MEMORANDUM

From: Ronald L. Ferrari
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Subject: Bonny Reservoir Bathymetric Survey

Background

In fall 2009, the Great Plains Regional Office requested a bathymetric survey of Bonny Reservoir to develop reservoir topography and current area/capacity conditions. For several years the reservoir has been operated at very low levels and in fall 2009, the reservoir elevation was around 3,651 feet (project elevation) making the launch of a large survey vessel nearly impossible due to shallow conditions at the boat ramp. Windy conditions are typical at the reservoir, so a larger vessel was preferable for data collection due to its added safety and stability. In April 2010 the reservoir reached an elevation of 3654.3, allowing a larger survey vessel to be used. At this elevation, the reservoir is around 30 percent full, but with reservoir levels predicted to begin to drop later in May, the survey was conducted on April 27 and 28 of 2010 by the Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center.

Kent Collins and Ron Ferrari of the Sedimentation Group conducted the bathymetric survey. Ron Ferrari processed the data to generate reservoir topography along with updated area/capacity tables. During this study, results were generated for reservoir elevation 3,557.0 and below. This is the highest elevation that recent data was available. Following is a brief description of the field collection, analysis, and final results.

Summary and Conclusions

The primary objectives of the Bonny Reservoir survey were to gather data needed to:

- develop reservoir topography;
- compute current area-capacity relationships; and
- estimate storage depletion, by sediment deposition, since dam closure.

A control survey was conducted using the on-line positioning user service (OPUS) and RTK GPS to establish a horizontal and vertical control network for the hydrographic survey. OPUS is operated by the National Geodetic Survey (NGS) and allows users to submit GPS data files for processing with known point data to determine positions relative to the national control network. The GPS

base was set over a temporary mark near the boat ramp. The coordinates were processed using OPUS and from this base the water surface was measured during calm conditions. The horizontal control was in feet, Colorado North state plane coordinates, in the North American Datum of 1983 (NAD83). The vertical control was in feet, tied to the North American vertical datum of 1988 (NAVD88) and the Reclamation project vertical datum. All elevations for the map and resulting tables are referenced to Reclamation's water surface gage reading at time of collection which was elevation 3,654.3 feet. The OPUS solution found the gage readings to be 1.1 feet lower than the NAVD88 and 0.5 feet higher than the National Geodetic Vertical Datum of 1929 (NGVD29). There was only one day of data available to submit to OPUS, so these vertical shifts should be verified.

The bathymetric survey was conducted using sonic depth recording equipment interfaced with the RTK GPS for determining sounding locations within the reservoir. Prior to collection the depth sounder was calibrated for the water conditions. The system continuously recorded depth and horizontal coordinates of the survey boat as it navigated along predetermined grid lines and along the shoreline. The positioning system provided information that allowed the boat operator to maintain a course along these grid lines. At times wind hindered the shallow water collection, but main hindrance was thick vegetation that developed along the shoreline during the reservoir drawdown. Water surface elevations recorded by a Reclamation gage during the time of collection were used to convert the sonic depth measurements to reservoir bottom elevations.

The initial above-water topography for the 2010 survey was developed by digitizing contour lines from the USGS quads of the reservoir area. Orthographic aerial images collected from 2004 through 2009 between water surface elevations 3,651.9 and 3,656.4 were downloaded from the USDA data web site for the analysis. Reservoir contours were developed at various water surface elevations by digitizing the edge of water from the aerial images, allowing development of new contours from elevation 3,657.0 and below. The aerial images were collected at high altitudes, making it difficult at times to distinguish the edge of the reservoir's water surface. However, these digitized contours were best available means to accurately locate the shoreline at the different elevations, Figures 1 and 2.

The 2010 Bonny Reservoir topographic map is a combination of the digitized water surface edges from the USDA orthographic aerial photographs and the 2010 underwater survey data points, Figure 3. The 2010 area and capacity tables were produced by a computer program that used the measured contour surface areas and a curve-fitting technique to compute the area and capacity values at prescribed elevation increments. The topographic computer program generated the 2010 reservoir surface areas at 1-foot increments from elevation 3,637.0 through 3,657.0 from the combined reservoir data.

