Trophic Classification of Texas Reservoirs

2010 Texas Water Quality Inventory and 303(d) List

(November 18, 2011)

Algae in rivers and lakes can have a profound influence on water quality and ultimately the ability of a water body to support healthy aquatic communities. Assessing water body condition based on algae is done by evaluating indicators that reflect nutrient dynamics that drive primary production and influence levels of dissolved oxygen. Eutrophication refers to overall a condition characterized by an abundant accumulation of nutrients that support a dense growth of algae and other organisms, the decay of which depletes the shallow waters of oxygen in summer.

Eutrophication is primarily influenced by the physical setting of the water body and can be affected by natural and anthropogenic processes in the surrounding watershed. In the southern United States this process is enhanced due to warm, fertile climates and the rate increases with the age of the water body. Human activities can accelerate the process by increasing the rate at which nutrients and organic substances enter the impoundments and their surrounding watersheds. Sewage discharges, agricultural and urban runoff, leaking septic tanks, and erosion of stream banks can increase the flow of nutrients and organic substances into reservoirs and lakes. These pollutants can over-stimulate the growth of algae and aquatic plants, creating conditions that interfere with contact recreation (swimming), boating (noncontact recreation), and the health and diversity of native fish, plant, and animal populations. Over-production of bacteria, fungi, and algae may also impart foul odors and tastes to the water.

Section 314 of the CWA of 1987 requires all states to classify lakes and reservoirs according to trophic state. The trophic state of a reservoir refers to its nutritional status that is indicated by measurements of nutrients and algae. Various classification schemes (Table 1-1) or indices have been developed that group reservoirs into discrete quality (trophic) states along a continuum from oligotrophic (poorly nourished) to hypereutrophic (over nourished). The basis for the trophic state index concept is that in many reservoirs the degree of eutrophication may be related to increased nutrient concentrations. Typically, phosphorus is the nutrient of concern and changes in its concentration may trigger a response that influences the amount of algae (estimated by chlorophyll *a*) in the reservoir. For example, increases in phosphorus can result in higher algal biomass, which in turn decreases water transparency (as measured by a Secchi disk or submarine photometer).

Table 1 - 1. Types of Trophic States in Reservoirs and Lakes

Trophic State	Water Quality Characteristics
Oligotrphic	Clear waters with extreme clarity, low nutrient concentrations, little organic matter or sediment, and minimal biological activity.
Mesotrophic	Waters with moderate nutrient concentrations and, therefore, more biological productivity. Waters may be lightly clouded by organic matter, sediment, suspended solids or algae.
Eutrophic	Waters extremely rich in nutrient concentrations, with high biological productivity. Waters clouded by organic matter, sediment, suspended solids, and algae. Some species may be eliminated.
Hypereutrophic	Very murky, highly productive waters due to excessive nutrient loading. Many clearwater species cannot survive.

Major Texas reservoirs have been evaluated and ranked every two years by the TCEQ using Carlson's Trophic State Index (TSI). Carlson's Index was developed to compare reservoirs using in-reservoir sampling data ()g (Carlson, 1977). Secchi disk depths, chlorophyll *a* concentrations, and total phosphorus concentrations are three variables that are highly correlated and considered estimators of algal biomass. The Carlson index uses regression analysis to relates these three parameters to determine trophic state. The TSI is determined from any of the three computational equations:

TSI (Secchi Disk) = 60 - 14.41 ln (*SD*), where *SD* is mean secchi disk depth in meters.

TSI (Chlorophyll *a*) = 9.81 ln(*Chla*) + 30.6, where *Chla* is mean chlorophyll *a* in ug/L.

TSI (Total Phosphorus) = 14.42 ln(*TP*) + 4.15, where *TP* is mean total phosphorus in ug/L.

Although chlorophyll *a* is the most direct measure of algal biomass, the TSI uses Secchi disk depth as the primary indicator. The index was scaled, so that TSI = 0 represents the largest measured Secchi disk depth (64 m) among reservoirs. Each halving of transparency represents an increase of 10 TSI units (Table 1-2). Since the relationships between Secchi disk and chlorophyll *a* was nonlinear a 10-unit TSI (Chl *a*) change does not correspond to a doubling of chlorophyll *a*. Instead, chlorophyll *a* approximately doubles for each 7-unit increase in TSI (chl *a*).

