Fort Gibson Lake Water Quality: 2020

The Fort Gibson Lake dam is located in Wagoner County, Oklahoma (OK) a at river mile 7.7 on the Grand (Neosho) River, about five miles north of the town of Fort Gibson and twelve miles northeast of Muskogee, OK. The impoundment extends ~22 miles north of the dam into Wagoner, Cherokee, and Mayes Counties, OK. The lake is within Hydrologic Unit Code (HUC) 11070209, and the watershed includes all eight-digit HUCs within six-digit HUC 110702. Fort Gibson Lake is a multi-purpose project for flood control, regulation of flows on the Grand (Neosho) River, water supply, hydropower, recreation, navigation, and other beneficial uses including fish & wildlife. Construction began in May 1946 and the conservation pool was filled in March 1953. The project was designed and is regulated to provide for maximum flood protection on the Grand (Neosho) and Arkansas Rivers when operated in conjunction with the Arkansas River Basin System. The total drainage area above the dam is ~12,500 square miles, including the Marion Reservoir and Council Grove Lake watersheds in Kansas (Figure 1). The uncontrolled drainage area (~960 square miles) is downstream of Markham Ferry (Hudson Lake) Reservoir. Land use/cover (Dewitz, 2023) in the basin is dominated by grassland/pasture (~52.5%), cropland (~18.5%), and forest (18%). Based on a 2012 bathymetric survey (OWRB, 2012), at the conservation pool elevation of 554.0 feet (NGVD 29), lake capacity had diminished by about 16% since impoundment due to sedimentation. Descriptive characteristics of Fort Gibson Lake are included in Table 1.

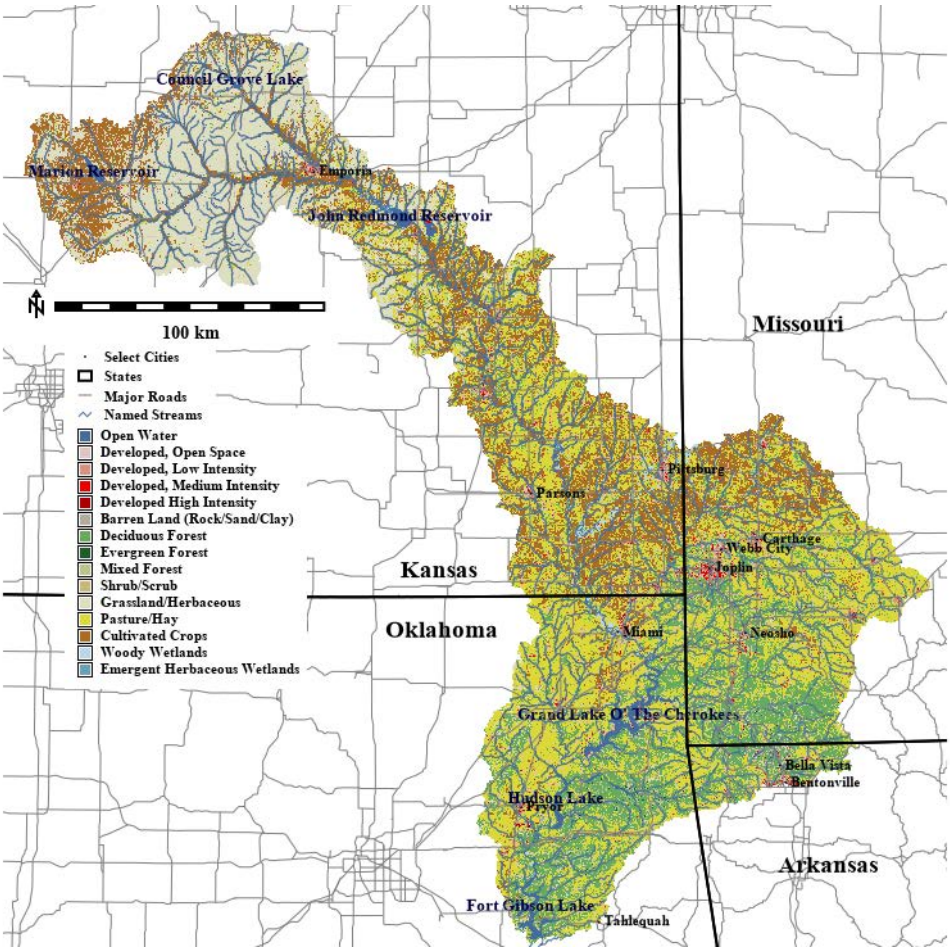

Figure 1. The Fort Gibson Lake (Grand (Neosho) River) Watershed above the Fort Gibson Lake Dam.

