Real-Time Water Quality Monitoring in **Lake Maumelle, Arkansas**

W. Reed Green and Paul R. Easley

Lake Maumelle – Central Arkansas' Major Drinking Water Supply

The U.S. Geological Survey (USGS), in cooperation with Central Arkansas Water, the water-supply utility serving 400,000 customers in the Little Rock, Arkansas, metropolitan area, has operated a real-time water-quality monitoring buoy, an "Environmental Sensing Platform" (LakeESP, Figure 1) since 2010 in Lake Maumelle, Central Arkansas' major water-supply reservoir. The LakeESP is designed to collect high-frequency (up to every 60 seconds) meteorological and water quality data, from surface to bottom, to examine changes over hours, days, weeks, seasons, and year-to-year. The LakeESP in Lake Maumelle measures air temperature, relative humidity, wind speed and direction, and long- and shortwave radiation, and via an underwater-telemetry cable, water temperature and dissolved oxygen concentrations are measured at 12 depths (1 meter increments), every five minutes, 24 hours a day. Meteorological data can be used to drive mathematical (mass balance) hydrodynamic and water quality models and the temperature and dissolved oxygen data over depth and time can be used to calibrate and validate these models. Precision Measurement Engineering, Inc. (http://www.pme.com/HTML%20Docs/LakeESP.html) manufactures the LakeESP.

Continuous Monitor Operations

The LakeESP is anchored by two mooring ropes 100 meters on either side, with submerged buoys to keep constant tension on the ESP as the pool elevation changes during the wet and dry seasons (Figure 2; http://www.pme.com/HTML%20Docs/LakeESP_Mooring.html). Thermistors (Figure 3) are spliced into the underwater telemetry cable (T-Chain) one meter apart; the optical dissolved oxygen sensors (Figure 4) are

Figure 1. The Lake Maumelle real-time meteorological and water-quality buoy (LakeESP). Photo: Reed Green.

