VOLUMETRIC SURVEY
OF
CHOKE CANYON RESERVOIR

Prepared for:

THE CITY OF CORPUS CHRISTI

Prepared by:

The Texas Water Development Board

March 10, 2003

Texas Water Development Board

Craig D. Pedersen, Executive Administrator

Texas Water Development Board

Charles W. Jenness, Chairman *Wesley E. Pittman, Vice Chairman*
William B. Madden *Noe Fernandez*
Diane E. Umstead *Othon Medina, Jr.*

Authorization for use or reproduction of any original material contained in this publication, i.e. not obtained from other sources, is freely granted. The Board would appreciate acknowledgement.

This report was prepared by the Hydrographic Survey group:

Carol R. Hearn, P.E., R.P.L.S.
Duane Thomas
Randall Burns

For more information, please call (512) 445-1471

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

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

CHOKE CANYON RESERVOIR
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrologic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Choke Canyon 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

Choke Canyon Reservoir is owned by the City of Corpus Christi (seventy-eight percent), Nueces River Authority (twenty percent), and the City of Three Rivers (two percent). The reservoir inundates parts of Live Oak and McMullen Counties and the dam is located three and one-half miles northwest of Three Rivers, Texas, on the Frio River (See Figure 1). Choke Canyon Dam was designed by the United States Department of the Interior Bureau of Reclamation, the engineer of record. The general contractor, Holloway Construction Company, began Construction in August, 1978 and completed the project in October, 1982. The reservoir filled in 1987.

Application No. 3631 was filed with the Texas Water Rights Commission on July 19, 1976 by the City of Corpus Christi and the Nueces River Authority to appropriate 139,100 acre-feet of water annually by impounding a maximum of 700,000 acre-feet at a normal operating elevation of 220.5 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.

Allocation of the 139,100 acre-feet of water was as follows: 59,770 acre-feet for municipal use in Nueces, San Patricio, Aransas, Jim Wells, Live Oak, Kleberg, Bee, McMullen and Atascosa Counties; 78,730 acre-feet for industrial use in Nueces, San Patricio, Aransas, Jim Wells, Live Oak, Kleberg, Bee, McMullen and Atascosa Counties; 500 acre-feet for domestic and livestock use in Live Oak and McMullen Counties; and 100 acre-feet for construction use in Live Oak County for four years during the period of construction of the dam and reservoir.

Permit No. 3358 was granted on October 12, 1976, with "Time Limitations" for the construction of the dam and "Special Conditions" for downstream releases following the completion and filling of Choke Canyon Dam and Reservoir. Certificate of Adjudication No. 3214 was issued May 11, 1984, to the City of Corpus Christi and the Nueces River Authority. The Certificate of Adjudication was essentially the same as Permit No. 3358, except for the following changes: 100 acre-feet used for the construction of the dam was no longer in affect; Duval County was added to the list of counties for municipal and industrial use; the owners were authorized to use the impounded waters of Choke Canyon Reservoir for nonconsumptive recreational purposes; and the "Time Limitations" were deleted but the "Special Conditions" remained. Records indicate the City of Corpus Christi granted two percent of its eighty percent interest in Certificate of Adjudication No. 3214 to the City of Three Rivers on December 3, 1984.

Choke Canyon Dam is a rolled earthfill structure approximately three and one-half miles long with a height of 114 feet above the streambed. The dam crest is at elevation 241.1 feet. A cutoff trench with an impermeable clay core and a sand and gravel-filled toe drain are integral elements of the structure. The service/emergency spillway is a concrete ogee structure, approximately 368 feet wide with a crest elevation of 199.5 feet. Controls for the spillway consist of seven radial gates (49.2 feet by 23.7 feet), with a top-of-gate elevation of 223.2 feet. The intake tower for the river outlet works is a concrete structure outfitted with four multilevel gates at elevations 203.0, 181.5, 150.0 and 136.4 feet. The engineer's estimate after construction indicates the storage capacity of the reservoir at the conservation pool elevation of 220.5 feet is 691,130 acre-feet with a surface area of 25,733 acres.

HYDROGRAPHIC SURVEYING TECHNOLOGY

The following sections will describe the equipment and methodology used to conduct this hydrographic survey. Some of the theory behind Global Positioning System (GPS) technology and its accuracy are also addressed.

GPS Information

The following is a brief and simple description of 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 utilized on February 22, 1978, when the initial 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, 23 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 Choke Canyon 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. The large positional errors experienced by a single receiver when S/A is active are greatly reduced by utilizing DGPS. The reference receiver calculates satellite corrections based on its known fixed position, which results in positional accuracies within 3 meters for the moving receiver. DGPS was used to determine horizontal position only. Vertical information was supplied by the depth sounder.

TWDB staff verified the horizontal accuracy of the DGPS used in the Choke Canyon survey to within the specified accuracy of three meters. The shore station was placed over a known United States Geological Service (USGS) first order monument and set in differential mode to broadcast positional corrections. The second receiver, directly connected to the boat with its interface computer, was placed over another known USGS first order monument and set to receive and process the corrections. Based on the differentially-corrected coordinates obtained and the published coordinates for these points, the results compared within 2.8 meters.

Equipment

The equipment used in the hydrographic survey of Choke Canyon 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 Model 449 Depth Sounder and Model 443 Velocity Profiler, a Trimble Navigation, Inc. 4000SE GPS receiver, a Motorola Radius radio with an Advanced Electronic Applications, Inc. packet modem, and an on-board computer. The computer 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. Reference to brand names does not imply endorsement by the TWDB.

The shore station included a second Trimble 4000SE GPS receiver, Motorola Radius radio and Advanced Electronic Applications, Inc. packet modem, and an omni-directional antenna mounted on a modular aluminum tower to a total height of 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.

As the boat traveled across the reservoir surface, the depth sounder gathered approximately ten readings of the reservoir bottom each second. Positional corrections were received once per 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 reservoir elevation. The set of data points logged during the survey were used to calculate the reservoir volume. Accurate estimates of the reservoir 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 reservoir volumes.

Survey Methods

The Hydrographic Survey crew set a benchmark in February, 1992 that would serve as a control point for the shore station site. A brass cap marked TWDB #005 was embedded into a concrete slab at the TWDB evaporation station located near the Choke Canyon maintenance facility. This location was chosen because of the close proximity to the reservoir, the unobstructed view of the reservoir, and the security of the area.

A static survey using the two Trimble 4000SE GPS receivers was performed to obtain coordinates for the TWDB benchmark. One GPS receiver was positioned over a USGS first-order monument named WHITSETT, located approximately twelve miles north of the reservoir. WHITSETT was established in 1952. 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 #005.

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, a geodetic representation of the earth. The WGS' 84 coordinates for TWDB #005 were determined to be North latitude 28° 28' 04.92", West longitude 98° 15' 08.03", and ellipsoid height of 54.06 meters. The approximate NGVD '29 elevation is 264.77 feet. Those coordinates were then entered into the shore station receiver located over TWDB #005 to fix its location and allow calculation and broadcasting of corrections through the radio and modem to the roving receiver located on the boat.

Due to the size of the reservoir, a second shore station site was required to maintain contact with the roving receiver. Once the survey began, the location for the second benchmark was determined from the range of the first shore station. The second shore station site is approximately 5 miles north of the intersection of Texas Farm Road 99 and Texas Highway 72, on Federal property that is managed by the Texas Parks and Wildlife Department. A brass cap marked TWDB #006 is located approximately seventy-seven feet north of the northwest fence corner.

The same procedure discussed above was used to establish coordinates for TWDB #006, with TWDB #005 as the known point. The WGS '84 coordinates for TWDB #006 were determined to be North Latitude 28° 31' 00.25", West Longitude 98° 24' 38.83", and ellipsoid height of 56.75 meters. The approximate NGVD '29 elevation height is 272.65 feet.

The reservoir surface area was determined by digitizing an approximation of the 220.5 contour from six USGS quad sheets that were dated from 1965 to 1968. The quad sheet that contains the dam was photorevised in 1984 from 1983 aerial photographs, and was incorporated into the graphical estimate of the boundary. Intergraph Microstation CADD software was used to digitize the boundary based in the North American Datum of 1927 (NAD '27) used for the quad sheets. The graphic boundary was then transformed from NAD '27 to the North American Datum of 1983 (NAD '83) using Microstation Projection Manager, since the positions received from the satellites are WGS '84 spherical positions. 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 transformed from WGS '84 to NAD '83. The resulting shape was modified slightly to match information gathered in the field, resulting in 25,989 acres at the normal pool elevation. This is one percent more than the record acreage of 25,733.

The survey layout was pre-planned, using approximately 210 survey lines at a spacing of 500 feet. Innerspace Technology Inc. software was utilized for navigation and to integrate and store positional data along with depths. In areas where vegetation or obstructions prevented the boat from traveling the planned line, random data were collected wherever the boat could maneuver. Additional random data were collected lengthwise in the reservoir. Data points were entered into the data set utilizing the DGPS horizontal position and manually poling the depth in shallow areas where the depth was less than the minimum recordable depth of the depth sounder, which is about 3.5 feet. Figure 2 shows the actual location of the data collection sites. Data were not collected in areas that were inaccessible due to shallow water or obstructions. The data set included approximately 150,000 data points.

.

For DGPS operation the reference station receiver was set to a horizontal mask of 0°, to acquire information on the rising satellites. A horizontal mask of 10° was used on the roving receiver for better satellite geometry and thus better horizontal positions. The DGPS positions were within acceptable limits of horizontal accuracy with a PDOP (Position Dilution of Precision) of seven (7) or less. The GPS receivers have an internal alarm that sounds if the PDOP rises above the maximum entered by the user, to advise the field crew that the horizontal position has degraded to an unacceptable level.

The depth sounder measures speed by measuring the time between the transmission of the sound pulse and the reception of its echo. The depth sounder was calibrated with the Innerspace Velocity Profiler typically once per day, unless the maximum depth varied by more than twenty feet. The velocity profiler calculates an average speed of sound through the water column of interest (typically set at a range of two feet below the surface to about ten feet above the maximum encountered depth), and the draft value or distance from the transducer to the surface. The velocity profiler probe is placed in the water to wet the transducers, then raised to the water surface where the depth is zeroed. The probe is then lowered on a cable to just below the maximum depth set for the water column, and then raised to the surface. The unit reads out an average speed of sound for the water column and the draft measurement, which are then entered into the depth sounder. The speed of sound can vary based on temperature, turbidity, density, or other factors. Based on the measured speed of sound for various depths, and the average speed of sound calculated for the entire water column, the depth sounder is accurate to within $\pm$0.2 feet, plus an estimated error of $\pm$0.3 feet due to boat movement for a total accuracy of $\pm$0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey. Further information on these calculations is presented in Appendix A, Page 1. Manual poling of depths within shallow areas agreed with the depth obtained by the depth sounder typically within $\pm$ 0.3 feet.

Analog charts were printed for each survey line as the data were collected. The gate mark, which is a known distance above the actual depth that was recorded in the data file, was also printed on the chart. Each analog chart was analyzed, and where the gate mark indicated that the recorded depth was other than the bottom profile, depths in the corresponding data files were modified accordingly. The depth sounder was set to record bad depth readings as 0, and all points with a zero depth were deleted.

Each data point consisted of a latitude, longitude and depth. The depths were transformed to elevations with a simple awk Unix command based on the water surface elevation each day of the survey. Elevations during the survey varied from 219.9 to 220.0 feet, or 0.5 to 0.6 feet below normal pool elevation, rounded to the nearest tenth of a foot since the depth sounder reads in tenths of a foot. The data set was then loaded into an existing Microstation design file with the Microstation ASCII Loader product. The design file contained the NAD '83 boundary previously discussed in this report. The data points along with the boundary were used to create a digital terrain model (DTM) of the reservoir's bottom surface using the Microstation Terrain Modeler product. This software uses a method known as Delauney's criteria for triangulation. A triangle is formed between three non-uniformly spaced points, including all points along the boundary. If there is another point within the triangle, additional triangles are created until all points lie on the vertex of a triangle. This method preserves all data points for use in determining the solution. The set of three-dimensional triangular planes represents the actual bottom surface. Once the triangulated irregular network (TIN) is formed, the software then calculates elevations along the triangle surface plane by solving the equations for elevation along each leg of the triangle. Areas that were too shallow for data collection or obstructed by vegetation were estimated by the Modeler product using this method of interpolation. Any 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. From this three-dimensional triangular plane surface representation, the Modeler product calculated the surface area and volume of the entire reservoir at one-tenth of a foot intervals.

The three-dimensional triangular surface was then converted to a regular matrix of elevation values, or a grid. A grid spacing of one hundred feet was chosen for this presentation, to produce an illustration that would be easy to visualize, but not so dense that it would obscure features. Figure 3 is a graphical representation of a grided version of the three-dimensional DTM.

The DTM was then smoothed and linear smoothing algorithms were applied to the smoothed model to produce smoother contours. The following smoothing options were chosen for this model: Douglas-Peucker option with a zero tolerance level to eliminate any duplicate points, and Round Corners with a delta of 50 feet in an attempt to smooth some of the angularity of the contours. Contours of the bottom surface at five foot intervals are presented in Figure 4. Typical cross-sections of the reservoir are included in Appendix B, Page 1.

