Wister Lake Water Quality: 2014, 2016

The Wister Lake dam is located on the Poteau River at river mile 60.9, about 2 miles south of Wister in Le Flore County, Oklahoma (OK). The reservoir extends west-southwest of the dam almost seven miles to the Fourche Maline Creek mouth. A broad mid-lake arm of the lake, trending south-southeast, follows the Poteau River channel. Wister Lake is a multiple purpose project authorized for flood control, water supply, and navigation. The project is also operated to benefit recreation, and fish and wildlife. The project was designed to provide maximum flood protection on the Poteau River from the dam to the confluence with the Arkansas River. The project also provides flood control benefits on the Arkansas River below the confluence of the Poteau River when operated in conjunction with the other flood control projects in the Arkansas River Basin. The lake and watershed are within Hydrologic Unit Code 11110105 (Poteau). Construction began in April 1946, final storage began in October 1949, and the conservation pool was filled in December 1949. The conservation pool was raised from 474.6 to 478.0 feet NGVD in 1996. The drainage area above the dam is 993 square miles extending from east of Waldron, in Scott County, Arkansas almost 80 miles west beyond Wilburton in Latimer County, OK averaging ~14 miles in width north to south (Figure 1). Land use/cover (Dewitz, 2019) is dominated by forest (74.4%) and pasture/grassland (17.8%). Bathymetric surveys conducted in 2011 (OWRB, 2012) and 2017 (Bowen Engineering & Surveying, Inc., 2017) support estimations of reduced lake capacity at conservation pool elevation (478.0-feet NGVD) of about 17.5% since impoundment due to sedimentation. Descriptive characteristics of Wister Lake are included in Table 1.

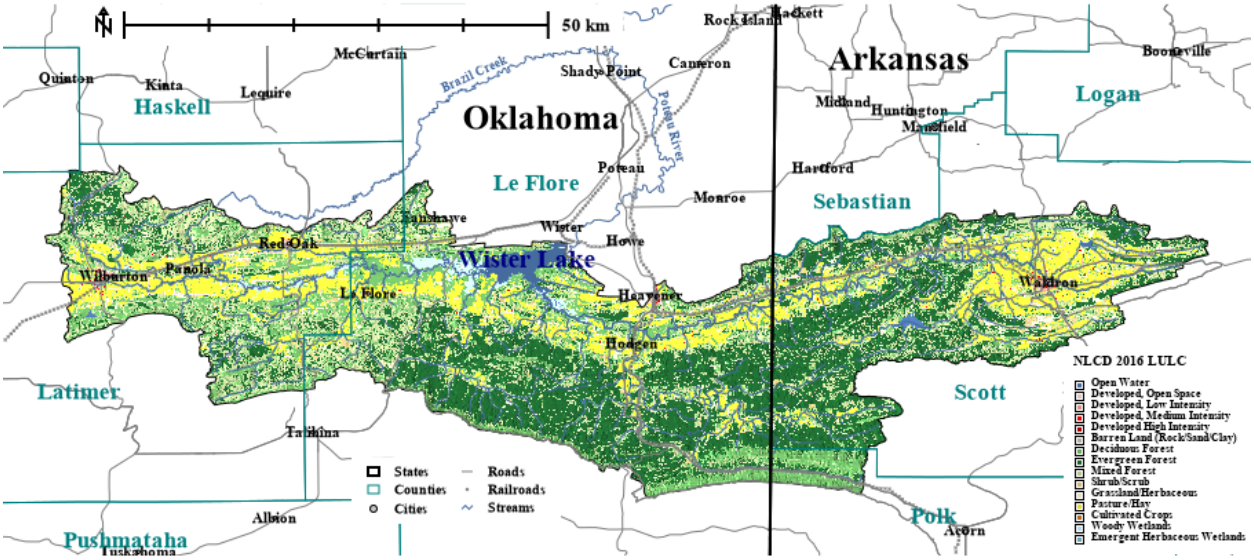

Figure 1. The Wister Lake (Poteau River) Watershed above the Wister Lake Dam.

