VOLUMETRIC SURVEY OF B. A. STEINHAGEN LAKE

Prepared for:

Deep East Texas Council of Governments

In cooperation with the

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

Prepared by:
Texas Water Development Board

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EXECUTIVE OVERVIEW

The Texas Water Development Board entered into a contract with the United States Army Corps of Engineers, Fort Worth District and Deep East Texas Council of Governments (representing Region I of the State's Regional Water Planning Groups) to perform a volumetric survey of B. A. Steinhagen Lake. The goal of the study was to produce updated elevation-area and elevation-volume tables using current GPS, acoustical depth sounder and GIS technology.

Records indicate the conservation pool elevation (CPE) for B. A. Steinhagen Lake is 83.0 feet above mean sea level. A lake boundary was digitized from digital orthophoto quadrangle images (DOQ's). Depth and positional data was collected along a layout of transects or pre-plotted navigation lines spaced approximately 500 feet using commercially available software.

Data were collected at B. A. Steinhagen Lake during the period of April 29 to May 7, 2003. The water levels varied between 82.94 ft and 83.16 ft. Approximately 106,500 data points were collected over 232 miles.

The results of the current survey indicate the lake encompasses 10,687 surface acres and contains a total of 66,972 ac-ft at the conservation pool elevation (83.0 ft.) When last surveyed in 1960, the lake encompassed 13,712 surface acres and had a total volume of 101,816 ac-ft. This survey indicates the lake has experienced a 22% reduction in surface area and a 34% reduction in total volume at cpe.

B. A. STEINHAGEN LAKE
VOLUMETRIC SURVEY REPORT

INTRODUCTION

Staff of the Surface Water Availability Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of B. A. Steinhagen Lake during the period of April 29 through May 7, 2003. The purpose of the survey was to determine the current volume of the lake at the conservation pool elevation. 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 reservoir elevation gauge at Town Bluff Dam. The datum for this gauge is reported as mean sea level (msl). Thus, elevations are reported here in feet (ft) above msl. Volume and area calculations in this report are referenced to water levels provided by the USACE gauge: USGS 08040000 B. A. Steinhagen Lk at Town Bluff, TX.[1]

B. A. Steinhagen Lake is located on the Neches River (Neches River Basin) in Tyler and Jasper Counties, one-half mile from Town Bluff, TX (Figure 1). Records[2] indicate at conservation pool elevation (cpe - 83.0 ft above msl) the lake has approximately 160 miles of shoreline and the drainage area is approximately 7,573 square miles.

LAKE HISTORY AND GENERAL INFORMATION

B. A. Steinhagen Lake and Town Bluff Dam also known as Dam B together make up one of four reservoirs originally authorized in the Angelina-Neches River Basins by the River and Harbor Act of 1945 (Public Law 14, 79th Congress, 1st Session)[3].

Town Bluff Dam, appurtenant structures and the surrounding shoreline of B. A. Steinhagen Lake are owned by the U. S. Government and operated by the U. S. Army Corps of Engineers (USACE), Fort Worth District. The multipurpose facility serves as a regulation dam for hydropower releases from Sam Rayburn Reservoir and game preserve for waterfowl management. The facility also provides water supply, water quality control, and recreation.

As one of the four reservoirs planned for the Neches-Angelina River Basin, this project was constructed pending contributions from local interests. The Lower Neches Valley Authority (LNVA) became a sponsor and contributed $5,000,000.00 ($2,000,000.00 towards the construction of B. A. Steinhagen Lake and $3,000,000.00 for Sam Rayburn Reservoir). Public Law 858 was passed and provides for the sponsoring agency to withdraw water from B. A. Steinhagen Lake at a rate not to exceed 2,000 cubic-feet per second (cfs). In addition, LNVA pays $200,000.00 per year for 50 years towards the total cost of the projects. A contract with LNVA was approved on January 22, 1957 to enforce these provisions.

LNVA own the water rights to B. A. Steinhagen Lake under Certificate of Adjudication No. 06-4411 issued by the Texas Water Commission (presently Texas Commission on Environmental Quality) on August 8, 1996. The certificate has been amended twice for issues other than the impoundment and use of the water in B. A. Steinhagen Lake. The current authorization, in part, permits LNVA to store water in an existing reservoir (B. A. Steinhagen Lake or Dam B Reservoir) on the Neches River.[4]

LNVA is authorized to divert and use not to exceed 50,000 ac-ft of water per annum from Lake Sam Rayburn and B. A. Steinhagen Lake for municipal purposes within the service area of the LNVA. For use in the service area of LNVA, permission is granted to divert and use not to exceed 660,000 ac-ft of water annually for industrial purposes and 110,000 ac-ft per year for irrigation purposes from Lake Sam Rayburn and B. A. Steinhagen Lake.

Construction started on Town Bluff Dam in March 1947 and deliberate impoundment of water began April 16, 1951. The U. S. Army Corps of Engineers designed the facility and the

Reynolds, William & Noonan Construction Company was the general contractor. The project cost $8,749,000.

Original design information[5] shows Town Bluff Dam (a.k.a. Dam B) is a compacted-earth structure with a six-inch protective slab. A concrete section spans the river channel. The majority (6,100 ft or about 91%) of the embankment is designed to serve as an uncontrolled spillway at crest elevation 85.0 ft msl. Total length of the dam is 6,698 ft and the maximum height is 45 ft.

The service spillway for Town Bluff Dam consists of six tainter gates, 40 ft long by 35 ft high, with a sill elevation of 50 ft msl. Discharge capacity of the service spillway is 80,000 cfs when the surface water elevation is at 85.0 ft msl.

Low-flow releases are through two, 4 ft by 6 ft gate-control conduits with an invert elevation at 52.0 ft.

The original design for B. A. Steinhagen Lake, at cpe 83.0 ft, indicates a surface area of 13,700 acres. The initial conservation storage capacity for B. A. Steinhagen Lake was 94,200 ac-ft of water and also being the total volume.[6]

The following table summarizes information for Town Bluff Dam and B. A. Steinhagen Lake based on information furnished by the USACE.

Table 1. Town Bluff Dam and B. A. Steinhagen Lake Pertinent Data

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Owner of Town Bluff Dam and Facilities

United States of America

Operator of Town Bluff Dam and Facilities

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

Engineer

U. S. Army Corps of Engineers (Design)

General Contractor

Reynolds, William & Noonan Construction Company

Location

On the Neches River (Neches River Basin) in Jasper and Tyler Counties, one-half mile north of Town Bluff, TX.

Drainage Area

7,573 square miles

Dam

Type	Compacted earth and concrete slab
Length (total)	6,698 ft
Maximum Height	45 ft

Spillway

Type	Sill (Concrete)
Length	240 ft
Crest elevation	50.0 ft
Control	Six- Tainter Gates, each 40 ft long by 35 ft high

Outlet Works

Type	Two conduits
Size	4 ft by 6 ft
Control	Two tractor-type gates
Type	Low-flow releases

Reservoir Data (Based on TWDB 2003 volumetric survey)

Feature	Elevation (Above msl)	Capacity (Acre-feet)	Area (Acres)
Top of Conservation Pool (Volume or Total Storage)	83.0	66,972	10,687
Conservation Pool (Between elev. 83.0 ft – 50.0 ft)	N/A	66,966	N/A
Inactive Pool below Spillway Sill	50.0	6	2

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the latest volumetric survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin (Hydro-survey boat), 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, a Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal, and an on-board 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 (River-runner) 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 from the computer and brought to the office for editing after the survey is completed. During editing, poor-quality data is removed or corrected, multiple data points are averaged to one data point per second, and the average depths are converted to elevation readings based on the water-level elevation recorded at the time the data was collected. Accurate estimates of the lake volume can be quickly determined by building a 3-D TIN[7] model of the lake from the collected data.

PRE-SURVEY PROCEDURES

The lake's boundary was digitized using Environmental Systems Research Institute's (ESRI)[8] ArcGIS 8.3 from digital orthophoto quadrangle images (DOQ's). The DOQ's were produced by VARGIS of Texas LLC for the TEXAS Orthoimagery Program (TOP). The DOQ products produced for the Department of Information Resources and the GIS Planning Council under the Texas Orthoimagery Program 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's boundary was created by digitizing the PACE HILL SW, PACE HILL SE, TOWN BLUFF NE, TOWN BLUFF SE and TOWN BLUFF SW, TEXAS DOQ's. The lake elevations, at the time the DOQ's were photographed (January 19, 1996 and February 5, 1995) were 80.03 ft and 82.10 ft, respectively. These photographs (DOQ's) were used to digitize lines around the boundary of the lake and were given elevations corresponding to the date of the photo. In order to utilize all the data collected from the survey boat, the 85.0 ft contour from the USGS 7.5 minute quadrangle maps was used as the elevation for the lake boundary. TWDB Staff utilized this updated boundary and the lines digitized from the DOQ's at their respective elevations in developing the model and interpolating the cpe contour (83.0 ft). The lake elevations varied between 82.94 ft and 83.16 ft during the survey.

The survey layout was designed by placing survey track lines at 500-foot intervals (Figure 2) within the digitized lake boundary using HYPACK[9] software. The survey design required the use of approximately 125 survey lines placed perpendicular to the original creek channel and tributaries along the length of the lake.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

Prior to collecting data each day on-board 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.

On-board the River-runner 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 the same as 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 ranged from 4,855 feet per second to 4,904 feet per second during the B. A. Steinhagen 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 $\pm$0.2 ft. An additional estimated error of $\pm$0.3 ft arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$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. Further information on these calculations is presented in Appendix G.

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 using the Omnistar receiver. The lake's initialization file used by the HYPACK data collection program was set up to perform an "on-the-fly" conversion from the collected Differential GPS positions to state-plane coordinates.

Field Survey

The water levels varied during the survey between 82.94 ft and 83.16 ft. The survey crew experienced excellent weather conditions with no weather related delays. Upon arriving at B. A. Steinhagen Lake, TWDB staff met with personnel from the U. S. Army Corps of Engineers Lake Project Office and representatives from the Lower Neches Valley Authority. After discussing the logistics for the survey, the crew began data collection that day with the Hydro-survey boat.

By the second day, the data were being collected with the River-runner (shallow draft) boat. The enormous amount of aquatic vegetation (lake weed) continually entangle in the propeller blocked the intake holes on the lower unit and caused the boat motor to overheat. In many cases the water hyacinth, water lily and other aquatic vegetation kept the survey crew from collecting data where water was apparent. (See Appendix H).

The catchment basin of B. A. Steinhagen Lake occupies the floodplain below the confluence of the Neches and Angelina Rivers. The Neches River flows in a north to south direction with Town Bluff Dam being located on the south end of the lake. U. S. Highway 190 (east/west direction) equally divides B. A. Steinhagen Lake (See Figure 1).

There are nine parks surrounding B. A. Steinhagen Lake. The upper reaches of the lake and the surrounding land on the Angelina and Neches Rivers are dedicated for wildlife management as a game preserve operated by the Texas Parks and Wildlife Department.

Approximately 106,500 data points were collected over the 232 miles traveled. The crew was able to collect data on 121 of the 125 pre-plotted lines. Random data were collected in those areas where the crew could not navigate the boat to stay on course. As the channel of the Angelina and Neches Rivers became too narrow for perpendicular transects, data were collected in a zigzag pattern. These data points were stored digitally on the boat's computer in 340 data files. 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, erroneous depths caused by vegetation interference 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 changes had been made to the raw data files, the edited files were saved and 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 8.3 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 from elevation 43.1 ft to 83.0 ft at one-tenth foot intervals using Arc/Info software. The computed lake volume table is presented in Appendix A and the area table in Appendix B. An elevation-volume graph and an elevation-area graph are presented in Appendix C and Appendix D respectively.

Other products developed from the model include a shaded relief map (Figure 3) and a shaded depth range map (Figure 4). To develop these maps, the TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command. Linear filtration algorithms were applied to the DTM to produce smooth cartographic contours. The resulting contour map of the bottom surface at 2-ft intervals is presented in Figure 5. Finally, the cross-section endpoints are in Appendix E and the corresponding cross-section plots are in Appendix F.

RESULTS

Results from the 2003 TWDB survey indicate B. A. Steinhagen Lake encompasses 10,687 surface acres and contains a total volume of 66,972 ac-ft at conservation pool elevation 83.0 ft. The lake boundary (shoreline miles) was calculated to be 156 miles and was derived from the digitized boundary of the DOQ's. The deepest point physically measured during the survey was a depth of 44.0 ft corresponding to elevation 39.9 ft and was located approximately five miles upstream of Town Bluff Dam.

SUMMARY AND COMPARISONS

Original design information was based on a 1947 USACE survey. Records indicate that B. A. Steinhagen Lake had a total surface area of 13,700 acres and a volume of 94,200 ac-ft of water at the top of cpe 83.0 ft.

In 1951 the USACE determined the area and volume totals at cpe 83.0 ft to be somewhat larger; the surface area increased to 13,842 acres and the volume increased to 100,595 ac-ft. This is probably due to use of an improved calculation methodology. In 1960 the USACE performed a resurvey of B. A. Steinhagen Lake.

