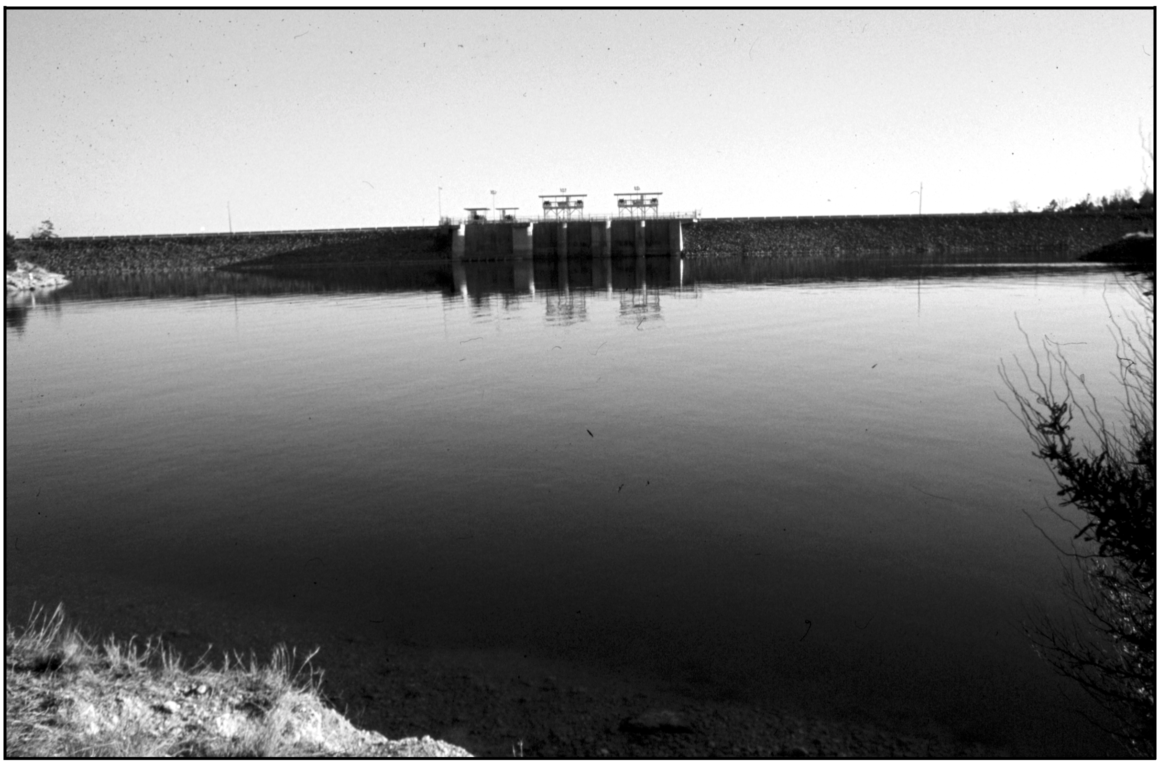
Reservoir and Lake Use Support Assessment



Spillway at Sam Rayburn Reservoir

Reservoir and Lake Use Support Assessment

For the 2002 report, 129 reservoirs and lakes (100 classified and 29 unclassified) encompassing 1,586,851 acres were surveyed and at least one designated beneficial use was assessed in each water body. The surveyed acres represent 94 percent of area covered (1,690,140 acres) by major reservoirs (>500 ac-ft) in the State and 81 percent of the area covered (1,954,600 acres) by all perennial reservoirs (> 10 acres)(Figure 9-1). Ten more reservoirs and lakes covering approximately 15,348 acres were surveyed in 2002 than in 2000, the year of the last full statewide assessment conducted by the TCEQ. The increase in surveyed acres is primarily due to additional monitoring of small unclassified reservoirs and lakes.

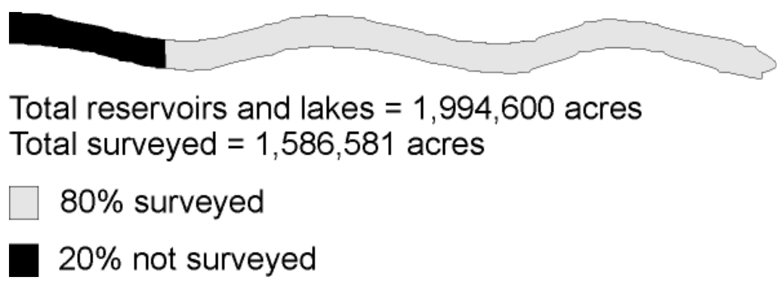


Figure 9-1. Reservoir and Lake Acres Surveyed

Of the 1 ,586,851 acres surveyed, sufficient data were available to provide assessment of at least one designated use in 1,574,071 acres (99%). About 70 percent of the 1,574,071 assessed acres fully support all their designated beneficial uses (Figure 9-2). Some form of pollution impairs the remaining 30 percent of assessed reservoir and lake acres. The framework, indicators, and criteria used to assess designated uses in reservoirs is discussed in the "Surface Water Assessment Methodology" section and shown in Tables 18-28.

Figure 9-3 indicates the causes and sources of pollutants that impair (i.e., prevent from fully supporting designated uses) reservoir and lake acres. Causes that contribute most to overall impairment of designated uses in reservoirs and lakes include mercury (fish consumption use), low and high pH values (general uses), and elevated average dissolved minerals (general uses).

The source of pollution for most reservoirs and lakes is atmospheric deposition of mercury that accounts for the largest category of known

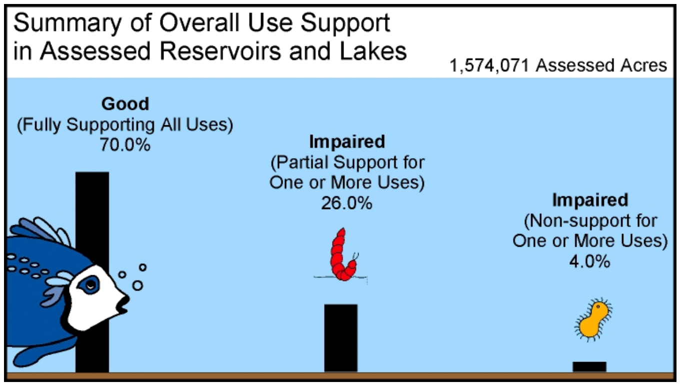
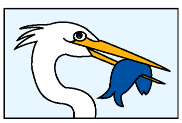


Figure 9-2 . Summary of Overall Use Support in Assessed Reservoirs and Lakes

pollution sources. Other sources causing nonsupport of designated uses are largely unknown.



Aquatic Life Use Support

Individual use support information provides additional detail about water quality problems in reservoirs and lakes. Approximately 1,586,851 acres were surveyed to determine support of the aquatic life use. Sufficient data were available to provide assessment of 669,855 acres (42.2% of surveyed acres) (Table 9-1). Of these assessed acres, about 98 percent fully supported the aquatic life use, one percent partially supported the use, and one percent failed to support the use.

Depressed instantaneous (grab sample) dissolved oxygen concentrations, compared to the absolute minimum criteria, was the most common indicator used to assess support of the aquatic life use (Table 9-2). Of the 666,157 acres assessed (42% of surveyed acres) by instantaneous dissolved oxygen, approximately 98 percent supported aquatic life uses, one percent partially supported the use, and one percent failed to support the use.

