

VOLUMETRIC SURVEY REPORT

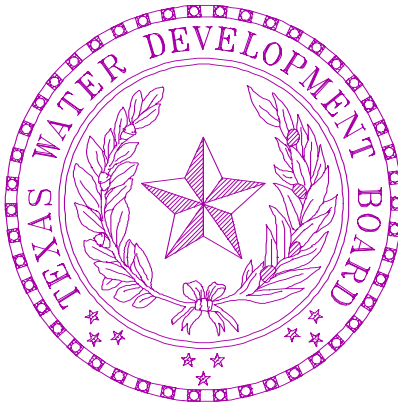
OF

AQUILLA LAKE

APRIL 2002 SURVEY

Prepared by the:

TEXAS WATER DEVELOPMENT BOARD



June 2003

Texas Water Development Board

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Brazos River Authority

In cooperation with the
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VOLUMETRIC SURVEY REPORT

ON AQUILLA LAKE

SURVEY OF APRIL 2002

INTRODUCTION

Staff of the Surface Water Availability Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Aquilla Lake during the period of April 9, 2002 through April 18, 2002. The primary purpose of the survey was to determine the current volume of the lake at conservation pool elevation (CPE) 537.5 ft. For the purpose of this report, the term “top of conservation (TOC) pool” will be used to mean the conservation pool elevation (537.5 ft) for Aquilla Lake. The results of the current survey will be compared to the baseline survey performed by TWDB in October of 1995, report date January 1996. Results from a sediment survey will be presented in a later report. Survey results are presented in the following pages in both graphical and tabular form.

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the lake elevation gage at Aquilla Lake. The station number and name is 08093350 Aquilla Lake above Aquilla, TX. The datum for this gage is reported as sea level (USGS, 2002). Thus, elevations are reported here in feet (ft) above sea level. Volume and area calculations in this report are referenced to water levels provided by the USGS gage.

Original design information for Aquilla Lake was based on information furnished by U.S. Army Corps of Engineers. The equipment and methodology used in the current

survey was similar to that used in the October 1995 survey. Please refer to the Volumetric Survey of Aquilla Lake (TWDB 1996) for more information.

TABLE 1. AQUILLA DAM AND AQUILLA LAKE PERTINENT DATA

Owner of Dam and Facilities:

U.S. Army Corps of Engineers

Operator of Dam and Facilities:

U. S. Army Corps of Engineers, Fort Worth District

Engineer and General Contractor

U. S. Army Corps of Engineers (Design)

Clearwater Construction (General Contractor)

Location:

Aquilla Lake is located in Hill County, on Aquilla Creek, a tributary of the Brazos River, downstream of the confluence with Hackberry Creek, approximately seven miles southeast of Hillsboro, TX. (Figure 1).

Purpose:

Multi-purpose reservoir for flood control, water supply, fish and wildlife enhancement, and general recreation.

Authorization:

Federal: Federal Flood Control Act 1968, Public Law 90-483, 90th Congress approved August 13, 1968.

State: Certificate of Adjudication 12-5158 was issued by the Texas Water Commission December 14, 1987 to the Brazos River Authority (BRA) to impound 52,400 ac-

ft of water at elevation 537.5 in an existing reservoir on Aquilla Creek. The BRA was authorized a priority right to divert and use not to exceed 13,896 ac-ft of water per annum for municipal, industrial and mining purposes. For the purposes of the system operation, the BRA was authorized to exceed the priority right and annually divert and use from Aquilla Lake not to exceed 17,000 ac-ft for municipal purposes; 18,200 ac-ft for industrial purposes and 200 ac-ft for mining purposes. Any diversions and use of water from Aquilla Lake in excess of 13,896 ac-ft of water in one calendar year would be charged against the sum of the amounts designated as priority rights in other reservoirs included in the System Operation Order. BRA was also authorized to use the water impounded in Aquilla Lake for non-consumptive recreation purposes. Certificate of Adjudication 12-5167 (issued December 14, 1987) states the BRA is authorized to divert and use not exceed, 30,000 ac-ft of water for municipal purposes and 170,000 ac-ft of water for industrial purposes, to be used in the San Jacinto-Brazos Coastal Basin. These waters are to be released from Aquilla Lake and other reservoirs owned and operated by the Brazos River Authority.

Drainage area:

255 square miles

Dam:

Type	Rolled earth fill
Length	11,890 ft
Maximum height	104.5 ft (above natural streambed)

Spillway:

Type	Concrete, ogee weir
Control	Uncontrolled
Length	1,200 ft

Outlet works:

Type	Gated conduit
------	---------------

Dimensions	Conduit 10 ft diameter
Floodgate invert elevation	503.0 ft
Control	Two 4.5 ft wide x 10 ft high sluice gates with hydraulic control

Existing Reservoir Data:

FEATURE	ELEVATION (Feet)	CAPACITY (Ac-ft)	AREA (Acres)
Top of Dam ¹	582.5	-----	-----
Maximum Design Water Surface ¹	577.5	359,900	14,495
Top of Flood Control Storage Space ¹	556.0	146,000	7,000
Spillway Crest ¹	564.5	213,800	8,980
<hr/>			
Top of Conservation Storage Space ²	537.5	45,962	3,266
Invert of Lowest Intake ²	503.0	291	142
Usable Conservation Storage Space ²	537.5	45,671	-----

1. Information at elevations above 537.5 ft from Aquilla Lake Design Memorandum No. 3, 1975 by the U.S. Army Corp of Engineers.

2. Information at elevation 537.5 ft and below based on 1996 area and capacity data provided to the U.S. Army Corp of Engineers by the Texas Water Development Board.

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the latest volumetric survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Honda outboard motors. (Reference to brand names throughout this report does not imply

endorsement by TWDB). Installed within the enclosed cabin are a Coastal Oceanographics' Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal and PC. A water-cooled 4.5 kW generator provides electrical power through an in-line uninterruptible power supply. In shallow areas and where navigational hazards such as stumps were present, a 20-foot aluminum shallow-draft flat bottom SeaArk craft with cabin and equipped with one 100-horsepower Yamaha outboard motor was used. The portable data collection equipment on-board the boat included a Knudsen 320 B/P Echosounder (depth sounder), a Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal and a laptop computer.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the pre-plotted transect lines, the depth sounder takes approximately ten readings of the lake bottom each second. The depth readings are stored on the computer along with the positional data generated by the boat's GPS receiver. The data files collected are downloaded and transferred 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 one data point per second, and the average depths are converted to elevation readings based on the water-level elevation recorded on the day the survey was performed. Accurate estimates of the lake volume can then be determined by building a 3-D TIN model of the lake from the collected data.

PRESURVEY PROCEDURES

The lake's boundary was digitized using Environmental Systems Research Institute's (ESRI) ArcGIS from digital orthophoto quadrangles (DOQ's). VARGIS of Texas LLC produced the DOQ's for the Texas Orthoimagery Program (TOP). The

DOQ's produced for the Department of Information Resources and the GIS Planning Council under the TOP reside in the public domain. More information can be obtained on the Internet at <http://www.tnris.state.tx.us/DigitalData/doqs.htm>. The lake elevation, at the time the DOQ's were photographed (January 31, 1995) was 537.87 ft. The lake and island boundaries were given an elevation of 537.9 ft and TWDB Staff utilized these updated boundary conditions in modeling Aquilla Lake for this report. The lake elevations varied between elevation 539.15 ft and 538.09 ft during the survey (April 09, 2002 – April 18, 2002).

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using the HYPACK software. The survey design required the use of approximately 155 survey lines placed perpendicular to the original river channel and tributaries along the length of the lake.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

Prior to collecting data onboard the Hydro-survey boat, the depth sounder was calibrated with the Innerspace 443 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 acclimate it. The probe was next raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again 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.

While collecting data onboard the River Runner (shallow draft) boat, the Knudsen depth sounder was calibrated using the DIGIBAR-Pro Profiling Sound Velocimeter by Odem Hydrographic Systems. The steps to determine the speed of sound are similar to those used for the Innerspace 443 Velocity Profiler. The probe was first placed in the water to acclimate it, raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again 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 velocimeter. The speed of sound was then entered into the bar check feature in the Knudsen software program. The depth was then checked manually with a stadia (survey) rod or weighted measuring tape to ensure that the depth sounder was properly calibrated and operating correctly.

The speed of sound in the water column was 4810 feet per second during the Aquilla Lake survey. 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 ft. An additional estimated error of ± 0.3 ft arises from variation in boat inclination. These two factors combine to give an overall accuracy of ± 0.5 ft for

any instantaneous reading. These errors tend to be fairly minimal over the entire survey, since some errors are positive and some are negative, canceling each other out.

During the survey, the horizontal mask setting on the onboard GPS receiver was set to 10 degrees and the PDOP (Position Dilution of Precision) limit was set to seven to maximize the accuracy of the horizontal positioning. An internal alarm sounds if PDOP rises above seven to advise the field crew that the horizontal position has degraded to an unacceptable level. Further positional accuracy is obtained through differential corrections from the Omnistar receiver. The lake's initialization file used by the HYPACK data collection program was set up to convert the collected Differential GPS positions to NAD 83, State Plane, Texas Central Zone coordinates on the fly.

Data Collection

TWDB staff collected data at Aquilla Lake for approximately 3 days during the period of April 9, through April 18, 2002. The USACE were able to maintain the lake levels above TOC during the survey. The lake level elevations varied between 538.09 ft and 539.15 ft, thus allowing the survey crew to collect data in most areas of the lake that would be inundated at TOC 537.5 ft.

The design layout for collecting data at Aquilla Lake required pre-plotting transects (range lines) that were perpendicular to the old river and creek channels. These transects had an average spacing of 500 ft. While collecting data, the boat operator would steer the boat on course (with GPS navigation) starting from one shore and heading to the opposite shore. The data collector would monitor the data display and depth sounder to make sure the latitude; longitude and depth (x,y,z) values were being logged. Adjustments could be made if the instruments were receiving bad data at that time. The depth sounder and GPS equipment records 10 data points every second. These

points are averaged to one data point per second for generating the model. The distance between data points depended on the speed of the boat. The maximum distance between data points during the 2002 survey of Aquilla Lake was approximately 30 ft.

Approximately 43,000 data points were collected over the 81 miles traveled during the data collection phase of Aquilla Lake. These points were stored digitally on the boat's computer in 181 data files. Random data were collected in those areas where the crew was not able to stay on course due to obstructions. Data were not collected in areas with significant obstructions or where the water was too shallow. Figure 2 shows the actual location of all data points collected.

Data Processing

The collected data were downloaded from diskettes onto TWDB's network computers. 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 files. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. After all adjustments had been made to the raw data files, the edited files were saved. The edited files were then combined into a single X, Y, Z data file, to be used with the GIS software to develop a model of the lake bottom elevation.

The resulting data file was imported into Environmental System Research Institute's (ESRI) Arc/Info Workstation GIS software. This 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 lake's bottom surface using Arc/Info's

TIN software module. The module generates a triangulated irregular network (TIN) 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 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 lake area and volume can be determined from the triangulated irregular network created using this method of interpolation.

Volumes and areas were calculated from the TIN for the entire lake at one-tenth of a foot interval from the lowest elevation to the contour used for the lake boundary during the current survey. From elevation 493.7 ft to 537.5 ft, the surface areas and volumes of the lake were computed using Arc/Info software. The computed lake volume table is presented in Appendix A and the area table in Appendix D for Aquilla Lake. The lake volume and area tables as originally reported in the 1996 Volumetric Survey of Aquilla Lake are presented in Appendix B and Appendix E. The 1996 lake volume and area tables were revised using the updated boundary conditions developed from 1995 photographs are presented in Appendix C and Appendix F. An elevation-volume graph and an elevation-area graph are presented in Appendix G and Appendix H respectively. Finally, endpoint coordinates for 18 range lines can be found in Appendix I. The range line plots for the three TIN models are presented in Appendix J.

The current survey shows an increase in both volume and area when compared to the revised 1996 numbers. This is due to the increased accuracy of the boundary and the use of the shallow water survey vessel (not available for the October 1995 survey) to collect data nearer the shoreline and in shallow areas in the upper reaches of the lake. These data points change the way the TIN model extrapolates to the boundary in the upper elevations and accounts for these differences in area and volume. The use of the shallow water survey vessel alleviates the need to interpolate points near the shoreline, as

was the case in the 1996 report. This report will use the 1996 original numbers for comparisons of volume and area. Figure 3 compares the 2002 data set to the 1995 data set and Figure 4 illustrates the differences between the 1996 boundary and the 2002 boundary.

Another product developed from the model includes a contour map. To develop this map, 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 2-ft intervals is presented in Figure 5.

RESULTS

Results from the 2002 TWDB survey indicate Aquilla Lake encompasses 3,020 surface acres and contains a total volume of 45,319 ac-ft at conservation pool elevation of 537.5 ft. The length of the shoreline at the digitized elevation of 537.9 ft was calculated to be approximately 48 miles. The deepest point physically measured during the survey was at elevation 493.8 ft corresponding to a depth of 43.7 ft below TOC and was located approximately 470 ft upstream of Aquilla Dam.

SUMMARY AND COMPARISONS

The Federal Flood Control Act approved September 3, 1954 and the Public Works Appropriation Act of 1958 authorized the construction of Aquilla Dam creation of Aquilla Lake. Construction commenced August 3, 1976. Deliberate impoundment began April 29, 1983. Initial storage calculations estimated the volume of the lake at the conservation pool elevation of 537.5 to be 52,400 ac-ft with a surface area of 3,280 acres.

Prior to this report, the most recent volumetric survey report on Aquilla Lake was published by the TWDB in January 1996 when the volume of Aquilla Lake was estimated to be 45,962 ac-ft with a surface area of 3,266 acres at elevation 537.5 ft.

At conservation pool elevation 537.5 ft, the current TWDB survey estimated 3,020 surface acres and reports a volume of 45,319 ac-ft of water. The capacity of the active pool (conservation storage) between elevations 537.5 ft and 503.0 ft is 45,092 ac-ft of water. The dead pool storage or that capacity of water below the invert of the lowest outlet (elevation 503.0 ft) was 227 ac-ft of water.

The 1996-revised elevation-area-capacity table indicates that Aquilla Lake had a volume of 44,462 ac-ft of water and a surface area of 2,900 acres at conservation pool elevation 537.5 ft. A comparative summary of the historical data and the results of the TWDB 2002 survey are presented in Table 2. As discussed previously, the distance between the 1996 surveyed points and the updated boundary is large enough that the TIN model underestimates the area and volume when interpolating to the boundary. Therefore, in this report the original 1996 area and volumes numbers are used for comparison.

Comparisons between original survey data (1964) and the TWDB volumetric surveys are difficult and some apparent changes might simply be due to methodological differences. It is recommended that a similar survey be performed in five to ten years or after major flood events to monitor changes to the lake's capacity.