The results of that survey show that the surface area had reduced to 13,712 acres but the volume had again increased, to 101,814 ac-ft of water at top of cpe. These figures are presented in Table 2.

The 2003 survey utilized a differential global positioning system, depth sounder and geographical information system technology to create a digital model of the lake's bathymetry. For the purpose of this report, comparisons are being made to the most recent survey (1960 USACE). At conservation pool elevation 83.0 ft, the current survey measured 10,687 surface acres, for a reduction of 3,025 surface acres (22%). The 2003 TWDB survey results indicate that the total volume at the cpe is 66,972 ac-ft of water. The inactive pool or dead pool storage, below elevation 50.0 ft, contains 6 ac-ft of water and thus the conservation storage or capacity found in this survey is 66,962 ac-ft. B. A. Steinhagen Lake lost 34,654 ac-ft of water or 35 percent in conservation storage compared to the 1960 USACE resurvey.

Comparisons between the historical USACE 1947 original design, the 1951 adjusted, the 1960 resurvey and the 2003 TWDB volumetric survey are difficult and some apparent changes might simply be due to methodological differences. The results of these surveys are presented in Table 2. It is recommended that another survey utilizing modern methods be performed in five to ten years or after major flood events to monitor changes to the lake’s capacity.

During fieldwork and from analysis of the aerial photographs (DOQs), it was noted that there exists a very large amount of aquatic vegetation (Appendix H) in an extensive and developing delta (Appendix G) in the upper reaches of the lake. Not only is this an impediment to navigation and flow, but it also has the potential to increase surface evaporation losses. Furthermore it makes the capacity estimate very problematic. The figures presented in this report from this survey represent the best estimates of lake capacity and area that can be obtained in an objective manner given current technology and resources.

Table 2. Area and Capacity Comparisons B. A. Steinhagen Lake

FEATURE	USACE Original Design	USACE Adjusted	USACE Resurvey	TWDB Current Survey
Year	1947	1951	1960	2003
Area @ Conser. Pool Elev. 83.0 ft (ac)	13,700	13,842	13,712	10,687
Volume @ Conser. Pool Elev. 83.0 ft (ac-ft)	94,200	100,595	101,814	66,972
Inactive Storage below Elev. 50.0 ft (ac-ft)	0	190	198	6
Conservation Capacity Elev. 50.0 - 83.0 ft (ac-ft)	94,200	100,405	101,616	66,966
Sediment Reserve in Conser. Storage Space (ac-ft)	16,600	16,600		
Usable Conservation Capacity (ac-ft)	77,600	83,805		

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Appendix A

B.A. Steinhagen Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD MAY 2003 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
43		0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	1	1	1	1	1	1
46	1	1	1	1	1	1	1	1	1	1
47	2	2	2	2	2	2	2	2	2	2
48	3	3	3	3	3	3	3	3	4	4
49	4	4	4	4	5	5	5	5	5	5
50	6	6	6	6	6	7	7	7	7	8
51	8	8	9	9	9	10	10	10	11	11
52	11	12	12	13	13	14	14	15	15	16
53	17	18	19	19	20	21	22	23	24	26
54	27	28	29	31	32	33	35	36	38	40
55	41	43	45	47	49	51	53	55	57	60
56	62	65	67	70	73	76	79	82	85	88
57	92	95	99	103	106	110	114	119	123	127
58	132	137	142	147	152	157	162	168	173	179
59	185	191	197	204	210	217	224	231	238	245
60	252	260	267	275	283	292	300	308	317	326
61	335	345	354	364	374	384	394	405	416	427
62	438	449	461	473	485	498	510	523	537	550
63	564	578	593	608	623	638	654	670	687	704
64	721	739	757	776	795	814	834	854	875	896
65	918	941	964	987	1011	1036	1061	1087	1113	1140
66	1167	1195	1224	1254	1284	1314	1346	1378	1411	1445
67	1479	1514	1550	1587	1625	1663	1703	1743	1784	1827
68	1870	1914	1960	2007	2054	2103	2153	2205	2258	2312
69	2368	2425	2485	2546	2610	2676	2745	2816	2889	2965
70	3044	3126	3211	3299	3390	3485	3583	3685	3791	3901
71	4014	4131	4254	4380	4512	4649	4792	4940	5094	5254
72	5420	5591	5769	5952	6140	6335	6534	6740	6951	7168
73	7391	7619	7852	8091	8334	8583	8836	9094	9358	9626
74	9899	10177	10460	10749	11044	11345	11651	11964	12282	12607
75	12939	13278	13624	13977	14338	14707	15083	15468	15859	16258
76	16664	17077	17496	17923	18356	18797	19246	19704	20170	20644
77	21127	21619	22119	22627	23144	23670	24205	24748	25300	25862
78	26433	27015	27606	28207	28818	29439	30071	30714	31367	32030
79	32703	33386	34079	34782	35494	36215	36946	37684	38431	39187
80	39950	40738	41541	42349	43162	43981	44805	45634	46469	47309
81	48154	49005	49860	50721	51587	52458	53335	54216	55103	55995
82	56892	57794	58781	59776	60779	61791	62811	63839	64875	65920
83	66972									

Appendix B

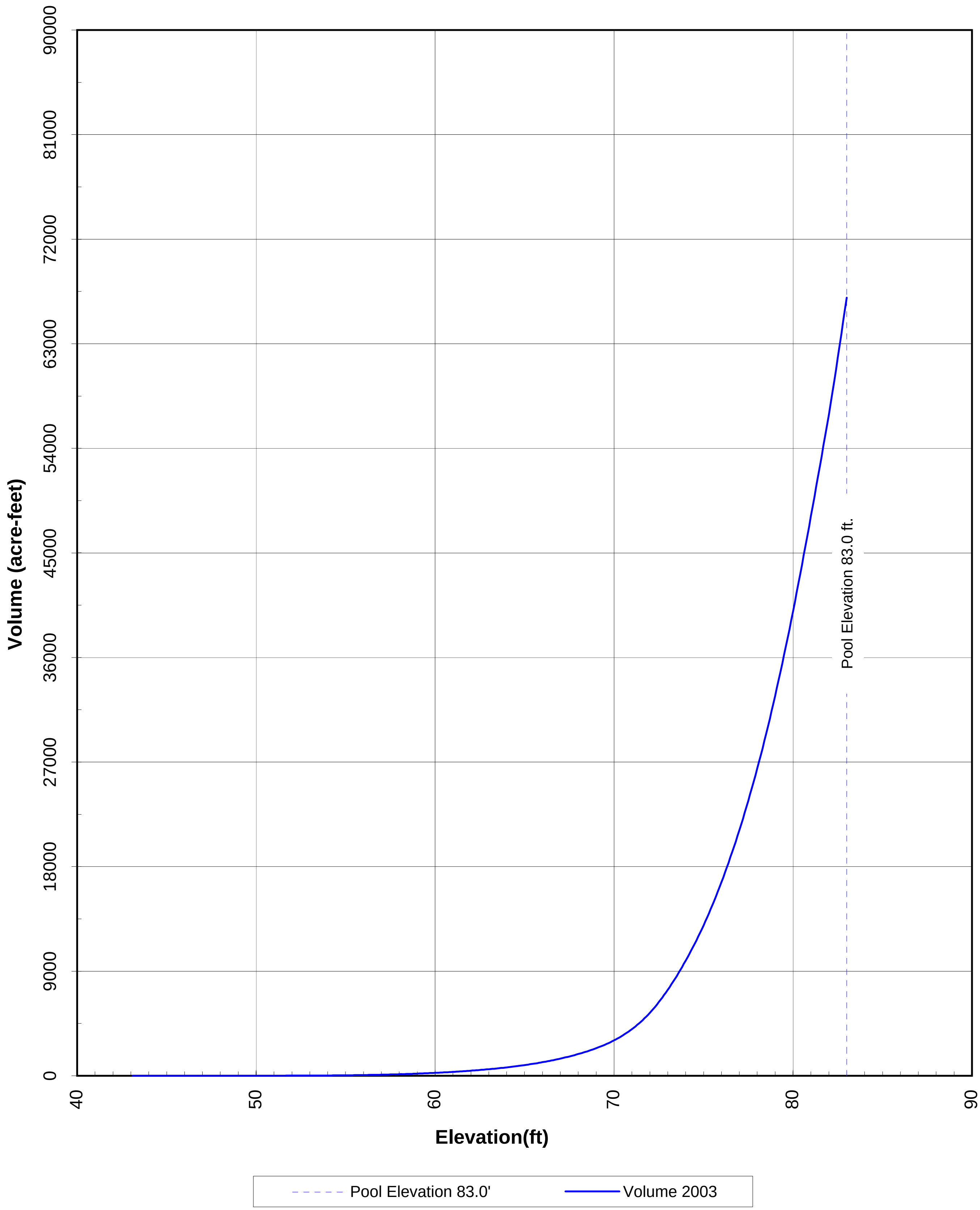
B.A. Steinhagen Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD MAY 2003 SURVEY

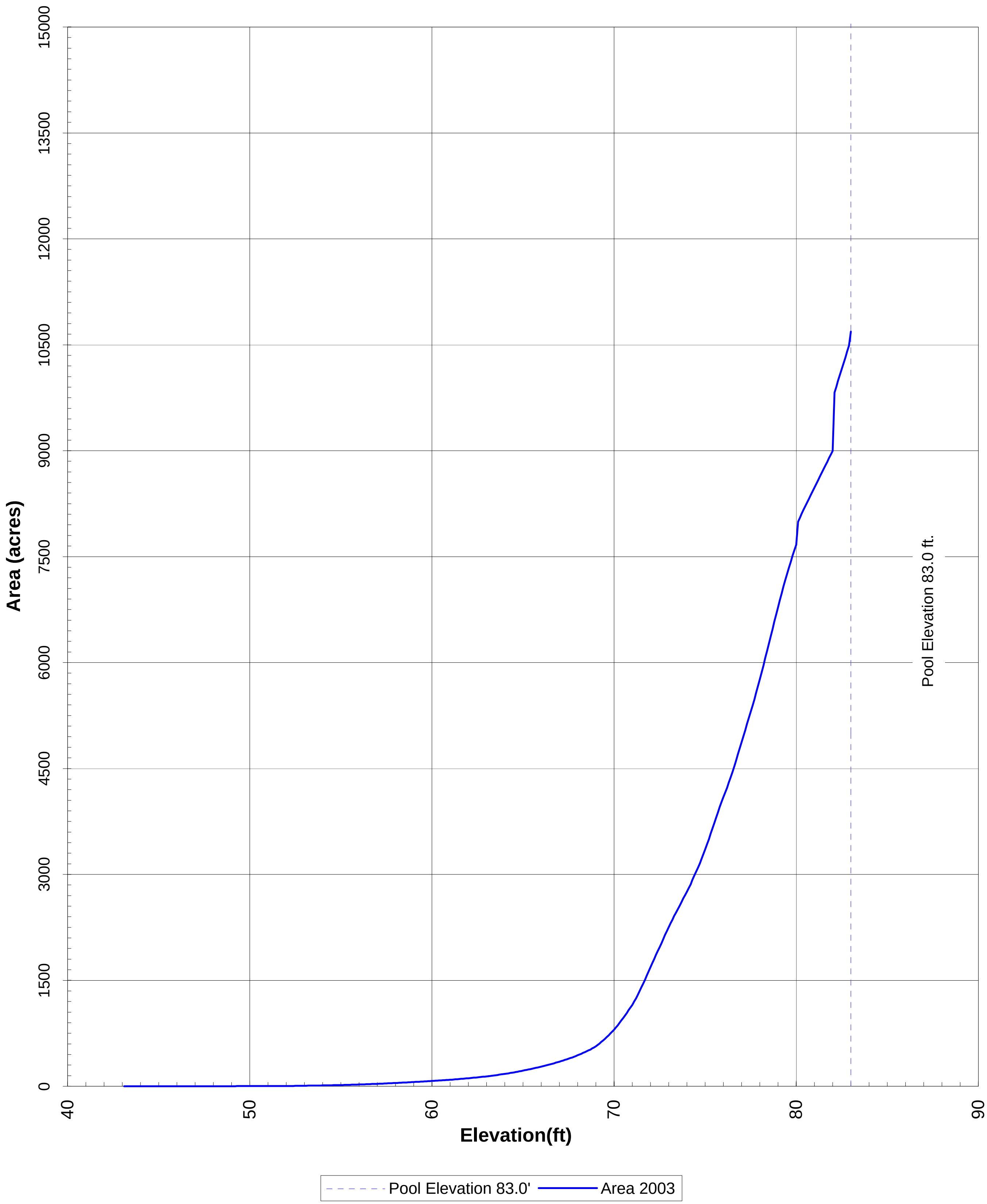
AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
43		0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	1	1
46	1	1	1	1	1	1	1	1	1	1
47	1	1	1	1	1	1	1	1	1	1
48	1	1	1	1	1	1	1	1	1	1
49	2	2	2	2	2	2	2	2	2	2
50	2	2	2	2	2	2	2	2	3	3
51	3	3	3	3	3	3	3	4	4	4
52	4	4	4	5	5	5	6	6	7	7
53	8	8	8	9	9	10	10	11	11	12
54	12	12	13	13	14	15	15	16	16	17
55	17	18	19	19	20	21	22	22	23	24
56	25	26	27	27	28	29	30	31	33	34
57	35	36	37	38	39	40	41	43	44	45
58	47	48	49	50	52	53	54	56	57	58
59	60	61	63	64	66	67	68	70	71	73
60	75	76	78	80	81	83	85	86	88	90
61	92	94	96	98	100	102	104	107	109	111
62	114	116	118	121	123	126	129	131	134	137
63	140	143	147	150	153	157	160	164	168	171
64	175	179	183	188	192	197	201	206	211	216
65	221	227	232	238	243	249	254	260	266	272
66	278	284	291	297	304	311	318	325	333	340
67	348	356	364	373	381	390	399	408	418	428
68	439	450	460	472	483	495	508	521	535	550
69	567	585	606	627	650	673	697	723	748	773
70	801	834	863	896	932	966	1001	1040	1077	1114
71	1153	1200	1244	1289	1347	1401	1455	1513	1569	1626
72	1686	1746	1802	1858	1915	1969	2025	2087	2143	2198
73	2254	2308	2360	2410	2459	2507	2558	2609	2658	2706
74	2756	2807	2858	2919	2981	3037	3093	3152	3214	3286
75	3355	3425	3496	3571	3648	3726	3803	3881	3953	4024
76	4095	4161	4227	4299	4374	4450	4531	4618	4702	4787
77	4871	4957	5044	5129	5215	5301	5388	5478	5569	5666
78	5762	5860	5961	6062	6163	6267	6374	6477	6578	6679
79	6782	6885	6982	7075	7166	7257	7345	7430	7512	7592
80	7668	7995	8052	8108	8162	8215	8268	8321	8373	8426
81	8478	8530	8582	8634	8686	8738	8790	8842	8894	8945
82	8997	9824	9908	9991	10074	10157	10240	10323	10405	10487
83	10687									