The aquatic life use in reservoirs and lakes was assessed in 106,170 acres (6.7% of surveyed acres) by evaluation of metals in water data (acute and chronic exposure to aquatic life) and 100 percent supported the use (Table 9-2). For the remaining six indicators (24-hour dissolved oxygen measurements, organic substances in water, water and sediment toxicity testing, and macrobenthos, fish, and habitat evaluations) data were so insufficient that less than one percent of reservoir and lake acres were assessed by each indicator. However, the aquatic life use was fully supported in the small acreages assessed by organic substances in water (860 acres) and habitat evaluations (3,555 acres).

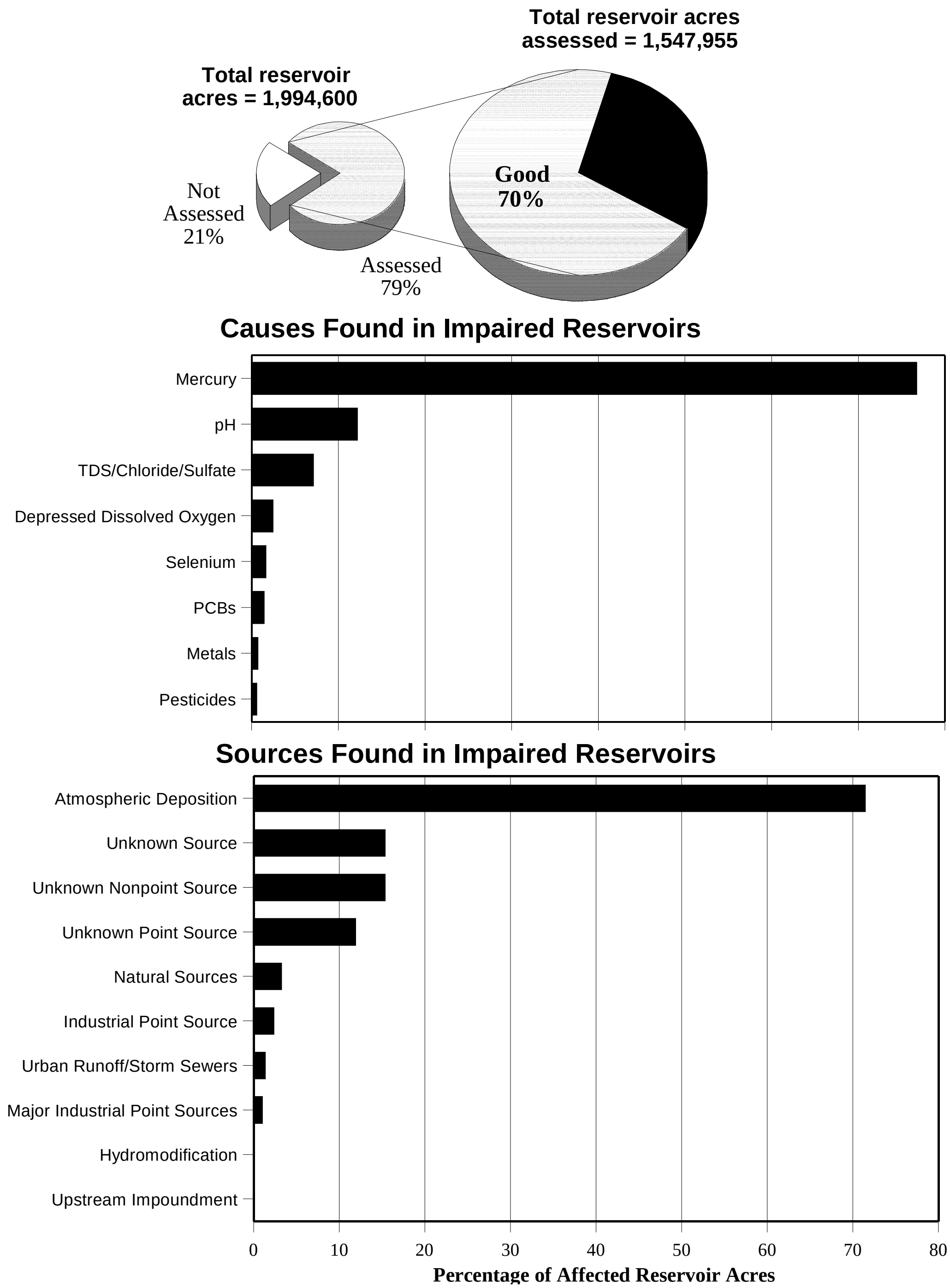
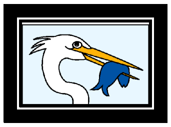
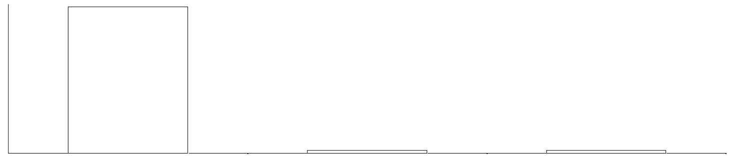
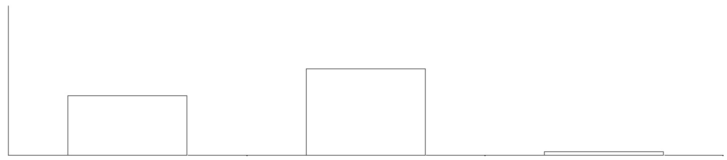
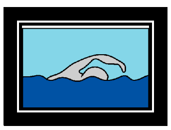
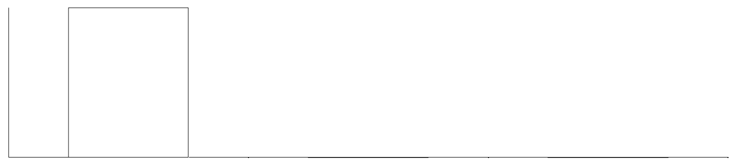
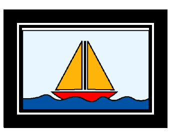
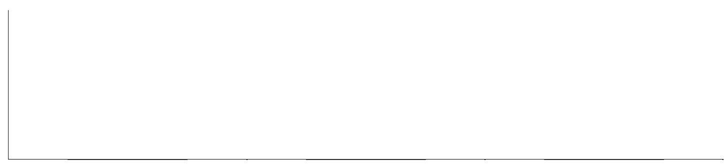
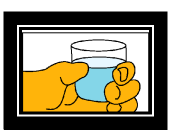
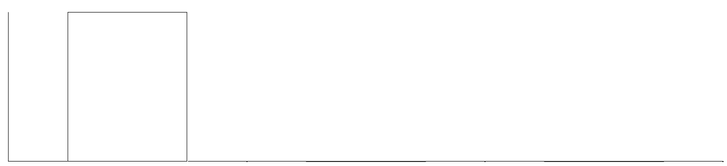
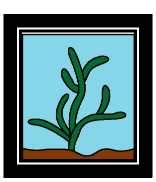
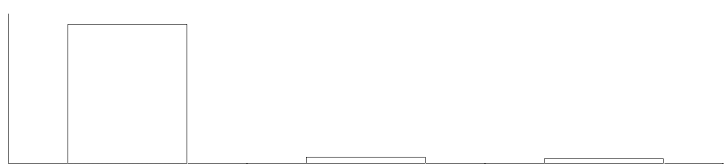