Table 2. Area and Volume Comparisons of Aquilla Lake

	USACE Original Design 1964	TWDB Volumetric Survey 1996	TWDB Volumetric Survey 2002
Area (acres)	3,280	3,266	3,020
Total Volume (ac-ft)	52,400	45,962	45,319

Notes:

1. All pre-1996 data provided by Fort Worth District USACE
2. All results for conservation pool elevation 537.5 ft

REFERENCES

1. <http://www.swf-wc.usace.army.mil/>
2. Texas Water Commission, 1976, Permit No. 3403
3. Texas Water Commission, 1977, ORDER partially withdrawing and partially canceling with consent Permit No. 3403
3. Texas Water Commission, 1979, Permit No. 3403A
4. Texas Water Commission, 1980, Permit No. 3403B
5. Texas Water Commission, 1986, Certificate of Adjudication 12-5158
6. Texas Water Development Board, 1996, “Volumetric Survey of Aquilla Lake”
7. United States Geological Survey, 2001, Water Data Report TX-01-3. “Water Resources Data Texas Water Year 2001”

Appendix A
Aquila Lake
RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

APRIL 2002 SURVEY

ELEVATION in Feet	VOLUME IN ACRE-FEET									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
493								0	0	0
494	0	0	0	0	0	0	0	0	0	0
495	0	0	0	0	0	0	0	0	0	0
496	0	0	0	0	0	0	0	0	0	1
497	1	1	1	1	1	1	2	2	2	2
498	3	3	4	4	5	6	6	7	8	9
499	10	11	13	14	15	17	18	20	22	24
500	27	29	32	35	38	41	44	48	51	56
501	60	65	70	75	81	87	94	101	109	116
502	125	133	142	151	161	171	181	192	203	215
503	227	239	252	265	279	293	307	322	337	353
504	369	385	402	420	437	456	474	493	513	532
505	553	573	594	616	638	660	683	706	730	755
506	779	805	830	857	883	911	938	966	995	1024
507	1053	1083	1113	1144	1175	1206	1238	1270	1303	1336
508	1369	1403	1437	1472	1507	1543	1579	1616	1652	1690
509	1728	1766	1805	1844	1884	1924	1965	2007	2048	2091
510	2134	2177	2221	2266	2311	2357	2403	2450	2497	2545
511	2594	2643	2693	2744	2795	2847	2899	2953	3007	3061
512	3117	3174	3231	3290	3349	3409	3470	3532	3595	3658
513	3723	3788	3853	3920	3987	4055	4124	4193	4263	4334
514	4406	4478	4550	4624	4698	4773	4848	4925	5002	5080
515	5158	5237	5317	5398	5479	5561	5644	5728	5812	5897
516	5982	6068	6155	6243	6331	6420	6510	6601	6692	6783
517	6876	6969	7062	7156	7251	7347	7444	7542	7640	7740
518	7841	7942	8044	8147	8250	8354	8459	8565	8671	8778
519	8887	8995	9105	9216	9327	9439	9552	9666	9780	9895
520	10010	10127	10244	10361	10480	10599	10718	10839	10960	11082
521	11204	11327	11451	11576	11701	11827	11953	12081	12209	12338
522	12468	12598	12729	12861	12993	13127	13261	13395	13531	13667
523	13804	13941	14080	14219	14358	14499	14640	14782	14925	15070
524	15214	15360	15507	15656	15805	15955	16106	16259	16413	16568
525	16724	16881	17040	17199	17360	17521	17684	17848	18013	18179
526	18346	18514	18683	18853	19024	19197	19370	19544	19719	19896
527	20074	20252	20432	20614	20796	20980	21165	21352	21539	21728
528	21918	22109	22302	22495	22690	22886	23083	23282	23481	23682
529	23884	24086	24290	24495	24702	24909	25117	25326	25536	25748
530	25960	26173	26388	26603	26820	27037	27256	27476	27697	27919
531	28142	28366	28591	28818	29046	29275	29505	29737	29970	30205
532	30441	30678	30916	31155	31396	31637	31880	32124	32369	32616
533	32863	33112	33362	33614	33867	34121	34377	34634	34893	35152
534	35413	35676	35940	36205	36471	36738	37007	37277	37548	37820
535	38093	38368	38644	38922	39200	39480	39761	40043	40327	40612
536	40899	41186	41475	41765	42056	42348	42640	42934	43229	43525
537	43822	44119	44418	44717	45018	45319	45622	45925	46230	46535

Values above Top of Conservation Pool Elevation

Appendix B
Aquila Lake
RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

OCTOBER 1995 SURVEY

ELEVATION in Feet	VOLUME IN ACRE-FEET									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
495						1	1	1	1	1
496	1	1	1	1	1	2	2	2	2	2
497	3	3	3	3	4	4	5	5	5	6
498	7	7	8	8	9	10	11	12	13	15
499	16	18	20	22	25	27	30	32	35	39
500	42	46	50	54	58	63	68	73	78	84
501	90	97	104	111	118	126	134	143	152	161
502	171	181	191	202	213	225	237	250	263	277
503	291	305	320	335	351	367	383	400	417	435
504	453	471	490	509	528	548	568	588	609	631
505	652	674	697	720	743	767	791	816	841	867
506	893	919	946	973	1001	1029	1058	1087	1117	1147
507	1178	1209	1240	1272	1305	1338	1372	1406	1440	1475
508	1511	1547	1584	1621	1659	1698	1736	1776	1816	1856
509	1897	1939	1981	2024	2067	2110	2155	2200	2245	2291
510	2338	2385	2432	2481	2530	2579	2629	2679	2730	2782
511	2834	2887	2940	2993	3048	3103	3158	3214	3271	3329
512	3387	3446	3507	3567	3629	3692	3756	3820	3886	3952
513	4018	4086	4154	4223	4293	4364	4435	4507	4580	4653
514	4727	4801	4876	4951	5027	5104	5181	5259	5338	5417
515	5497	5577	5659	5740	5823	5906	5990	6075	6160	6247
516	6333	6421	6509	6598	6688	6778	6870	6962	7055	7149
517	7244	7340	7436	7533	7631	7730	7829	7930	8031	8134
518	8237	8341	8446	8552	8660	8768	8876	8986	9097	9208
519	9320	9433	9547	9661	9776	9892	10008	10125	10243	10362
520	10481	10601	10721	10842	10964	11086	11209	11333	11457	11582
521	11708	11834	11961	12089	12218	12347	12478	12609	12740	12873
522	13006	13140	13275	13410	13546	13683	13820	13958	14097	14236
523	14377	14518	14660	14802	14946	15090	15235	15382	15529	15677
524	15826	15977	16128	16281	16434	16589	16745	16901	17059	17218
525	17377	17538	17699	17862	18025	18189	18354	18520	18687	18855
526	19023	19193	19363	19535	19707	19880	20054	20230	20406	20583
527	20762	20941	21121	21303	21485	21668	21852	22038	22224	22411
528	22599	22788	22978	23169	23361	23554	23748	23943	24139	24336
529	24534	24733	24933	25134	25335	25538	25742	25947	26152	26359
530	26566	26775	26984	27194	27405	27617	27830	28044	28258	28474
531	28690	28908	29126	29346	29567	29789	30012	30236	30461	30687
532	30914	31142	31372	31603	31835	32069	32304	32540	32778	33018
533	33259	33503	33748	33995	34243	34492	34742	34994	35247	35501
534	35756	36013	36271	36531	36792	37055	37319	37586	37854	38124
535	38395	38680	38966	39253	39542	39831	40122	40415	40708	41004
536	41300	41597	41896	42197	42498	42801	43109	43419	43731	44044
537	44359	44676	44995	45316	45638	45962				

Appendix C
Aquila Lake
RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

OCTOBER 1995 SURVEY

REVISED

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
493								0	0	0
494	0	0	0	0	0	0	0	0	0	0
495	0	0	0	0	0	1	1	1	1	1
496	1	1	1	1	1	2	2	2	2	2
497	3	3	3	3	4	4	5	5	5	6
498	7	7	8	8	9	10	11	12	13	15
499	16	18	20	22	24	27	30	32	35	39
500	42	46	50	54	58	63	68	73	78	84
501	90	97	104	111	118	126	134	143	152	161
502	171	181	191	202	213	225	237	250	263	277
503	291	305	320	335	351	367	383	400	417	434
504	452	470	489	508	527	547	567	588	608	630
505	651	673	696	719	742	766	790	814	839	865
506	891	917	944	971	999	1027	1056	1085	1115	1145
507	1175	1206	1238	1270	1302	1335	1368	1402	1437	1472
508	1507	1544	1580	1617	1655	1693	1732	1772	1811	1852
509	1893	1934	1976	2018	2062	2105	2149	2194	2239	2285
510	2331	2378	2426	2474	2523	2572	2622	2672	2723	2774
511	2826	2879	2932	2985	3039	3094	3149	3205	3262	3319
512	3378	3437	3497	3558	3619	3682	3745	3810	3875	3940
513	4007	4074	4142	4211	4281	4351	4422	4494	4566	4639
514	4713	4787	4862	4937	5013	5089	5166	5244	5322	5401
515	5480	5561	5642	5723	5806	5889	5972	6057	6142	6227
516	6314	6401	6489	6577	6667	6757	6848	6940	7033	7126
517	7221	7316	7412	7509	7606	7704	7803	7903	8004	8106
518	8208	8312	8417	8522	8629	8736	8845	8954	9064	9174
519	9286	9398	9510	9624	9738	9853	9969	10085	10202	10320
520	10438	10557	10676	10797	10917	11039	11160	11283	11406	11530
521	11655	11780	11906	12033	12160	12288	12417	12547	12677	12809
522	12940	13073	13206	13340	13474	13609	13745	13882	14019	14157
523	14295	14434	14574	14715	14857	14999	15143	15287	15432	15578
524	15725	15873	16023	16173	16324	16476	16630	16784	16939	17095
525	17252	17410	17568	17728	17888	18049	18211	18374	18538	18703
526	18868	19034	19201	19369	19538	19707	19878	20050	20222	20396
527	20570	20745	20922	21099	21277	21456	21636	21817	21999	22181
528	22365	22549	22735	22921	23108	23297	23486	23676	23867	24059
529	24252	24446	24640	24836	25033	25230	25428	25628	25828	26029
530	26231	26433	26637	26841	27046	27252	27459	27666	27874	28084
531	28294	28505	28717	28930	29144	29359	29575	29791	30009	30228
532	30448	30668	30890	31113	31338	31563	31790	32018	32247	32478
533	32710	32945	33181	33418	33656	33894	34134	34375	34616	34859
534	35103	35347	35593	35840	36088	36337	36588	36840	37093	37349
535	37605	37866	38129	38392	38657	38922	39188	39456	39724	39993
536	40263	40535	40807	41080	41354	41629	41906	42185	42465	42747
537	43029	43313	43598	43885	44173	44462	44753	45045	45338	45634

Values above Top of Conservation Pool Elevation

Appendix D
Aquila Lake
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

APRIL 2002 SURVEY

ELEVATION in Feet	AREA IN ACRES									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
493								0	0	0
494	0	0	0	0	0	0	0	0	0	0
495	0	0	0	0	0	0	0	0	0	0
496	0	0	0	0	0	0	0	1	1	1
497	1	1	1	1	2	2	2	3	3	4
498	4	5	5	6	7	7	8	9	9	10
499	11	12	13	14	15	16	17	19	20	22
500	23	25	27	29	31	33	35	37	39	42
501	45	49	53	57	61	65	69	73	76	80
502	83	87	90	94	98	102	106	110	114	118
503	122	126	130	134	138	141	145	150	154	159
504	163	167	172	176	180	184	188	192	196	200
505	205	209	213	217	222	226	231	236	241	246
506	251	255	260	265	270	274	278	283	287	291
507	295	299	304	308	312	316	320	324	328	332
508	337	341	345	350	354	359	363	367	372	376
509	381	386	391	396	401	406	411	416	422	427
510	432	438	443	448	454	460	466	471	477	484
511	490	496	503	509	515	522	529	536	543	552
512	562	571	580	588	598	607	615	623	631	639
513	647	654	662	669	676	683	691	698	704	711
514	718	724	731	738	745	752	760	767	774	781
515	789	796	803	810	817	824	831	838	845	852
516	859	866	873	880	887	894	901	908	914	920
517	926	932	939	947	954	963	972	982	992	1001
518	1009	1016	1024	1031	1038	1045	1053	1060	1068	1077
519	1085	1093	1101	1109	1118	1125	1132	1139	1146	1153
520	1160	1166	1173	1180	1187	1194	1201	1207	1214	1221
521	1228	1234	1241	1248	1256	1263	1271	1278	1285	1293
522	1300	1307	1314	1322	1329	1336	1343	1351	1358	1365
523	1372	1379	1386	1394	1401	1409	1417	1427	1436	1445
524	1455	1465	1475	1486	1497	1509	1521	1533	1545	1556
525	1567	1578	1589	1600	1610	1621	1632	1643	1654	1665
526	1676	1686	1697	1707	1717	1727	1738	1748	1759	1771
527	1782	1794	1807	1820	1833	1845	1857	1869	1881	1894
528	1906	1919	1931	1943	1955	1966	1978	1989	2000	2012
529	2023	2034	2045	2056	2066	2076	2087	2097	2107	2118
530	2128	2139	2150	2160	2171	2181	2192	2203	2214	2225
531	2237	2248	2261	2273	2285	2298	2311	2324	2338	2351
532	2364	2376	2388	2399	2411	2422	2434	2445	2457	2469
533	2483	2497	2510	2523	2536	2550	2564	2578	2592	2605
534	2617	2631	2644	2656	2668	2680	2692	2704	2716	2729
535	2742	2754	2767	2779	2791	2804	2818	2831	2844	2857
536	2870	2882	2893	2904	2914	2923	2933	2943	2952	2962
537	2972	2981	2991	3001	3010	3020	3030	3040	3049	3130

Values above Top of Conservation Pool Elevation

Appendix E
Aquilla Lake
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

OCTOBER 1995

ELEVATION in Feet	AREA IN ACRES									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
495						1	1	1	1	1
496	1	1	1	1	2	2	2	2	2	2
497	3	3	3	3	4	4	4	5	5	5
498	6	6	7	7	8	9	10	12	13	15
499	17	19	20	22	24	26	27	29	31	33
500	35	38	40	43	45	48	51	54	57	60
501	63	66	69	72	76	80	84	88	92	95
502	99	103	106	111	115	120	125	129	134	138
503	142	146	150	154	158	162	166	170	174	177
504	181	185	188	192	196	199	203	207	211	215
505	219	223	227	231	235	240	245	249	254	258
506	263	267	271	276	280	285	289	294	299	303
507	308	313	318	323	328	333	338	343	348	354
508	359	365	371	376	381	386	392	397	402	408
509	413	418	424	429	434	440	446	451	457	463
510	469	474	480	486	491	497	502	507	513	518
511	523	529	534	540	546	552	558	565	572	580
512	589	597	606	614	623	632	641	649	657	664
513	671	679	687	695	702	710	717	723	729	735
514	741	746	752	758	764	770	776	782	788	795
515	802	809	816	823	830	837	843	850	857	864
516	871	878	886	894	902	911	919	928	936	944
517	952	960	968	975	983	991	1000	1009	1018	1027
518	1037	1047	1057	1067	1076	1085	1093	1101	1109	1117
519	1125	1132	1139	1146	1154	1161	1168	1175	1182	1189
520	1195	1201	1208	1214	1220	1226	1233	1240	1247	1254
521	1261	1268	1275	1283	1290	1298	1306	1314	1321	1329
522	1336	1343	1350	1357	1363	1370	1377	1384	1391	1399
523	1406	1414	1422	1431	1440	1449	1458	1467	1476	1487
524	1498	1509	1520	1531	1542	1552	1562	1572	1582	1591
525	1600	1610	1619	1628	1637	1646	1655	1664	1673	1682
526	1691	1700	1709	1718	1728	1738	1748	1758	1768	1778
527	1789	1799	1809	1818	1828	1837	1847	1856	1866	1876
528	1886	1896	1906	1915	1925	1935	1945	1955	1965	1975
529	1984	1994	2004	2013	2023	2033	2042	2052	2061	2071
530	2080	2088	2097	2106	2114	2123	2132	2141	2150	2161
531	2171	2181	2192	2203	2213	2224	2234	2245	2256	2267
532	2279	2291	2303	2315	2329	2343	2357	2371	2386	2402
533	2433	2447	2460	2473	2485	2498	2510	2523	2536	2549
534	2562	2575	2589	2604	2620	2636	2653	2671	2689	2709
535	2840	2853	2866	2878	2891	2904	2917	2930	2943	2956
536	2970	2983	2996	3009	3023	3071	3089	3107	3125	3143
537	3161	3179	3197	3215	3233	3266				