Table 1. Descriptive Characteristics of Fort Gibson Lake, OK.

Parameter	English Units	Metric Units
Lake Elevation (Conservation Pool)	554.0 ft. NGVD	168.86 m
Lake Surface Area (Conservation Pool)	19,000 ac	7,869 ha
Lake Volume (Conservation Pool)	365,200 ac-ft	$450.468*10^6$ m^3
Total Drainage Area (contributing)	12,500 mi^2	32,375 km^2
Mean Depth	19.2 ft.	5.85 m
Maximum Depth (Conservation Pool)	60.2 ft.	18.35 m
Shoreline Length	329.2 mi	529.8 km
Shoreline Development Index	16.84	16.84
Annual Inflow, Average 1923 – 2020 [Water Years]	6,593,690 ac-ft	$8,133.2*10^6$ m^3
Annual Inflow, 2020 [Calendar Year]	10,587,580 ac-ft	$13,059.6*10^6$ m^3
Hydraulic Residence Time, 2021 [Calendar Year]	15 d	0.04 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 Fort Gibson Lake (U.S. ACE - Tulsa District, 2023), and the 2012 bathymetric survey (OWRB, 2012).

Designated beneficial uses of the impoundment created by the Fort Gibson 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 below Hudson Lake 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), Fort Gibson Lake is listed as impaired by low dissolved oxygen affecting Fish and Wildlife Propagation as a Warm Water Aquatic Community. A Total Maximum Daily Load report has been prepared for ODEQ (Dynamic Solutions, LLC, 2023) to address low dissolved oxygen issues.

Physical and chemical water quality data were collected approximately monthly by USACE from six 'fixed' in-lake sites and randomly selected sites beginning 22 June and ending 15 November 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. Sampled sites included GIBOKN0003 (channel at the dam), GIBOKN0004 (14-Mile Creek Arm near Wildwood Park), GIBOKN0005 (mouth of Long Bay), GIBOKN0006 (mouth of Flat Rock Creek), GIBOKN0007 (mouth of Spring Creek), and GIBOKN0008 (Hwy 412 bridge). Ten 'random' sites were selected each month (June through September) based on a one km^2 grid of the lake for collection of vertical profile data, chlorophyll-a data, and surface total phosphorus and total Kjeldahl nitrogen samples. In-lake sites were accessed by boat, and samples for 'fixed' sites were collected from locations over the deepest portion of the stream channel (thalweg). Sampling locations are identified in Figure 2.