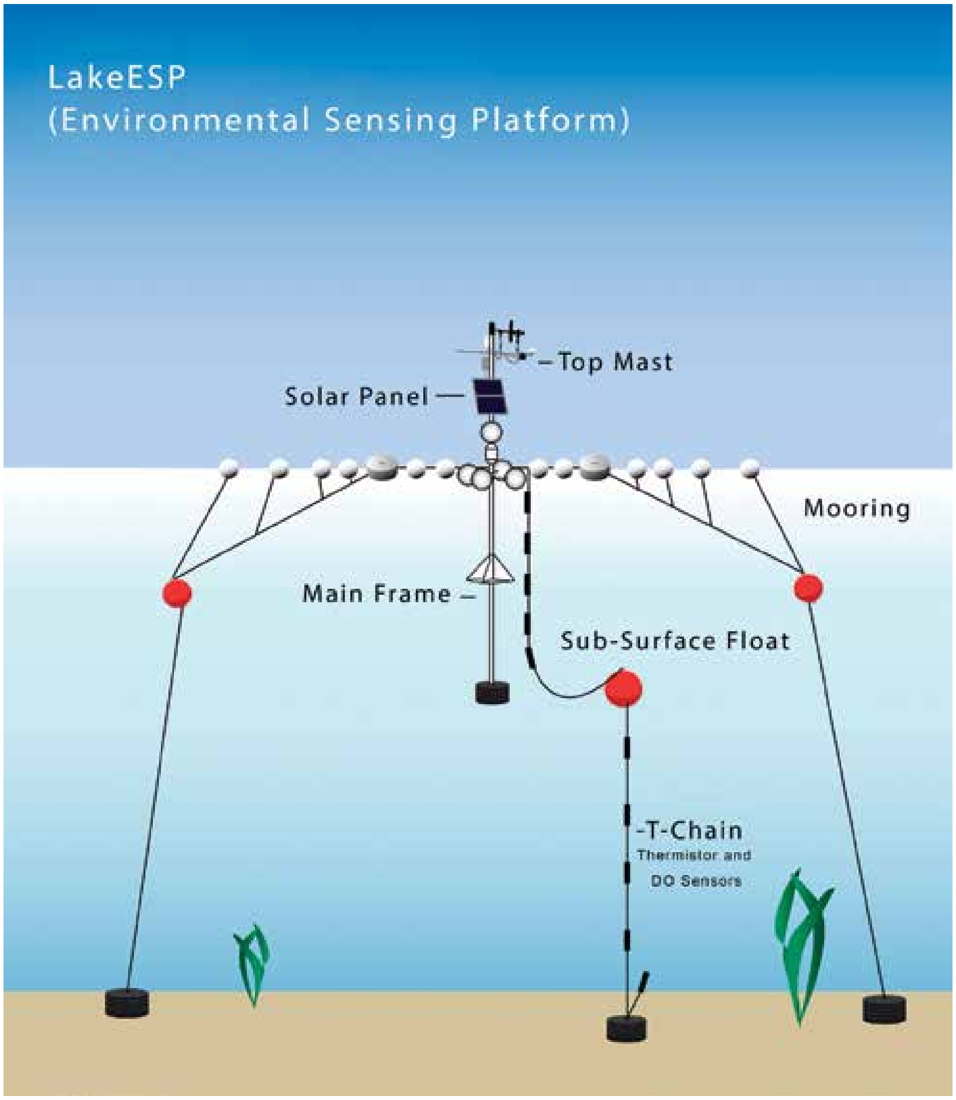


Figure 2. Schematic diagram showing an example of a continuous water-quality monitoring system (LakeESP) with multiple fixed-depth sensors. Nine sensors instead of the 12 Lake Maumelle LakeESP instrument sensors and the pressure transducer are shown for graphical purposes only. (Diagram courtesy of Precision Measurement Engineering, Inc., Vista, California.)

Figure 3. Thermistor (metal rod) spliced into the telemetry cable. The car key is shown for scale. Photo: W. Reed Green.

"pig-tailed" into the telemetry cable. A ten-meter length of cable with no temperature or dissolved oxygen sensors is looped between the section suspended from the surface and that suspended off the bottom by a subsurface float, so the cable will not be pulled off the bottom when the pool elevation is extremely high. A pressure transducer located one meter above the bottom is used to measure water depth (Figure 5). A thermistor and dissolved oxygen sensor is also located one meter above the bottom.

Continuous Monitor Data

Data are transferred (via mobile Wi-Fi) hourly from the LakeESP to a computer on the shore where files are transferred through file transfer protocol (FTP) to the USGS Arkansas Water Science Center computer. Each constituent time series is plotted individually (Figure 6) on the USGS National Water Information System (NWIS) web site (http://waterdata.usgs.gov/ar/nwis/uv/?site_no=072632995), and individual unit values can be downloaded through the USGS NWIS database (Table 1). Water temperature and dissolved oxygen concentrations are further post-processed from NWIS data retrievals into contour plots, depth over time, to observe and interpret trends over the past seven days (Figures 7 and 8). Each year during winter (typically January or February), the instrument is removed from the lake and sensors are returned to the factory for recalibration. The instrument is redeployed before the onset of thermal stratification in the spring (typically late March or early April). Water temperature and dissolved oxygen concentrations are checked against a second, calibrated multiparameter data sonde at a frequency of every four to six weeks during deployment. At this time, underwater sensors and cable are removed from the water, cleaned, and redeployed.

