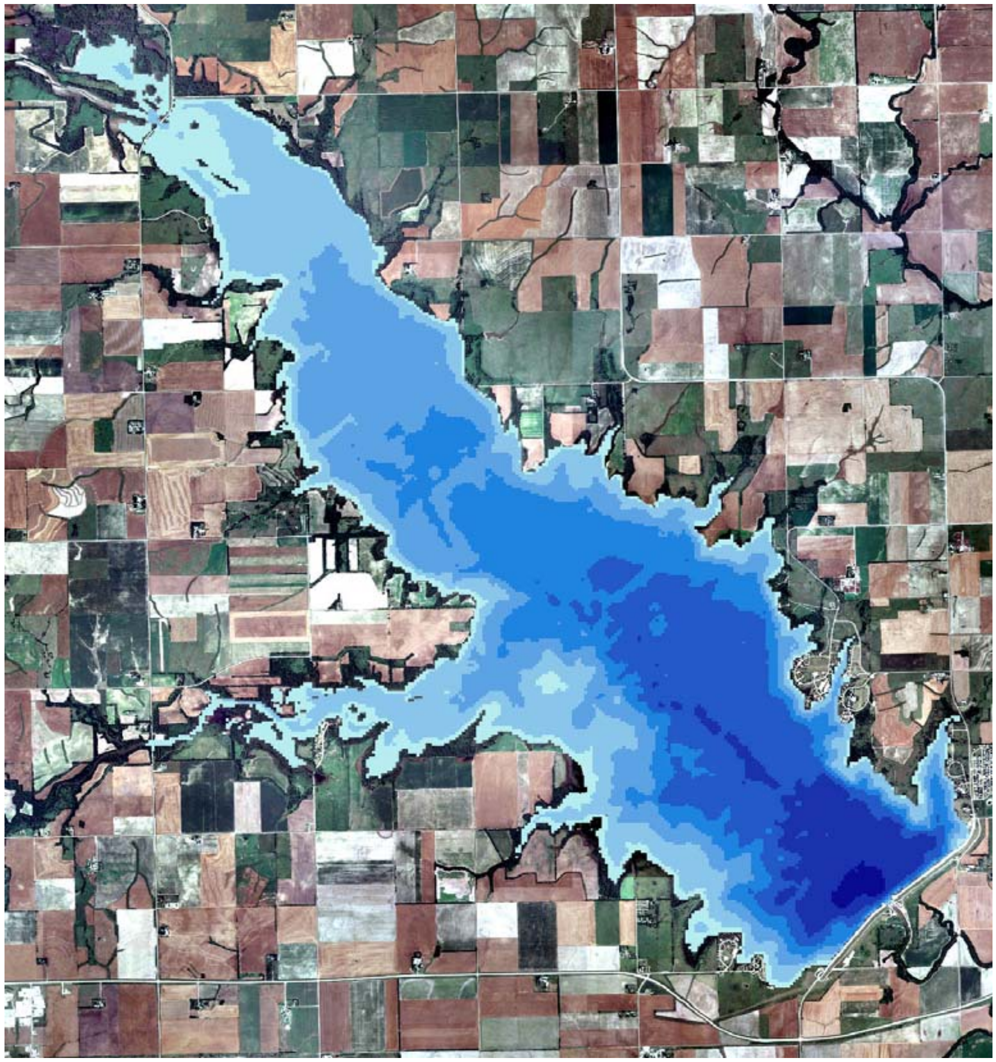
Bathymetric and Sediment Survey of Marion Reservoir, Marion County, Kansas



Kansas Biological Survey

Applied Science and Technology for Reservoir Assessment (ASTRA) Program

Report 2008-03 (May 2009)

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SUMMARY

In 2008, the Kansas Biological Survey (KBS) performed a bathymetric survey of Marion Reservoir in Marion County, Kansas. The survey was carried out using acoustic echosounding apparatus linked to a global positioning system. The bathymetric survey was georeferenced to both horizontal and vertical reference datums.

Six sediment cores were extracted from the lake to determine accumulated sediment thickness at locations distributed across the reservoir. Sediment samples were taken from the top six inches of each core and analyzed for particle size distributions. Additional sediment samples were taken in April 2009 and also analyzed for particle size distributions.

Summary Data:

Bathymetric Survey:		
	Dates of survey:	April 28, 2008 June 13, 2008
	Water elevation on date(s) of survey:	1352.40 ft. 1350.65 ft.
Reservoir Statistics:		
	Elevation of pool on reference date (NAIP photography, 2006)	1349.5 ft.
	Area on reference date:	6065 acres
	Volume on reference date:	74,581 acre-feet
	Maximum depth on reference date:	30.5 ft.
	Year constructed:	1964-1968
Sediment Survey:		
	Date of sediment survey:	May 28, 2008 April 8, 2009

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LAKE HISTORY AND PERTINENT INFORMATION

(This section summarized from Kansas Water Office Reservoir fact sheets, the National Dam Inventory database, and Corps of Engineers Tulsa District website descriptions)

http://www.kwo.org/ReservoirInformation/ReservoirFactSheets/Marion_Lake.pdf
http://www.swt.usace.army.mil/PROJECTS/civil/civil_projects.cfm?number=22
https://nid.usace.army.mil

Figure 1. Marion Reservoir, Kansas.

Location: On the Cottonwood River at river mile 126.7, 3 miles northwest of Marion in Marion County, Kansas, and 46 miles north-northeast of Wichita, Kansas.

Purpose: Flood control, water supply, water quality, and recreation.

Construction: Construction began in March 1964; embankment closure was completed in October 1967; and the project was placed in full flood control operation in February 1968. The rolled earthfill embankment is 8,375 feet long, excluding the concrete spillway and non-overflow sections; rises about 67 feet above the streambed; and has a 24-foot road across the embankment and spillway.

Spillway & Outlet Works: The spillway is a gate-controlled, concrete, gravity, ogee weir with a gross width of 136 feet. The spillway is located near the right abutment and connects to the embankment with two concrete non-overflow sections 142 feet long.