DATA

Choke Canyon Reservoir inundates more than 30 river miles of the Frio River. The reservoir is comprised of a large open body approximately six and one-half miles long and an average of four miles wide. Upstream of the large body, the main channel is an average of one mile in width for over eleven miles, and then narrows into the old river channel. Finger inlets can be found surrounding the entire lake. The deepest portions of the reservoir are found within the area immediately adjacent to the dam. The cross sections reflect a well defined channel cut through a relatively flat flood plain with moderately steep side slopes throughout the wider portions of the reservoir. Once into the upper reaches, the cross-sections do not depict the wide inundated flood plain evident in the lower portion.

Choke Canyon Reservoir was estimated by this survey to encompass 25,989 acres and to contain a volume of 695,271 acre-feet at the normal pool elevation of 220.5 feet. The reservoir volume table is presented in Appendix C, Page 1, and the area table in Appendix D, Page 1. The one-tenth foot intervals are based on actual calculations from the model. The one-hundredth foot intervals are interpolated based on a straight line interpolation between one-tenth foot intervals. An elevation-area-volume graph is presented in Appendix E, Page 1. Since the surface elevation of the reservoir was approximately 0.5 feet low on date of the survey and the boat can only negotiate in approximately 1.8 feet of water, at a minimum the upper 2.3 feet are estimated based on a straight-line interpolation from the last data points collected to the normal pool elevation reservoir boundary as digitized. Any difference between the actual bottom and the estimated bottom is not believed to significantly effect the volume calculation, since the total volume within the shallow areas is small. The positional data collected in the field corresponds well with the boundary obtained from the USGS maps. 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 six tenths of one percent more than the previous estimated capacity for the reservoir, and is attributed to different and improved calculation techniques. An aerial topo of the upper four feet of the lake or an aerial photo taken when the lake is at the normal pool elevation would more closely determine the present boundary. However, at this stage, the minimal increase in accuracy does not appear to offset the cost of these services.

The low flow outlet is at elevation 136.4 feet, resulting in an estimated dead storage of nine (9) acre-feet. Therefore the conservation storage for the reservoir is calculated to be 695,262 acre-feet.

SUMMARY

The lowest elevation encountered during this survey was 127.5 feet, or 93 feet of depth. The conservation storage was calculated to be 695,262 acre-feet. The estimated storage capacity is 4,738 acre-feet less than that recorded in the permit, and 4,141 acre-feet (six tenths of one percent) more than the estimated capacity after construction. Use of the same calculation methodology in five to ten years or after major flood events should remove any noticeable differences due to improved calculation techniques and will help isolate any storage loss due to sedimentation.

CALCULATION OF DEPTH SOUNDER ACCURACY
CHOKE CANYON RESERVOIR SURVEY

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

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

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

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

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

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

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

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

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

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

$$D_{20} = [((20-1.2)/4832)(4808)]+1.2$$
$$= 19.9' \qquad (-0.1')$$

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

$$D_{30} = [((30-1.2)/4832)(4808)]+1.2$$
$$= 29.9' \qquad (-0.1')$$

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

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

For the water column from 2 to 60 feet: V = 4799 fps Assumed V_{80} = 4785 fps

$$t_{60} =(60-1.2)/4799$$
$$=0.01225 \text{ sec.}$$

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

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

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

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

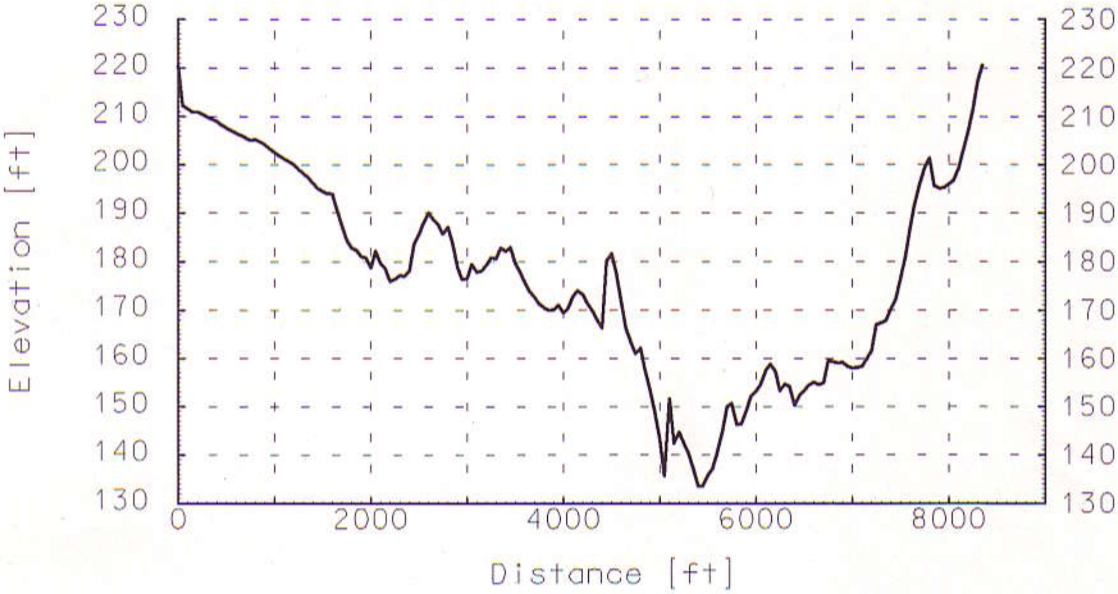
For a measurement at 45 feet (within the 2 to 45 foot column with V = 4808 fps):

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

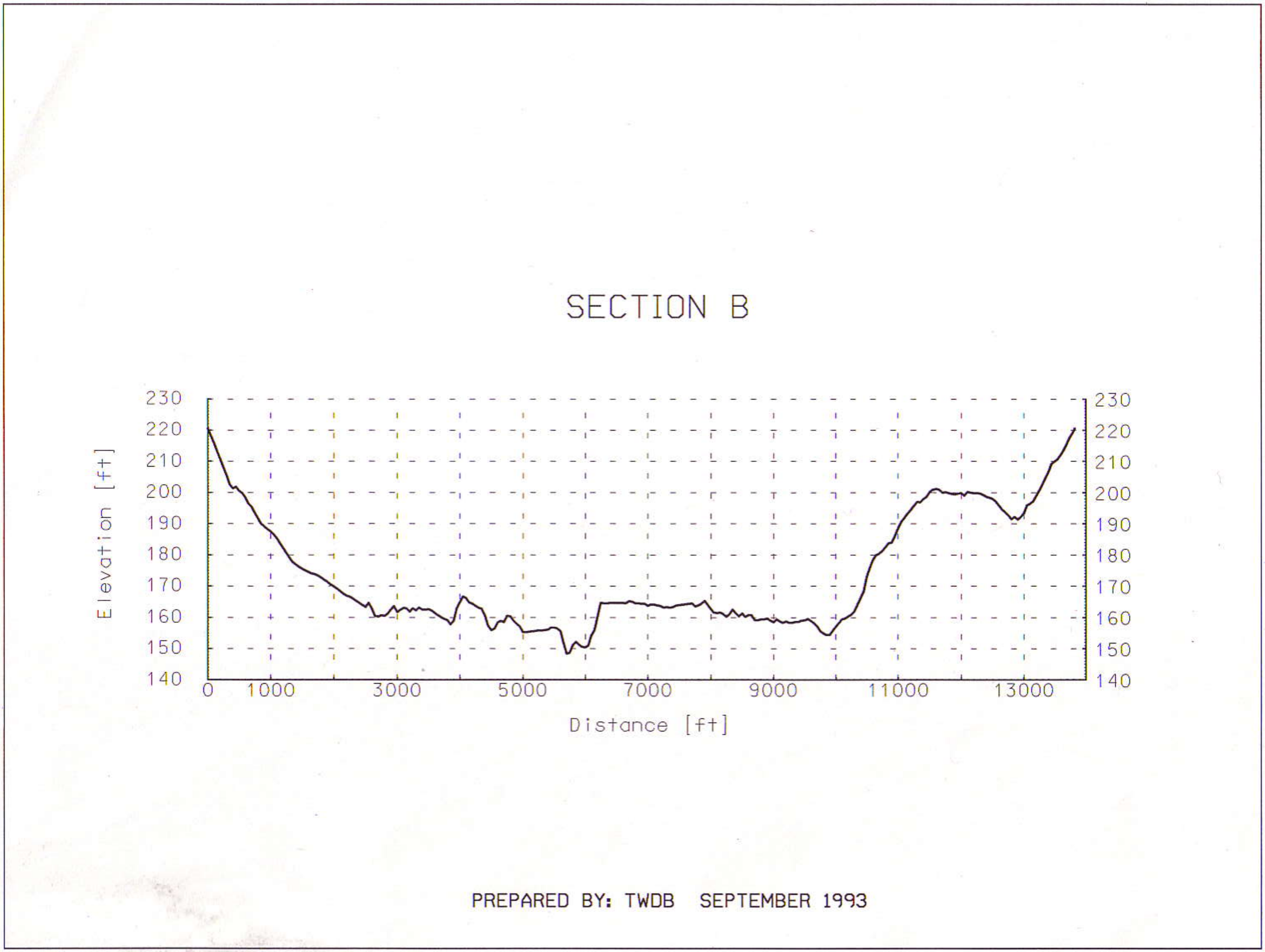
For a measurement at 45 feet (within the 2 to 45 foot column with V = 4808 fps):

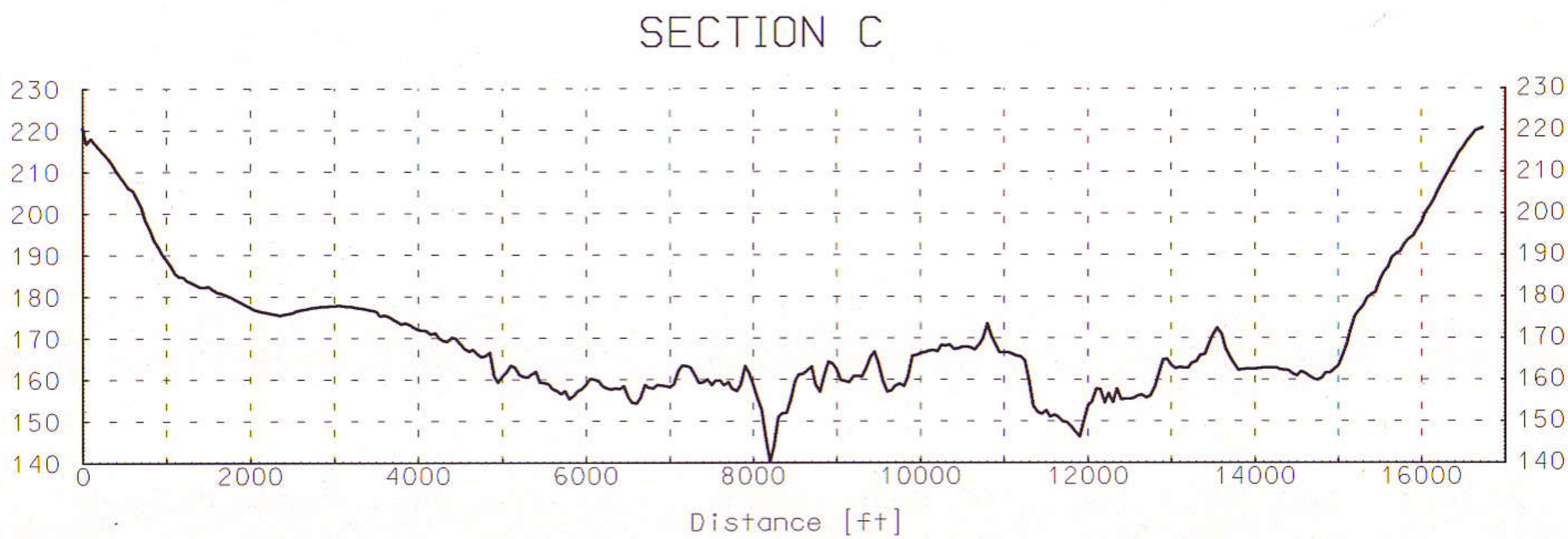
$$D_{80} = [((80-1.2)/4785)(4799)]+1.2$$
$$= 80.2' \quad (+0.2')$$