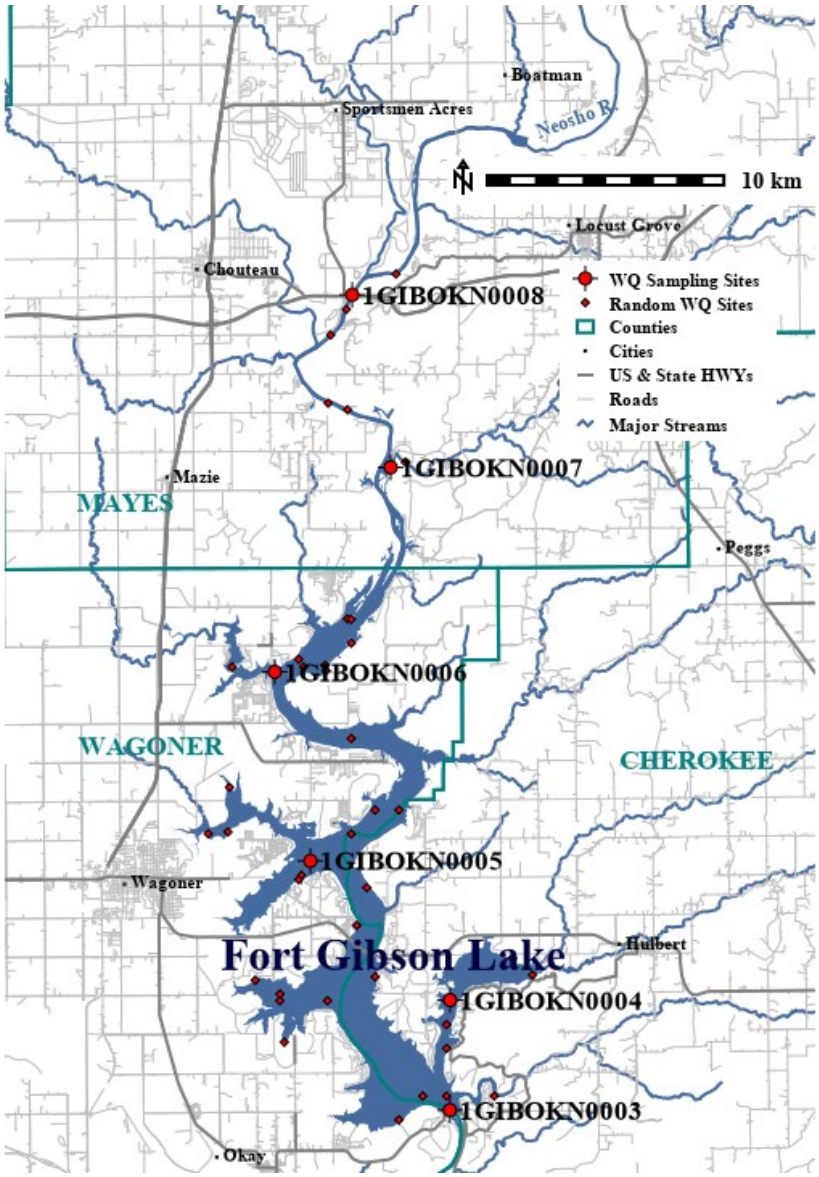

Figure 2. Locations of water quality sampling sites at Fort Gibson Lake, OK, 2020.

The Fort Gibson Lake pool was near the conservation pool elevation June through September, and ~3.5 feet above in November. 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 due to high lake levels.

