Bathymetric and Sediment Survey of Madison City Lake, Greenwood County, Kansas

Kansas Biological Survey

Applied Science and Technology for Reservoir Assessment (ASTRA) Program

Report 2009-07 (February 2010)

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SUMMARY

On November 9, 2009, the Kansas Biological Survey (KBS) performed a bathymetric survey of Madison City Lake in Greenwood 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.

Sediment samples were collected from three sites within the reservoir: One sample was taken near the dam; a second at mid-lake; and a third in the upper end. Sampling was performed on the same day as the bathymetric survey, following completion of the survey. Sediment samples were analyzed for particle size distributions.

<u>Summary Data:</u>

Bathymetric Survey:		
	Date of survey:	November 9, 2009
Reservoir Statistics:		
	Elevation on survey date	1157.59 ft
	Area on survey date:	100 acres
	Volume on survey date:	1412 acre-feet
	Maximum depth:	34.1 ft.
Elevation Benchmark (if applicable)		
	UTM location of elevation benchmark:	749951.6, 4221016.4
	UTM Zone:	14N
	UTM datum:	NAD83
	Elevation of benchmark, from GPS:	1158.73 ft.
	Vertical datum, all data:	NAVD88
Sediment Survey:		
	Date of sediment survey:	November 9, 2009

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LAKE HISTORY AND PERTINENT INFORMATION

Figure 1. Madison City Lake, Greenwood County, Kansas.

Madison City Lake is located approximately one mile south of the city of Madison, Kansas, in Greenwood County. Constructed in 1970 on a tributary of Holderman Creek, the lake provides drinking water to the City of Madison. The city's surface water treatment plant at the lake can produce about one half million gallons of water per day. In addition to its own residents, Madison provides wholesale water to Greenwood County RWD No. 3 and to the City of Hamilton.