Appendix F
Aquila Lake
RESERVOIR AREA TABLE

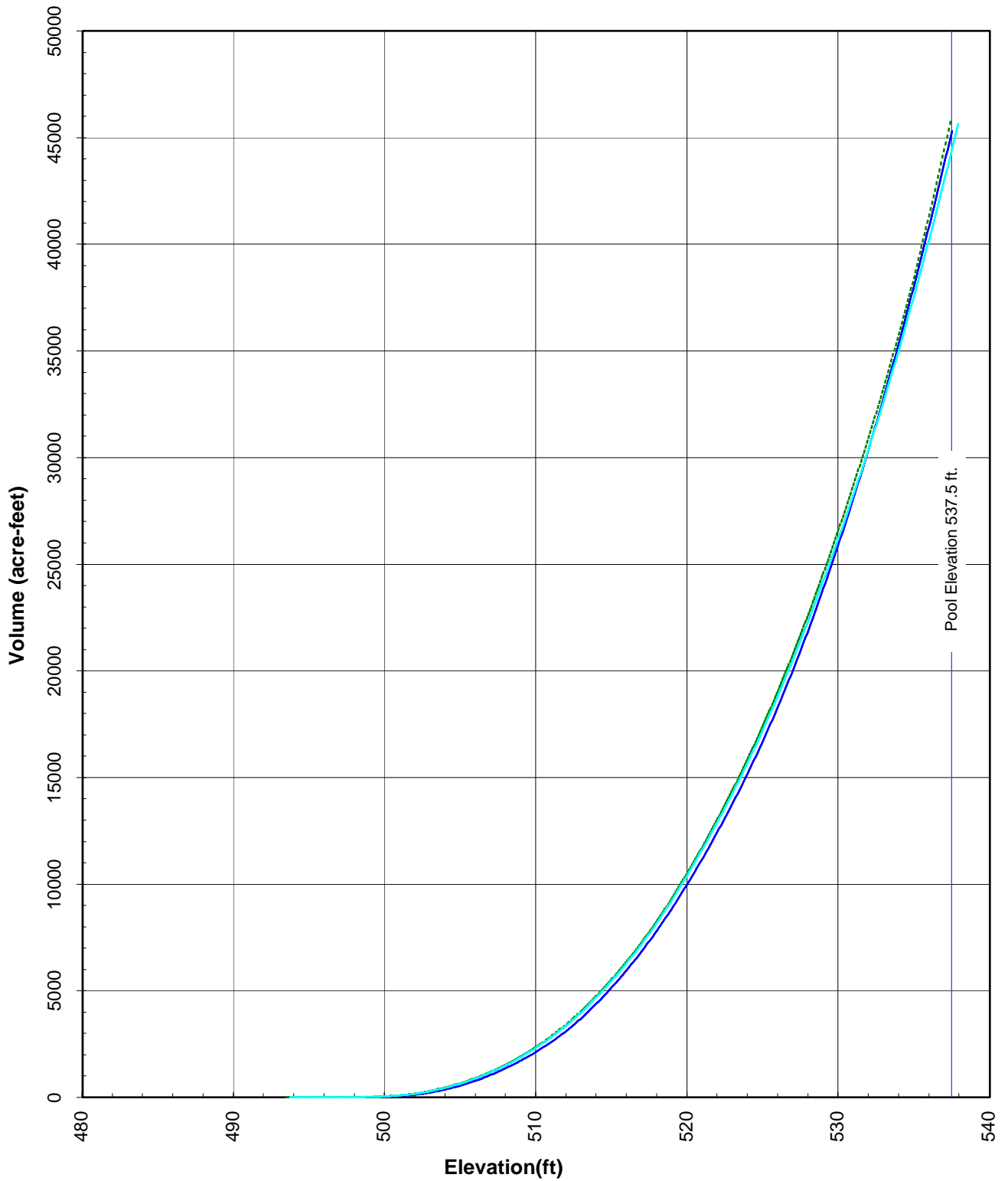
TEXAS WATER DEVELOPMENT BOARD

OCTOBER 1995

REVISED

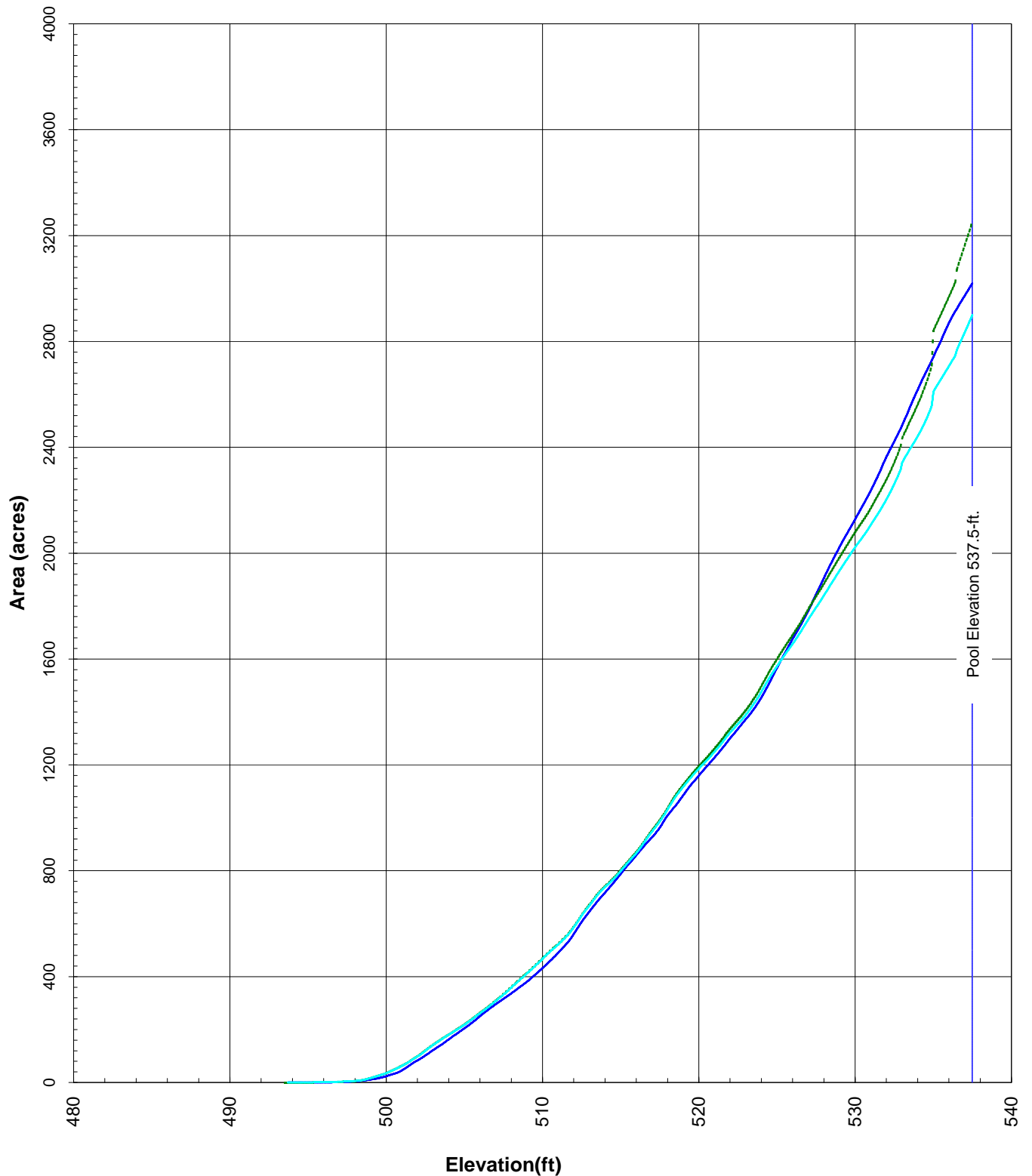
ELEVATION in Feet	AREA IN ACRES									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
493								0	0	0
494	0	0	0	0	0	0	0	0	0	0
495	0	0	0	0	0	1	1	1	1	1
496	1	1	1	1	2	2	2	2	2	2
497	3	3	3	3	4	4	4	5	5	5
498	6	6	7	7	8	9	10	12	13	15
499	17	18	20	22	24	26	27	29	31	33
500	35	38	40	43	45	48	51	54	57	60
501	63	66	69	72	76	80	84	88	91	95
502	99	102	106	111	115	120	125	129	134	138
503	142	146	150	154	158	162	166	169	173	177
504	181	184	188	191	195	199	203	206	210	214
505	218	222	226	231	235	239	244	249	253	258
506	262	266	271	275	280	284	289	293	298	303
507	307	312	317	322	327	332	337	342	347	353
508	358	364	369	375	380	385	391	396	401	406
509	412	417	422	428	433	439	444	450	455	461
510	467	473	479	484	490	495	501	506	511	516
511	522	527	533	538	544	550	556	563	570	578
512	587	595	604	612	621	630	639	647	655	662
513	669	677	685	692	700	707	714	721	727	732
514	738	744	749	755	761	767	773	779	785	793
515	799	806	813	820	827	833	840	847	854	860
516	867	874	882	890	899	907	915	924	932	940
517	948	956	963	971	978	987	995	1003	1012	1022
518	1032	1042	1052	1061	1070	1078	1087	1095	1102	1110
519	1117	1125	1132	1139	1146	1153	1160	1167	1173	1180
520	1186	1192	1198	1204	1210	1216	1222	1229	1236	1243
521	1250	1256	1263	1271	1278	1285	1293	1300	1308	1315
522	1322	1329	1335	1341	1348	1354	1361	1367	1375	1382
523	1389	1396	1404	1413	1421	1429	1438	1447	1456	1466
524	1477	1487	1497	1508	1518	1528	1538	1547	1556	1565
525	1573	1582	1590	1599	1607	1616	1624	1633	1641	1649
526	1658	1666	1675	1683	1692	1702	1711	1720	1730	1740
527	1750	1759	1768	1777	1786	1795	1804	1812	1821	1831
528	1840	1850	1859	1868	1878	1887	1896	1906	1915	1925
529	1934	1943	1952	1961	1970	1979	1988	1997	2006	2014
530	2023	2031	2039	2047	2055	2063	2071	2079	2088	2097
531	2107	2116	2125	2134	2144	2153	2163	2172	2182	2192
532	2203	2214	2225	2236	2249	2261	2274	2287	2301	2316
533	2341	2353	2363	2373	2383	2393	2402	2412	2422	2432
534	2442	2452	2463	2475	2487	2499	2513	2527	2542	2558
535	2610	2620	2629	2639	2649	2658	2668	2678	2687	2697
536	2707	2717	2727	2736	2746	2768	2780	2793	2806	2819
537	2832	2846	2859	2873	2887	2900	2914	2928	2943	3130

Values above Top of Conservation Pool Elevation



Pool Elevation 537.5' Volume 2002 Volume 1996 Volume 96 revised

Aquilla Lake
 April 2002
 Prepared by: TWDB



Pool Elevation 537.5' Area 2002 Area 1996 Area 96 revised

Aquilla Lake
 April 2002
 Prepared by: TWDB

Appendix I
Aquilla Lake

TEXAS WATER DEVELOPMENT BOARD

APRIL 2002 SURVEY

Range Line Endpoints
 State Plane NAD83 Units-feet

L-Left endpoint
 R-right endpoint

<u>Range Line</u>	<u>X</u>	<u>Y</u>
Line 01-L	2373800.0	6649937.0
Line 01-R	2368100.8	6649473.0
Line 02-L	2374604.0	6653008.5
Line 02-R	2367861.0	6652461.5
Line 03-L	2370250.8	6655132.5
Line 03-R	2367619.0	6653833.5
Line 04-L	2368917.8	6659423.0
Line 04-R	2365285.0	6657678.5
Line 05-L	2367118.5	6661955.0
Line 05-R	2365796.0	6661330.0
Line 06-L	2367242.3	6663038.5
Line 06-R	2363587.3	6661354.0
Line 07-L	2364432.5	6664903.0
Line 07-R	2361840.8	6663029.5
Line 08-L	2361942.3	6666799.0
Line 08-R	2360601.3	6665732.0
Line 09-L	2374174.5	6652358.5
Line 09-R	2370614.8	6655231.5
Line 10-L	2375105.5	6656750.5
Line 10-R	2373514.5	6657962.5
Line 11-L	2379072.0	6662419.5
Line 11-R	2378141.0	6663275.5
Line 12-L	2380426.5	6665406.0
Line 12-R	2378899.8	6665288.5
Line-13-L	2380194.3	6666995.5
Line-13-R	2379007.5	6668617.0
Line 14-L	2382583.0	6668840.5
Line 14-R	2382022.0	6669564.0
Line 15-L	2387062.5	6669401.5
Line 15-R	2386518.0	6669627.0

Appendix I (Continued)
Grapevine Lake

TEXAS WATER DEVELOPMENT BOARD

APRIL 2002 SURVEY

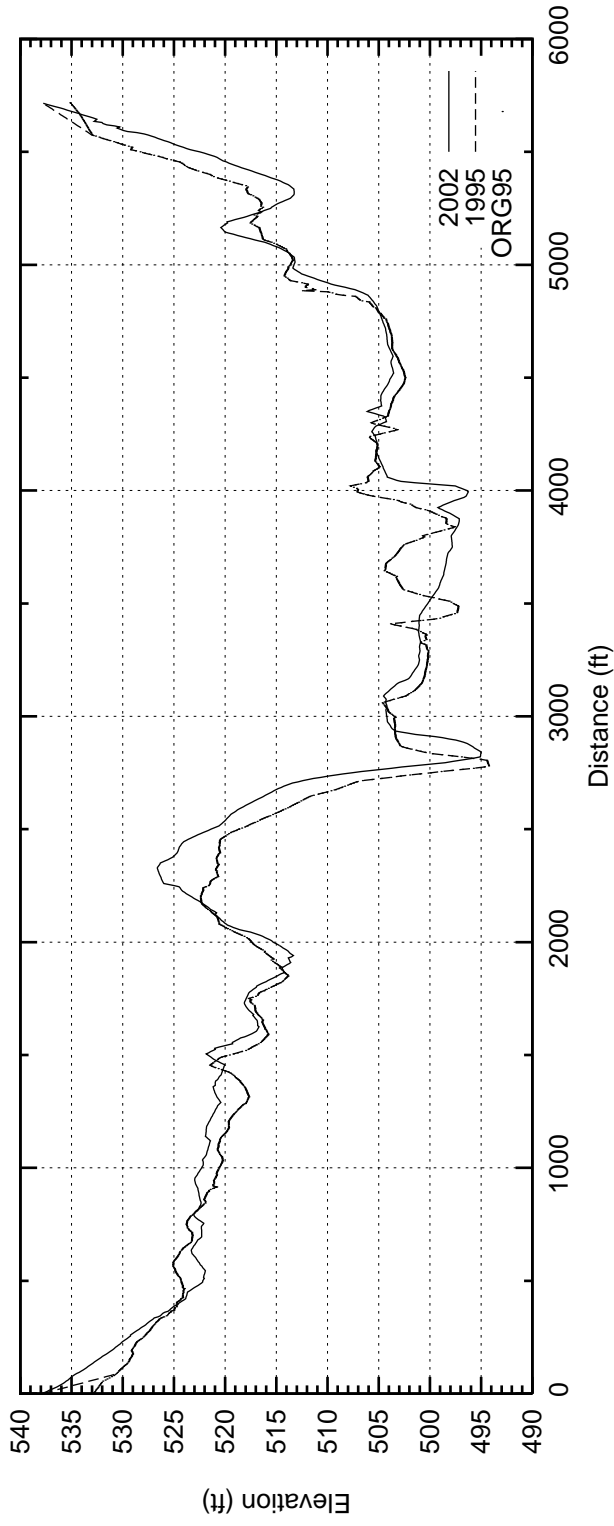
Range Line Endpoints
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