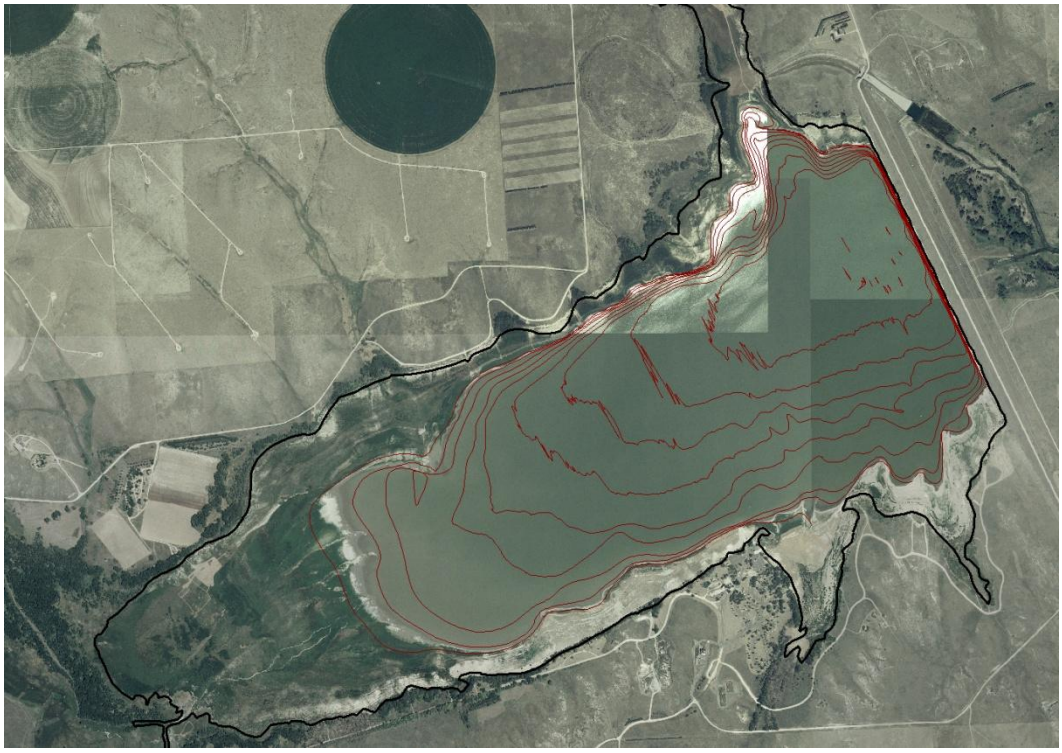

Figure 1 - Bonny Reservoir 2005 aerial photo, elevation 3,654.4.

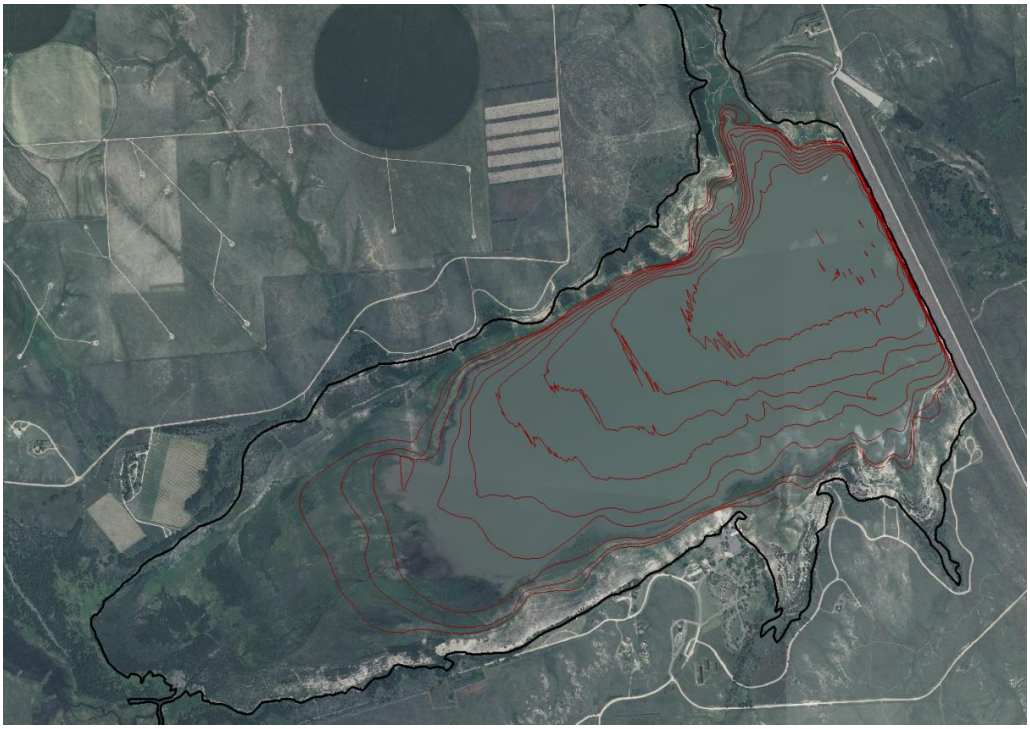

Figure 2 - Bonny Reservoir 2009 aerial photo, elevation 3,651.9.

