VOLUMETRIC SURVEY OF MARTIN LAKE

Prepared for:

U. S. Army Corps of Engineers
Fort Worth District

In conjunction with
Sabine River Authority
And
TXU Electric Company

Prepared by:
Texas Water Development Board

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Texas Water Development Board

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INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a volumetric survey of Martin Lake (also known as Martin Creek Lake) during the period of May 12, 13 and June 2, 1999. The purpose of the survey was to determine the 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 over time 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 noted otherwise. The conservation pool elevation for Martin Lake is 306.0 feet. Original design information in 1971 (TWDB, 1974) estimated the surface area at this elevation to be 5,020 acres and the storage volume to be 77,619 acre-feet of water.

LAKE HISTORY AND GENERAL INFORMATION

Historical information on Fairfield Lake was obtained from Texas Water Development Board Report 126, Part I (TWDB, 1974) and Martin Lake Sediment Survey from Jones and Boyd Inc. (Jones and Boyd Inc., 1984). The TXU Electric Company (formerly Texas Utilities) owns the water rights to Martin Lake. The company also owns the land surrounding Martin Lake, and operates and maintains the associated Martin Lake Dam. The lake is located on Martin Creek (Sabine River Basin) in Rusk and Panola Counties, three and one-half miles southwest of Tatum, Texas (see Figure 1). Records indicate the drainage area is approximately 130 square miles. At the conservation pool elevation, the lake has approximately 52.8 miles of shoreline and is 7.4 miles long. The widest point of the reservoir is approximately 4.0 miles and is located approximately 0.75 miles upstream of the dam.

Water Rights Permit No. 2693 (Application No. 2932) was issued to Texas Power and Light Company (presently TXU Electric Company) on November 19, 1971 and authorized the construction of a dam to impound 77,619 acre-feet of water. The permit allowed annual use not to exceed 18,750 acre-feet of water for cooling three 750,000 kw steam-electric generators. The Texas Water Commission issued Certificate of Adjudication No. 05-4649 on December 10, 1986. The certificate basically re-enforces Permit No. 2693 and authorizes TXU Electric Company to maintain an existing dam and reservoir on Martin Creek (Martin Lake) that impounds 77,619 acre-feet of water at elevation 306.0 feet. The owner was authorized to divert and use not to exceed 18,750 acre-feet of water per year from Martin Lake for industrial (thermal-electric power generation) purposes. As part of the Special Conditions in the Certificate an additional 6,250 acre-feet of water can be diverted upon the installation of a fourth 750-megawatt power unit. An amendment is pending with TNRCC addressing the balance of the water right.

Records indicate the construction for Martin Lake and Martin Lake Dam started May 31, 1972. Deliberate impoundment began on September 30, 1974. The design engineer for the project was Forrest and Cotton, Inc. and the general contractor was Central Plains Contracting Company. The estimated cost of the dam, spillway and channel was $5,200,000.

Martin Dam and appurtenant structures consist of a rolled-earthfill embankment approximately 6,875 feet in length, with a maximum height of 67 feet and a crest elevation of 321.5 feet. The service spillway is located near the left (west) end of the embankment and consists of concrete ogee crest and chute. The crest is 160 feet in net length at elevation 294.0 feet. Four tainter gates, each 14 feet tall and 40 feet wide, control the service spillway. The outlet works include one 3 by 5 feet conduit that has a sluice gate control with an invert elevation of 284.0 feet. An additional 8-inch diameter pipe with an invert elevation of 286.0 feet is controlled by a downstream sluice gate. The emergency spillway, located at the left (west) abutment is an earth trench cut through natural ground. The uncontrolled broad-crested weir is 1,000 feet in length at elevation 312.0 feet.

The minimum operating (lake-level) elevation for the intake to the power plant is 294.0 feet.

Original design information in 1971 estimated the surface area at elevation 306.0 feet to be 5,020 acres and the storage volume to be 77,619 acre-feet of water. In 1984, Jones and Boyd Inc. Consulting Engineers performed a sedimentation survey of Martin Lake. Results of that survey showed the surface area at elevation 306.0 feet (normal pool) to be 5,010 acres and a volume of 69,822 acre-feet. This report will present a comparison of the 1999 survey results to the 1971 design and the 1984 survey findings.

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, a 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 306.0 feet) with AutoCad software. The boundary file was created from 7.5-minute USGS quadrangle maps, Tatum, TX. (Provisional 1983) and Fairplay, TX. (Provisional 1983). The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using HyPack software. The survey design for this lake required approximately 177 survey lines to be placed along the length of the lake.

SURVEY PROCEDURES

The following procedures were followed during the volumetric survey of Martin 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 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 Martin Lake, the speed of sound in the water column varied from 4,913 to 4,925 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 in the main basin of Martin Lake on May 12 and 13, 1999. The survey crew returned to Martin Lake on June 2, 1999 to collect data where the larger survey vessel could not gain access. A smaller boat with portable equipment was used to collect data on Wesson Creek upstream of the bridge of County Road 2658 and on Weir Creek upstream of the bridge of County Road 3231. During data collection, the crew had excellent weather with moderate temperatures and mild winds. Approximately 47,769 data points were collected over the 90 miles traveled. These points were stored digitally on the boat's computer in over 155 data files. Data were not collected in areas with significant obstructions unless these areas represented a large amount of water. These restricted areas were encountered in the upper reaches of Martin Creek, the upper reaches of Wesson Creek and the upper reaches of Panther Creek. Figure 2 shows the actual location of all data collection points.

Martin Creek flows in a southwest to northeast direction with Martin Lake Dam being at the northeast end of the lake basin. TWDB staff observed the land surrounding the lake to be generally flat to rolling hills. There was no residential or commercial development around the perimeter of the lake. At the time of the survey, there was some mining activity taken place to the east of the lake near

Caney Branch. Martin Lake State Park is located immediately west of Martin Lake Dam on Rocky Ford Creek. The Texas Utilities electric generating power plant is located across Rocky Ford Creek from the state park.

While performing the survey on the lake, the field crew noted on the depth sounder chart that the bathymetry or contour of the lake bottom reflected the characteristics of the terrain surrounding the lake. A gradual slope was noticed as the boat traveled from the shoreline to the center of the lake. There was a defined channel (thalweg) of Martin Creek in the main basin of the lake. The crew observed minimal erosion along the shoreline of Martin Lake. The digitized boundary match fairly well to the actual shoreline in the main basin of the lake. Adjustments had to be made for the lake boundary when the field crew observed islands and an extended peninsula near the on-site storage ponds at the power plant. The boundary was also adjusted in the upper reaches of Martin Creek and Wesson Creek based on field observations by TWDB and Texas Utilities staff. As the field crew collected data in the upper reaches of these two creeks, navigational hazards such as submerged trees and stumps became numerous. In addition, sediment deposits and standing vegetation were observed. The crew was able to collect data in these areas, but at a much slower pace. Data collection in the headwaters was limited when the boat could no longer cross the lake due to shallow water and extensive vegetation. The survey crew returned to Martin Lake on June 2nd to collect data in these areas with a smaller boat. The crew was restricted from gathering data in the intake and discharge channels. These channels were cabled or fenced off at the time of the survey.

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

The collected data were downloaded from diskettes onto TWDB's computer network. Tape backups were made for future reference as needed. 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 elevation varied from 305.83 feet to 306.0 feet as provided by TXU Electric Company. 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.

In areas of significant sedimentation, the boundary file was downsized as deemed necessary 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 a foot intervals. From elevation 263.2 to elevation 306.0, 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.

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. Finally, cross-sections from the original survey and the 1984 re-survey by Jones and Boyd Inc. Consulting Engineers, shown on the map in Figure 5, are compared to cross-sections obtained from the current survey in the plots in Appendix D.

RESULTS

Results from the 1999 TWDB survey indicate Martin Lake encompasses 4,981 surface acres and contains a total volume of 75,116 acre-feet at the conservation pool elevation of 306.0 feet. The shoreline at this elevation was calculated to be 52.8 miles. The deepest point of the lake, at elevation 263.16 feet and corresponding to a depth of 42.8 feet, was located approximately740 feet upstream from the center of Martin Lake Dam.

SUMMARY AND COMPARISONS

Martin Lake was initially impounded in April 1974. Storage calculations in 1971 reported the volume at conservation pool elevation 306.0 feet to be 77,619 acre-feet with a surface area of 5,020 acres. A second survey in 1984 found the volume at conservation pool elevation to be 69,822 acre-feet and the area to be 5,010 acres.

During May 12, 13 and June 2, 1999, staff from the Texas Water Development Board's Surface Water Section completed a volumetric survey of Martin 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 306.0 feet is 75,116 acre-feet, with a corresponding area of 4,981 acres.

Comparing the findings from the original (1971) survey and the current survey, the estimated reduction in area at conservation pool elevation 306.0 feet is 39 surface acres. The reduction in volume at conservation pool elevation is 2,503 acre-feet (–3.2%) or 89.4 acre-feet/year since (1971). The average annual deposition rate of sediment in the reservoir can be estimated at 0.7 acre-feet/square mile of drainage area. This compares to sedimentation rates based on the 1971 and 1984 surveys of 600 acre-feet/year and 4.6 acre-feet/square mile. Discrepancies between results may arise from differences in surveying procedures and technology. Based on the amount of data collected (over 140 survey lines were 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

Texas Water Development Board. 1974. Engineering data on dams and reservoirs in Texas. Part I. Report 126.