Table 1. Descriptive Characteristics of Wister Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	478.0 ft NGVD	145.69 m
Lake Surface Area (Conservation Pool)	6,882 ac	2,785 ha
Lake Volume (Conservation Pool)	50,737 ac-ft	$62.583*10^6$ m^3
Drainage Area	993 mi^2	2,572 km^2
Mean Depth	7.4 ft	2.26 m
Maximum Depth (Conservation Pool)	38 ft	11.6 m
Shoreline Length	91.3 mi	146.93 km
Shoreline Development Index	8.2	8.2
Annual Inflow, Average 1939 – 2016 [Water Years]	851,100 ac-ft	$1,049.82*10^6$ m^3
Annual Inflow, 2016 [Calendar Year]	476,116.35 ac-ft	$587.28*10^6$ m^3
Hydraulic Residence Time, 2016 [Calendar Year]	59.52 d	0.16 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2021), the FY 2016 Annual Water Control Report (U.S. ACE - SWD RCC, 2017), Tulsa District's Water Control page for Wister Lake (U.S. ACE - Tulsa District, 2024), and bathymetric surveys (OWRB, 2012; Bowen Engineering & Surveying, Inc., 2017).

Designated beneficial uses of the impoundment created by the Wister Lake Dam include Public and Private Water Supply, Fish and Wildlife Propagation as a Warm Water Aquatic Community, Agriculture, Primary Body Contact Recreation, and Aesthetics. The reservoir and watershed are designated as a Nutrient-Limited Watershed (OAC, 2023). Based on the biennial Integrated Water Quality Assessment prepared by the Oklahoma Department of Environmental Quality (ODEQ, 2022), Wister Lake (Waterbody ID: OK220100020020_00) is listed as impaired by: algal concentrations affecting Public and Private Water Supply; mercury concentrations affecting Fish Consumption; low pH and turbidity affecting the Warm Water Aquatic Community; and phosphorus concentrations affecting Aesthetics.

Physical and chemical water quality data were collected July through September 2014 and June through September 2016 by CESWT-ODR from five in-lake sites and the tailwater to define existing limnological conditions, provide a basis for future water quality investigations, and to support operational and environmental missions of the Tulsa District. Water quality sampling in 2014 and 2016 aligned with a Poteau Valley Improvement Authority nutrient inactivation project. Sampled sites included WISOKS0090 (channel at the dam), WISOKS0290 (between Victor and Wister Public Use Areas (PUA)), WISOKS0292 (W of Victor PUA), WISOKS0293 (W of Fanny Creek Cove), WISOKS0291 (Quarry Cove), and WISOKS0082 (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.

The source of Fourche Maline Creek is in the hill region north of Wilburton, OK. It flows easterly through a wide valley that drains the Sans Bois Mountains on the north and the Winding Stair Mountains to the south. The Fourche Maline, with an average annual flow rate of 441 cfs (2011-2015), joins the Poteau River at Wister Lake. The main stem of the Poteau River flows westerly from its source in the mountainous region east of Waldron, Arkansas. The river flows about 70 miles through a valley that drains the Poteau Mountains to the north and the Black Fork and Winding Stair Mountains to the south before it joins the Fourche Maline at Wister Lake. The Black Fork River is the main tributary of the upper part of the Poteau River. Average annual flow rate of the Poteau River entering Wister Lake for the period 2011 through 2015 was 1,250 cfs.