SECTION A



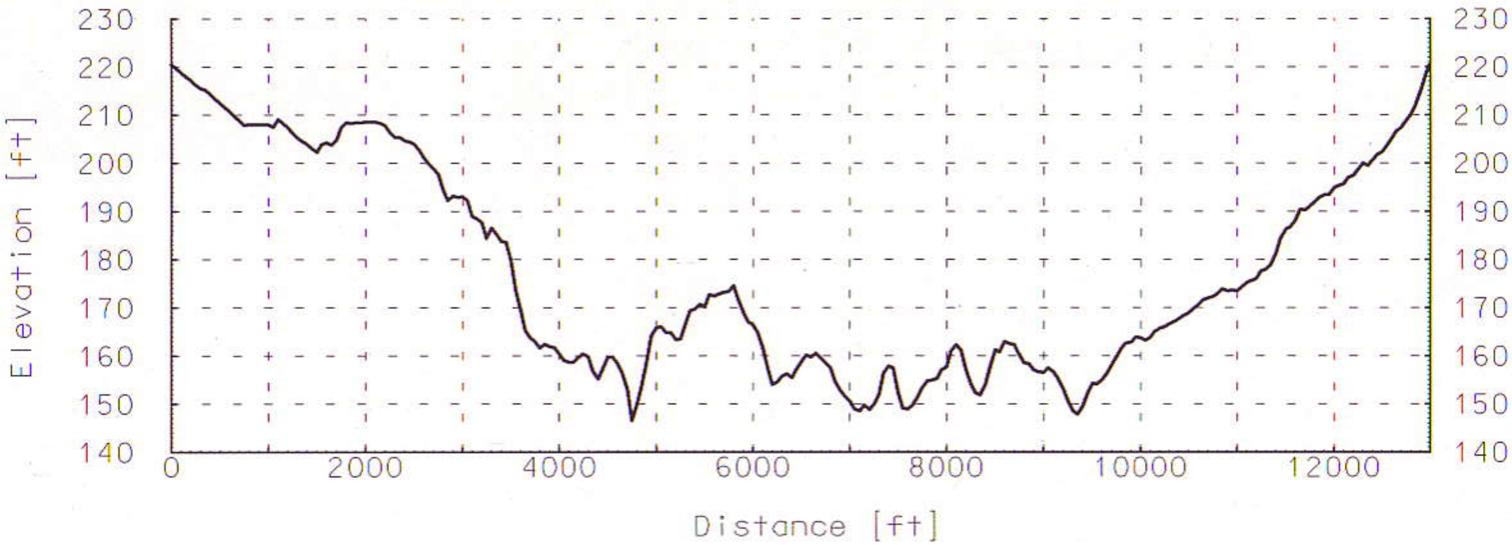
PREPARED BY: TWDB SEPTEMBER 1993


SECTION B
Elevation [ft]
230
220
210
200
190
180
170
160
150
140
0
1000
3000
5000
7000
9000
11000
13000
Distance [ft]
PREPARED BY: TWDB SEPTEMBER 1993

