Great Salt Plains Lake Water Quality: 2020

The Great Salt Plains Lake dam is located in Alfalfa County, Oklahoma (OK) a at river mile 103.3 on the Salt Fork of the Arkansas River, about twelve miles east of Cherokee, OK. The impoundment extends about six miles southwest of the dam, and the watershed is oriented northwest of the dam and is roughly eighty-five miles long and forty-five miles wide. The lake is within Hydrologic Unit Code (HUC) 11060004, and the watershed includes HUCs 11060002 and 11060003. It is a multi-purpose project for flood control and conservation, including recreation and fish and wildlife. Construction began September 1938, and the conservation pool was filled in November 1941. The next structure downstream on the Arkansas River is Keystone Lake. Kaw Lake and Keystone Lake are operated as a system with Great Salt Plains Lake in the multi-purpose plan for flood control, hydropower, navigation, and allied water uses on the Arkansas River and its tributaries. The total drainage area above the dam is ~3,155 square miles including headwaters in Comanche, Kiowa, Pratt, and Harper Counties in Kansas; and Woods County, OK (Figure 1). Land use/cover (Dewitz, 2023) in the basin is dominated by grassland/pasture (64%), and cropland (29%). Based on 2010 LiDar acquisition (Wilson & Company, Inc., 2010), at the conservation pool elevation of 1,125.0 feet (NGVD 29), lake capacity had diminished by more than 50% since completion due to sedimentation. Descriptive characteristics of Great Salt Plains Lake are included in Table 1.

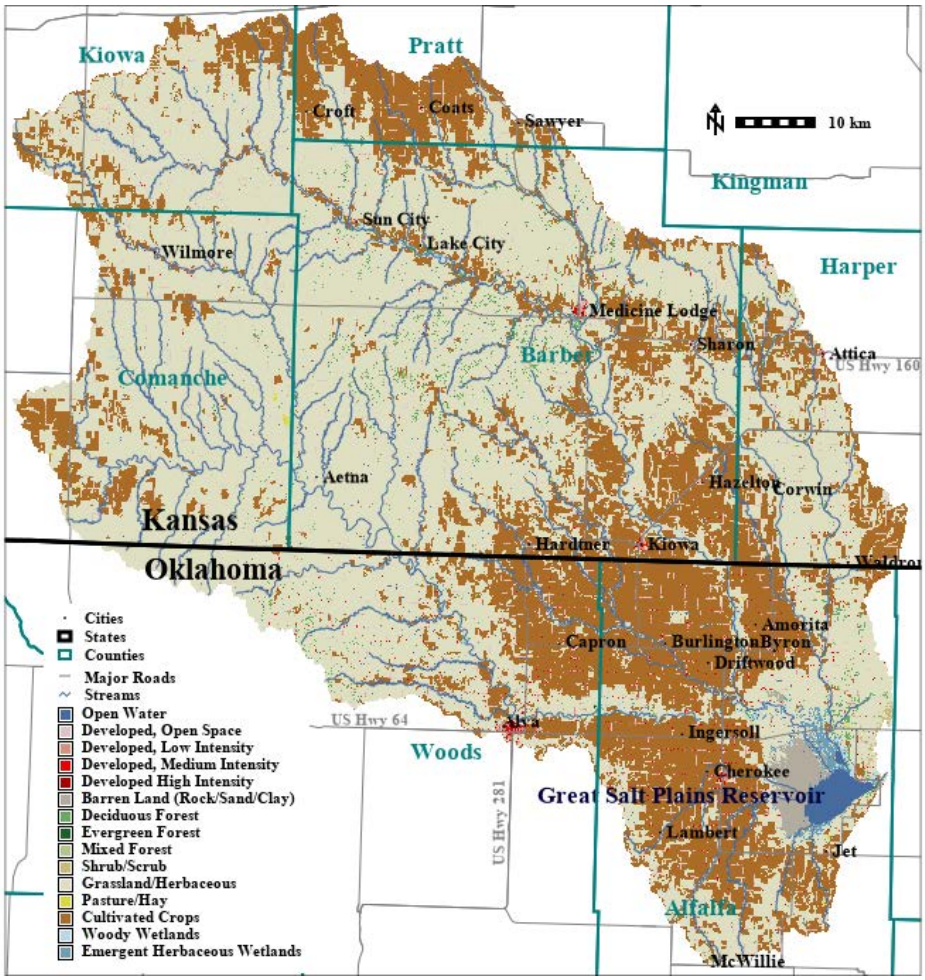

Figure 1. The Great Salt Plains Lake (Salt Fork of the Arkansas River) Watershed above the Great Salt Plains Dam.