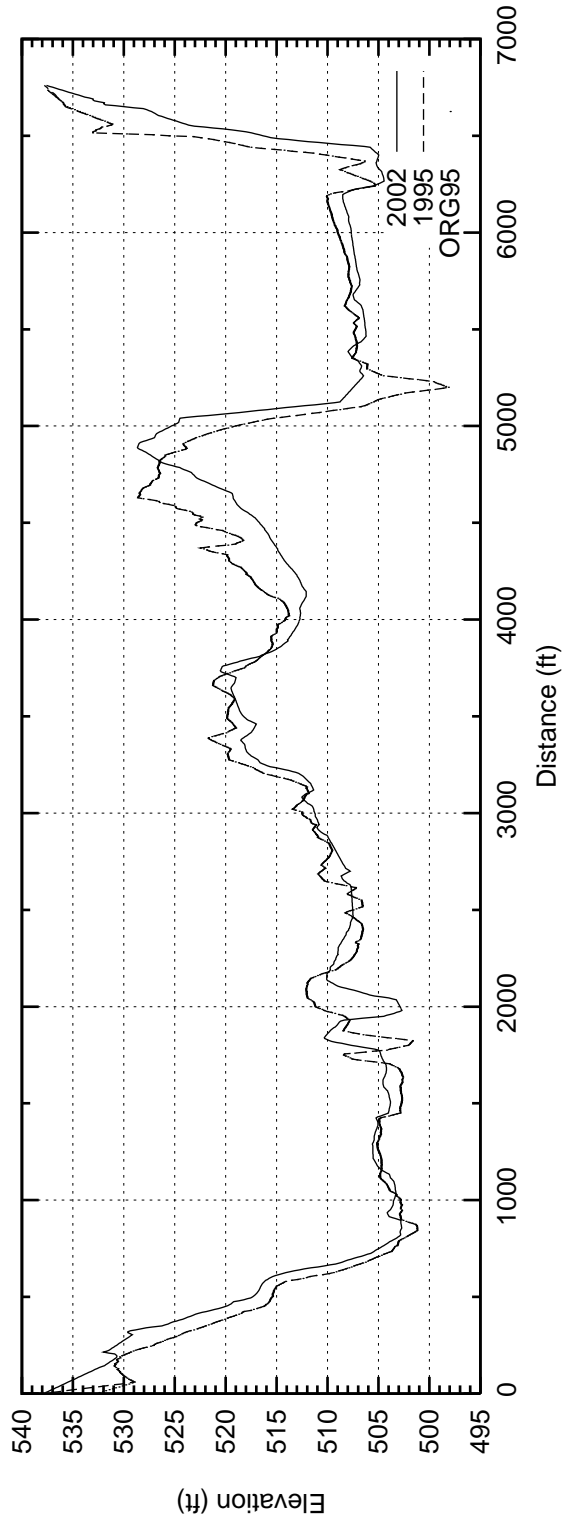
<u>Range Line</u>	<u>X</u>	<u>Y</u>
Line 16-L	2365027.5	6655091.5
Line 16-R	2365584.8	6654592.5
Line 17-L	2364260.3	6653741.0
Line 17-R	2364813.8	6652978.5
Line 18-L	2364330.8	6659560.5
Line 18-R	2364046.3	6658818.5

