

Elk City Lake Water Quality: 2023

The Elk City Lake dam is located at river mile 8.7 on the Elk River, a tributary of the Verdigris River, about six miles northwest of the city of Independence in Montgomery County, Kansas (KS) within Hydrologic Unit Code 11070104. The conservation pool of Elk City Lake was first filled in June 1967 after embankment closure in March 1966. Authorized purposes of the lake include flood damage reduction, water supply, water quality, recreation, and fish and wildlife. The project was designed to provide maximum flood protection on the Elk and Verdigris Rivers and is operated in conjunction with the Arkansas River Basin System. The watershed above the Elk City Lake dam site extends northwest ~47 miles with headwaters in Butler and Greenwood Counties, KS. The watershed, with land use/cover (Dewitz, 2023) dominated by pasture/range land (67%), forest (16.7%), and cropland (12%), encompasses ~637 square miles (Figure 1). Basin elevations range from about 770 feet below the dam to ~1,675 feet. At the conservation pool elevation of 796 feet (NGVD 29), lake capacity and surface area have progressively diminished due to sedimentation. The most recent bathymetric survey conducted in 2010 indicated an annual conservation pool sedimentation rate of 340 ac-ft/yr since embankment closure reducing the original conservation pool volume by 28.8%. Descriptive characteristics of Elk City Lake are included in Table 1.