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

Martin Lake Sediment Survey, Jones and Boyd Inc. (1984)

Appendix A

Martin Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — May-June 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
263			0	0	0	0	0	0	0	0
264	0	0	0	0	0	0	0	0	0	0
265	0	0	0	0	0	0	0	0	0	1
266	1	1	1	1	1	1	2	2	2	3
267	3	3	4	4	5	6	7	8	9	10
268	11	12	14	16	18	20	23	26	30	34
269	38	43	48	54	61	68	75	84	93	102
270	113	124	136	148	161	175	189	204	220	236
271	254	271	290	309	329	349	370	391	413	436
272	460	484	509	534	561	588	615	644	673	702
273	733	764	796	829	862	897	932	968	1005	1043
274	1082	1122	1163	1204	1247	1290	1335	1381	1427	1475
275	1525	1575	1627	1679	1733	1788	1844	1901	1959	2018
276	2077	2137	2198	2259	2321	2383	2447	2510	2575	2640
277	2706	2772	2839	2906	2974	3043	3112	3182	3253	3325
278	3398	3471	3545	3621	3697	3774	3852	3932	4011	4092
279	4174	4257	4341	4426	4512	4599	4687	4777	4867	4959
280	5051	5145	5239	5335	5432	5530	5629	5729	5829	5931
281	6034	6137	6241	6347	6453	6560	6668	6777	6887	6998
282	7109	7222	7336	7450	7566	7683	7801	7920	8040	8161
283	8283	8406	8530	8655	8781	8908	9036	9166	9296	9427
284	9559	9693	9827	9964	10101	10240	10379	10521	10663	10806
285	10951	11098	11245	11394	11544	11695	11848	12002	12157	12313
286	12472	12631	12792	12954	13118	13282	13448	13615	13783	13952
287	14123	14295	14468	14642	14818	14995	15174	15354	15536	15719
288	15904	16091	16279	16469	16661	16854	17050	17247	17446	17647
289	17851	18058	18267	18479	18693	18909	19127	19347	19568	19791
290	20015	20241	20468	20697	20927	21158	21391	21626	21862	22099
291	22338	22578	22820	23063	23308	23554	23801	24050	24300	24551
292	24804	25058	25314	25570	25829	26088	26349	26611	26875	27139
293	27406	27673	27942	28213	28484	28757	29032	29308	29585	29863
294	30143	30425	30708	30992	31278	31565	31853	32143	32434	32727
295	33021	33316	33613	33911	34211	34513	34815	35120	35425	35733
296	36041	36351	36663	36976	37291	37607	37925	38244	38565	38888
297	39212	39538	39865	40194	40524	40856	41190	41525	41861	42199
298	42539	42880	43223	43567	43913	44261	44610	44961	45313	45667
299	46022	46380	46738	47099	47460	47824	48189	48555	48923	49293
300	49665	50038	50412	50788	51166	51546	51927	52310	52695	53081
301	53470	53860	54253	54647	55043	55441	55841	56243	56646	57052
302	57460	57869	58281	58694	59109	59526	59944	60365	60788	61212
303	61637	62064	62493	62922	63354	63787	64221	64657	65094	65533
304	65973	66415	66858	67303	67750	68198	68648	69099	69552	70006
305	70462	70920	71380	71840	72303	72768	73234	73702	74171	74643
306	75116									

Appendix B

Martin Lake

RESERVOIR AREA TABLE

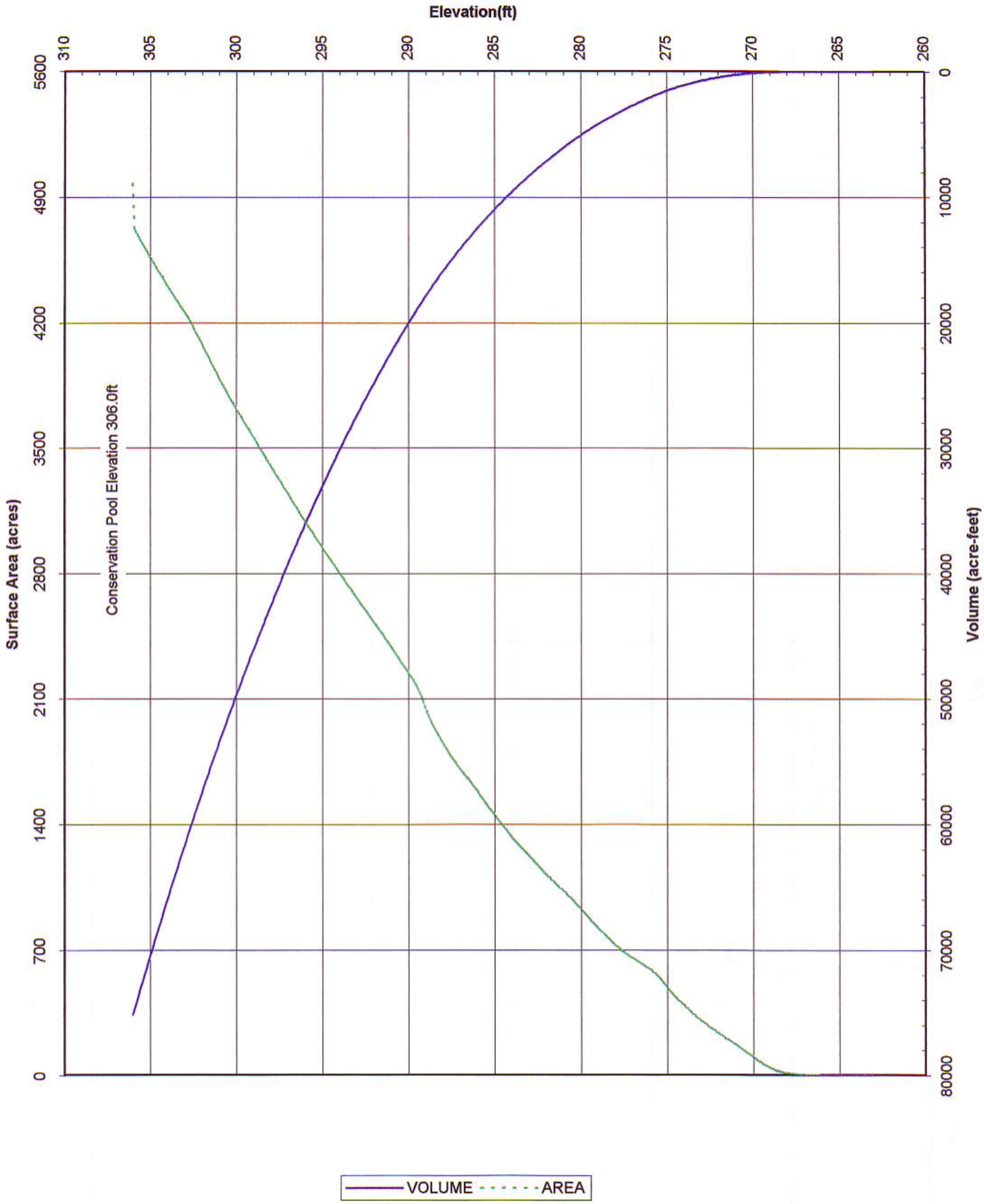
TEXAS WATER DEVELOPMENT BOARD

May-June 1999 SURVEY

AREA IN ACRES

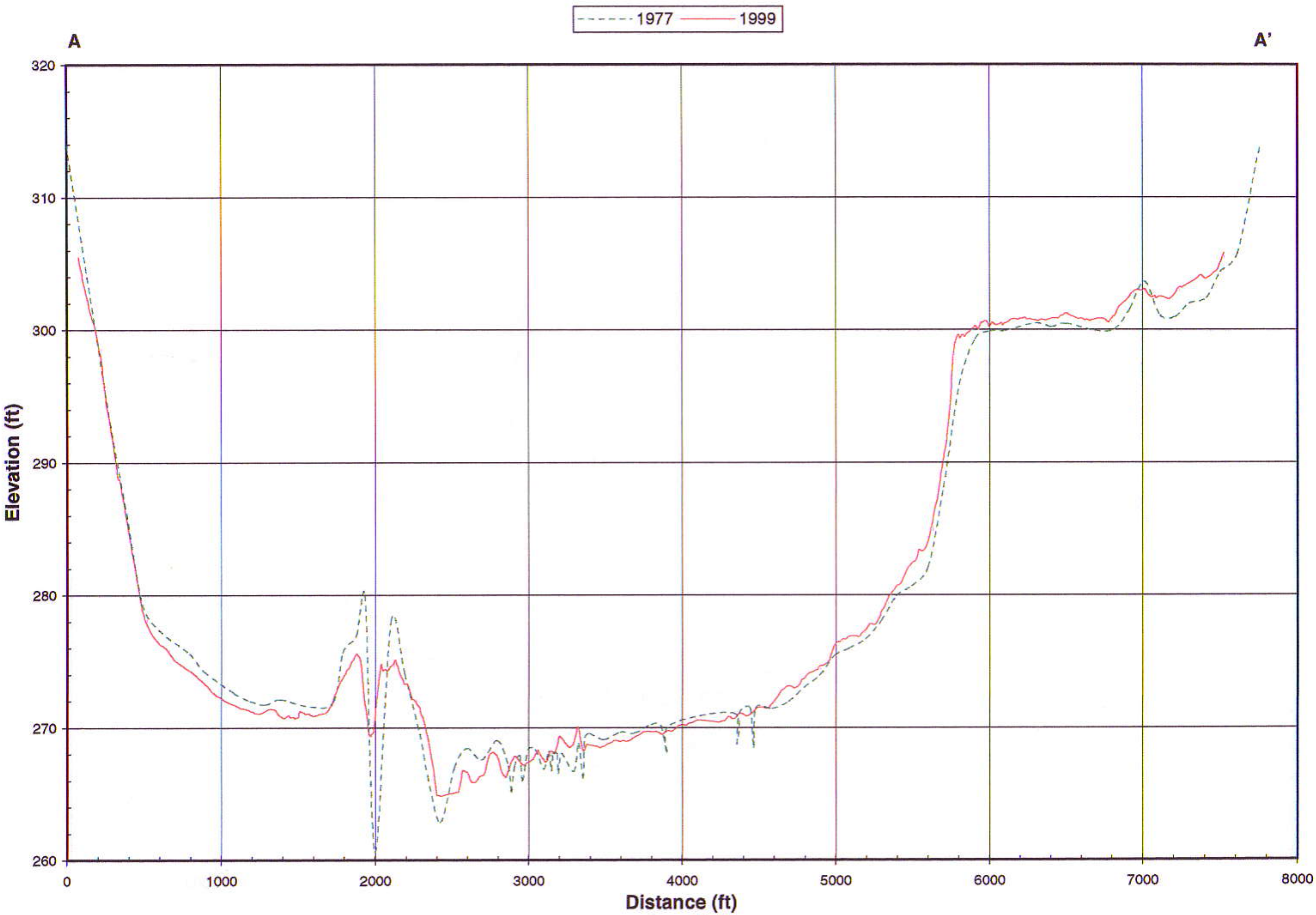
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
263			0	0	0	0	0	0	0	0
264	0	0	0	0	0	0	0	0	0	0
265	0	0	0	0	0	1	1	1	1	1
266	1	1	1	2	2	2	3	3	3	4
267	4	5	5	6	7	8	8	9	11	12
268	13	15	18	20	22	25	29	33	37	42
269	46	51	56	61	67	74	80	87	94	100
270	107	114	121	127	133	140	147	154	161	168
271	175	182	188	194	200	206	212	218	225	232
272	239	245	252	259	266	273	280	288	295	302
273	309	316	324	331	340	348	357	366	375	384
274	393	402	411	421	430	440	451	462	474	486
275	498	510	522	533	544	555	565	574	582	590
276	597	604	610	616	622	629	635	641	647	653
277	659	665	671	677	684	691	698	706	714	722
278	730	739	748	758	768	777	787	795	804	814
279	824	834	844	854	864	876	889	900	910	920
280	931	941	952	963	974	984	994	1003	1012	1022
281	1031	1039	1048	1057	1066	1076	1085	1094	1103	1112
282	1121	1131	1141	1151	1163	1174	1184	1195	1206	1216
283	1226	1236	1246	1256	1266	1276	1286	1296	1306	1317
284	1329	1342	1355	1368	1380	1393	1405	1417	1430	1443
285	1455	1468	1481	1494	1506	1519	1532	1546	1560	1574
286	1589	1602	1615	1628	1640	1652	1664	1675	1687	1699
287	1711	1724	1737	1751	1766	1780	1795	1811	1826	1842
288	1858	1874	1891	1908	1925	1943	1961	1981	2001	2025
289	2053	2081	2107	2129	2151	2171	2189	2206	2222	2237
290	2251	2265	2279	2293	2307	2322	2337	2352	2367	2382
291	2396	2411	2425	2439	2452	2466	2480	2494	2507	2521
292	2534	2548	2562	2575	2589	2602	2615	2628	2641	2655
293	2669	2683	2696	2710	2723	2738	2751	2765	2779	2793
294	2807	2822	2836	2850	2864	2878	2892	2904	2918	2932
295	2947	2962	2976	2991	3005	3021	3036	3050	3064	3079
296	3093	3108	3123	3139	3155	3171	3186	3202	3218	3234
297	3250	3266	3281	3296	3312	3327	3343	3358	3373	3388
298	3404	3420	3436	3452	3468	3483	3498	3514	3531	3548
299	3564	3580	3595	3611	3626	3642	3657	3673	3690	3706
300	3721	3737	3753	3770	3787	3804	3821	3839	3858	3877
301	3895	3914	3933	3951	3971	3989	4008	4027	4046	4066
302	4086	4105	4123	4141	4159	4177	4197	4218	4233	4247
303	4262	4276	4291	4306	4321	4336	4350	4365	4380	4396
304	4411	4426	4442	4457	4473	4489	4505	4521	4537	4553
305	4569	4586	4603	4619	4636	4653	4670	4687	4705	4722
306	4981									