Figure 9-3. Causes and Sources of Pollution in Reservoirs and Lakes

Table 9-1. Individual Overall Use Support in Reservoirs and Lakes - 2002

Designated Use	Acres Surveyed	Acres Assessed	Percent of Acres Assessed	Percent of Assessed Acres		
				Good (Fully supporting)	Fair (Partially Supporting)	Poor (Not Supporting)
 Aquatic Life Support	1,586,851	669,855	42.21	 98	1	1
 Fish Consumption	1,586,851	623,573	39.30	 40	58	2
 Contact Recreation	1,586,327	407,324	25.68	 100	X*	< 1
 Noncontact Recreation	524	0	0.00	 0	X*	100
 Public Water Supply	1,532,153	1,532,153	100.00	 100	0	0
 General Uses	1,552,827	1,348,889	86.87	 93	4	3

* Category not applicable
X* - Category not applicable

Table 9-2. Individual Indicators for Assessment of Aquatic Life, Fish Consumption, and General Use Support in Reservoirs and Lakes - 2002

Designated Use	Acres Surveyed	Acres Assessed	Percent of Acres Assessed	Percent of Assessed Acres		
				Good (Fully supporting)	**Fair (Partially Supporting)**	**Poor (Not Supporting)**
Aquatic Life Support						
Instantanous Dissolved Oxygen - min	1,586,851	666,157	41.98	98	1	1
24-hour Dissolved Oxygen	1,586,851	0	0.00	0	0	0
Metals in Water	1,586,851	106,170	6.69	100	0	0
Organics Substances in Water	1,586,851	860	0.05	100	0	0
Water Toxicity	1,586,851	0	0.00	100	0	0
Sediment Toxicity	1,586,851	0	0.00	0	0	0
Macrobenthos Community	1,586,851	0	0.00	0	0	0
Fish Community	1,586,851	3,555	0.22	5	0	95
Habitat	1,586,851	3,365	0.21	100	0	0

Table 9-2. Individual Indicators for Assessment of Aquatic Life, Fish Consumption, and General Use Support in Reservoirs and Lakes, 2002 (Continued)

Designated Use	Acres Surveyed	Acres Assessed	Percent of Acres Assessed	Percent of Assessed Acres: Good (Fully supporting)	Percent of Assessed Acres: Fair (Partially Supporting)	Percent of Assessed Acres: Poor (Not Supporting)
Fish Consumption						
Advisories / Closures	1,586,851	539,807	34.02	31	67	3
Human Health Criteria	1,586,851	132,132	8.33	100	0	0
General Uses						
Water Temperature	1,552,827	663,330	42.72	100	0	0
pH	1,552,827	643,476	41.44	91	7	2
Chloride	1,552,827	1,284,488	82.72	99	X*	1
Sulfate	1,552,827	1,269,213	81.74	100	X	0

Table 9-2. Individual Indicators for Assessment of Aquatic Life, Fish Consumption and General Use Support in Reservoirs-2002

Designated Use	Acres Surveyed	Acres Assessed	Percent of Acres Assessed	Percent of Assessed Acres		
				Good (Fully supporting)	**Fair (Partially Sup-porting)**	**Poor (Not Supporting)**
Total Dissolved Solids	1,552,827	1,311,489	84.46	 98	X	2

* Category not applicable
X* - Category not applicable

The fourth most common cause of impaired aquatic life uses in reservoirs is depressed dissolved oxygen concentrations. Generally, reservoir areas impacted by low dissolved oxygen concentrations are localized in headwater regions near tributary inflows that transport point and nonpoint pollutant sources. The headwater areas may be marshy and shallow in depth. Reduced velocity and little physical turbulence (low re-aeration) in these headwater areas are natural factors that contribute equally to lower dissolved oxygen concentrations. Assimilation of organic materials, nutrients and sediment oxygen demand act to lower dissolved oxygen in these areas. In some cases, heavy point and nonpoint source nutrient loading overloads reservoir and lake systems and accelerates eutrophication. Algal blooms, depressed dissolved oxygen concentrations, and abundance of aquatic weeds are symptoms of excessive nutrient loading in some reservoirs and lakes. Hypolimnectic releases of nearly anoxic water from upstream deep-storage reservoirs is another cause of depressed dissolved oxygen levels in reservoirs located downstream.

The aquatic life use in only four reservoirs was either not supported (Caddo Lake, Segment 0401) or partially supported (Lake Wright Patman, Segment 0302; Toledo Bend, Segment 0504; and Inks Lake, Segment 1407)(Table 9-3). All of the impairments were based on instantaneous measurements compared to the minimum criteria. Although 24-hour dissolved oxygen measurements were no in sufficient number to provide assessment of the aquatic life use in any reservoir, they identified Tier 1 concerns in portions of Lake Wright Patman (Segment 0302), Lake O' Pines (Segment 0403), and the extreme upper Angelina River Arm of Sam Rayburn Reservoir (Segment 0615). Comparison of instantaneous

Table 9-3. Reservoirs with Partial and Nonsupported Aquatic Life Uses, Tier 1 Concerns, and Tier 2 Concerns

Segment Number	Segment Name	DO Grab Average	DO Grab Minimum	24hr-avg	24hr-min
0302	Wright Patman Lake	T2	PS	T1	T1
0401	Caddo Lake	T2	NS/T1		
0403	Lake O' the Pines	T2		T1	T1
0504	Toledo Bend Reservoir	T2	PS		
0507	Lake Tawakoni	T2	T1		
0605	Lake Palestine		T1		
0610	Sam Rayburn Reservoir	T2			
0615	Angelina River/Sam Rayburn Reservoir	T2	T2	T1	T1
0701D	Shallow Prong Lake (unclassified water body)		T1		
0809	Eagle Mountain Reservoir	T2			
0818	Cedar Creek Reservoir	T2			
0821	Lake Lavon	T2			
1002	Lake Houston	T2			
1008F	Lake Woodlands (unclassified water body)		T1		
1012	Lake Conroe	T2			
1203	Whitney Lake	T2			
1210	Lake Mexia	T2			
1222	Proctor Lake	T2			
1233	Hubbard Creek Reservoir	T2			
1403	Lake Austin	T2	T2		
1404	Lake Travis	T2			
1405	Marble Falls Lake	T2			
1406	Lake Lyndon B. Johnson	T2			
1407	Inks Lake	T2	PS		
1433	O. H. Ivie Reservoir	T2			

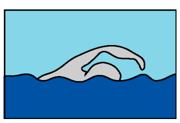
Table 9-3. Reservoirs with Partial and Nonsupported Aquatic Life Uses, Tier 1 Concerns, and Tier 2 Concerns

Segment Number	Segment Name	DO Grab Average	DO Grab Minimum	24hr-avg	24hr-min
1604	Lake Texana	T2			
2116	Choke Canyon Reservoir		T1		

dissolved oxygen measurements to 24-hour criteria identified 23 reservoirs with Tier 2 concerns.

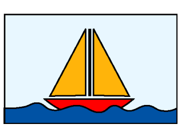
Aquatic life uses in reservoirs were fully supported based on assessment of metals and organic substances in water (Table 9-2). Tier 1 concerns were identified for Lake Bob Sandlin (Segment 0408, chronic cadmium) and Sam Rayburn Reservoir (Segment 0610, acute aluminum and acute copper).