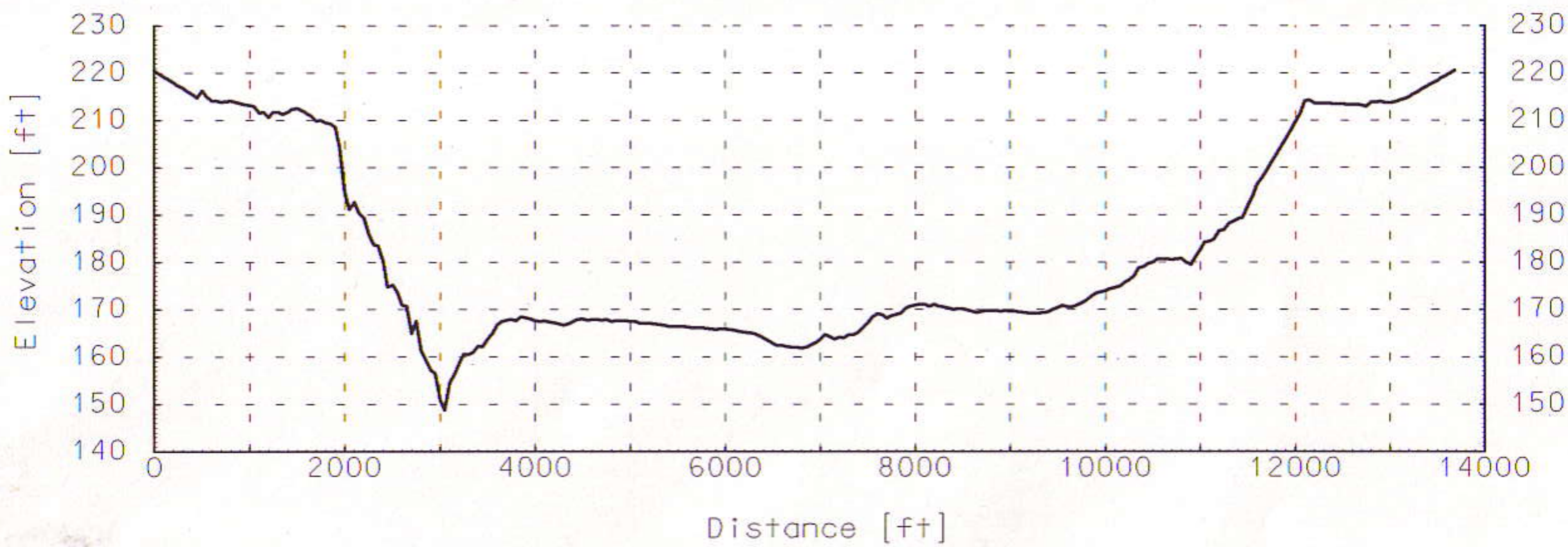


PREPARED BY: TWDB SEPTEMBER 1993

SECTION D

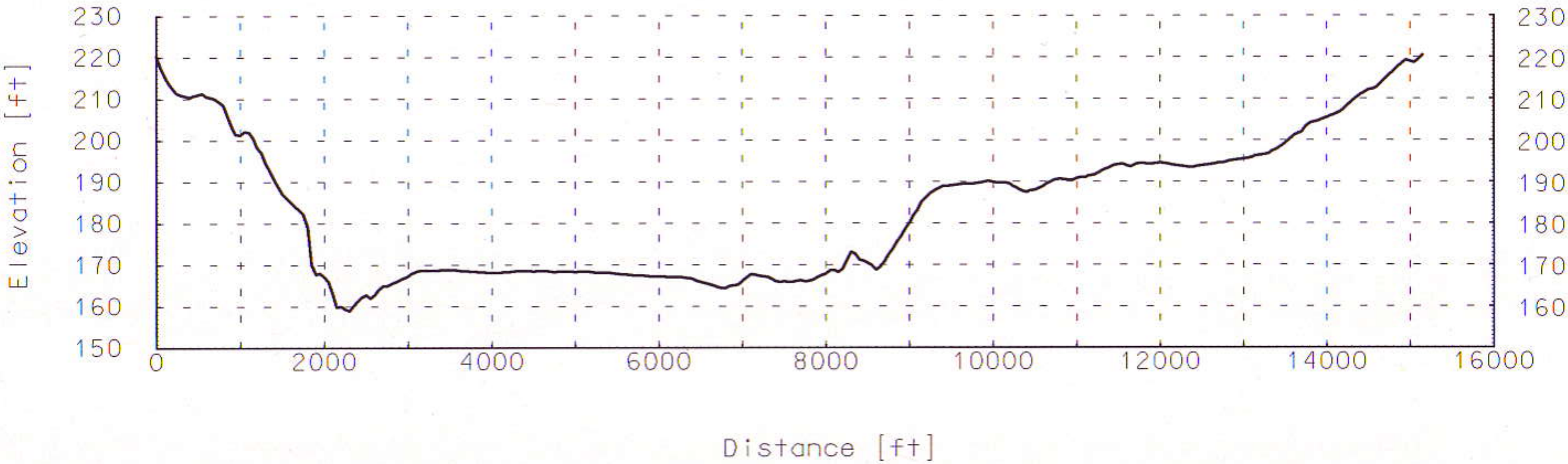


SECTION E



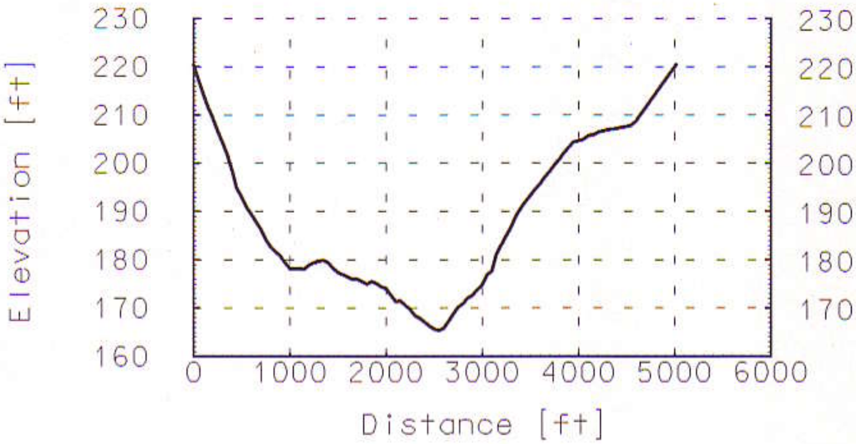
PREPARED BY: TWDB SEPTEMBER 1993

SECTION F

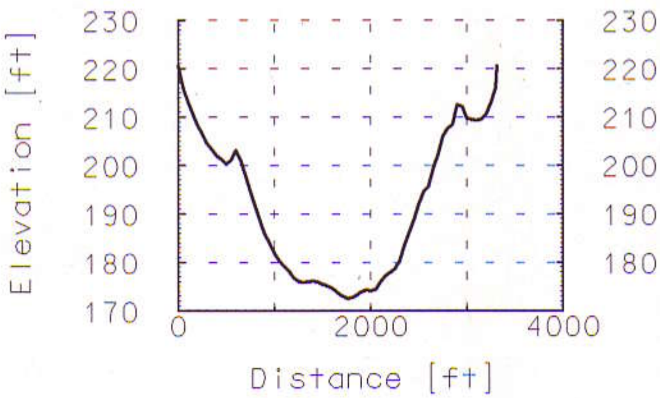


PREPARED BY: TWDB SEPTEMBER 1993

SECTION G

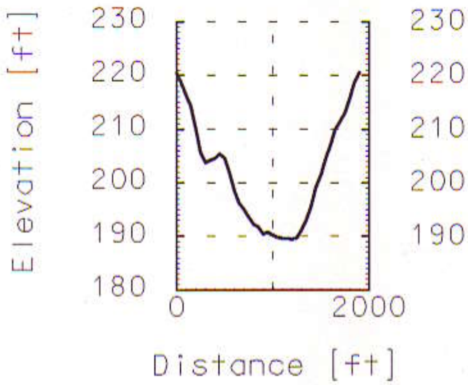


SECTION H

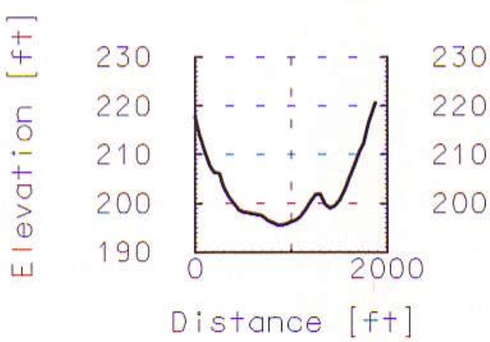


PREPARED BY: TWDB SEPTEMBER 1993

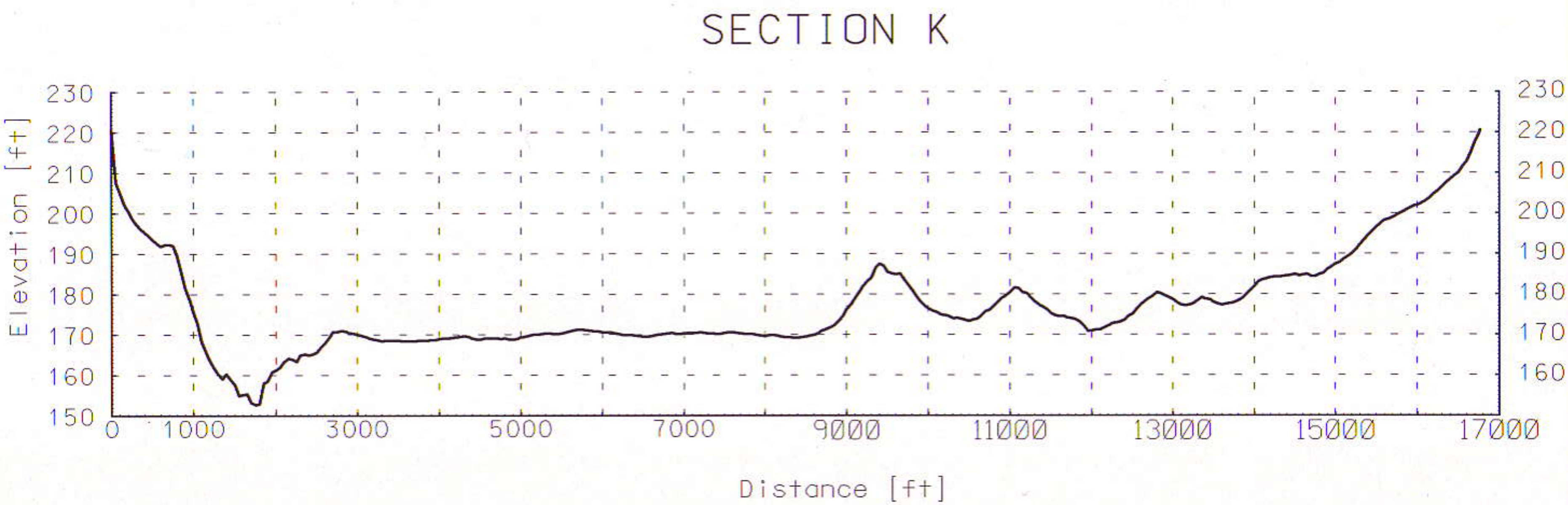
SECTION I



SECTION J

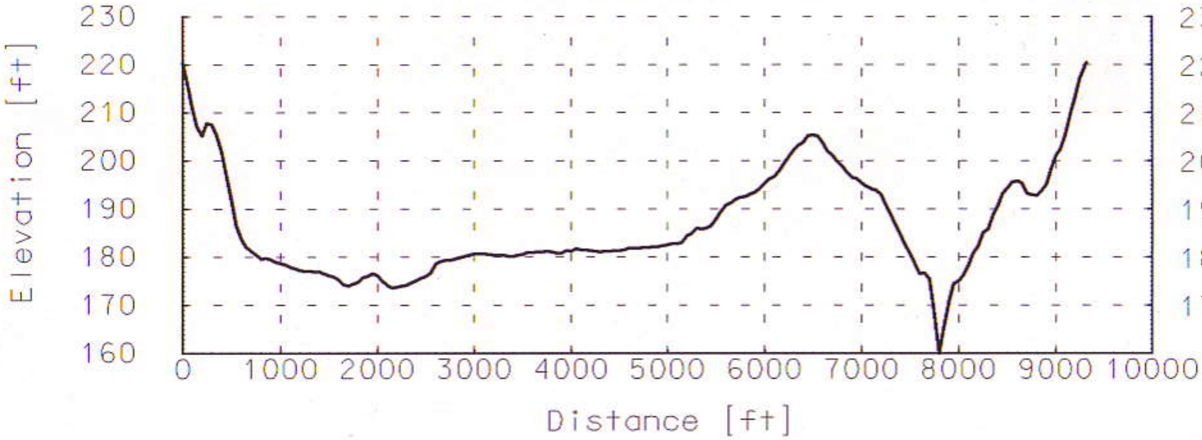


PREPARED BY: TWDB SEPTEMBER 1993

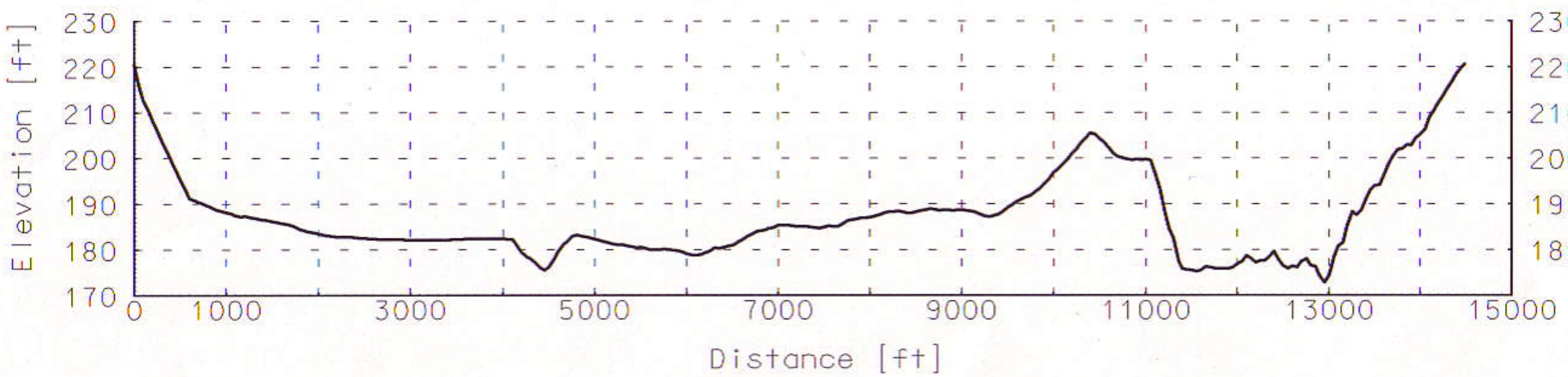


PREPARED BY: TWDB SEPTEMBER 1993

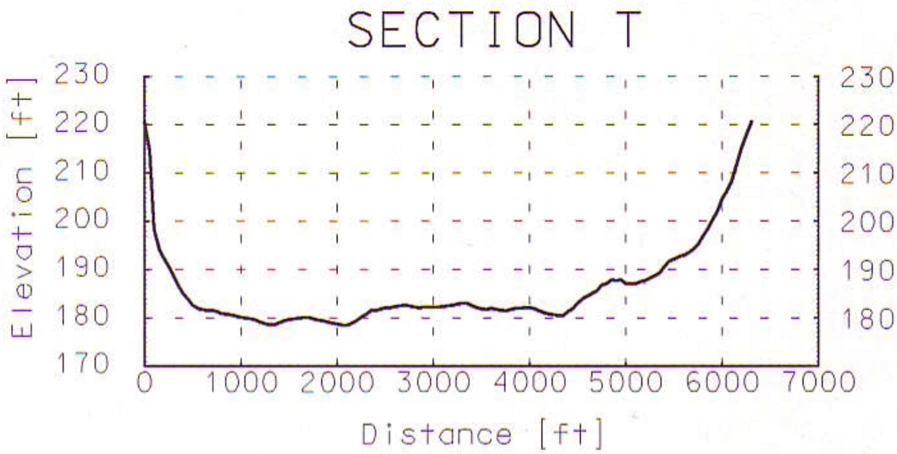
SECTION R

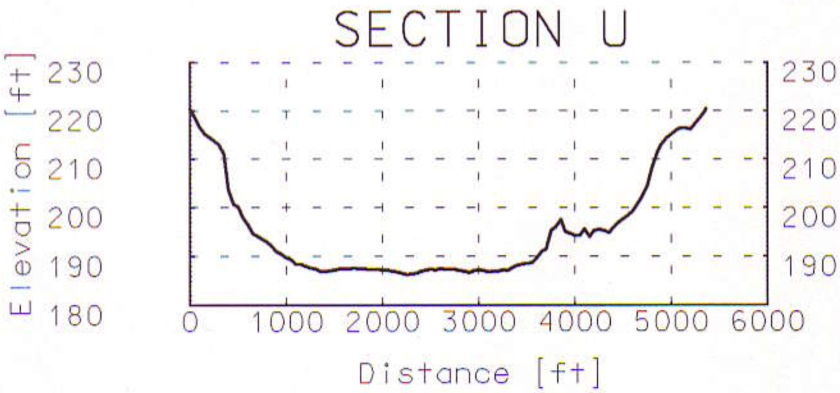


SECTION S



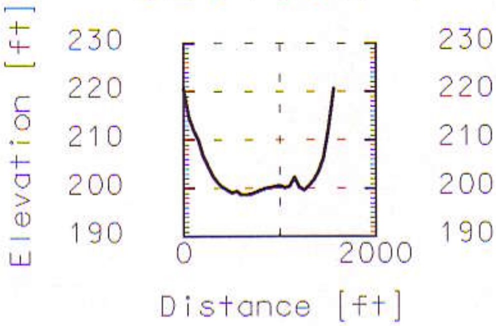
PREPARED BY: TWDB SEPTEMBER 1993



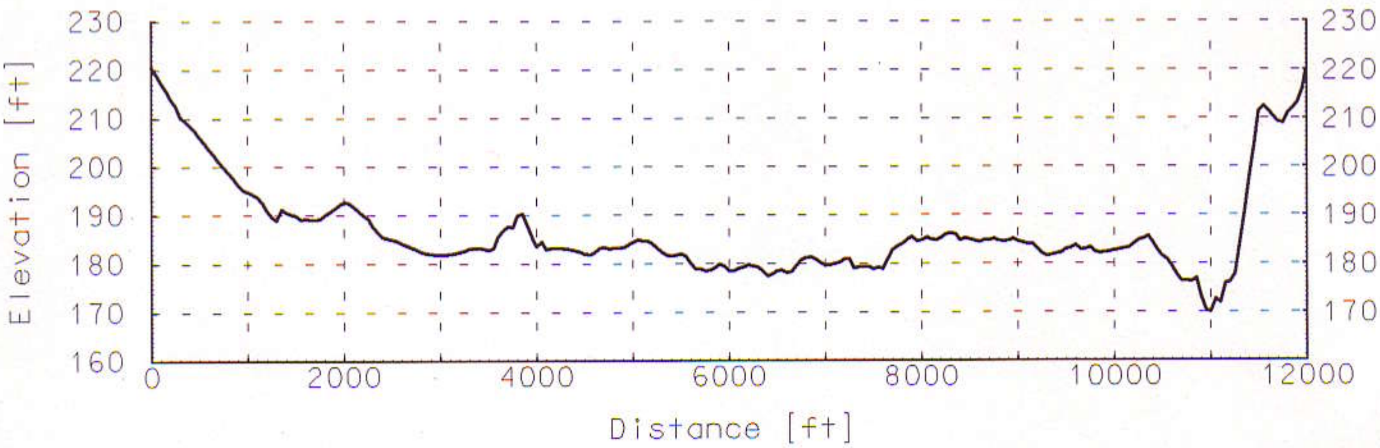


PREPARED BY: TWDB SEPTEMBER 1993

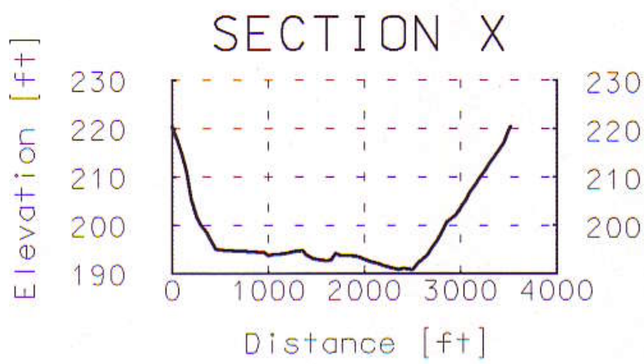
SECTION V

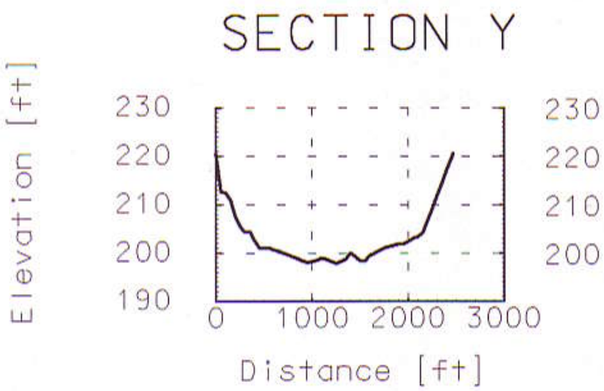


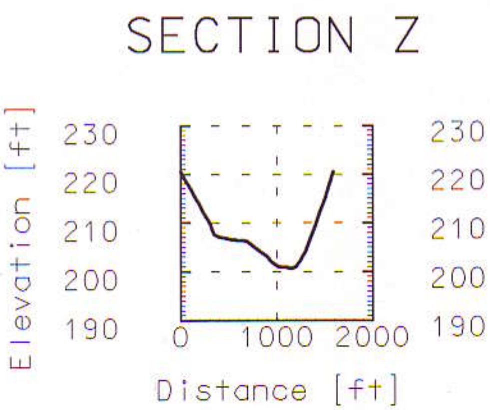
SECTION W



PREPARED BY: TWDB SEPTEMBER 1993

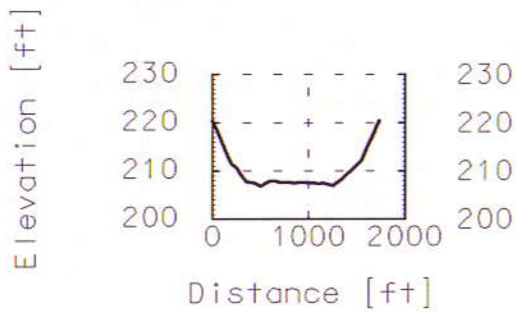




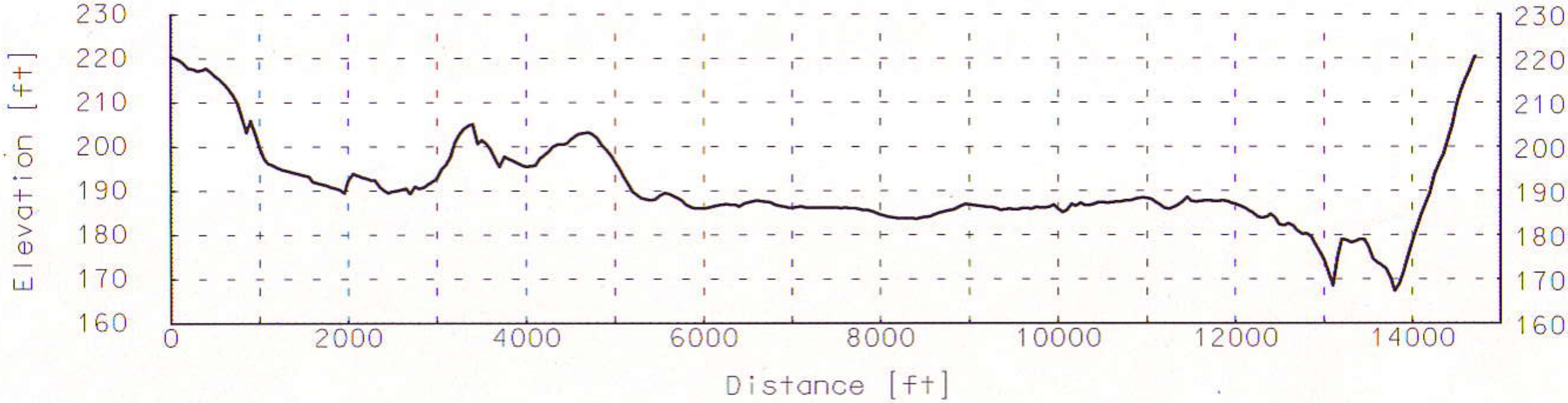


PREPARED BY: TWDB SEPTEMBER 1993

SECTION AA

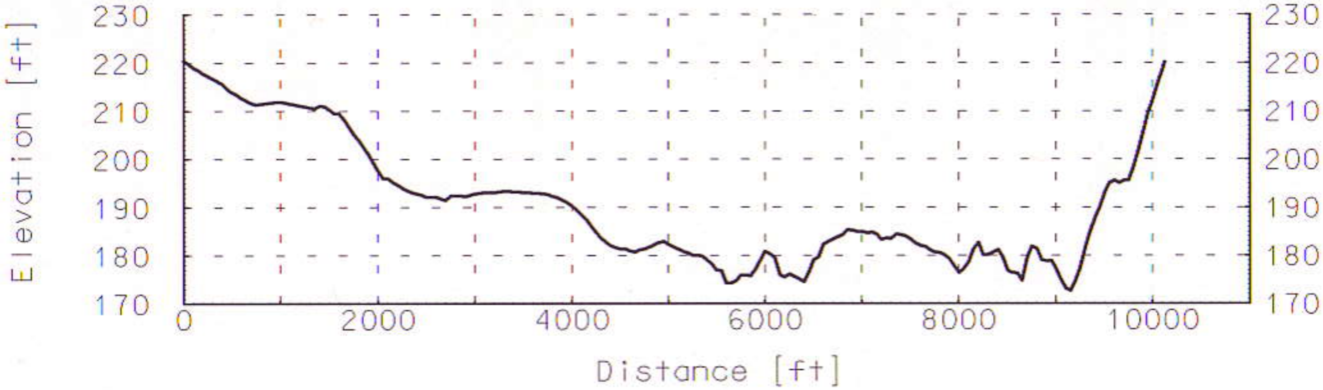


SECTION BB

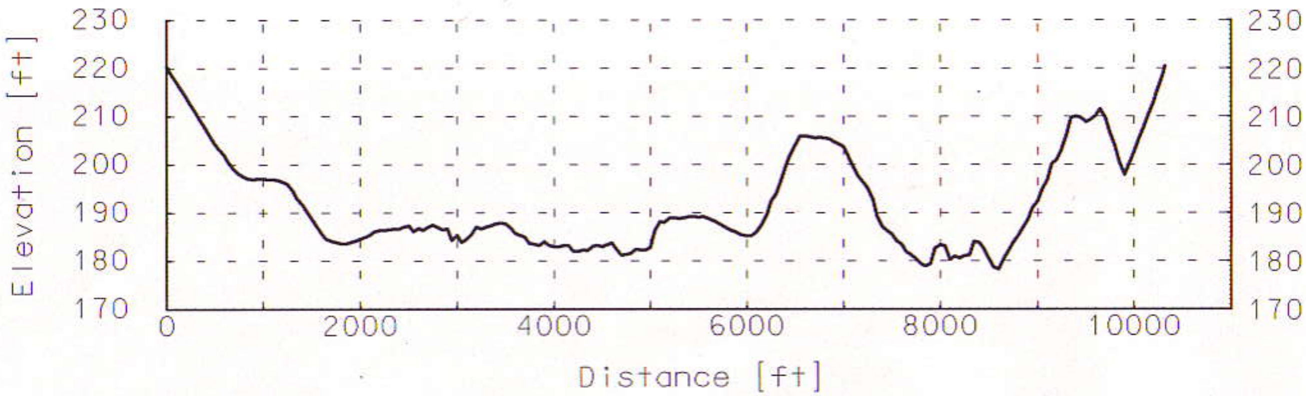


PREPARED BY: TWDB SEPTEMBER 1993

SECTION CC