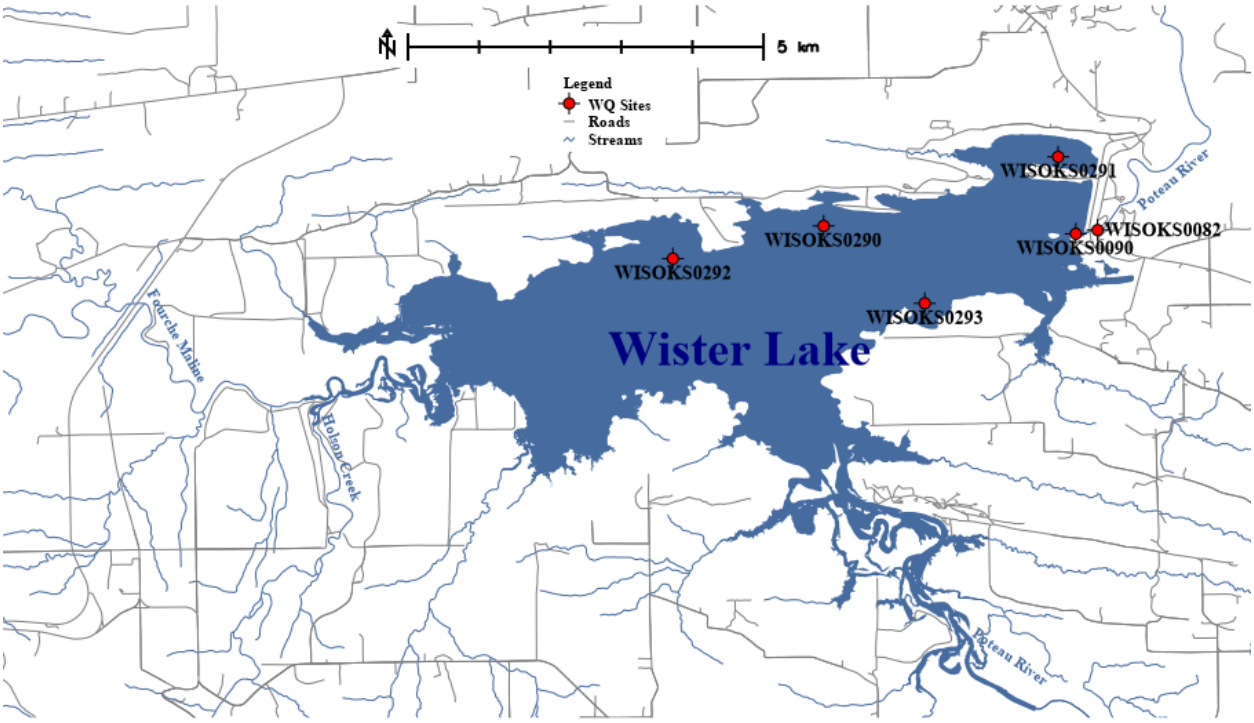

Figure 2. Locations of water quality sampling sites at Wister Lake, OK in 2014 and 2016.

Mean annual temperature in nearby Wister, OK is 60.3 °F and average annual precipitation is 49.9 inches (1981 – 2010 normals). On average, wettest months are April, May, and September. In calendar year 2014, recorded basin precipitation was 52.99 inches. Calendar year 2015 annual basin precipitation was 96.9 inches with higher than normal precipitation in March and April, and ~20 inches in May (325% of normal May precipitation). Pool elevation in 2015 peaked at >30 feet above conservation elevation in late May 2015, precluding water quality sampling efforts. Late calendar year 2015 precipitation (November and December) was also significantly higher than normal. Annual basin precipitation in calendar year 2016 was 37.7 inches. Lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling events for calendar years 2014 through 2016 are shown in Figure 3.

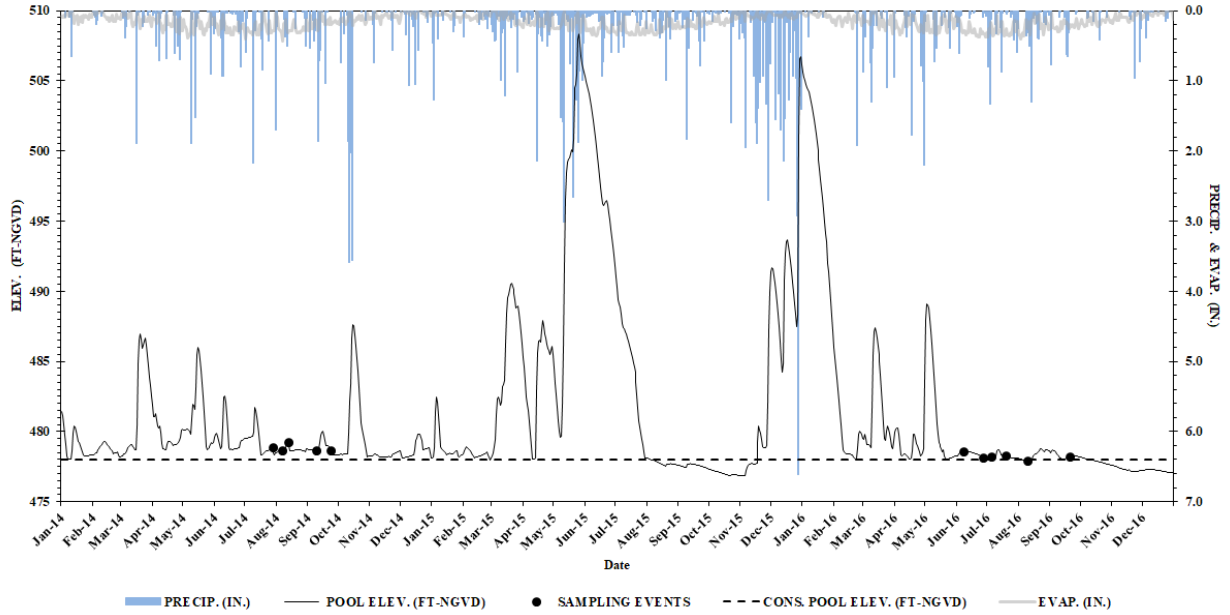

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Wister Lake, OK, 2014 through 2016.

