM to produce smooth cartographic contours. The resulting contour map of the bottom surface at two-foot intervals is presented in Figure 5.

RESULTS

Results from the 1999 TWDB survey indicate Hubert H. Moss Lake encompasses 1,140 surface acres and contains a total volume of 24,155 acre-feet at the conservation pool elevation of 715.0 feet. The shoreline at this elevation was calculated to be 22.3 miles. The deepest point in the lake is at elevation 648.46 feet and corresponds to a depth of 66.5 feet, and is located approximately 1,229 feet upstream from the center of Fish Creek Dam.

SUMMARY AND COMPARISONS

Hubert H. Moss Lake was initially impounded in April 1966. Storage calculations in 1961 reported the volume at conservation pool elevation 715.0 feet to be 23,210 acre-feet with a surface area of 1,125 acres.

During May 18, 1999, staff from the Texas Water Development Board's Surface Water Section completed a volumetric survey of Hubert H. Moss Lake. The 1999 survey took advantage of technological advances such as differential global positioning system and geographical information system technology to create a digital model of the reservoir's bathymetry. With these advances, the survey was completed more quickly and significantly more bathymetric data were collected than in previous surveys. Results indicate that the lake's volume at the conservation pool elevation of 715.0 feet is 24,155 acre-feet, with a corresponding area of 1,140 acres.

Comparing the findings from the current and the original (1961) surveys, the estimated area at conservation pool elevation 715.0 feet for the current survey is 15 acres greater than in the 1961 survey. The volume at conservation pool elevation is also larger in the current survey by 945 acre-feet (+4.1%). There is no clear reason for the apparent increase in both area and volume, although differences in surveying procedures and technology may be the cause. Freese, Nichols, and Endress (1961) estimated sedimentation rates over the 69 square mile watershed of 0.70 acre-feet per square mile per year. At this rate over the 33 years between the impoundment date (1966) and the current survey (1999), this would produce approximately 1,590 acre-feet of sediment. A coarse estimate of the error bound in the current volume measurements based on the surface area and assumed accuracy of ±0.5 feet for the depth measurements yields an accuracy in the current survey of ±563 acre-feet. This is within the accuracy that would be needed to detect the estimated sedimentation rate and leads to the possibility that technological and methodological differences between the two surveys may have resulted in the increases found in area and volume.

Based on the amount of data collected and the improved methods and technology used in the current survey, the current data set is considered to be an improvement over previous survey procedures. It is recommended that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage volume.

REFERENCES

Freese, Nichols, and Endress. 1961. Development of Surface Water Supplies on Fish Creek for the City of Gainesville.

Texas Water Development Board. 1967. Dams and Reservoirs in Texas, Historical and Descriptive Information, Report 48.

Texas Water Development Board. 1974. Engineering Data on Dams and Reservoirs in Texas. Report 126, Part I.

U.S. Geological Survey. 1997. Water Resources Data Texas, Water Year 1997. Volume 1, Surface Water.

Appendix A

Moss Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — MAY 1999 SURVEY

VOLUME IN ACRE-FEET — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
648						0	0	0	0	0
649	0	0	0	0	0	0	0	0	0	0
650	0	0	0	0	0	0	0	0	0	0
651	0	0	0	0	0	0	0	0	0	0
652	0	0	0	0	0	0	0	0	0	0
653	0	0	0	0	0	0	0	0	0	0
654	0	0	0	0	0	0	0	0	0	0
655	0	0	0	0	0	0	0	0	0	0
656	0	0	1	1	1	1	1	1	1	1
657	1	1	1	1	1	2	2	2	2	2
658	2	2	2	2	3	3	3	3	3	3
659	4	4	4	4	4	4	5	5	5	5
660	6	6	6	7	7	8	8	8	9	9
661	10	10	11	12	12	13	14	14	15	16
662	17	18	19	20	21	22	23	24	25	26
663	28	29	30	32	33	35	37	38	40	42
664	44	46	48	50	52	55	57	59	62	64
665	67	70	72	75	78	81	84	87	90	94
666	97	101	104	108	111	115	119	123	127	131
667	135	140	144	149	154	158	163	168	174	179
668	184	189	195	201	206	212	218	224	230	237
669	243	250	256	263	270	277	284	291	298	306
670	313	321	329	336	344	352	360	368	377	385
671	393	402	410	419	428	436	445	454	463	473
672	482	491	501	510	520	529	539	549	559	570
673	580	590	601	612	623	634	645	656	668	679
674	691	703	715	727	739	752	764	777	790	802
675	815	828	842	855	868	882	895	909	923	936
676	950	965	979	993	1008	1023	1038	1054	1069	1085
677	1101	1117	1133	1149	1166	1182	1199	1216	1233	1250
678	1267	1285	1303	1320	1339	1357	1375	1394	1413	1432
679	1451	1471	1490	1510	1530	1551	1571	1592	1613	1634
680	1655	1677	1699	1721	1743	1766	1788	1811	1834	1858
681	1881	1905	1929	1953	1977	2001	2026	2051	2076	2102
682	2127	2153	2179	2206	2232	2259	2286	2313	2341	2368
683	2396	2424	2453	2481	2510	2539	2568	2597	2627	2657
684	2687	2717	2748	2779	2810	2841	2873	2904	2936	2968
685	3001	3033	3066	3099	3132	3165	3199	3232	3266	3300
686	3335	3369	3404	3439	3474	3510	3546	3582	3618	3654
687	3691	3728	3765	3802	3840	3878	3916	3954	3992	4031
688	4070	4109	4149	4189	4229	4269	4309	4350	4391	4433
689	4474	4516	4558	4600	4643	4686	4729	4772	4816	4860
690	4904	4949	4994	5039	5085	5131	5177	5224	5270	5318
691	5365	5413	5461	5509	5558	5607	5656	5705	5755	5805
692	5855	5906	5956	6008	6059	6112	6164	6217	6270	6323
693	6377	6431	6486	6541	6596	6651	6707	6763	6819	6876
694	6933	6991	7048	7106	7164	7223	7282	7341	7400	7460
695	7519	7579	7640	7700	7761	7822	7883	7945	8007	8069
696	8131	8193	8256	8319	8382	8446	8509	8573	8638	8702
697	8767	8832	8897	8962	9028	9094	9160	9227	9293	9360
698	9427	9495	9562	9630	9698	9767	9835	9904	9973	10043
699	10112	10182	10252	10322	10392	10463	10534	10605	10676	10748

Appendix A (continued)

Moss Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — MAY 1999 SURVEY

VOLUME IN ACRE-FEET — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
700	10820	10892	10964	11036	11109	11182	11255	11328	11401	11475
701	11549	11623	11697	11771	11846	11921	11996	12071	12146	12222
702	12298	12374	12450	12526	12603	12680	12757	12834	12911	12989
703	13066	13144	13223	13301	13380	13458	13538	13617	13696	13776
704	13856	13936	14017	14098	14179	14260	14341	14423	14505	14587
705	14669	14752	14835	14918	15001	15084	15168	15252	15336	15421
706	15505	15590	15675	15761	15846	15932	16018	16105	16191	16278
707	16365	16452	16540	16627	16715	16803	16891	16980	17069	17158
708	17247	17336	17426	17516	17606	17696	17787	17878	17969	18060
709	18152	18244	18336	18428	18521	18614	18707	18800	18894	18987
710	19082	19176	19270	19365	19460	19556	19652	19748	19844	19940
711	20037	20135	20232	20330	20428	20527	20626	20725	20824	20924
712	21025	21126	21227	21328	21429	21531	21633	21735	21838	21941
713	22044	22147	22250	22354	22458	22562	22667	22771	22876	22981
714	23087	23192	23298	23405	23511	23618	23725	23832	23939	24047
715	24155									