Continuous Monitor Applications

The LakeESP in Lake Maumelle is located at the east end of the lake near the dam and Central Arkansas Water's intake structure (Figure 9). The lake is about 12 miles long from west-northwest (upper end) to east-southeast (lower end). When sustained winds blow from the east to the west during thermal

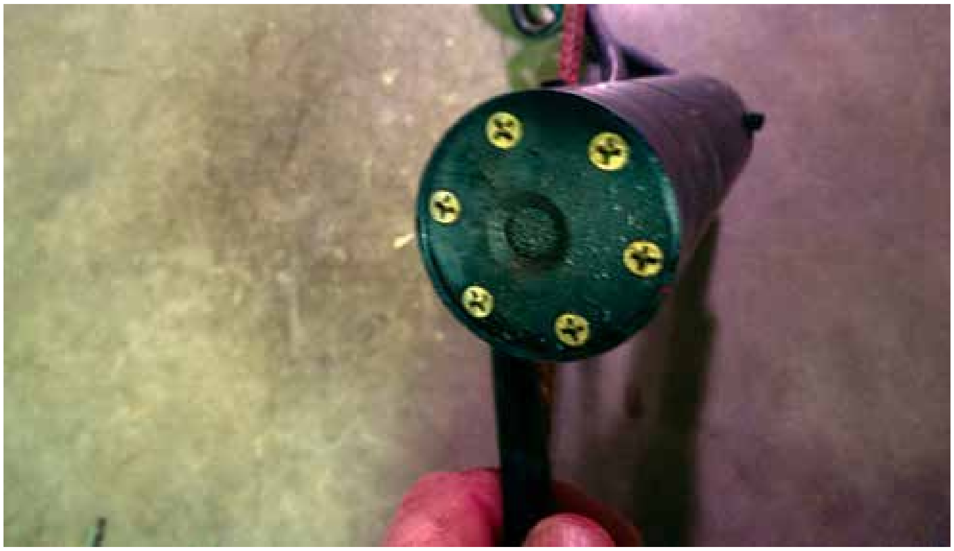


Figure 4. Face of the optical dissolved oxygen sensor (two-inch diameter). Photo: W. Reed Green.

Current Conditions for Arkansas: Water Quality -- 1 site(s) found

PROVISIONAL DATA SUBJECT TO REVISION

Customize table to display other current-condition parameters

Station Number	Station name	Date/Time	Temperature, water, deg C	Dissolved oxygen, mg/L	Specific conductance, wat unf uS/cm @ 25 degC	pH, water, unfltrd field, std units	Turbidity, IR LED light, det ang 90 deg, FNU	Nitrate + nitrite water, fltrd, mg/L as N	Dissolved solids, sum of constituents, mg/L	Oxidation reduction potential, mV	Chloride, water, fltrd, mg/L
• Arkansas River Basin											
072632995	Lake Maumelle at Natural Steps										
	.9m above bottom	02/20 09:38 CST	14.9	--	--	--	--	--	--	--	--
	0.5m below surface	02/20 09:38 CST	--	10.2	--	--	--	--	--	--	--
	0.6m below surface	02/20 09:38 CST	14.9	--	--	--	--	--	--	--	--
	1.0 above bottom	02/20 09:38 CST	--	10.1	--	--	--	--	--	--	--
	1.5m below surface	02/20 09:38 CST	--	10.1	--	--	--	--	--	--	--
	1.6m below surface	02/20 09:38 CST	14.9	--	--	--	--	--	--	--	--
	1.9m above bottom	02/20 09:38 CST	14.9	--	--	--	--	--	--	--	--
	2.0m above bottom	02/20 09:38 CST	--	9.9	--	--	--	--	--	--	--