The following tables and plots summarize the results of the 2010 Bonny Reservoir survey and analysis from elevation 3,657.0 and below. Detailed aerial data would be required to accurately develop full reservoir topography and resulting capacity information. The storage-elevation relationships based on the measured surface areas were developed using an area-capacity computer program that can compute area and capacity at elevation increments from 0.01 to 1.0 foot by linear interpolation between known surface areas. The following table presents the results in 0.1 increments. If requested the tables can be developed in 0.01 and 1.0 foot increments. The original and 2010 area-capacity relationships are listed on Table 1 and the curves plotted on Figure 4. As of April 2010, at elevation 3,657.0 feet, the surface area was 1,166 acres with a total capacity of 11,998 acre-feet.

The maximum depth measured during the 2010 survey was at elevation 3,637.7 feet. The computed surface area at elevation 3,638.0 feet was 0.2 acre-feet, indicating there is virtually no storage available due to sediment deposition in the dead (elevation 3,635.5 feet) and inactive (elevation 3,638.0) zones. At the maximum elevation that could be developed by this study (elevation 3,657.0 feet) an original capacity loss of 4,832 acre-feet due to sediment deposition was computed. A detailed aerial survey would be required to determine present capacity and loss of original capacity above elevation 3,657.0 feet.

The following plots and table summarize the results from the April 2010 survey conducted by the Sedimentation Group. If additional information is needed on this study please contact Ron Ferrari of the Sedimentation Group at 303-445-2551.