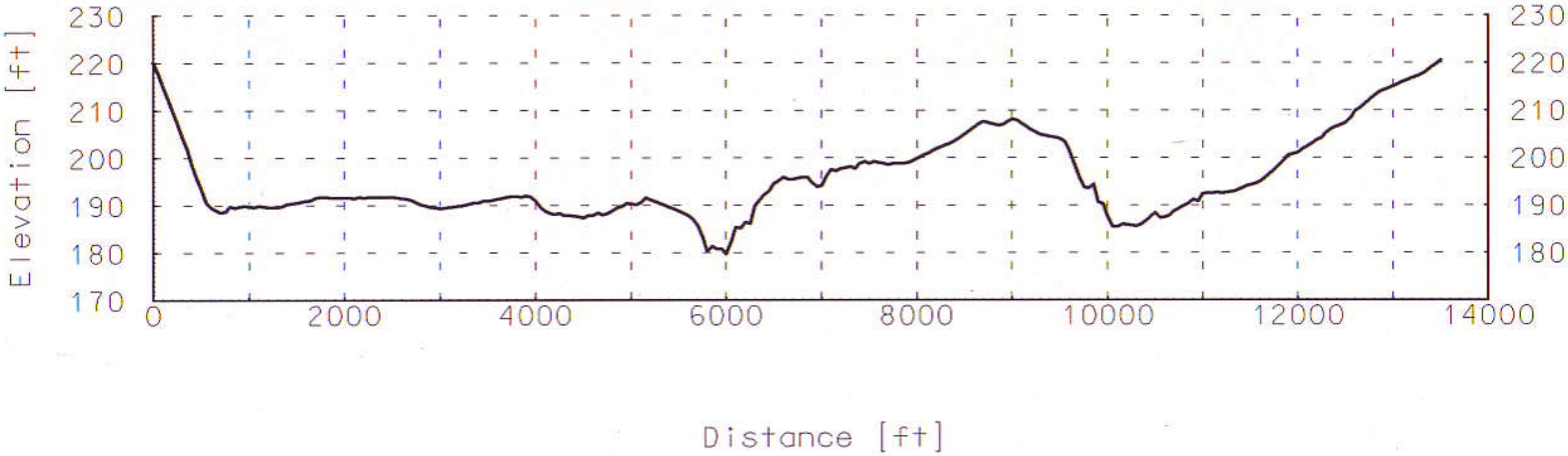


SECTION DD



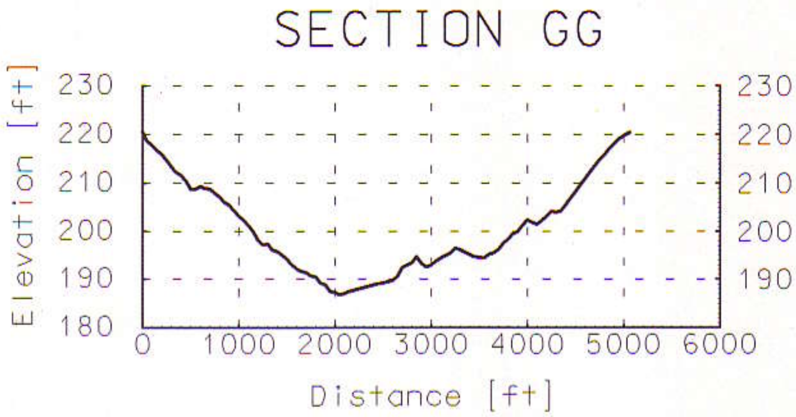
PREPARED BY: TWDB SEPTEMBER 1993

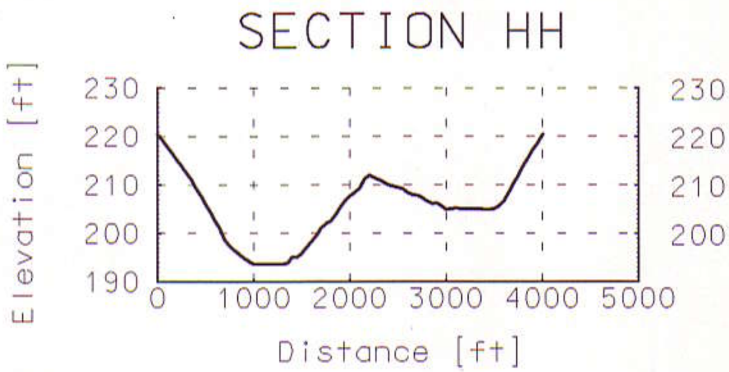
SECTION EE

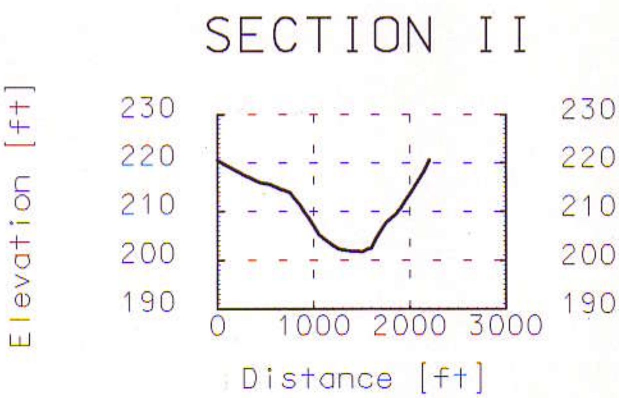


SECTION FF

PREPARED BY: TWDB SEPTEMBER 1993

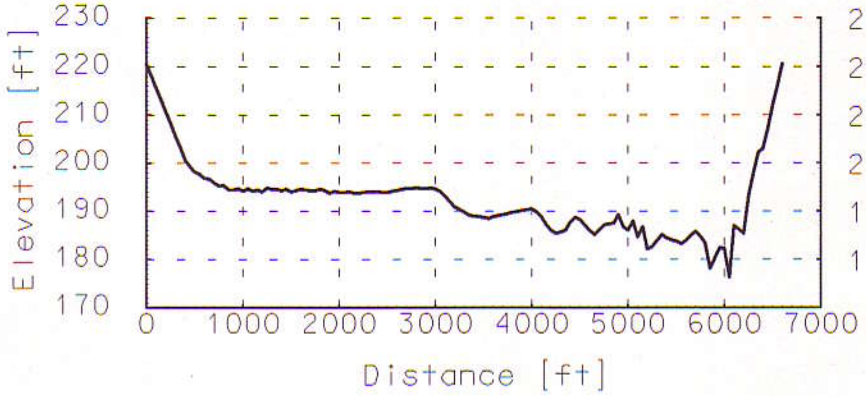




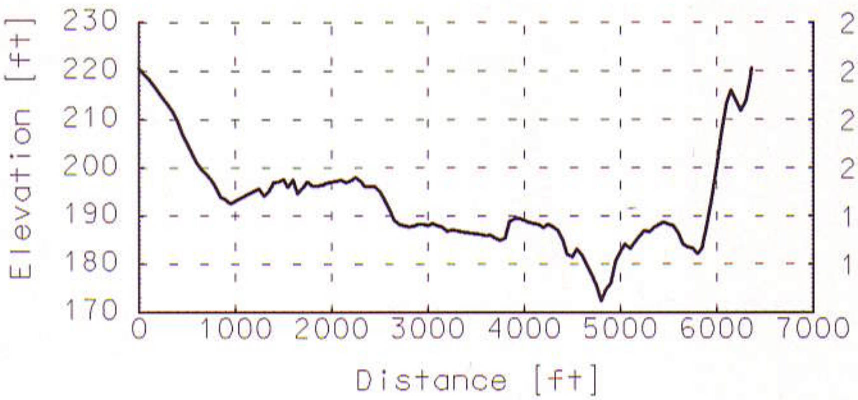


PREPARED BY: TWDB SEPTEMBER 1993

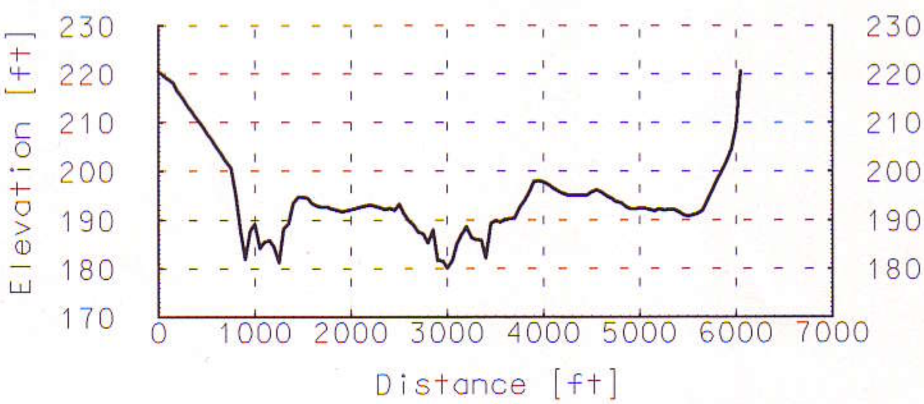
SECTION JJ



SECTION KK

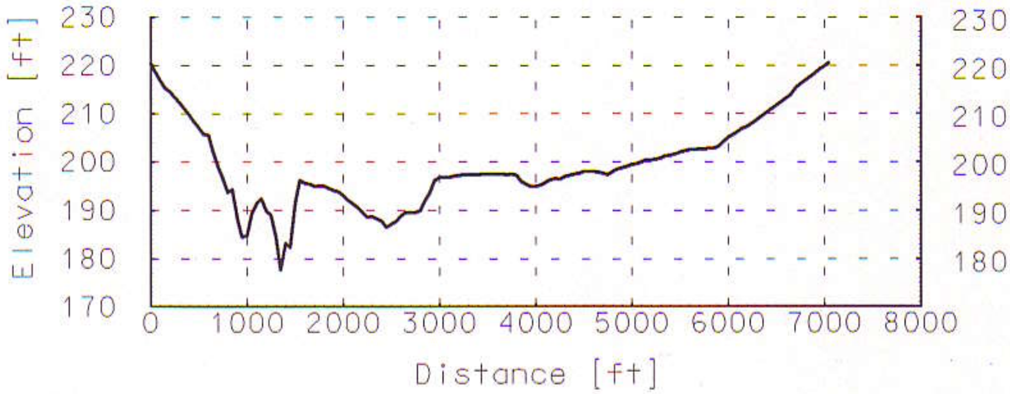


SECTION LL

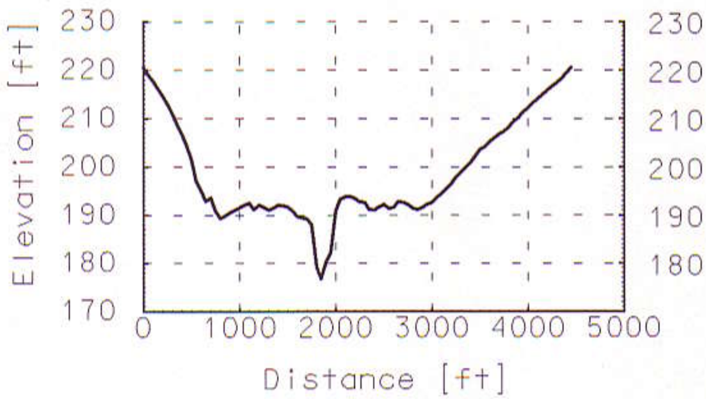


PREPARED BY: TWDB SEPTEMBER 1993

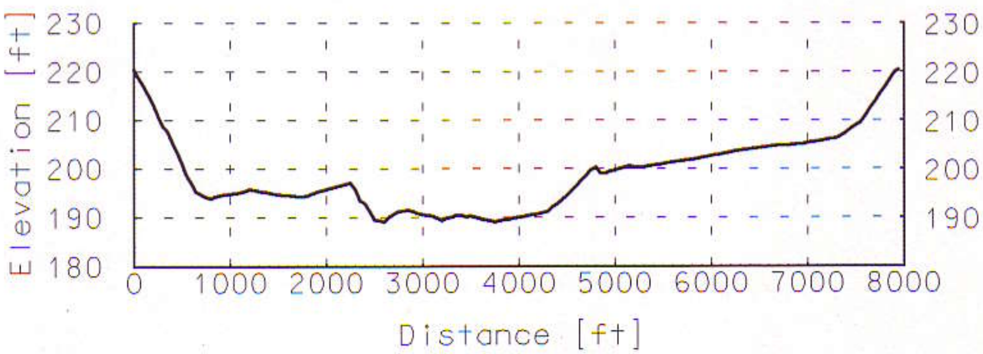
SECTION MM



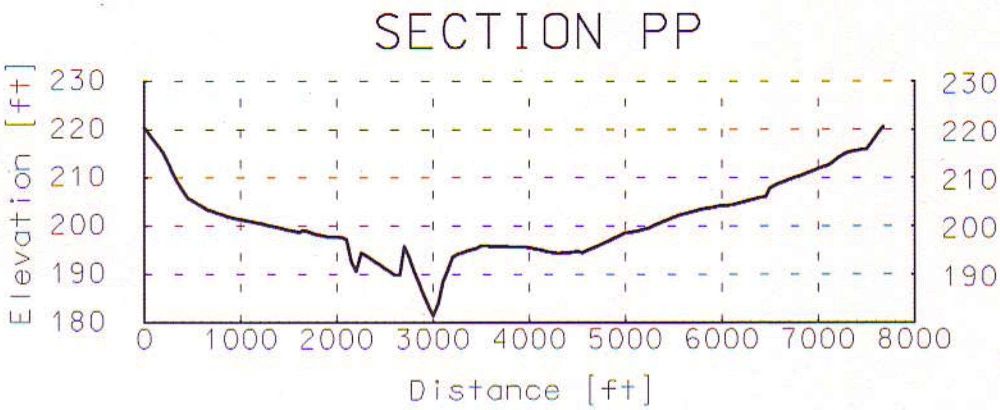
SECTION NN

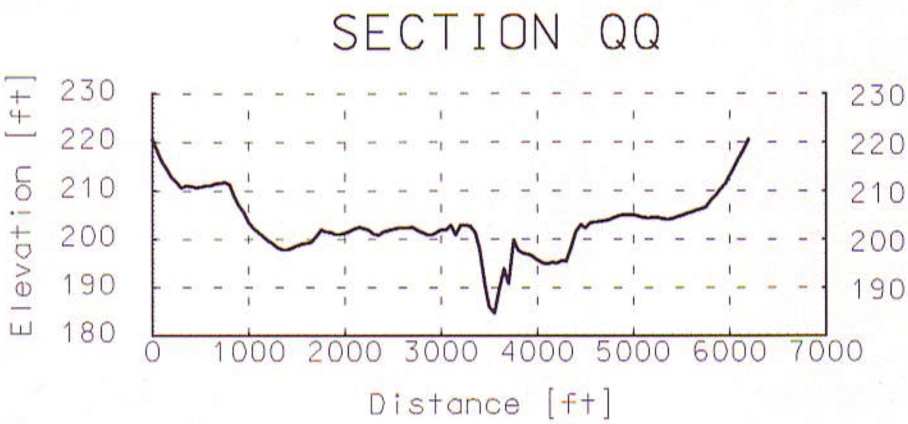


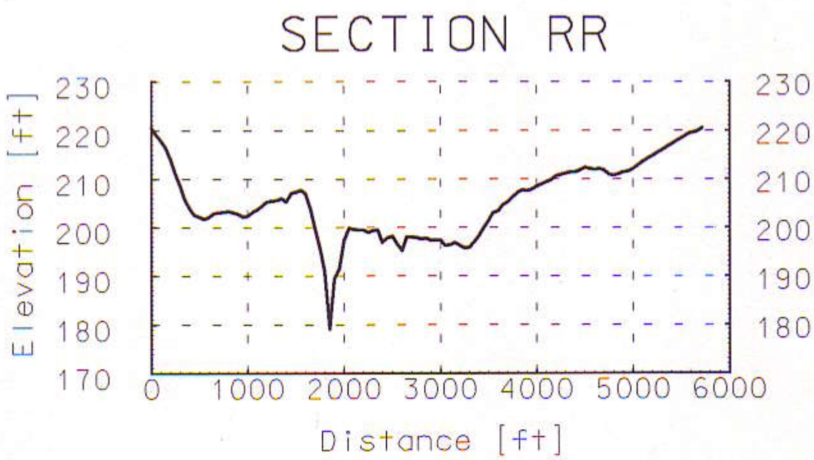
SECTION OO



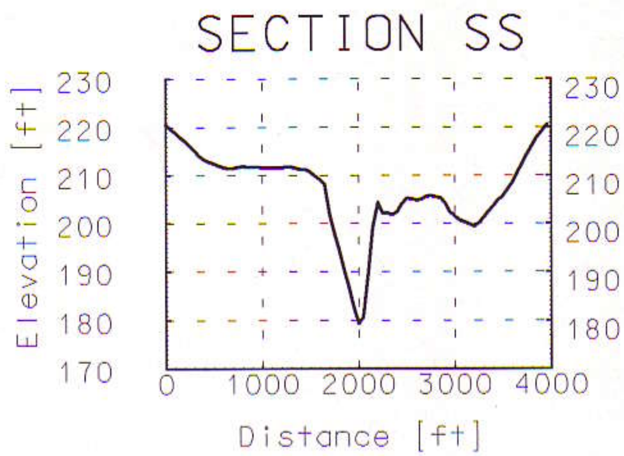
PREPARED BY: TWDB SEPTEMBER 1993

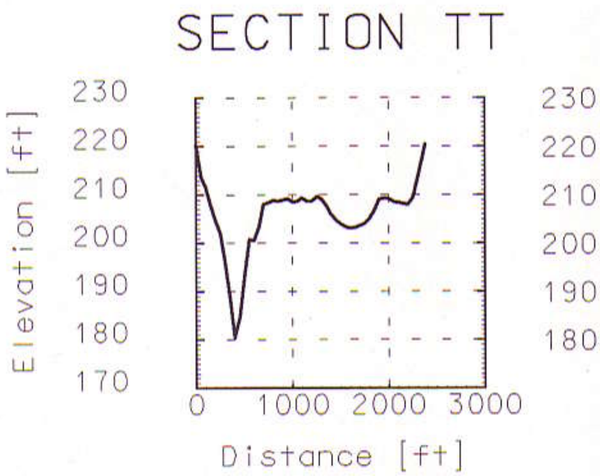


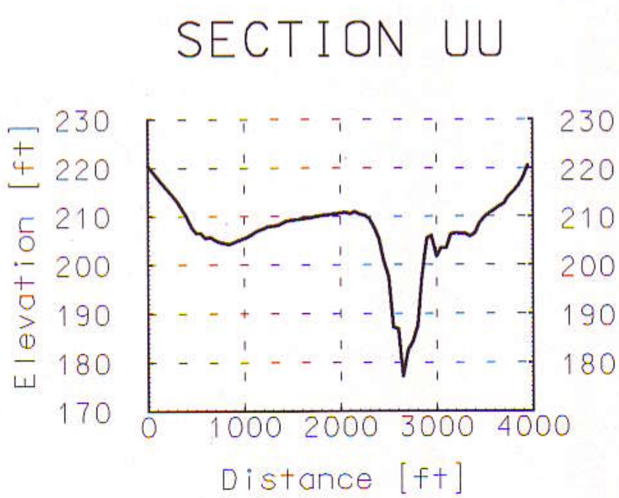




PREPARED BY: TWDB SEPTEMBER 1993

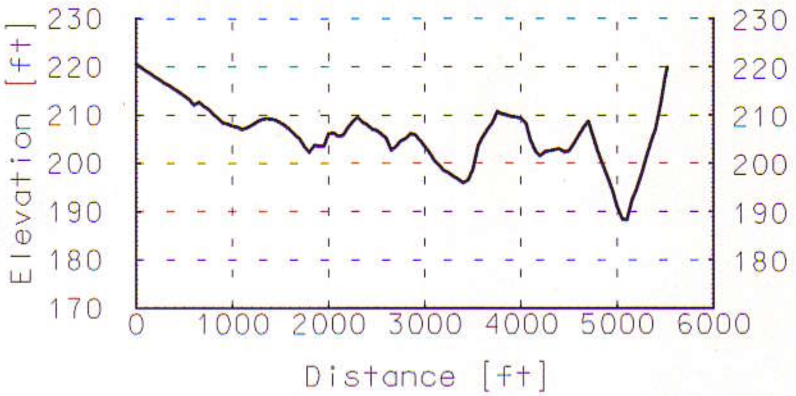




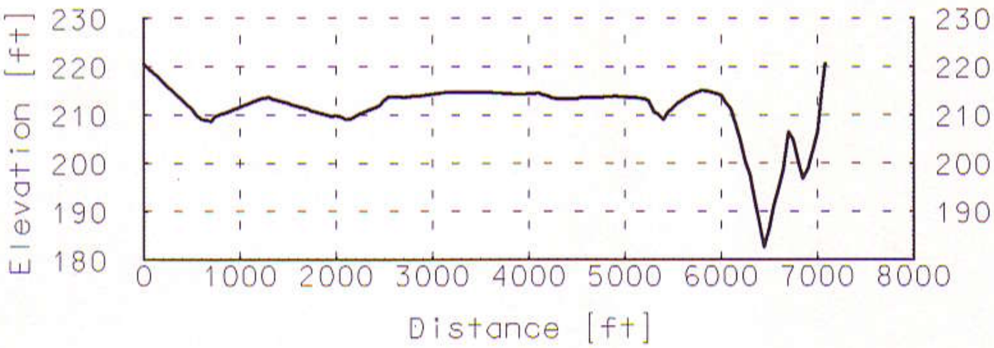


PREPARED BY: TWDB SEPTEMBER 1993

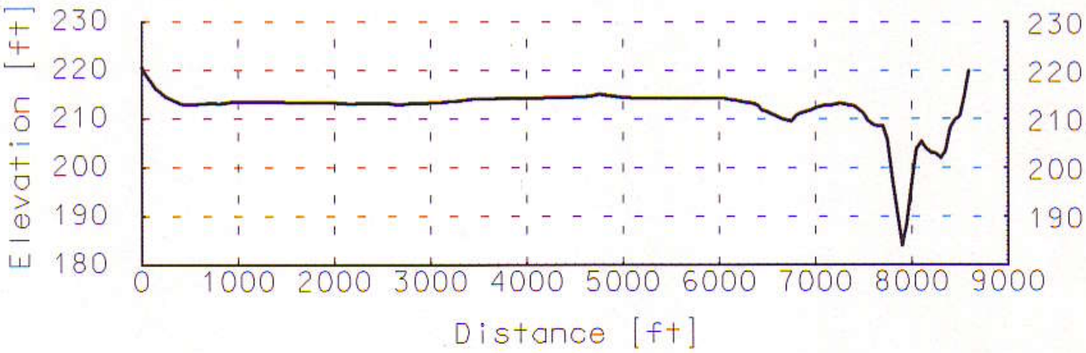
SECTION VV



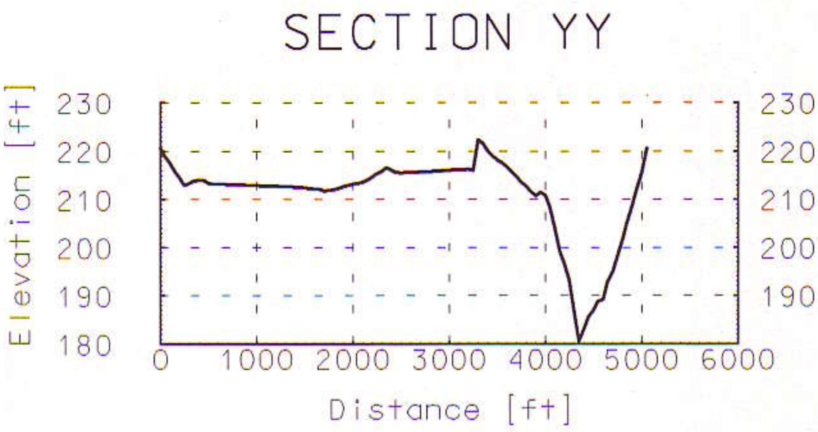
SECTION WW

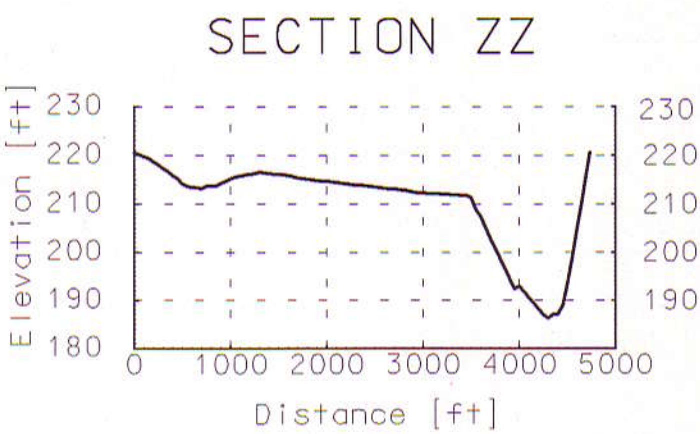


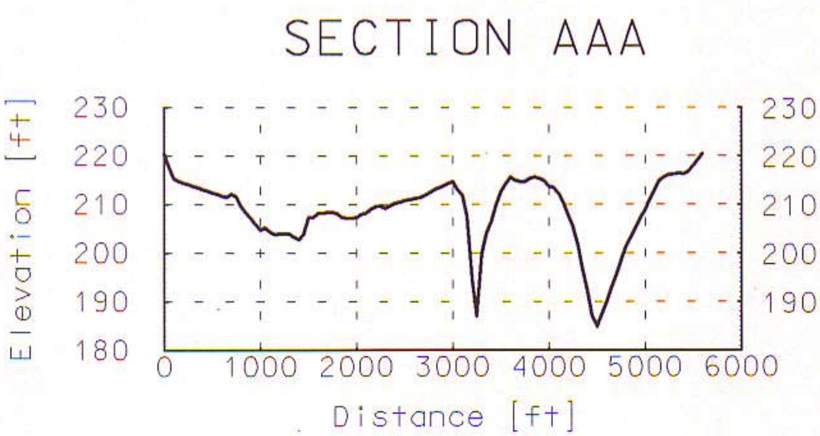
SECTION XX



PREPARED BY: TWDB SEPTEMBER 1993

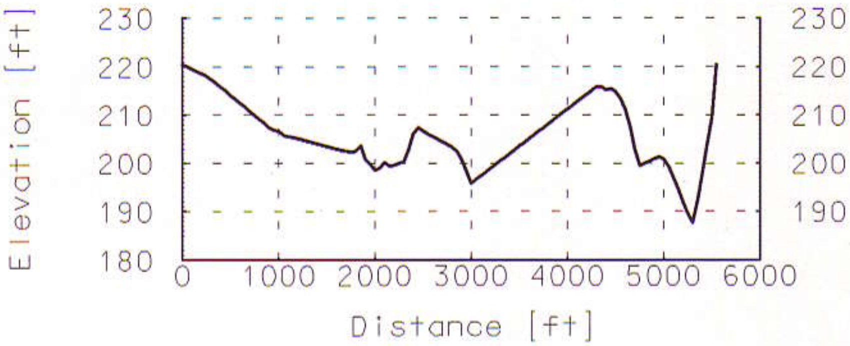