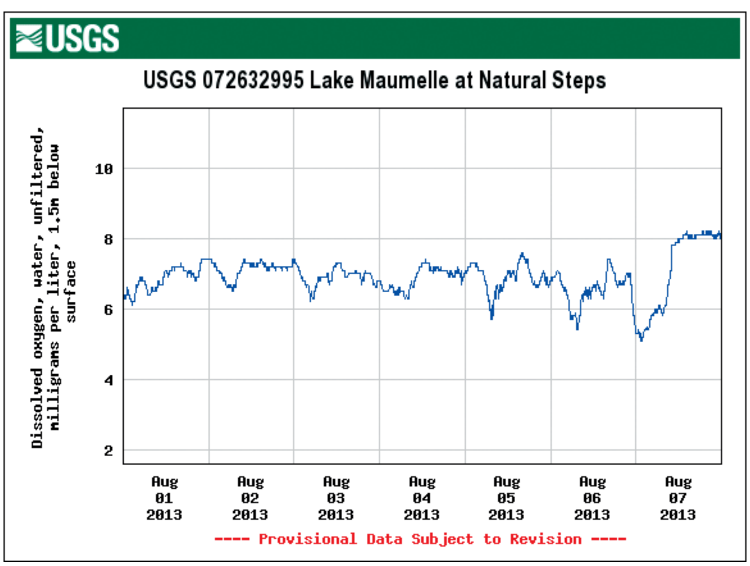


Figure 6. Example of the USGS National Water Information System website – dissolved oxygen concentrations, August 01 through 07, 2013, 1.5 meter below the surface. Each water temperature and dissolved oxygen sensor, and each meteorological parameter are plotted individually.

Figure 5. Pressure transducer, thermistor, and dissolved oxygen sensor suspended one meter above the anchor at the bottom of the telemetry cable. Photo: W. Reed Green.

stratification, warm water stacks up at the surface in the shallow western end, squeezing cooler hypolimnetic water near the bottom toward the deeper eastern end of the lake. The cooler, more dense water is pushed west to east along the bottom slope of the lake, eventually hitting the dam wall and welling up to the surface. Continuous monitoring of dissolved oxygen and temperature by the LakeESP captures these upwelling events (Figures 7 and 8). The anoxic hypolimnetic water in Lake Maumelle is rich in dissolved iron, manganese, and other metals that are soluble under anoxic/suboxic conditions (Green 1993). Central Arkansas Water staff can use the real-time data (wind speed and direction, time and depth contours of water temperature, and dissolved oxygen concentrations) to properly treat the elevated iron and manganese concentrations that can occur during these upwelling events. Prior to the LakeESP installation, these iron and manganese spikes were considered "random" events. Data provided by the LakeESP allow a better understanding of

Table 1. Example of a Data Table Produced for Viewing on the USGS NWIS Website. (Data can also be selected for output and imported into Microsoft Excel or other software programs.)

USGS 072632995 Lake Maumelle at Natural Steps [PROVISIONAL DATA SUBJECT TO REVISION]

Date / Time	Dissolved oxygen, mg/L, 0.5m below surface	Dissolved oxygen, mg/L, 1.5m below surface	Dissolved oxygen, mg/L, 2.5m below surface	Dissolved oxygen, mg/L, 3.5m below surface	Dissolved oxygen, mg/L, 4.5m below surface
08/18/2013 00:00 CDT	6.9[P]	7.1[P]	5.6[P]	6.3[P]	6.5[P]
08/18/2013 00:03 CDT	6.9[P]	7.1[P]	5.6[P]	6.3[P]	6.5[P]
08/18/2013 00:08 CDT	6.9[P]	7.0[P]	5.6[P]	6.3[P]	6.5[P]
08/18/2013 00:13 CDT	6.8[P]	7.0[P]	5.6[P]	6.5[P]	6.5[P]
08/18/2013 00:18 CDT	6.8[P]	7.0[P]	5.6[P]	6.3[P]	6.4[P]
08/18/2013 00:23 CDT	6.8[P]	7.0[P]	5.5[P]	6.2[P]	6.2[P]
08/18/2013 00:28 CDT	6.8[P]	7.0[P]	5.6[P]	6.3[P]	6.1[P]
08/18/2013 00:33 CDT	6.8[P]	7.0[P]	5.5[P]	6.3[P]	5.9[P]
08/18/2013 00:38 CDT	6.8[P]	7.0[P]	5.6[P]	6.3[P]	6.0[P]
08/18/2013 00:43 CDT	6.8[P]	7.0[P]	5.7[P]	6.4[P]	6.0[P]

[P] = Provisional data subject to revision.