Table 1 - 2. Carlson's Trophic State Index and Associated Parameters

Trophic State Index	Secchi Disc (m)	Total Phosphorus (ug/L)	Chlorophyll *a* (ug/L)
0	64	0.75	0.04
10	32	1.5	0.12.
20	16	3	0.34
30	8	6	0.94
40	4	12	2.6
50	2	24	6.4
60	1	48	20.0
70	0.5	96	56
80	0.25	192	154
90	0.12	384	427
100	0.062	768	1,183

Carlson's Index provides a useful tool for assessing a reservoir's condition and evaluating changes over time. For instance, the index would provide a quantitative estimate of the degree of improvement for a reservoir in which the TSI (Chl *a*) decreased from 60 to 40 units following implementation of restoration measures. The index provides useful information which explains possible causes of the water body condition. For example, if TSI (TP) > TSI (Chl *a*), phosphorus is probably not the limiting nutrient; TSI (SD) > TSI (Chl *a*) indicates the presence of non-algal turbidity.

Carlson's Index provides a simple model for evaluating condition which provides both advantages and disadvantages. The trophic state is developed on a continuous numeric scale and is useful for approximating the oligotrophic-hypereutrophic nomenclature required by the EPA. Secchi disk depths and total phosphorus and chlorophyll *a* concentrations are routinely determined at TCEQ and CRP fixed monitoring stations on reservoirs and lakes, so input data are readily available for computation of Carlson's Index. The index does not perform well for certain water quality conditions: (1) where transparency is affected by suspended erosional materials rather than phytoplankton, (2) where primary production is controlled by attached algae or aquatic macrophytes rather than phytoplankton, and (3) when phosphorus is not the nutrient limiting phytoplankton growth.

Although the index can be used to classify and rank Texas reservoirs by trophic state, priority ranking for restoration is difficult. Carlson's Index does not replace the need to use attainment determinations. Assessment of reservoir water quality depends to a large degree on the assignment of beneficial uses and determinations to evaluate if the uses are being maintained and/or impaired. For this reason, the Integrated Report and 303(d) List provides a ranking of priorities for protection and restoration for all water bodies including reservoirs.

Texas reservoirs are ranked in Appendix A according to Carlson's TSI for chlorophyll *a* as an average calculated from 10 years of SWQM data (December 1, 1998 - November 30, 2008). In order to maximize comparability among reservoirs, data from the monitoring station nearest the dam in the main pool of each reservoir were utilized if available. For many reservoirs, these are the only sites monitored by the TCEQ and Clean Rivers Program. Chlorophyll *a* was given priority as the primary trophic state indicator because it has proven to be most useful for estimating algal biomass in most reservoirs. A minimum of four chlorophyll *a* measurements, two total phosphorus and two Secchi disk measurements were required for a reservoir to be included in the ranking. Of the 191 reservoir stations surveyed, 100 had enough data to be included in the ranking. Based on this assessment, the 100 reservoirs show a range of eutrophication, from oligotrophic to hypereutrophic (Table 1 - 3). Rankings are also provided for total phosphorus (TP) and Secchi disk transparency (SD). Comparing TSI indicators between the reservoirs provides indications of the clearest reservoirs (low TSI SD), and identifies reservoirs with low and high total phosphorus concentrations.

Table 1 - 3. Number of Texas Reservoirs Assessed in Each Trophic Class

Trophic Class	TSI (Chl a) Index Range	Number of Texas Reservoirs
Oligotrophic	0 - 35	1
Mesotrophic	>35 - 45	9
Eutrophic	>45 - 55	48
Hypereutrophic	>55	42

Reservoirs with the clearest water (highest Secchi disk transparency) occur primarily in the central portion of the state and are listed in descending order: Stillhouse Hollow Lake (1216), Lake Travis (1404), Lake Alan Henry (1241A), Medina Lake (1909), and Canyon Lake (Segment 1805). Reservoirs with the highest turbidity (poorest light transparency, lowest Secchi disk transparency) listed in descending order are: Rita Blanca Lake (0105), Springfield Lake (1253A), Cox Lake (2454A), Lake JB Thomas (1413), and Lake Wichita (0219).