Appendix B

Moss Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — MAY 1999 SURVEY

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
648						0	0	0	0	0
649	0	0	0	0	0	0	0	0	0	0
650	0	0	0	0	0	0	0	0	0	0
651	0	0	0	0	0	0	0	0	0	0
652	0	0	0	0	0	0	0	0	0	0
653	0	0	0	0	0	0	0	0	0	0
654	0	0	0	0	0	0	0	0	0	0
655	0	0	0	0	0	0	0	0	0	0
656	0	0	1	1	1	1	1	1	1	1
657	1	1	1	1	1	1	1	1	1	1
658	1	1	1	1	1	1	1	2	2	2
659	2	2	2	2	2	2	2	2	3	3
660	3	3	4	4	4	4	4	5	5	5
661	5	6	6	6	7	7	7	8	8	8
662	9	9	9	10	10	11	11	11	12	13
663	13	14	15	15	16	16	17	18	18	19
664	19	20	21	21	22	23	23	24	25	26
665	26	27	28	29	29	30	31	32	33	33
666	34	35	36	36	37	38	39	40	41	43
667	44	45	46	46	48	49	50	51	52	53
668	54	55	56	57	58	59	60	61	62	63
669	64	66	67	68	70	71	72	72	73	74
670	75	76	77	78	79	80	81	82	83	83
671	84	85	86	87	88	88	89	90	91	92
672	93	94	95	96	97	98	99	100	101	103
673	104	106	107	108	110	111	113	114	115	117
674	118	119	121	122	123	125	126	127	128	129
675	130	131	132	133	134	135	136	137	138	139
676	141	143	145	147	149	151	153	154	156	158
677	159	161	162	164	165	167	168	170	171	172
678	174	176	178	180	182	184	186	188	190	192
679	193	195	197	199	202	204	207	209	211	213
680	215	217	220	222	224	226	228	230	232	234
681	236	238	240	242	244	246	249	251	253	255
682	257	260	262	264	267	269	271	273	275	278
683	280	283	285	287	289	291	293	295	297	300
684	302	305	307	309	312	314	316	318	320	322
685	324	326	328	330	332	334	336	338	340	342
686	344	347	349	352	354	356	359	361	363	366
687	368	370	372	374	377	379	381	384	386	389
688	391	394	397	399	402	404	407	409	411	414
689	416	419	422	424	427	430	433	436	439	442
690	445	448	451	454	457	461	464	467	470	473
691	476	479	482	484	487	490	492	495	498	501
692	504	508	511	515	519	522	526	530	533	536
693	540	543	546	550	553	556	560	563	566	569
694	572	575	578	581	584	587	589	592	594	597
695	599	601	604	607	609	612	614	616	619	621
696	624	626	628	631	633	636	638	641	643	646
697	649	651	653	656	658	660	663	665	668	670
698	673	675	678	680	683	685	687	690	692	694
699	696	699	701	703	705	708	710	712	714	716

Appendix B (continued)

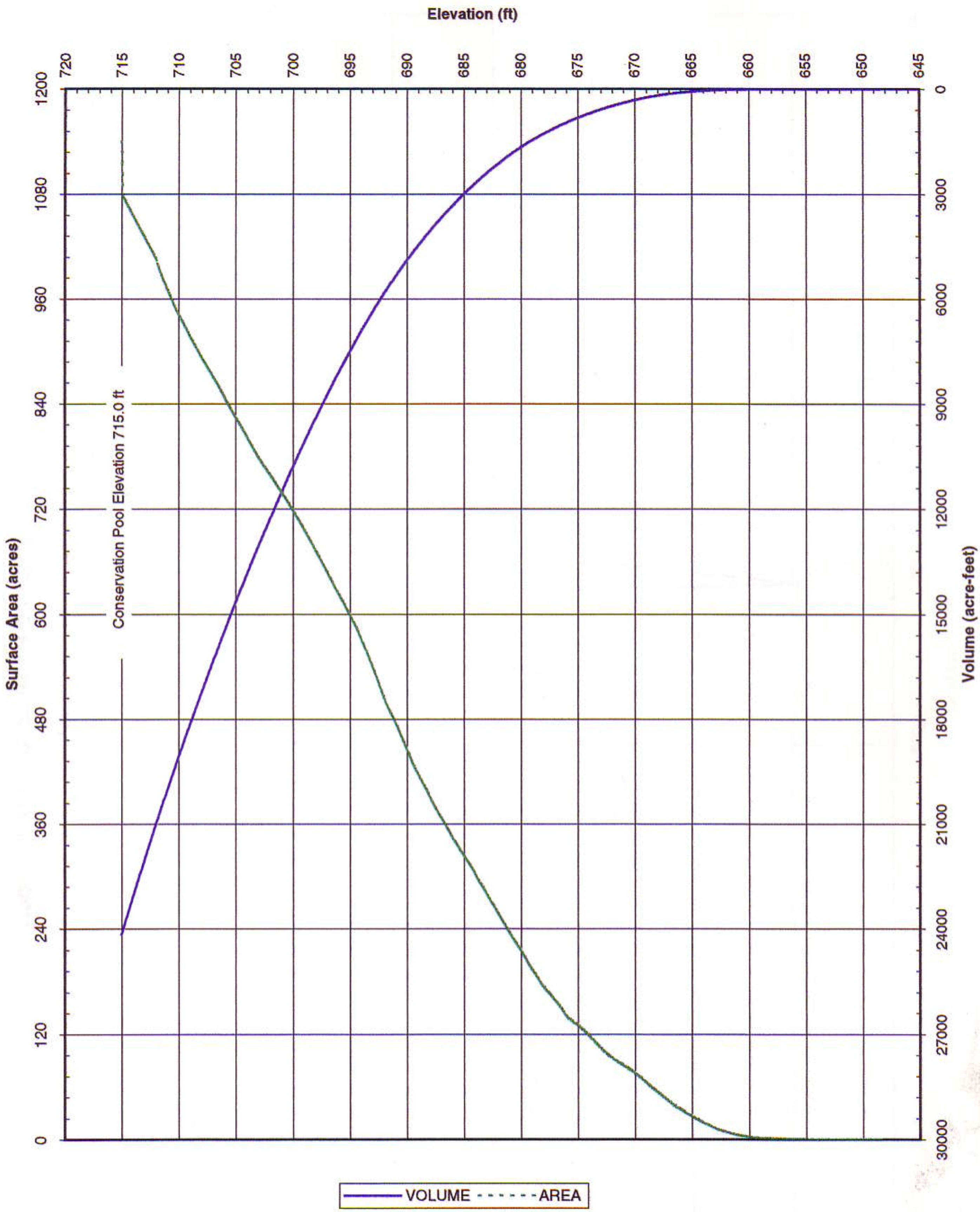
Moss Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD MAY 1999 SURVEY