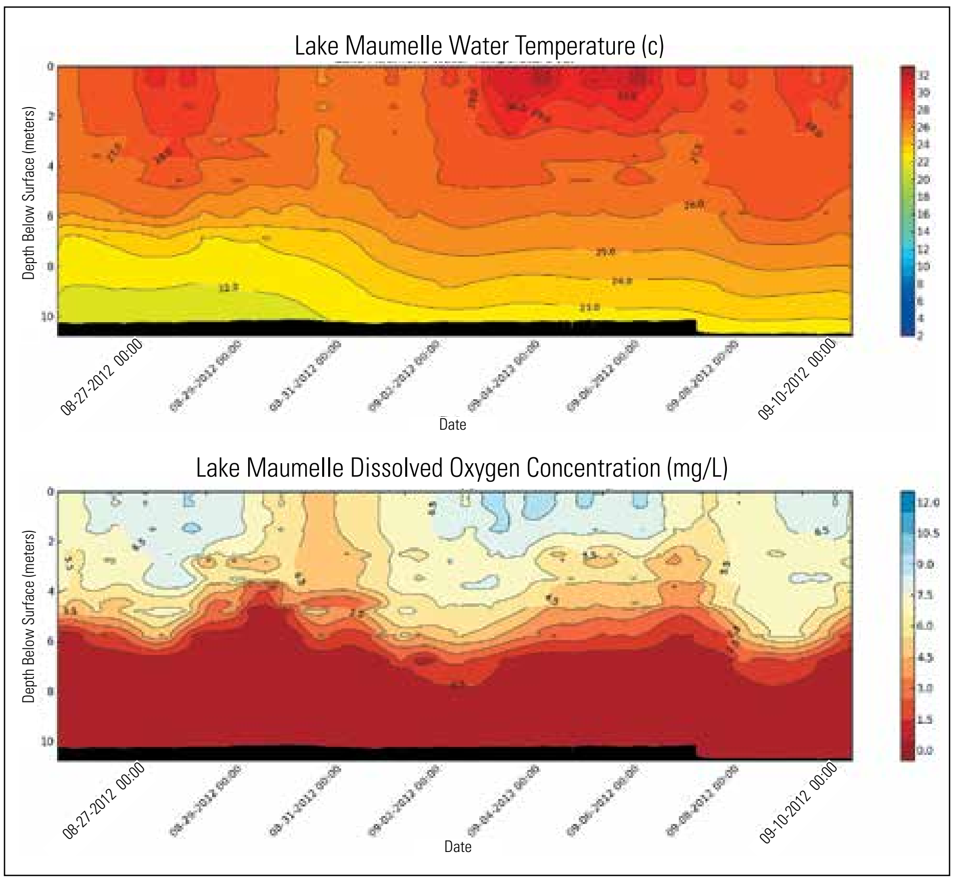


Figure 7. Time and depth contour plots of water temperature (top) and dissolved oxygen concentration (bottom), August 26, 2012 through September 10, 2012. Notice the upwelling of the hypolimnetic water, low in dissolved oxygen concentrations, mixing and reaching the surface around August 31 and again around September 7. Lake bottom designated by black-shaded area on the x-axis. Underwater thermistors and dissolved oxygen sensors were pulled out of the water, cleaned and redeployed September 7.

the mixing dynamics in Lake Maumelle and the phenomena that drive them.