B.A. Steinhagen Lake
May 2003
Prepared by: TWDB

Appendix C Elevation vs. Volume



B.A. Steinhagen Lake

MAY 2003

Prepared by: TWDB

Appendix D Elevation vs. Area

Appendix E
B.A. Steinhagen

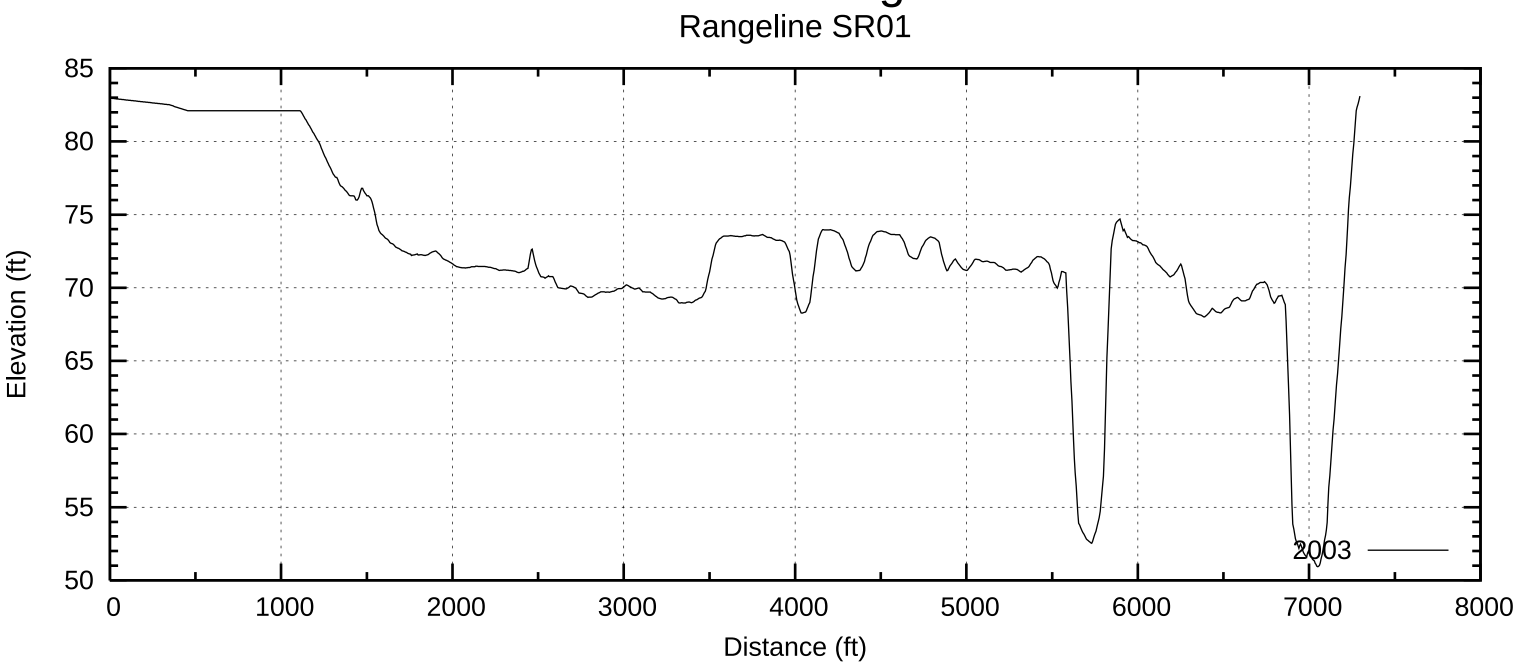
TEXAS WATER DEVELOPMENT BOARD MAY 2003 SURVEY

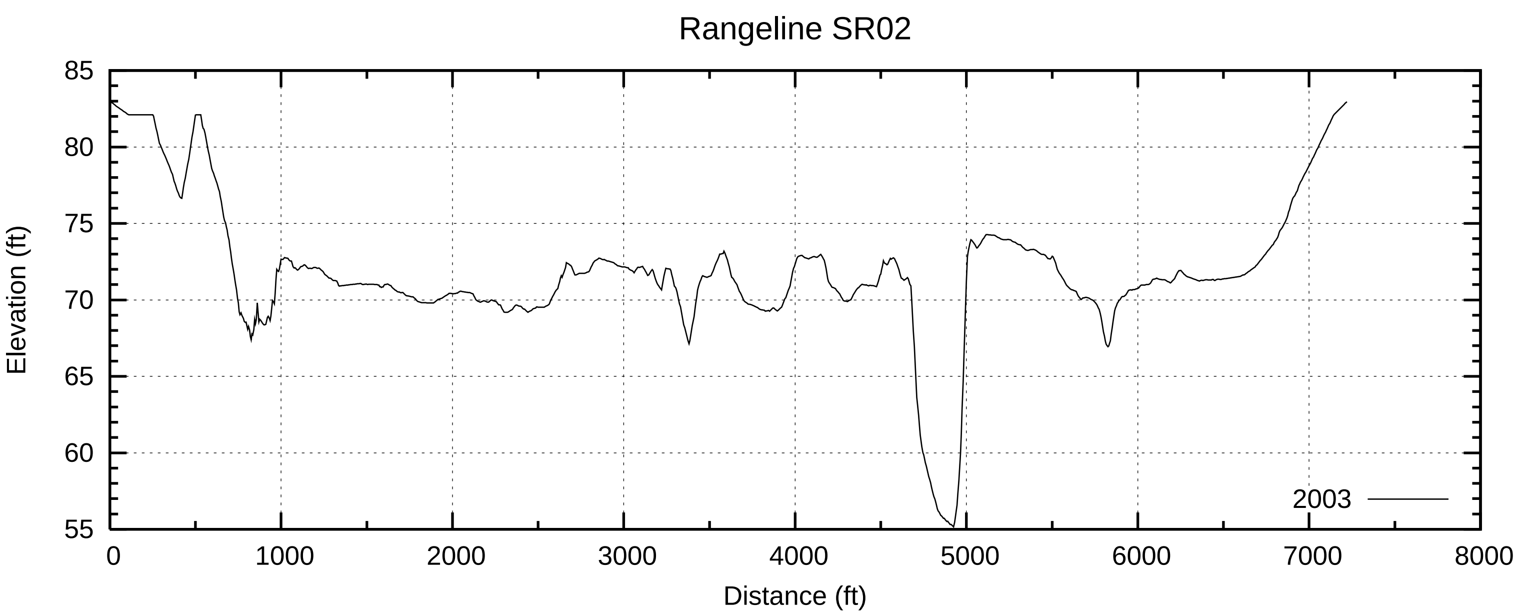
Range Line Endpoints
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

Range Line	X	Y
SR 01-L	4232432.5	10311500.0
SR 01-R	4226873.5	10306774.0
SR 02-L	4229946.0	10314983.0
SR 02-R	4223660.0	10311430.0
SR 03-L	4232255.0	10317518.0
SR 03-R	4218291.0	10318134.0
SR 04-L	4232337.0	10321067.0
SR 04-R	4218548.5	10321568.0
SR 05-L	4228829.5	10325257.0
SR 05-R	4214267.5	10325232.0
SR 06-L	4219374.5	10330590.0
SR 06-R	4216988.5	10327278.0
SR 07-L	4221268.0	10333400.0
SR 07-R	4220176.5	10330956.0
SR 08-L	4213523.5	10337564.0
SR 08-R	4209425.0	10332944.0
SR 09-L	4217231.5	10335313.0
SR 09-R	4212609.0	10328893.0
SR 10-L	4211067.0	10340872.0
SR 10-R	4207373.5	10339641.0
SR 11-L	4220338.5	10342129.0
SR 11-R	4216569.5	10343016.0
SR 12-L	4217385.0	10350641.0
SR 12-R	4217113.5	10350482.0
SR-13-L	4221934.5	10343491.0
SR-13-R	4220957.5	10345739.0
SR 14-L	4228927.5	10347638.0
SR 14-R	4228994.5	10348722.0