Reservoirs with the lowest total phosphorus concentrations listed in descending order are: Lake Marble Falls (1405), Ellison Creek Reservoir (0404), Lake Jacksonville (0614), Medina Lake (1909), and Greenbelt Reservoir (0223). Reservoirs with the highest total phosphorus concentrations listed in descending order are: Rita Blanca Lake (0105), Lake Tanglewood (0230), Lake Woodlands (1008F), Squaw Creek (1229A), and Country Club Lake (1209).

Water Quality Differences in Reservoirs

Carlson's TSI Chl *a* values for 100 reservoirs from the 2000 and 2010 reporting cycles were compared to indicate temporal differences (Appendix A). Differences could not be calculated for 17 reservoirs (17%), due to the lack of reporting information in 2000. The 2000 period of record was September 1, 1989 - August 31, 1999; for 2010, the period of record was December 1, 1998 - November 30, 2008.

TSI Chl *a* values, which estimate the amount of algal biomass, can indicate improvement when values decrease. However, changes in data reporting and improved laboratory detection of low – level chlorophyll *a* may significantly contribute to decreasing TSI Chl a values in 8 of 100 (8%) reservoirs. Reservoirs with the largest 10 year differences for decreasing algal content are Lake Bridgeport (0811), Lake Bob Sandlin (0408), Wright Patman Lake (0302), Falcon Lake (2303) and Lake Georgetown (1249). Increases in algal biomass (increase in TSI Chl *a* values) are indicated in 92 of 100 (92%) reservoirs. Reservoirs with the largest differences for increasing algal content (substantial positive TSI Chl *a* values) are Rita Blanca Lake (0105), White River Lake (1240), Lake Mackenzie (0228), Lake Whitney (1203), and Diversion Lake (0215).

A reservoir's trophic rank may differ from that in the last assessment due to changes in data reporting rather than changes in water quality. Many individual values in the SWQMIS water quality database are reported as less than analytical reporting limits (non-detects or censored data). There is no generalized way to determine the true value for an individual result in the range between zero and the reporting limit. For the trophic classification assessment of Texas reservoirs, 50 percent of an analytical reporting limit is computed for these results. This is done to maximize the amount of data used in this analysis and to indicate the level of monitoring effort. For more information please contact the Surface Water Quality Monitoring Team at swqm@tceq.state.tx.us.

Reservoir Control Programs

Texas implements several reservoir pollution control procedures to ensure high-quality water for recreational, aquatic life, domestic, and industrial uses. Surface water quality standards have been adopted for significant reservoirs throughout the state. The Texas Surface Water Quality Standards establish uses for classified (designated uses) and unclassified (presumed uses) segments and include numerical criteria to protect those uses. Designated uses are determined by taking into account the reservoir's physical and biological characteristics, natural water quality, and existing uses. Criteria, depending on parameter, are based on background levels or accepted levels for protection of human health and aquatic life. The TCEQ issues permits that include limits designed to protect these uses. Each major reservoir is routinely monitored to assess the overall condition of the water body in comparison to the criteria and determine short- or long-term water quality trends. Reservoirs with non-supported uses are placed on the State of Texas 303(d) List. When a water body is identified as impaired and in need of remedial efforts a TMDL is conducted to determine the assimilative capacity of the segment and to determine discharge treatment levels and nonpoint source loads necessary to meet the criteria. Compliance with wastewater permits is monitored through on-site inspections by TCEQ personnel and through self-reporting procedures. When noncompliance with permits is found, enforcement actions may be required to attain compliance. The uses, criteria, TMDLs, and permits are periodically reviewed and, if necessary, revised.