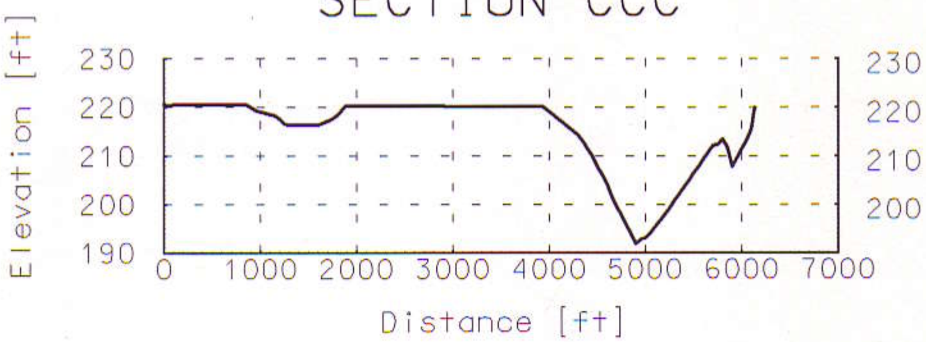


PREPARED BY: TWDB SEPTEMBER 1993

SECTION BBB

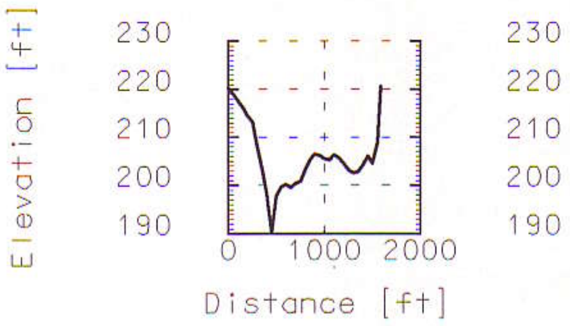


SECTION CCC

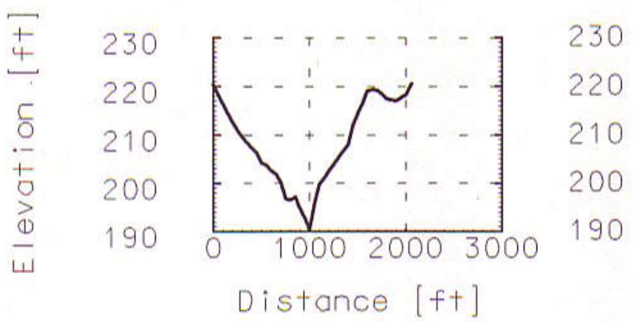


PREPARED BY: TWDB SEPTEMBER 1993

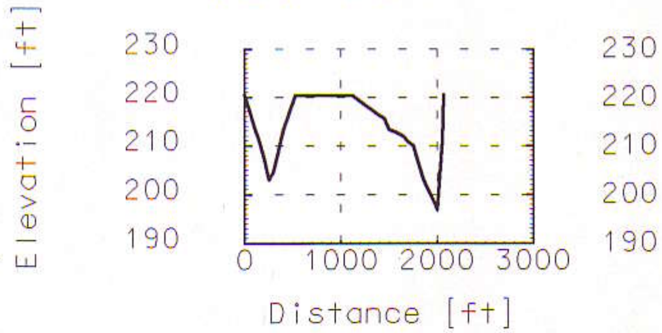
SECTION DDD



SECTION EEE



SECTION FFF



PREPARED BY: TWDB SEPTEMBER 1993

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR VOLUME TABLE

Aug 10 1993

CHOKE CANYON RESERVOIR

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

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
127										
128										
129										
130										
131										
132			1	1	1	1	1	1	1	1
133	1	1	1	1	1	1	2	2	2	2
134	2	2	2	3	3	3	3	3	4	4
135	4	4	5	5	5	5	6	6	6	7
136	7	7	8	8	9	9	9	10	10	11
137	11	12	12	13	14	14	15	15	16	17
138	18	18	19	20	21	22	23	24	25	26
139	27	28	29	30	31	33	34	35	36	38
140	39	41	43	44	46	48	50	52	54	56
141	59	61	64	67	70	73	76	79	82	85
142	88	92	95	99	102	106	109	113	117	121
143	125	129	133	137	141	146	150	154	159	164
144	168	173	178	183	188	193	198	203	209	214
145	220	226	231	237	244	250	256	263	269	276
146	283	290	298	305	313	321	330	338	347	357
147	366	376	386	397	407	418	430	441	453	465
148	477	489	502	515	528	541	555	568	583	597
149	611	626	641	656	672	688	704	720	737	754
150	771	789	806	824	843	861	880	900	919	939
151	959	980	1001	1022	1043	1065	1087	1110	1133	1156