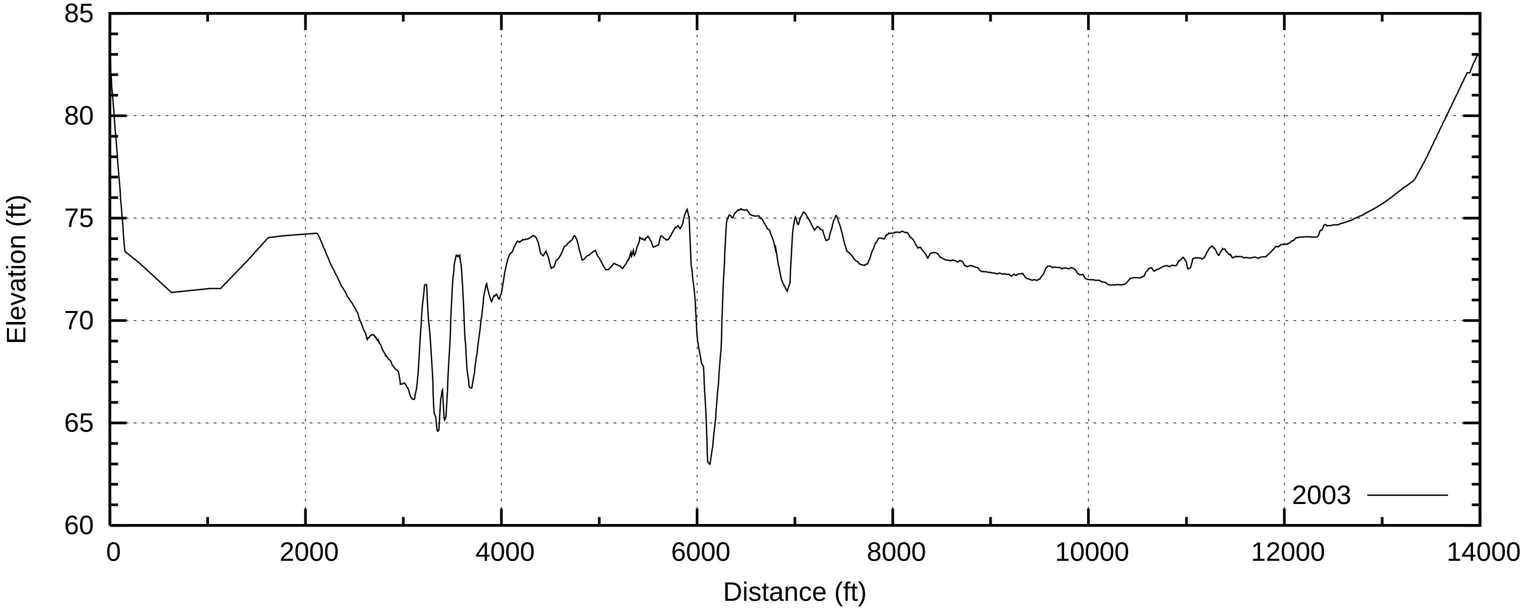
B.A. Steinhagen Lake



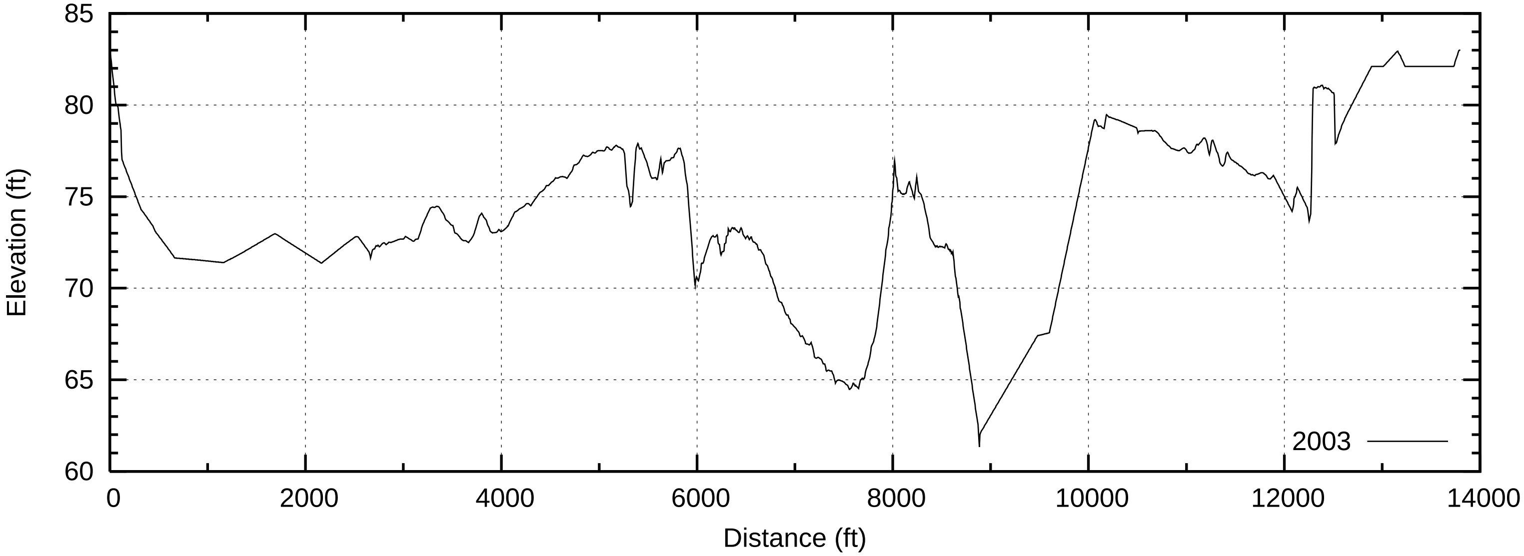


B.A. Steinhagen Lake

Rangeline SR03

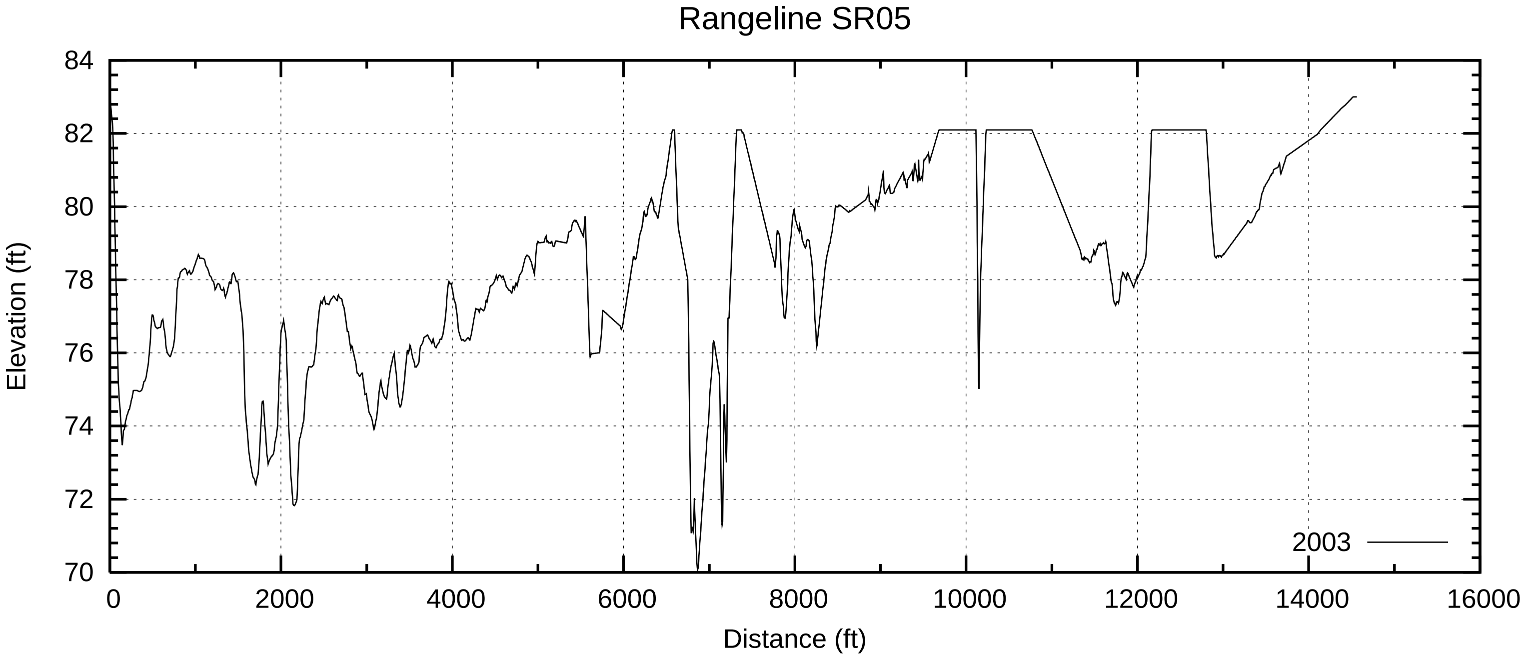


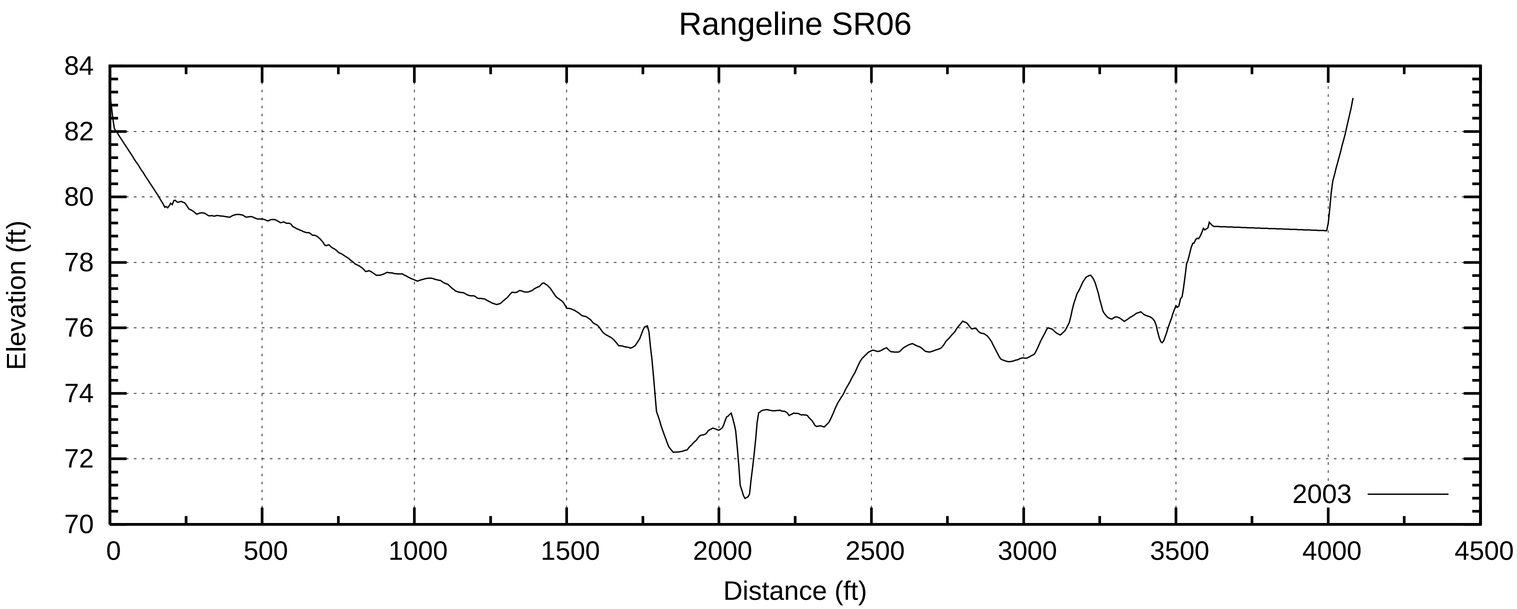
Rangeline SR04



Appendix F

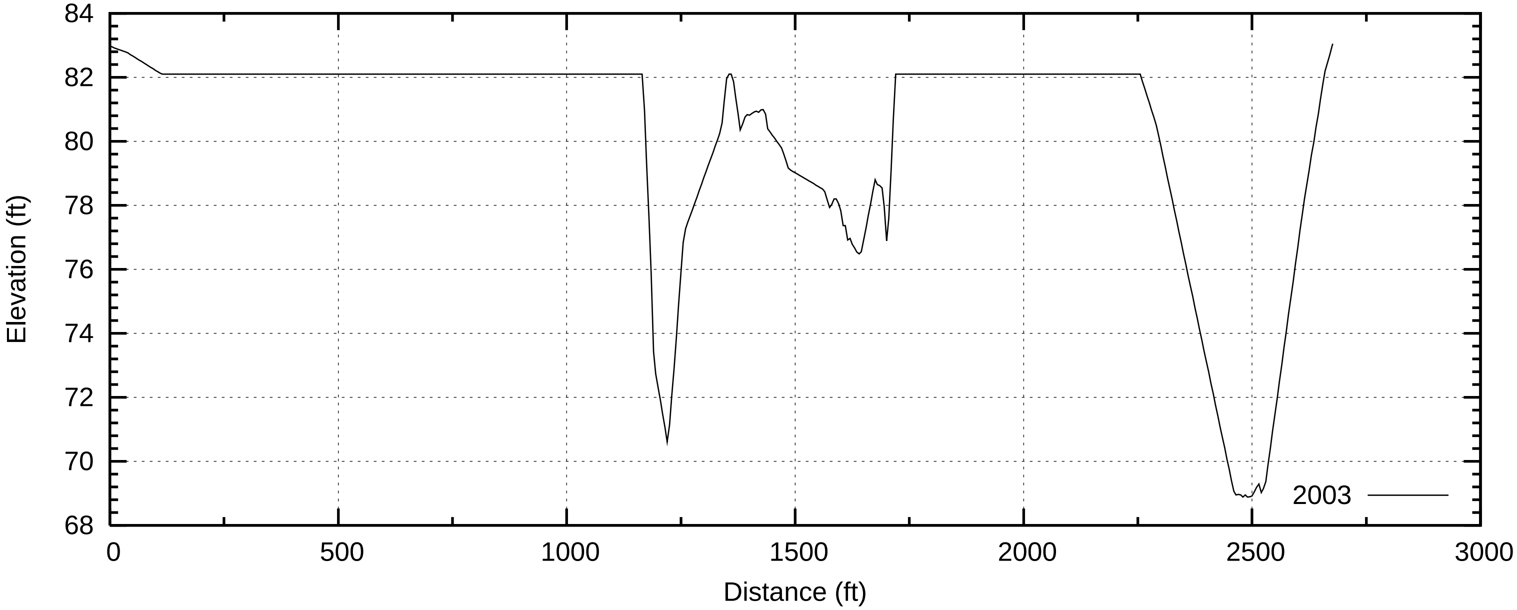
B.A. Steinhagen Lake



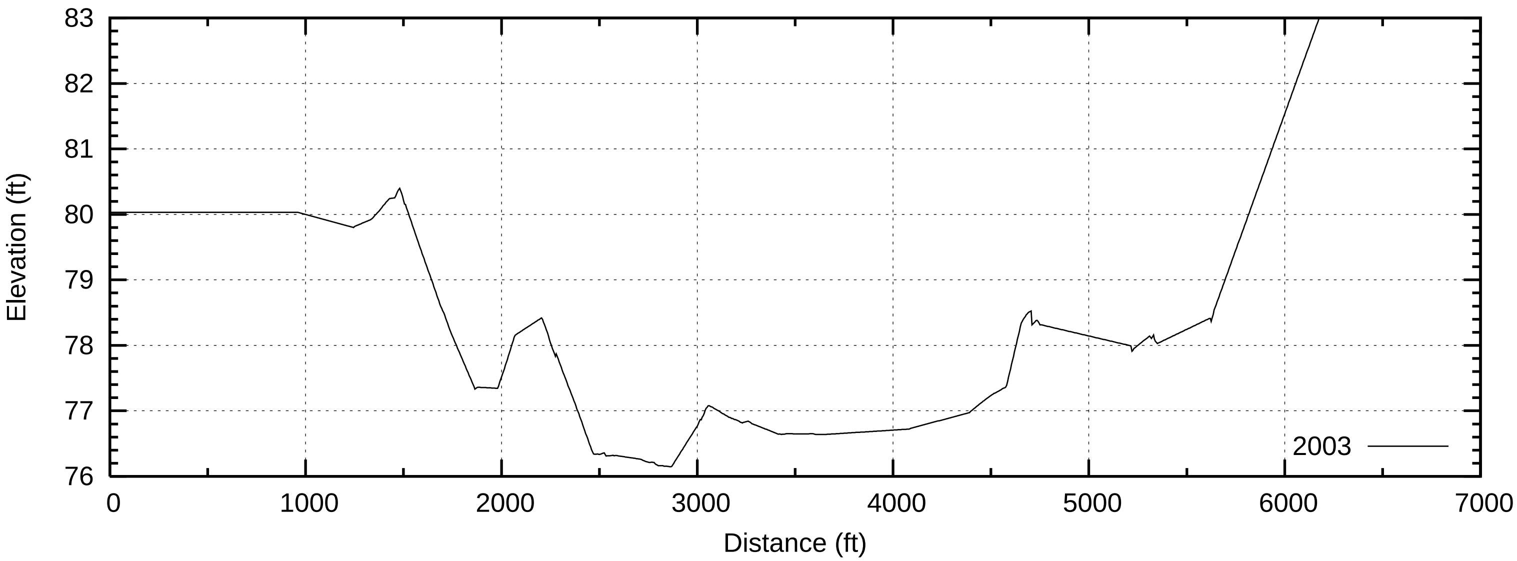


B.A. Steinhagen Lake

Rangeline SR07

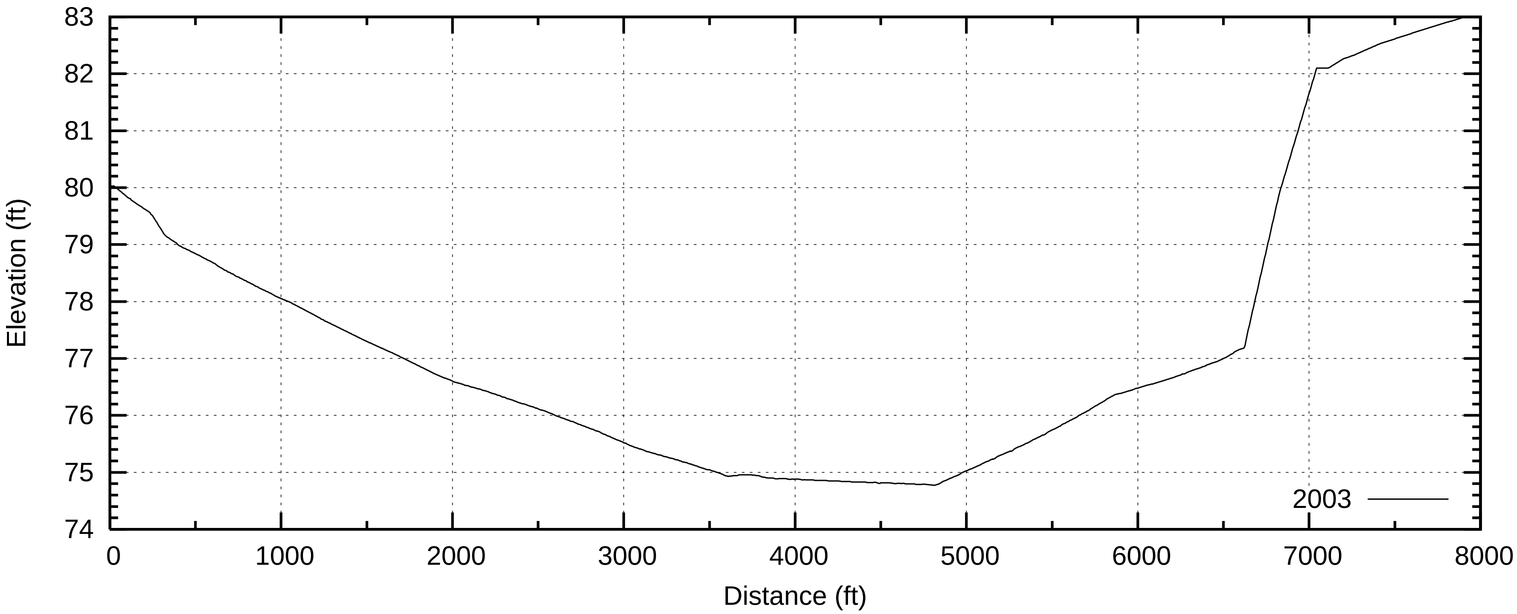


Rangeline SR08

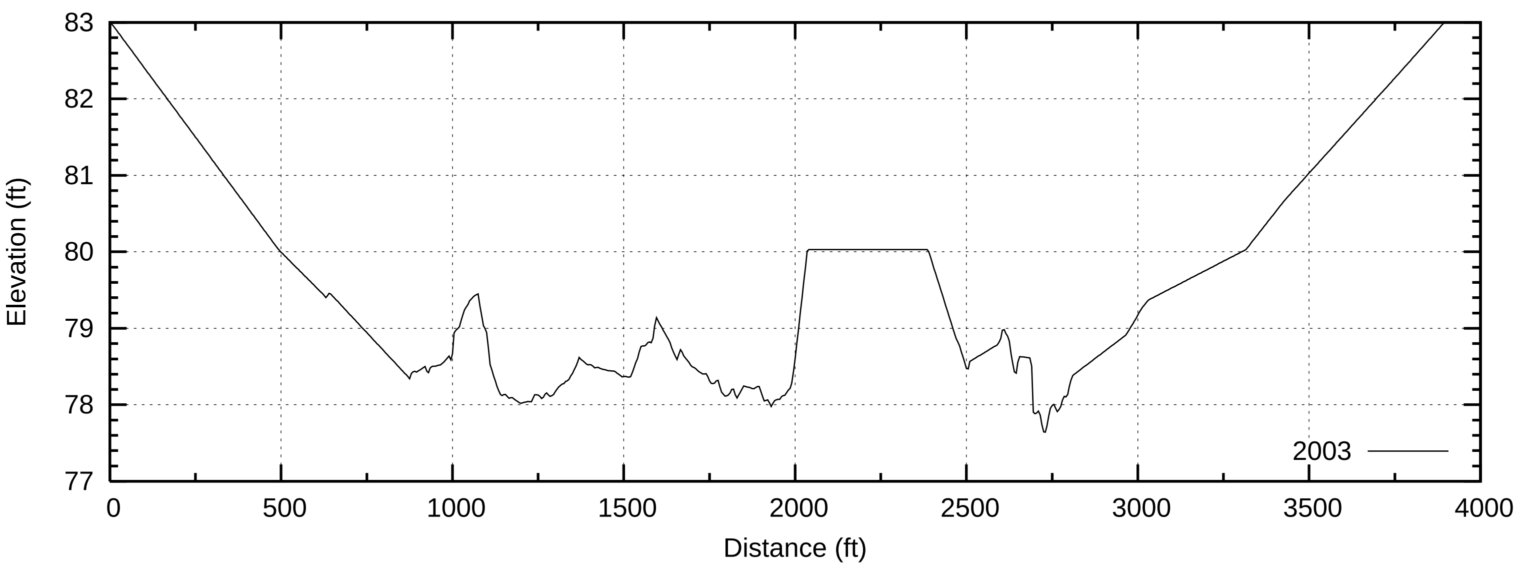


B.A. Steinhagen Lake

Rangeline SR09



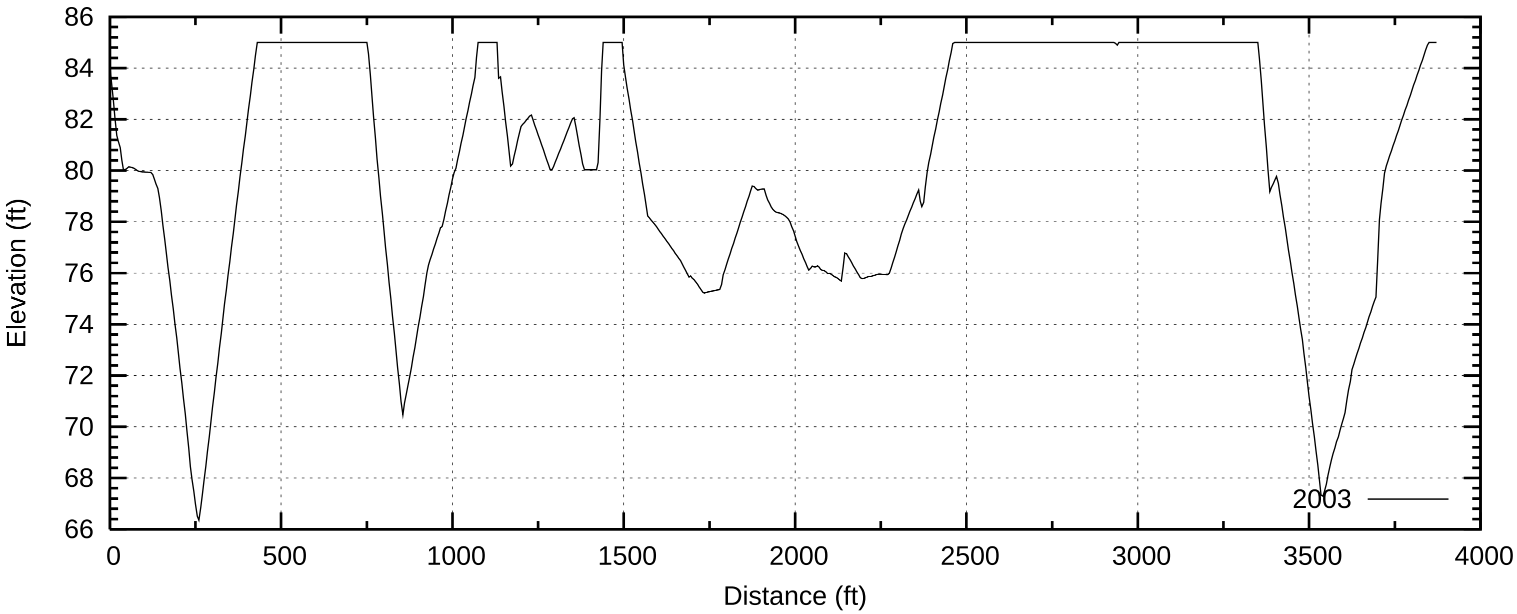
Rangeline SR10



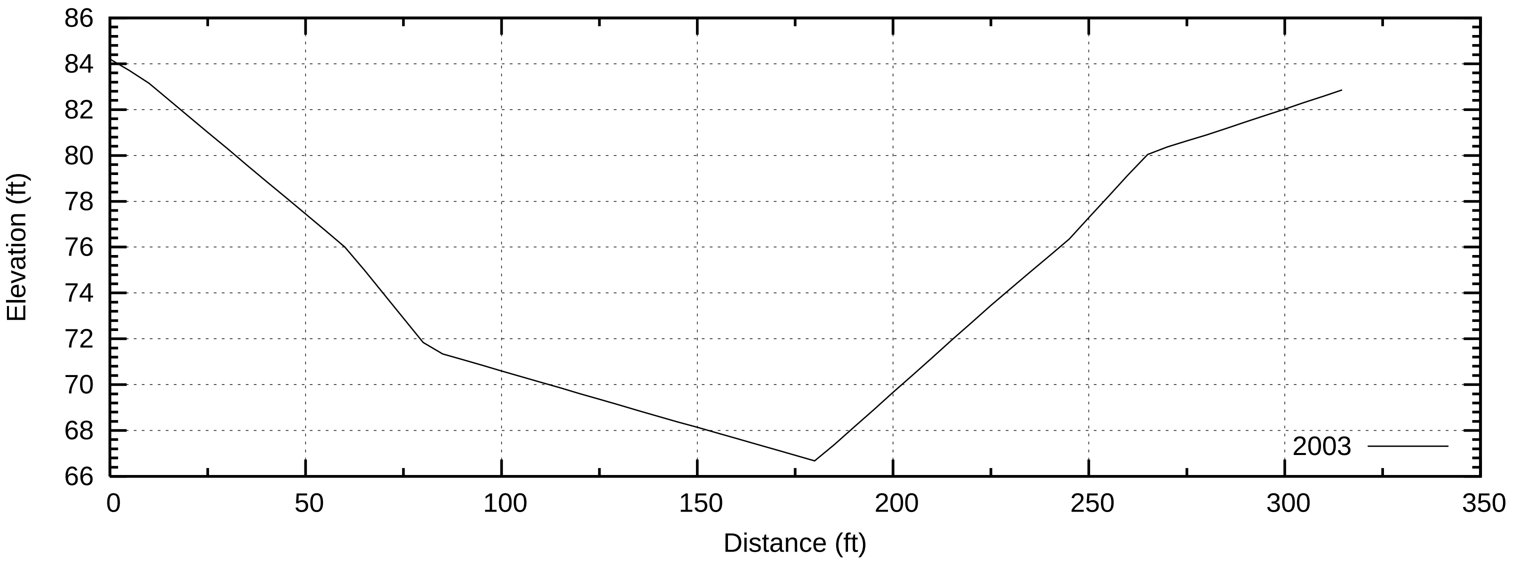