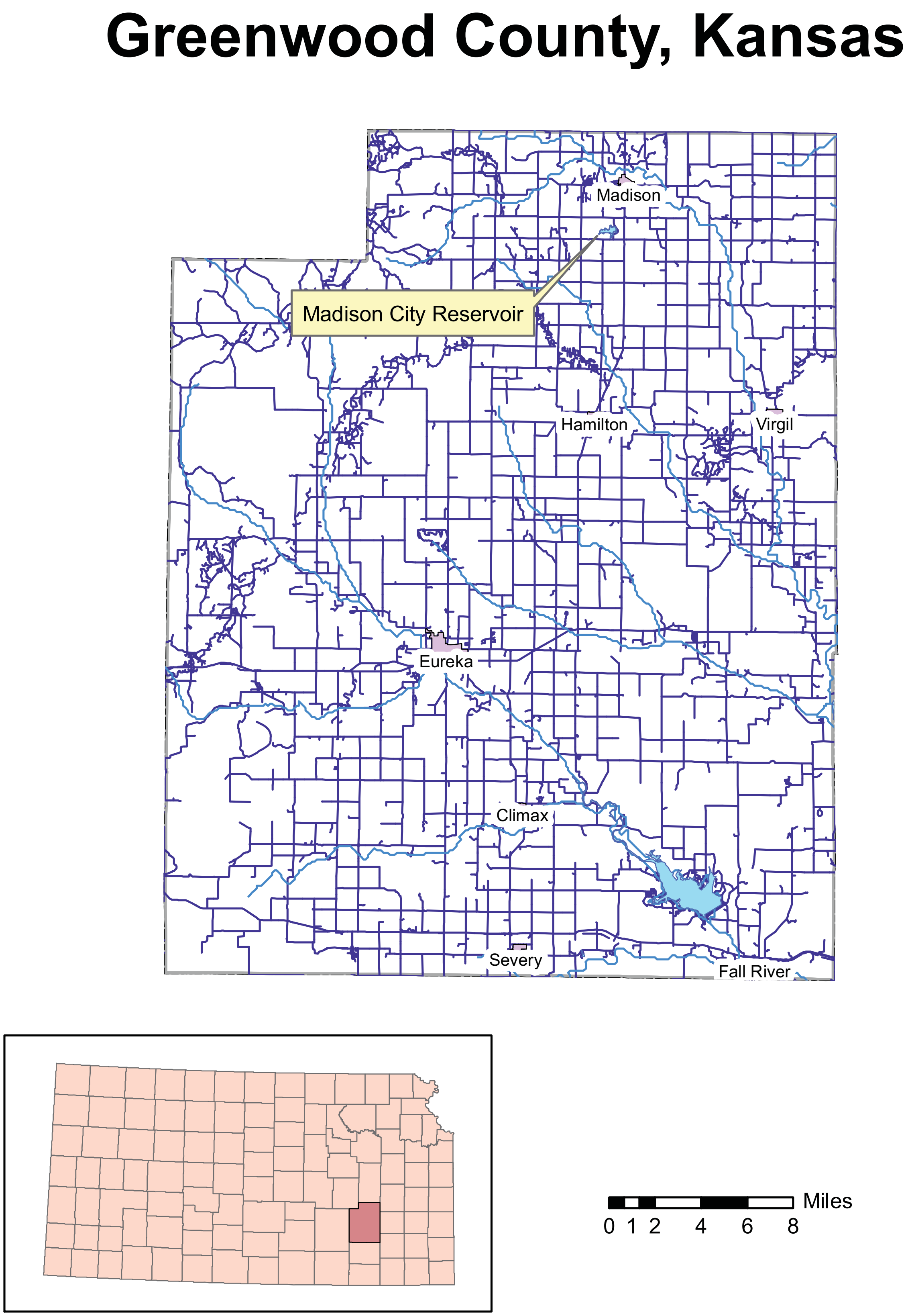

Figure 2. Location of Madison City Reservoir in Greenwood County, Kansas

Reservoir Bathymetric (Depth) Surveying Procedures

KBS operates a Biosonics DT-X echosounding system (www.biosonicsinc.com) with a 200 kHz split-beam transducer and a 38-kHz single-beam transducer. Latitude-longitude information is provided by a 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). Prior to the lake survey, a series of transect lines are created as a shapefile in ArcGIS for guiding the boat during the survey.

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. 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:

State and Local Reservoirs:

Most state and local lakes in Kansas do not have water surface elevation gauges. Therefore, a local benchmark at the edge of a lake is established, typically a concrete pad or wall adjacent to the water. The location of the benchmark is photographed and a description noted. On the day of the survey, the vertical distance between the water surface and the surface of the benchmark is measured. In cases where the benchmark must be established a distance away from the lake, a survey-grade laser level is used to establish the vertical distance between benchmark and water surface.

A TopCon HiPerLite+ survey-grade static global positioning system is used to establish the height of the benchmark. The unit is set at a fixed distance above the benchmark, and the vertical distance between the benchmark and the Antenna Reference Point recorded. The unit is allowed to record data points for a minimum of two hours at a rate of one point every 10 seconds.

Following GPS data acquisition, the data are downloaded at the office from the GPS unit, converted from TopCon proprietary format to RINEX format, and uploaded to the National Geodetic Survey (NGS) On-line Positioning User Service (OPUS). Raw data are processed by OPUS with respect to three NGS CORS (Continuously Operating Reference Stations) locations and results returned to the user.

The elevation of the benchmark is provided in meters as the orthometric height (NAVD88, computed using GEOID03). The vertical difference between the lake surface on the survey day is subtracted from the OPUS-computer orthometric height to produce the lake elevation value, in meters. This lake elevation value is entered as an attribute of the lake perimeter polygon shapefile in postprocessing.

The ASTRA elevation benchmark for Madison City Lake is the northeast corner of a concrete pad for the floating dock immediately adjacent to the boat ramp on the south side of the lake (Figure 3a, Figure 3b).

The water surface elevation of Madison City Lake on November 9, 2009 was 1157.59 feet AMSL.

Location of Lake Elevation Benchmark:

Madison City Lake:

UTM (Zone 14) Easting (X) [meters] 749951.65, Northing (Y) [meters] 4221016.40

Figure 3a. View of concrete pad benchmark site.

Figure 3b. Close-up view of lake elevation benchmark site.