Water temperature ranged from 23.28 to 30.59 ºC in 2014, and 20.63 to 31.34 ºC in 2016. All recorded water temperatures <23 ºC in 2016 were observed in June. Surface water temperatures >30 ºC were recorded in July 2014, and June through August in 2016. Thermal stratification was evident in August 2014 at WISOKS0090 and WISOKS0290 with hypoxia (dissolved oxygen concentration <2 mg/l) beginning at 3 to 5 meters and 2 to 4 meters depth, respectively. The Quarry Cove site (WISOKS0291) exhibited thermal stratification July through early September 2014 with hypoxia beginning at 2 to 4 meters depth. In 2016, stratification was noted at WISOKS0090, WISOKS0290, and WISOKS0291 beginning June and continuing through August with anoxia (dissolved oxygen concentration <0.5 mg/l) in later July and early August beginning at 4 to 5 meters depth. Lakewide median dissolved oxygen (DO) concentration was 4.63 mg/l in 2014 and 5.63 mg/l in 2016. DO observations ranged from 0.0 to 7.91 mg/l in 2014, and 0.14 to 9.91 mg/l in 2016. Site median DO concentrations were lowest at sites with significant hypoxia or anoxia (WISOKS0090, WISOKS0290, and WISOKS0291). Lakewide, total organic carbon concentrations were moderate in 2014 with a median of 4.7 mg/l, and significantly higher in 2016 with a median of 7.5 mg/l. Lakewide total organic carbon concentration range in 2014 was 4.1 to 5.3 mg/l, and the range in 2016 was 6.4 to 17.6 mg/l with the highest concentration in a bottom sample (8 meters depth) at WISOKS0090 in July.

Specific conductance ranged from 70.0 to 107.0 µS/cm in 2014 (lakewide median 84.0 µS/cm). Conductance observations in 2016 were comparable ranging from 60.0 to 116.0 µS/cm (median 76.5 µS/cm). Total dissolved solids lakewide median concentration was 77.15 mg/l in 2014, and 60.0 mg/l in 2016. Lakewide chloride and sulfate concentrations (medians 3.20 and 9.16 mg/l, respectively, in 2014; and 2.85 and 8.95 mg/l, respectively, in 2016) were similar across sampling periods. Alkalinity levels were low in both years, median 20.9 mg/l as $CaCO_3$ in 2014 and median 21.3 mg/l as $CaCO_3$ in 2016, and imply a system moderately susceptible to unstable pH levels. Observed in-lake pH ranged from 6.50 to 8.86 in 2014, and 6.76 to 8.96 in 2016. Highest pH observations in 2014 were found near the surface in August. In 2016,

highest pH observations were observed near the surface in June and July. Hardness levels, median 22.9 mg/l as $CaCO_3$ in 2014 and 22.0 mg/l as $CaCO_3$ in 2016, indicate 'soft' water.

Lakewide median Secchi depth was 0.55 meters (2014) and 0.54 meters (2016). Lowest site Secchi depth observations occurred at upper lake sites (WISOKS0292 and WISOKS0293) each year. Lakewide median turbidity was 25.0 NTU in 2014 and 26.6 NTU in 2016. 51% and 56% of turbidity observations were ≥25 NTU in 2014 and 2016, respectively. Median lakewide total suspended solids concentrations were 9.0 mg/l in 2014 and 10.0 mg/l in 2016. Medians of surface total suspended solids observations were significantly lower than median bottom observations in both years. The euphotic zone ranged from 1.5 to 2.7-meters in 2014 peaking in August. In 2016, measured euphotic zone depth ranged from 1.7 to 2.7-meters peaking in August.

Lakewide median ammonia concentrations in 2016 (median 0.13 mg/l) were nearly two times higher than 2014 (0.07 mg/l). Nitrite plus nitrate concentrations were generally low with highest detectable concentrations in September 2014 (0.03 to 0.15 mg/l). All observed nitrite plus nitrate concentrations in 2016 were below the analytical detection limit. Total Kjeldahl nitrogen concentration median in 2014 (1.80 mg/l) was more than two times higher than the 2016 median (0.64 mg/l). Consequently, estimated lakewide median surface total nitrogen concentration in 2014 (1.68 mg/l) was significantly higher than in 2016 (0.65 mg/l). Total phosphorus concentrations in 2014 ranged from 0.01 to 0.09 mg/l with a lakewide median of 0.02 mg/l. Total phosphorus concentrations in 2016 ranged from 0.01 to 0.20 mg/l with a lakewide median of 0.05 mg/l. All observations of dissolved ortho-phosphate in 2014 were below the analytical detection limit (<0.05 mg/l). In 2016, 4 of 40 observations of dissolved ortho-phosphate revealed detectable concentrations with the highest, 0.035 mg/l, from a WISOKS0291 bottom sample. Lakewide surface total nitrogen to phosphorus ratio (N:P) in 2014 was 77.2, and in 2016, 20.6. N:P ratios >10 indicate a tendency toward phosphorus limitation of phytoplankton growth.