Marion County, Kansas

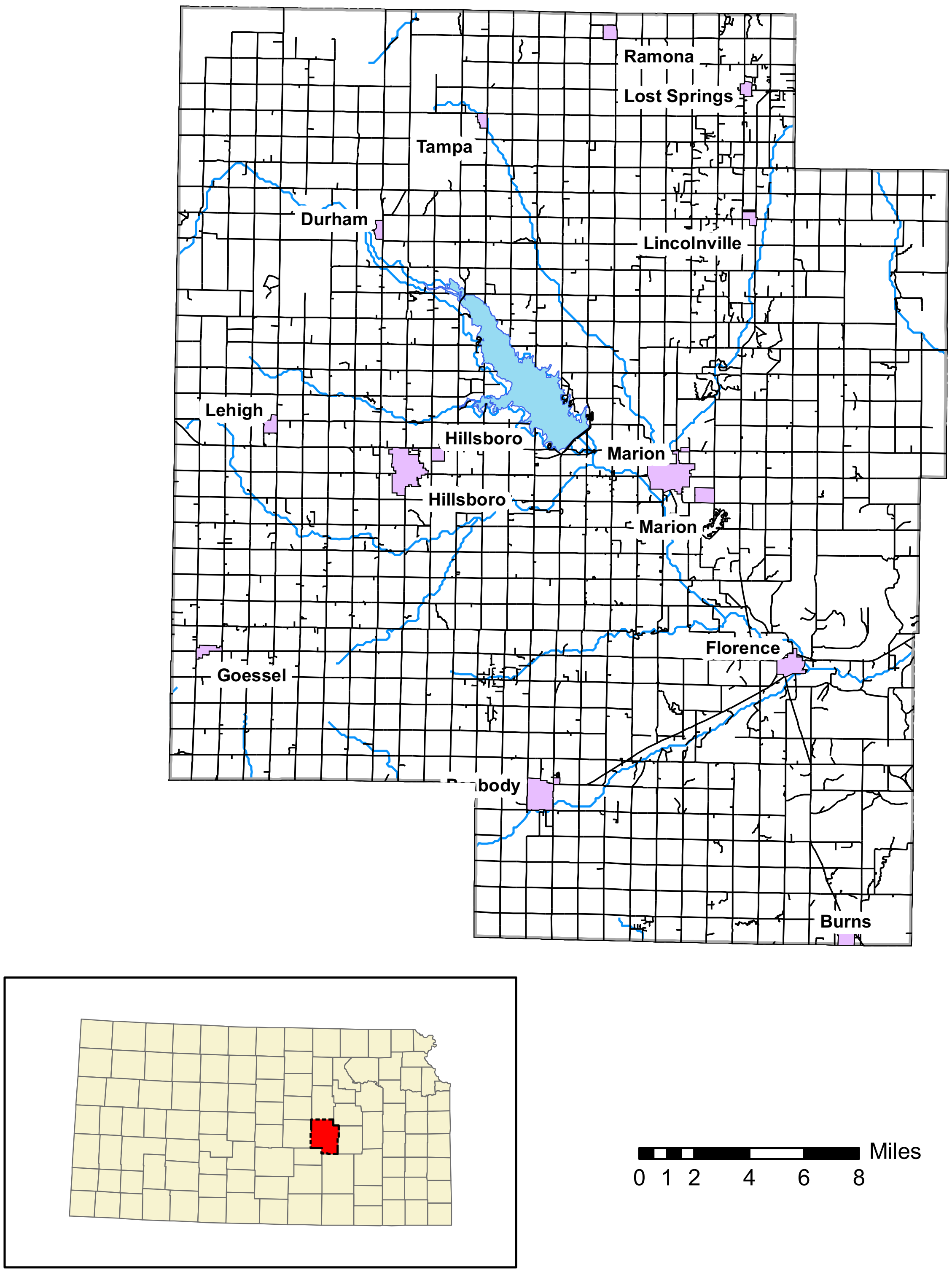

Figure 2. Location of Marion Reservoir in Marion County, Kansas

Reservoir Bathymetric (Depth) Surveying Procedures

KBS operates a Biosonics DT-X acoustic echosounding system (www.biosonicsinc.com) with a 200 kHz split-beam transducer and a 38-kHz single-beam transducer. In addition to providing basic information on reservoir depth profiles, the Biosonics system also permits the assessment of bottom sediment composition. Latitude-longitude information is provided by a JRC global positioning system (GPS) that interfaces with the Biosonics system. ESRI's ArcGIS is used for on-lake navigation and positioning, with GPS data feeds provided by the Biosonics unit through a serial cable. Power is provided to the echosounding unit, command/navigation computer, and auxiliary monitor by means of a inverter and battery backup device that in turn draw power from the 12-volt boat battery.

Pre-survey preparation:
Geospatial reference data: Prior to conducting the survey, geospatial data of the target lake is acquired, including georeferenced National Agricultural Imagery Project (NAIP) photography. The lake boundary is digitized as a polygon shapefile from the FSA NAIP georeferenced aerial photography obtained online from the Data Access and Service Center (DASC) at the Kansas Geological Survey. Prior to the lake survey, a series of transect lines are created as a shapefile in ArcGIS for guiding the boat during the survey. Transect lines are spaced more closely (25-50 meters separation) on smaller state/local lakes, while a spacing of 100-150 meters is used for federal reservoirs.

Survey procedures:
Calibration (Temperature and ball check): After boat launch and initialization of the Biosonics system and command computer, system parameters are set in the Biosonics Visual Acquisition software. The temperature of the lake at 1-2 meters is taken with a research-grade metric electronic thermometer. This temperature, in degrees Celsius, is input to the Biosonics Visual Acquisition software to calculate the speed of sound in water at the given temperature at the given depth. Start range, end range, ping duration, and ping interval are also set at this time. A ball check is performed using a tungsten-carbide sphere supplied by Biosonics for this purpose. The ball is lowered to a known distance (1.0 meter) below the transducer faces. The position of the ball in the water column (distance from the transducer face to the ball) is clearly visible on the echogram. The echogram distance is compared to the known distance to assure that parameters are properly set and the system is operating correctly.
On-lake survey procedures: Using the GPS Extension of ArcGIS, the GPS data feed from the GPS receiver via the Biosonics echosounder, and the pre-planned transect pattern, the location of the boat on the lake in real-time is shown on the command/navigation computer screen. To assist the boat operator in navigation, an auxiliary LCD monitor is connected to the computer and placed within the easy view of the boat operator. Transducer face depth on all dates is 0.5 meters below the water surface. The transect pattern is maintained except when modified by obstructions in the lake (e.g., partially submerged trees) or shallow water and mudflats. Data are automatically logged in new files every half-hour (approximately 9000-ping files) by the Biosonics system.

Establishment Of Lake Level On Survey Dates:

Federal Reservoirs:

Lake levels on the survey dates are obtained from the US Army Corps of Engineers web sites for those lakes:

Reservoir Names	Corps of Engineers District	Website for Lake Level
Clinton Lake, Hillsdale Lake, Kanopolis Lake, Melvern Lake, Milford Lake, Perry Lake, Pomona Lake, Tuttle Creek Lake, Wilson Lake	Kansas City	http://www.nwk.usace.army.mil/WaterManagement/EightDayReservoirReport.cfm
Big Hill Lake, Council Grove Reservoir, El Dorado Lake, Elk City Lake, Fall River Lake, John Redmond Reservoir, Marion Reservoir, Toronto Lake	Tulsa	http://www.swt-wc.usace.army.mil/old_resvrept.htm

Marion Reservoir Water Surface Elevations:

Survey Date	Elevation (feet)	Elevation (meters)
April 28, 2008	1352.40	412.21
June 13, 2008	1350.65	411.67

NAIP Photography date	Elevation (feet)	Elevation (meters)
June 19, 2006	1349.53	411.34

Reservoir shoreline perimeters were digitized off the 2006 NAIP aerial photography, and the elevation of the reservoir on the date of aerial photography was used as the water surface elevation in all productions of TINs or interpolations from point data to raster data.