The TCEQ has several specific rules that prescribe permit limitations for discharges of domestic wastewater into reservoirs. Chapter 309 of the effluent standards portion of the TCEQ rules requires discharges located within five river miles upstream of certain reservoirs to achieve a minimum effluent quality of 10 mg/L BOD5 and 15 mg/L TSS as a 30-day average. This rule applies to reservoirs that are subject to private sewage facilities regulation or that may be used as a source for a public drinking water supply. Currently, 92 Texas reservoirs are designated for the public water supply use. Additional rules under Chapter 311, Watershed Protection, have been promulgated that protect specific reservoirs:

Subchapter D: §§311.31- .36.
This rule requires all domestic and industrial permittees in the entire Lake Houston watershed to meet effluent limitations equal to or commensurate with 10 mg/L BOD5, 15 mg/L TSS, and 3 mg/L NH3-N as a 30-day average. All wastewater effluents disposed of on land shall meet an effluent quality of 20 mg/L BOD5 and 20 mg/L TSS. Domestic facilities must submit a solids management plan. Additionally, all domestic and industrial facilities with gaseous chlorination disinfection systems must have dualfeed chlorination systems and must meet a minimum chlorine residual of 1 mg/L and a maximum chlorine residual of 4.0 mg/L.

Subchapter A, B and F: §§311.1-.5, 311.11-.15 and 311.51-.55.
These rules apply to a series of reservoirs on the Colorado River, which are commonly referred to as the Highland Lakes, including Lake Austin (Segment 1403), Lake Travis (Segment 1404), Lake Marble Falls (Segment 1405), Lake LBJ, (Segment 1406), Inks Lake (Segment 1407), and Lake Buchanan (Segment 1408). Water quality areas, those portions of the watersheds within 10 river miles of the reservoirs, were established for each reservoir. New wastewater facilities constructed in these areas will be issued no-discharge permits, meaning that treated wastewater will not be discharged to surface waters. Any existing facility that requires a permit amendment for expansion or is not meeting permit requirements because of sewage overloading will be issued a no-discharge permit. Proposed new or expanded treatment facilities in the watersheds of these reservoirs will be issued no-discharge permits unless the applicant can establish that any alternative proposed wastewater disposal will protect and maintain the existing quality of the reservoirs.

Subchapter G: §§311.61.-311.66.
This rule applies to Lakes Worth, Eagle Mountain, Bridgeport, Cedar Creek, Arlington, Benbrook, and Richland-Chambers. With the exception of oxidation pond systems, domestic discharges within the water quality areas of the watersheds of these reservoirs are required to meet advanced treatment limits of 10 mg/L BOD5, and filtration is required to supplement suspended solids removal by January 1, 1993.

Reservoir and Lake Restoration Efforts

Section 314 of the Clean Water Act makes federal grant funds available to states under the Clean Lakes Program. The TCEQ is currently not administering any grant funding under this program. There are several lakes and reservoirs throughout the State where restoration efforts are currently under way to improve water quality. These include the following:

Caddo Lake – Watershed Protection Plan
Lake O' the Pines – TMDL Implementation Plan
E.V. Spence Reservoir – TMDL Implementation Plan
Lake Austin – TMDL Implementation Plan
Lake Worth – TMDL Implementation Plan
Granger Lake – Watershed Protection Plan
Benbrook Lake – Watershed Protection Plan
Lake Bridgeport – Watershed Protection Plan

Eagle Mountain Reservoir – Watershed Protection Plan
Richland Chambers Reservoir – Watershed Protection Plan
Stillhouse Hollow Lake – Watershed Protection Plan

Low pH in Texas Waterbodies

Data from one reservoir, eight freshwater streams, and one tidal stream have indicated low pH (high acidity) in at least one assessment location resulting in the waterbodies being included on the 303(d) List of impaired waters. Most of these waterbodies are located in the eastern portion of the state, where natural geologic buffering capacity is limited. TCEQ is continuing routine monitoring and initiating a project to identify waterbodies requiring special studies to determine if a TMDL or review of the water quality standard is needed.

Table 1 - 4. Texas Waterbodies with Low pH

Segment Number	Reservoir Name
0401	Caddo Lake
0402	Big Cypress Creek below Lake O' the Pines
0406	Black Bayou
0407	James Bayou
0511	Cow Bayou Tidal
0606	Neches River above Lake Palestine
0608	Village Creek
1407A	Clear Creek

High pH in Texas Waterbodies

Data from eight reservoirs and two freshwater streams have indicated elevated pH (high basicity) in at least one assessment location. A likely cause of elevated pH is consumption of dissolved carbon dioxide by photosynthetic processes. Excessive amounts of photosynthetically active algae and macrophytes can increase consumption of carbon dioxide during the day, increasing pH in the water column. All of these waterbodies are included in the project to determine if a TMDL or review of the water quality standard is needed.

