Heyburn Lake Water Quality: 2013

The Heyburn Lake dam is located at river mile 48.6 on Polecat Creek, a tributary of the Arkansas River, ~4.5 miles west of Kellyville in Creek County, Oklahoma. Heyburn Lake is a multi-purpose project designed for flood control, water supply, recreation, and fish and wildlife. The project was designed and is regulated to provide maximum benefits for flood protection on Polecat Creek and for minor reduction of flooding on the Arkansas River. Heyburn Lake was designed to minimize downstream flooding damages, however, flood releases through the modified morning glory drop inlet are uncontrolled. The impoundment extends north-northwest from the dam forming two arms, one trending west follows the channel of Polecat Creek, and the other trending north to the confluence of Browns Creek and Tiger Creek. The lake and watershed are within Hydrologic Unit Code 1111010101 (Polecat Creek). Construction of the Heyburn Lake dam began in March 1948 and was completed for full flood control operation in September 1950. The total drainage area above the dam is ~123 square miles (Figure 1). Land use/cover (U.S. Geological Survey, 2014) in the basin is dominated by forest (61%) and grassland/pasture (~34%). Based on a 2015 bathymetric survey (Bowen Engineering & Surveying, Inc., 2015), at the conservation pool elevation of 761.5 feet (NGVD 29), lake capacity has diminished by about 46% since construction. Descriptive characteristics of Heyburn Lake are included in Table 1.

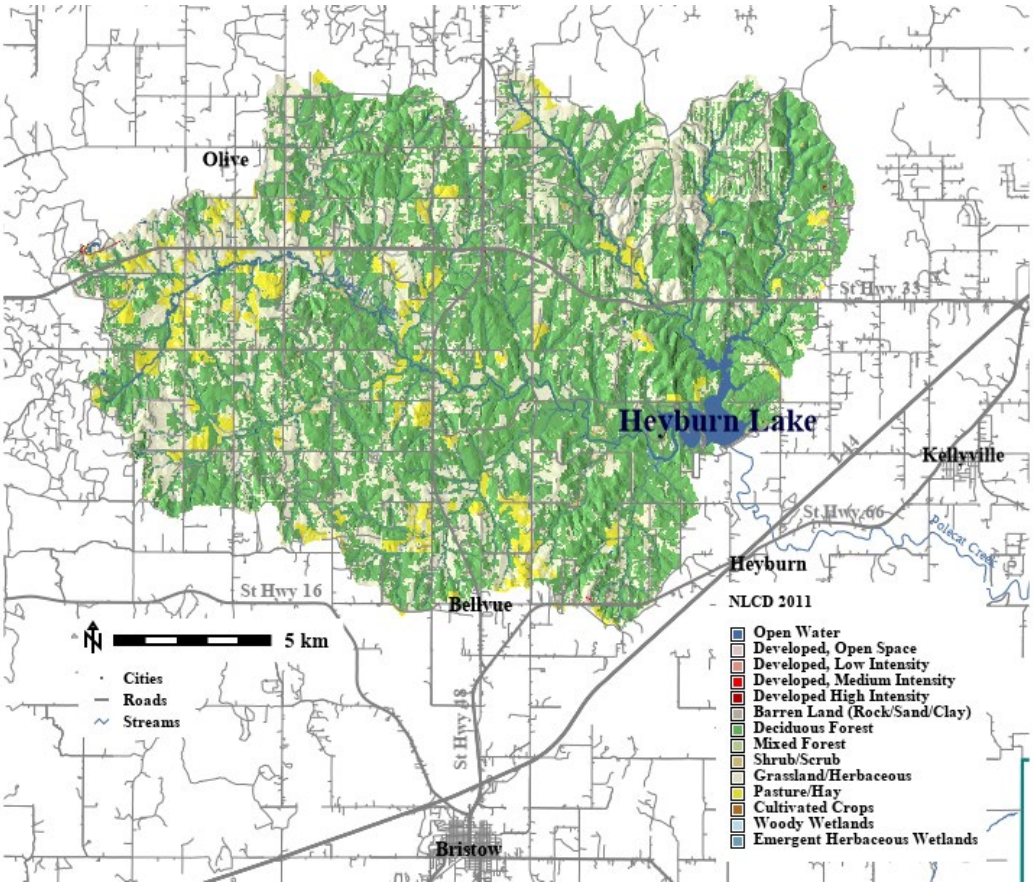

Figure 1. The Heyburn Lake (Polecat Creek) Watershed above the Heyburn Lake Dam.