Aquilla Lake

Rangeline SR01

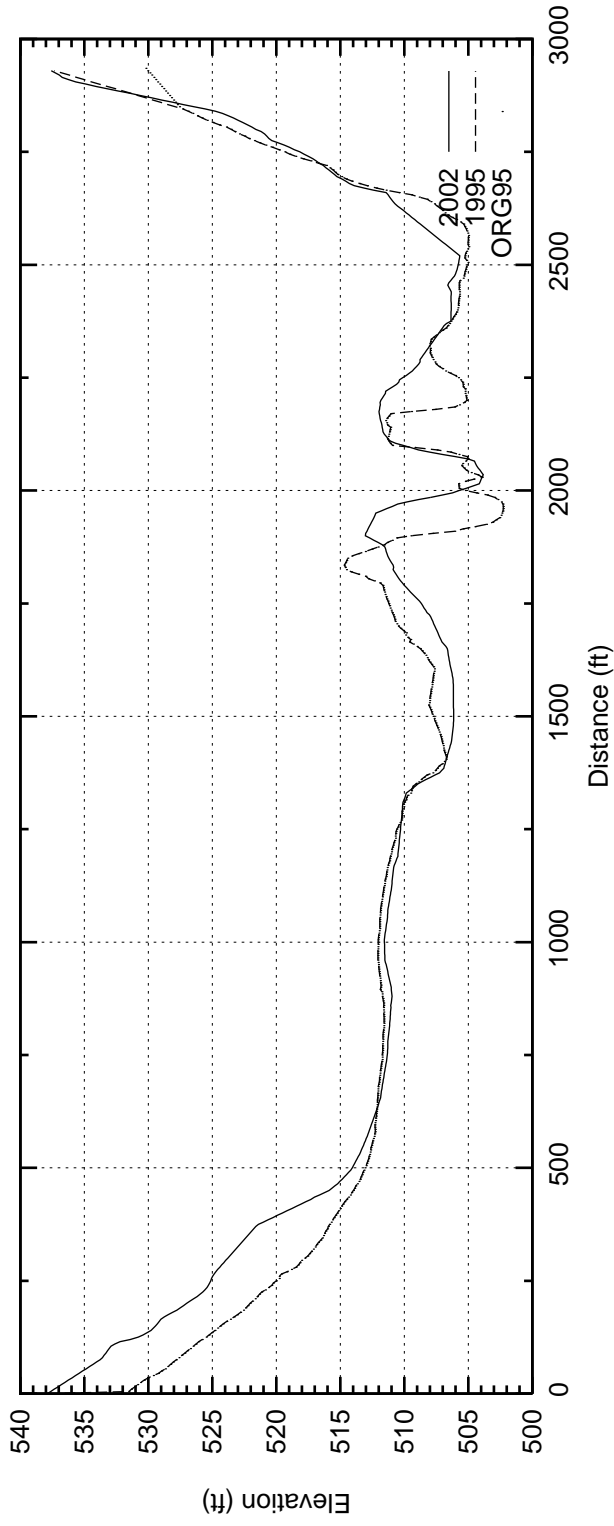


Rangeline SR02

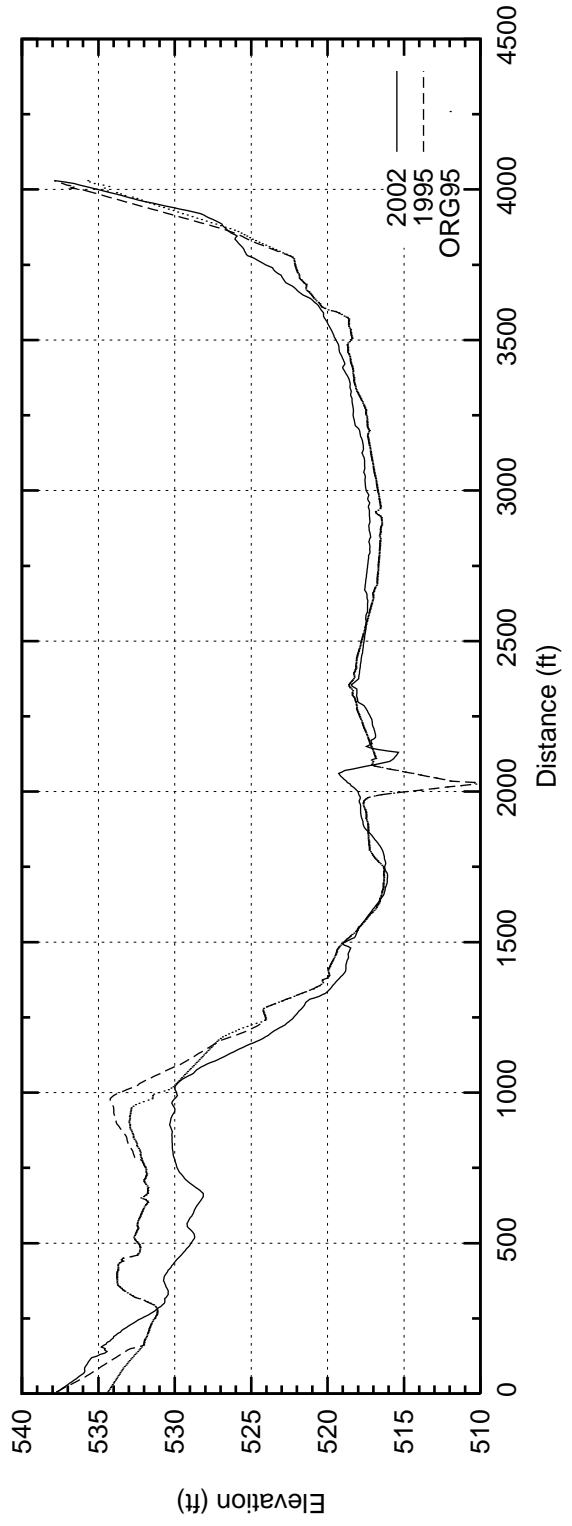


Aquilla Lake

Rangeline SR03

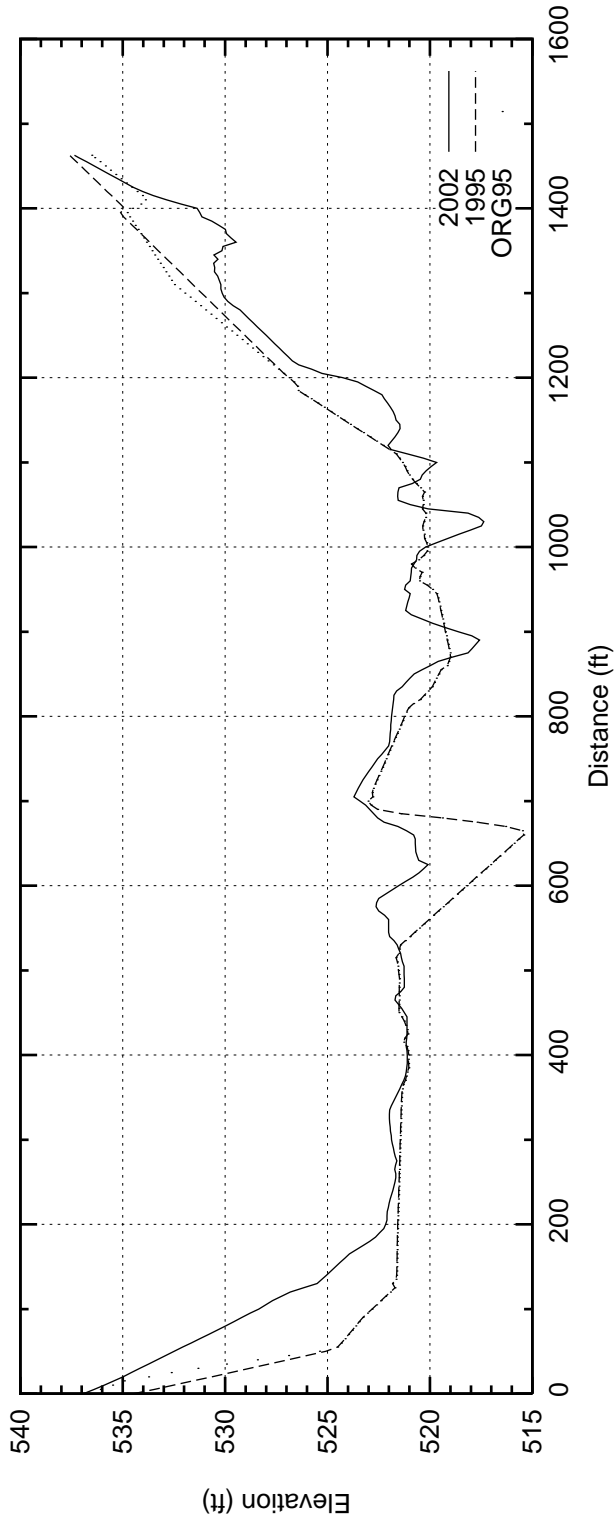


Rangeline SR04

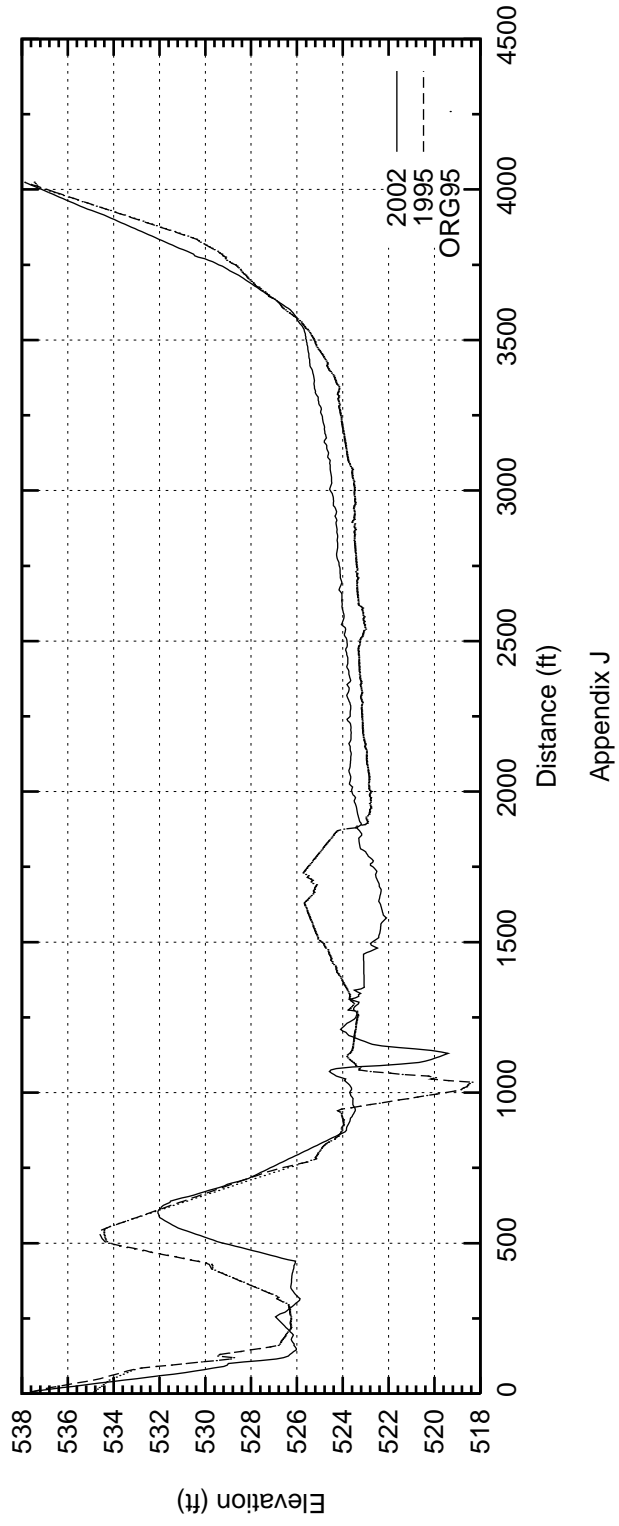


Aquila Lake

Rangeline SR05

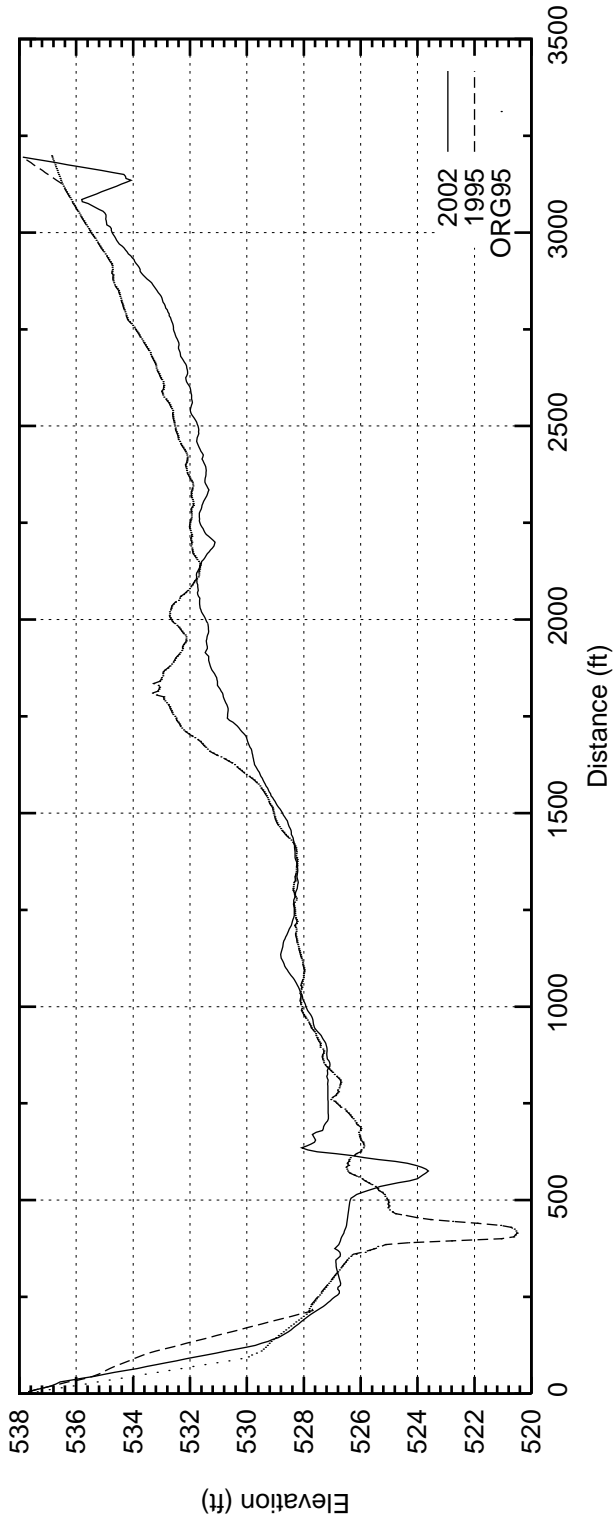


Rangeline SR06

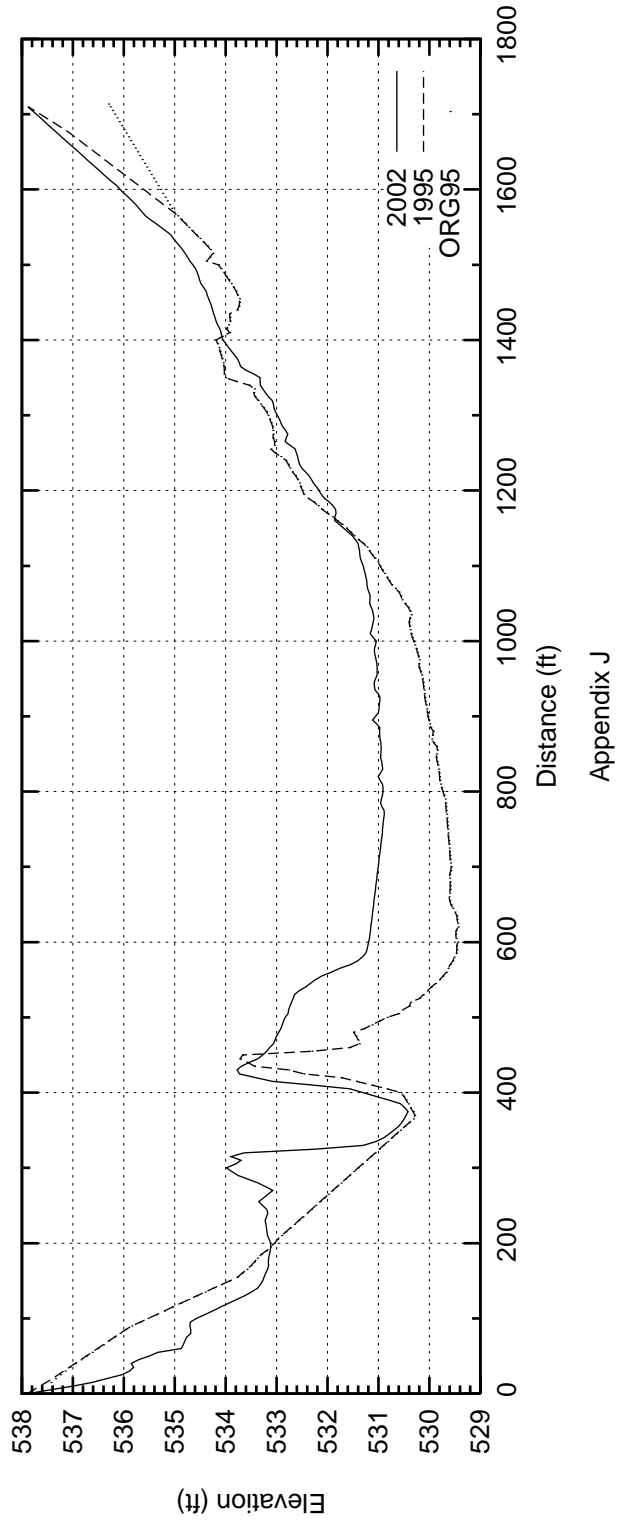


Aquilla Lake