Table 1. Descriptive Characteristics of Great Salt Plains Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	1,125 ft. NGVD	342.9 m
Lake Surface Area (Conservation Pool)	8,375 ac	3,389 ha
Lake Volume (Conservation Pool)	26,409 ac-ft	$32.575*10^6$ m^3
Total Drainage Area (contributing)	3,155 mi^2	8,171 km^2
Mean Depth	3.15 ft.	0.96 m
Maximum Depth (Conservation Pool)	20.0 ft.	6.1 m
Shoreline Length	24.4 mi	39.3 km
Shoreline Development Index	1.91	1.91
Annual Inflow, Average 1923 – 2020 [Water Years]	358,880 ac-ft	$442.67*10^6$ m^3
Annual Inflow, 2020 [Calendar Year]	373,031 ac-ft	$460.13*10^6$ m^3
Hydraulic Residence Time, 2021 [Calendar Year]	31.6 d	0.09 yr

Data derived from the Tulsa District's Pertinent Data Book (U.S. ACE - Tulsa District, 2004), the FY 2020 Annual Water Control Report (U.S. ACE - SWD RCC, 2021), Tulsa District's Water Control page for Great Salt Plains Lake (U.S. ACE - Tulsa District, 2023), and 2010 LiDar data (Wilson & Company, Inc., 2010).

Designated beneficial uses of the impoundment created by the Great Salt Plains Lake Dam include Fish and Wildlife Propagation as a Warm Water Aquatic Community, Primary Body Contact Recreation, Aesthetics, and the entire watershed above the dam is designated as a Nutrient Limited (adversely affected by excess nutrients) Watershed (OAC, 2023). Based on the 2022 Integrated Water Quality Assessment prepared by the Oklahoma Department of Environmental Quality (ODEQ 2022), Great Salt Plains Lake is listed as impaired by turbidity affecting Fish and Wildlife Propagation as a Warm Water Aquatic Community, and *Enterococcus* (indicative of contamination by fecal waste) affecting Primary Body Contact Recreation.

Physical and chemical water quality data were collected monthly by USACE from two in-lake sites and one site below the dam beginning 8 June and ending 9 September 2020 to define existing limnological conditions, provide a basis for future water quality investigations, and to support operational and environmental missions of the Tulsa District. 12,000 acres of salt flats are adjacent to the reservoir, and water from the Salt Fork of the Arkansas River typically carries high concentrations of dissolved solids as it enters Oklahoma. The salt plains consist principally of alluvial sand saturated with salt water, with surface salt incrustation formed by evaporation. In certain areas, gypsum and salt solutions in the sand are sufficiently concentrated to promote growth of selenite crystals. Sampled sites included GSPOKN0246 (dam at spillway), GSPOKN0247 (near Sandy Creek mouth at Sandy Beach), and GSPOKN0268 (below stilling basin). In-lake sites were inaccessible by boat due to shallow lake depth. GSPOKN0246 was accessed from the spillway structure, samples for GSPOKN0247 were collected from a boat ramp near the desired location, and GSPOKN0268 samples were collected from the State Highway 38 bridge over the Salt Fork of the Arkansas River below the dam. Sampling locations are identified in Figure 2.