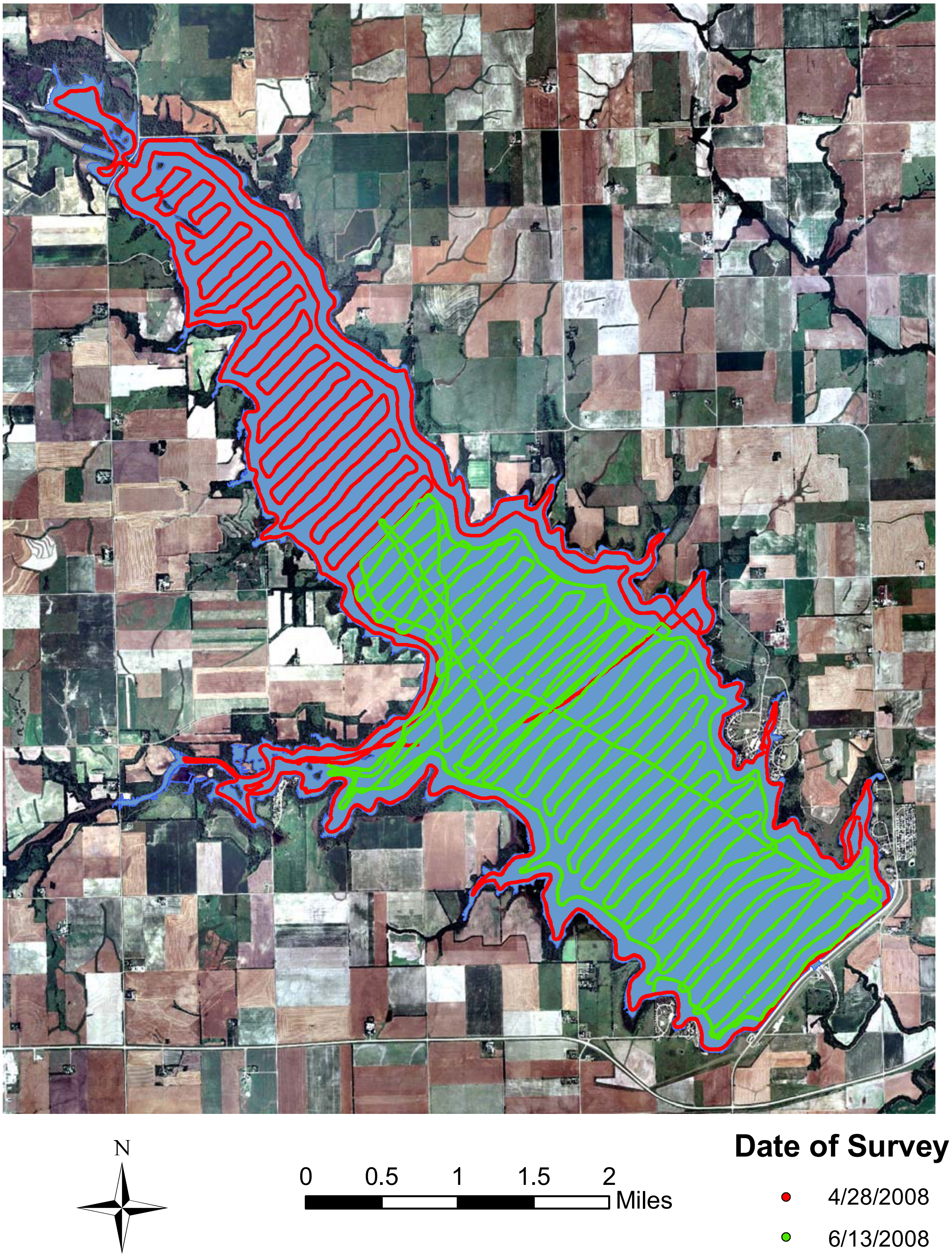

Figure 3. Bathymetric survey transects in Marion Reservoir

Post-processing *(Visual Bottom Typer)*

The Biosonics DT-X system produces data files in a proprietary DT4 file format containing acoustic and GPS data. To extract the bottom position from the acoustic data, each DT4 file is processed through the Biosonics Visual Bottom Typer (VBT) software. The processing algorithm is described as follows:

> *"The BioSonics, Inc. bottom tracker is an "end_up" algorithm, in that it begins searching for the bottom echo portion of a ping from the last sample toward the first sample. The bottom tracker tracks the bottom echo by isolating the region(s) where the data exceeds a peak threshold for N consecutive samples, then drops below a surface threshold for M samples. Once a bottom echo has been identified , a bottom sampling window is used to find the next echo. The bottom echo is first isolated by user_defined threshold values that indicate (1) the lowest energy to include in the bottom echo (bottom detection threshold) and (2) the lowest energy to start looking for a bottom peak (peak threshold). The bottom detection threshold allows the user to filter out noise caused by a low data acquisition threshold. The peak threshold prevents the algorithm from identifying the small energy echoes (due to fish, sediment or plant life) as a bottom echo."* (Biosonics Visual Bottom Typer User's Manual, Version 1.10, p. 70).

Data is output as a comma-delimited (*.csv) text file. A set number of qualifying pings are averaged to produce a single report (for example, the output for ping 31 {when pings per report is 20} is the average of all values for pings 12-31). Standard analysis procedure for all 2008 and later data is to use the average of 7 pings to produce one output value.

All raw *.csv files are merged into one master *.csv file using the shareware program File Append and Split Tool (FAST) by Boxer Software (Ver. 1.0, 2006).

Post-processing **(*Excel*)**

The master *.csv file created by the FAST utility is imported into Microsoft Excel. Excess header lines are deleted (each input CSV file has its own header), and the header file is edited to change the column headers "#Ping" to "Ping" and "E1' " to "E11", characters that are not ingestable by ArcGIS. Entries with depth values of zero (0) are deleted, as are any entries with depth values less than the start range of the data acquisition parameter (typically 0.49 meters or less) (indicating areas where the water was too shallow to record a depth reading).

In Excel, depth adjustments are made. A new field – Adj_Depth – is created. The value for AdjDepth is calculated as AdjDepth = Depth + (Transducer Face Depth), where the Transducer Face Depth represents the depth of the transducer face below water level in meters (Typically, this value is 0.5 meters). Four values are computed in Excel: DepthM, DepthFt, ElevM and ElevFt, where:

DepthM = Adj_Depth
DepthFt = Adj_Depth * 3.28084

These water depths are RELATIVE water depths that can vary from day-to-day based on the elevation of the water surface. In order to normalize all depth measurements to an absolute reference, water depths must be subtracted from an established value for the elevation of the water surface at the time of the bathymetric survey. Determination of water surface elevation has been described in an earlier section on establishment of lake levels.

To set depths relative to lake elevation, another field is added to the attribute table of the point shapefile, ElevM. The value for this attribute is then computed as Depth_ElevM = (Elevation of the Water Surface in meters above sea level) - Adj_Depth. Elevation of the water surface in feet above sea level is also computed by converting ElevM to elevation in feet (ElevM * 3.28084).