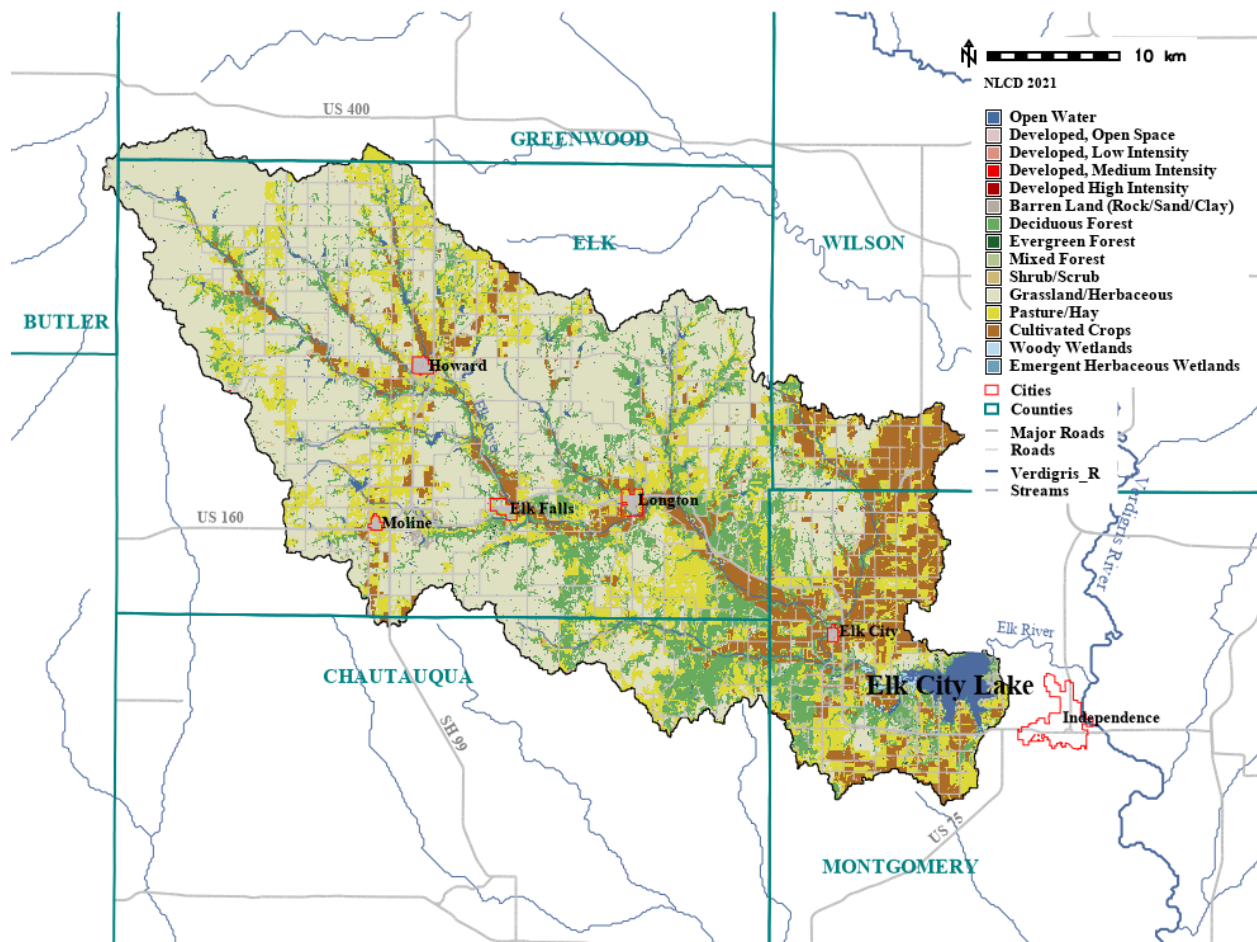


Figure 1. The Elk City Lake, KS Watershed above the Elk City Lake Dam.

Table 1. Descriptive Characteristics of Elk City Lake, KS.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	796.0 ft. NGVD	242.62 m
Lake Surface Area (Conservation Pool)	3,515 ac	1,422.47 ha
Lake Volume (Conservation Pool)	37,422 ac-ft	46,159,350 m ³
Total Drainage Area	637 mi ²	1,650 km ²
Mean Depth	10.6 ft	3.25 m
Maximum Depth (Conservation Pool)	35 ft	10.6 m
Shoreline Length	34 mi	54.7 km
Shoreline Development Index	4.2	4.2
Annual Inflow, Average 1922 – 2022 [Water Years]	296,650 ac-ft	365,912,387 m ³
Annual Inflow, 2023 [Calendar Year]	11,560 ac-ft	14,259,050 m ³
Hydraulic Residence Time, 2023 [Calendar Year]	801.9 d	2.20 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2004), the FY 2022 Annual Water Control Report (U.S. ACE - SWD RCC, 2023), Tulsa District's Water Control page for Elk City Lake (U.S. ACE - Tulsa District, 2023), and the 2010 KBS Bathymetric Survey (Kansas Biological Survey, 2011).

Use designations (KDHE, 2021) for Elk City Lake include expected aquatic life (AL), secondary contact recreation (CR), domestic water supply (DS), food procurement (FP), ground water recharge (GR), industrial water supply (IW), irrigation use (IR), and livestock watering (LW). Based on the 2022 Kansas Integrated Water Quality Assessment (KDHE, 2022), Elk City Lake is listed as impaired by eutrophication affecting aquatic life, and siltation affecting water supply.

Physical and chemical water quality data were collected by USACE approximately monthly from two in-lake sites and the stilling basin at Elk City Lake, KS beginning 4 April and ending 5 September 2023 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 ELKKSS0008 (near dam), ELKKSS0010 (mid-lake at mouth of Chetopa Creek), and ELKKSS0050 (stilling basin below the dam). 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.