Madison City Lake GPS-OPUS Output

```
 FILE: log0237s.09O 000110752

 1008   NOTE:  Antenna offsets supplied by the user were zero.  Coordinates
 1008   returned will be for the antenna reference point (ARP).
 1008

                              NGS OPUS SOLUTION REPORT
                              ========================


All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: www.ngs.noaa.gov/OPUS/Using_OPUS.html#accuracy

      USER: mjakub@ku.edu                          DATE: September 14, 2009
RINEX FILE: log0237s.09o                           TIME: 14:48:33 UTC

  SOFTWARE: page5  0909.08 master28.pl 081023      START: 2009/08/25  18:29:00
 EPHEMERIS: igs15462.eph [precise]                  STOP: 2009/08/25  21:01:00
  NAV FILE: brdc2370.09n                        OBS USED:  2115 /  5918   :  36%
  ANT NAME: TPSHIPER_PLUS   NONE             # FIXED AMB:    46 /    66   :  70%
ARP HEIGHT: 0.0                              OVERALL RMS: 0.028(m)


 REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00 (EPOCH:2009.6488)

         X:      -538357.036(m)   0.317(m)          -538357.765(m)   0.317(m)
         Y:     -4996758.843(m)   0.431(m)         -4996757.473(m)   0.431(m)
         Z:      3914594.361(m)   1.053(m)          3914594.229(m)   1.053(m)

       LAT:   38  6  8.67795      0.587(m)        38  6  8.70028      0.587(m)
     E LON:  263 51  2.16865      0.361(m)       263 51  2.13288      0.361(m)