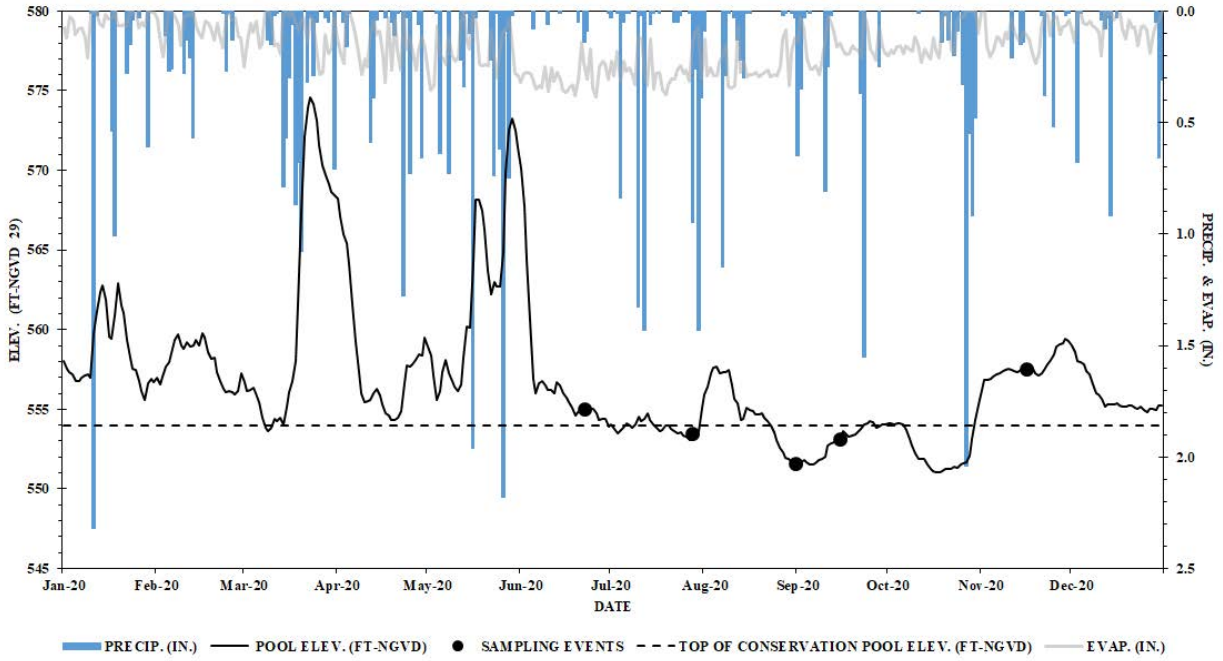

Figure 3. Daily lake elevation (feet, NGVD at 0800 hours), conservation pool elevation (feet), basin precipitation and evaporation (in.), and water quality sampling events at Fort Gibson Lake, OK, 2020.

To aid reporting, the lake was divided into three sections. GIBOKN0003, GIBOKN0004, and associated random sites represent the 'Lower' lake. 'Mid' lake is represented by GIBOKN0005, GIBOKN0006, and associated random sites. The 'Upper' lake is represented by GIBOKN0007, GIBOKN0008, and random sites. Water temperatures varied seasonally (ranging from 13.10 to 29.94 ºC) peaking in July. All water temperature observations <15 ºC occurred in November 2020. Weak thermal stratification was observed beginning in June at GIBOKN0003, GIBOKN0004, and GIBOKN0005. The study period lakewide median dissolved oxygen concentration (DO) was 6.23 mg/l. Median DO was lowest in the Lower lake (5.62 mg/l) and highest in the Upper lake (6.61 mg/l). Observed in-lake DO ranged from 0.07 to 12.15 mg/l. Lowest DO concentrations (<2 mg/l) were exclusively observed at depth in the Lower lake in June, July, and September. Highest DO concentrations were observed near the surface at in June in the Lower and Mid lake areas, and at greater depths in the Mid and Upper lake in November. Lakewide total organic carbon concentrations were moderate with a study period median of 5.14 mg/l. Observed median total organic carbon concentrations were comparable across lake areas (Upper 4.58, Mid 5.47, and Lower 5.36 mg/l).

Specific conductance (median 252 µS/cm) was moderate, consistent with regional geology. Total dissolved solids median concentration was 150.5 mg/l with lake area medians ranging from 162.0 (Upper) to 144.0 (Lower) mg/l. Low chloride and sulfate concentrations (medians 7.80 and 22.40 mg/l, respectively) were observed. Alkalinity levels (median 90.75 mg/l as $CaCO_3$) imply a system capable of maintaining pH levels. Hardness levels, median 103.0 mg/l as $CaCO_3$, indicate moderately 'hard' water. Observed in-lake pH (6.72 to 9.32) ranged within regional norms. Highest pH was recorded near the surface in the Mid and Lower lake in June, and lowest pH was recorded in July and September at depth at in the Lower lake.

Median Secchi depth was 0.65 meters. Through the sampling period, median Secchi depth was lowest in the Mid lake area (0.60 m) compared to the Upper lake (0.76 m) and Lower lake (0.78

m). In-lake median turbidity was 17.8 NTUs, and 18% of all in-lake observations were greater than or equal to 25 NTUs. The majority of turbidity observations >25 NTUs were recorded in the Mid lake area. Median lakewide total suspended solids concentration was 8.45 mg/l, with median Mid lake area concentration (11.5 mg/l) higher than Upper (8.9 mg/l) and Lower (7.1 mg/l) lake areas. The euphotic zone at Fort Gibson Lake ranged from 3.5 to 4.0 meters with greatest depths in September.