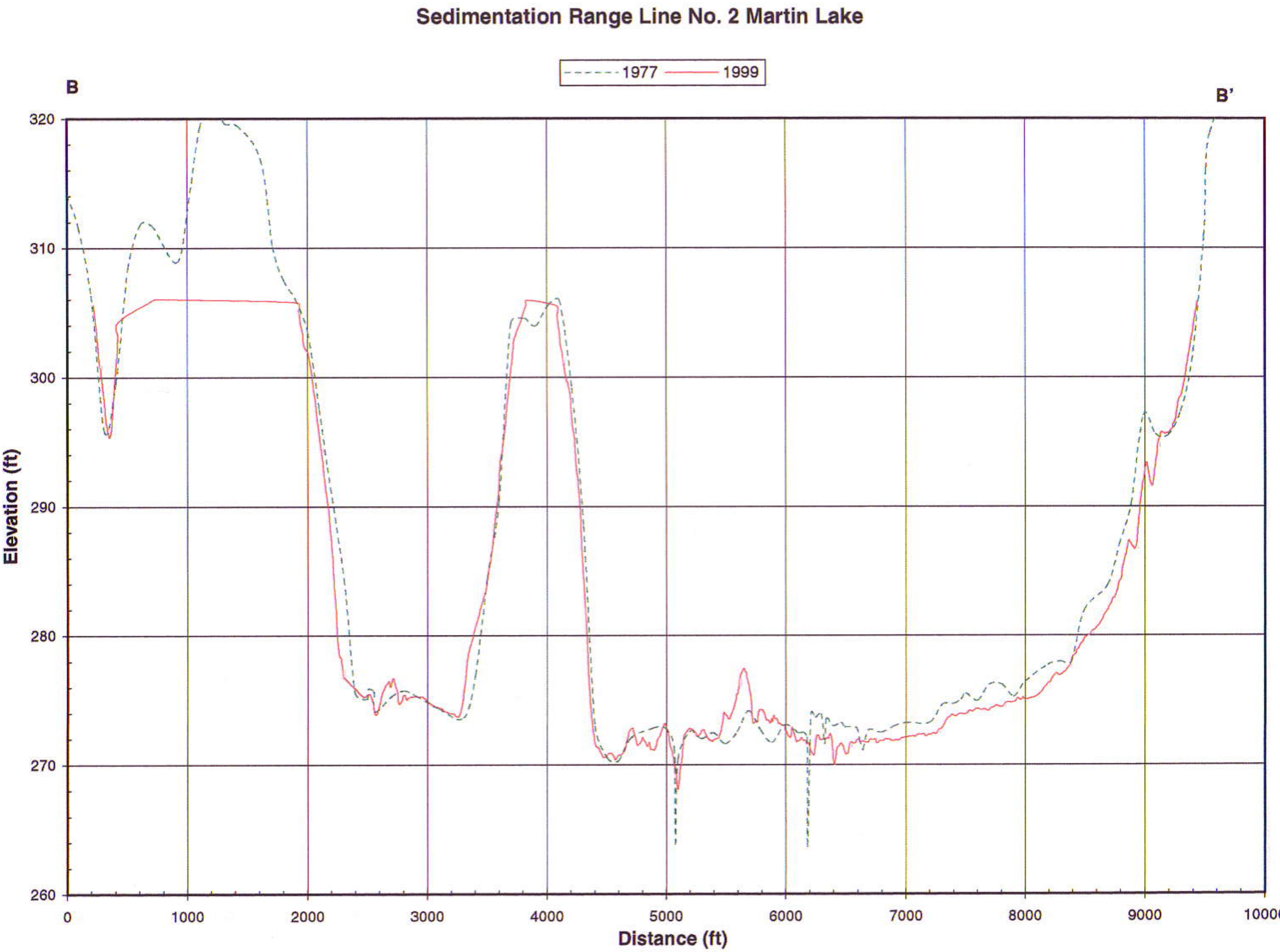


Martin Lake
May-June 1999
Prepared by: TWDB August 1999

Sedimentation Range Line No.1 Martin Lake

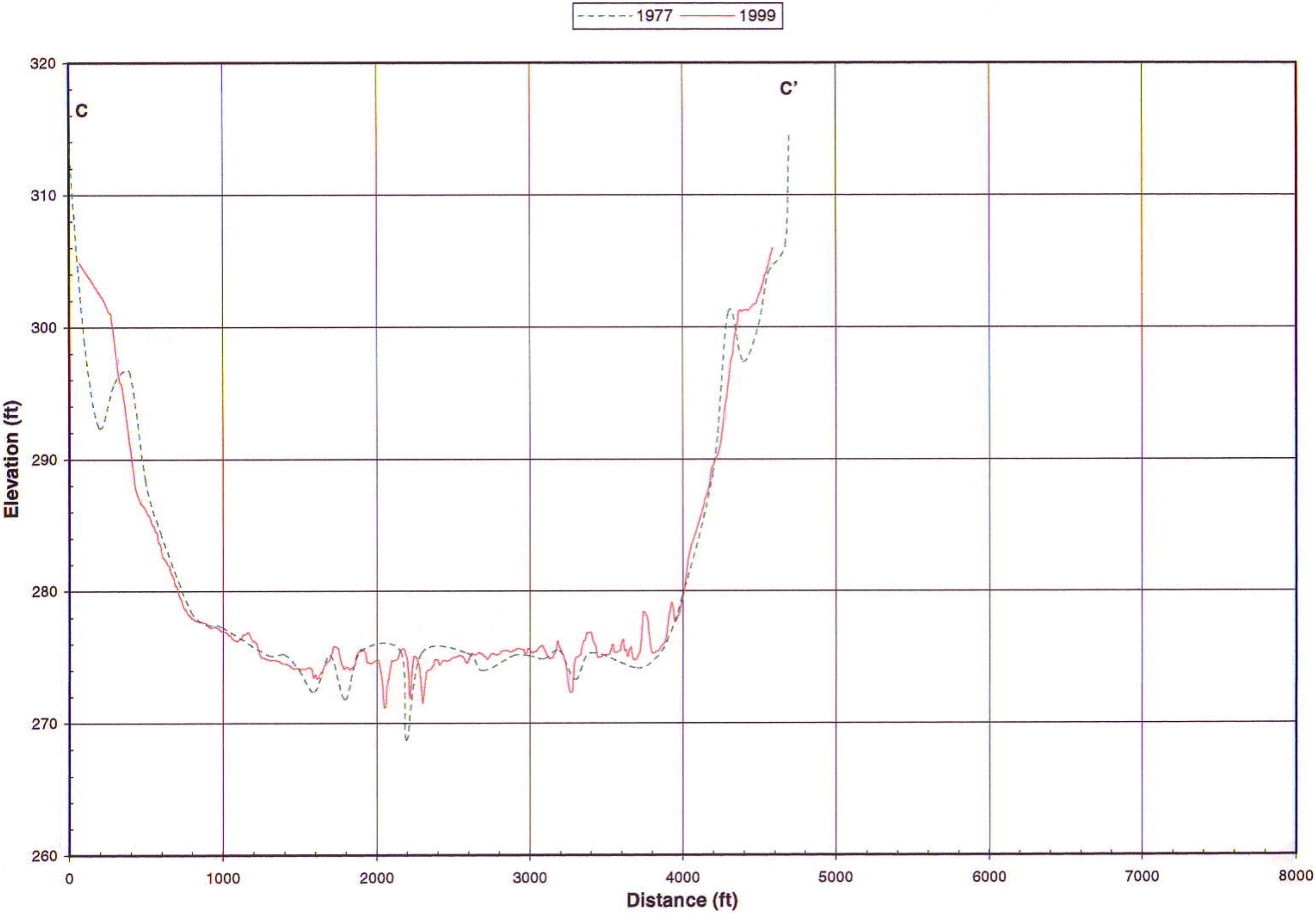


Appendix D


Sedimentation Range Line No. 2 Martin Lake
1977
1999
B
B'
Elevation (ft)
320
310
300
290
280
270
260
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (ft)