     W LON:   96  8 57.83135      0.361(m)        96  8 57.86712      0.361(m)
    EL HGT:          322.639(m)   0.960(m)                321.547(m)   0.960(m)
 ORTHO HGT:          353.182(m)   0.963(m)  [NAVD88 (Computed using GEOID03)]


                        UTM COORDINATES    STATE PLANE COORDINATES
                         UTM (Zone 14)         SPC (1502 KS S)
Northing (Y) [meters]    4221016.409           561945.279
Easting (X)  [meters]     749951.652           606137.768
Convergence  [degrees]    1.75992871           1.44451126
Point Scale               1.00036952           0.99994110
Combined Factor           1.00031888           0.99989048

US NATIONAL GRID DESIGNATOR: 14SQH4995221016(NAD 83)


                              BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE DISTANCE(m)
AF9527 HBRK HILLSBORO CORS ARP             N381816.715 W0971736.655  102700.0
DK6491 ICT3 WICHITA ICT3 CORS ARP          N374509.312 W0971258.381  101516.9
DJ3673 KST6 TOPEKA 6 CORS ARP              N390239.667 W0960220.831  105007.4


                 NEAREST NGS PUBLISHED CONTROL POINT
JF0185      23+200                         N380544.    W0960633.       3606.0

This position and the above vector components were computed without any
knowledge by the National Geodetic Survey regarding the equipment or
field operating procedures used.
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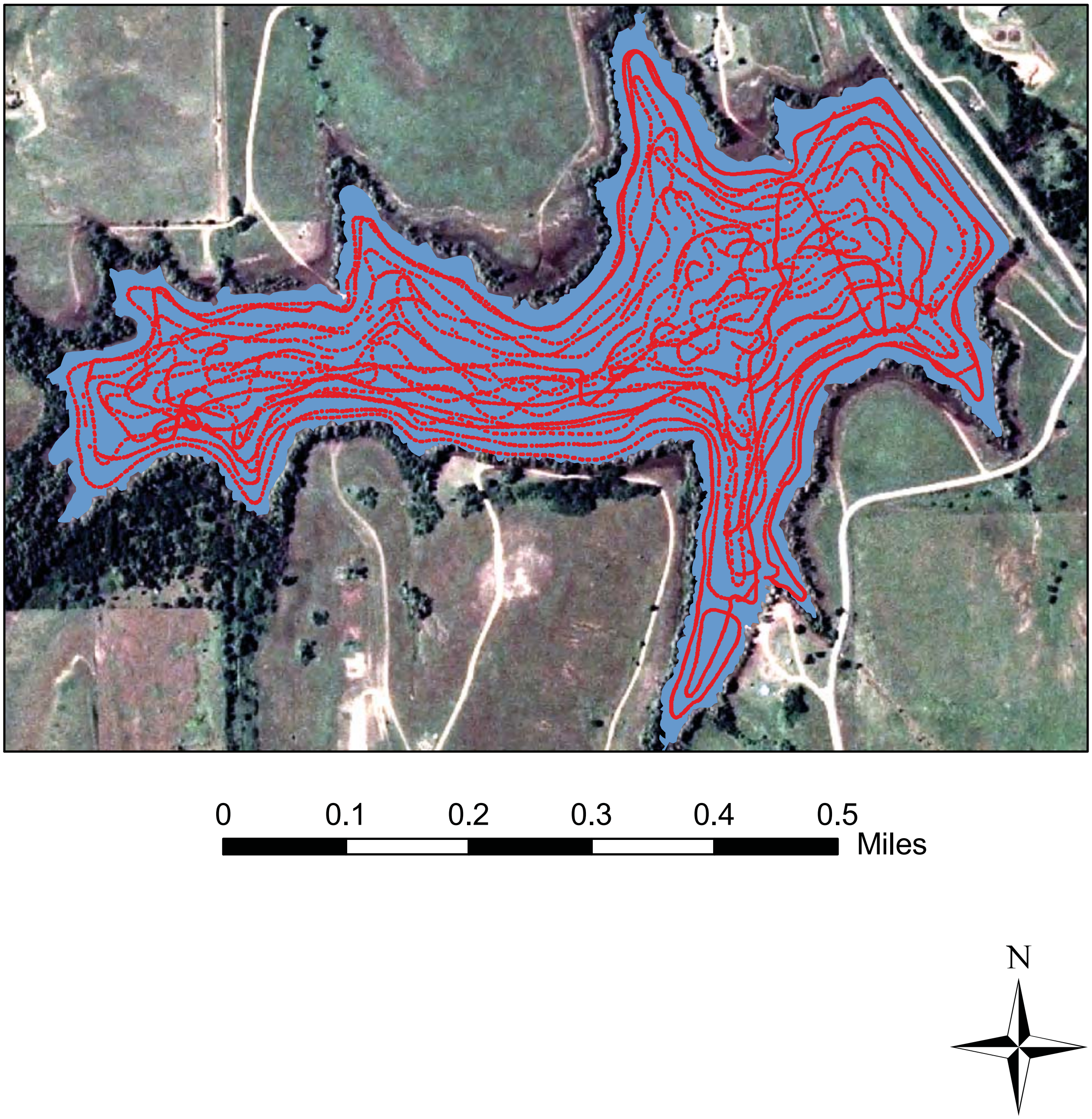