Particularly for multi-day surveys, ADJ_DEPTH, Depth_M, and Depth_Ft should **NOT** be used for further analysis or interpolation. If water depth is desired, it should be produced by subtracting Elev_M or Elev_Ft from the reference elevation used for interpolation purposes (for federal reservoirs, the elevation of the water surface on the day that the aerial photography from which the lake perimeter polygon was digitized).

Post-processing *(ArcGIS):*

Ingest to ArcGIS is accomplished by using the Tools – Add XY Data option. The projection information is specified at this time (WGS84). Point files are displayed as Event files, and are then exported as a shapefile (filename convention: ALLPOINTS_WGS84.shp). The pointfile is then reprojected to the UTM coordinate system of the appropriate zone (14 or 15) (filename convention ALLPOINTS_UTM.shp).

Raster interpolation of the point data is performed using the same input data and the Topo to Raster option within the 3D Extension of ArcGIS. The elevation of the reservoir on the date of aerial photography used to create the perimeter/shoreline shapefile was used as the water surface elevation in all interpolations from point data to raster data.

Contour line files are derived from the raster interpolation files using the ArcGIS command under 3D Analyst – Raster Surface – Contour.

Area-elevation-volume tables are derived using an ArcGIS extension custom written for and available from the ASTRA Program. Summarized, the extension calculates the area and volume of the reservoir at 1/10-foot elevation increments from the raster data for a series of water surfaces beginning at the lowest elevation recorded and progressing upward in 1/10-foot elevation increments to the reference water surface. Cumulative volume is also computed in acre-feet.

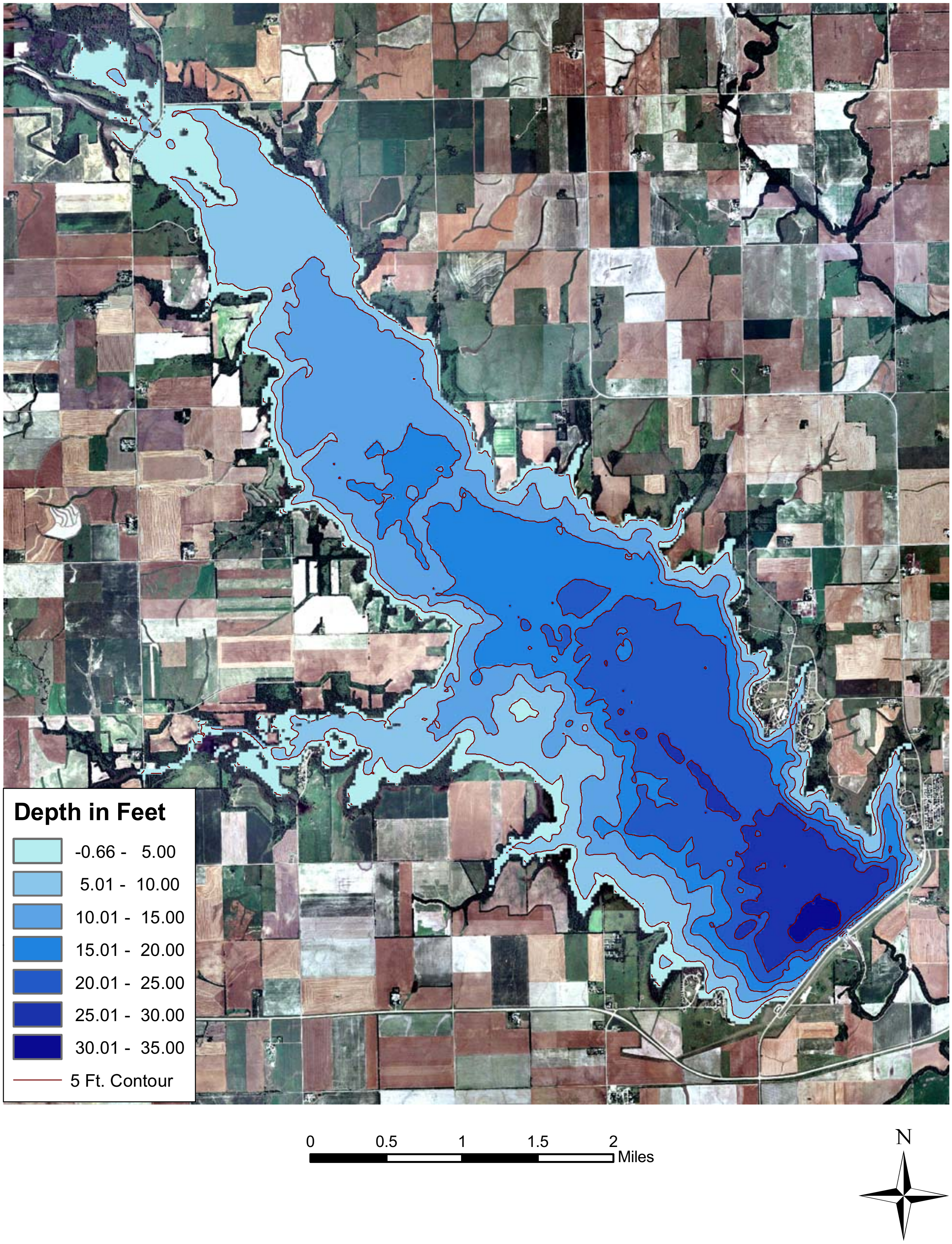

Figure 4. Water depth based on April/June 2008 bathymetric survey. Depths are based on a pool elevation of 1349.53 feet.

Table 1

Cumulative area in acres by tenth foot elevation increments

Elevation (ft NGVD)	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
1319	1	2	4	6	7	9	11	13	16	19
1320	22	25	27	30	32	34	37	39	42	44
1321	47	49	52	55	57	60	63	67	70	74
1322	78	82	86	90	94	99	104	108	113	118
1323	124	130	136	142	148	154	161	169	178	187
1324	196	205	213	221	229	237	246	257	272	297
1325	321	348	376	399	417	433	447	461	472	483
1326	494	507	520	536	553	573	594	619	644	669
1327	694	718	739	762	784	805	826	850	871	891
1328	913	935	957	978	998	1019	1039	1060	1080	1098
1329	1116	1134	1151	1168	1185	1205	1224	1244	1267	1290
1330	1318	1345	1370	1397	1422	1446	1470	1490	1510	1529
1331	1547	1563	1579	1596	1613	1632	1650	1666	1683	1699
1332	1715	1731	1747	1763	1779	1796	1812	1829	1846	1864
1333	1882	1900	1919	1938	1957	1975	1995	2016	2038	2062
1334	2084	2105	2127	2149	2169	2189	2208	2227	2248	2267
1335	2287	2307	2328	2347	2367	2388	2410	2432	2457	2484
1336	2510	2534	2558	2584	2608	2631	2654	2679	2706	2731
1337	2758	2788	2816	2844	2871	2900	2927	2953	2981	3009
1338	3038	3068	3096	3126	3156	3185	3213	3241	3268	3294
1339	3322	3352	3383	3414	3444	3475	3507	3538	3568	3599
1340	3631	3660	3688	3716	3742	3767	3792	3816	3842	3870
1341	3896	3922	3948	3974	3999	4024	4050	4077	4104	4129
1342	4154	4178	4202	4227	4250	4274	4299	4323	4348	4372
1343	4396	4421	4447	4471	4495	4519	4545	4570	4593	4617
1344	4640	4665	4690	4716	4741	4767	4792	4819	4844	4870
1345	4896	4923	4951	4976	5002	5030	5058	5085	5114	5142
1346	5171	5200	5229	5261	5292	5321	5351	5381	5412	5441
1347	5472	5503	5536	5569	5603	5636	5668	5700	5730	5761
1348	5791	5820	5850	5877	5901	5922	5940	5957	5973	5989
1349	6004	6019	6031	6043	6054	6065				