Table 1. Descriptive Characteristics of Heyburn Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	761.5 ft. NGVD	232.11 m
Lake Surface Area (Conservation Pool)	695 ac	281.26 ha
Lake Volume (Conservation Pool)	5,508 ac-ft	$6.794*10^6$ m^3
Total Drainage Area (contributing)	123 mi^2	318.57 km^2
Mean Depth	7.9 ft	2.41 m
Maximum Depth (Conservation Pool)	31 ft	9.45 m
Shoreline Length	24.4 mi	39.27 km
Shoreline Development Index	6.8	6.8
Annual Inflow, Average 1929 – 2013 [Water Years]	50,000 ac-ft	$61.674*10^6$ m^3
Annual Inflow, 2013 [Calendar Year]	12,050 ac-ft	$14.863*10^6$ m^3
Hydraulic Residence Time, 2013 [Calendar Year]	154.7 d	0.42 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2021), the FY 2013 Annual Water Control Report (U.S. ACE - SWD RCC, 2014), Tulsa District's Water Control page for Heyburn Lake (U.S. ACE - Tulsa District, 2024), and the 2015 bathymetric survey (Bowen Engineering & Surveying, Inc., 2015).

Designated beneficial uses of the reservoir created by the Heyburn Lake Dam include Public and Private Water Supply, Fish and Wildlife Propagation as a Warm Water Aquatic Community, Agriculture, Primary Body Contact Recreation, Aesthetics, and the lake and watershed are designated as Sensitive Public and Private Water Supply (OAC, 2023a). Protocols assessing support of designated beneficial uses, in accordance with the Clean Water Act (CWA) Sections 303(d) and 305(b), are included in OAC 2023b. Impairments of designated uses are listed in the biennial Integrated Water Quality Assessment prepared by the Oklahoma Department of Environmental Quality (ODEQ). The 2022 Integrated Report (ODEQ, 2022) documents Heyburn Lake water quality as impaired with respect to designated beneficial uses Public and Private Water Supply and Fish and Wildlife Propagation as a Warm Water Aquatic Community. Identified issues include excess algal growth, low dissolved oxygen concentrations, and turbidity. Fish and Shellfish Consumption impairment by mercury is also noted in the report.

Physical and chemical water quality data were collected monthly, March through September 2013, from three in-lake sites and the tailwater at Heyburn Lake to define existing limnological conditions, provide a basis for future water quality investigations, and to support operational and environmental missions of the Tulsa District. Sampled sites included HEYOKN0072 (channel near dam), HEYOKN0073 (Browns Creek/Tiger Creek arm), HEYOKN0074 (Polecat Creek arm, near Rocky Point), and HEYOKN0245 (tailwater). In-lake sites were accessed by boat, and samples were collected from locations over the deepest portion of the stream channel (thalweg). Sampling locations are identified in Figure 2.