Figure 4. Bathymetric survey lines for Madison City Lake

<u>Post-processing</u> *(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 5 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).

<u>Post-processing</u> (*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 (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 0.2 meters; however, if changes were made in the field, the correct level is taken from field notes and applied to the data). Depth in feet is also calculated as 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, two additional fields are added to the attribute table of the point shapefile: LakeElevM, the reference surface elevation (the elevation of the water surface on the day that the aerial photography from which the lake perimeter polygon was digitized)and Elev_Ft, the elevation of the water surface in feet above sea level (Elev_ft), computed by converting ElevM to elevation in feet (ElevM * 3.28084).

Particularly for multi-day surveys, Adj_Depth 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.

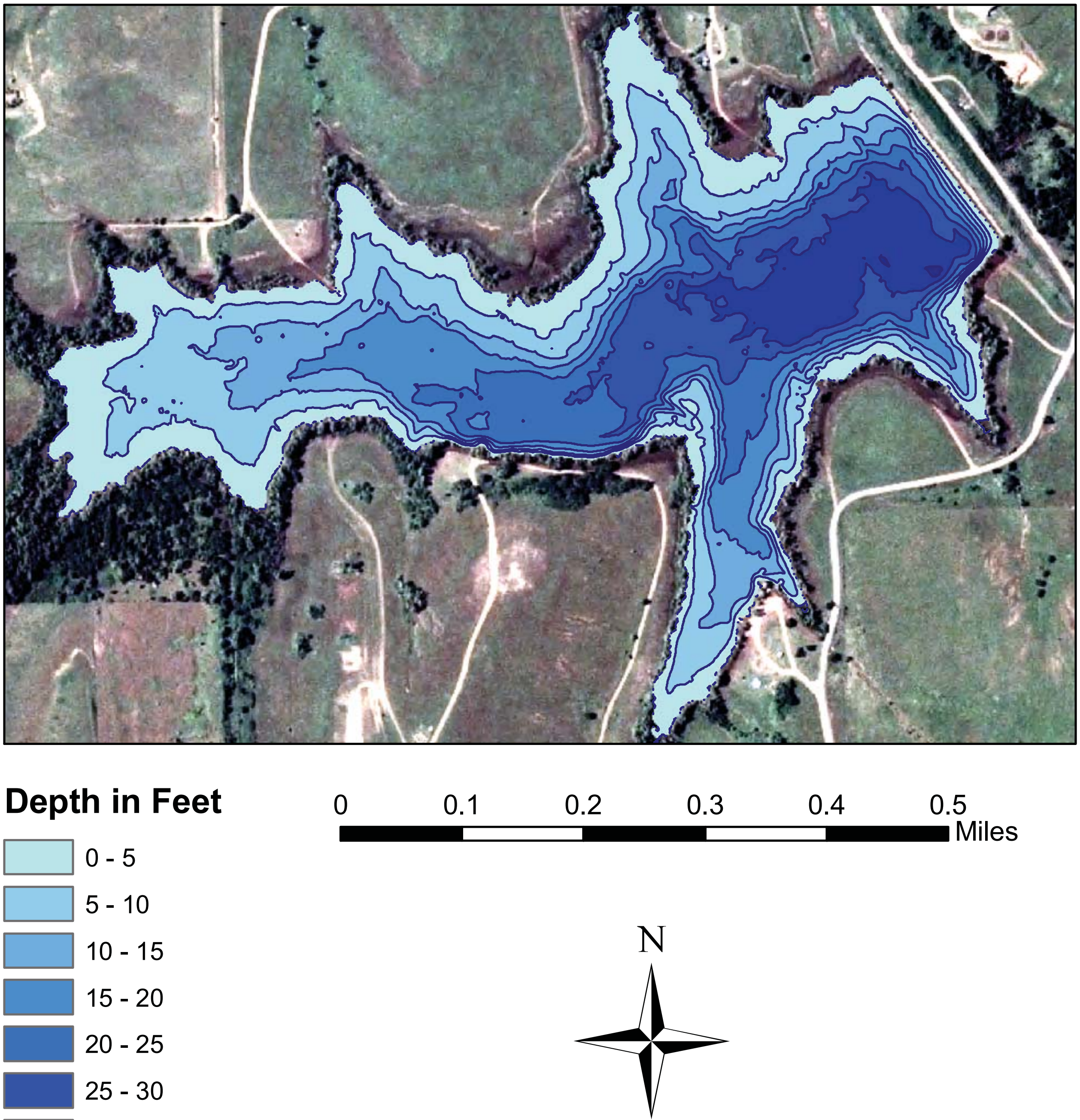

Figure 5. Water depth based on November 9, 2009 bathymetric surveys for Madison City Lake. Depths are based on a pool elevation of 1157.59 ft.

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
1123	1	1	1	1	1	1	1	2	2	2
1124	2	3	3	3	3	4	4	4	4	4
1125	4	5	5	5	5	5	5	6	6	6
1126	6	6	7	7	7	7	7	8	8	8
1127	8	9	9	9	9	10	10	10	10	10