The LakeESP can also be used to drive quasi real-time two- and three-dimensional mathematical hydrodynamic and water-quality models. Wind speed and direction mix the lake water in the models; air temperature, relative humidity (evaporation), and solar radiation heats and cools the lake water. Thermistors suspended in the water column can be used to validate density driven lake water dynamics and the suspended dissolved oxygen sensors can be used to validate both biological and water-quality processes. Updating and validating models in this way, from real-time data gathered by the LakeESP along with inflow and outflow data from real-time stream gaging stations would allow the models to be updated daily, 24 hours at a time, or more frequently, if needed. This would allow water-resource managers the ability to follow lake conditions almost up to the minute, hour, or day to assist in making informed management decisions.

References

Green, W.R. 1993. Water quality assessment of Maumelle and Winona reservoir systems, central Arkansas, May 1989-October 1992: U.S.

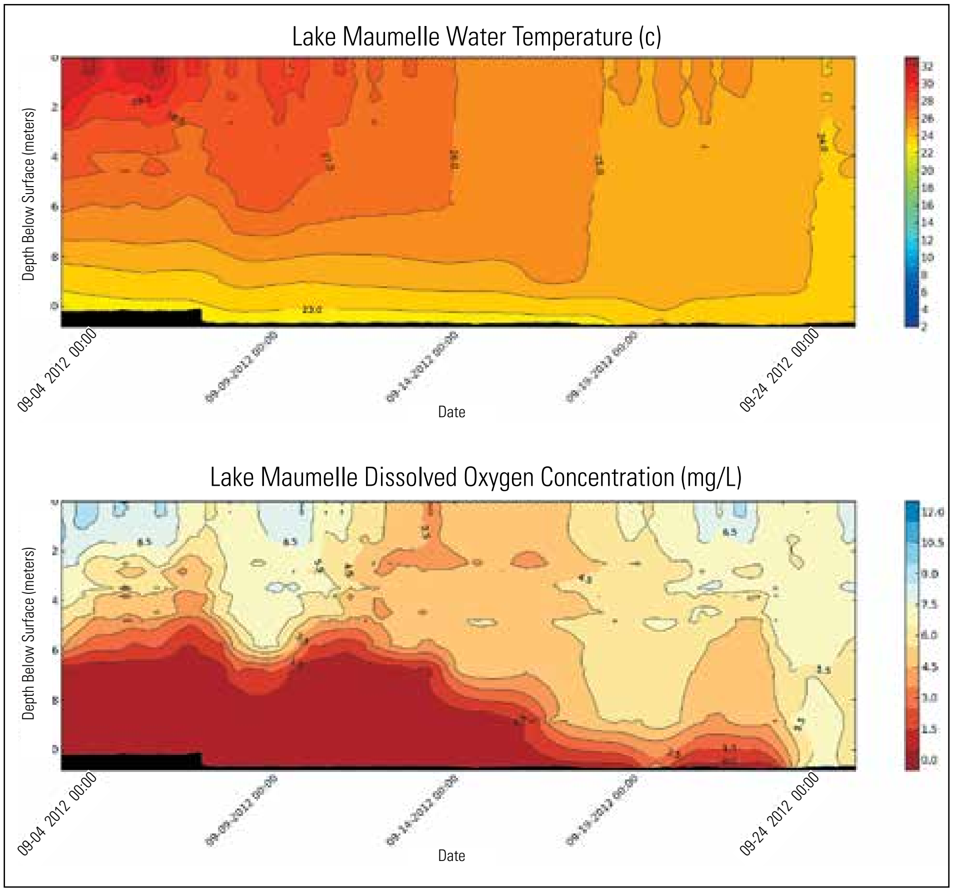
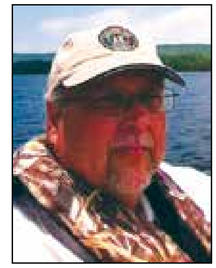


Figure 8. Time and depth contour plot of water temperature (top) and dissolved oxygen concentrations (bottom), September 4, 2012 through September 24, 2012. Notice the gradual disintegration of the anoxic hypolimnion as the lake thermal structure breaks down through September 24, 2012. Lake bottom designated by black-shaded area on the x-axis. Underwater thermistors and dissolved oxygen sensors were pulled out of the water, cleaned and redeployed September 7.