Appendix D

Sedimentation Range Line No. 3 Martin Lake



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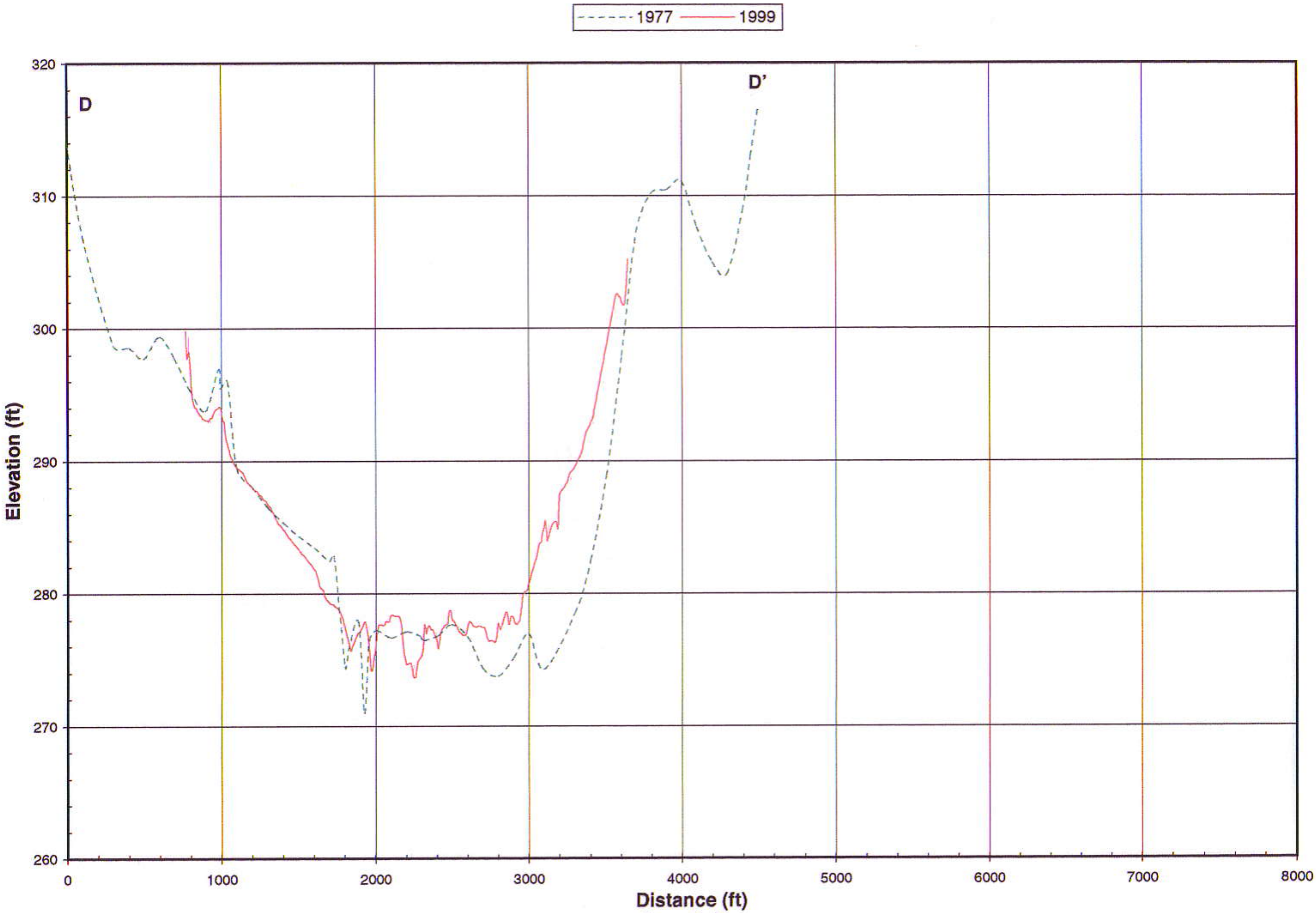
Sedimentation Range Line No. 4 Martin Lake



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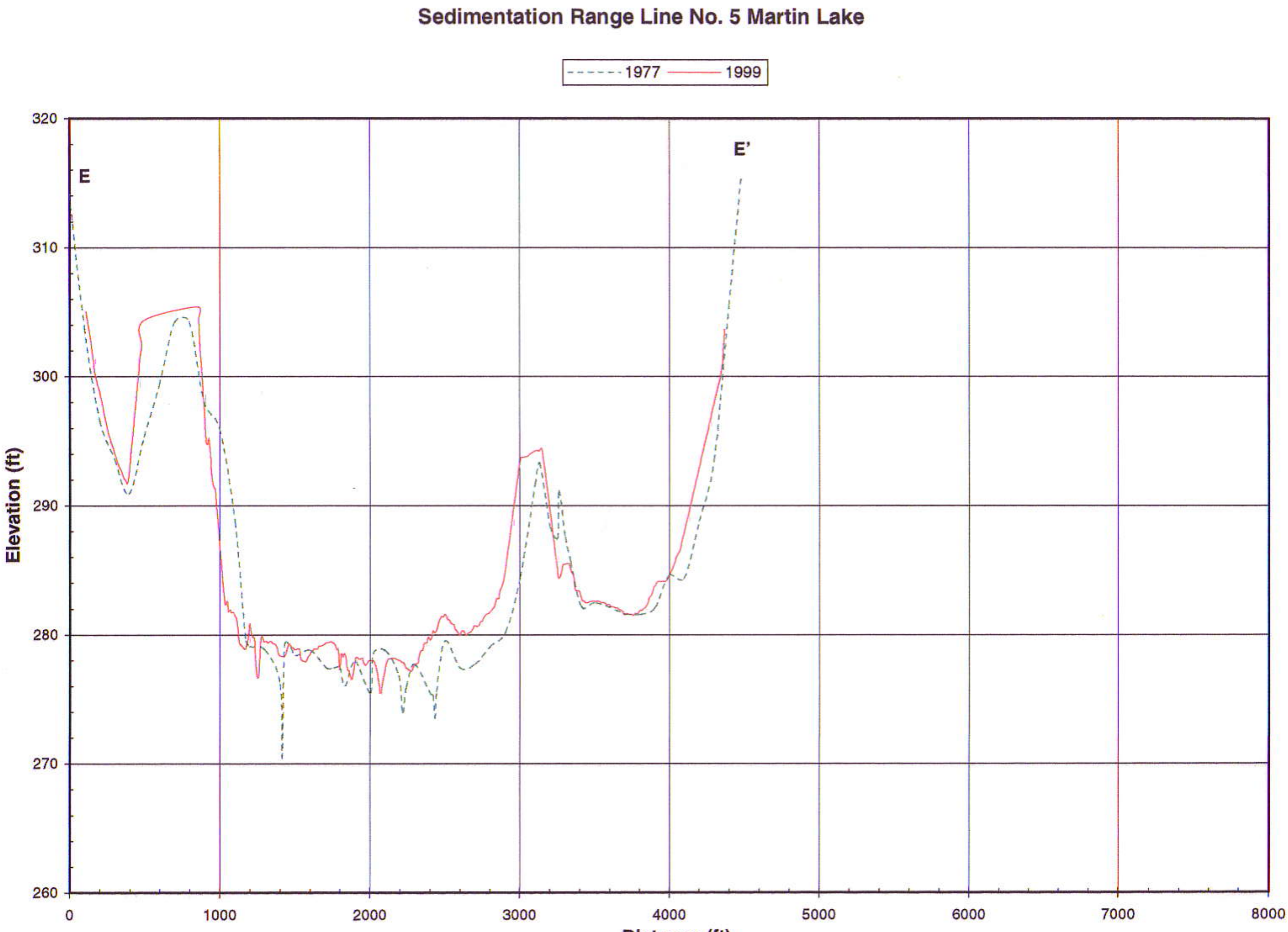
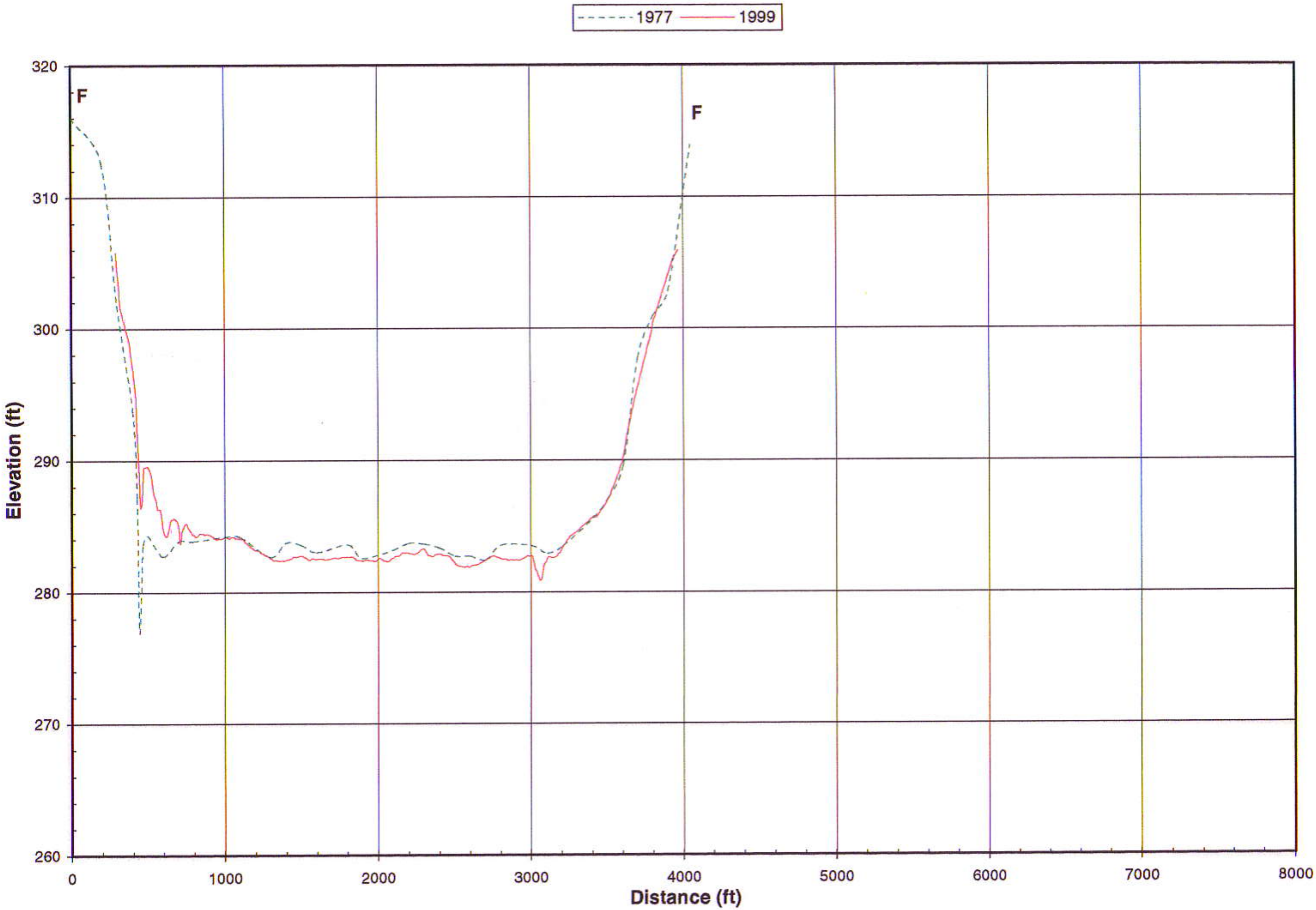

Sedimentation Range Line No. 5 Martin Lake
1977
1999
E
E'
Elevation (ft)
320
310
300
290
280
270
260
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (ft)