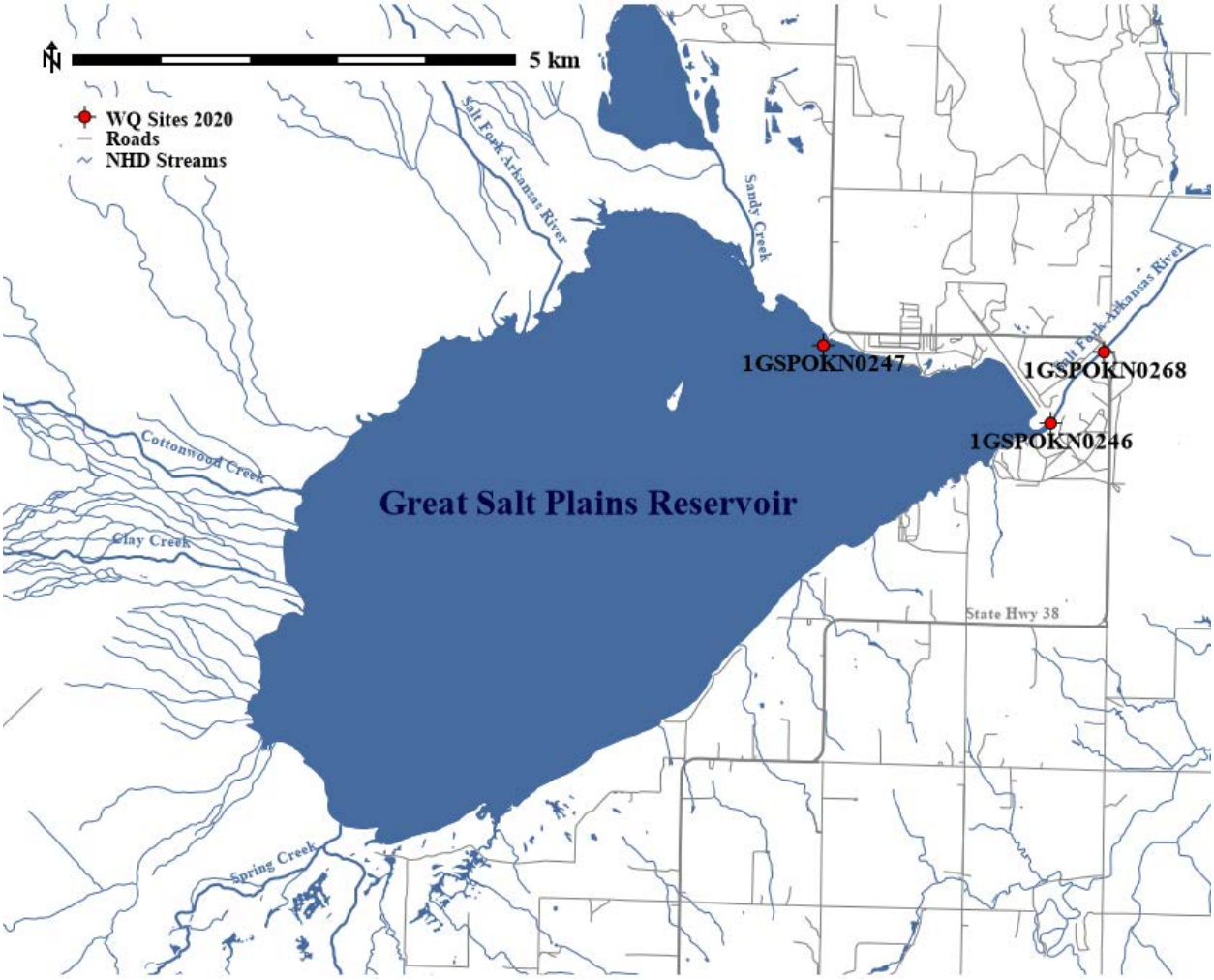

Figure 2. Locations of water quality sampling sites at Great Salt Plains Lake, OK, 2020.

The Great Salt Plains Lake pool was near the conservation pool elevation June through September. Calendar year 2020 lake elevation, conservation pool elevation, basin precipitation, calculated evaporation rate, and water quality sampling events are shown in Figure 3. Water quality samples were not collected in April and May 2020.