The only reservoir in which the aquatic life use was directly evaluated by biological and habitat assessment was the extreme upper Angelina River Arm of Sam Rayburn Reservoir (Segment 0615). Fish community assessment indicated the aquatic life use was not supported. Habitat data were not sufficient to provide full assessment of the use, but they identified a Tier 1 concern.



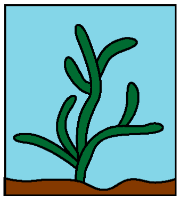
Contact Recreation Use Support

Contact recreation use is assigned to most reservoirs and lakes. Elevated fecal coliform or *E. coli* densities (pathogens) play only a very minor contributing role in overall use impairment of reservoirs and lakes. Bacterial data were sufficient to provide assessment of contact recreation in 407,324 of 1,586,327 acres surveyed (25.7%) (Table 9-1). Of the 407,324 acres assessed, 100 percent fully supported the contact recreation use. However, Tier 1 concerns were identified for Lake Tawakoni (Segment 0507) and Falcon Reservoir (Segment 2303), and a Tier 2 concern was identified for Ray Roberts Lake (Segment 0840).



Noncontact Recreation Use Support

Rita Blanca Lake (Segment 0105) is the only reservoir designated for noncontact recreation. Due to insufficient bacterial data, the noncontact recreation use was not assessed in 2002.



General Use Support

Field measurements of pH and water temperature and laboratory analysis of dissolved minerals (chloride, sulfate, and TDS) are used to determine support of the general water quality uses. Together these constituents comprise the second major cause of nonsupport of overall uses in reservoirs and lakes (Figure 9-3). Most of the classified reservoirs and lakes are assigned water body specific dissolved mineral criteria to safeguard general water quality, rather than for protection of specific uses. Water temperature, pH, and dissolved mineral criteria are not assigned to unclassified reservoirs and lakes, so their acreage was not assessed for general use attainment. Together, water temperature, pH, and dissolved mineral data were sufficient to provide assessment of general uses in 1,348,899 of 1,552,827 acres surveyed (86.9%) (Table 9-1).

Chloride, sulfate, and TDS were assessed in more than 80 percent of reservoir and lake acres surveyed (Table 9-2). Water temperature and pH measurements were made less frequently providing assessment of about 665,053 acres (42.8% of surveyed acres) and 643,476 acres (41.4%), of surveyed acres, respectively. All water temperature measurements fully supported general uses in lakes and reservoirs. More than 90 percent of assessed acres were fully supported by pH, chloride, sulfate, and TDS data.

Low and high pH values are the cause of most general use impairments, affecting six reservoirs and lakes (Table 9-4). Low pH (acidic water) values are common in East Texas water bodies due to the low prevalence of acid-neutralizing materials in the sandy soils. The upper portion of Sommerville Lake (Segment 1212) is the only reservoir with partially supported general uses due to low pH values. High pH values may result from photosynthesis by aquatic plants which removes carbon dioxide from the water and increases the pH during daylight hours. Portions of Cooper Lake (Segment 0307), and Cedar Creek Reservoir (Segment 0818) have high pH values which cause partial support of general uses in one portion of the impoundments and nonsupport in other areas. High pH values in Lake Tawakoni (Segment 0507), Lake Wright Patman (Segment 0302), Lake Livingston (Segment 0803), Richland-Chambers Reservoir (Segment 0836), and Lake Sommerville (Segment 1212) cause partial support of general uses.

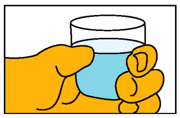
Dissolved minerals occur naturally in water, as a result of leaching from common minerals in the watershed. In some cases, dissolved minerals may be increased by industrial and domestic wastewater effluents. Elevated average chloride concentrations in surface water cause nonsupport of general uses in

Table 9-4. Reservoirs with Partial and Nonsupported General Uses, Tier 1 Concerns, and Tier 2 Concerns

Segment Number	Water Body	General Use Support Indicator					
		Temp	Low pH	High pH	Chloride	Sulfate	TDS
0209	Pat Mayse Lake			T1			
0302	Wright Patman Lake	T1		T1/T2/PS			
0307	Cooper Lake			T2/PS/NS			
0401	Caddo Lake		T1/T2	T2			
0504	Toledo Bend Reservoir		T2	T2			
0507	Lake Tawakoni			T2			
0510	Lake Cherokee		T1				
0605	Lake Palestine			T1			
0613	Lake Tyler/Lake Tyler East			T1/T2			
0803	Lake Livingston			T1/T2/PS			
0818	Cedar Creek Reservoir			T1/PS/NS			
0826	Grapevine Lake			T1			
0836	Richland-Chambers Reservoir			PS			
1012	Lake Conroe			T2			
1212	Somerville Lake		T2/PS	T2/PS			
1231	Lake Graham						T1
1240	White River Lake				NS		
1411	E. V. Spence Reservoir				T1	T1	T1
1425	O. C. Fisher Lake				NS		NS
2116	Choke Canyon Reservoir						NS

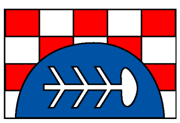
two reservoirs and TDS concentrations cause nonsupport of the use in two reservoirs (Table 9-4).

Tier 1 concerns were identified for temperature (one reservoir), low pH values (two reservoirs), high pH values (six reservoirs), chloride (one reservoir), sulfate (one reservoir), and TDS (two resrervoirs). The Tier 1 concerns were identified due to small sample sizes. Tier 2 concerns were identified for low pH (three reservoirs), and high pH (nine reservoirs).



Public Water Supply Use Support

Public water supply is a use that is not assigned to all reservoirs and lakes, so slightly less total acres were surveyed (1,532,153 acres)(Table 9-1). Support of the use is determined by exceedances of organic chemical criteria in finished drinking water (after treatment at the point of entry into the distribution system). Data were sufficient to provide assessment of all 1,532,153 acres surveyed. Of the assessed acres, 100 percent fully supported the public water supply use.



Fish Consumption Use Support

Approximately 1,586,851 acres were surveyed to determine support of the fish consumption use. Sufficient data were available to provide assessment of 623,573 acres (39% of surveyed acres) (Table 9-1). Of the assessed acres, about 40 percent fully supported the fish consumption use, 58 percent partially supported the use, and two percent failed to support the use. Issuance of fish consumption advisories and aquatic life closures by the TDH was the most common indicator used to assess support of the fish consumption use in reservoirs and lakes (Table 9-2). Of the 539,807 acres assessed (34% of surveyed acres) by issuance of advisories and closures, approximately 31 percent fully supported the fish consumption use, 67 percent partially supported the use, and three percent failed to support the use. Human health criteria in water were also evaluated to determine support of the fish consumption use. Human health criteria are back-calculated from concentrations in fish tissue. Exceedance of the criteria by average toxic substances concentrations in water suggest that concentrations in fish tissue could also be elevated. Only 132,132 acres (8% of surveyed acres) were assessed with human health criteria due to insufficient data. All of the assessed acres fully supported the fish consumption use based on evaluation of human health criteria in water.