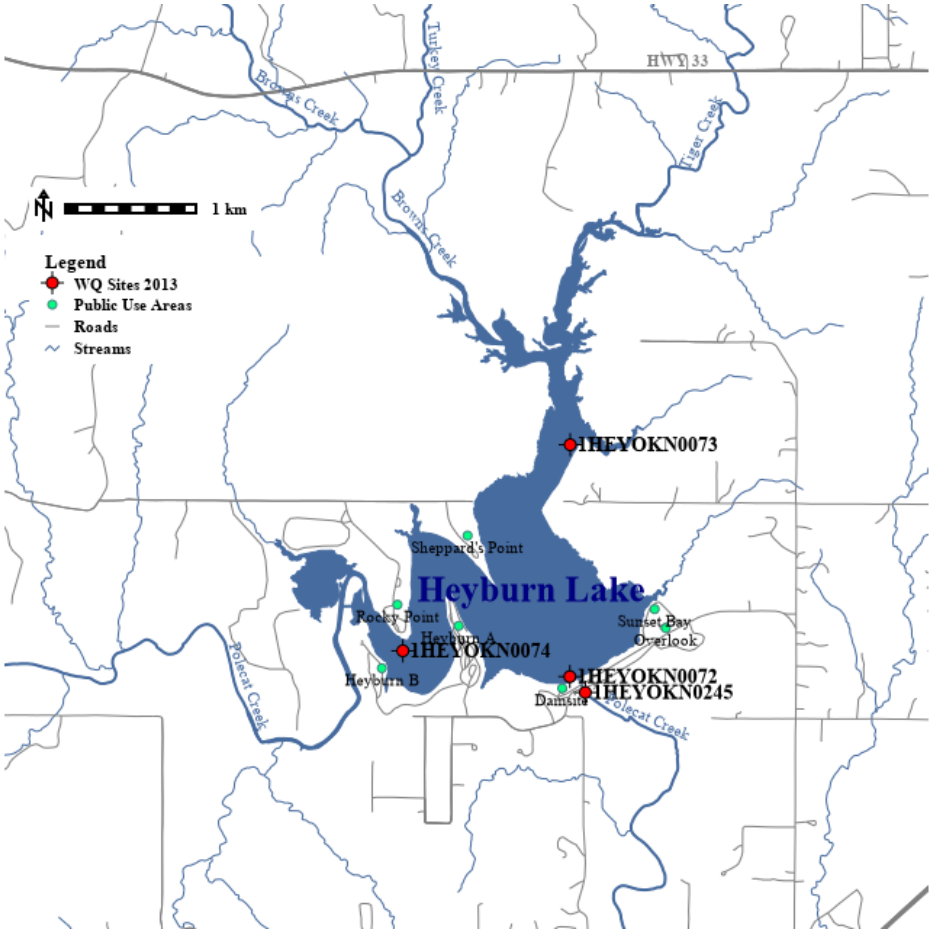

Figure 2. Locations of water quality sampling sites at Heyburn Lake, OK, 2013.

The Heyburn Lake pool was above or near conservation elevation (761.5 feet) for March through June collection events, and below for July, August, and September sampling efforts. During calendar year 2013, annual basin precipitation totaled 32.9 inches, 79% of the 1981 – 2010 normal, and the annual average temperature recorded at the dam was 59.6 °F, almost equivalent to the long-term normal. Total calendar year 2013 inflow to Heyburn Lake was ~25% of the 1929 - 2013 water year average. Calendar year 2013 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling events are shown in Figure 3.