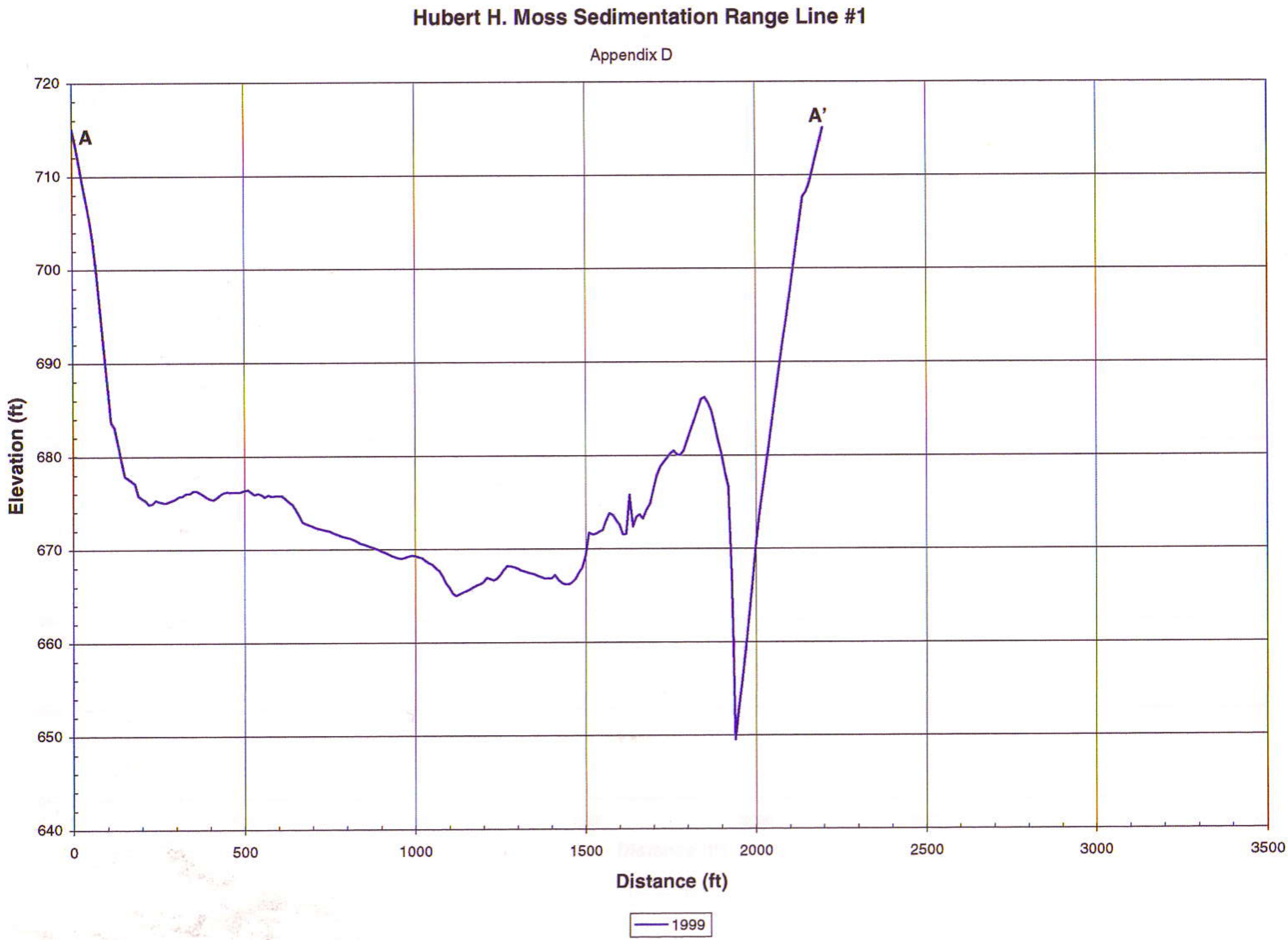
AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
700	719	721	723	725	727	729	731	733	735	737
701	739	741	743	745	747	749	751	753	755	757
702	759	761	763	765	766	768	770	772	774	776
703	779	781	783	785	787	790	792	794	797	799
704	802	804	806	809	811	813	816	818	820	822
705	824	827	829	831	833	836	838	840	843	845
706	848	850	853	855	857	860	862	864	867	869
707	871	873	876	878	880	882	884	886	889	891
708	893	895	898	900	902	905	907	910	912	914
709	917	920	923	925	927	930	932	935	937	940
710	942	945	947	950	953	956	959	962	965	968
711	971	974	977	980	984	987	990	994	998	1004
712	1006	1009	1011	1014	1016	1019	1021	1024	1026	1028
713	1031	1033	1036	1038	1041	1043	1046	1048	1051	1053
714	1055	1058	1060	1063	1065	1068	1070	1073	1075	1078
715	1140									



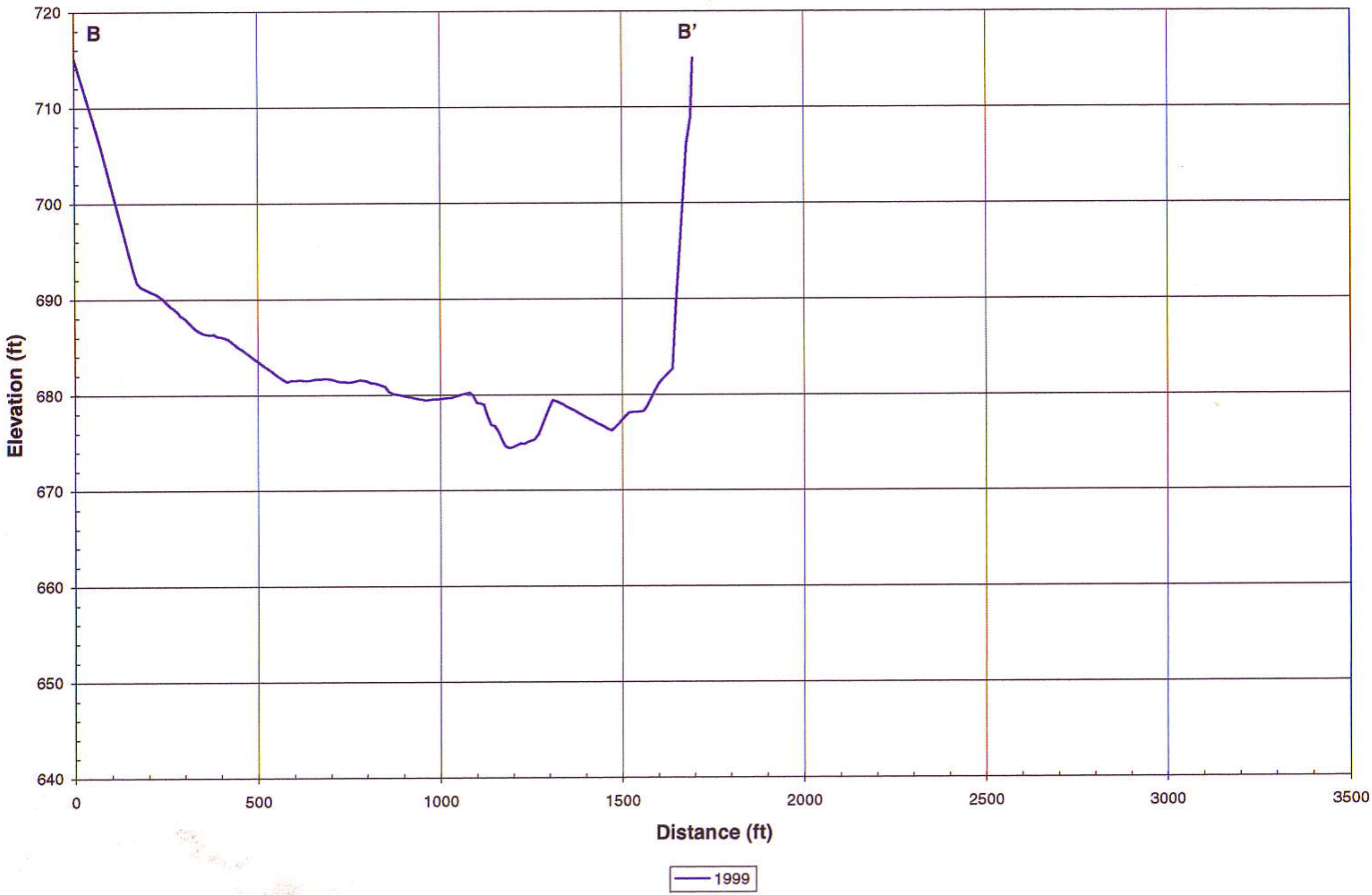
Hubert H. Moss Lake
May 1999
Prepared by: TWDB August 1999