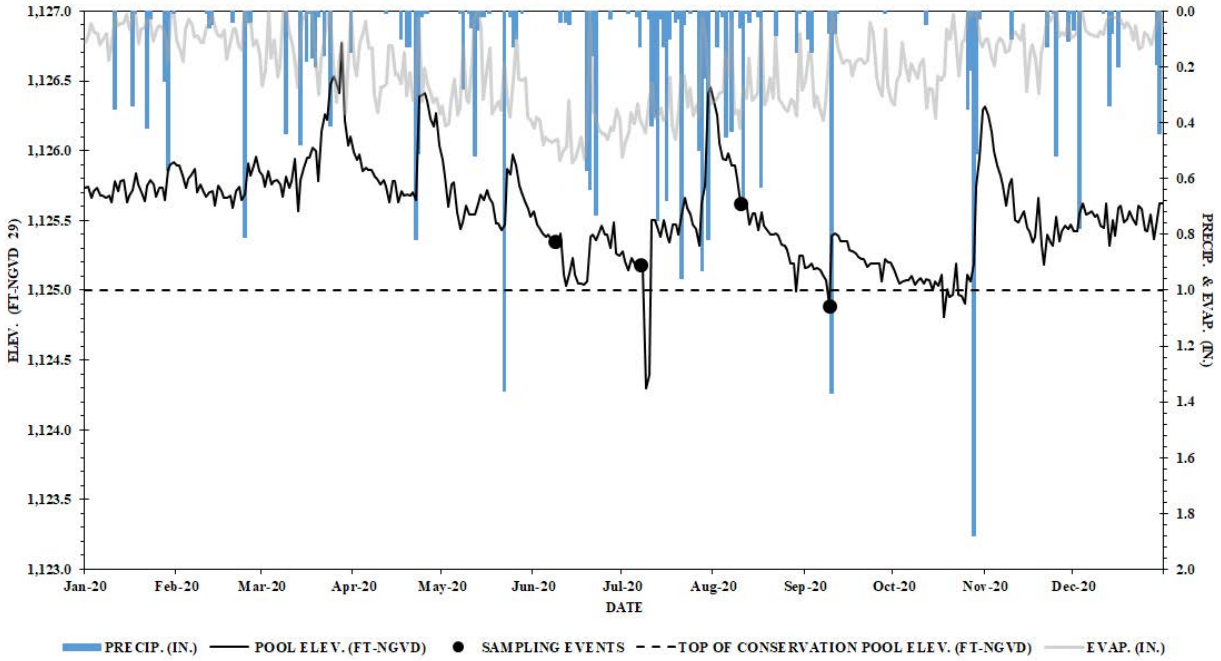

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Great Salt Plains Lake, OK, 2020.

In-lake water temperatures varied seasonally (ranging from 15.32 to 28.31 ºC) peaking near the surface in July. Water temperature observations <18 ºC occurred in September 2020 at depth (4-meters) at GSPOKN0246, and at GSPOKN0247. Thermal stratification was not noted although vertical profiles indicated decreasing water temperature from surface to depth in June and July at GSPOKN0246. The study period lake-wide median dissolved oxygen concentration (DO) was 4.22 mg/l. Median DO was lowest at GSPOKN0246 (3.76 mg/l) and highest at GSPOKN0247 (8.48 mg/l). Observed in-lake DO ranged from 1.87 to 9.63 mg/l. All DO observations at GSPOKN0246 in July and September 2020, surface to depth, were <3.5 mg/l. Highest DO concentrations were observed at GSPOKN0246 in August, surface to depth (8.21 to 8.73 mg/l), and at GSPOKN0247 (surface, 9.63 mg/l) in September. Lake-wide total organic carbon concentrations were high with an in-lake study period median of 13.45 mg/l.

Specific conductance (median 6,627 µS/cm) was high, consistent with regional geology. Total dissolved solids median concentration was 3,915 mg/l. High chloride and sulfate concentrations (medians 1,765.0 and 601.5 mg/l, respectively) were observed. Alkalinity levels (median 120.0 mg/l as $CaCO_3$) imply a system capable of maintaining pH levels. Hardness levels, median 664.0 mg/l as $CaCO_3$, indicate 'very hard' water. Observed in-lake pH (7.84 to 8.78) ranged within regional norms. Highest pH was recorded at GSPOKN0246 in July and August, surface to depth, and lowest was recorded in September, surface to depth at GSPOKN0246.

Median Secchi depth was 0.15 meters, ranging from 0.10 to 0.20 meters. In-lake median turbidity was 111.75 NTUs. Only one in-lake turbidity observation, at GSPOKN0247 in July (47.7 NTUs), was <50 NTUs. Median in-lake total suspended solids concentration was 105 mg/l, ranging from 24 to 205 mg/l. The euphotic zone at Great Salt Plains Lake ranged around 0.5 meters.