Table 2

Cumulative volume in acre-feet by tenth foot elevation increments

Elevation (ft NGVD)	**0.00**	**0.10**	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**
1319	0	0	0	1	2	2	3	5	6	8
1320	10	12	15	18	21	24	27	31	35	40
1321	44	49	54	59	65	71	77	83	90	97
1322	105	113	121	130	139	148	158	169	180	191
1323	203	215	229	242	257	272	287	303	320	338
1324	357	377	398	420	442	465	489	514	541	569
1325	600	633	669	708	749	791	835	881	927	975
1326	1024	1074	1126	1179	1233	1289	1348	1409	1472	1537
1327	1605	1676	1748	1823	1900	1979	2060	2144	2230	2318
1328	2409	2501	2595	2692	2790	2890	2994	3098	3205	3314
1329	3424	3537	3652	3767	3885	4004	4126	4249	4375	4503
1330	4633	4766	4902	5040	5181	5325	5471	5619	5770	5922
1331	6075	6231	6387	6546	6707	6869	7033	7199	7367	7536
1332	7706	7879	8052	8228	8405	8584	8765	8947	9131	9316
1333	9504	9693	9885	10078	10272	10469	10668	10868	11071	11276
1334	11483	11693	11904	12118	12334	12552	12772	12994	13218	13444
1335	13672	13901	14133	14367	14602	14840	15080	15322	15566	15814
1336	16063	16316	16570	16827	17087	17349	17614	17880	18150	18422
1337	18696	18974	19255	19538	19825	20113	20405	20700	20996	21295
1338	21597	21903	22211	22522	22836	23153	23474	23797	24122	24450
1339	24781	25114	25451	25791	26133	26479	26829	27181	27536	27895
1340	28257	28621	28989	29359	29732	30107	30485	30866	31249	31635
1341	32024	32416	32810	33206	33605	34006	34410	34816	35226	35638
1342	36053	36469	36889	37310	37734	38160	38589	39020	39454	39890
1343	40329	40770	41214	41660	42108	42559	43013	43469	43928	44389
1344	44852	45318	45786	46257	46730	47206	47684	48165	48648	49135
1345	49624	50115	50609	51107	51606	52108	52613	53121	53631	54144
1346	54660	55179	55701	56227	56754	57286	57820	58358	58898	59442
1347	59988	60538	61091	61647	62206	62769	63336	63905	64478	65053
1348	65632	66213	66797	67384	67973	68565	69158	69753	70350	70950
1349	71551	72154	72758	73364	73973	74581				