Table 1 - 5. Texas Waterbodies with High pH

Segment Number	Reservoir Name	Trophic Class
0105	Rita Blanca Lake	Hypereutrophic
0229	Upper Prairie Dog Town Fork of Red River	Unknown
0302	Wright Patman Lake	Eutrophic
0306	Upper South Sulphur River	Unknown
0307	Cooper Lake	Too few samples to determine
0507	Lake Tawakoni	Hypereutrophic
0605	Lake Palestine	Hypereutrophic
0803	Lake Livingston	Hypereutrophic
0818	Cedar Creek Reservoir	Too few samples to determine
1212	Lake Somerville	Hypereutrophic

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
1249	12111	LAKE GEORGETOWN	1	4	1.5	34.58	-2.48	14	78	2.08	49.5	60	30	0.04	59.3
0408	10329	LAKE BOB SANDLIN	2	7	2.96	41.22	-3.53	30	7	1.46	54.64	33	7	0.04	54.5
1404	12302	LAKE TRAVIS	3	44	2.98	41.28	+3.07	2	42	3.42	42.24	35	56	0.04	54.9
0811	10970	LAKE BRIDGEPORT	4	6	3.4	42.6	-4.01	44	6	1.22	57.14	53	6	0.04	57.3
1403	12294	LAKE AUSTIN	5	43	3.5	42.92	+4.56	19	40	1.94	50.46	10	55	0.02	52.1
0611Q	15801	LAKE NACOGDOCHES OCHES	6	15	3.64	43.28	NA	25	17	1.58	53.5	82	17	0.08	65.8
1216	11894	STILLHOUSE HOLLOW LAKE	7	10	4	44.2	+12.12	1	81	3.58	41.6	44	42	0.04	56.2
0223	10173	GREENBELT RESERVOIR	8	16	4.04	44.3	+7.98	11	26	2.22	48.46	6	27	0.02	51.7
1909	12825	MEDINA LAKE	9	19	4.04	44.32	+10.37	4	22	3.04	44.02	4	30	0.02	51.5
0102	10036	LAKE MEREDITH	10	15	4.1	44.44	+8.37	23	25	1.74	52.1	31	24	0.04	54.3
0611	17824	LAKE STRIKER	11	16	4.42	45.18	NA	56	18	1.02	59.8	92	18	0.1	71
0614	10639	LAKE JACKSONVILLE	12	27	4.58	45.52	+9.23	13	36	2.08	49.42	3	38	0.02	51.1

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
1419	12398	LAKE COLEMAN	13	11	4.6	45.56	+4.49	41	15	1.28	56.36	18	14	0.02	52.7
0840	17834	RAY ROBERTS LAKE	14	7	4.76	45.92	NA	38	26	1.3	56.22	55	14	0.04	58
0834	11063	LAKE AMON G. CARTER	15	7	5	46.38	+8.12	20	12	1.84	51.18	11	12	0.02	52.2
1220	11921	BELTON RESERVOIR	16	8	5.18	46.74	+10.62	12	70	2.16	48.88	37	32	0.04	55.2
1418	12395	LAKE BROWNWOOD	17	14	5.2	46.78	+6.56	49	18	1.16	57.76	16	17	0.02	52.6
0204B	15447	MOSS LAKE	18	19	5.38	47.12	NA	37	24	1.34	55.84	33	25	0.04	54.5
1433	12511	O H IVIE RESERVOIR	19	26	5.46	47.26	+4.73	10	34	2.24	48.32	9	31	0.02	51.9
1805	12597	CANYON LAKE	20	16	5.52	47.36	+11.06	7	27	2.72	45.58	16	27	0.02	52.6
0302	10213	WRIGHT PATMAN LAKE	21	5	5.54	47.38	-2.79	98	5	0.58	67.7	92	5	0.1	71
1231	11979	LAKE GRAHAM	23	11	5.56	47.44	+8.27	71	22	0.82	62.88	41	22	0.04	56
1233	12002	HUBBARD CREEK RESERVOIR	23	12	5.56	47.44	+9.52	34	20	1.38	55.4	19	21	0.02	53.1
0504	10404	TOLEDO BEND RESERVOIR	24	70	5.66	47.6	-0.55	17	109	1.98	50.14	21	6	0.04	53.2