1128	11	11	11	11	11	11	12	12	12	12
1129	12	12	13	13	13	13	13	14	14	14
1130	14	14	15	15	15	15	15	16	16	16
1131	16	16	17	17	17	17	17	18	18	18
1132	18	19	19	19	19	20	20	20	20	20
1133	20	21	21	21	21	22	22	22	22	22
1134	22	22	23	23	23	23	23	24	24	24
1135	24	25	25	25	25	26	26	26	26	26
1136	27	27	27	27	27	28	28	28	28	29
1137	29	29	29	29	30	30	30	30	31	31
1138	31	31	32	32	32	32	33	33	33	33
1139	34	34	34	34	35	35	35	35	35	36
1140	36	36	36	37	37	37	37	38	38	38
1141	38	38	39	39	39	39	39	40	40	40
1142	40	40	41	41	41	41	41	42	42	42
1143	42	43	43	43	43	44	44	44	44	45
1144	45	45	45	46	46	46	46	47	47	47
1145	48	48	48	48	49	49	49	49	50	50
1146	50	51	51	51	51	52	52	52	52	53
1147	53	53	54	54	54	55	55	55	56	56
1148	56	57	57	57	58	58	58	59	59	59
1149	60	60	61	61	61	62	62	63	63	64
1150	64	64	65	65	66	66	67	67	68	68
1151	69	70	70	71	71	72	73	73	74	75
1152	75	76	77	77	78	79	79	80	80	81
1153	82	82	83	83	84	85	85	86	86	87
1154	87	87	88	88	89	89	89	90	90	90
1155	91	91	91	92	92	92	93	93	93	94
1156	94	95	95	95	96	96	97	97	98	99
1157	100	100	100	100	100	100				

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
1123					1	1	1	1	1	1
1124	2	2	2	2	3	3	3	4	4	5
1125	5	6	6	7	7	8	8	9	9	10
1126	10	11	12	12	13	14	14	15	16	17
1127	18	18	19	20	21	22	23	24	25	26
1128	27	28	29	30	31	33	34	35	36	37
1129	39	40	41	42	44	45	46	48	49	50
1130	52	53	55	56	58	59	61	62	64	66
1131	67	69	70	72	74	76	77	79	81	83
1132	84	86	88	90	92	94	96	98	100	102