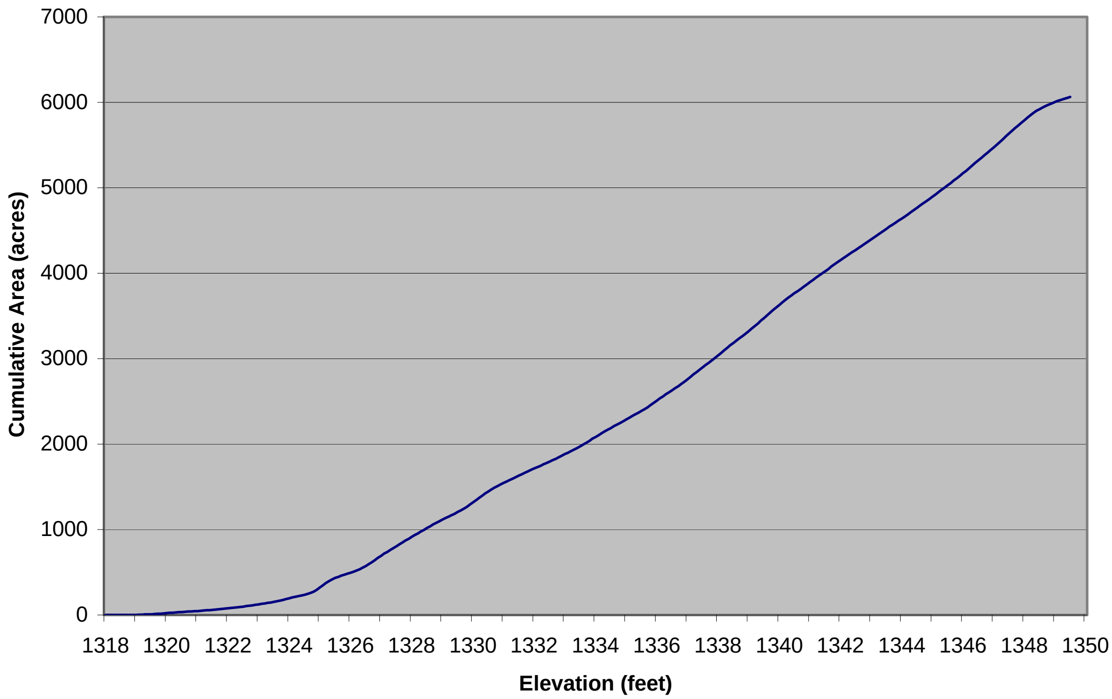

Figure 5. Cumulative area-elevation curve

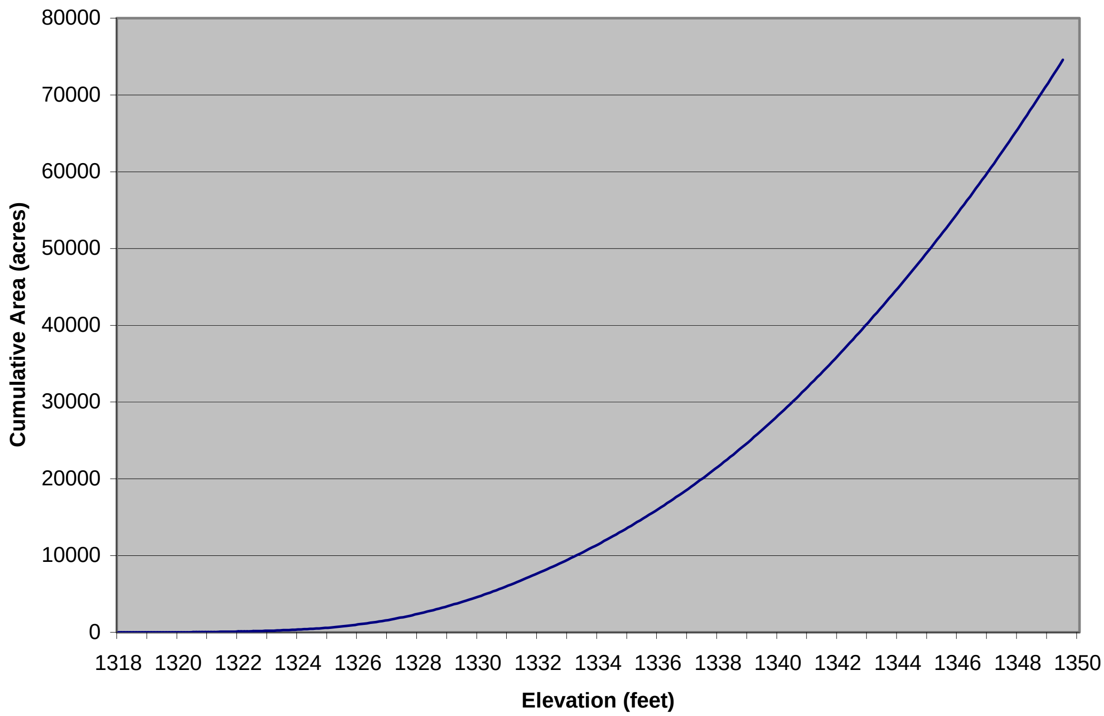

Figure 6. Cumulative volume-elevation curve

PRE-IMPOUNDMENT MAP

Pre-impoundment topographic map sheets dated September 1963 with a contour interval of four feet (4') were obtained in digital form from the US Army Corps of Engineers (USACE) via the Kansas Water Office. The original map sheets were prepared by the Survey Branch of the Fort Worth District of the US Army Corps of Engineers.

Upon examination of the scanned files, a critical map sheet (Panel VIII) encompassing the upper third of the reservoir was missing. Attempts to locate the missing map sheet were unsuccessful. Archival US Geological Survey contour maps were prepared subsequent to the impoundment of the reservoir and thus did not contain pre-impoundment contours for the reservoir conservation pool area. As such, no pre-impoundment digital elevation model was generated for Marion Reservoir.

SEDIMENT CORING/SAMPLING PROCEDURES

KBS operates a Specialty Devices Inc. sediment vibracorer mounted on a dedicated 24' pontoon boat. The vibracorer uses 3" diameter aluminum thinwall pipe in user-specified lengths (KBS has used up to 10' sections). The vibracorer runs off 24-volt batteries, and uses an electric motor with counter-rotating weights in the vibracorer head unit to create a high-frequency vibration in the pipe, allowing the pipe to penetrate even solidly packed sediments and substrate as it is lowered into the lake using a manually operated winch system. Once the open end of the core pipe has penetrated to the substrate, the unit is turned off and the unit is raised to the surface using the winch. At the surface, the pipe containing the sediment core is disconnected from the vibracore head for further onboard processing. The sediment core can be cut into sections while in the pipe, the pipe bisected longitudinally for taking samples along the length of the core, or it can be extruded from the tube and measured.

KBS vibe-core system.

At each site, determined using GPS, the core boat is anchored and the vibracore system used to extract a sediment core down to and including the upper several inches of pre-impoundment soil (substrate). The location of each core site is recorded using a GPS linked to a laptop running ArcGIS and the ArcGIS GPS extension. Cores are carefully extruded from the core pipe, and the interface between sediment and substrate identified. Typically, this identification is relatively easy, with the interface being identifiable by changes in material density and color, and the presence of roots or sticks in the substrate. For most analyses, the top six inches of sediment are collected and sealed in a sampling container.

Sediment re-sampling:

Several samples were damaged in shipping for analysis. On April 8, 2009, the sites were re-sampled. A GPS linked to ArcGIS and the map of original coring sites was used to locate the boat within ±5 meters of the original site. At each location, a Ponar dredge was used to take a sediment sample from the top 3-5 inches of sediment. The sample was manually mixed to ensure uniformity and a sample amount of 32 volumetric ounces (~940 cubic centimeters) was taken. The samples were then sealed and shipped to MidWest Laboratories for texture analysis.

Sediment Coring and Sampling Results:

Sediment coring sites were distributed across the length of the reservoir (Figure 7). At the request of the local Corps of Engineers lake manager, two additional samples (not cores) were taken in French Creek Cove on the western side of the reservoir (sites MRFCW and MRFCE).

Sediment thickness ranged from a low of 38 centimeters at site MR#4 (located in the center of the reservoir)(Figure 8, Table 3) to a high of 89 centimeters at site MR#5 in the lower main basin. Although sediment thicknesses were generally slightly less in the upper end of the reservoir (sites MR#1, 54 cm; MR#2, 57 cm; and MR#3, 62 cm) versus the sites in the lower end (MR#5, 89 cm; and MR#6, 76 cm), overall sediment thicknesses did not exhibit strong trends throughout the reservoir (Figure 8).

Sites in the lower parts of the reservoir (MR#4, MR#5, and MR#6) are similar in that they exhibit a high percentage of sand in the particle size analysis (Figure 9, Figure 10), a pattern similar to that observed for Council Grove Reservoir. Particle size distributions for two adjacent sites in the upper end (MR#1 and MR#2), however, are very different from each other, with MR#1 dominated by sand (50%) and a minor fraction of clay (18%), and MR#2 exhibiting the converse (sand fraction 10%, clay fraction 60%)(Figure 9, Figure 10).

The high variability in spatial trends in particle size distributions within the reservoir underscores the inadequacy of six cores/eight sediment samples to fully characterize and understand sediment movement and distribution within a large reservoir.