Appendix F

B.A. Steinhagen Lake

Rangeline SR11

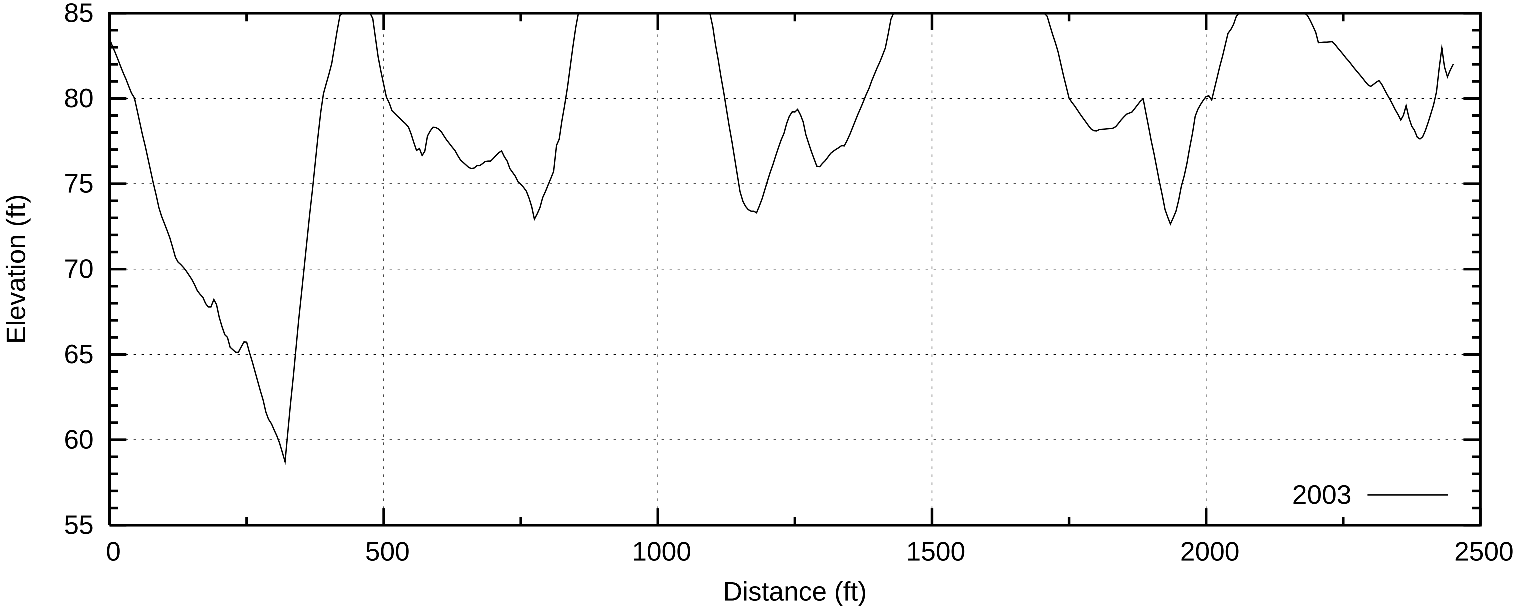


Rangeline SR12

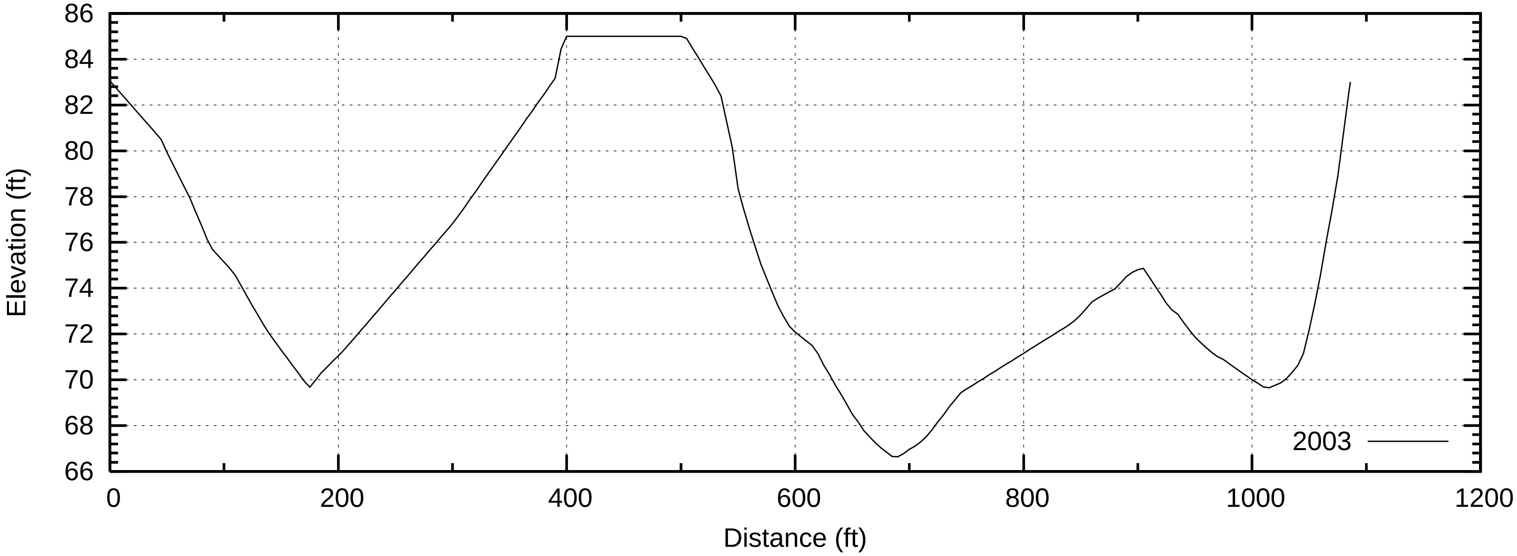


B.A. Steinhagen Lake

Rangeline SR13



Rangeline SR14



Appendix G

Historical Aerial Photos near Highway 190

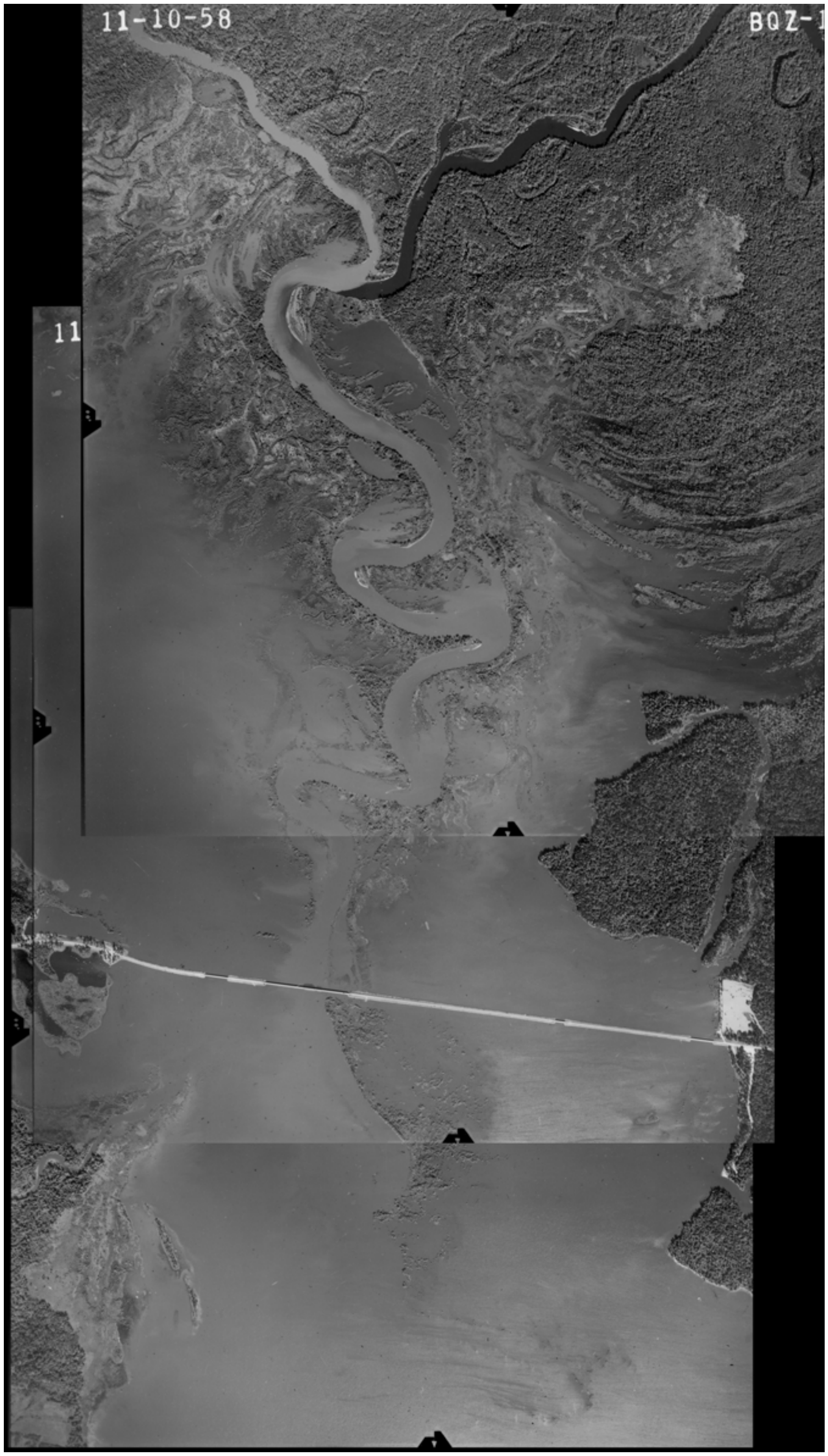
The following series of photographs illustrate the deltaic formation in B. A. Steinhagen Lake. They cover the years 1958, 1968, 1976, and 1995. Water surface elevations have not been determined except for the 1995 photo series. The photos are presented here only as an example of physical processes occurring in B. A. Steinhagen Lake. No analyses using these photos were conducted for this report.