1133	104	106	108	110	112	114	117	119	121	123
1134	125	128	130	132	135	137	139	142	144	146
1135	149	151	154	156	159	161	164	166	169	172
1136	174	177	180	182	185	188	191	194	196	199
1137	202	205	208	211	214	217	220	223	226	229
1138	232	235	238	242	245	248	251	254	258	261
1139	265	268	271	275	278	282	285	289	292	296
1140	299	303	307	310	314	318	321	325	329	333
1141	336	340	344	348	352	356	360	364	368	372
1142	376	380	384	388	392	396	400	404	408	413
1143	417	421	425	430	434	438	443	447	452	456
1144	460	465	470	474	479	483	488	493	497	502
1145	507	512	516	521	526	531	536	541	546	551
1146	556	561	566	571	576	581	586	592	597	602
1147	607	613	618	623	629	634	640	645	651	656
1148	662	668	673	679	685	691	696	702	708	714
1149	720	726	732	738	744	750	757	763	769	776
1150	782	788	795	801	808	815	821	828	835	842
1151	848	855	862	869	876	884	891	898	906	913
1152	921	928	936	943	951	959	967	975	983	991
1153	999	1007	1016	1024	1032	1041	1049	1058	1066	1075
1154	1084	1092	1101	1110	1119	1128	1137	1146	1155	1164
1155	1173	1182	1191	1200	1209	1218	1228	1237	1246	1256
1156	1265	1275	1284	1294	1303	1313	1322	1332	1342	1352
1157	1362	1372	1382	1392	1402	1412				

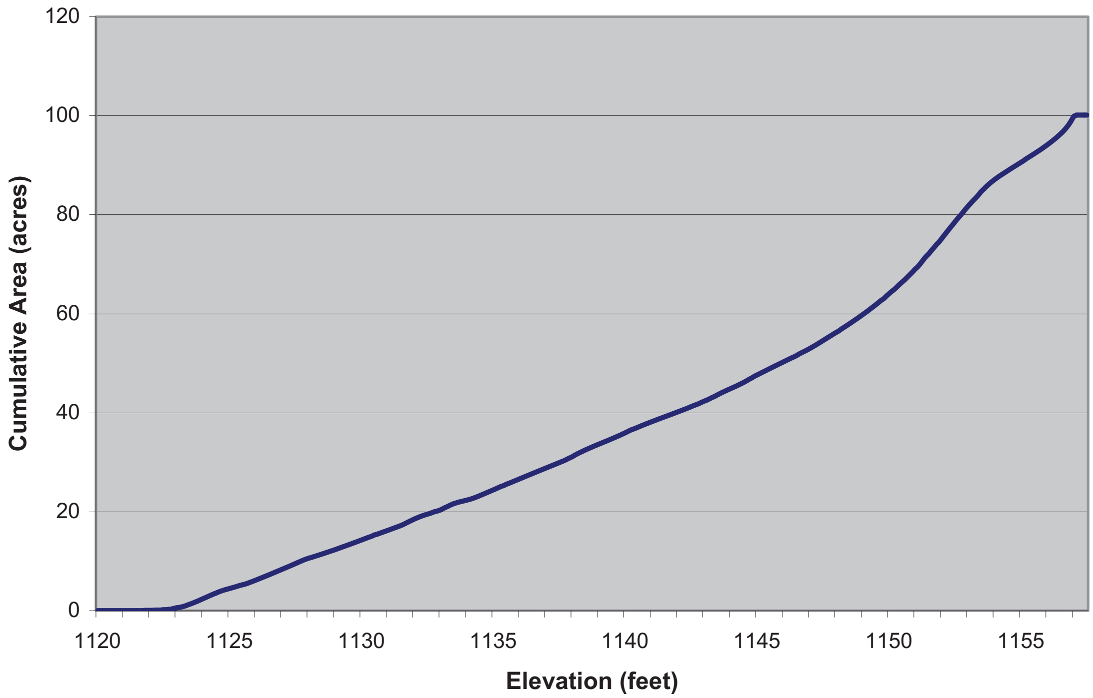

Figure 6. Cumulative area-elevation curve

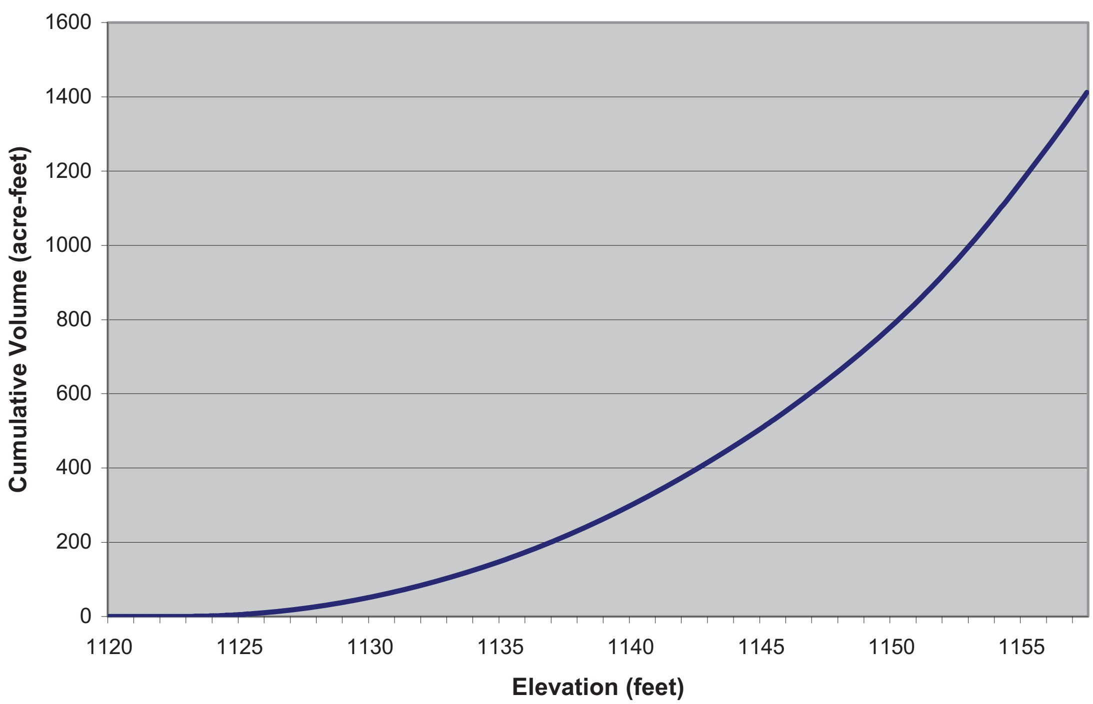

Figure 7. Cumulative volume-elevation curve

SEDIMENT SAMPLING PROCEDURES