Rangeline SR07

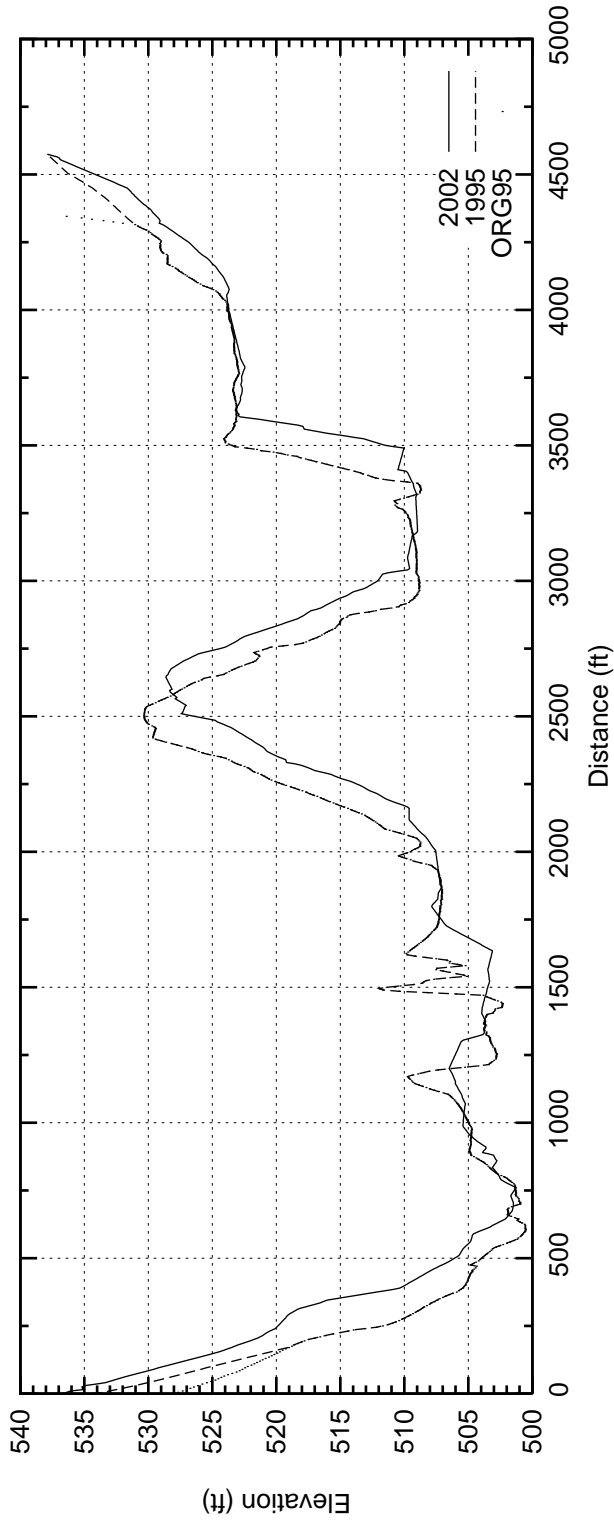


Rangeline SR08

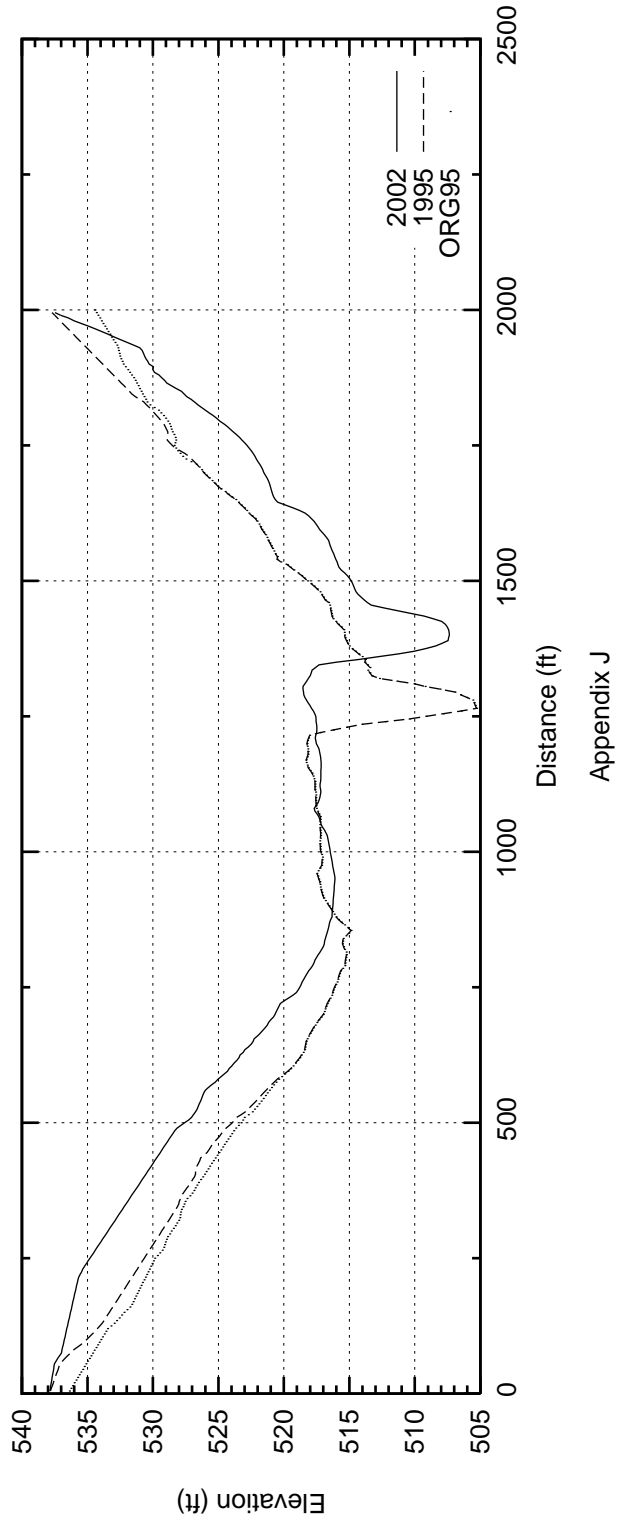


Aquilla Lake

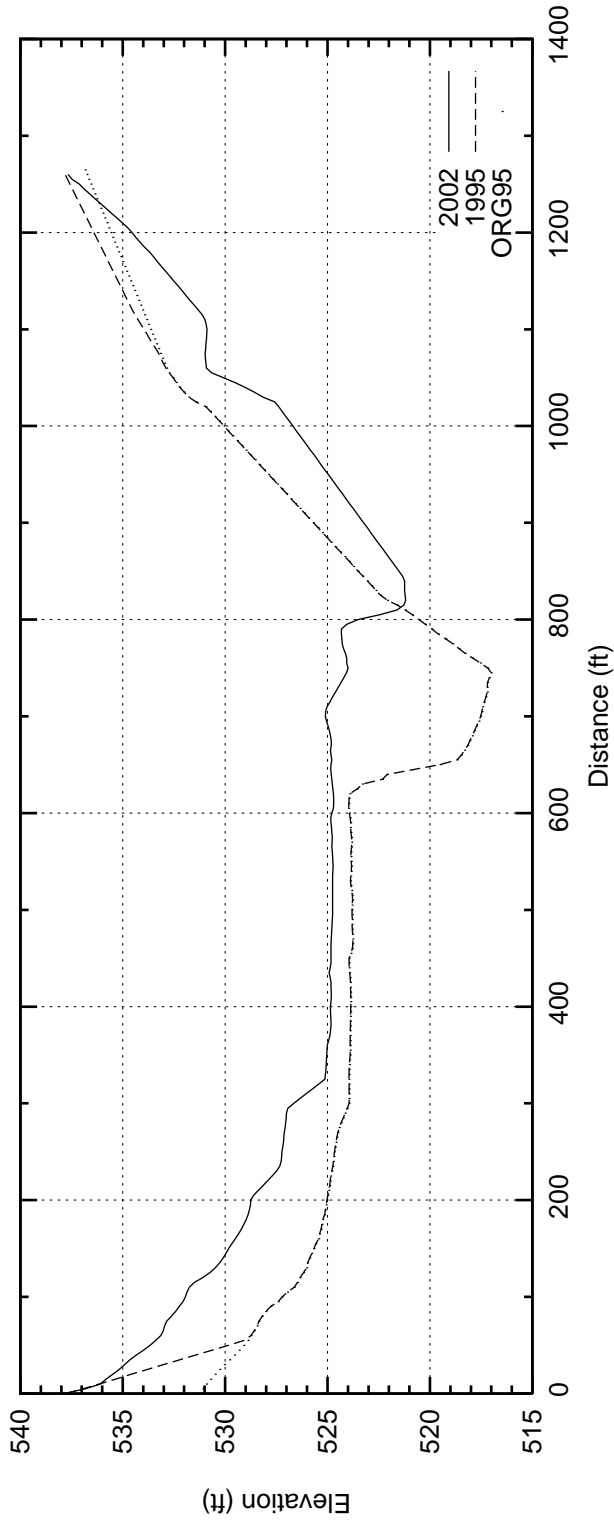
Rangeline SR09



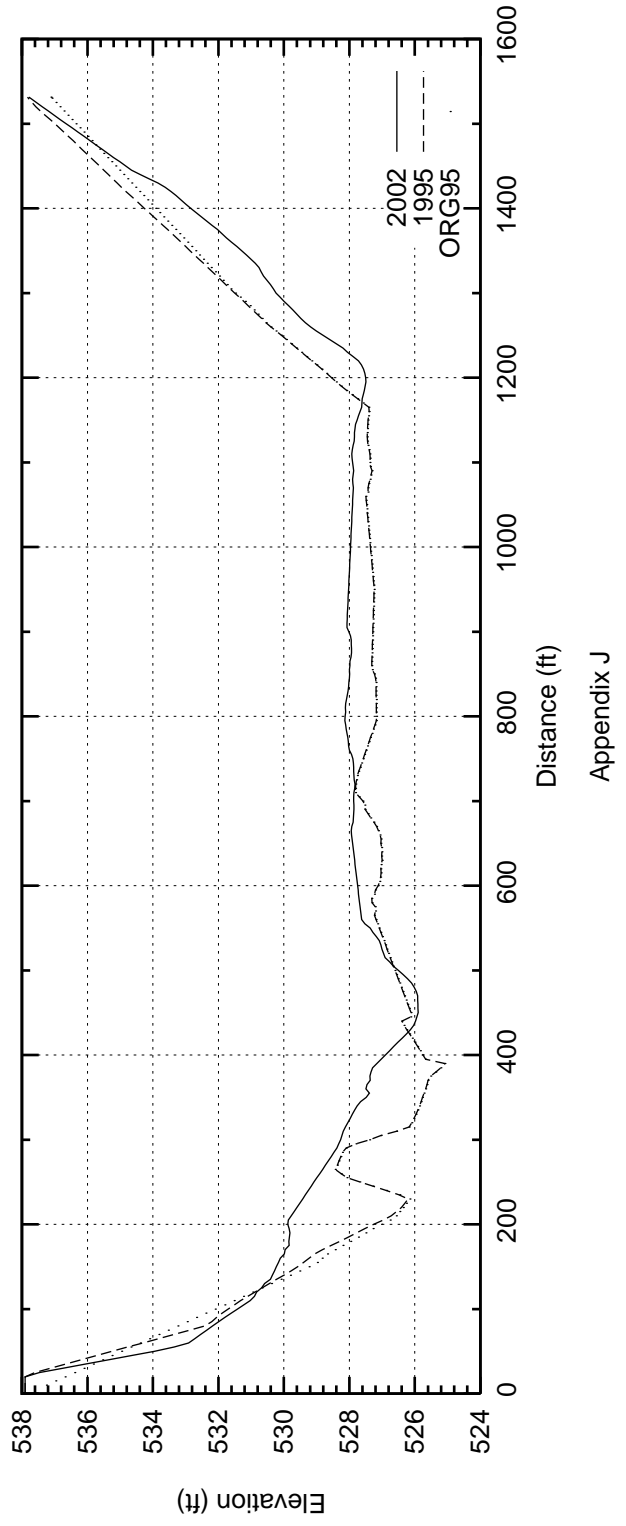
Rangeline SR10



Aquilla Lake Rangeline SR11

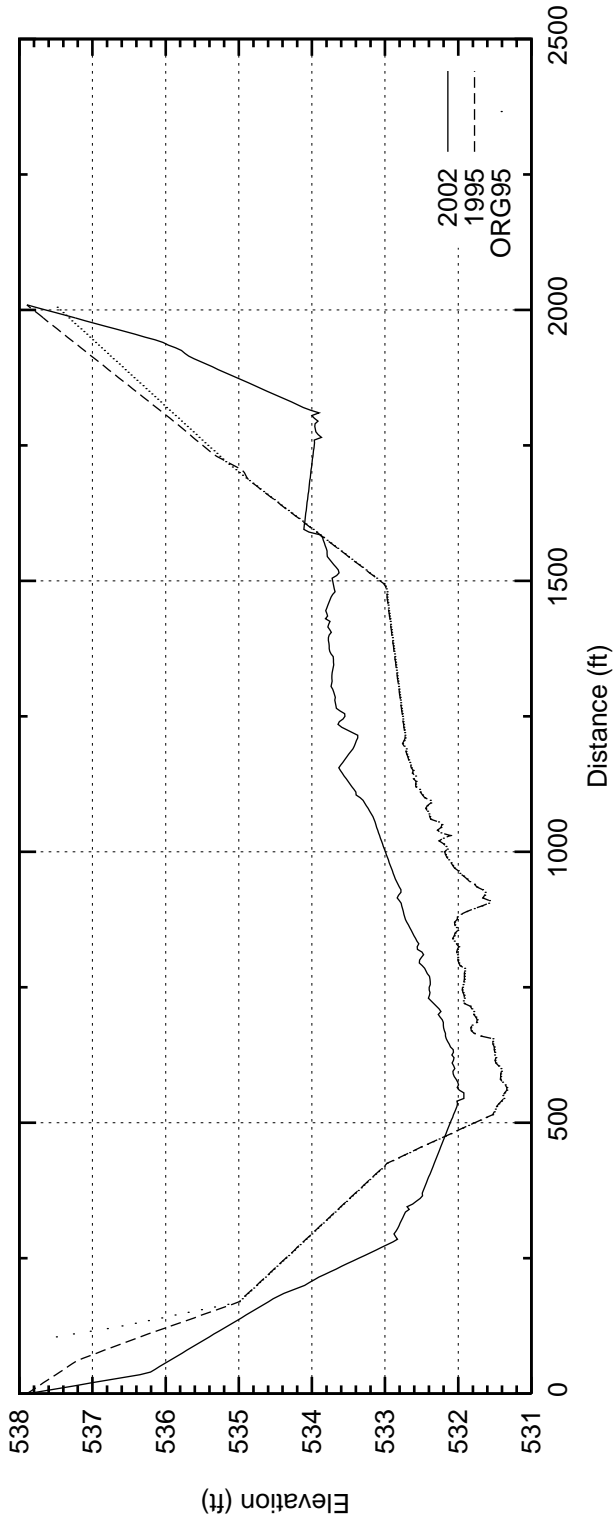


Rangeline SR12

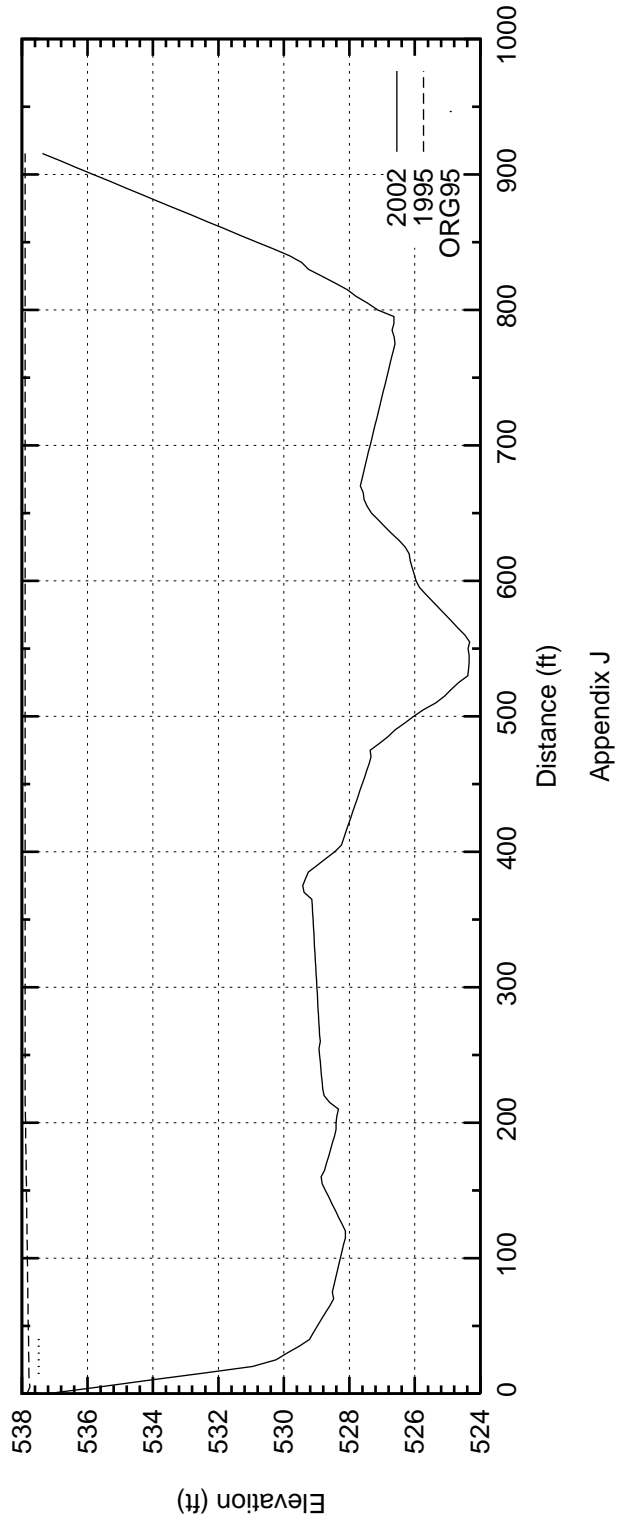


Aquilla Lake

Rangeline SR13