Appendix C


Hubert H. Moss Sedimentation Range Line #1
Appendix D
A
A'
720
710
700
690
680
670
660
650
640
Elevation (ft)
0
500
1000
1500
2000
2500
3000
3500
Distance (ft)
1999

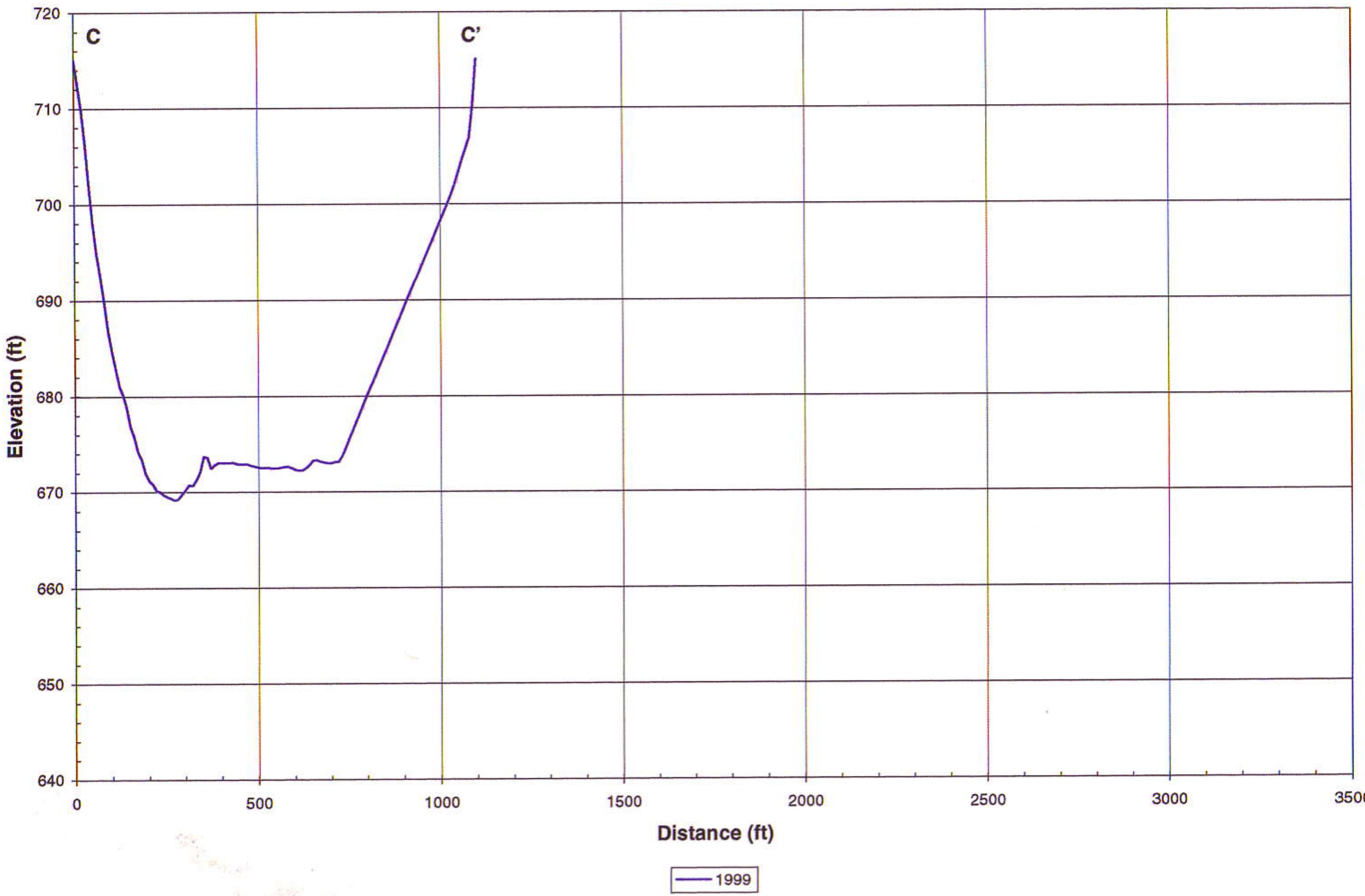
Hubert H. Moss Sedimentation Range Line #2

Appendix D



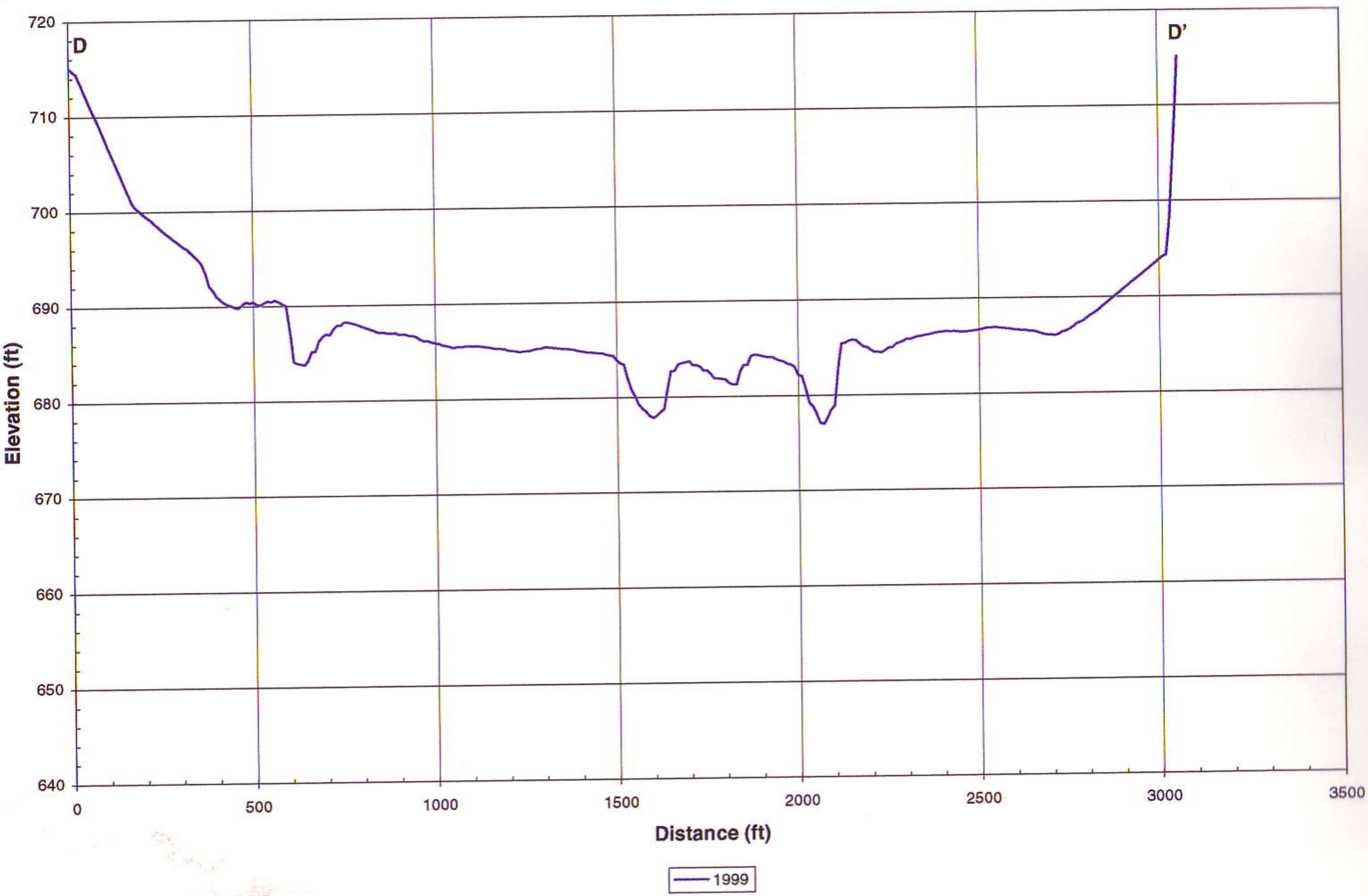
Hubert H. Moss Sedimentation Range Line #3