A paper describing methods using satellite photos to track deltaic accretion can be found at the following link:
http://www.utdallas.edu/~cornelo/Research/RSweb/index.htm (February 26, 2004)

An additional paper using aerial photographs similar to the ones presented here is "Character and Growth of Deltaic Deposits in Lewisville Lake, Texas" by Harry F.L. Williams; and was published in the Texas Journal of Science- Vol. 43, No. 4, 1991.

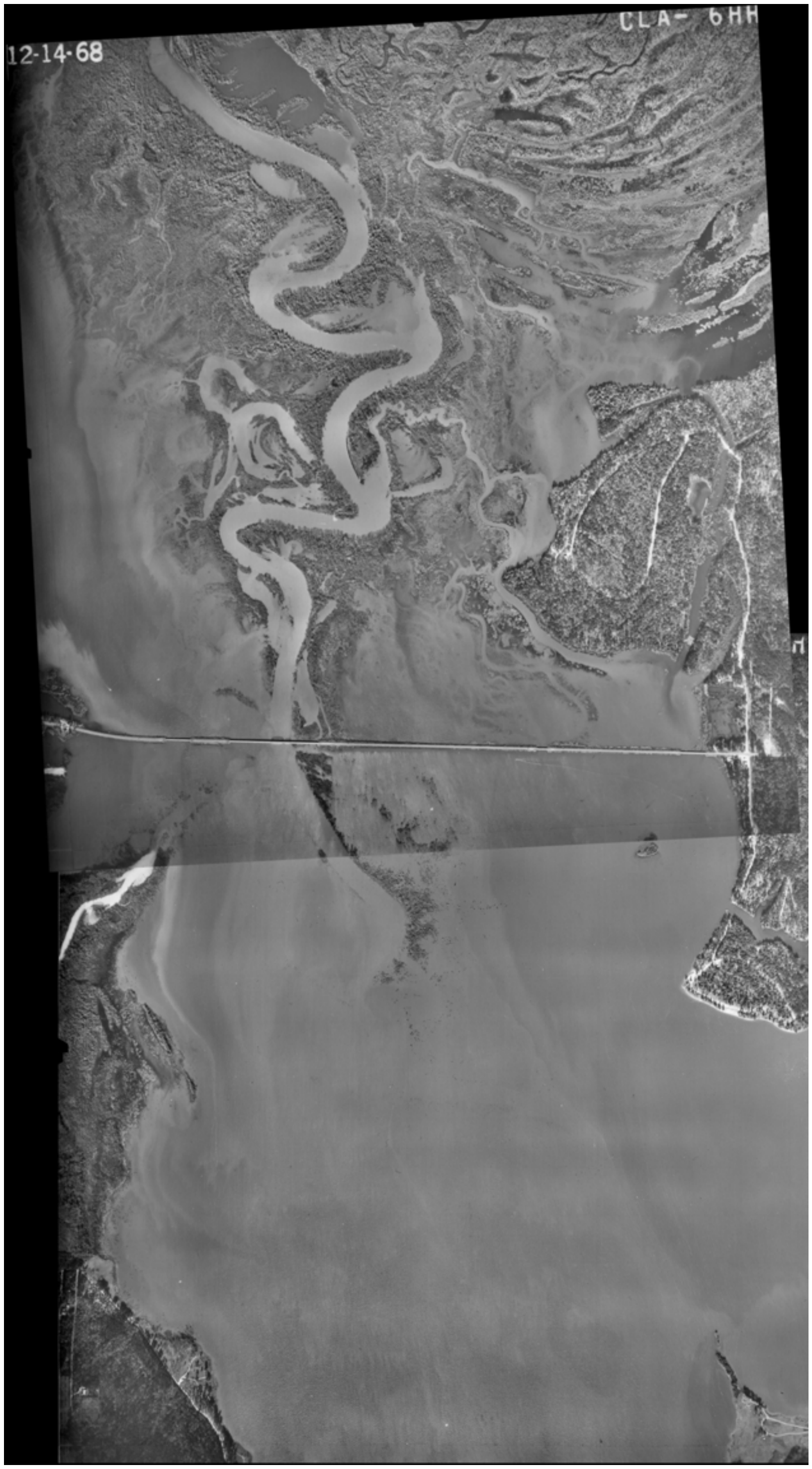
February 5, 1995
Water Surface Elevation – 82.1 ft
Conservation Pool Elevation – 83.0 ft