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
0610	14906	SAM RAYBURN RESERVOIR	25	56	5.92	48.06	+12.69	15	92	2.04	49.72	78	95	0.06	64.7
1247	12095	GRANGER LAKE	26	4	6.18	48.46	+7.15	102	74	0.48	70.66	71	30	0.06	62.9
0210	10139	FARMERS CREEK RESERVOIR/NOCONA LAKE	27	13	6.3	48.66	+9.65	40	18	1.3	56.32	29	18	0.04	54
1230	11977	LAKE PALO PINTO	28	18	6.56	49.04	+11.94	75	25	0.78	63.52	58	25	0.04	58.4
0605	17575	LAKE ATHENS	29	13	6.9	49.54	NA	24	25	1.68	52.46	6	24	0.02	51.7
1429	12476	TOWN LAKE	30	30	6.92	49.58	+13.22	21	24	1.8	51.46	14	38	0.02	52.5
0217	10159	LAKE KEMP	31	11	7.2	49.96	+10.94	17	18	1.98	50.14	8	16	0.02	51.8
0404A	14473	ELLISON CREEK RESERVOIR	32	4	7.22	50	+8.28	43	8	1.22	57.06	2	3	0.02	50.6
1207	11865	POSSUM KINGDOM RESERVOIR	33	4	7.5	50.36	+8.17	8	80	2.62	46.12	65	31	0.04	59.8
0603	10582	B A. STEINHAGEN RESERVOIR	34	26	7.78	50.74	+0.72	104	35	0.46	71.5	86	36	0.08	67.3
1224	11939	LEON RESERVOIR	35	13	7.86	50.82	+11.59	27	20	1.54	53.82	50	19	0.04	56.9
0613	10638	LAKE TYLER	36	29	8	50.98	+5.93	46	34	1.18	57.58	16	35	0.02	52.6

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0212	10142	LAKE ARROWHEAD	37	12	8.04	51.06	+7.99	70	17	0.84	62.62	102	16	0.18	78.4
1413	12367	LAKE J B THOMAS	38	12	8.08	51.1	+1.93	111	14	0.34	75.3	63	13	0.04	59.6
1405	12319	LAKE MARBLE FALLS	40	44	8.22	51.26	+5.26	33	40	1.4	55.2	1	54	0.02	50.3
0836	15168	RICHLAND-CHAMBERS RESERVOIR	40	5	8.22	51.26	-0.38	54	5	1.06	59.28	59	5	0.04	58.9
1408	12344	LAKE BUCHANAN	41	44	8.52	51.6	+9.03	22	40	1.76	51.88	50	54	0.04	56.9
1254	12127	AQUILLA RESERVOIR	42	32	8.54	51.64	+9.68	83	46	0.7	65.28	47	38	0.04	56.8
1418A	12178	HORDS CREEK RESERVOIR	43	6	9.02	52.18	+8.26	45	8	1.18	57.54	23	8	0.04	53.5
2303	13189	FALCON LAKE	44	23	9.06	52.22	-2.64	93	21	0.62	66.7	81	22	0.08	65.6
1240	12027	WHITE RIVER LAKE	45	21	9.26	52.44	+18.7	100	35	0.52	69.56	68	31	0.06	61.8
1406	12324	LAKE LYNDON B JOHNSON	46	44	9.5	52.68	+13.87	39	40	1.3	56.24	39	55	0.04	55.7
0405	10312	LAKE CYPRESS SPRINGS	47	27	9.64	52.82	+3.87	42	35	1.28	56.5	25	35	0.04	53.6
0817	10981	NAVARRO MILLS RESERVOIR	48	19	9.78	52.96	+1.91	103	23	0.46	71.16	78	26	0.06	64.7