The fish consumption use is partially supported for one lake and six reservoirs located in East Texas and one in the panhandle due to issuance by the TDH of restricted-consumption advisories for mercury. Caddo Lake (Segment 0401), Toledo Bend Reservoir (Segment 0504), B. A. Steinhagen Reservoir (Segment

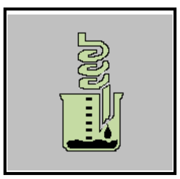
0603), Lake Kimball (Segment 0608G), Sam Rayburn Reservoir (Segment 0610), Lake Daingerfield (Segment 0404), and Lake Ratcliff (Segment 0604), and Lake Meredith (Segment 0102) are affected by the advisories. Mercury is a naturally occurring element that can be toxic if consumed in contaminated fish by humans and animals. Sources of mercury include weathering of the earth's crust, the burning of fossil fuels and garbage, and factories that use mercury. The specific source of mercury in fish from East Texas is atmospheric deposition. Bioaccumulation of mercury in east Texas fishes occurs primarily because of natural processes in streams and reservoirs related to low pH, elevated organic carbon, and low dissolved oxygen concentrations (Twidwell, 2000).

Welsh Reservoir (Segment 0404D), Brandy Branch Reservoir (Segment 0505E), and Martin Creek Reservoir (Segment 0505F) are used by power companies for cooling of steam electric condensers. Coal is burned at the plants to provide heat to run the steam-electric generators. Selenium in the coal is liberated during the burning process, ending up in the bottom ash and fly ash. Runoff from fly ash disposal areas is the suspected source of selenium contamination in the reservoirs. The fish consumption use for these three reservoirs is not supported due to issuance in May 1992 by the TDH of a no-consumption advisory for a sensitive subpopulation (children and women of child bearing age) due to elevated selenium concentrations in fish tissue. All fish species are covered by the advisory.

Aquatic life closures for Como (Segment 0829A) and Fosdic Lakes (Segment 0806A), issued in April 1985 by the TDH, cause nonsupport of the fish consumption use due to elevated toxic organic substances (chlordane, PCBs, DDE, and dieldrin) in edible tissue. A similar aquatic life closure was issued in April 1996 for Mountain Creek Lake (Segment 0810), but in addition includes tissue contaminants DDD, DDT, and heptachlor epoxide. All three lakes are small, urban reservoirs located in the Fort Worth area. Aquatic life closures issued in December 1995 by the TDH for Echo Lake (Segment 0806B) and the Donna Reservoir System (Segment 2202A) in February 1994 and a no-consumption advisory for Lake Worth (Segment 0807) in April 2000, due to elevated PCBs in edible fish tissue, cause nonsupport of the fish consumption use in the three reservoirs. The organic chemicals found in the tissue of fish from these reservoirs are used for various pest control and industrial purposes and were probably carried into the reservoirs from urban runoff. The source of PCBs in the Donna Reservoir System is unknown. The aquatic life closures prohibit possession of any fish from the reservoirs.

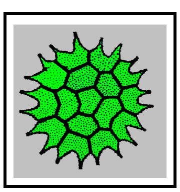
Reservoir and Lakes Secondary Concerns Assessment

The TCEQ and the CRP have developed screening levels to identify water bodies with elevated nutrient and chlorophyll *a* concentrations in water, elevated toxic substances in sediment, and elevated toxic substances in fish tissue. Water quality criteria have not been developed by the TCEQ in the TSWQS for these constituents. Water quality concerns are identified when greater than 25 percent of samples exceed screening levels. Public water supply concerns are identified for water bodies when average dissolved mineral concentrations in finished drinking water samples exceed the secondary drinking water criteria. Public water supply concerns are also identified for surface water when average dissolved mineral concentrations exceed secondary finished drinking water criteria. Water bodies that provide supply to systems which experience increased costs for demineralization due to high dissolved solids are also identified with concerns. The framework, indicators, and criteria for evaluation of water quality concerns are discussed in the "Surface Water Assessment Methodology" section and are shown in Tables 29-33. Reservoirs and lakes with identified concerns are targeted by the TCEQ and CRP for increased fixed station monitoring or special studies to identify possible causes and sources.



Nutrient Concerns

Approximately 1,586,581 reservoir and lake acres were surveyed to identify areas of concern caused by elevated concentrations of ammonia nitrogen, nitrite plus nitrate nitrogen, orthophosphorus, and total phosphorus (Table 9-5). Sufficient data were available to provide assessment of about 400,000 acres (about 25% of surveyed acres) for each nutrient indicator. Of the acres assessed in reservoirs and lakes, water quality concerns were identified in only 10 percent for ammonia nitrogen, 20 percent for nitrite plus nitrate nitrogen, 12 percent for orthophosphorus, and 16 percent for total phosphorus. Thirteen reservoirs and lakes were identified with concerns for ammonia nitrogen, 22 for nitrite plus nitrate nitrogen, 10 for orthophosphorus, and 14 for total phosphorus (Table 9-6).



Chlorophyll a Concerns

Approximately 1,586,851 reservoir and lake acres were surveyed to identify areas of concern caused by elevated chlorophyll *a* concentrations (Table 9-5). Sufficient data were available to provide assessment of 355,697 acres (22% of surveyed acres). Of the assessed acres, 25 percent were identified with elevated chlorophyll *a* concentrations. The 14 reservoirs and lakes with elevated chlorophyll *a* concentrations are located in several different areas of the state

Table 9-5. Individual Nutrient and Chlorophyll *a* Concerns in Reservoirs and Lakes - 2002

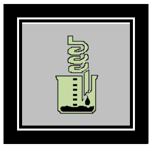
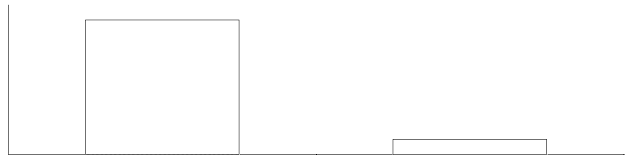
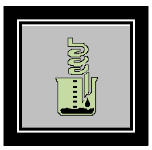
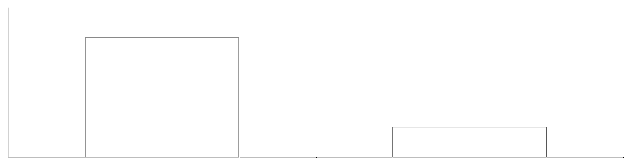
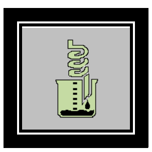
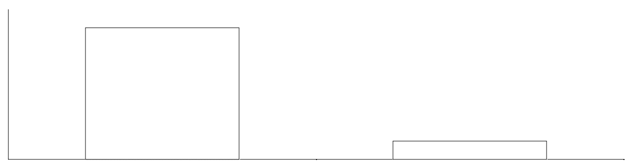
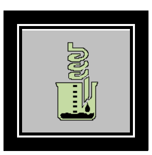
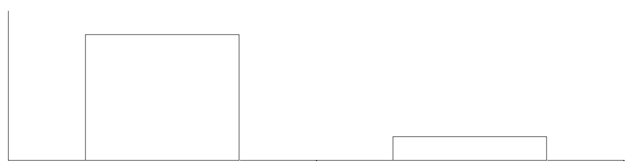
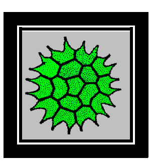
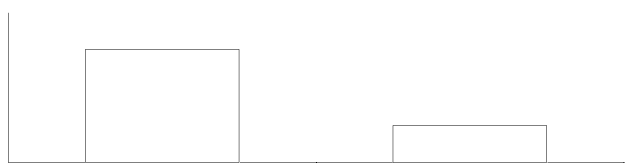
Concern Parameter	Acres Surveyed	Acres Assessed	Percent of Acres Assessed	Percent of Assessed Acres		
					No Concern	Concern
 Ammonia	1,586,851	482,733	30.42		90	10
 Nitrate + Nitrite	1,586,851	537,762	33.89		80	20
 Orthophosphorus	1,586,851	527,212	33.22		88	12
 Total Phosphorus	1,586,851	366,213	23.08		84	16
 Chlorophyll a	1,586,851	355,697	22.42		75	25