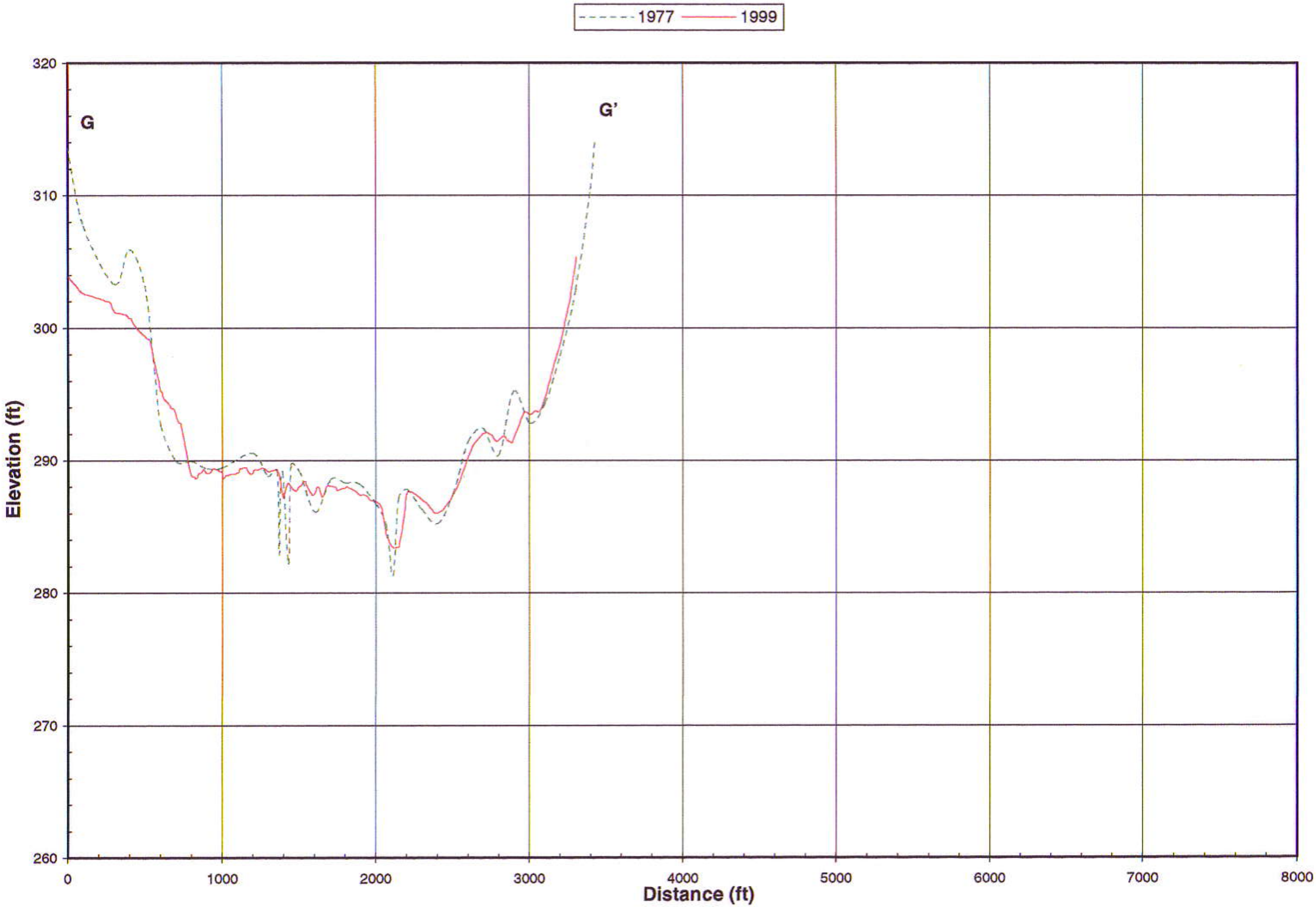
Appendix D

Sedimentation Range Line No. 6 Martin Lake



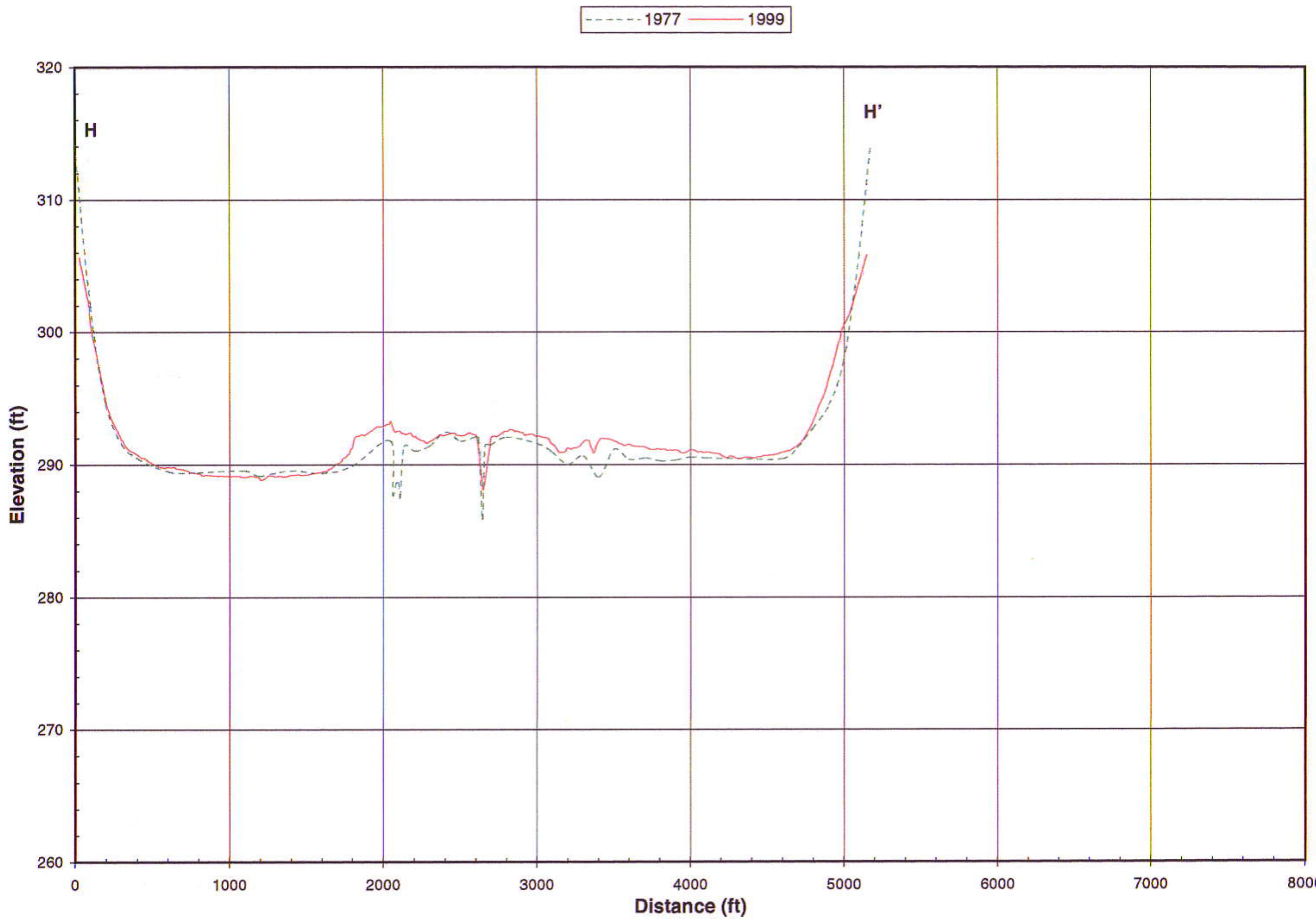
Appendix D

Sedimentation Range Line No. 7 Martin Lake

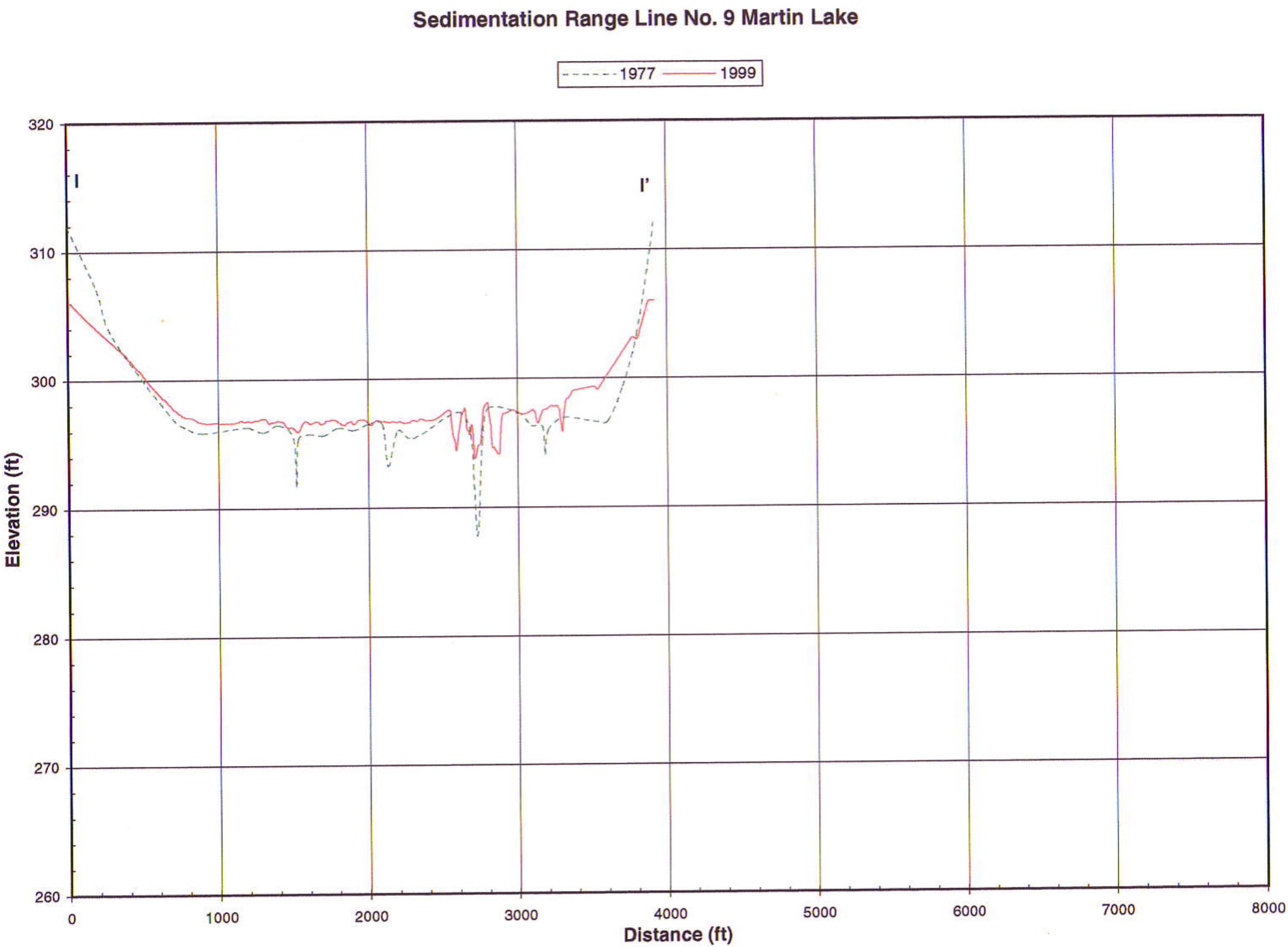


Appendix

Sedimentation Range Line No. 8 Martin Lake

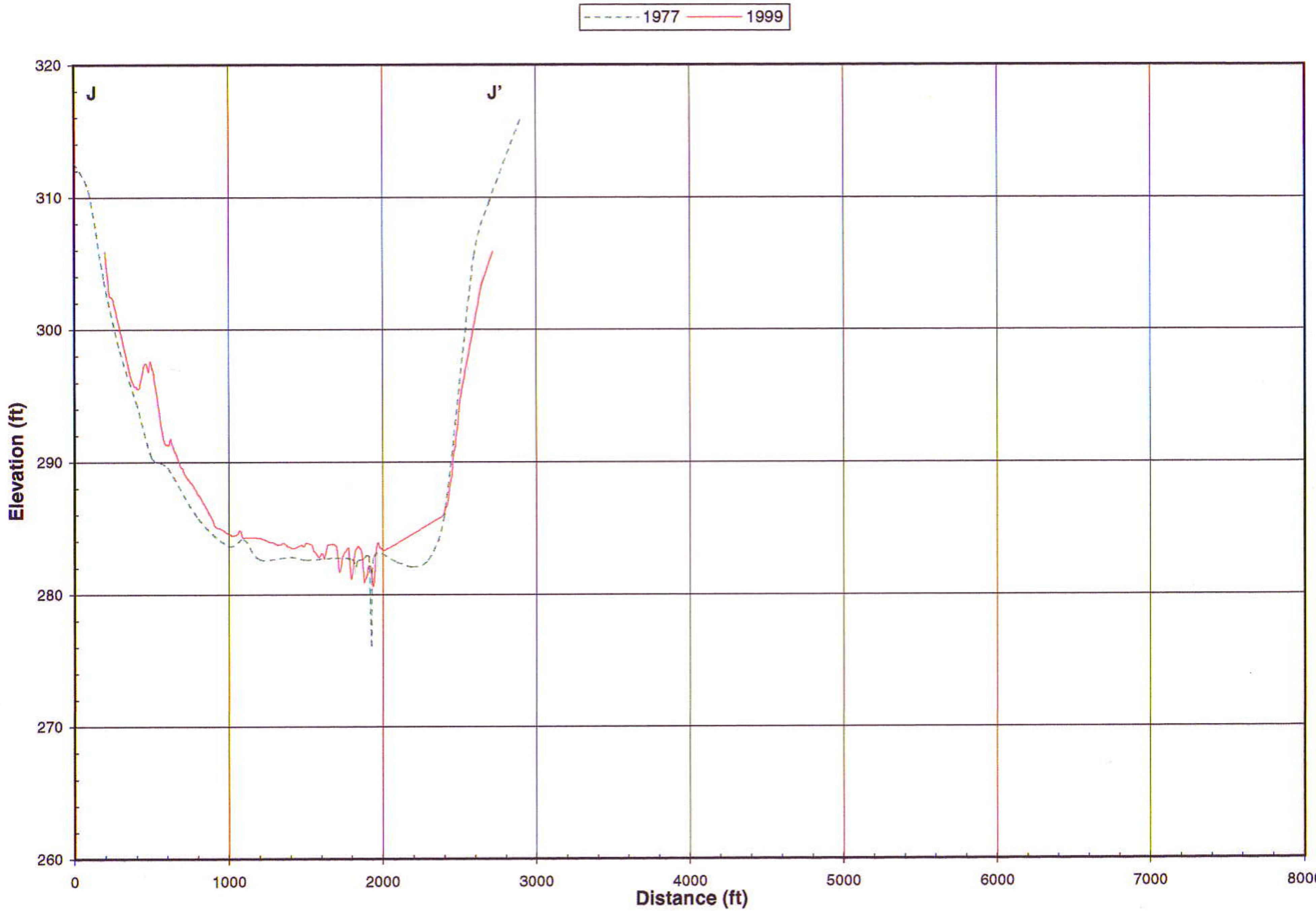