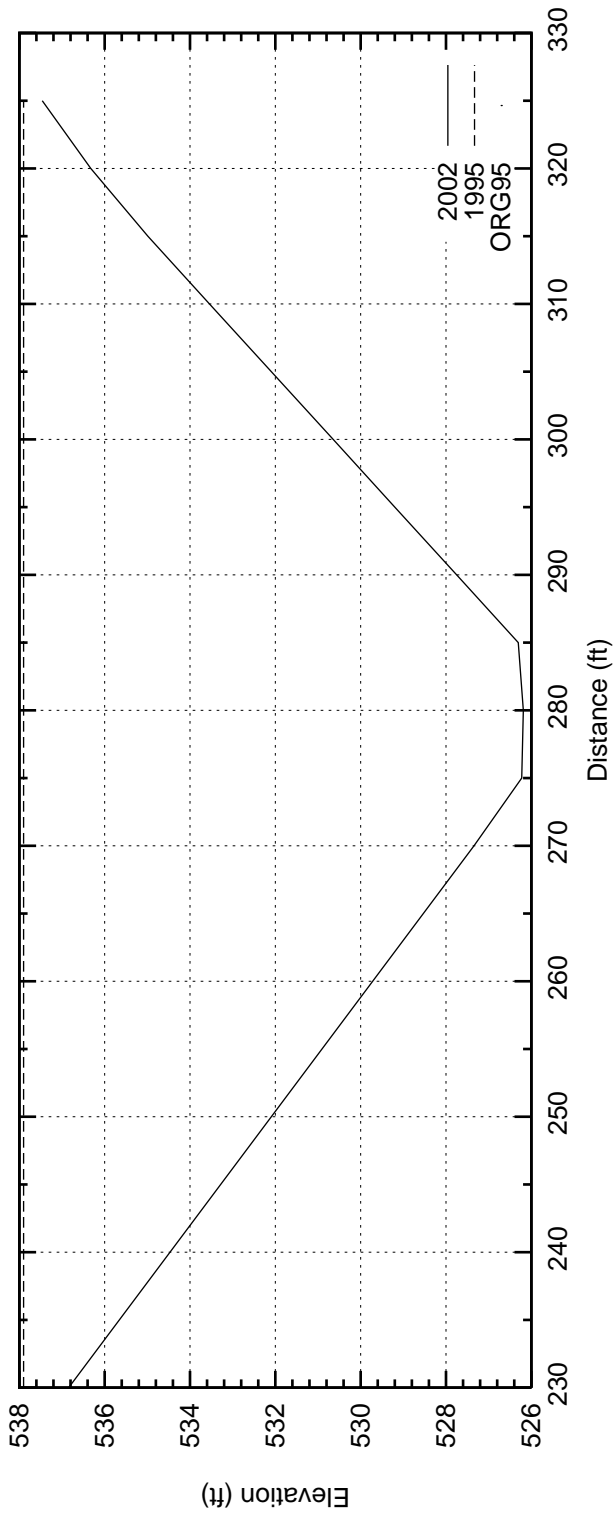


Rangeline SR14

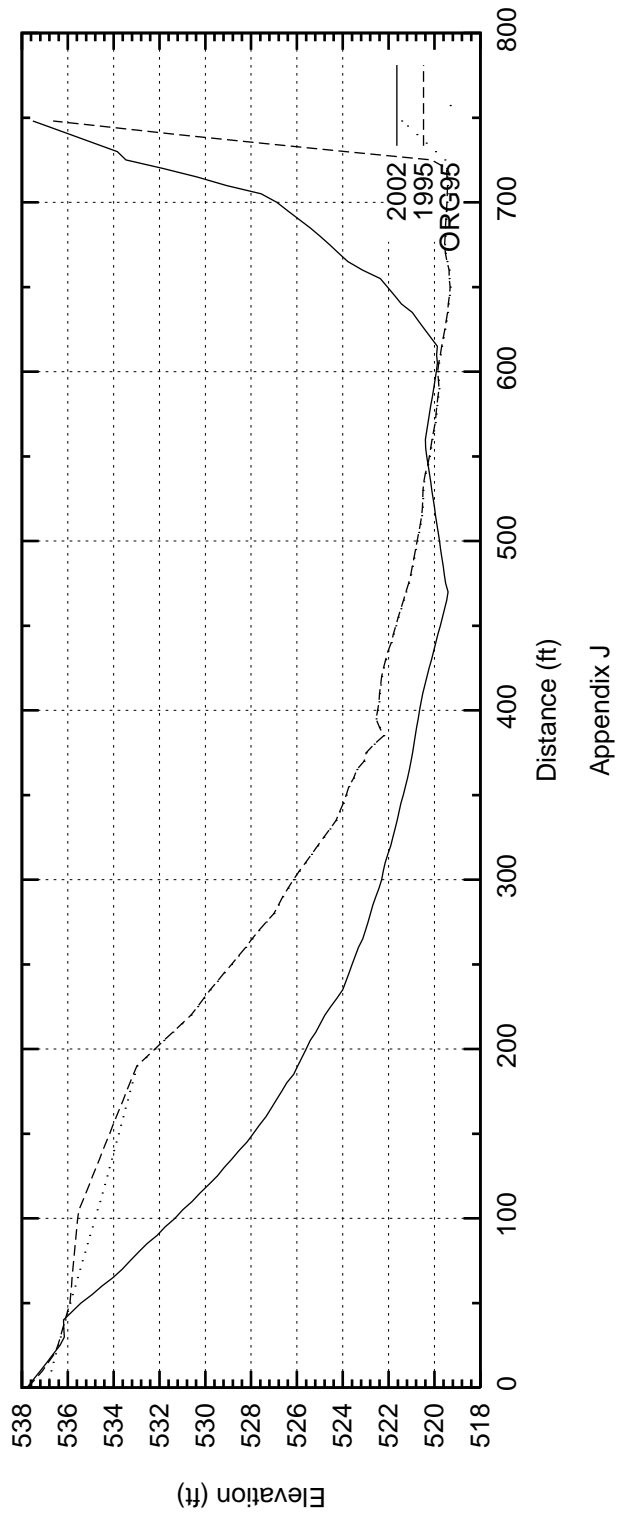


Aquilla Lake

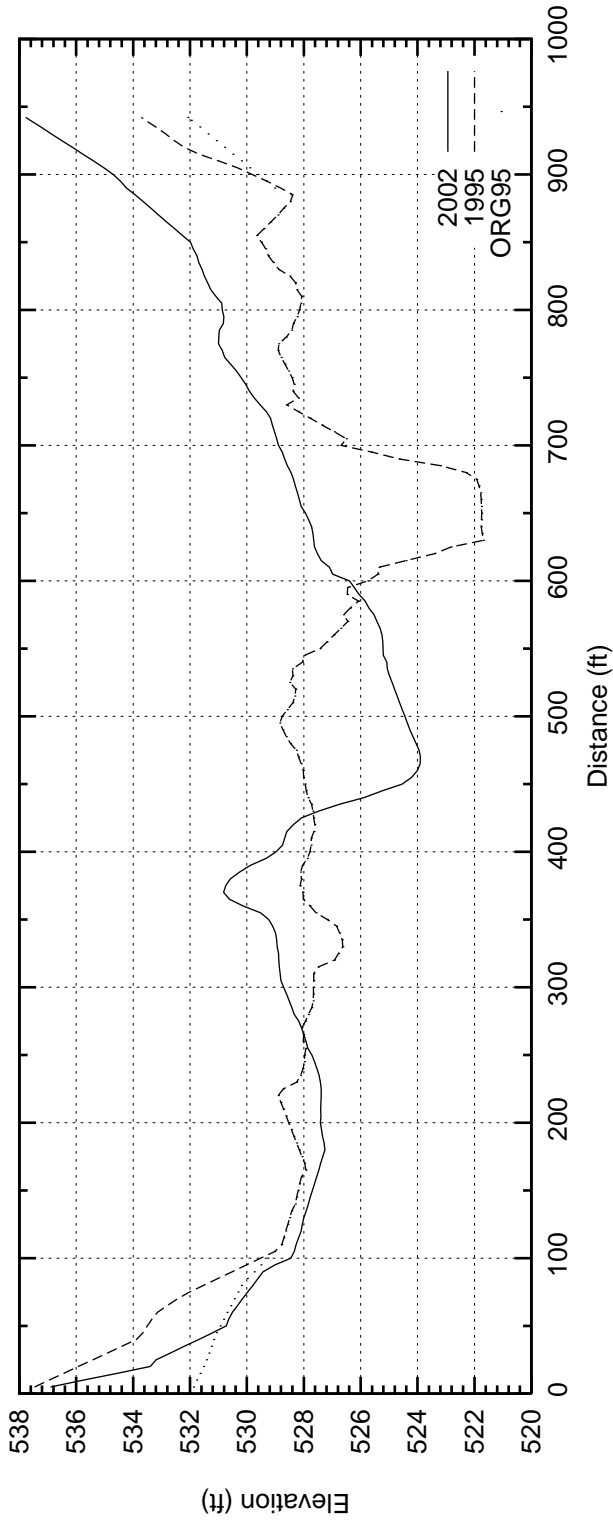
Rangeline SR15



Rangeline SR16



Aquilla Lake Rangeline SR17



Rangeline SR18

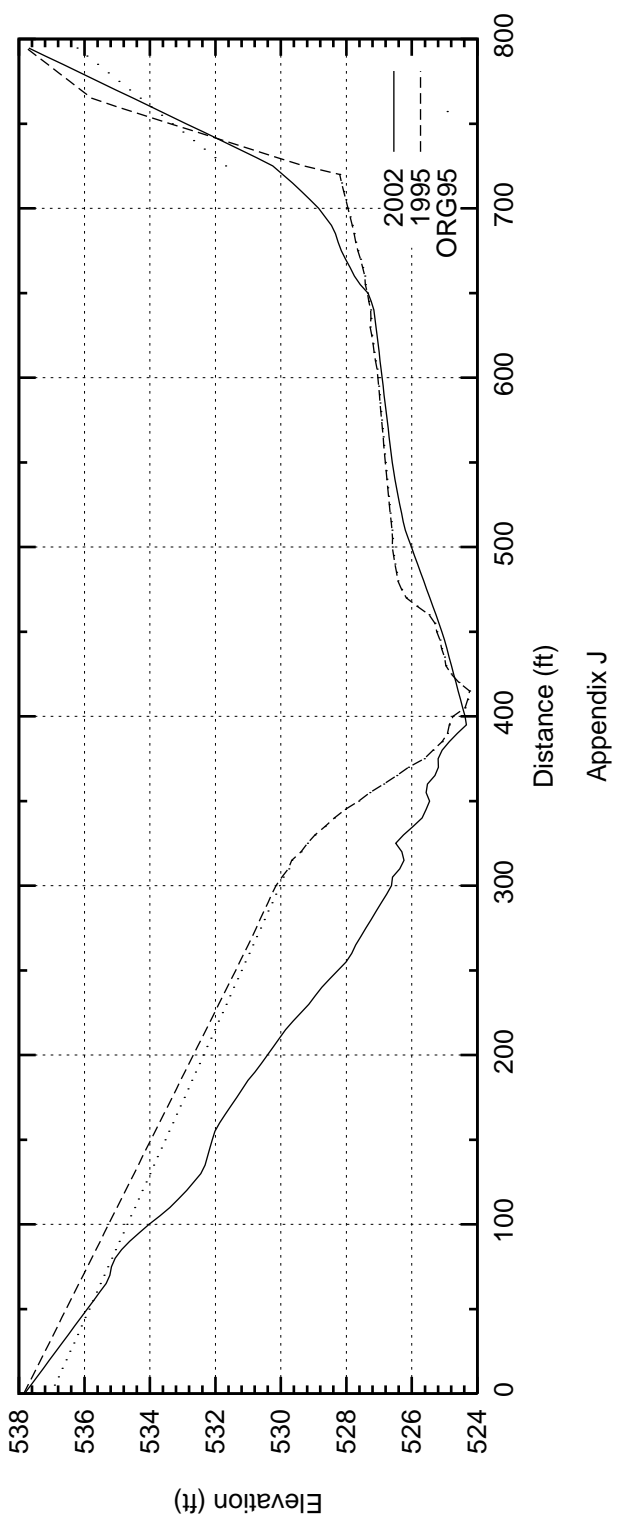


Figure 1

AQUILLA LAKE

Location Map

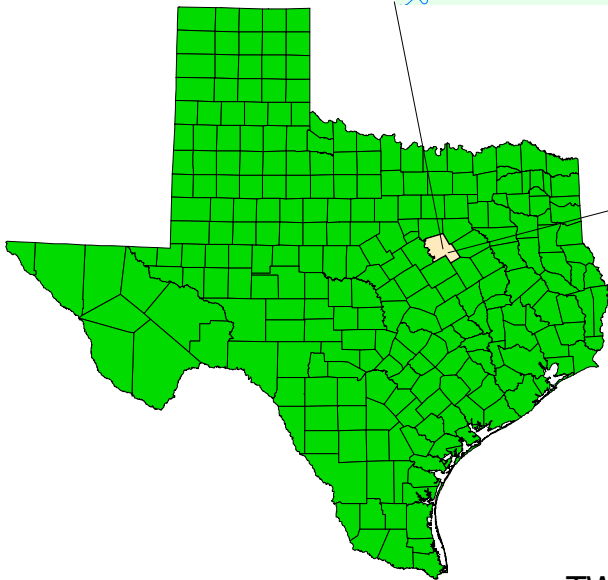
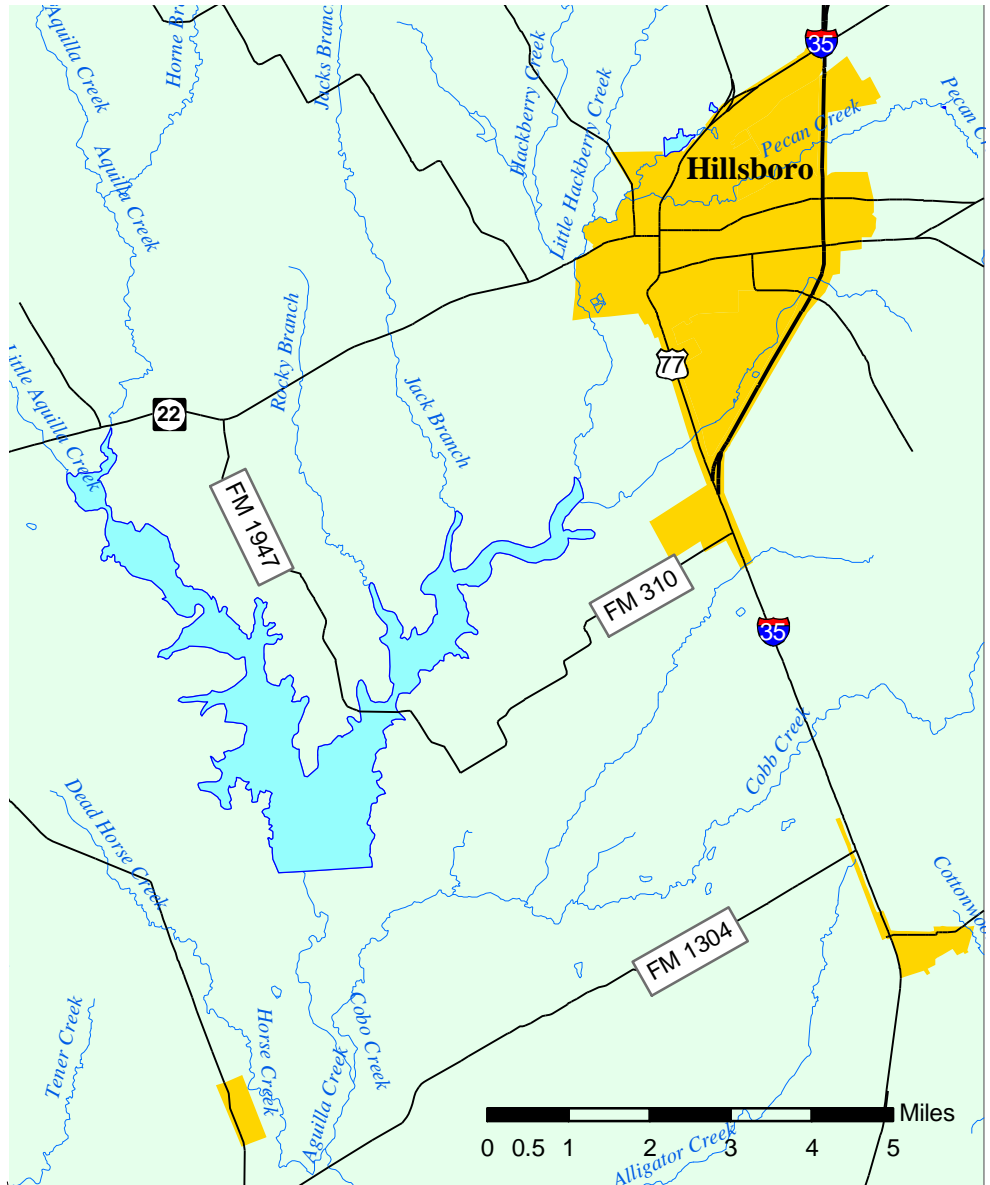