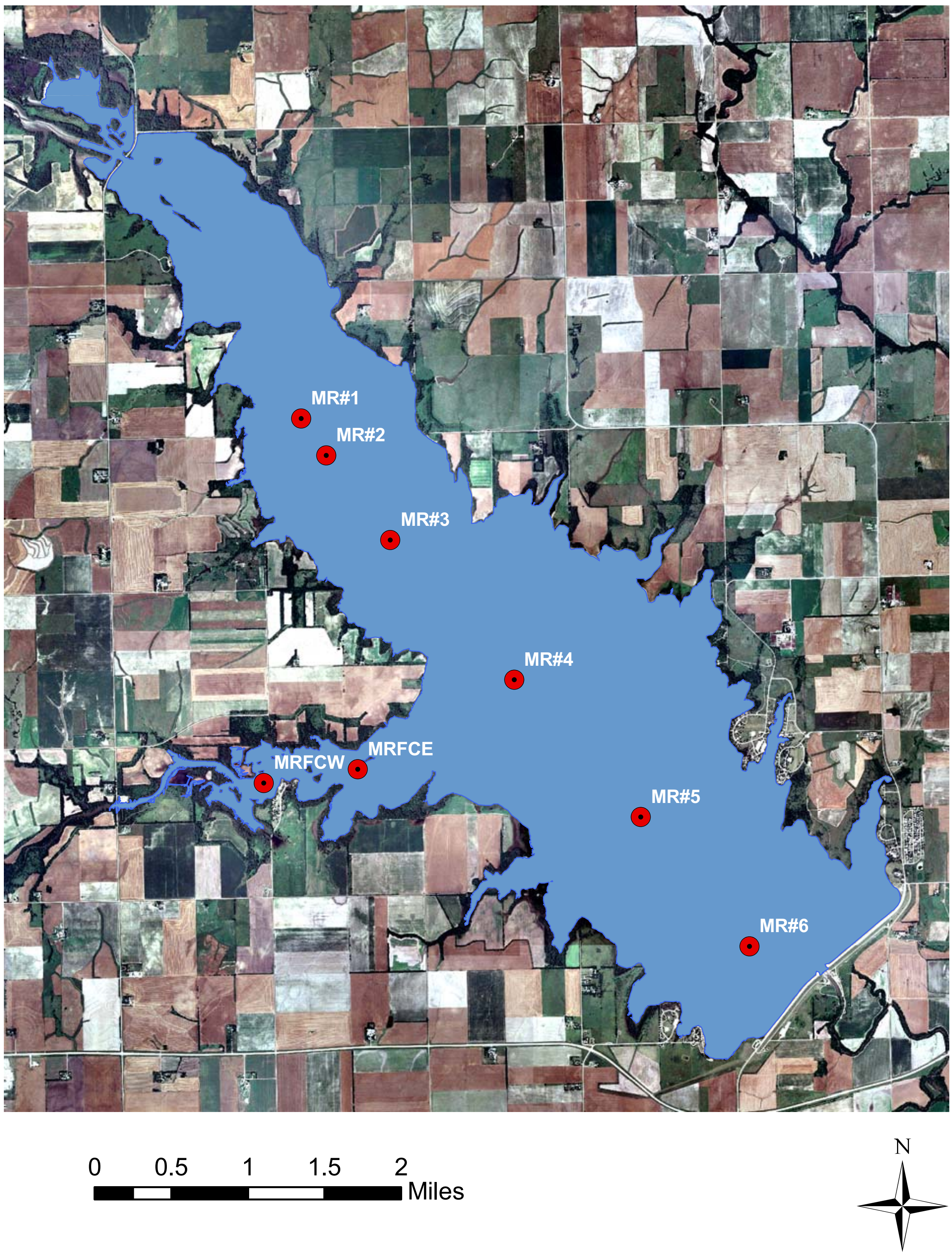

Figure 7. Sediment coring sites in Marion Reservoir

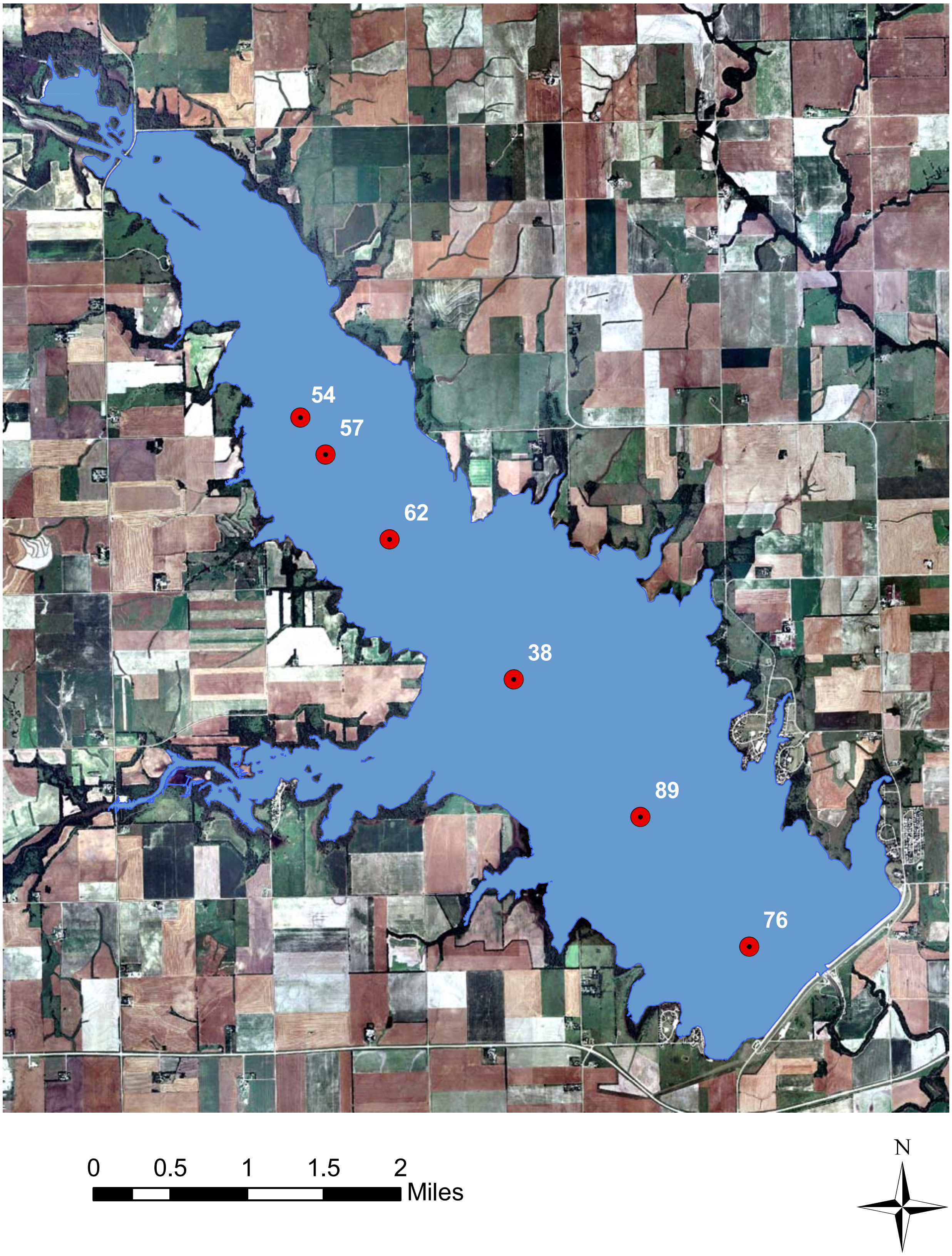

Figure 8. Sediment thickness in centimeters at coring sites in Marion Reservoir

Table 3
Marion Reservoir Sediment Coring /Sampling Site Data

CODE	UTMX	UTMY	Sediment Thickness (cm)	Sand %	Silt %	Clay %
MR-1	661831.2	4254307.1	54	50	32	18
MR-2	662094.6	4253918.4	57	10	30	60
MR-3	662768.1	4253030.8	62	20	28	52
MR-4	664066.2	4251567.1	38	42	40	18
MR-5	665396.6	4250124.7	88.5	33	24	43
MR-6	666532.6	4248767.8	76	38	14	48
MRFCE	662427.4	4250626.4	*n/s* [1]	36	40	24
MRFCW	661440.7	4250482.9	*n/s* [1]	60	22	18