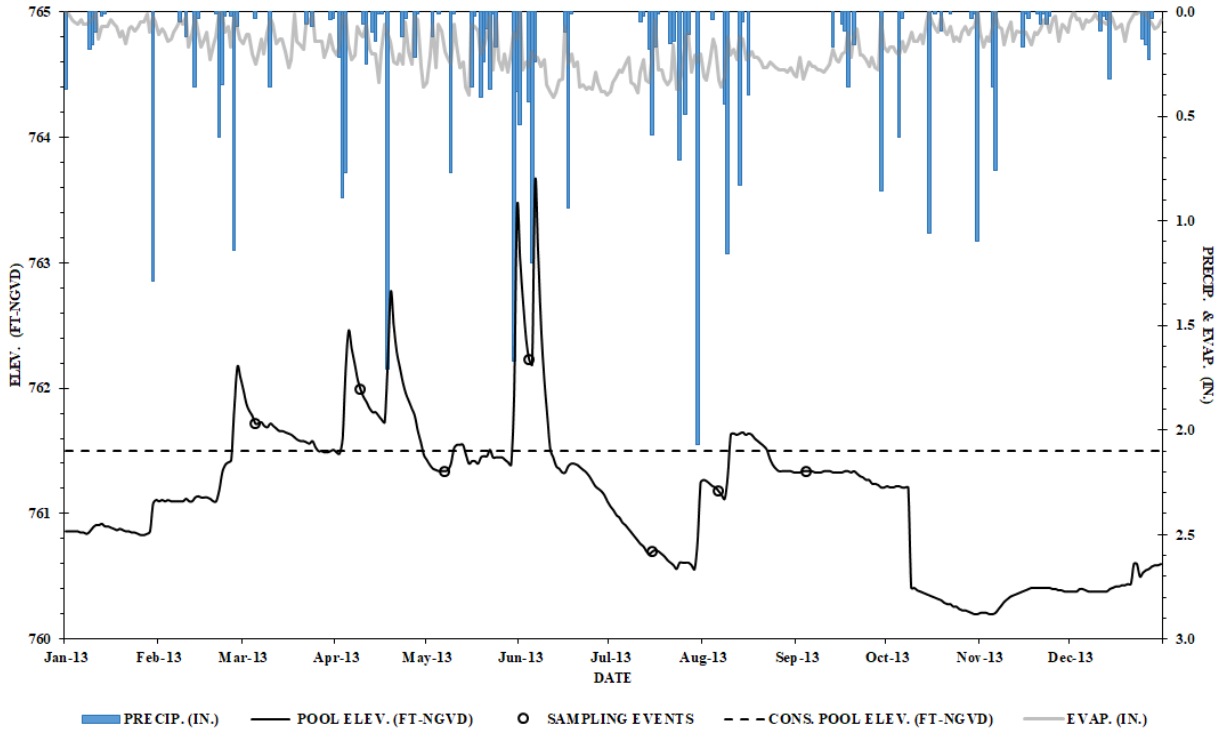

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Heyburn Lake, OK, 2013.

Water temperatures varied seasonally (ranging from 5.5 to 29.0 ºC). Highest recorded water temperatures occurred in September with all recorded in-lake temperatures greater than 25.0 ºC. Water temperatures warmed progressively March through May but varied nominally from surface to bottom. Vertical profiles in June at HEYOKN0072 indicated development of thermal stratification. Hypoxia at depth was noted near the dam in June, continuing and expanding to all in-lake sites through September. Dissolved oxygen (DO) concentrations were ≤2 mg/l about 3 to 4 meters below the surface at HEYOKN0072 and HEYOKN0073 in July, and at all three in-lake sites August through September. The lakewide study period DO ranged from 0.29 to 11.79 mg/l, and median DO concentration was 6.77 mg/l. All in-lake observations of DO in March were >11 mg/l. Lakewide median total organic carbon concentration was 7.2 mg/l. Total organic carbon concentrations were lowest in March (6.25 mg/l) and peaked in May (8.10 mg/l).

Specific conductance (median 228.0 µS/cm) was moderate, consistent with regional geology. Total dissolved solids median concentration was 216.0 mg/l. Moderate chloride and sulfate concentrations (medians 23.7 and 10.9 mg/l, respectively) were observed. Alkalinity levels, median 55.3 mg/l as $CaCO_3$, were moderate, and the system appears capable of maintaining pH levels. Observed pH, ranging from 7.03 to 8.26, was within regional norms. All pH observations >8 occurred in March, and lowest observations were at depth at HEYOKN0072 and HEYOKN0073 in July. Hardness levels, median 84.4 mg/l as $CaCO_3$, indicated moderately hard water.

Secchi depth (SD) at Heyburn Lake during the study period ranged from 0.16 to 0.30 meters with a median value of 0.20 meters. SD observations were comparably low at each in-lake site on all sampling dates. In-lake median turbidity was 89.1 NTU, and all observations were greater than or equal to 25 NTU (minimum observed, 40.1 NTU). Total suspended solids

concentrations, lakewide median 13.0 mg/l, were comparable at each in-lake site, with median surface concentration (11.0 mg/l) slightly lower than the bottom median concentration (16.0 mg/l). The euphotic zone at Heyburn Lake ranged from 0.8 to 1.8 meters with highest estimates occurring in September.