Chlorophyll-*a* (CHLa) concentrations ranged from 7.4 to 23.2 µg/l in 2014, and from 15.0 to 41.3 µg/l in 2016, with lakewide medians of 14.5 and 27.5 µg/l, respectively. As a designated Nutrient-Limited Watershed, OK Water Quality Standards (OAC, 2023) define a CHLa criterion for Wister Lake at 10 µg/l. Wister Lake sampling site CHLa distributions by year, compared to the criterion, are shown in Figure 4.

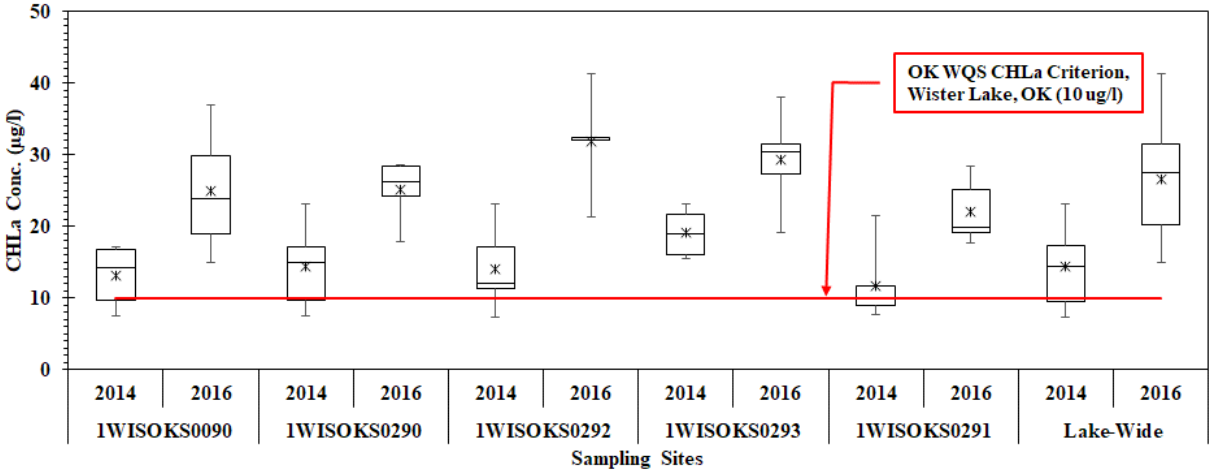

Figure 4. Wister Lake CHLa concentration distributions by sampling site and year (2014, 2016).

Trophic status of Wister Lake was assessed using all three metrics of Carlson's trophic state index (TSI (Carlson, 1977)) at each lake site and the lake as a whole, for each year (2014 and 2016). Median lakewide indexes based on Secchi depth (TSI(SD)) were similar for each year (68.6 and 69.4). TSI based on CHLa concentrations (TSI(CHLa)) in 2014 and 2016, 56.8 and 63.1, respectively, indicated eutrophy. The median lakewide TSI value based on surface total phosphorus concentrations (TSI(TP)) in 2014, 47.1, was lower than the 2016 TSI(TP) of 58.7 (Figure 5).