Appendix D

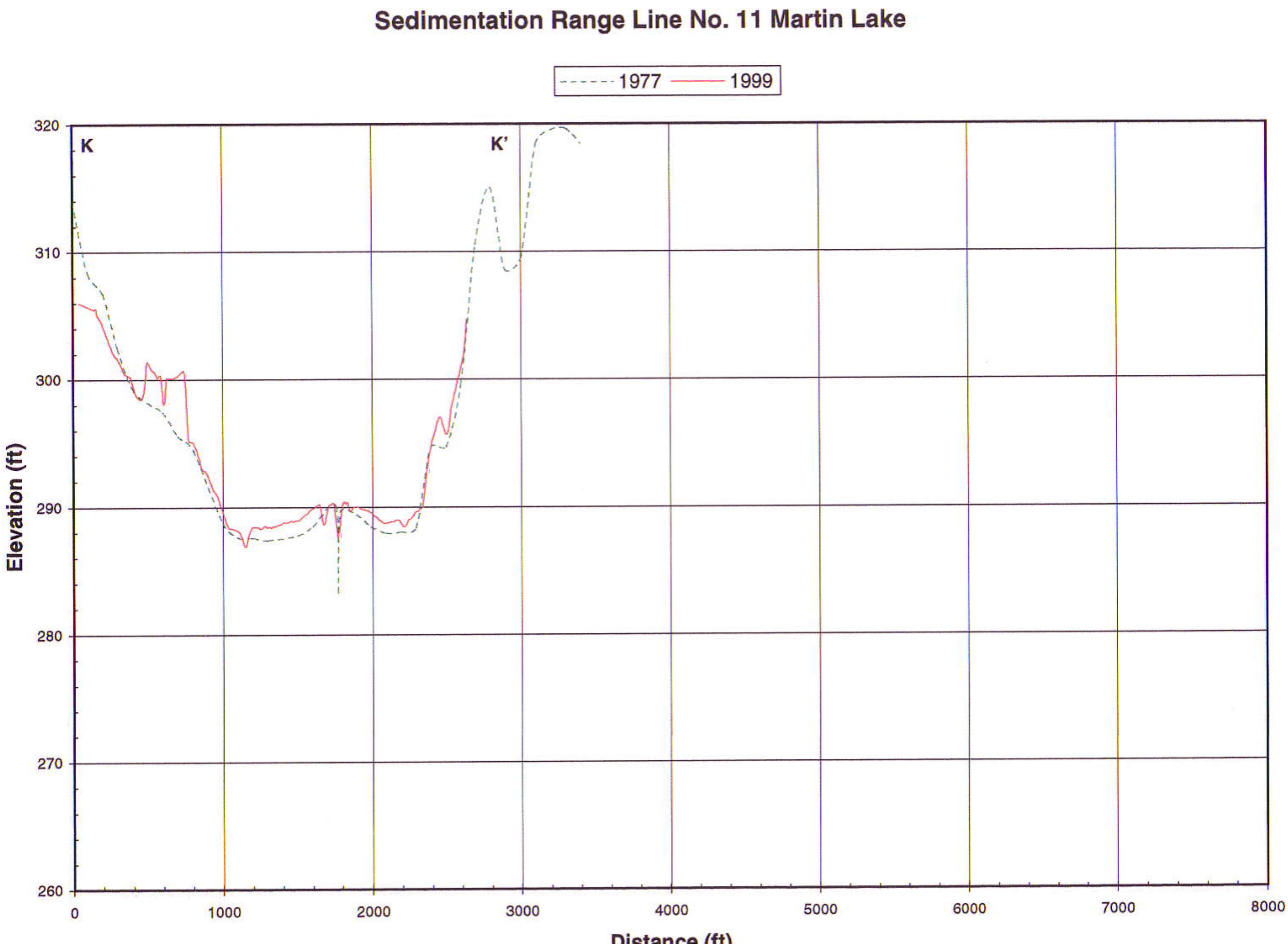

Sedimentation Range Line No. 9 Martin Lake
1977
1999
I
I'
320
310
300
290
280
270
260
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (ft)

Appendix D

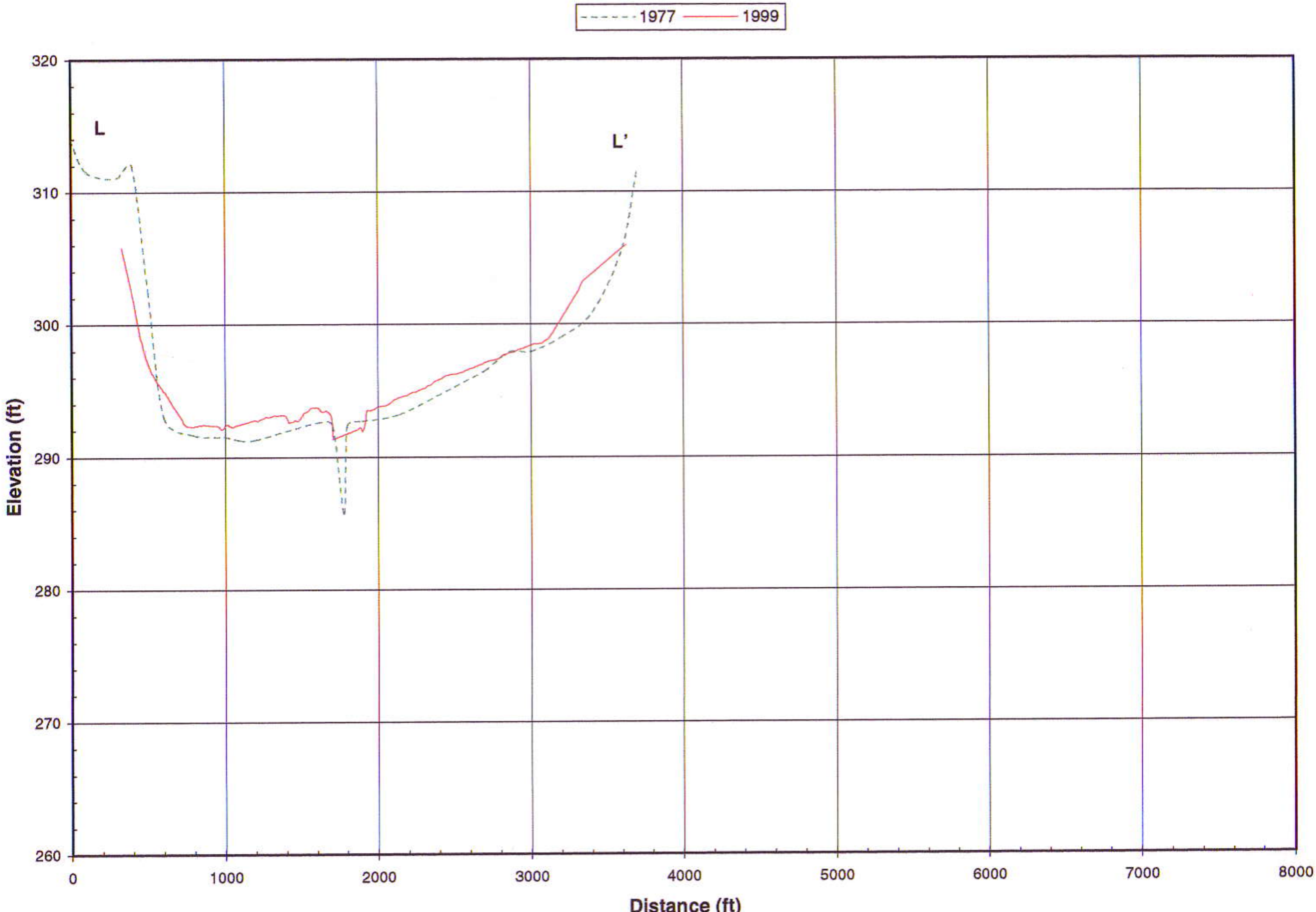
Sedimentation Range Line No. 10 Martin Lake