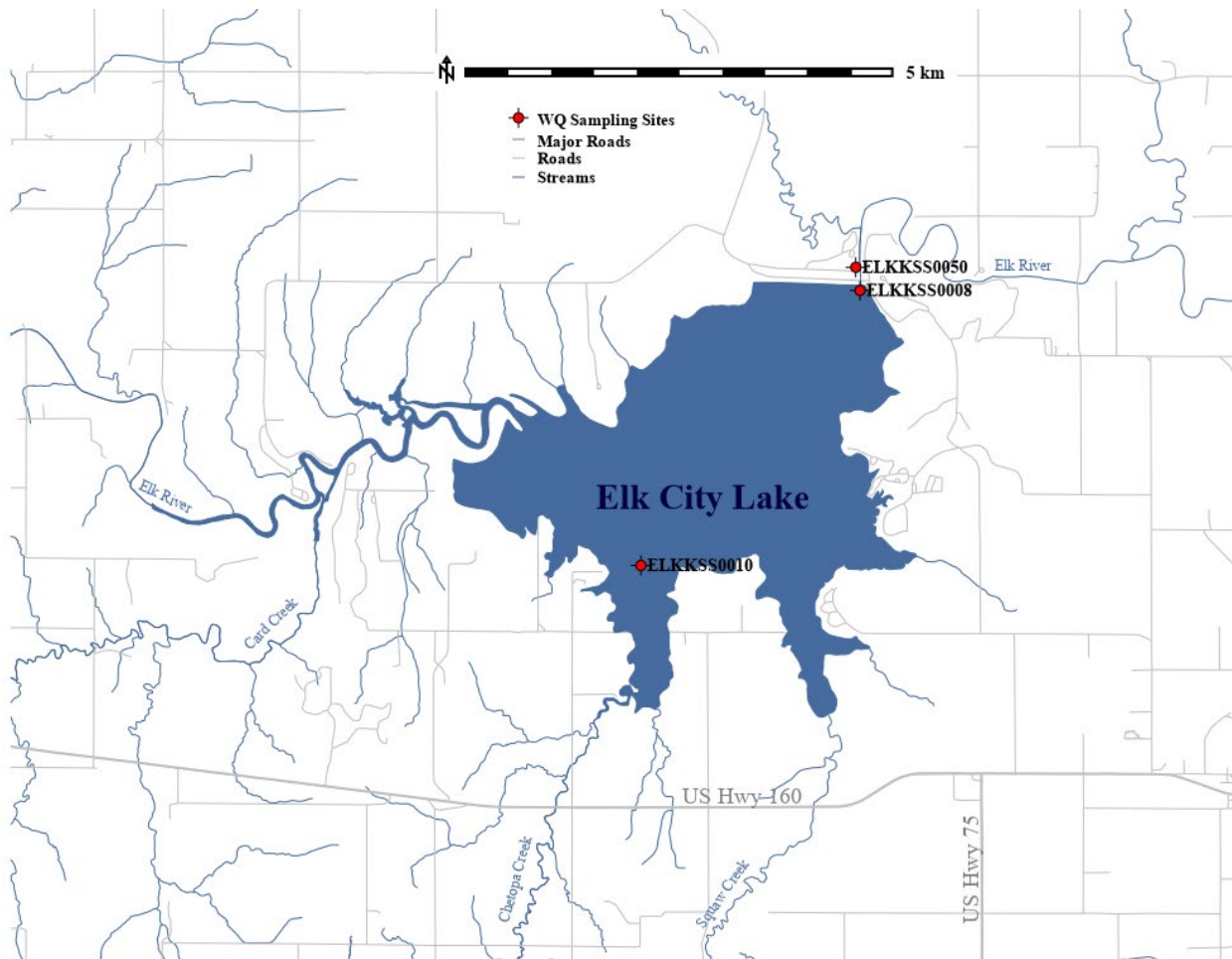


Figure 2. Locations of water quality sampling sites at Elk City Lake, KS, 2023.

Water quality in Elk City Lake, KS, during the period from April to September 2023, was influenced by the gradually diminishing pool elevation. The highest sampling date pool elevation (April, 793.33 feet) was below conservation pool elevation. Cumulative precipitation in the Elk City Lake watershed in calendar year 2023, about 25-inches, was well below the 30-year (1990 - 2020) average of about 42-inches (SCIPP, 2024). Calendar year 2023 Elk City Lake pool elevation, conservation pool elevation, basin precipitation, and water quality sampling dates are shown in Figure 3.