Appendix G (continued)



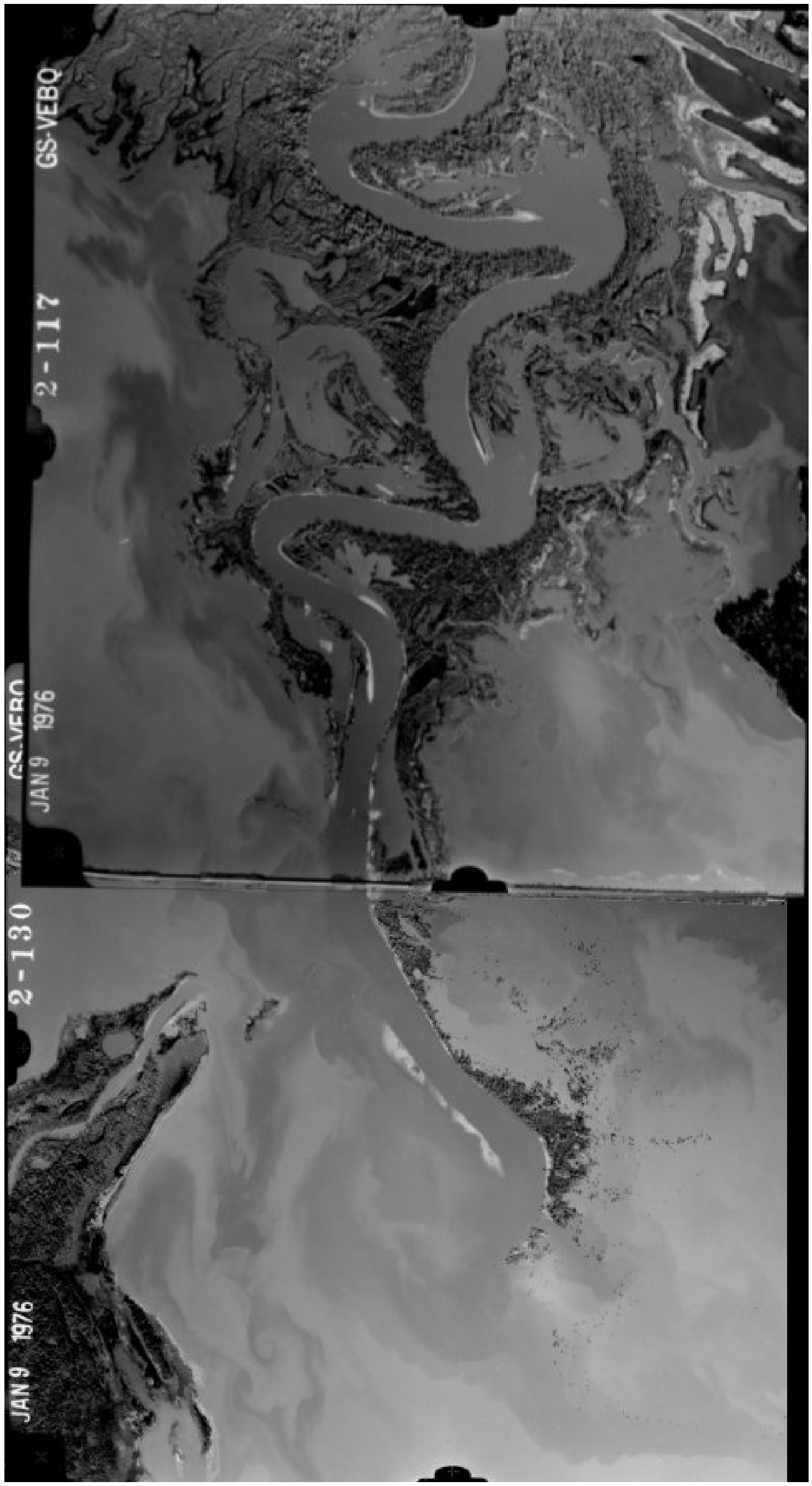
3-photo composite where US Highway 190 crosses B. A. Steinhagen Lake

Appendix G (continued)



2-photo composite 12-14-68

Appendix G (continued)



2-photo composite 01-09-76

Appendix H
Aquatic Vegetation

The survey crew took the following series of photographs April 30, 2003. They illustrate the invasion of aquatic vegetation into B.A. Steinhagen Lake. Measuring the area between the last end points on the boat transects and the calculated 83 ft contour in Figure 2, a conservative estimate of 2,300 surface acres of vegetative cover was present during the survey.

Photo taken at Boat Ramp # 2 in Magnolia Ridge Park, looking east.

Appendix H (continued)

West shoreline of Magnolia Ridge Park.

Shoreline Magnolia Ridge Park.

Appendix H (continued)

North end of Magnolia Ridge Park, looking north.

Northwest reaches of lake.

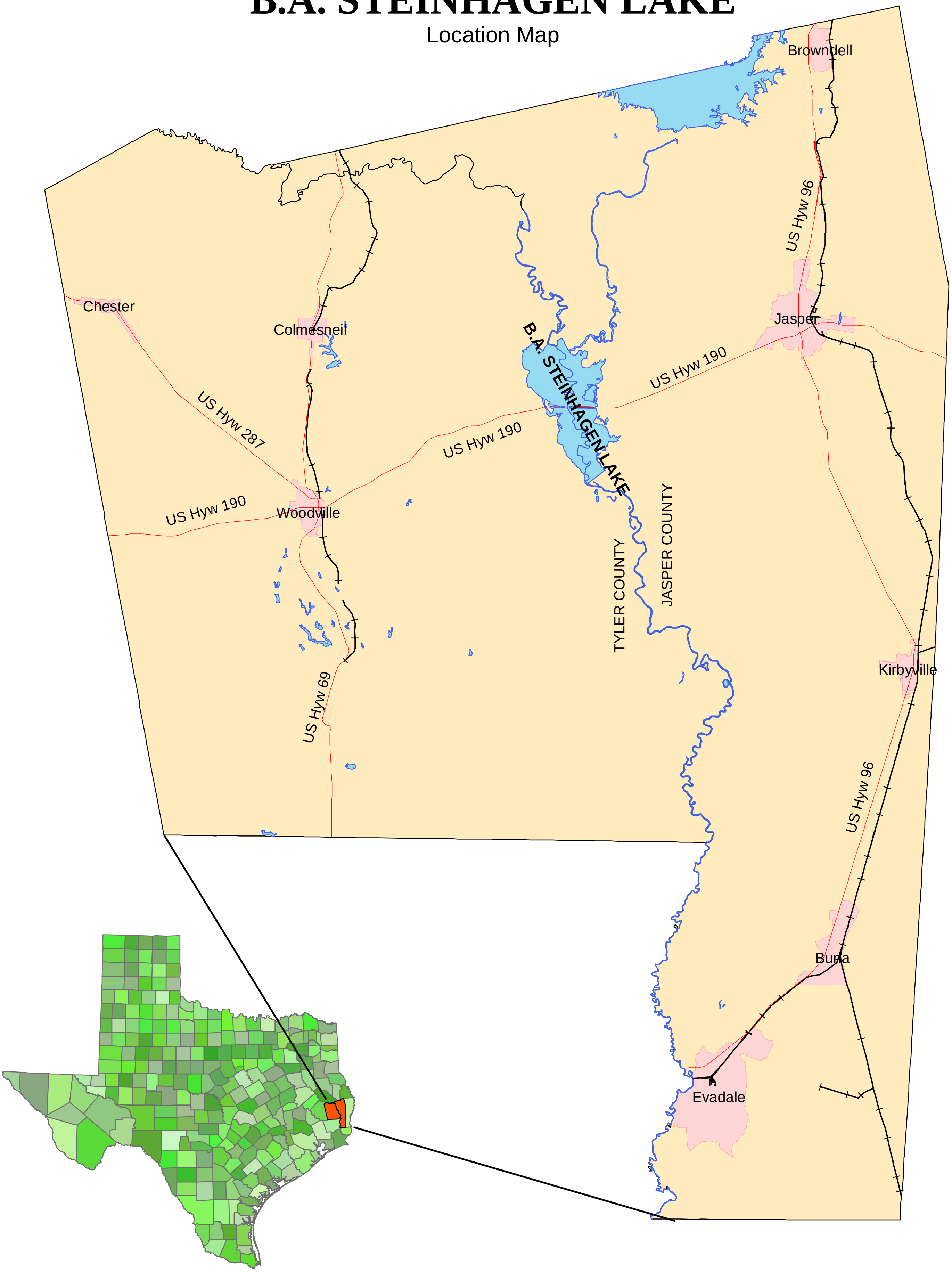
Appendix H (continued)

Northern most shoreline of Magnolia Ridge Park.