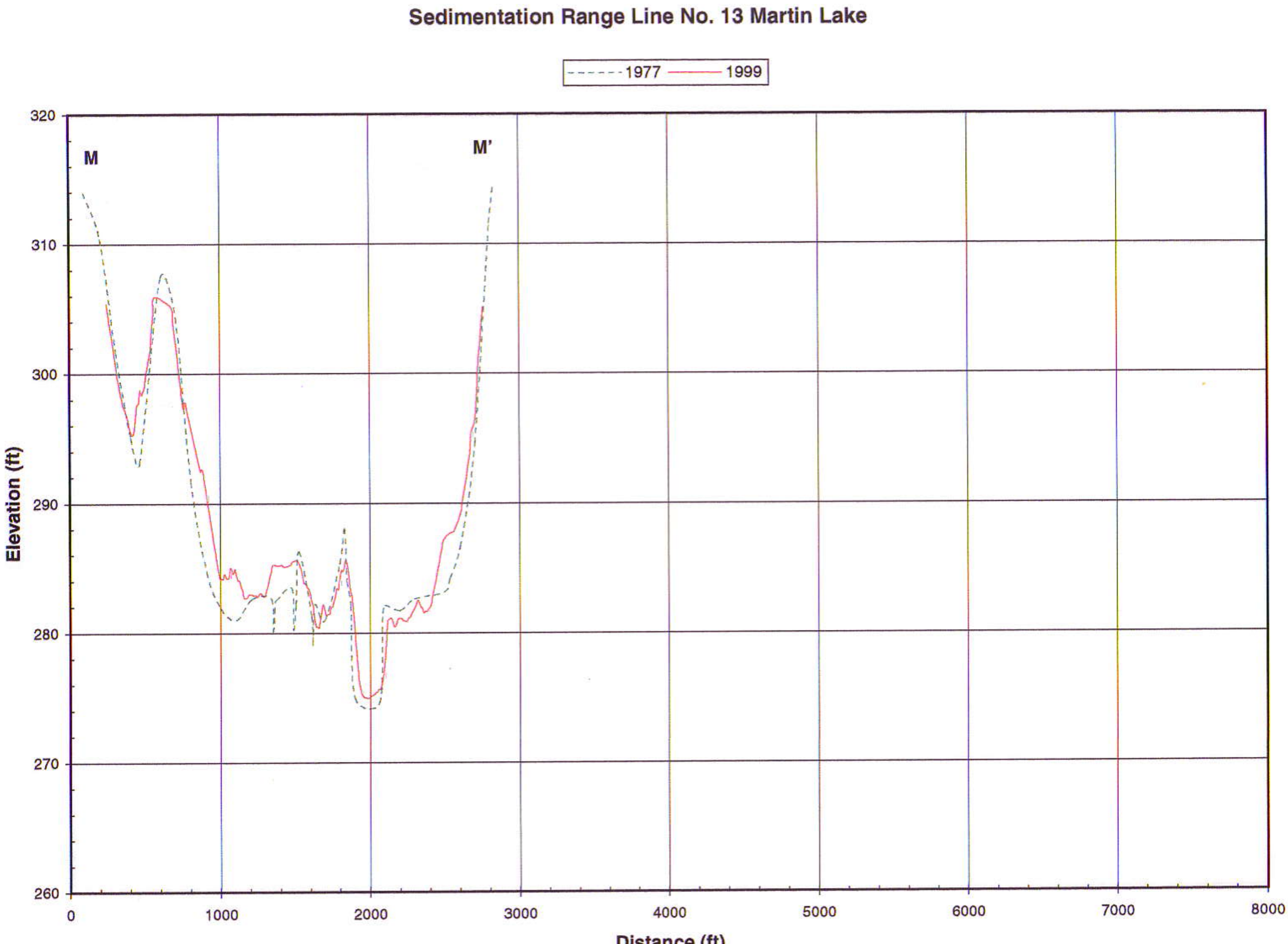
Appendix D


Sedimentation Range Line No. 11 Martin Lake
1977
1999
K
K'
Elevation (ft)
320
310
300
290
280
270
260
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (ft)
Appendix D

Sedimentation Range Line No. 12 Martin Lake



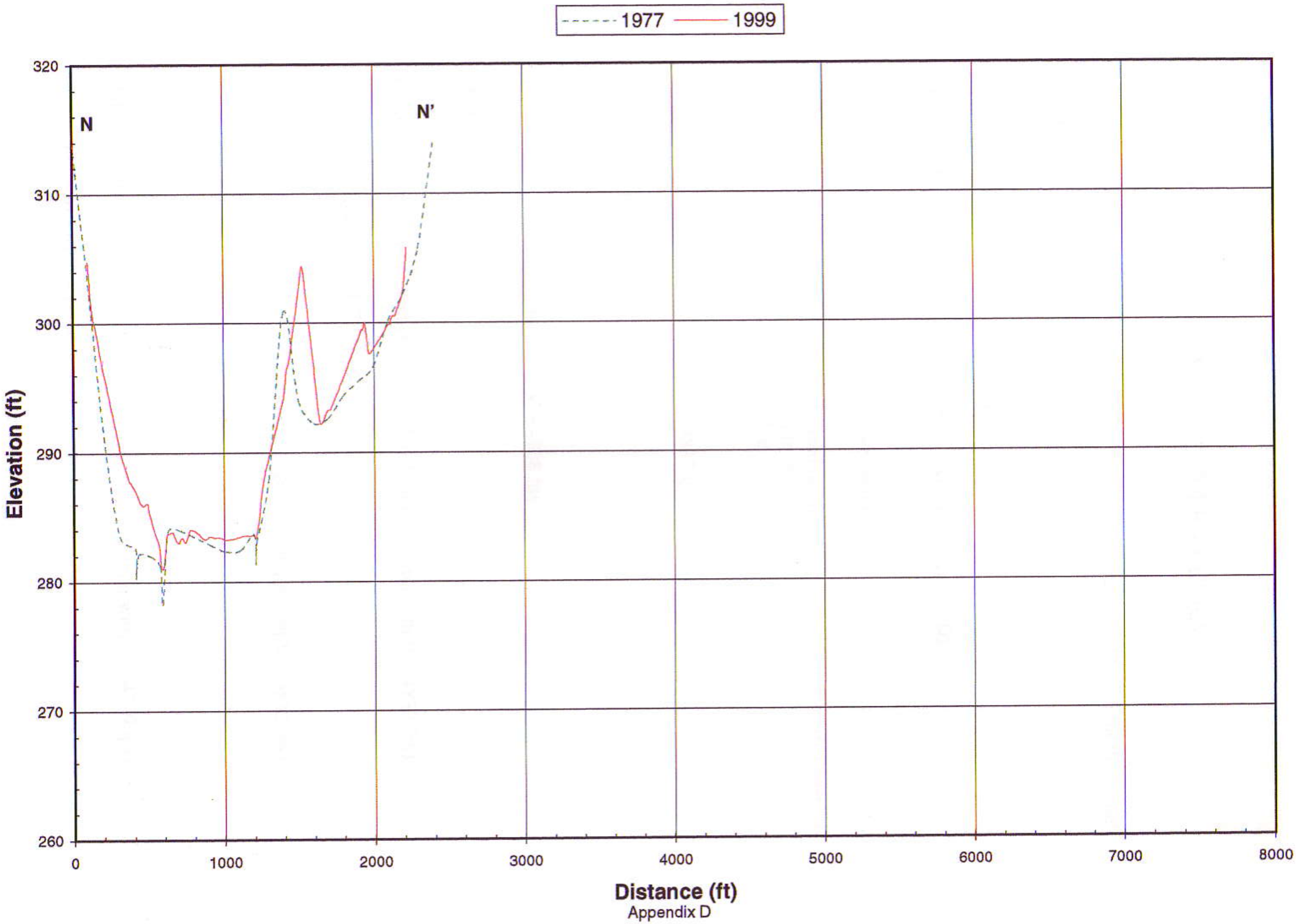
Appendix D



Sedimentation Range Line No. 13 Martin Lake
1977
1999
M
M'
Elevation (ft)
320
310
300
290
280
270
260
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (ft)

Appendix D

Sedimentation Range Line No. 14 Martin Lake



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.