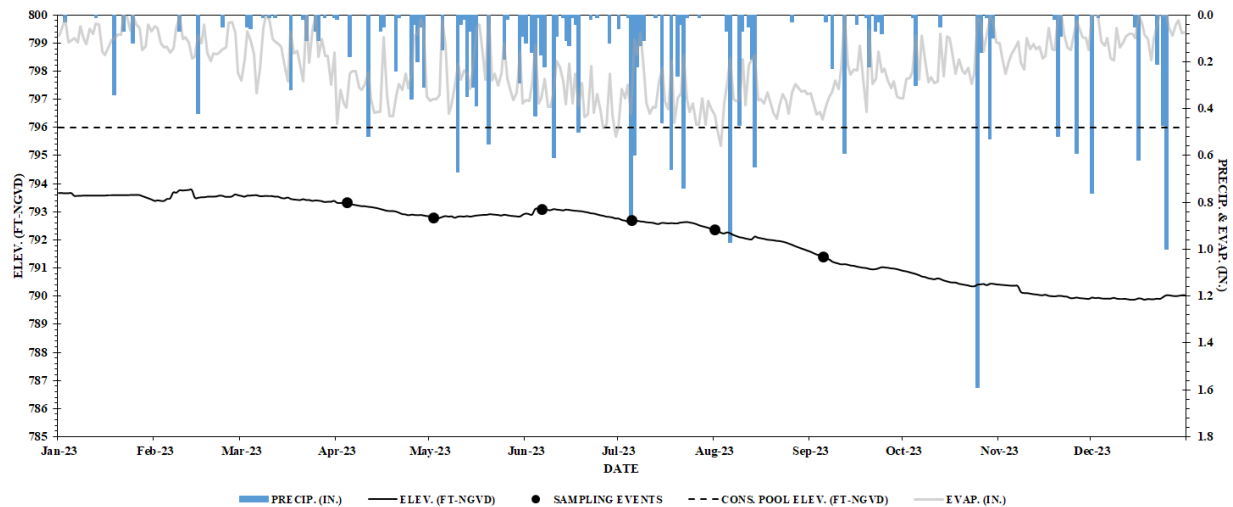


Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation (in.), and water quality sampling dates at Elk City Lake, KS, 2023.

Water temperatures varied seasonally (ranging from 15.00 to 30.28 °C) peaking in August, but lakewide water temperatures, on individual sampling dates, displayed nominal variation. The generally shallow reservoir did experience observable temporary thermal stratification from June through August at ELKKSS0008 (dam site). Observations of dissolved oxygen concentrations less than or equal to 2.0 mg/l were noted starting at depths ~6 meters below the surface at the dam site in June, July, and August. The study period median dissolved oxygen concentration was 6.96 mg/l. Lakewide total organic carbon concentrations were moderately high with a study period median of 6.81 mg/l.

Specific conductance (median 319 $\mu\text{S}/\text{cm}$) was moderately elevated, consistent with regional norms. Median observed chloride and sulfate concentrations were 6.4 and 17.8 mg/l, respectively. Alkalinity levels (median 135.5 mg/l as CaCO_3) imply a well-buffered system capable of maintaining pH levels. Hardness levels (median 143.0 mg/l as CaCO_3) indicated 'hard' water. Observed pH (7.53 to 8.50) ranged within regional norms.

The lake was consistently turbid through the 2023 study, primarily due to suspended inorganic particles. Maximum recorded Secchi depth was 0.52 meters, and the study period median was 0.27 meters. Eighty-four percent of recorded turbidity measurements were greater than or equal to 25 NTU (lakewide median 50.2 NTU). Total suspended solids concentrations (lakewide median 38.0 mg/l) were influenced by re-suspension of bottom sediment through wind and wave action. Median total suspended solids concentration at the shallower mid-lake site, ELKKSS0010, was 55.0 mg/l. The euphotic zone measured at ELKKSS0008, near the Elk City Lake dam, was between 1.4 and 1.9 meters.

Ammonia concentrations were moderate (median 0.08 mg/l), and nitrite plus nitrate concentrations were moderate to low (median 0.09 mg/l). Total Kjeldahl nitrogen concentrations (median 0.57 mg/l) were moderately elevated. Estimated total nitrogen concentration through the study period was 0.61 mg/l. Total phosphorus concentrations ranged between 0.08 and 0.15 mg/l (median 0.10 mg/l) with highest observations occurring in July. All samples revealed detectable dissolved ortho-phosphate concentrations (median 0.04 mg/l). Nitrogen to phosphorus (N:P) ratios varied little through the study period, with a lakewide study period median of 6.5, indicating a tendency toward limited nitrogen availability. Limited nitrogen

availability can provide conditions favorable for some blue-green algae (cyanophytes) that are capable of assimilating (fixing) atmospheric nitrogen.