Appendix D



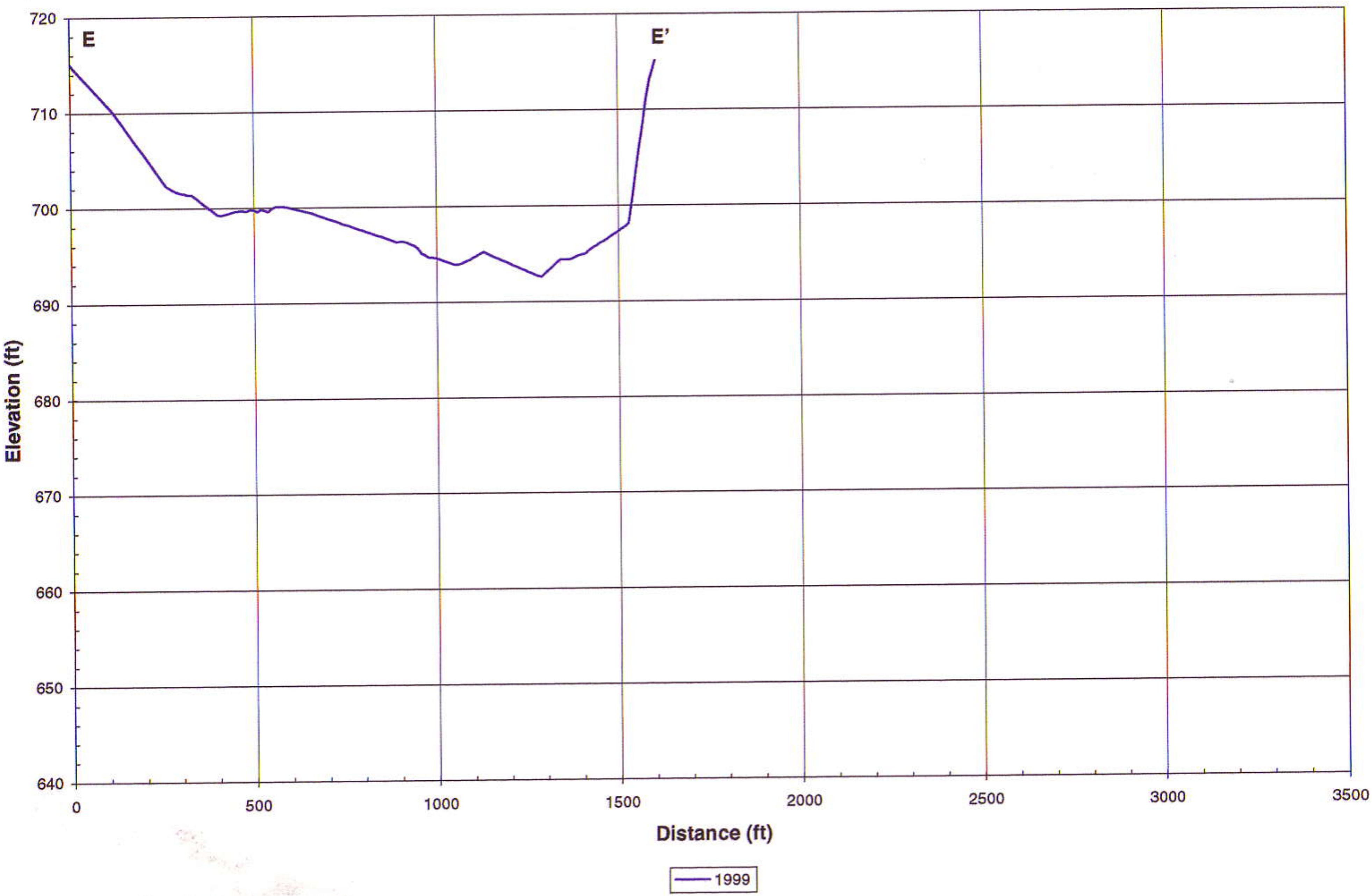
Hubert H. Moss Sedimentation Range Line #4

Appendix D



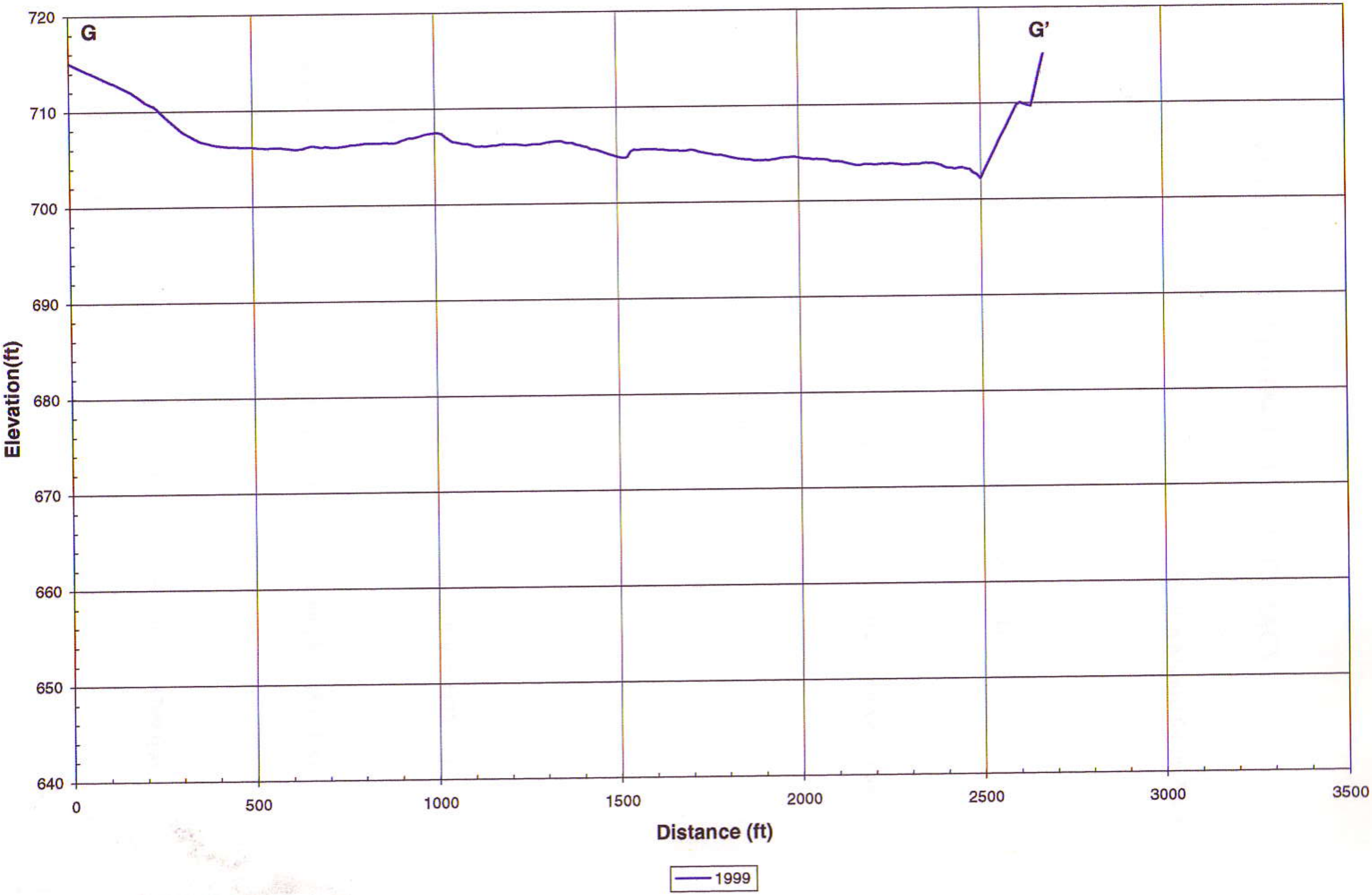
Hubert H. Moss Sedimentation Range Line #5