Lakewide ammonia concentrations, median 0.05 mg/l, were moderate ranging from 0.01 to 0.22 mg/l. Median lakewide bottom ammonia concentration was about two times higher than surface concentration. Nitrite plus nitrate concentrations, median 0.30 mg/l, were moderate to high. Total Kjeldahl nitrogen concentrations, median 0.63 mg/l, were moderately high. Estimated lakewide median surface total nitrogen concentration during the 2013 study was 0.93 mg/l. Total phosphorus concentrations ranged between 0.01 and 0.07 mg/l (median 0.03 mg/l). All observations of dissolved ortho-phosphate were below the analytic detection limit of 0.05 mg/l. The ratio of surface total nitrogen to total phosphorus concentrations (N:P ratio) suggested phosphorus limitation of algal growth. By sampling date, the lowest lakewide N:P ratio was observed in July (19.9) while the highest occurred in May (47.6). Lakewide median N:P ratio was 26.1.

Chlorophyll-*a* concentrations (CHLa) ranged from 2.8 to 14.4 µg/l, with a lakewide median concentration of 8.1 µg/l. Median in-lake site CHLa concentrations were comparable. Figure 4, below, shows sampling date distributions of lakewide CHLa observations. Consistent low water clarity and the resulting shallow euphotic zone likely limited algal growth. Also included in Figure 4, for comparison, is the Oklahoma Water Quality Standard CHLa criterion for Sensitive Public and Private Water Supply waterbodies (red dashed line, 10 µg/l, (OAC, 2023)).

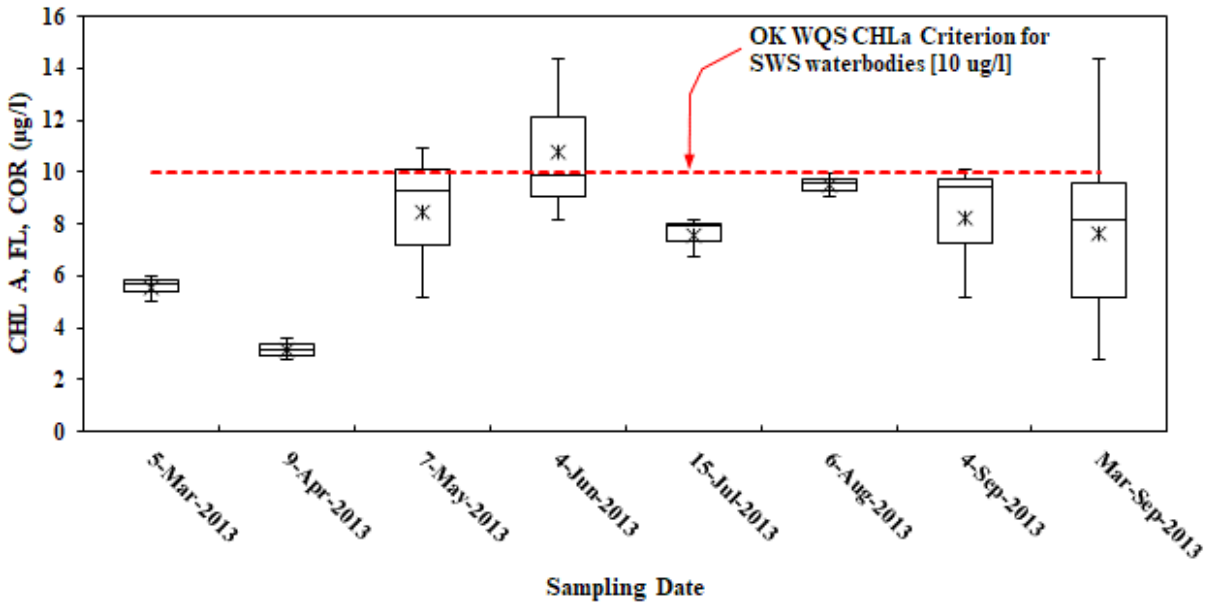

Figure 4. Chlorophyll-a concentration distributions by sampling date, and combined dates, at Heyburn Lake, OK, March through September 2013. In the box-and-whiskers, '⁎' represents mean concentration, and the horizontal bar within each box represents median concentration.

Trophic status of Heyburn Lake was assessed using all three metrics of Carlson's (Carlson, 1977) trophic state index (TSI) at each in-lake site. Shown in Figure 5, lakewide (LW) median TSI(SD) of 83.2 indicates eutrophy. The LW median based on total phosphorus [TSI(TP)] is

lower, 53.0, but still indicates enhanced lake productivity. TSI(CHLa), with a LW median value of 51.1, corresponds closely with TSI(TP).