Chlorophyll-*a* concentrations ranged from 8.7 to 40.7 µg/l through the study period, with a median concentration of 18.4 µg/l, indicating a productive system. Highest lakewide chlorophyll-*a* concentrations were observed in July (lakewide average >30 µg/l). Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton sampled at select Elk City Lake sites. Abundance of varying phytoplankton divisions remained relatively stable through the sampled period, while relative biovolume reveals the varying seasonal representation influenced by site specific characteristics. Figure 5 summarizes zooplankton densities observed in 2023 (note the log scale density axis). Cladocerans, Copepods, and Rotifers were generally well represented across the sampling period, while notable Ostracod and Bivalve densities (exclusively *Dreissena*, or zebra mussel, veligers) were highly seasonal.

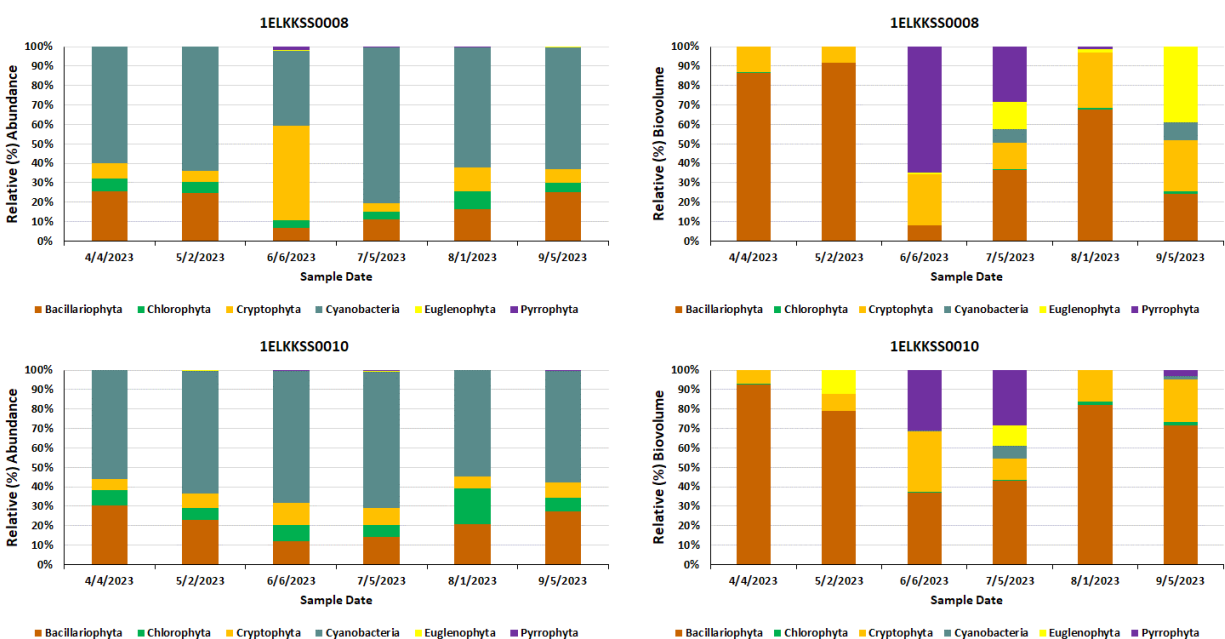


Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at ELKKSS0008 and ELKKSS0010 April through September 2023.



Figure 5. Zooplankton density at ELKKSS0008 and ELKKSS0010 April through September 2023.

The trophic status of Elk City Lake during the 2023 study period, assessed by Carlson's trophic state index (TSI) based on chlorophyll-*a* concentrations (TSI (CHLa)) resulted in a median index value of 59.1, indicating a eutrophic lake (Figure 4). TSI (CHLa) reflects algal productivity

moderated by high levels of inorganic turbidity (TSI(SD) median 79.2) limiting the depth of the euphotic zone, and suspended sediment-bound growth nutrients (TSI(TP) median 70.1).