Sediment samples were collected from three sites within the reservoir using a Wildco drop-corer (Wildlife Supply Company, Buffalo, NY). One sample is taken near the dam; a second at mid-lake; and a third in the upper end/transitional area. Sampling was performed on the same day as the bathymetric survey, following completion of the survey. As the drop-corer samples only the upper sediment, the entire sample in each case was collected and sealed in a sampling container. The samples were then shipped to the Kansas State University Soil Testing Laboratory (Manhattan, KS), for texture analysis. No bulk density sampling or analysis was performed for Madison City Lake.

SEDIMENT SAMPLING RESULTS:

Sampling sites were distributed across the length of the reservoir (Figure 8). Silt percentages were highest at the inflow end (MCL-1, 62%), decreasing to 26% at the dam end. No sand was detected in any of the three samples (Table 3; Figure 9; Figure 10).

Table 3
Madison City Lake Sediment Sampling Site Data

CODE	UTMX	UTMY	%Sand	% Silt	% Clay
MCL-1	749183.4	4221255.9	0	62	38
MCL-2	749694.0	4221304.7	0	42	58
MCL-3	749953.5	4221488.8	0	26	74

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

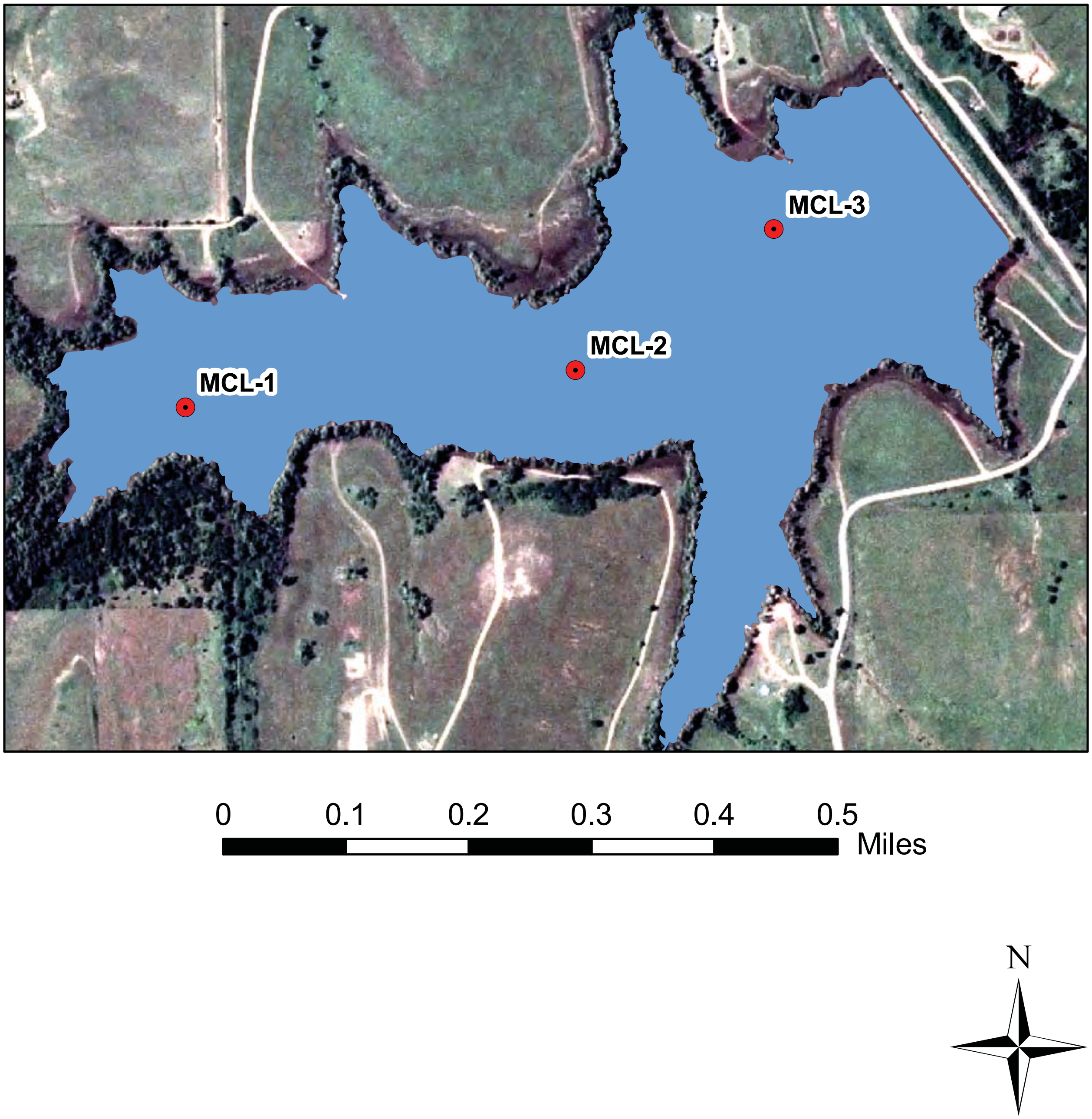

Figure 8. Location of sediment samples in Madison City Lake.

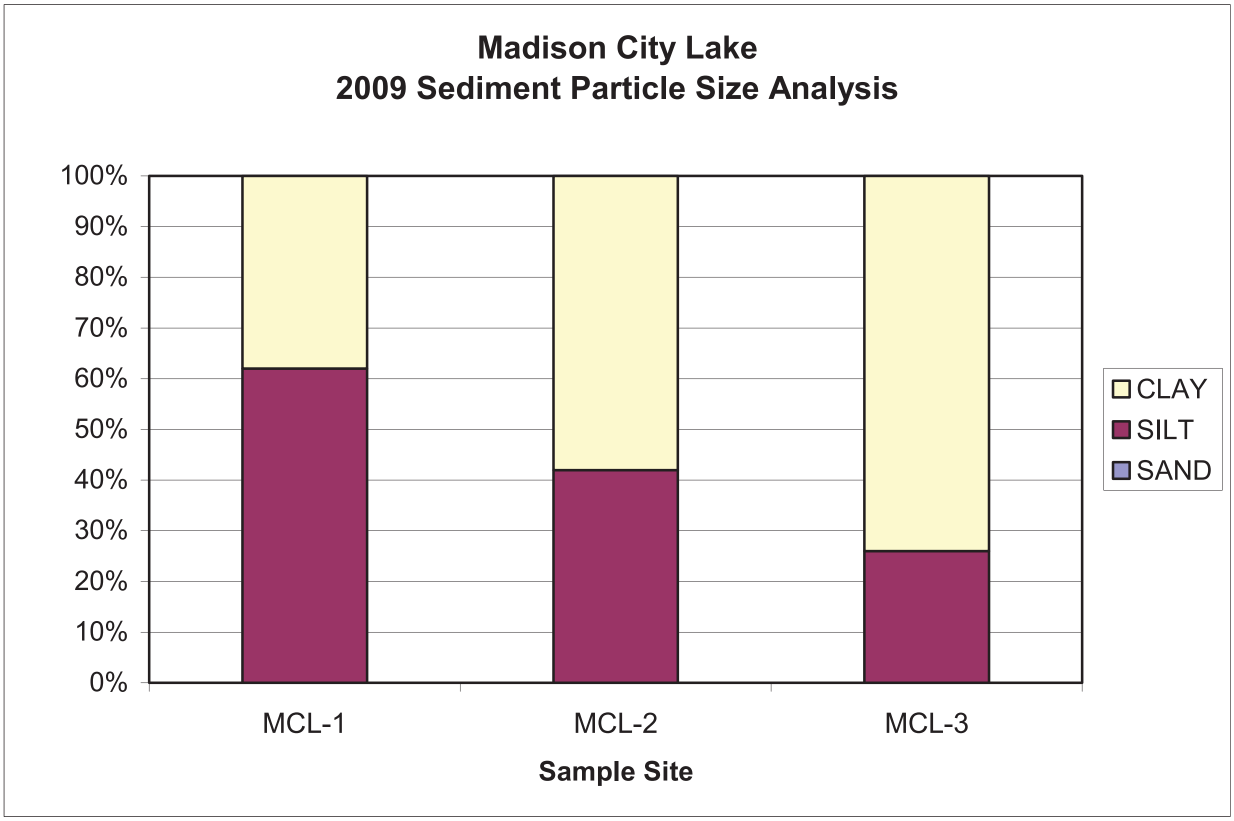

Figure 9. Sediment particle size analysis.

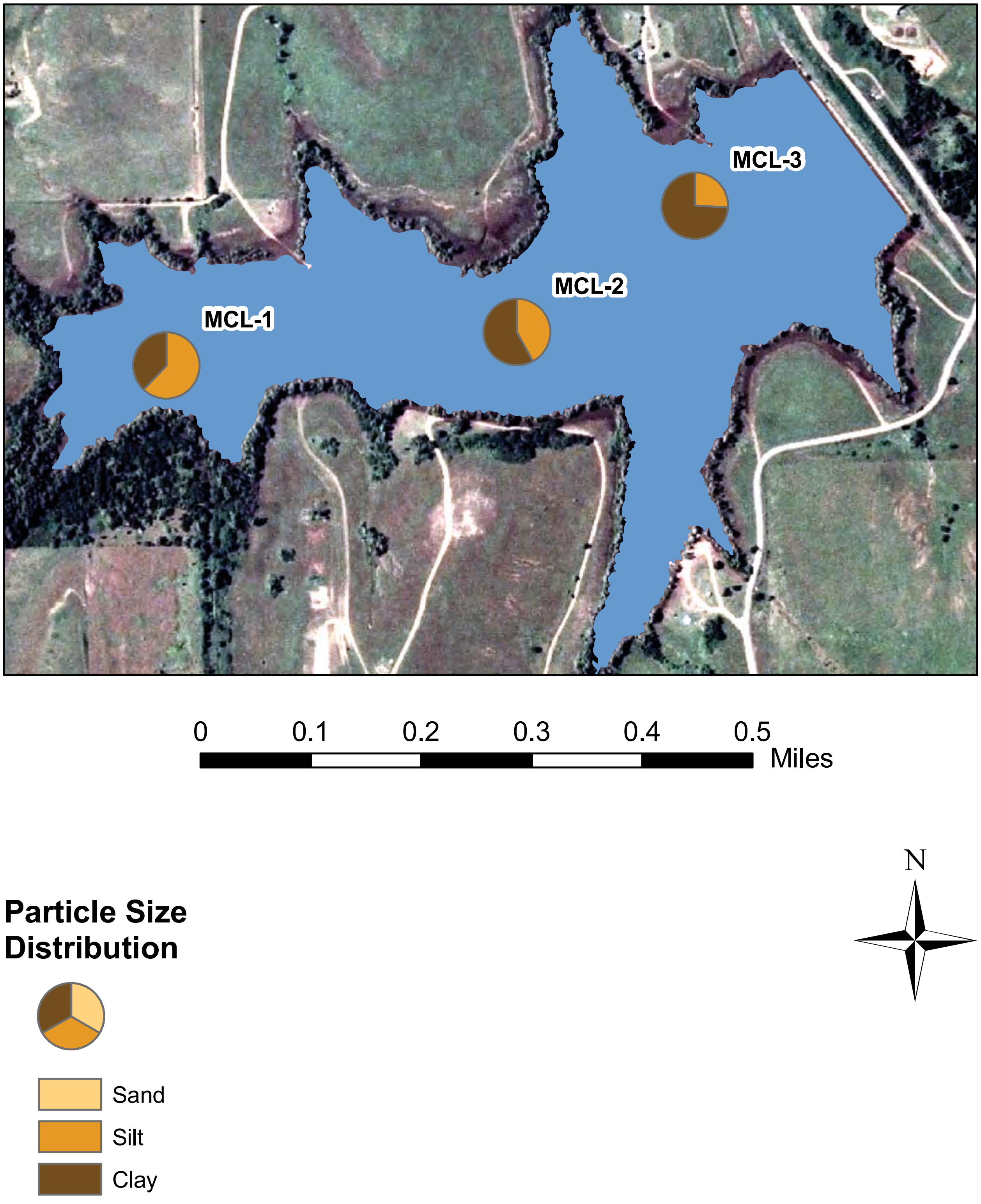

Figure 10. Particle size distribution of sediment samples in Madison City Lake.