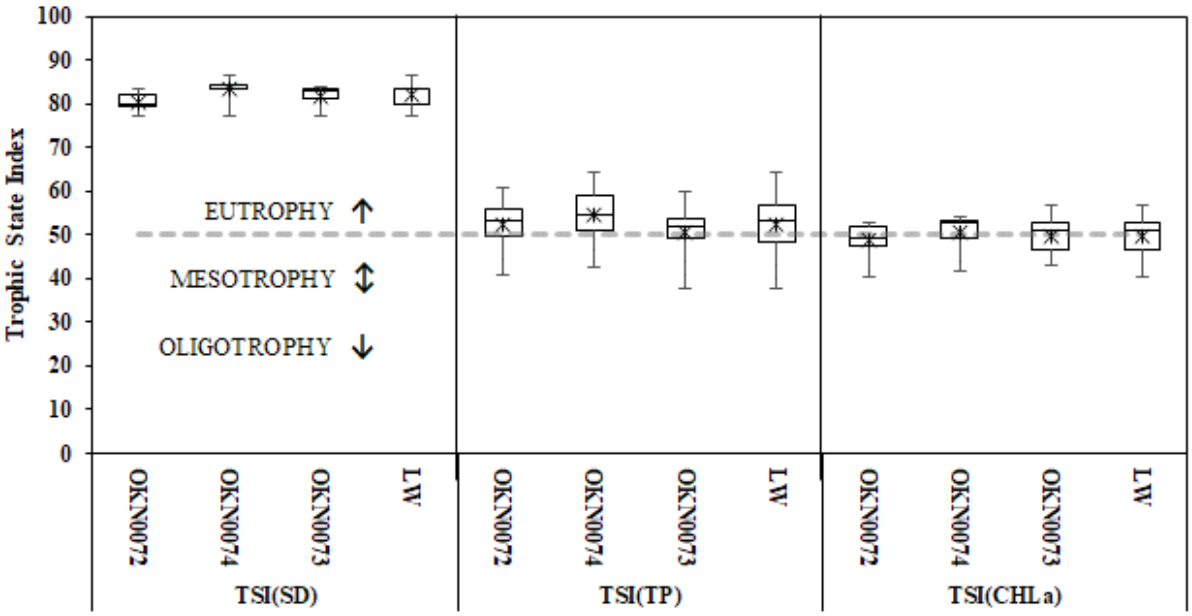

Figure 5. Distributions of Carlson's Trophic Sate Index (TSI), by sampling site and lakewide (LW), based on observations of Secchi Depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) at Heyburn Lake, OK, March through September 2013.

Total iron concentrations ranged from 0.49 to 2.49 mg/l with a median concentration of 1.08 mg/l. Total manganese concentrations ranged from 0.041 to 1.480 mg/l with a median concentration of 0.090 mg/l. Reportable concentrations of chromium, copper, lead, nickel, and zinc were found in all samples collected. Reportable concentrations of arsenic and mercury were present in 85 and 50%, respectively, of all samples collected.

Water samples were collected from the Heyburn Lake stilling basin (site HEYOKN0245) only in March, April and June. There was no discharge from the morning glory drop inlet (elevation 761.5 feet) on sampling dates in May and July through September. Generally, mean and median parameter results are directly comparable to in-lake data collected near the dam (HEYOKN0072).

USACE previously conducted water quality sampling at Heyburn Lake, OK in 1999. Thermal stratification and hypoxia in the hypolimnion were noted beginning in June. July through mid-August hypoxia began just 3 meters below the water surface at each in-lake site. With observation frequency focused on mid-summer months, median in-lake dissolved oxygen concentration was 5.1 mg/l. Lake waters were turbid (Secchi depth and turbidity medians of 0.21 meters and 109.0 NTU, respectively). High concentrations of iron and manganese were reported. Calendar year 1999 inflows and releases from Heyburn Lake were nearly ten times greater than 2013.