n/s [1] = *Sediment sample only, no core taken for thickness.*

Coordinates are Universal Transverse Mercator (UTM), NAD83, Zone 14 North

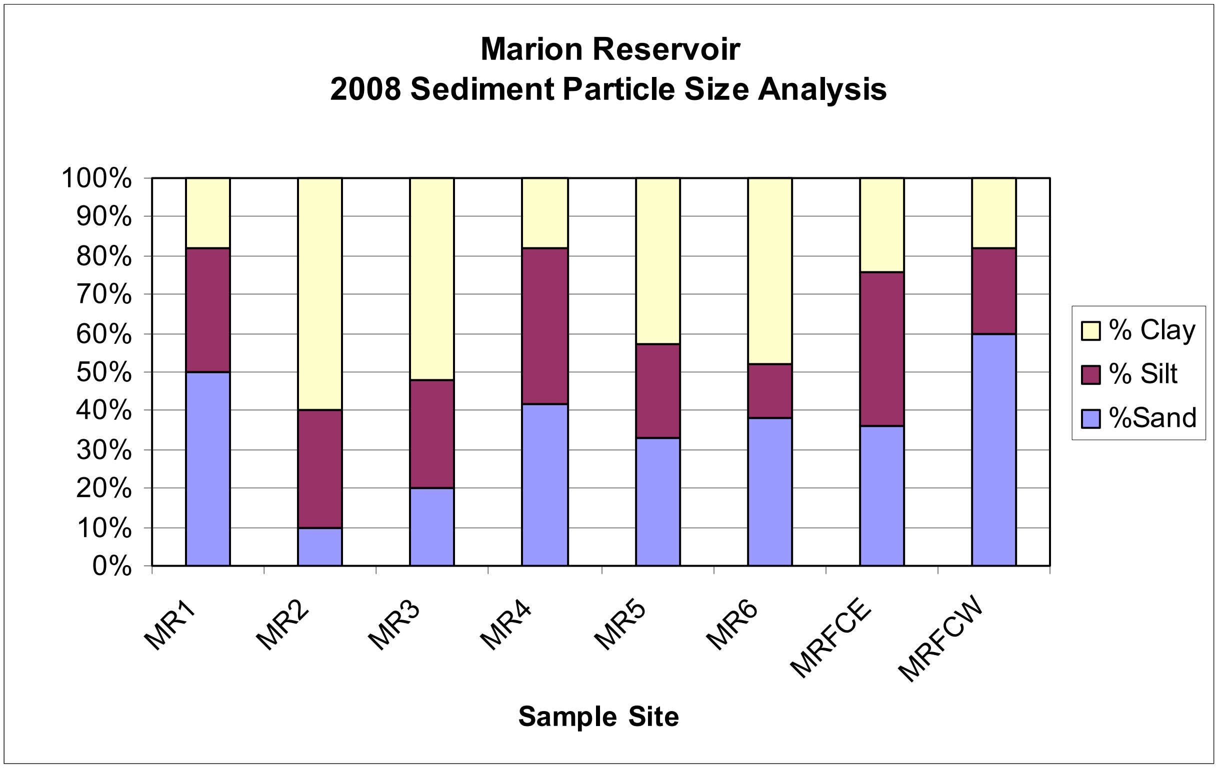

Figure 9. Sediment particle size analysis.

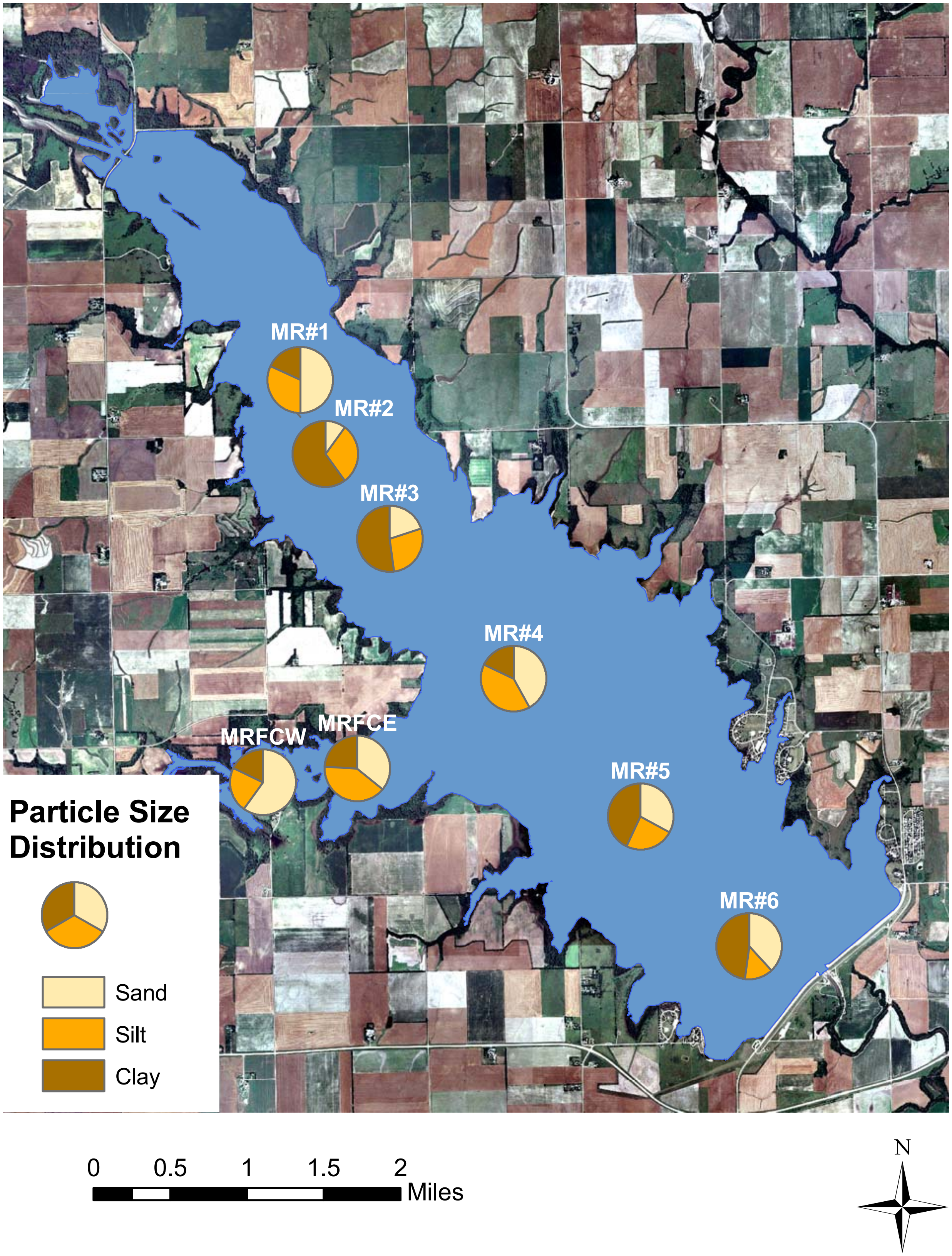

Figure 10. Particle size distribution of sediment samples taken from Marion Reservoir.