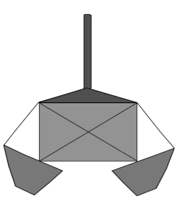
Table 9-6. Reservoirs with Secondary Concerns for Nutrients and Chlorophyll *a*

Segment Number	Water Body	Nutrient				Chl *a*
		NH_3-N	NO_2+NO_3 -N	OPhos	TPhos	
0199A	Palo Duro Reservoir (unclassified water body)	X	X	X	X	
0229A	Lake Tanglewood (unclassified water body)		X	X	X	X
0302	Wright Patman Lake				X	X
0401	Caddo Lake	X				
0403	Lake O' the Pines		X		X	
0504	Toledo Bend Reservoir			X		X
0507	Lake Tawakoni			X		X
0512	Lake Fork Reservoir					X
0605	Lake Palestine	X	X			
0610	Sam Rayburn Reservoir				X	
0615	Angelina River/Sam Rayburn Reservoir	X	X	X	X	
0803	Lake Livingston		X	X	X	X
0809	Eagle Mountain Reservoir				X	X
0815	Bardwell Reservoir		X			
0818	Cedar Creek Reservoir	X		X	X	X
0820	Lake Ray Hubbard	X	X			X
0821	Lake Lavon		X			
0823	Lewisville Lake	X	X			
0830	Benbrook Lake	X				X
0836	Richland-Chambers Reservoir		X			X
0840	Ray Roberts Lake	X	X	X	X	
1002	Lake Houston		X	X	X	
1203	Whitney Lake		X			
1210	Lake Mexia				X	
1220	Belton Lake		X			

Table 9.6. Reservoirs with Secondary Concerns for Nutrients and Chlorophyll *a* (Continued)

Segment Number	Water Body	Nutrient				Chl *a*
		NH_3-N	NO_2+NO_3 -N	OPhos	TPhos	
1225	Waco Lake		X			X
1247	Granger Lake		X			
1252	Lake Limestone		X			
1254	Aquilla Reservoir		X			
1402G	Fayette Reservoir (unclassified water body)					X
1407	Inks Lake	X				
1408	Lake Buchanan					X
1422	Lake Nasworthy	X				
1425	O. C. Fisher Lake	X				
1429	Town Lake		X			
1604	Lake Texana	X	X	X	X	
2305	International Amistad Reservoir				X	
2312	Red Bluff Reservoir		X			

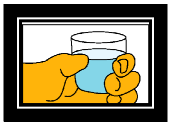
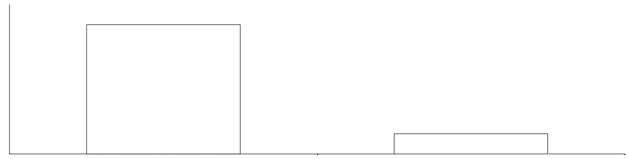
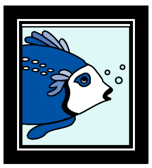
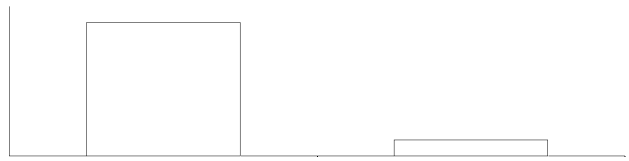
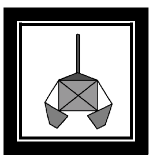
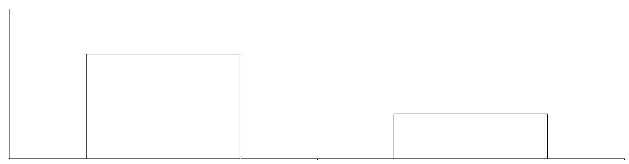
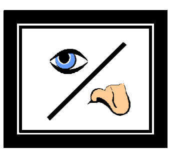
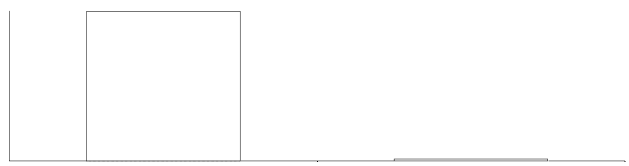
(Table 9-6). Eleven of 14 reservoirs with elevated chlorophyll *a* concentrations also were identified with concerns for one or more of the nutrient indicators, suggesting that nutrient loading may be responsible for stimulation of algal growth in many of the impoundments.

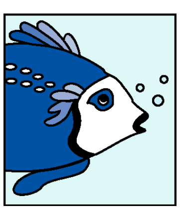


Sediment Concerns

Due to high cost associated with analytical laboratory determinations of metals and organic substances, sediment sampling is not widespread in reservoirs and lakes. Most of the sampling is targeted to reservoirs and lakes likely to be contaminated by point and nonpoint sources. Of the 1,586,851 reservoir and lake acres surveyed for elevated sediment contaminants, sufficient data were available to provide assessment in only 20,065 acres (1.2% of surveyed acres) (Table 9-8). Of the 20,065 acres assessed, 30 percent were identified with concerns for one or more sediment contaminants. Caddo Lake (Segment 0401) was the only reservoir identified with sediment concerns due to elevated concentrations of barium, lead, manganese, mercury, and zinc.

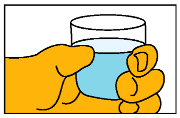
Table 9-7. Overall Concerns for Public Water Supply, Fish Tissue Contaminants, Sediment Contaminants, and Narrative Criteria in Reservoirs and Lakes - 2002

Concern Parameter	**Acres Surveyed**	**Acres Assessed**	**Percent of Acres Assessed**	**Percent of Assessed Acres**	
				No Concern	**Concern**
 Public Water Supply	1,532,153	1,532,153	100.00	 86	14
 Fish Tissue Contaminant	1,586,851	51,642	3.25	 89	11
 Sediment Contaminant	1,586,851	20,065	1.26	 70	30
 Narrative Criteria	1,586,851	1,586,851	100.00	 99	1



Fish Tissue Concerns

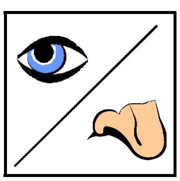
Of the 1,586,851 acres surveyed for elevated contaminants in fish tissue, only 51,642 acres (3.3% of surveyed acres) were assessed (Table 9-8). The high cost of associated with tissue preparation and analytical laboratory determinations of metals and organic substances limits the amount of statewide fish tissue sampling. Of the 51,642 acres assessed, only about 11 percent were identified with fish tissue concerns. Caddo Lake (Segment 0401) and Lake Kimball (Segment 0608) were identified with secondary concerns due to elevated mercury concentrations in edible fish tissue. The TDH has issued restricted consumption advisories for both reservoirs due to the elevated mercury concentrations in fish tissue.