Appendix D



Hubert H. Moss Sedimentation Range Line #6

Appendix D



APPENDIX E - DEPTH SOUNDER ACCURACY

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

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

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 sec.

For a measurement at 10 feet (within the 2 to 30 foot column with V = 4832 fps):

D_{10} = [((10-1.2)/4832)(4799)]+1.2
= 9.9' (-0.1')

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

D_{30} = [((30-1.2)/4832)(4799)]+1.2
= 29.8' (-0.2')

For a measurement at 45 feet (within the 2 to 45 foot column with V = 4808 fps):

D_{45} = [((45-1.2)/4808)(4799)]+1.2
= 44.9' (-0.1')

For a measurement at 80 feet (outside the 2 to 60 foot column, assumed V = 4785 fps):

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

APPENDIX F - GPS BACKGROUND

GPS Information

The following is a brief and simple description of Global Positioning System (GPS) technology. GPS is a relatively 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 satellite broadcasts 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 located in space, and is ignored, while the second is the point of interest located on earth. 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.

The United States Air Force and the defense establishment developed GPS technology in the 1960’s. 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 was reached on April 27, 1995 when the NAVSTAR (NAVigation System with Time And Ranging) satellite constellation was composed of 24 Block II satellites. Initial operational capability, a full constellation of 24 satellites, in a combination of Block I (prototype) and Block II satellites, was achieved December 8, 1993. The NAVSTAR satellites provide data based on the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to the 1983 North American Datum (NAD '83).

The United States Department of Defense (DOD) is currently responsible for implementing and maintaining the satellite constellation. In an attempt to discourage the use of these survey units as a guidance tool by hostile forces, DOD 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, of which one 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) is an advance mode of satellite surveying in which positions of moving objects can be determine in real-time or "on-the-fly." This technological breakthrough was the backbone of the development of the TWDB’s Hydrographic Survey Program. In the early stages of the program, 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 another 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. This type of operation can provide horizontal positional accuracy within one meter. In addition, the large positional errors experienced by a single receiver when S/A is active are negated. The lake surface during the survey serves as the vertical datum for the bathymetric readings from a depth sounder. The sounder determines the lake's depth below a given horizontal location at the surface.

The need for setting up a stationary shore receiver for current surveys has been eliminated by registration with a fee-based satellite reference position network (OmniSTAR). This service works on a worldwide basis in a differential mode basically the same way as the shore station. For a given area in the world, a network of several monitoring sites (with known positions) collect GPS signals from the NAVSTAR network. GPS corrections are computed at each of these sites to correct the GPS signal received to the known coordinates of the site. The correction corresponding to each site is automatically sent to a “Network Control Center” where they are checked and repackaged for up-link to a “Geostationary” L-band satellite. The “real-time” corrections are then broadcast by the satellite to users of the system in the area covered by that satellite. The OmniSTAR receiver translates the information and supplies it to the on-board Trimble receiver for correction of the boat’s GPS positions. The accuracy of this system in a real-time mode is normally 1 meter or less.

Previous Survey Procedures

Originally, reservoir surveys were conducted by stretching a rope across the reservoir along pre-determined range lines and, from a small boat, poling 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 recorded at selected intervals. This method, used mainly by the Soil Conservation Service, worked well for small reservoirs.

Larger bodies of water required more involved means to accomplish the survey, mainly due to increased size. Cables could not be stretched across the body of water, so surveying instruments were utilized to determine the path of the boat. Monuments were set at the end points of each line so the same lines could be used on subsequent surveys. Prior to a survey, each end point had to be located (and sometimes reestablished) in the field and vegetation cleared so that line of sight could be maintained. One surveyor monitored the path of the boat and issued commands via radio to insure that it remained on line while a second surveyor determined the horizontal location 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.