Geological Survey Water-Resources Investigations Report 93-4218, 42 p.

Hart, R.M., W.R. Green, D.A.Westerman, J.C. Petersen and J.L. De Lanois, 2012. Simulated effects of hydrologic, water quality, and land-use changes of the Lake Maumelle watershed, Arkansas, 2004–10: U.S. Geological Survey Scientific Investigations Report 2012–5246, 119 p. (Revised February, 2013.)

Reed Green is a hydrologist (limnology) with the U.S. Geological Survey Arkansas Water Science Center, and has monitored and assessed water quality in lakes and reservoirs his entire career, often applying hydrodynamic and water-quality models to aid in water-quality diagnostics and forecasting. Reed is also an adjunct faculty member in both the Biology and Earth Sciences Departments at the University of Arkansas at Little Rock, and in his spare time helps mentor students, teaches an occasional class, and has a laboratory he uses to identify and enumerate phytoplankton for various projects. You can reach Reed at: wrgreen@usgs.gov.



Paul R. Easley is the Director of Water Quality at Central Arkansas Water (CAW). Mr. Easley is responsible for managing the activities of the analytical laboratory, water quality, and watershed management programs. CAW's watershed and lake management efforts help provide high-quality drinking water to approximately 400,000 people in central Arkansas. You can reach him at: randy.easley@carkw.com.

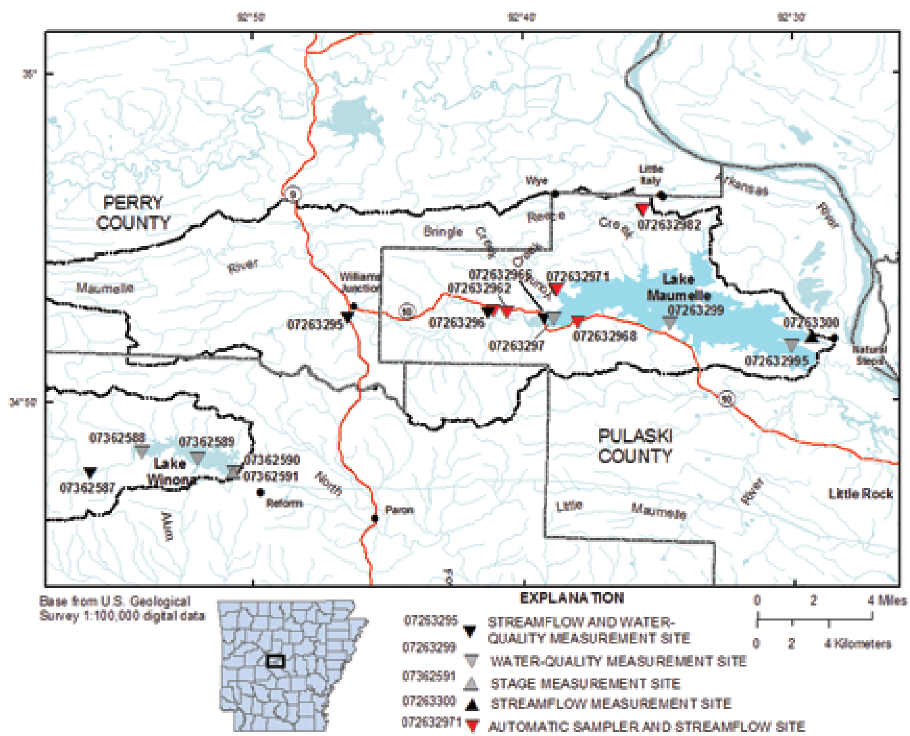


Figure 9. Lake Maumelle (and Winona) study-area map. Lake Maumelle LakeESP located at station number 072632995 at the eastern end of Lake Maumelle.