Public Water Supply Concerns

Concerns are identified in finished drinking water (after treatment at the point of entry to the distribution system) and surface samples from reservoirs and lakes designated for public water supply if average concentrations exceed secondary standards for chloride (300 mg/L), sulfate (300 mg/L) and TDS (1,000 mg/L). Public water supply systems that experience increased costs for demineralization are also identified as concerns. The public water supply use is not assigned to all reservoirs and lakes. Data were available to provide assessment of all 1,532,153 acres surveyed and about 14 percent were identified with public water supply concerns (Table 9-7).

Surface water concentrations of dissolved minerals cause public water supply concerns for eight reservoirs (Table 9-8). Seven reservoirs and lakes are also identified with concerns due to elevated dissolved mineral concentrations in finished drinking water. Advanced waste treatment for removal of dissolved minerals is required for three reservoirs that provide water for domestic supply. These reservoirs are identified as having public water supply concerns due to the increased cost associated with demineralization treatment. Most of the reservoirs identified with public water supply concerns are located in the Canadian and upper regions of the Red, Colorado, and Brazos River basins. In these areas, natural conditions (brine seepage, high evaporation rates, groundwater seepage, and rainfall runoff from salt bearing strata) or inadequate disposal of brine water produced by oil and gas operations influence dissolved mineral concentrations in surface waters.



Narrative Criteria Concerns

Examples of narrative criteria include such categories as floating debris and oil sheens, suspended solids and excessive foam, odor producing substances, dramatic changes in turbidity or color, and excessive algal blooms. All 1,586,851 reservoir and lake acres were assessed for narrative criteria concerns, and less than one percent was identified with concerns (Table 9-7). The extreme headwater region of Sam Rayburn Reservoir in the Angelina Arm (Segment 0615) is identified with a narrative concern for color. The color and odor of water in the upper end of the reservoir is influenced by effluent from a paper mill. Elevated metals in sediment cause narrative concerns for Ellison Creek Reservoir (Segment 0404, metals), Country Club Lake (Segment 1209, metals), and Finfeather Lake (Segment 1209, metals).

Table 9-8. Reservoirs with Secondary Public Water Supply Concerns

Segment Number	Water Body	Finished Drinking Water			Surface Water			Increased Costs for Demineral-ization
		Cl	SO_4	TDS	Cl	SO_4	TDS	
0102	Lake Meredith	X	X	X	X	X	X	
0203	Lake Texoma	X	X	X				X
1203	Whitney Lake				X			
1205	Lake Granbury				X		X	X
1207	Possum Kingdom Lake	X	X	X	X	X	X	X
1235	Lake Stamford	X	X	X				
1237	Lake Sweetwater		X					
1411	E. V. Spence Reservoir				X	X	X	
1412A	Lake Colorado City (unclassi-fied water body)		X	X				
1422	Lake Nasworthy				X	X		
1425	O. C. Fisher Lake				X			
1426A	Oak Creek Reservoir (unclassi-fied water body)		X					
1433	O. H. Ivie Reservoir				X		X	

Trophic Classification of Reservoirs and Lakes

Eutrophication is a natural aging process in reservoirs and lakes. Even without human influences, most reservoirs and lakes are likely to gradually become eutrophic. Eutrophication of reservoirs and lakes in southern states is enhanced due to warm, fertile climates. 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 substances often times overstimulate 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. Various classification schemes or indices have been developed that group reservoirs into discrete quality (trophic) states along a continuum from oligotrophic (poorly nourished) to hypereutrophic (over nourished) (Table 9-9). 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 an increase in its concentration may trigger a responding increase in the amount of algae (estimated by chlorophyll *a*) in the reservoir. Due to increased algal biomass, water transparency, as measured by a Secchi disk or submarine photometer, would be expected to decrease.

Table 9-9. Types of Trophic States in Reservoirs and Lakes

Trophic State	Water Quality Characteristics
Oligotrohic	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 by the TCEQ using Carlson's Trophic State Index (TSI). Carlson's Index was developed to compare among reservoirs Secchi disk depths, chlorophyll *a* concentrations, and total phosphorus concentrations obtained by in-reservoir sampling (Carlson, 1977). These three variables are highly correlated and are considered estimators of algal biomass. By using regression analysis, Carlson related Secchi disk depth to total phosphorus concentration and to chlorophyll *a* concentration. The TSI is determined from any of the three computational equations:

$$\text{TSI (Secchi Disk)} = 10\left(6 - \frac{\ln SD}{\ln 2}\right)$$

$$\text{TSI (Chlorophyll } a\text{)} = 10\left(6 - \frac{2.04 - 0.68 \ln Chl}{\ln 2}\right)$$

$$\text{TSI (Total Phosphorus)} = 10\left(6 - \frac{\ln \frac{48}{TP}}{\ln 2}\right)$$

Although chlorophyll *a* is the most direct measure of algal biomass, Carlson used 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 9-10). The relationships between Secchi disk and chlorophyll *a* was nonlinear, so a 10-unit TSI (Chl *a*) change does not correspond to a factor-of-two change for chlorophyll *a*. Instead, chlorophyll *a* approximately doubles for each 7-unit increase in TSI (chl *a*).

Table 9-10. Carlson's Trophic State Index and Associated Parameters

Trophic State Index	**Secchi Disk (m)**	**Total Phosphorus (mg/m^3)**	**Chlorophyll *a* (mg/m^3)**
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	26
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 current condition and monitoring for change 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 rehabilitation measures. The index provides useful information in cases where the values are different, e.g., if TSI (TP) > TSI (Chl *a*), phosphorus is probably not the limiting nutrient; TSI (SD) > TSI (Chl *a*) indicates the presence of nonalgal turbidity. Carlson's Index has the advantage of presenting trophic state on a continuous numeric scale and can approximate 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

Table 9-11. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (TSI)

			Chlorophyll *a*					Total Phosphorus				Secchi Disk			
Segment Number	**SWQM Station ID**	**Reservoir Name**	**Rank** *	**No. Meas.**	**Mean mg/m³** **	**TSI Chl *a*** **	**Trend** ***	**Rank**	**No. Meas.**	**Mean mg/m³**	**TSI TP**	**Rank**	**No. Meas.**	**Mean m**	**TSI SD**
1230	11977	Lake Palo Pinto	1	6	0.50	30.57	-6.53	47	5	41.00	57.18	71	7	1.00	64.49
1904	12825	Medina Lake	2	10	0.63	31.13	-2.82	8	11	17.27	49.07	7	4	2.20	49.07
1216	11894	Stillhouse Hollow	3	10	0.79	31.46	-0.62	10	10	19.50	49.83	5	43	3.01	44.65
2305	13211	Amistad	4	5	0.73	31.56	-1.96	87	22	781.70	71.62	3	36	3.37	44.31
1403	12294	Lake Austin	5	59	3.01	33.83	-4.53	44	54	78.62	56.95	10	54	2.14	50.08
0838	11073	Joe Pool	6	13	1.36	33.91	-2.30	7	17	21.76	48.16	37	13	1.33	56.60
0614	10639	Lake Jacksonville	7	11	1.41	34.08	-2.21	17	11	19.09	51.85	14	13	1.93	50.73
0228	10188	Lake Mackenzie	8	19	1.70	34.70	-0.06	5	19	21.05	47.66	26	20	1.54	54.23
1240	12027	White River Lake	9	4	1.46	34.84	+1.10	26	4	22.50	53.98	81	9	0.78	67.42
0102	10036	Lake Meredith	10	23	2.12	35.05	-1.02	14	22	37.50	50.94	6	23	2.44	48.66
0223	10173	Greenbelt	11	18	2.23	35.24	-1.08	3	18	15.56	46.01	11	19	2.06	50.18
1234	12005	Lake Cisco	12	10	1.85	35.33	-3.71	12	10	21.50	49.92	24	8	1.61	54.01
1429	12476	Austin Town Lake	13	58	3.56	35.76	-0.06	41	52	75.12	56.16	16	54	2.07	50.80
1220	11921	Belton	14	15	1.93	35.93	-0.19	13	15	25.00	50.56	13	49	2.04	50.55
0204	15447	Moss Lake	15	6	1.81	35.96	-----	65	6	25.00	60.59	41	5	1.24	57.53
1805	12598	Canyon Lake	16	62	2.06	35.98	-0.32	46	122	55.14	57.13	2	3	3.43	42.27
1249	12111	Lake Georgetown	17	16	2.40	35.99	-1.07	1	16	21.25	44.83	8	47	2.23	49.15
0217	10159	Lake Kemp	18	15	2.37	36.00	-3.02	15	15	26.00	51.44	29	8	1.65	55.28
0610	14906	Sam Rayburn	19	14	1.78	36.11	+0.63	11	14	20.00	49.84	9	16	2.12	49.34