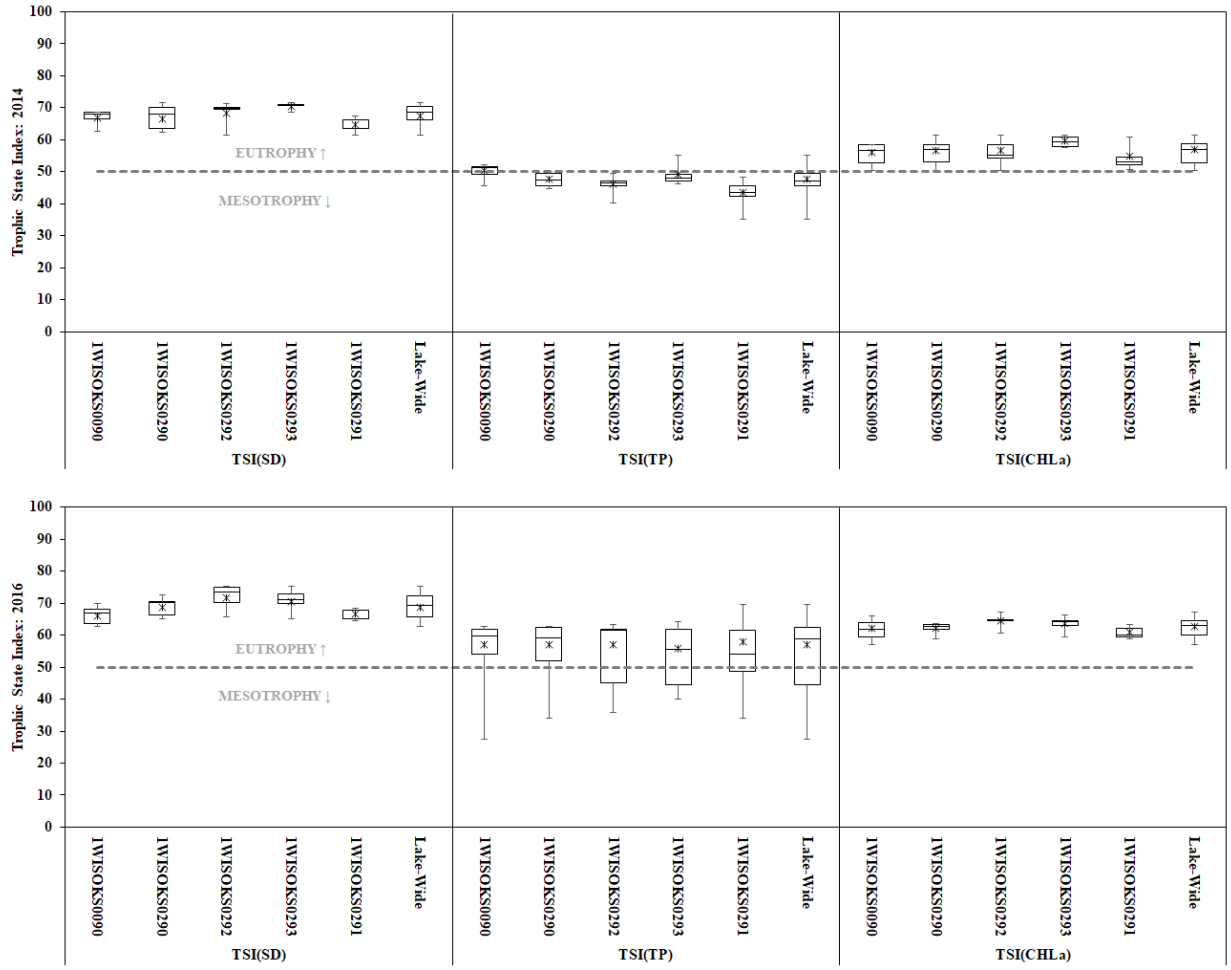

Figure 5. Distributions of Carlson's Trophic State Index (TSI), by sampling site, lakewide, and year (2014, top; 2016, bottom), based on Secchi depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) at Wister Lake, OK.

Total iron and manganese concentrations were moderate to high each sampled year (lakewide medians 0.39 and 0.0.22 mg/l (2014), and 0.37 and 0.40 mg/l (2016), respectively. Median bottom sample total iron and manganese concentrations were at least two times higher than surface medians. Highest iron and manganese concentrations were from bottom samples at depth at WISOKS0090 and WISOKS0291. Reportable concentrations of arsenic, copper, and nickel were noted in all in-lake samples each year. Reportable concentrations of chromium, lead, and zinc were present in >65% of all samples collected each year. No detectable mercury concentrations were noted in 2014, but in 2016, 35% of samples collected had reportable concentrations.

Water quality data collected from WISOKS0082 (tailwater) was generally comparable to data collected at WISOKS0090 (dam site, bottom samples).

The Oklahoma Water Resources Board prepared a 2001 water quality study of Wister Lake for USACE (OWRB, 2003). Analysis of water quality data, collected from May through October 2001, revealed elevated turbidity, seasonally elevated chlorophyll-a concentrations, and a 90-day mid-summer anoxic hypolimnion of significant volume (estimated as 35.9% of total conservation pool volume).