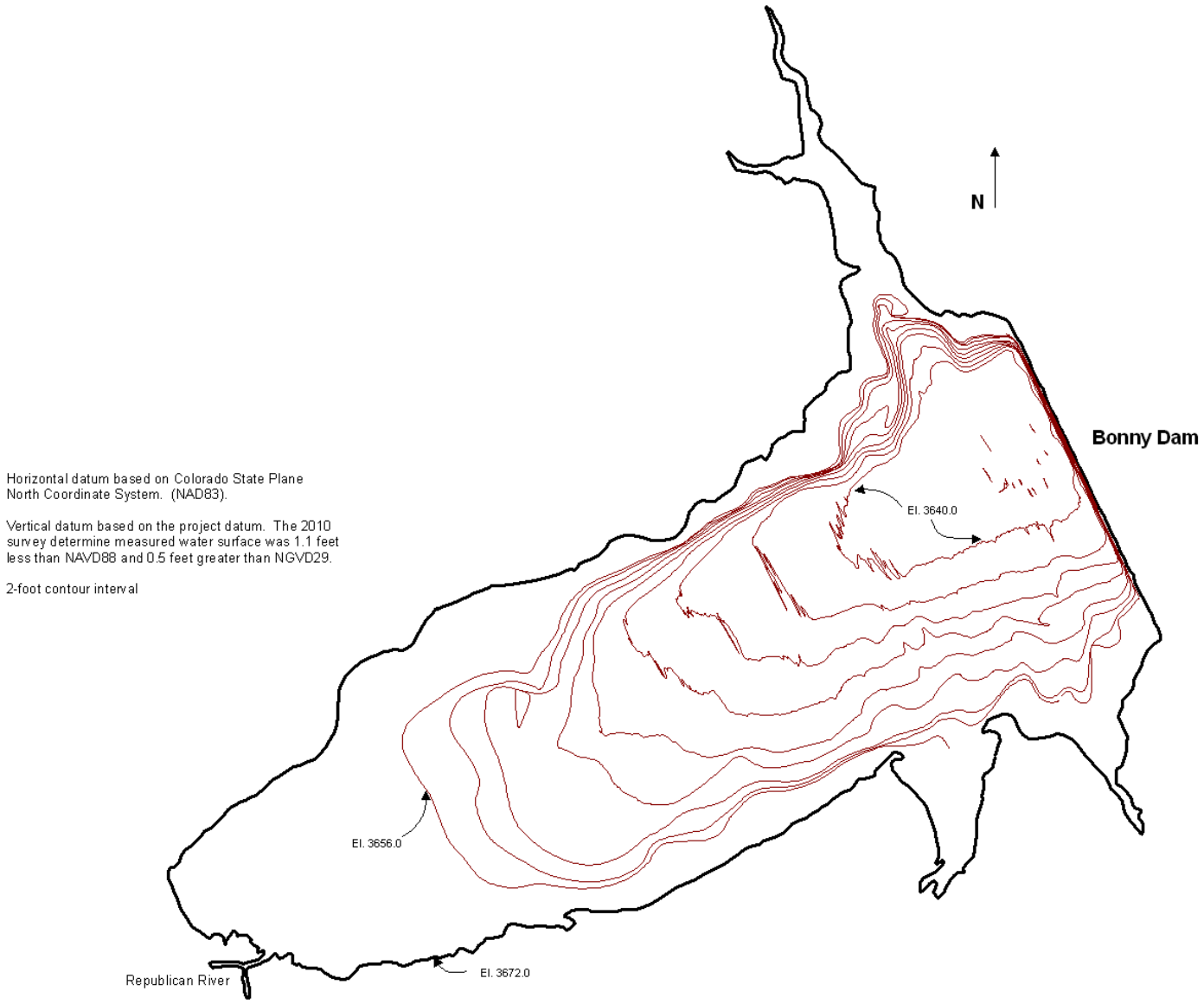

Figure 3 – 2010 Bonny Reservoir 2-foot topography from elevation 3,657.0 and below.

1	2	3	4	5	6		
					2010		
	Original	Original	2010	2010	Sediment		
Elevation	Area	Capacity	Area	Capacity	Volume		
Feet	Acres	Ac-Ft	Acres	Ac-Ft	Ac-Ft		
3,657.0	1,253	16,830	1,166	11,998	4,832		
3,655.0	1,157	14,420	1,095	9,733	4,687		
3,653.0	1,049	12,214	1,000	7,641	4,573		
3,651.0	940	10,226	825	5,774	4,452		
3,650.0	886	9,312	785	4,969	4,343		
3,649.0	838	8,451	730	4,212	4,239		
3,647.0	741	6,872	606	2,872	4,000		
3,645.0	644	5,487	467	1,803	3,684		
3,643.0	548	4,296	354	982	3,314		
3,641.0	451	3,297	236	390	2,907		
3,640.0	403	2,870	176	185	2,685		
3,639.0	367	2,485	97	49	2,436		
3,638.0	331	2,136	0	0	2,136		Inactive Zone
3,637.0	296	1,822	0	0	1,822		
3,635.5	242	1,419	0	0	1,419		Dead Storage Zone
3,635.0	224	1,302	0	0	1,302		
3,630.0	103	485	0	0	485		
3,625.0	43	120	0	0	120		
3,620.0	3	5	0	0	5		
3,617.0	0	0	0	0	0		
1	Reservoir water surface elevation.						
2	Original reservoir surface area.						
3	Original reservoir capacity recomputed using ACAP.						
4	2010 reservoir surface area.						
5	2010 reservoir capacity.						
6	2010 computed sediment volume, column (3) - column (5).						