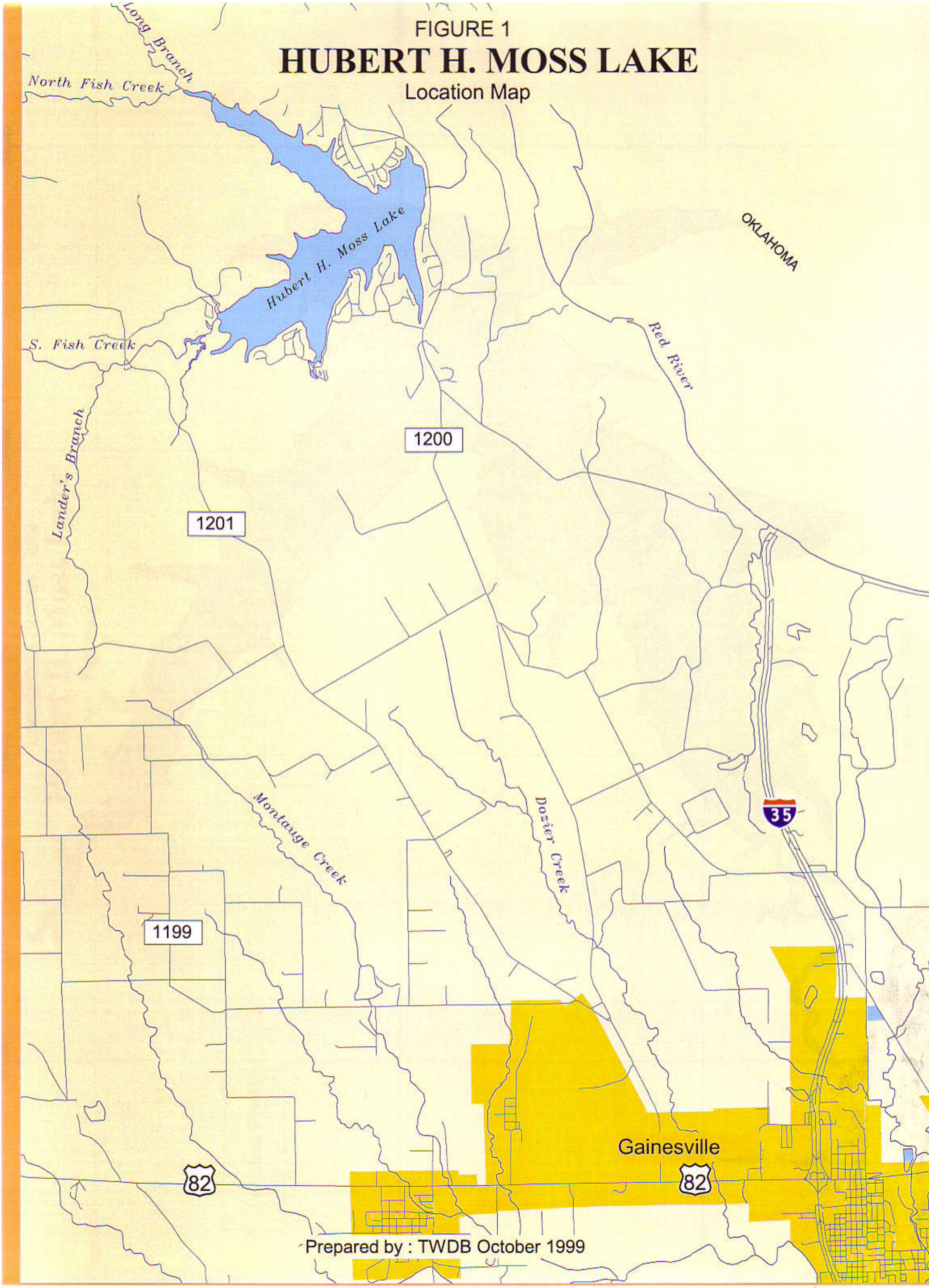
Electronic positioning systems were the next improvement. Continuous horizontal positioning by electronic means allowed for the continuous collection of depth soundings by boat. A set of microwave transmitters positioned around the lake at known coordinates allowed the boat to receive data and calculate its position. Line of site was required, and the configuration of the transmitters had to be such that the boat remained within the angles of 30 and 150 degrees with respect to the shore stations. The maximum range of most of these systems was about 20 miles. Each shore station had to be accurately located by survey, and the location monumented for future use. Any errors in the land surveying resulted in significant errors that were difficult to detect. Large reservoirs required multiple shore stations and a crew to move the shore stations to the next location as the survey progressed. Land surveying remained a major cost with this method.

More recently, aerial photography has been used prior to construction to generate elevation contours from which to calculate the volume of the reservoir. Fairly accurate results could be obtained, although the vertical accuracy of the aerial topography is generally one-half of the contour interval or ± five feet for a ten-foot contour interval. This method can be quite costly and is applicable only in areas that are not inundated.

FIGURE 1

HUBERT H. MOSS LAKE

Location Map

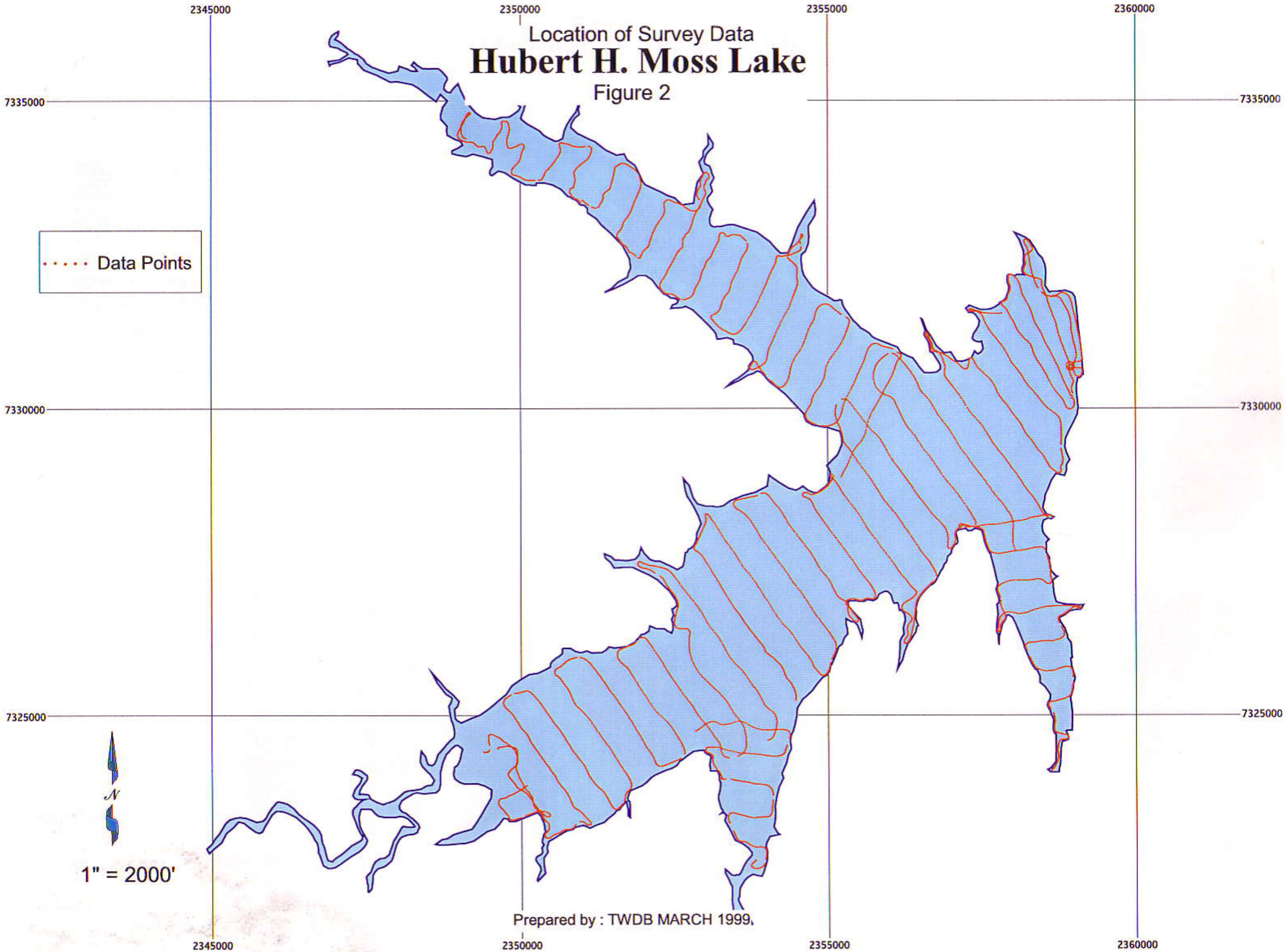


Prepared by : TWDB October 1999

Location of Survey Data

Hubert H. Moss Lake

Figure 2



Prepared by : TWDB MARCH 1999.