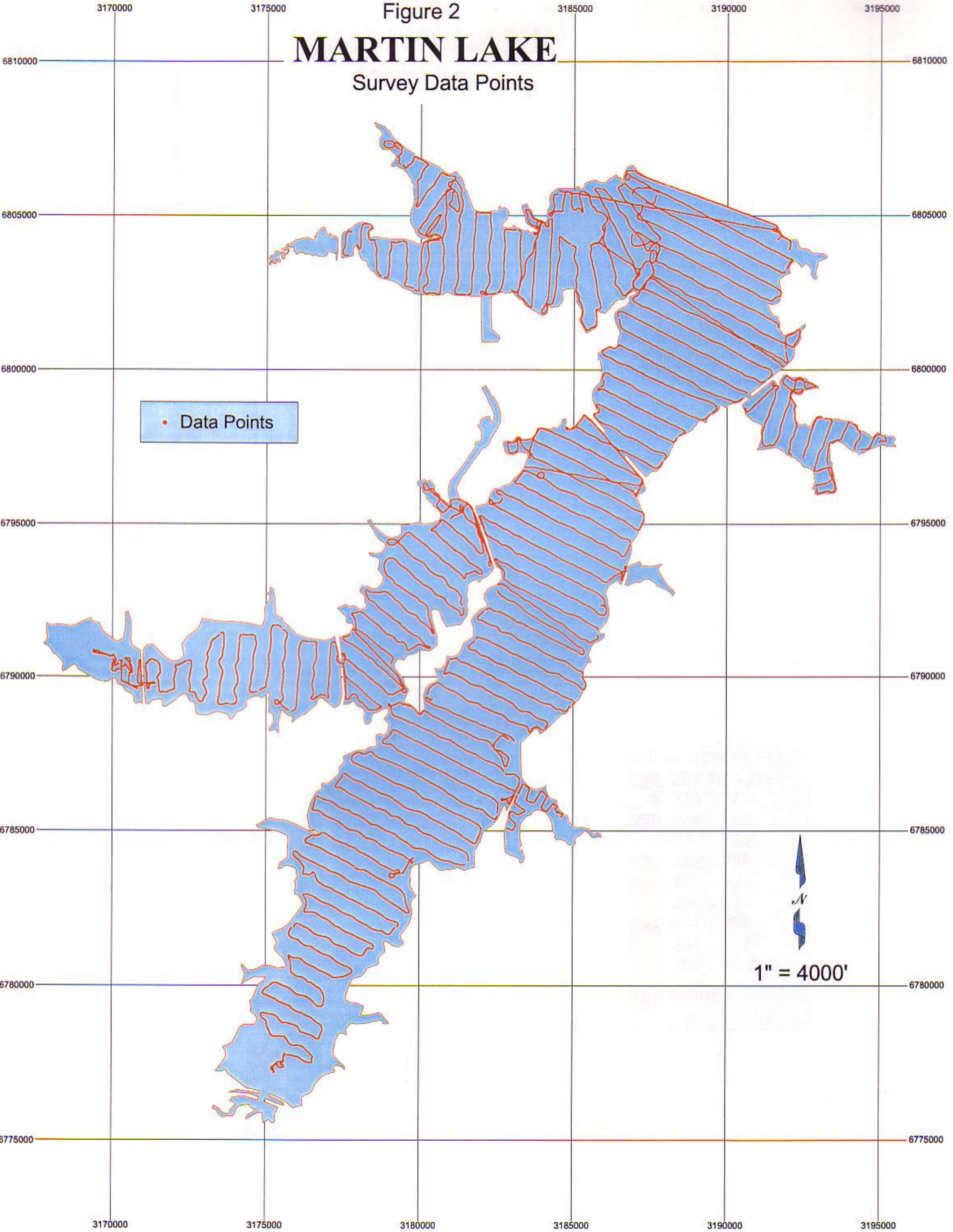
More recently, aerial photography has been used prior to construction to generate elevation contours from which to calculate the volume of the reservoir. Fairly accurate results could be obtained, although the vertical accuracy of the aerial topography is generally one-half of the contour interval or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

Prepared by : TWDB September 1999

Figure 2

MARTIN LAKE

Survey Data Points

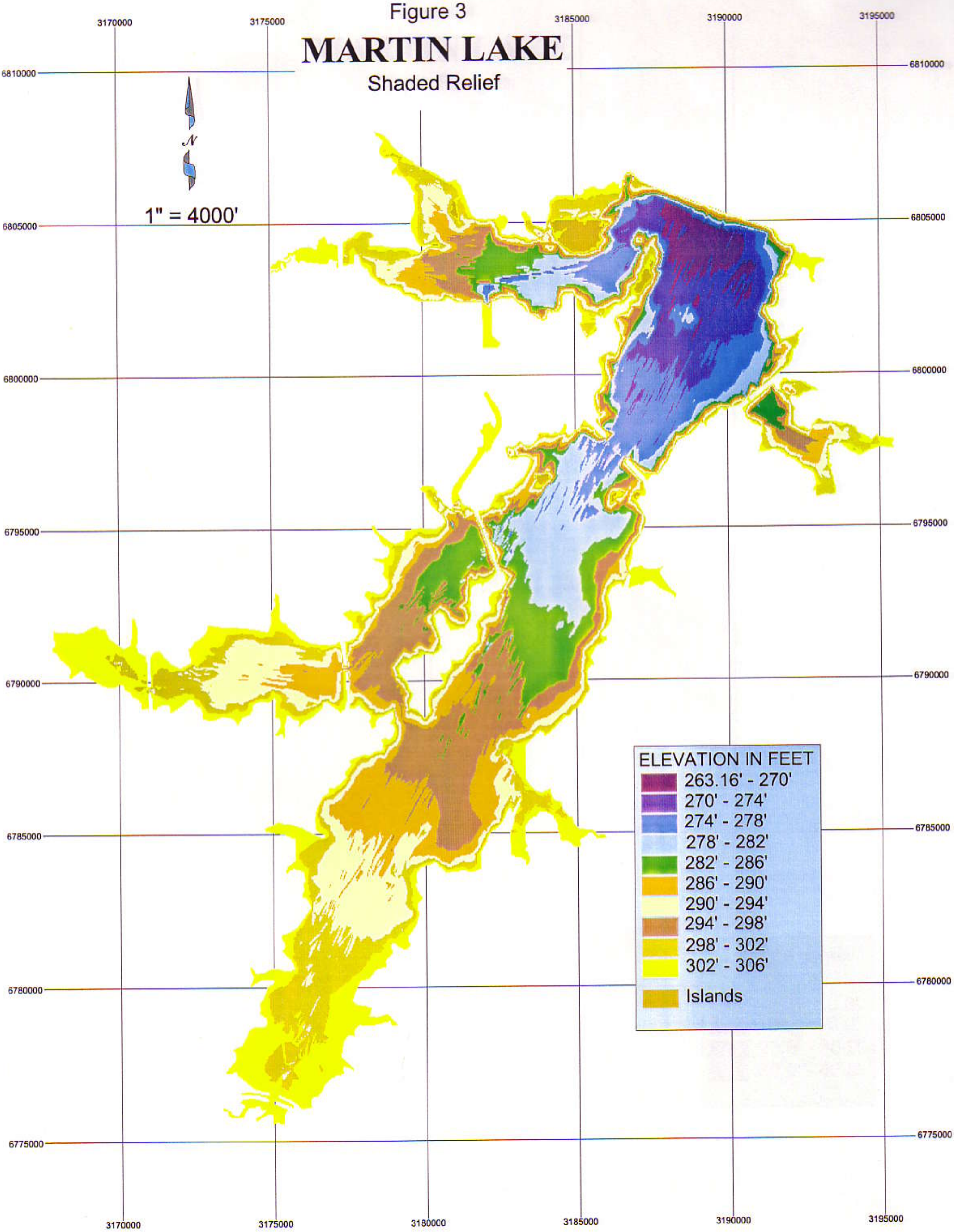


Prepared by: TWDB SEPTEMBER

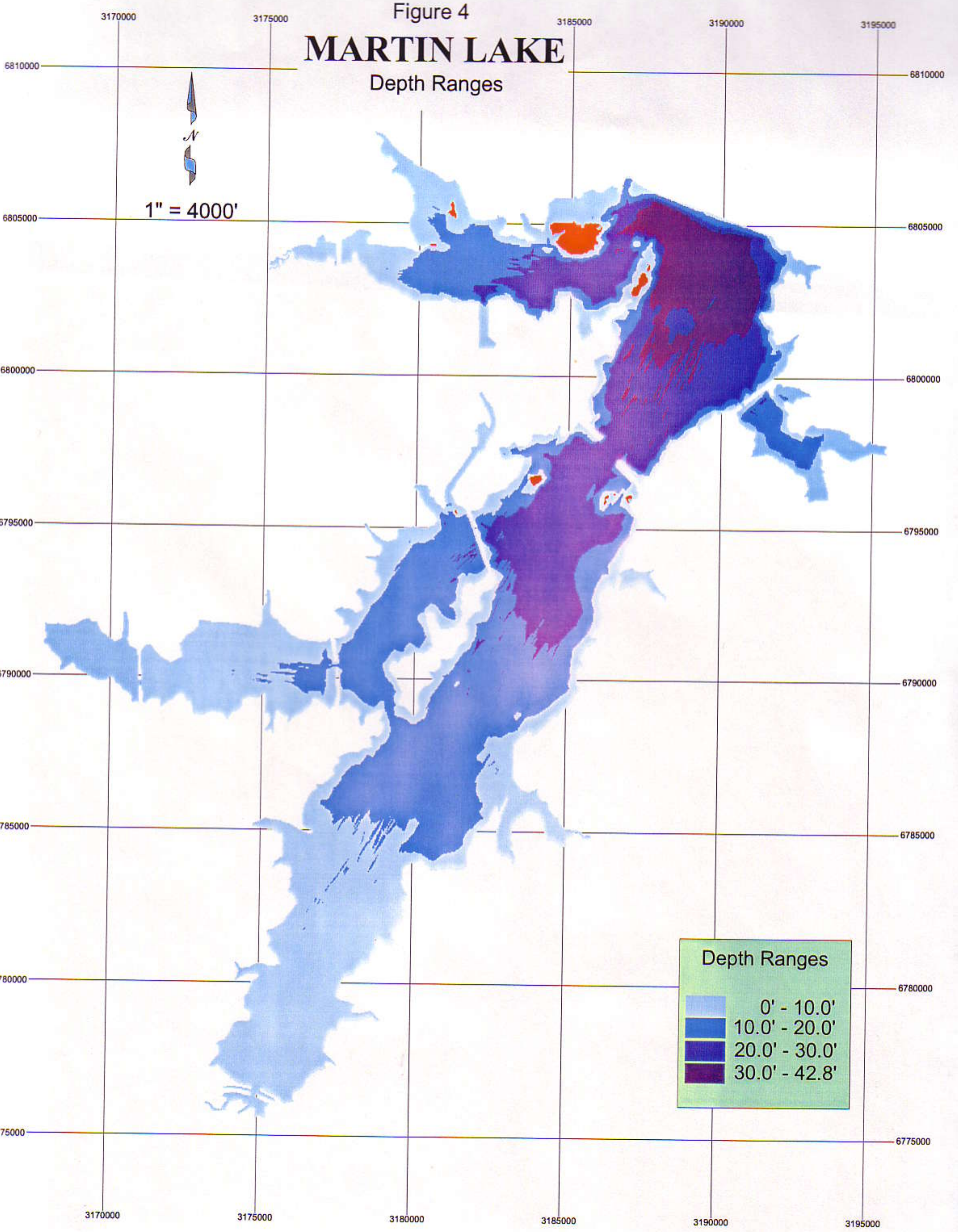
Figure 3

MARTIN LAKE

Shaded Relief



Prepared by : TWDB MARCH 1999



Prepared by : TWDB SEPTEMBER 1999