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
0228	10188	LAKE MACKENZIE	50	17	10.02	53.2	+18.44	36	22	1.34	55.82	47	22	0.04	56.8
1241A	18414	LAKE ALAN HENRY	50	8	10.02	53.2	NA	3	8	3.32	42.76	25	13	0.04	53.6
0401	10283	CADDO LAKE	51	22	10.04	53.24	+7.55	72	131	0.82	62.94	95	33	0.12	73.7
1229	17110	SQUAW CREEK RESERVOIR	52	11	10.34	53.52	NA	26	9	1.56	53.54	109	11	0.48	93.1
0813	10973	HOUSTON COUNTY LAKE	53	25	10.42	53.58	+13.9	29	34	1.48	54.42	31	35	0.04	54.3
0215	10157	DIVERSION LAKE	54	11	10.62	53.78	+16.42	48	18	1.18	57.7	6	15	0.02	51.7
1225	11942	LAKE WACO	55	13	10.88	54.02	+10.75	67	87	0.86	62.22	84	80	0.08	66.5
0816	10980	LAKE WAXAHACHIE	56	20	11.08	54.18	+11.94	81	25	0.7	65.14	57	29	0.04	58.1
0403	10296	LAKE O THE PINES	57	30	11.36	54.44	+9.09	52	38	1.1	58.7	28	41	0.04	53.9
1422	12418	LAKE NASWORTHY	58	44	11.72	54.74	+8.24	99	62	0.54	68.92	66	60	0.04	60.3
2454A	12514	COX LAKE	59	21	12.32	55.24	+8.02	112	29	0.32	76.04	107	30	0.28	85.3
0832	11061	LAKE WEATHERFORD	60	17	12.34	55.26	+2.86	84	24	0.68	65.44	64	23	0.04	59.7

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
0512	10458	LAKE FORK RESERVOIR	61	69	12.54	55.42	+7.38	28	117	1.54	53.86	43	6	0.04	56.1
1426A	12180	OAK CREEK RESERVOIR	62	11	12.76	55.58	+14.07	81	36	0.7	65.14	50	16	0.04	56.9
0807	10942	LAKE WORTH	64	6	13.04	55.78	-0.04	82	6	0.7	65.24	63	6	0.04	59.6
1235	12006	LAKE STAMFORD	64	7	13.02	55.78	+11.64	92	11	0.62	66.68	72	12	0.06	64
1002	11204	LAKE HOUSTON	65	39	13.48	56.12	+12.46	108	35	0.36	74.88	101	167	0.16	77.9
0409	17478	LAKE GILMER	66	19	14.14	56.58	NA	47	28	1.18	57.68	57	27	0.04	58.1
0104	17465	LAKE FRYER	67	16	14.66	56.94	NA	101	24	0.5	70.14	94	24	0.12	73.3
1407	12336	INKS LAKE	68	44	14.86	57.08	+10.4	32	40	1.42	55.02	41	51	0.04	56
0506	17585	LAKE GLADEWATER	69	14	15.36	57.4	NA	86	24	0.68	65.54	54	24	0.04	57.6
1203	11851	LAKE WHITNEY	70	13	15.5	57.48	+17.52	31	67	1.44	54.74	12	24	0.02	52.4
0803	10899	LAKE LIVINGSTON	71	69	15.58	57.54	+1.59	77	66	0.78	63.66	96	60	0.14	75
1434C	17020	LAKE BASTROP	72	44	16.66	58.2	NA	35	40	1.36	55.48	43	54	0.04	56.1

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
0830	15151	BENBROOK LAKE	73	6	16.8	58.28	NA	78	6	0.74	64.24	73	6	0.06	64.1
0815	10979	BARDWELL RESERVOIR	74	19	16.92	58.34	+6.04	96	30	0.6	67.3	61	27	0.04	59.5
1222	11935	PROCTOR LAKE	75	14	17.52	58.68	+6.45	91	58	0.64	66.36	87	20	0.08	68.2
1416A	12179	BRADY CREEK RESERVOIR	76	20	17.8	58.84	+4.48	85	33	0.68	65.46	38	31	0.04	55.6
1012	11342	LAKE CONROE	77	16	17.9	58.9	+5.42	57	32	0.98	60.24	67	66	0.04	60.5
1209A	11792	COUNTRY CLUB LAKE	78	10	18.22	59.08	+9.62	106	9	0.38	74.06	108	10	0.36	88.7
1242N	18457	TRADINGHOUSE CREEK RESERVOIR	79	6	18.76	59.36	NA	74	17	0.8	63.18	34	17	0.04	54.8
1209B	11798	FIN FEATHER LAKE REET	80	12	20.6	60.28	+7.88	63	10	0.94	61.04	100	13	0.16	77.5
1411	12359	E V SPENCE RESERVOIR	81	14	20.8	60.38	+12.41	55	15	1.02	59.62	27	15	0.04	53.8
2103	12967	LAKE CORPUS CHRISTI	82	13	21.6	60.74	+10.97	68	57	0.86	62.26	104	33	0.18	78.5
0820	10998	LAKE RAY HUBBARD	83	8	22.3	61.06	+14.74	62	29	0.94	60.9	70	14	0.06	62.7
0605	16159	LAKE PALESTINE	84	28	23.22	61.46	+10.45	64	38	0.9	61.44	36	38	0.04	55