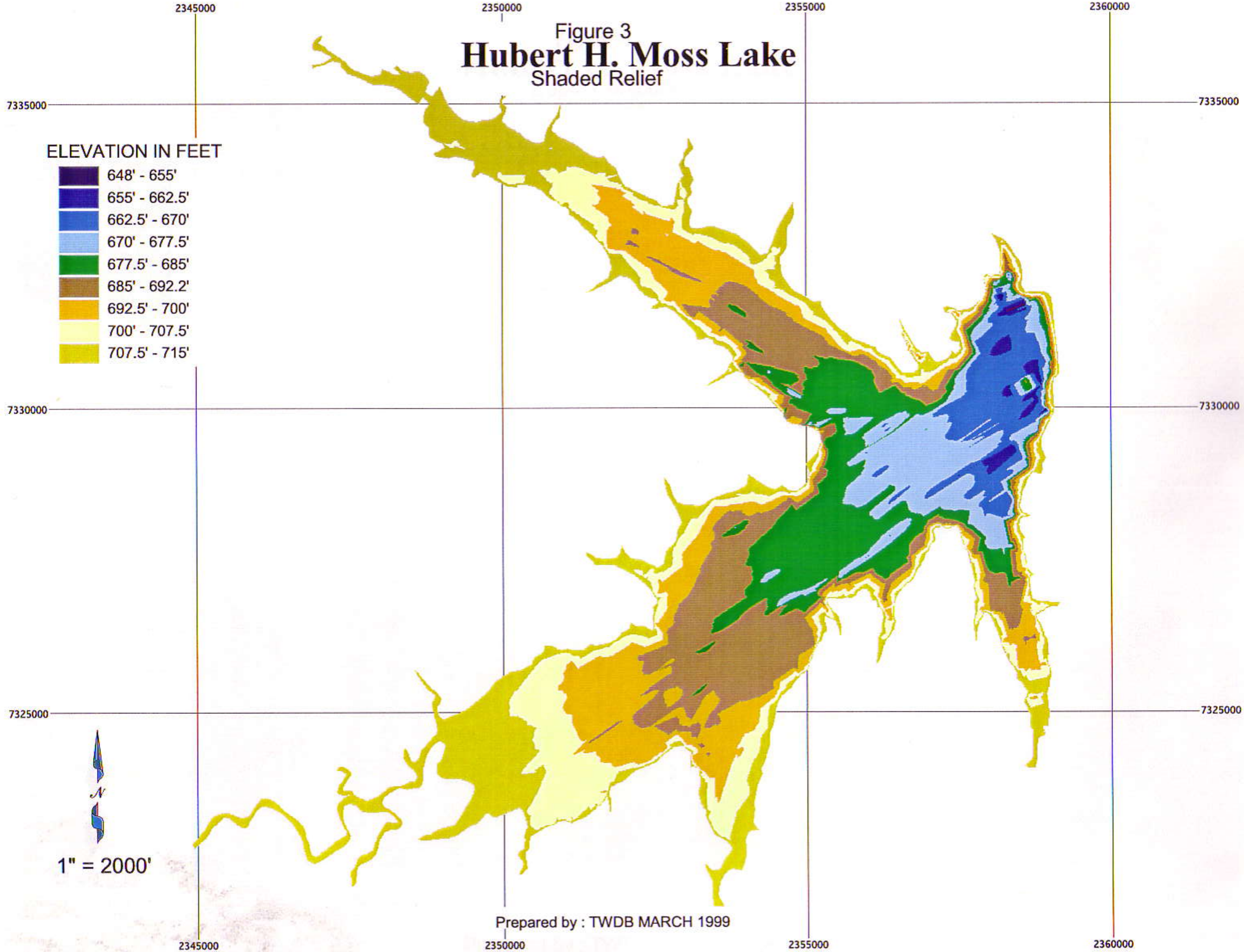


Figure 3
Hubert H. Moss Lake
Shaded Relief
ELEVATION IN FEET
648' - 655'
655' - 662.5'
662.5' - 670'
670' - 677.5'
677.5' - 685'
685' - 692.2'
692.5' - 700'
700' - 707.5'
707.5' - 715'
1" = 2000'
2345000
2350000
2355000
2360000
7335000
7330000
7325000
Prepared by : TWDB MARCH 1999

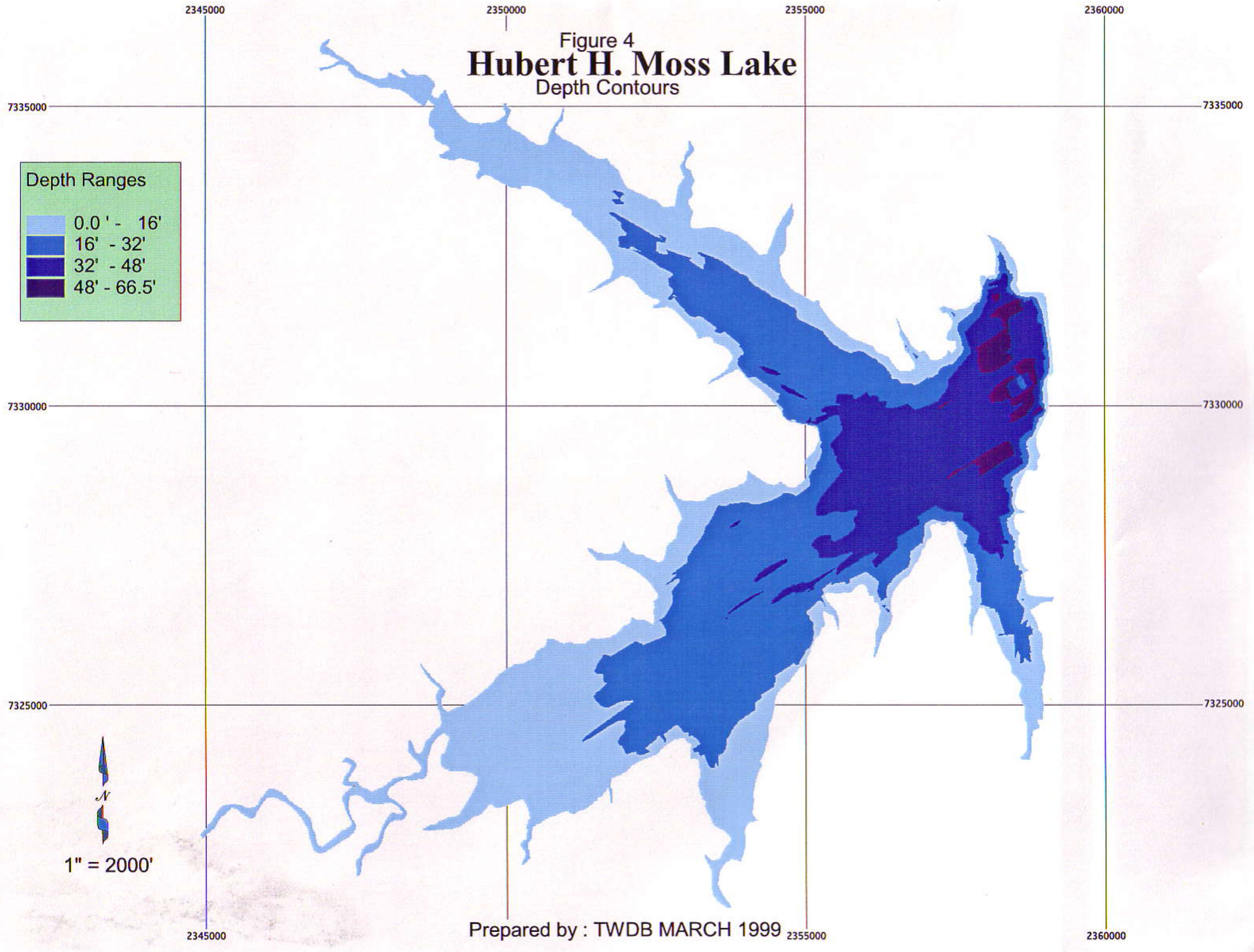


Figure 4
Hubert H. Moss Lake
Depth Contours
Depth Ranges
0.0 ' - 16'
16' - 32'
32' - 48'
48' - 66.5'
1" = 2000'
N
2345000
2350000
2355000
2360000
7335000
7330000
7325000
Prepared by : TWDB MARCH 1999