Lake-wide ammonia concentrations (median 0.43 mg/l) were high, and nitrite plus nitrate concentrations (median 0.03 mg/l) were low. Total Kjeldahl nitrogen concentrations (in-lake median 1.64 mg/l) were high. Estimated lake-wide median surface total nitrogen concentration during the 2020 study was 1.63 mg/l. Total phosphorus concentrations lake-wide ranged between 0.31 and 0.85 mg/l (median 0.57 mg/l). Detectable concentrations of dissolved ortho-phosphate, median 0.04 mg/l, were present in all samples collected. Nitrogen to phosphorus ratios (N:P) in 2020 were <10 (median 3.44) indicating a tendency toward limited nitrogen availability and the potential for phytoplankton dominance by cyanophytes.

Chlorophyll-a concentrations (in-lake) ranged from 28.1 to 94.0 µg/l, with a median concentration of 64.6 µg/l. Median GSPOKN0247 chlorophyll-a concentration (59.5 µg/l) was lower than median GSPOKN0246 concentration (75.5 µg/l). Highest chlorophyll-a concentrations were observed at GSPOKN0246 in August (90.5 µg/l), and both GSPOKN0246 (92.0 µg/l) and GSPOKN0247 (94.0 µg/l) in September. Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton sampled at Great Salt Plains Lake site GSPOKN0246. Chlorophyte (green algae), Cyanophyte (blue green 'algae' that are photosynthetic bacteria), and Cryptophyte abundance transitioned through the sampled period. Biovolume shows shifting representation of Bacillariophytes (diatoms), Cryptophytes (flagellated algae), Chlorophytes, Haptophytes (notably genus *Chrysochromulina*, found globally in brackish and marine water in September), and Pyrrophyta (Dinoflagellates). Figure 5 summarizes zooplankton densities observed in 2020 (note the log scale density axis) at GSPOKN0246. Copepods and Rotifers were represented across the sampling period while Cladocerans and Ostracods were noted only in June.

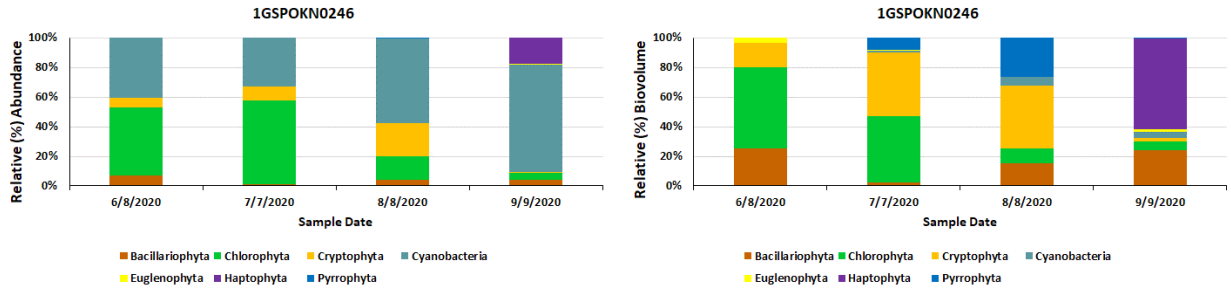

Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at GSPOKN0246, June through September 2020.

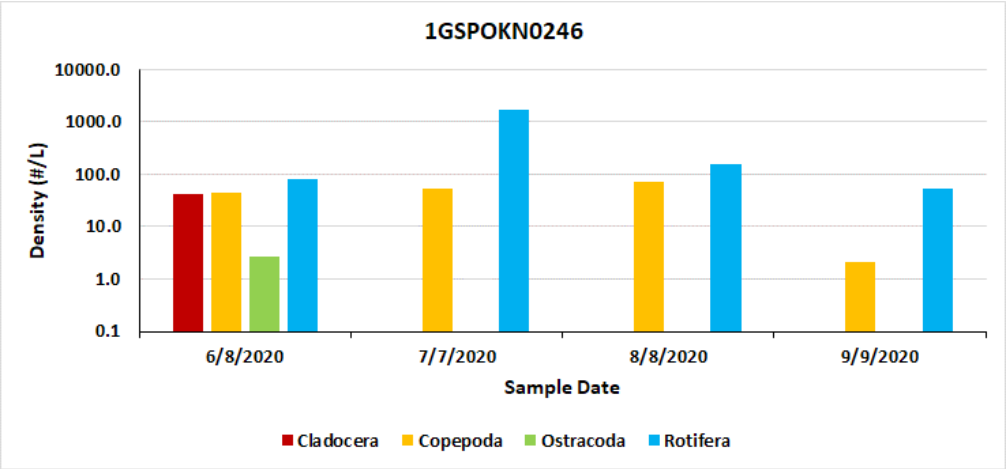

Figure 5. Zooplankton density at GSPOKN0246 June through September 2020.