Figure 2
AQUILLA LAKE
Location of Survey Data

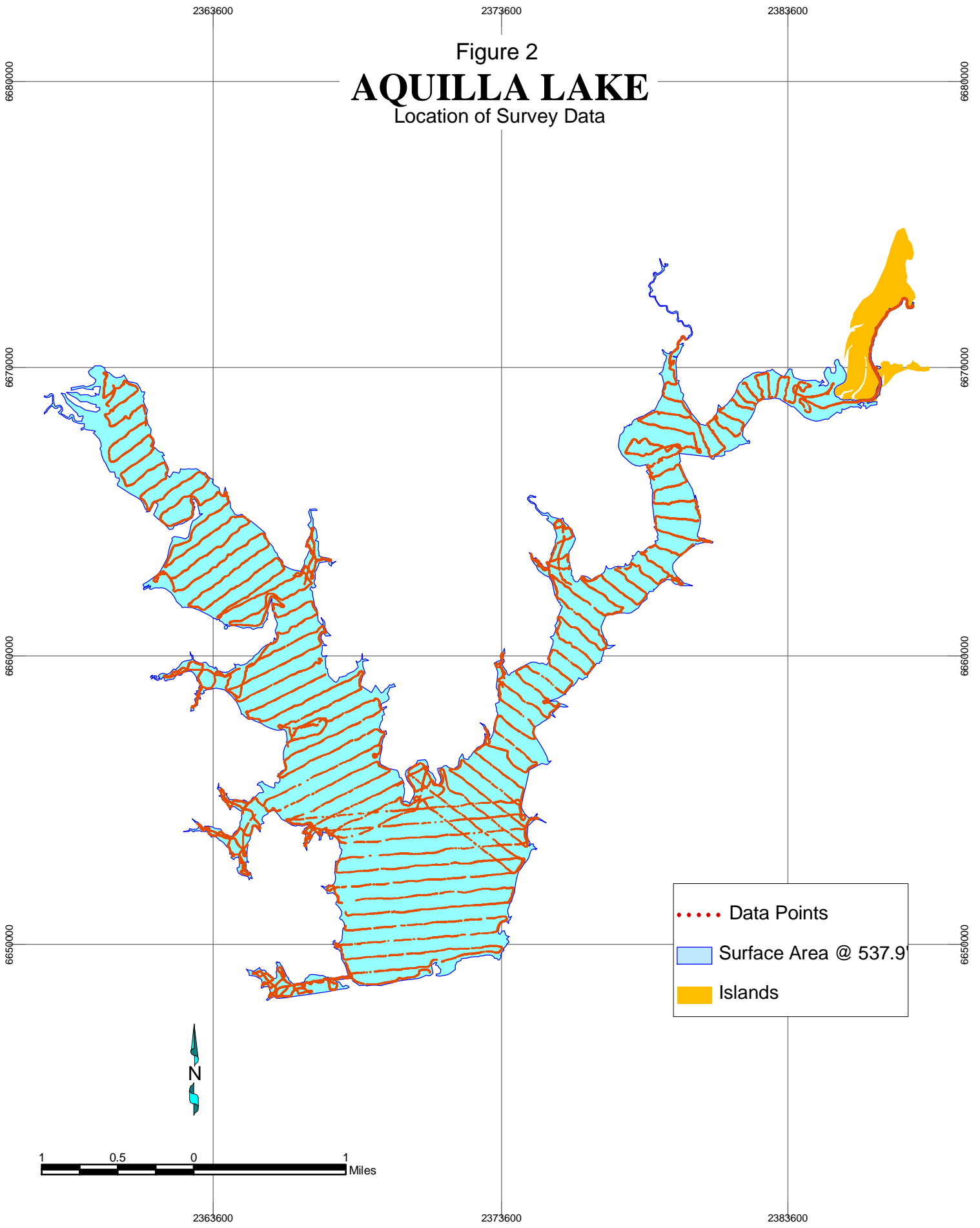


FIGURE 3

AQUILLA LAKE

1996 Data Points vs. 2002 Data Points

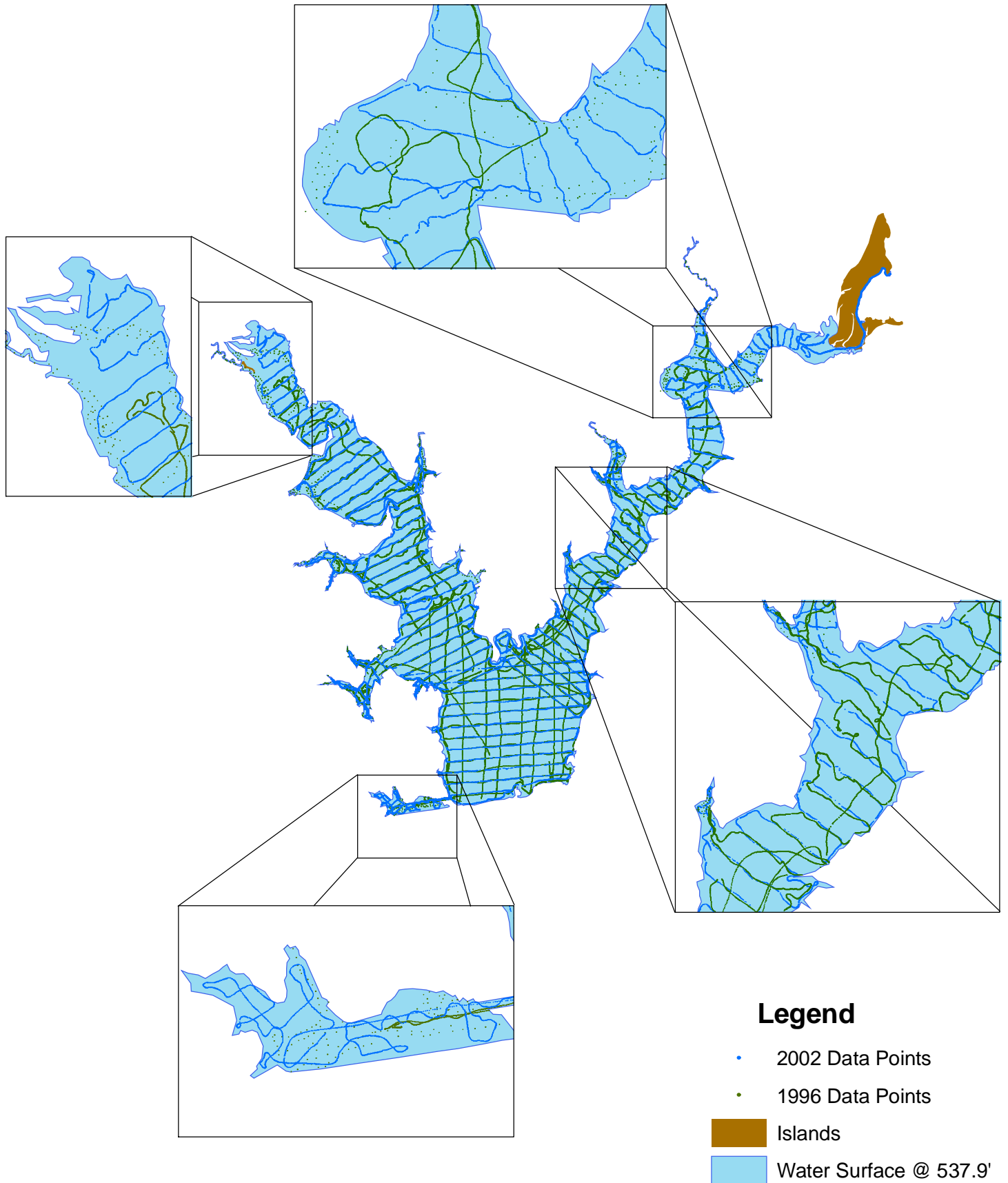


FIGURE 4

AQUILLA LAKE

1996 Boundary vs. 2002 Boundary

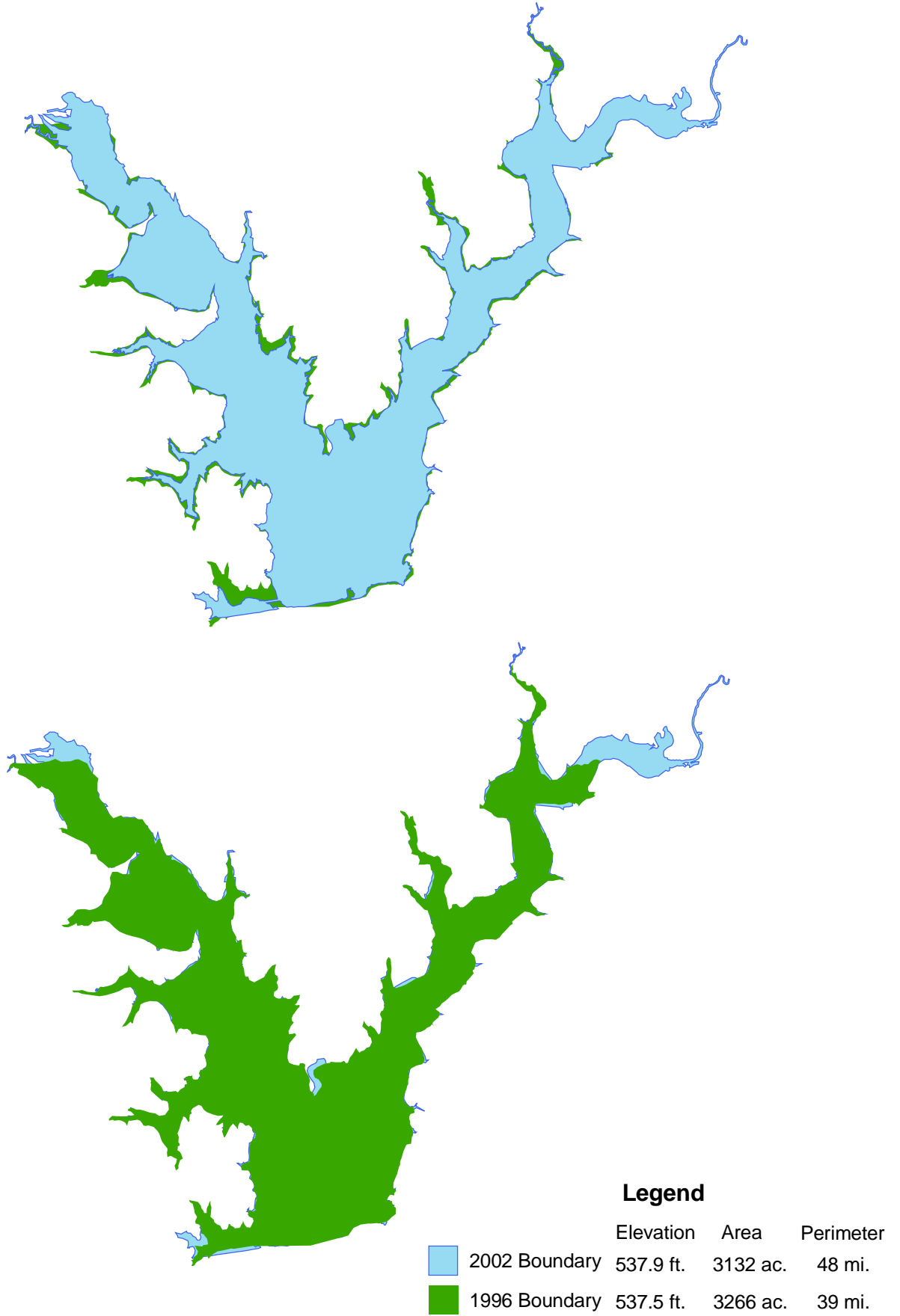


Figure 5

AQUILLA LAKE

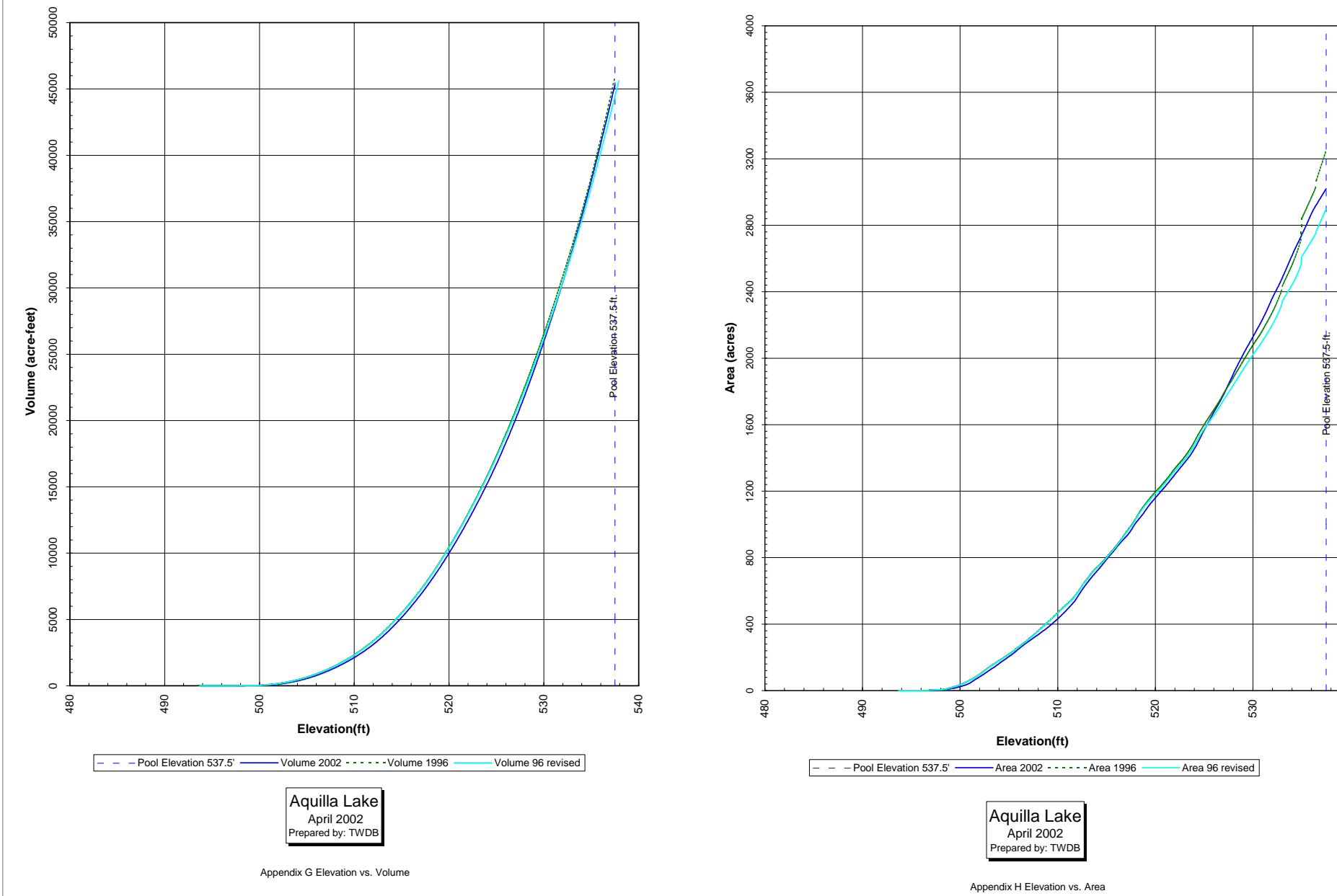
2' - Contour Map



1,500 750 0 1,500 3,000 Feet

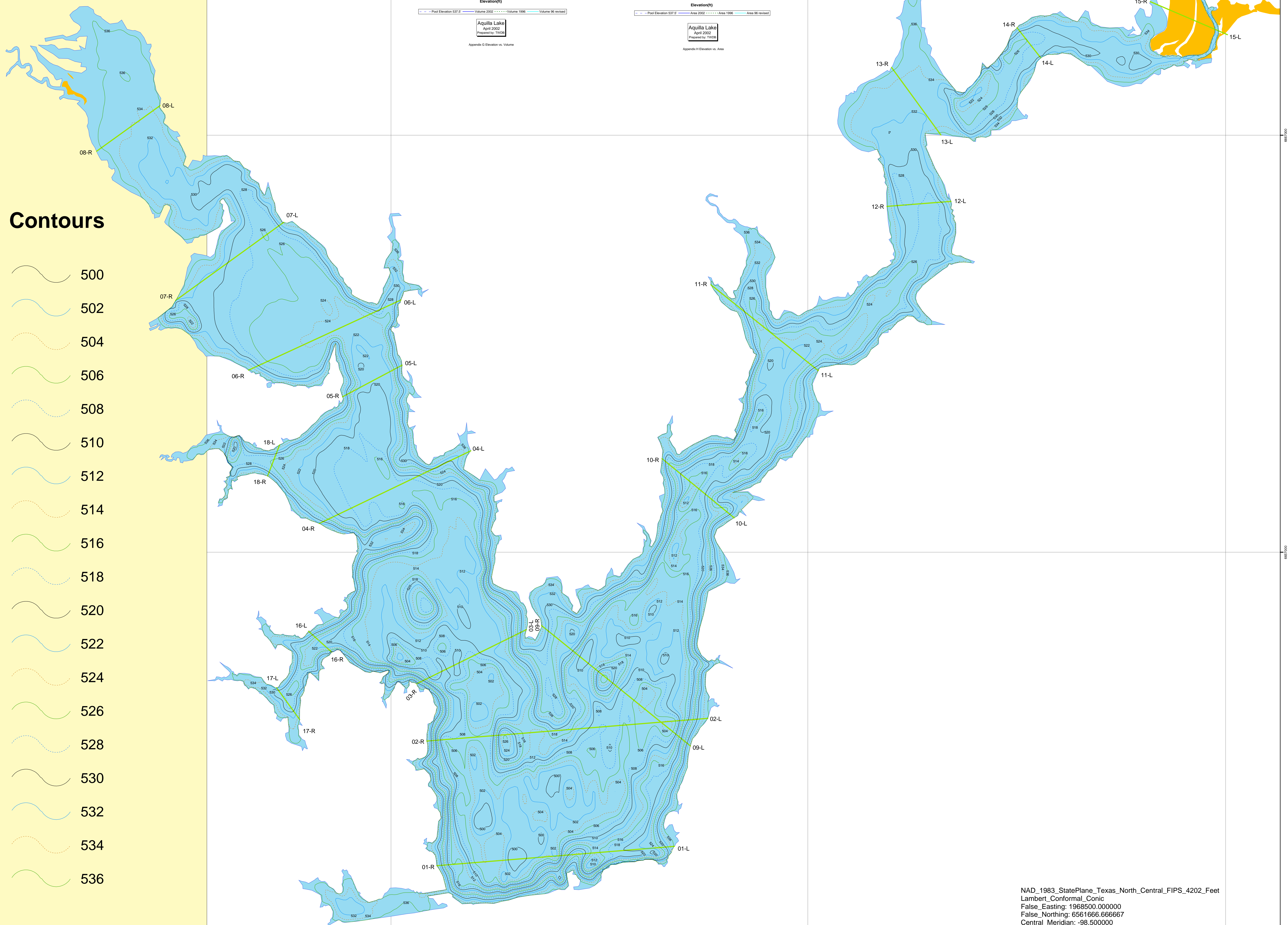
- Water Surface @ 537.9'
- Islands
- Elevation 537.9'
- Cross Sections

Top of Conservation Pool 537.5'



Contours

- 500
- 502
- 504
- 506
- 508
- 510
- 512
- 514
- 516
- 518
- 520
- 522
- 524
- 526
- 528
- 530
- 532
- 534
- 536



NAD_1983_StatePlane_Texas_North_Central_FIPS_4202_Feet
 Lambert_Conformal_Conic
 False_Easting: 1968500.000000
 False_Northing: 6561666.666667
 Central_Meridian: -98.500000
 Standard_Parallel_1: 32.133333
 Standard_Parallel_2: 33.966667
 Latitude_Of_Origin: 31.666667
 GCS_North_American_1983

This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Aquilla Lake. The Texas Water Development Board makes no representations nor assumes any liability.