Lakewide ammonia concentrations (median 0.06 mg/l) and nitrite plus nitrate concentrations (median 0.21 mg/l) were moderate to high. Median Upper lake nitrite plus nitrate concentration was 0.60 mg/l. Total Kjeldahl nitrogen concentrations (lakewide median 0.61 mg/l) were highest in the Mid lake area (0.68 mg/l). Estimated lakewide median surface total nitrogen concentration during the 2020 study was 0.74 mg/l. Total phosphorus concentrations lakewide ranged between 0.09 and 0.40 mg/l (median 0.15 mg/l). Detectable concentrations of dissolved ortho-phosphate, median 0.05 mg/l, were present in 97% of samples collected. Nitrogen to phosphorus ratios (N:P) in 2020 were <10 (median 3.86) indicating a tendency toward limited nitrogen availability and the potential for phytoplankton dominance by cyanophytes.

Chlorophyll-*a* concentrations (in-lake) ranged from 9.9 to 59.7 µg/l, with a median concentration of 31.0 µg/l. Median lake area chlorophyll-a concentrations increased from Upper lake (22.1 µg/l) to Lower Lake (34.3 µg/l). Highest median fixed site chlorophyll-a concentration was 35.6 µg/l at GIBOKN0005. Figure 4, below, summarizes relative abundance and biovolume of divisions of phytoplankton sampled at Fort Gibson Lake site GIBOKN0003. Cyanophyte (blue green 'algae' that are photosynthetic bacteria) abundance dominated through the sampled period (June, July, and September) while biovolume shows seasonal representation of Bacillariophytes (diatoms), Cryptophytes (flagellated algae), Chlorophytes (greens), and others. Figure 5 summarizes zooplankton densities observed in 2020 (note the log scale density axis) at the dam site (GIBOKN0003) and the HWY 412 Bridge (GIBOKN0008). Cladocerans, Copepods, and Rotifers were generally well represented across the sampling period.

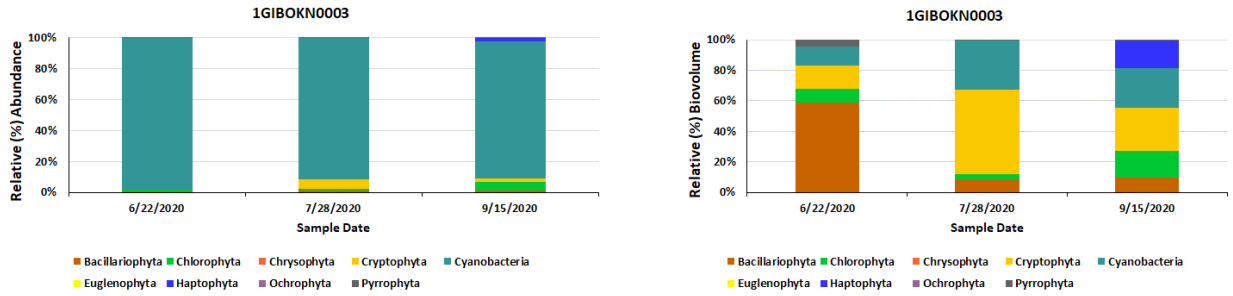

Figure 4. Phytoplankton relative abundance (left) and relative biovolume (right) at GIBOKN0003, June, July, and September 2020.

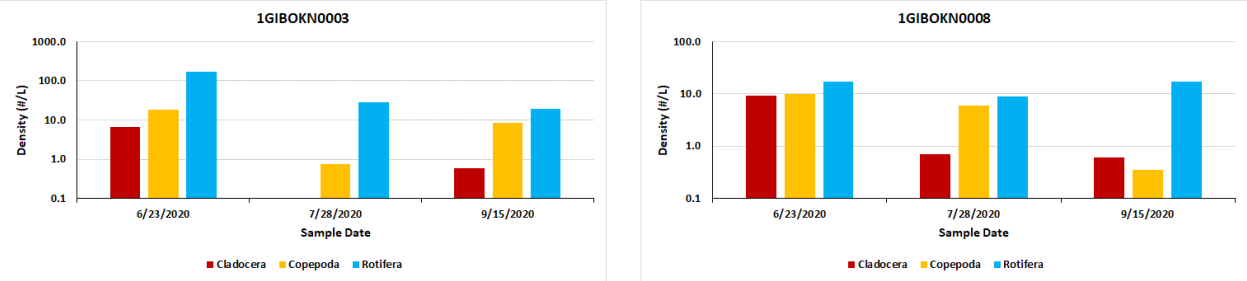

Figure 5. Zooplankton density at GIBOKN0003 (left) and GIBOKN0003 (right) June, July, and September 2020.