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
2312	13267	RED BLUFF RESERVOIR	85	14	23.52	61.58	+10.75	66	21	0.88	61.96	27	20	0.04	53.8
1423	12422	TWIN BUTTES RESERVOIR	86	20	23.98	61.76	+16.16	76	30	0.78	63.64	88	29	0.08	68.3
0809	10944	EAGLE MOUNTAIN RESERVOIR	87	5	24.46	61.96	+8.4	61	5	0.94	60.86	85	5	0.08	67.2
1402G	17017	FAYETTE RESERVOIR	88	44	24.86	62.12	NA	50	40	1.12	58.38	45	56	0.04	56.4
1008F	16482	LAKE WOODLANDS	89	16	26.46	62.74	NA	105	84	0.38	73.6	110	36	0.88	102
0229A	10192	LAKE TANGLEWOOD	90	25	28.48	63.46	+10.58	53	35	1.08	58.92	111	36	1.14	105.6
1425	12429	O C FISHER RESERVOIR	91	20	30.04	63.98	+15.14	107	31	0.36	74.46	98	29	0.16	76.6
1253	16247	SPRINGFIELD LAKE	92	31	30.64	64.18	NA	113	38	0.3	76.98	105	42	0.18	79.1
0507	10434	LAKE TAWAKONI	93	76	31.32	64.38	+10.13	60	147	0.94	60.82	74	20	0.06	64.2
1412A	12167	LAKE COLORADO CITY	94	4	37.2	66.08	+11.46	95	24	0.6	67.16	90	4	0.08	68.6
0509	10444	LAKE MURVAUL	95	22	38.3	66.36	+1.55	97	31	0.6	67.32	69	33	0.06	62.1
1212	11881	SOMERVILLE LAKE	96	12	42.14	67.3	+15.93	79	64	0.72	64.56	89	26	0.08	68.5

Segment	Station	Reservoir	Chla Rank	Chla Records	Chla Mean (ug/L)	Chla TSI	10 - Year Change (Chla TSI)	Secchi Rank	Secchi Records	Secchi Mean (Meters)	Secchi TSI	TP Rank	TP Records	TP Mean (mg/L)	TP TSI
1242A	16781	OLD MARLIN CITY LAKE	97	21	42.96	67.48	NA	109	27	0.36	74.94	100	31	0.16	77.5
1241A	11529	BUFFALO SPRINGS LAKE	98	8	55.08	69.92	+3.98	59	12	0.94	60.74	83	13	0.08	65.9
0219	10163	LAKE WICHITA	99	9	107.02	76.44	+14.87	110	13	0.34	75.26	106	13	0.22	82
0105	10060	RITA BLANCA LAKE	100	13	366.84	88.52	+20.13	115	23	0.08	97.74	112	21	3.48	121.7

* Reservoirs are ranked in priority by TSI (Chl). A true rank was used which can result in a tied rank for reservoirs with the same TSI (Chl) The rank resumes with subsequent rank value.

** The Carlson's TSI (Chl), (TP), and (SD) were computed for each reservoir by calculating the arithmetic average for the TSI values from each sample date. The effect of these computations is that the ranking of Carlson's TSI (Chl), (TP), and (SD) values may vary slightly from a ranking based on the arithmetic average of chlorophyll *a*, total phosphorus, and Secchi disk values.

***Some ranking assignments are skipped by the computational data model

**** A minus(-) preceding a value in the change column indicates decreased algal content between the 2000 and 2010 reporting cycles; a plus (+) indicates increased algal content; NA indicates a comparison cannot be made due to absence of comparable data.

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