152	1180	1204	1229	1254	1279	1305	1331	1358	1385	1412
153	1440	1469	1498	1527	1557	1587	1618	1649	1681	1713
154	1746	1779	1813	1847	1882	1917	1953	1989	2026	2063
155	2101	2139	2178	2218	2258	2299	2340	2382	2425	2469
156	2513	2558	2603	2650	2697	2745	2793	2843	2893	2944
157	2996	3048	3101	3156	3211	3266	3323	3380	3439	3498
158	3558	3620	3682	3745	3810	3875	3941	4009	4078	4148
159	4219	4291	4364	4439	4514	4591	4669	4749	4830	4912
160	4995	5079	5165	5252	5341	5430	5521	5614	5708	5803
161	5900	5998	6098	6199	6302	6406	6512	6619	6727	6837
162	6949	7062	7176	7292	7409	7528	7648	7770	7894	8020
163	8147	8277	8408	8541	8676	8812	8950	9090	9231	9374
164	9519	9665	9813	9963	10114	10267	10421	10577	10735	10894
165	11055	11218	11382	11548	11716	11885	12056	12228	12402	12578
166	12755	12935	13116	13299	13484	13671	13860	14051	14244	14440
167	14637	14837	15039	15242	15449	15657	15868	16082	16298	16517
168	16737	16961	17186	17415	17645	17879	18115	18354	18596	18841
169	19090	19341	19595	19851	20111	20374	20639	20908	21180	21454
170	21732	22013	22297	22584	22874	23168	23464	23763	24066	24371
171	24681	24991	25305	25624	25944	26267	26593	26921	27254	27590
172	27929	28271	28618	28967	29318	29674	30032	30393	30758	31127
173	31499	31873	32252	32633	33019	33407	33797	34194	34594	34995
174	35402	35813	36226	36641	37062	37484	37909	38338	38770	39206
175	39644	40085	40530	40978	41428	41882	42339	42801	43264	43730