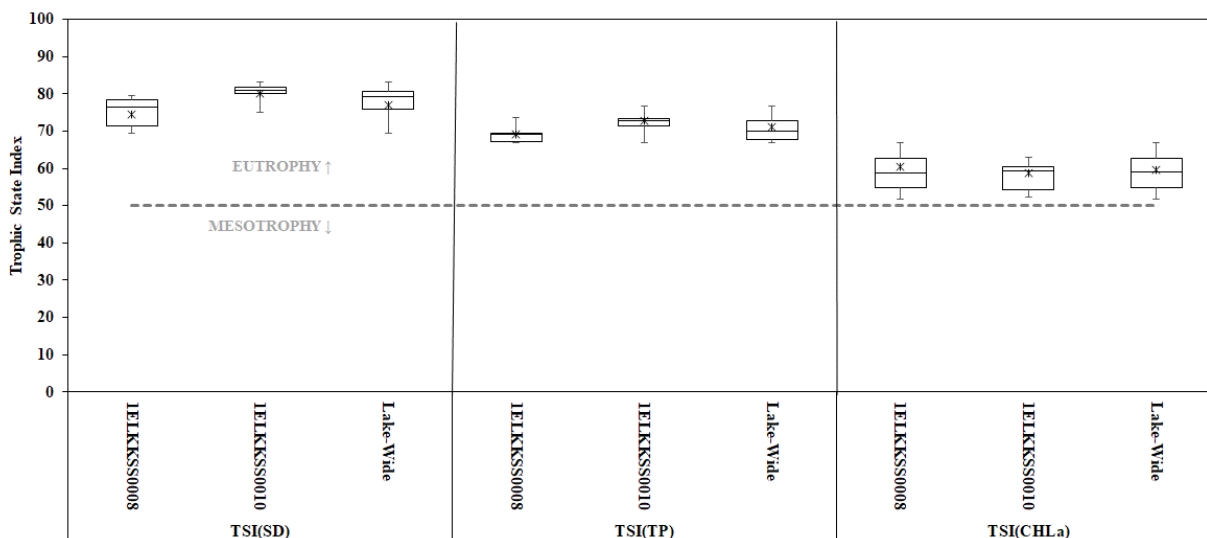


Figure 6. Distributions of Carlson's Trophic State Index based on observations of Secchi depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-a concentrations (TSI(CHL a)), at ELKKSS0008, ELKKSS0010, and lakewide at Elk City Lake, 4 April through 5 September 2023.

Total iron (median 0.78 mg/l) and manganese (median 0.12 mg/l) concentrations were high. Median iron concentration was higher at ELKKSS0010 (0.99 mg/l) than at ELKKSS0008 (0.68 mg/l). Observed manganese concentrations exceeded the recommended criterion (0.05 mg/l) in all in-lake samples. Reportable low concentrations of arsenic were found in all in-lake samples collected, with a median concentration of 0.0034 mg/l. Reportable concentrations of chromium, copper, lead, nickel, and zinc were found in all samples collected. One (of twenty-four) detectable mercury concentration was noted.

Water samples were collected each sampling trip from the stilling basin below the Elk City Lake dam at site ELKKSS0050. Generally, mean and median parameter results mirrored in-lake data collected from the lake bottom near the dam (ELKKSS0008).

USACE contracted a water quality study of Elk City Lake, KS in 1980 and noted mercury concentrations occasionally exceeded U.S. EPA water quality criteria (1976). A 1992 USACE-Tulsa District study encountered brief weak thermal stratification. Surface total phosphorus concentrations indicated hyper-eutrophy while chlorophyll-a concentrations indicated mesotrophy. Mercury was present in water samples and identified as a concern due to the potential for human consumption of concentrated quantities in fish tissues. A water quality study at Elk City Lake in 2008 found a consistently turbid lake with relatively high nutrient levels, high iron and manganese concentrations, and chlorophyll-a concentrations indicating a mesotrophic lake. Hydraulic residence time at Elk City Lake in calendar year 2008 was 0.08 years, significantly lower than calendar year 2023 (2.20 years).