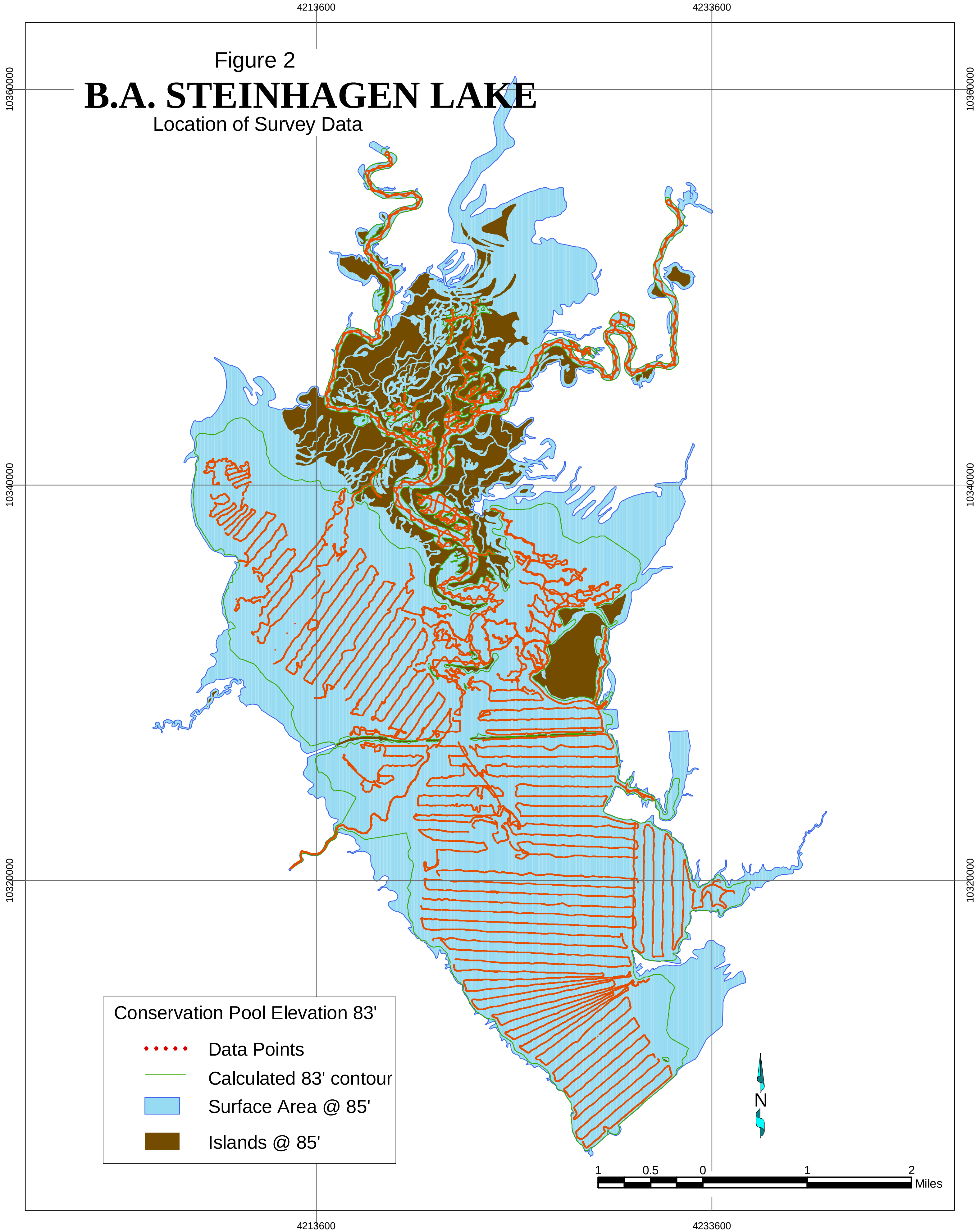
Figure 1

B.A. STEINHAGEN LAKE

Location Map



TWDB Survey May 2003

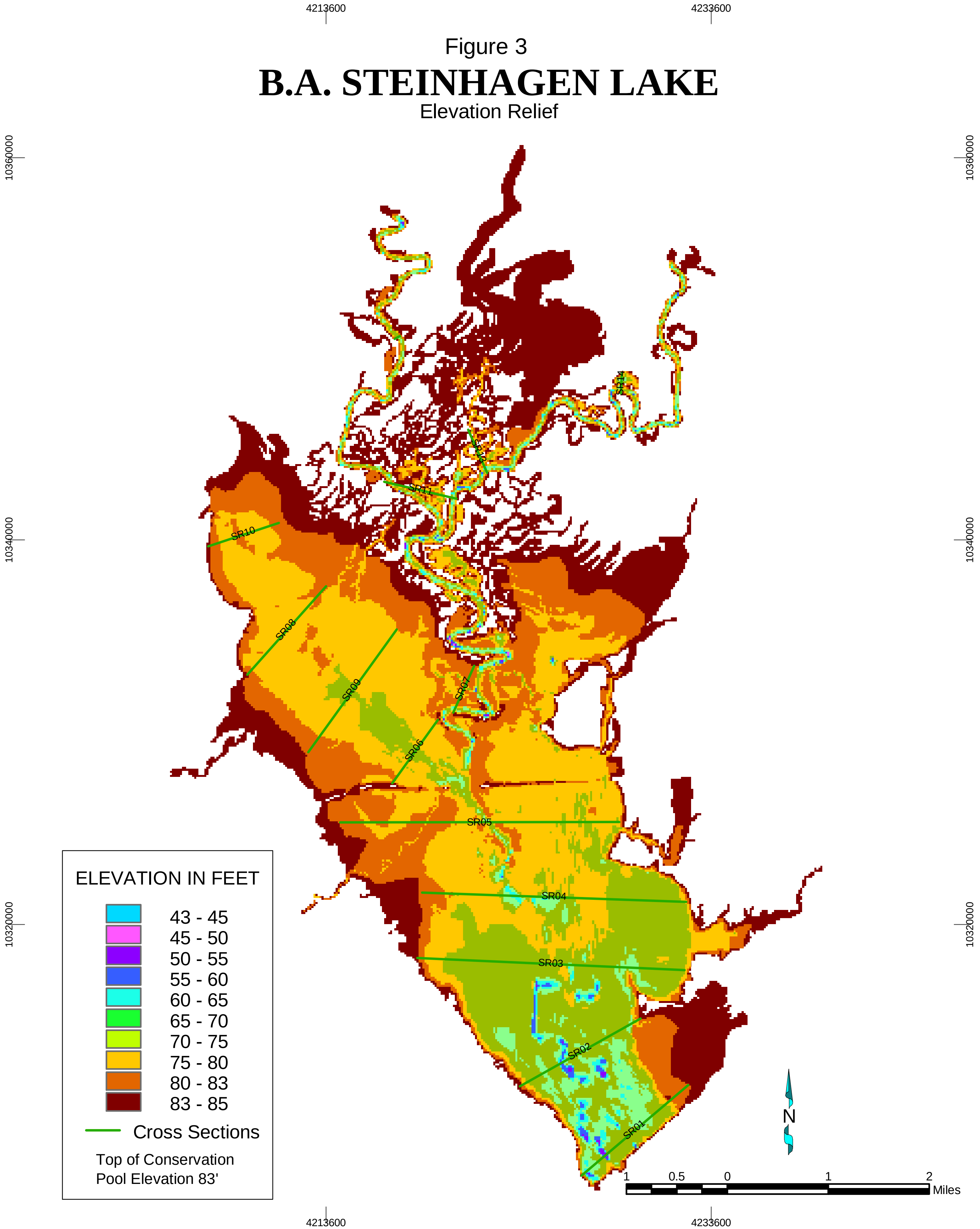


TWDB Survey May 2003

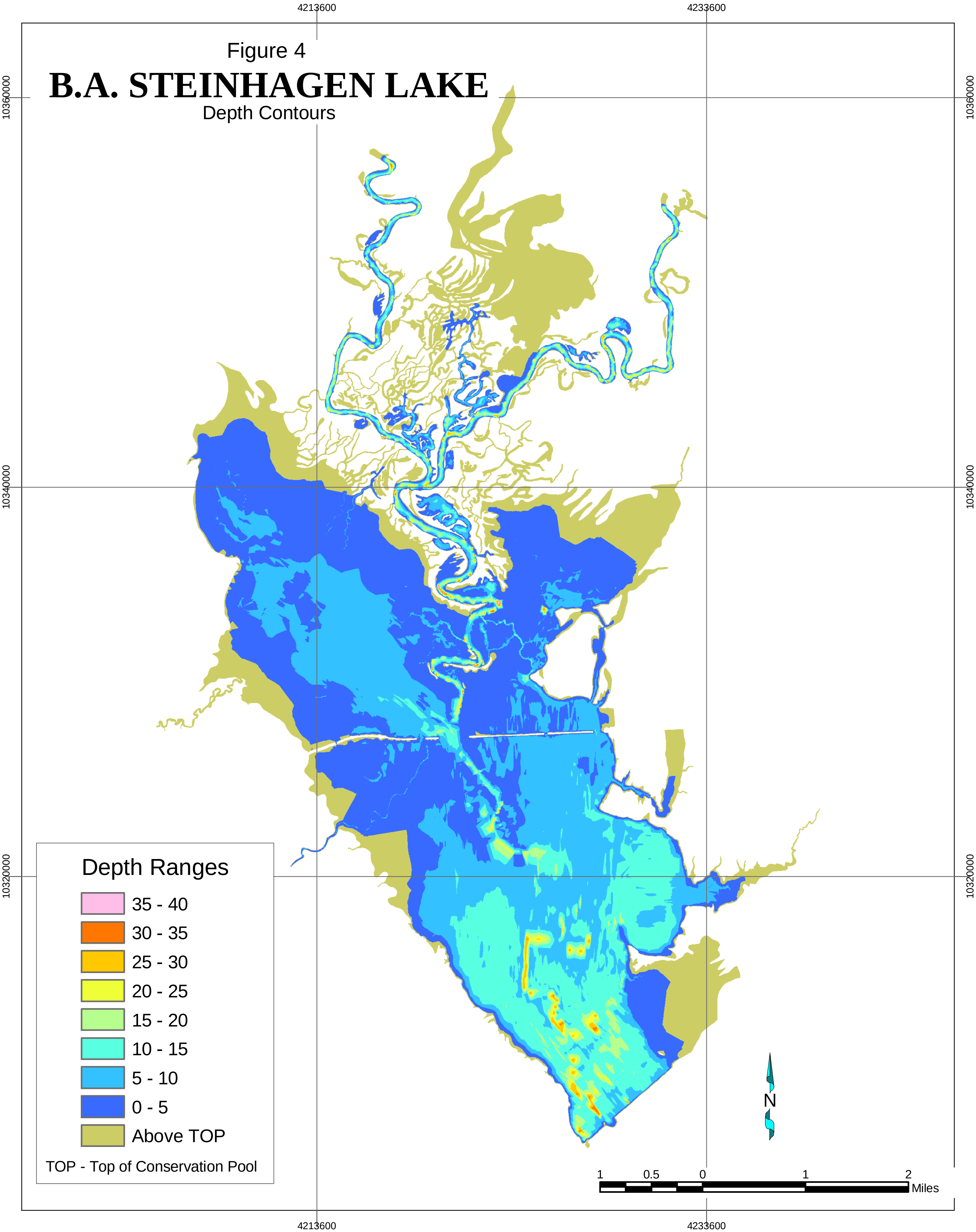
Figure 3

B.A. STEINHAGEN LAKE

Elevation Relief



TWDB Survey May 2003



TWDB Survey May 2003

Figure 5

2' - Contour Map

B.A. STEINHAGEN LAKE

N

2,000 1,000 0 2,000 4,000 Feet

Approximate Water Surface @ 85.0'

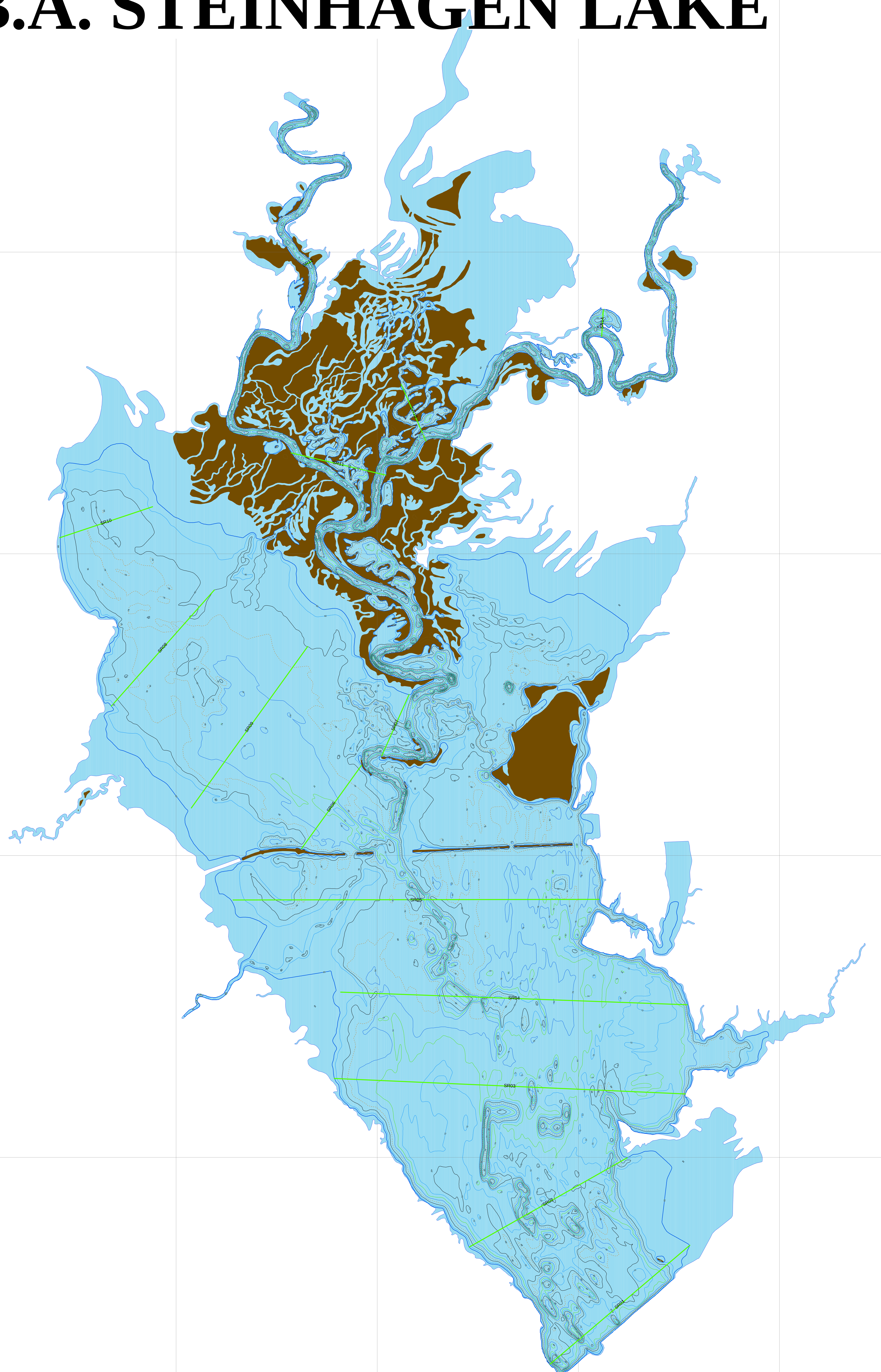
Islands

Elevation 83.0' (calculated)

Cross Sections

Contours

48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
83



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

TEXAS WATER DEVELOPMENT BOARD MAY 2003 SURVEY