Trophic status of Fort Gibson Lake was assessed using all three metrics of Carlson's trophic state index (TSI) at each fixed in-lake site and the lake as a whole. Median indexes based on Secchi depth (TSI(SD)) and chlorophyll-a concentrations (TSI(CHLa)) were 60.0 or higher at all sites. The surface total phosphorus index (TSI(TP)) values were greater than 70.0 at all sites. The median lakewide index developed from chlorophyll-*a* concentrations (TSI(CHLa)), 63.3, indicated a moderate to high level of eutrophy (Figure 6).

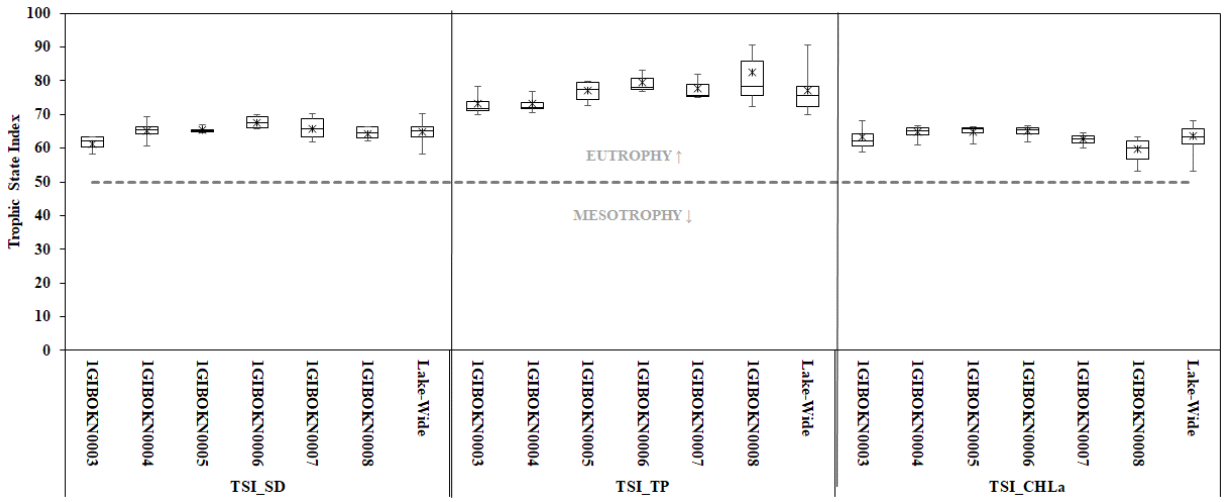

Figure 6. Distributions of Carlson's Trophic Sate Index (TSI), by fixed sampling site and lakewide, based on observations of Secchi Depth (TSI(SD)), surface total phosphorus concentrations (TSI(TP)), and chlorophyll-*a* concentrations (TSI(CHLa)) at Fort Gibson, OK, June through September 2020.

Total iron (median 0.17 mg/l) and manganese (median 0.07 mg/l) concentrations were moderate. Reportable concentrations of arsenic were found in all in-lake samples collected with a median concentration of 0.0017 mg/l. Reportable concentrations of copper, nickel, and zinc were noted in all in-lake samples. Reportable concentrations of chromium, lead, and mercury were present in 66, 78, and 21%, respectively, of all samples collected.

USACE previously conducted water quality sampling at Fort Gibson, OK in 1979, 1991, and 2003 through 2006. All efforts indicated summer month thermal stratification with associated hypoxia at depth. Nutrients, both nitrogen and phosphorus, were present in concentrations sufficiently high to support a highly productive system. Median lakewide chlorophyll-a concentrations have steadily increased across sampling efforts. Iron and manganese concentrations were high shifting to moderate across efforts.