Table 1 - Reservoir Sediment Data Summary

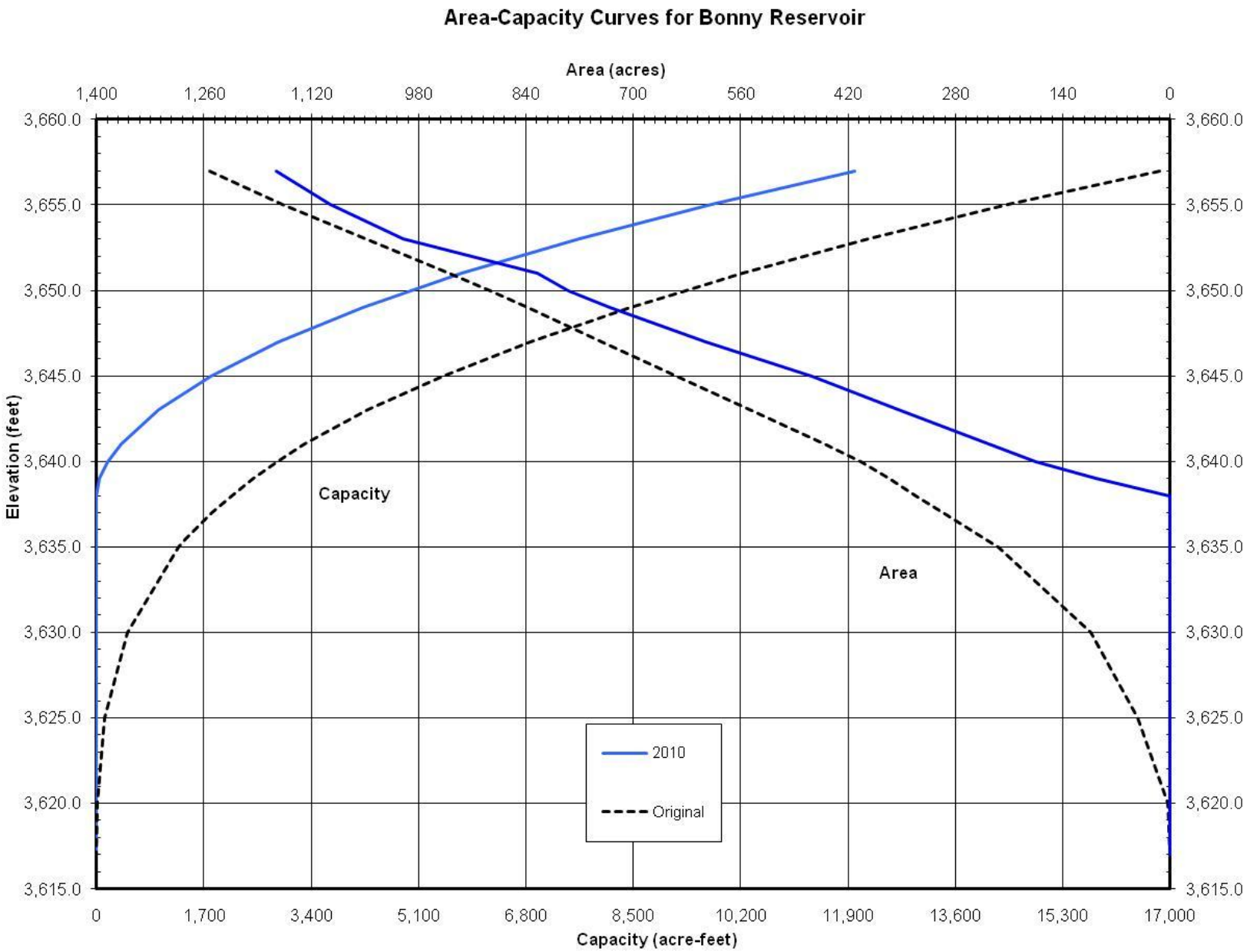

Figure 4 - Bonny Reservoir Area and Capacity Plots

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Bonny Reservoir

April 2010 Area and Capacity Tables

EQUATIONS --> AREA = A2 + X*(A3 + A3)

$$\text{--> CAPACITY} = A3*X^2 + A2*X + A1$$

WHERE X = THE DIFFERENCE BETWEEN THE BASE ELEVATION AND A GIVEN ELEVATION. AREA IS IN ACRES AND CAPACITY IS IN ACRE-FEET

Bonny Reservoir
2010 AREA-CAPACITY TABLES

EQUATION NUMBER	ELEVATION BASE	CAPACITY BASE	COEFFICIENT A1(INTERCEPT)	COEFFICIENT A2(1ST TERM)	COEFFICIENT A3(2ND TERM)
1	3637.00	0	.0000	.0000	.1000
2	3638.00	0	.1000	.2000	48.2000
3	3639.00	48	48.5000	96.6000	39.5000
4	3640.00	184	184.6000	175.6000	30.2500
5	3641.00	390	390.4500	236.1000	30.1500
6	3642.00	656	656.7000	296.4001	28.7999
7	3643.00	981	981.9000	353.9999	28.4001
8	3644.00	1364	1364.3000	410.8001	27.9999
9	3645.00	1803	1803.1001	466.7998	32.8003
10	3646.00	2302	2302.7002	532.4003	36.8497
11	3647.00	2871	2871.9502	606.0997	32.7503
12	3648.00	3510	3510.8004	671.5994	29.3506
13	3649.00	4211	4211.7504	730.3002	27.1501
14	3650.00	4969	4969.2008	784.5999	20.1000
15	3651.00	5773	5773.9008	824.8002	64.6998
16	3652.00	6663	6663.3418	954.5346	22.6246
17	3654.00	8662	8662.8505	1044.7004	25.3498
18	3655.00	9732	9732.9006	1095.3986	19.6014
19	3656.00	10847	10847.9004	1134.5997	15.8003