Trophic status of Great Salt Plains Lake was assessed using all three metrics of Carlson's trophic state index (TSI) at in-lake sites and the lake as a whole. The index based on Secchi depth (TSI(SD)) was generated only for GSPOKN0246 (median 87.9). The median index value based on chlorophyll-a concentrations (TSI(CHLa)) was 71.5. The surface total phosphorus index (TSI(TP)) median value was 94.9. TSI indexes generated from Great Salt Plains 2020 data indicate hypereutrophy (Figure 6).

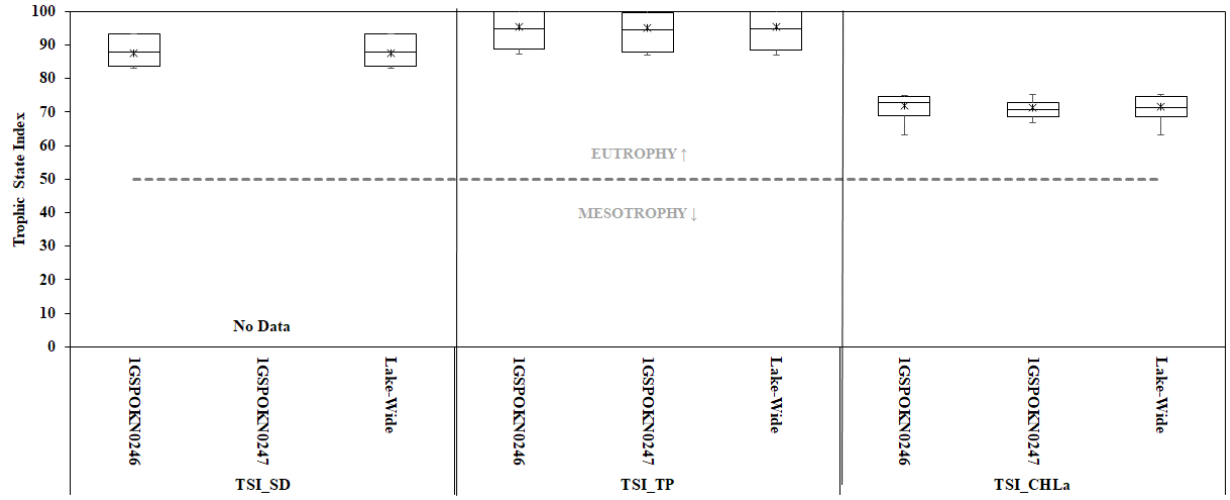

Figure 6. Distributions of Carlson's Trophic Sate Index (TSI), by fixed sampling site and lake-wide, based on observations of Secchi Depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) at Great Salt Plains, OK, June through September 2020.

Total iron (median 0.98 mg/l) and manganese (median 0.17 mg/l) concentrations were high. Reportable concentrations of arsenic were found in all in-lake samples collected with a median concentration of 0.0065 mg/l. Reportable concentrations of chromium, copper, lead, nickel, and zinc were noted in all in-lake samples. Reportable concentrations of selenium and mercury were present in 25, 31%, respectively, of all samples collected. A summary of data collected at GSPOKN0268 (below the dam) mirrored data collected at GSPOKN0246 (dam site) with higher median DO (7.64 mg/l).

USACE previously conducted water quality sampling at Great Salt Plains Lake, OK in calendar year 2000. All efforts indicate lake water is not suitable for municipal or industrial uses. High concentrations of chloride and sulfate, and reduced water clarity were noted. Nutrients were present in concentrations sufficiently high to support a highly productive system. Chlorophyll-a concentrations indicated hypereutrophy. Iron and manganese concentrations were high. Priority pollutant metals cadmium, chromium, and lead were detected at low concentrations.