CHOKE CANYON RESERVOIR

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
176	44201	44676	45152	45634	46118	46607	47098	47596	48097	48602
177	49109	49624	50140	50661	51185	51713	52245	52782	53322	53866
178	54412	54966	55521	56084	56648	57218	57789	58368	58949	59536
179	60124	60719	61318	61919	62525	63134	63747	64364	64984	65608
180	66237	66869	67507	68145	68790	69438	70092	70748	71407	72073
181	72741	73411	74089	74768	75452	76141	76834	77532	78232	78937
182	79646	80358	81074	81795	82521	83248	83983	84720	85461	86208
183	86958	87714	88471	89236	90005	90776	91552	92332	93115	93903
184	94697	95494	96295	97101	97911	98726	99545	100367	101196	102027
185	102860	103701	104543	105390	106242	107096	107955	108815	109681	110551
186	111426	112303	113184	114068	114956	115849	116745	117645	118549	119458
187	120370	121286	122206	123129	124056	124991	125925	126866	127810	128760
188	129713	130668	131630	132594	133563	134536	135512	136492	137477	138466
189	139458	140455	141453	142456	143462	144474	145487	146504	147525	148551
190	149580	150613	151648	152691	153733	154782	155833	156892	157950	159015
191	160083	161155	162231	163310	164394	165480	166573	167668	168767	169871
192	170980	172094	173209	174332	175459	176591	177727	178868	180014	181166
193	182321	183480	184644	185813	186986	188166	189348	190537	191731	192929
194	194132	195340	196552	197769	198992	200218	201451	202686	203928	205174
195	206426	207681	208942	210207	211476	212753	214031	215317	216605	217899
196	219197	220500	221809	223120	224438	225760	227087	228421	229752	231107
197	232438	233792	235147	236524	237879	239256	240634	242011	243411	244812
198	246212	247612	249013	250436	251860	253306	254752	256198	257645	259114
199	260583	262075	263545	265037	266529	268044	269536	271051	272567	274105
200	275620	277158	278696	280257	281795	283356	284917	286478	288062	289624
201	291208	292792	294399	295983	297590	299197	300803	302433	304040	305670
202	307300	308930	310583	312213	313866	315519	317172	318848	320500	322176
203	323852	325551	327227	328926	330624	332323	334022	335721	337443	339164
204	340886	342608	344353	346074	347819	349564	351309	353076	354821	356589
205	358356	360124	361915	363682	365473	367264	369054	370868	372658	374472
206	376286	378122	379936	381772	383609	385445	387305	389164	391024	392883
207	394743	396625	398508	400390	402296	404178	406084	407989	409917	411823
208	413751	415680	417608	419536	421488	423439	425390	427342	429293	431267
209	433242	435216	437190	439187	441162	443159	445156	447176	449174	451194
210	453214	455234	457254	459298	461341	463384	465427	467470	469536	471579
211	473646	475735	477801	479890	481956	484045	486134	488246	490335	492447
212	494559	496671	498806	500918	503053	505188	507346	509481	511639	513797
213	515955	518136	520317	522498	524679	526883	529086	531290	533517	535744
214	537971	540197	542447	544697	546947	549197	551469	553742	556038	558310
215	560606	562925	565220	567539	569858	572176	574518	576860	579201	581543
216	583907	586249	588613	591001	593366	595753	598141	600528	602939	605349
217	607759	610170	612580	615014	617447	619881	622314	624748	627204	629660
218	632117	634573	637052	639509	641988	644467	646970	649449	651951	654454
219	656979	659481	662006	664532	667057	669605	672130	674679	677227	679798
220	682346	684917	687511	690083	692677	695271				

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR AREA TABLE

Aug 10 1993

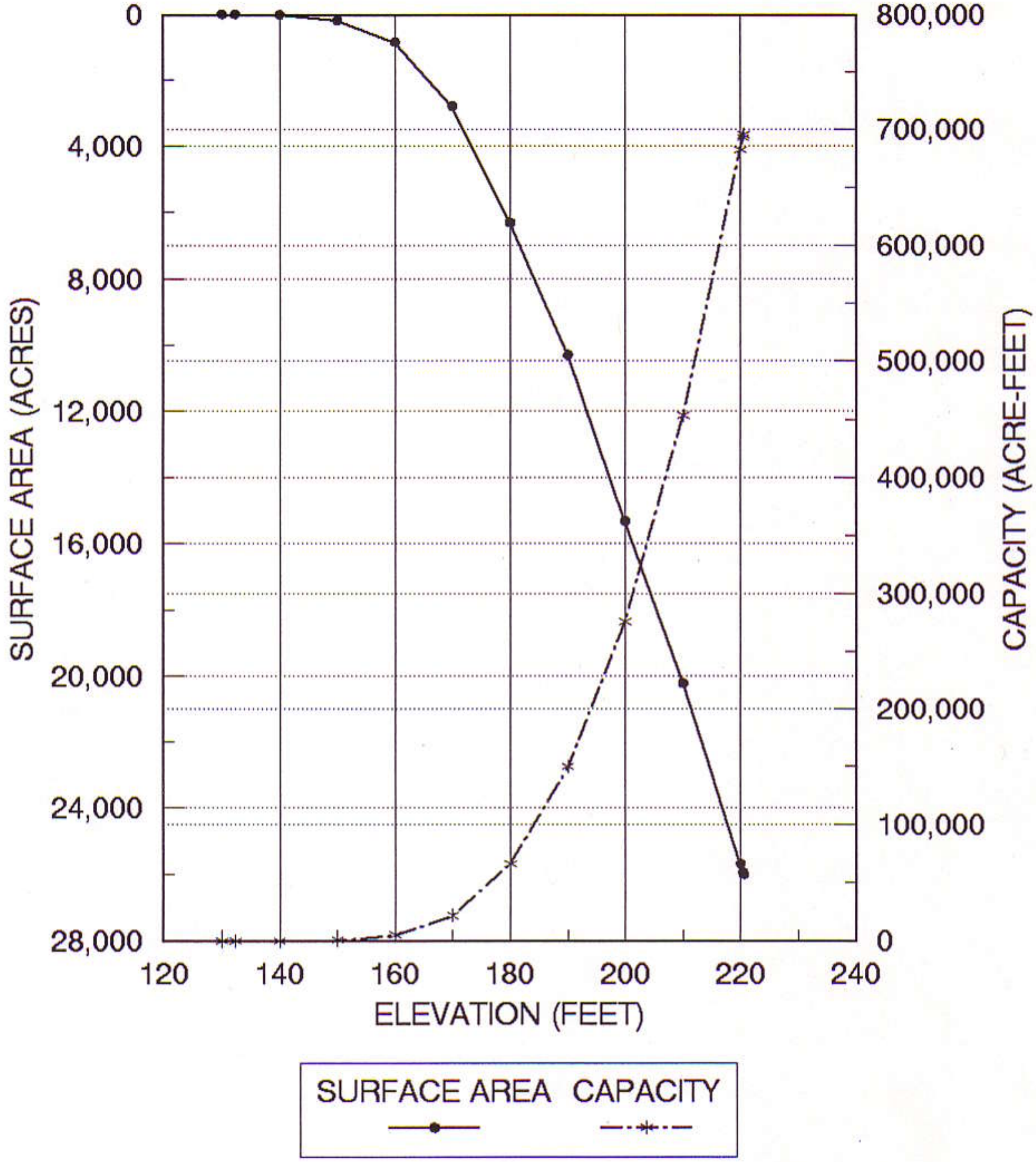
CHOKE CANYON RESERVOIR

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
127										
128										
129										
130										
131										
132				1	1	1	1	1	1	1
133	1	1	1	1	1	1	1	1	1	1
134	1	2	2	2	2	2	2	2	2	2
135	2	2	3	3	3	3	3	3	3	3
136	4	4	4	4	4	4	4	5	5	5
137	5	5	6	6	6	6	7	7	7	7
138	8	8	8	8	9	9	9	10	10	10
139	11	11	11	12	12	13	13	14	14	15
140	15	16	17	17	18	19	20	21	22	23
141	25	26	27	28	29	30	30	31	32	32
142	33	34	34	35	36	36	37	38	38	39
143	40	41	41	42	43	43	44	45	46	46
144	47	48	49	50	51	52	53	54	55	56
145	57	58	59	60	62	63	64	66	67	69
146	71	73	75	77	80	83	85	89	92	95
147	98	100	103	106	108	111	113	116	118	120
148	123	125	128	130	132	135	137	139	142	144
149	147	149	152	154	157	160	162	165	168	171
150	174	176	179	182	185	188	191	194	197	200
151	203	207	210	214	217	221	224	228	232	236
152	240	243	248	252	256	260	264	269	273	278
153	282	287	291	296	301	305	310	315	320	325
154	330	335	340	345	350	355	360	365	370	376
155	382	387	393	399	405	411	418	425	431	438
156	445	452	460	467	475	483	490	498	506	513
157	521	529	537	545	553	562	570	579	588	598
158	608	618	628	639	649	660	671	682	693	704
159	716	728	739	751	763	776	789	801	814	826
160	839	852	864	877	890	904	918	932	946	961
161	975	990	1005	1019	1034	1049	1064	1078	1093	1107
162	1121	1135	1150	1165	1180	1196	1212	1230	1248	1268
163	1285	1303	1321	1338	1356	1373	1389	1406	1422	1438
164	1454	1470	1487	1504	1520	1536	1552	1569	1585	1601
165	1618	1635	1652	1668	1685	1701	1716	1732	1749	1765
166	1783	1802	1821	1840	1860	1881	1902	1923	1943	1964
167	1985	2006	2027	2050	2074	2099	2124	2149	2172	2196
168	2220	2244	2270	2295	2320	2347	2376	2406	2438	2468
169	2496	2526	2555	2583	2611	2640	2670	2701	2733	2764
170	2794	2825	2856	2887	2918	2949	2979	3010	3041	3070
171	3100	3130	3159	3188	3217	3247	3278	3308	3339	3372
172	3406	3439	3472	3504	3536	3569	3601	3633	3665	3699
173	3733	3765	3799	3832	3866	3900	3936	3976	4012	4047
174	4080	4113	4146	4179	4210	4241	4272	4304	4335	4368
175	4400	4431	4464	4495	4527	4558	4589	4621	4653	4685

CHOKE CANYON RESERVOIR

	AREA IN ACRES				ELEVATION INCREMENT IS ONE TENTH FOOT				
ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
176	4720	4754	4789	4826	4864	4905	4947	4989	5029	5070
177	5108	5148	5188	5227	5264	5301	5340	5379	5419	5459
178	5501	5543	5586	5629	5670	5713	5754	5796	5838	5879
179	5919	5959	5998	6037	6075	6113	6151	6189	6228	6264
180	6302	6341	6380	6423	6464	6505	6544	6583	6622	6661
181	6700	6740	6781	6823	6866	6909	6949	6989	7028	7067
182	7107	7146	7185	7226	7268	7312	7356	7398	7440	7483
183	7526	7569	7612	7657	7699	7740	7780	7820	7861	7905
184	7950	7995	8038	8080	8124	8167	8209	8251	8292	8331
185	8371	8411	8451	8490	8528	8565	8602	8638	8676	8714
186	8753	8790	8829	8866	8905	8944	8983	9022	9061	9101
187	9140	9180	9220	9261	9301	9342	9382	9427	9467	9507
188	9547	9586	9626	9666	9707	9747	9786	9825	9864	9902
189	9940	9977	10013	10049	10085	10121	10157	10195	10232	10270
190	10307	10346	10385	10423	10463	10503	10542	10582	10621	10660
191	10699	10738	10776	10815	10854	10894	10934	10976	11019	11063
192	11107	11153	11200	11246	11294	11341	11388	11434	11480	11527
193	11572	11618	11666	11713	11760	11809	11860	11909	11959	12008
194	12056	12102	12149	12196	12245	12295	12343	12390	12437	12484
195	12532	12580	12628	12677	12726	12774	12820	12867	12914	12961
196	13008	13056	13102	13150	13199	13247	13295	13344	13392	13441
197	13492	13542	13593	13644	13698	13755	13812	13868	13924	13979
198	14036	14096	14164	14237	14315	14394	14469	14538	14605	14669
199	14733	14798	14862	14925	14985	15043	15100	15157	15216	15271
200	15325	15379	15431	15484	15536	15588	15640	15692	15742	15791
201	15840	15890	15940	15989	16038	16087	16135	16183	16230	16278
202	16325	16372	16419	16467	16514	16560	16607	16654	16700	16747
203	16794	16841	16887	16933	16980	17026	17072	17117	17160	17204
204	17247	17291	17334	17379	17424	17470	17516	17563	17609	17655
205	17702	17749	17796	17844	17892	17939	17987	18036	18085	18135
206	18184	18235	18287	18340	18396	18455	18515	18574	18629	18684
207	18737	18789	18840	18891	18943	18993	19043	19094	19144	19194
208	19244	19294	19343	19393	19442	19492	19541	19591	19641	19690
209	19738	19786	19834	19881	19928	19975	20021	20067	20114	20160
210	20208	20255	20303	20351	20399	20447	20493	20539	20584	20630
211	20675	20721	20766	20812	20858	20904	20952	20999	21046	21094
212	21142	21192	21243	21294	21347	21400	21453	21506	21560	21618
213	21678	21741	21802	21866	21931	21999	22065	22128	22193	22257
214	22322	22388	22455	22522	22588	22654	22719	22783	22846	22910
215	22975	23039	23104	23163	23225	23283	23343	23402	23462	23519
216	23577	23634	23689	23744	23797	23850	23916	23969	24020	24070
217	24118	24167	24217	24265	24314	24362	24412	24461	24509	24559
218	24607	24658	24706	24757	24807	24858	24908	24959	25009	25062
219	25115	25168	25220	25273	25328	25383	25438	25496	25553	25611
220	25670	25730	25792	25856	25921	25989				



CHOKE CANYON RESERVOIR

March 1993

Prepared by: TWDB 8/11/93

FIGURE 1

CHOKE CANYON RESERVOIR

LOCATION MAP