Bonny Reservoir (ACAP92) COMPUTED
6/ 2/2010
2010 AREA-CAPACITY TABLES 14: 8:58

THE AREA TABLE IS IN ACRES THE ELEVATION INCREMENT IS IN ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3637	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3638	0.	10.	19.	29.	39.	48.	58.	68.	77.	87.
3639	97.	105.	112.	120.	128.	136.	144.	152.	160.	168.
3640	176.	182.	188.	194.	200.	206.	212.	218.	224.	230.
3641	236.	242.	248.	254.	260.	266.	272.	278.	284.	290.
3642	296.	302.	308.	314.	319.	325.	331.	337.	342.	348.
3643	354.	360.	365.	371.	377.	382.	388.	394.	399.	405.
3644	411.	416.	422.	428.	433.	439.	444.	450.	456.	461.
3645	467.	473.	480.	486.	493.	500.	506.	513.	519.	526.
3646	532.	540.	547.	555.	562.	569.	577.	584.	591.	599.
3647	606.	613.	619.	626.	632.	639.	645.	652.	659.	665.
3648	672.	677.	683.	689.	695.	701.	707.	713.	719.	724.
3649	730.	736.	741.	747.	752.	757.	763.	768.	774.	779.
3650	785.	789.	793.	797.	801.	805.	809.	813.	817.	821.
3651	825.	838.	851.	864.	877.	890.	902.	915.	928.	941.
3652	954.	959.	964.	968.	973.	977.	982.	986.	991.	995.
3653	1000.	1004.	1009.	1013.	1018.	1022.	1027.	1031.	1036.	1041.
3654	1045.	1050.	1055.	1060.	1065.	1070.	1075.	1080.	1085.	1090.
3655	1095.	1099.	1103.	1107.	1111.	1115.	1119.	1123.	1127.	1131.
3656	1135.	1138.	1141.	1144.	1147.	1150.	1154.	1157.	1160.	1163.
3657	1166.									

Bonny Reservoir (ACAP92) COMPUTED
6/ 2/2010
2010 AREA-CAPACITY TABLES 14: 8:58

THE CAPACITY TABLE IS IN ACRE FEET THE ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3637	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3638	0.	1.	2.	4.	8.	12.	18.	24.	31.	39.
3639	49.	59.	69.	81.	93.	107.	121.	135.	151.	167.
3640	185.	202.	221.	240.	260.	280.	301.	322.	344.	367.
3641	390.	414.	439.	464.	490.	516.	543.	570.	599.	627.
3642	657.	687.	717.	748.	780.	812.	845.	878.	912.	947.
3643	982.	1018.	1054.	1091.	1128.	1166.	1205.	1244.	1283.	1324.
3644	1364.	1406.	1448.	1490.	1533.	1577.	1621.	1666.	1711.	1757.
3645	1803.	1850.	1898.	1946.	1995.	2045.	2095.	2146.	2198.	2250.
3646	2303.	2356.	2411.	2466.	2522.	2578.	2635.	2693.	2752.	2812.
3647	2872.	2933.	2994.	3057.	3120.	3183.	3247.	3312.	3378.	3444.
3648	3511.	3578.	3646.	3715.	3784.	3854.	3924.	3995.	4067.	4139.
3649	4212.	4285.	4359.	4433.	4508.	4584.	4660.	4736.	4813.	4891.
3650	4969.	5048.	5127.	5206.	5286.	5367.	5447.	5528.	5610.	5692.
3651	5774.	5857.	5941.	6027.	6114.	6202.	6292.	6383.	6475.	6569.
3652	6663.	6759.	6855.	6952.	7049.	7146.	7244.	7343.	7441.	7541.
3653	7641.	7741.	7841.	7942.	8044.	8146.	8249.	8351.	8455.	8559.
3654	8663.	8768.	8873.	8979.	9085.	9192.	9299.	9407.	9515.	9624.
3655	9733.	9843.	9953.	10063.	10174.	10286.	10397.	10509.	10622.	10735.
3656	10848.	10962.	11075.	11190.	11304.	11419.	11534.	11650.	11766.	11882.
3657	11998.									