Table 9-11. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (Continued)

Segment Number	SWQM Station ID	Reservoir Name	Chlorophyll *a*					Total Phosphorus				Secchi Disk			
			Rank *	No. Meas.	Mean mg/m^3 **	TSI Chl *a* **	Trend ***	Rank	No. Meas.	Mean mg/m^3	TSI TP	Rank	No. Meas.	Mean m	TSI SD
0215	10157	Diversion Lake	20	11	2.20	36.18	-1.18	30	11	28.64	54.59	49	7	1.06	59.86
1233	12002	Hubbard Creek	21	5	2.53	36.63	-1.29	38	5	62.00	55.83	17	2	1.97	51.41
1404	12302	Lake Travis	22	54	3.13	37.23	-0.98	33	53	78.23	54.90	1	76	4.02	41.09
0834	11063	Lake Amon G. Carter	23	7	3.18	37.77	-0.49	31	7	42.14	54.70	12	2	1.97	50.31
1224	11939	Leon	24	11	3.29	38.25	-0.98	21	11	31.36	53.10	47	7	1.14	58.58
1203	11851	Lake Whitney	25	9	3.47	38.96	-1.00	19	9	25.56	52.72	21	53	1.67	53.44
1231	11979	Lake Graham	26	8	2.75	39.18	+0.01	34	7	39.29	55.16	85	5	0.58	68.98
0821	11020	Lake Lavon	27	10	3.45	39.30	-1.20	51	9	43.33	57.89	63	10	0.84	63.58
0210	10139	Farmers Creek	28	14	3.46	39.50	+0.49	20	14	28.93	52.81	54	6	1.04	60.32
1254	12127	Aquilla	29	17	3.23	39.64	-2.32	57	17	45.00	58.88	82	26	0.65	67.46
1247	12095	Granger Lake	30	16	3.97	39.64	-1.67	24	16	35.69	53.54	89	48	0.49	70.74
0813	10973	Houston County Lake	31	10	3.04	39.69	+0.01	29	10	24.50	54.47	25	12	1.53	54.23
1419	12398	Lake Coleman	32	9	3.58	39.77	-1.30	4	9	18.89	46.51	36	5	1.30	56.53
1418	12395	Lake Brownwood	33	13	3.02	39.93	-0.29	9	13	55.38	49.46	52	5	1.05	60.21
0203	10128	Lake Texoma	34	4	5.37	40.92	-3.13	27	4	32.50	54.26	18	5	1.76	51.96
0408	10329	Lake Bob Sandlin	35	11	3.99	41.24	-3.51	32	11	32.27	54.77	28	11	1.46	54.69
1433	12511	O.H. Ivie	36	8	4.66	41.29	-1.24	22	8	103.12	53.26	20	13	1.69	53.23
0613	10637	Lake Tyler	37	14	4.58	41.45	+1.98	25	14	27.14	53.76	43	16	1.17	58.01
1423	12422	Twin Buttes	38	9	4.31	41.68	-3.92	28	9	53.89	54.35	72	9	1.16	64.56
1002	11204	Lake Houston	39	33	4.55	41.89	-1.77	95	46	234.13	81.32	93	41	0.38	75.35

Table 9-11. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (Continued)

Segment Number	SWQM Station ID	Reservoir Name	Chlorophyll *a*					Total Phosphorus				Secchi Disk			
			Rank *	No. Meas.	Mean mg/m^3 **	TSI Chl *a* **	Trend ***	Rank	No. Meas.	Mean mg/m^3	TSI TP	Rank	No. Meas.	Mean m	TSI SD
2103	12967	Lake Corpus Christi	40	12	5.10	42.05	-7.72	96	11	240.82	81.45	69	19	1.74	64.08
0212	10142	Lake Arrowhead	41	13	4.81	42.26	-0.81	93	14	178.57	78.68	92	5	0.43	73.71
0404	14473	Ellison Creek	42	8	3.92	42.61	+0.54	6	8	23.12	48.10	32	11	1.32	56.13
0811	10970	Lake Bridgeport	43	7	3.81	42.62	-3.99	23	7	35.71	53.27	45	37	1.32	58.15
1237	12021	Lake Sweetwater	44	5	4.92	42.71	-4.73	37	5	36.00	55.71	46	2	1.12	58.40
1236	12010	Lake Fort Phantom Hill	45	8	4.81	42.79	+0.29	62	8	51.25	59.64	67	4	0.54	63.87
0213	10143	Lake Kickapoo	46	6	4.86	42.84	-1.01	53	6	48.33	58.19	100	2	0.25	80.05
1422	12418	Lake Nasworthy	47	14	5.82	42.90	-3.60	64	14	55.36	60.05	84	19	0.59	68.79
0816	10980	Lake Waxahachie	48	9	4.43	43.39	+1.15	49	9	44.44	57.60	65	8	0.86	63.76
0613	10638	Lake Tyler East	49	20	5.81	43.83	-1.22	16	20	24.50	51.80	44	21	1.17	58.06
1408	12344	Lake Buchanan	50	54	6.51	43.91	+1.34	52	53	78.70	58.17	15	60	2.16	50.75
1235	12006	Lake Stamford	51	10	5.05	44.36	+0.22	73	10	70.50	62.61	79	6	0.45	66.69
0403	10296	Lake O The Pines	52	31	6.06	44.54	-0.81	75	31	220.97	64.51	40	34	1.29	57.20
1225	11942	Lake Waco	53	23	5.14	44.59	+1.32	83	99	93.90	68.20	62	107	0.85	63.27
0401	10283	Caddo Lake	54	30	8.60	44.70	-0.99	69	30	88.58	62.02	68	32	0.80	63.99
1406	12324	Lake LBJ	55	49	6.43	44.86	+6.05	40	48	56.95	56.12	33	52	1.43	56.29
0605	16159	Lake Palestine	56	10	7.10	44.97	-6.04	60	10	38.00	59.43	60	12	0.89	61.97
1604	12529	Lake Texana	57	4	7.41	45.19	+1.17	90	4	145.00	75.73	98	4	0.36	79.87
0603	10582	B.A. Steinhagen	58	8	6.99	45.24	-4.78	84	7	102.86	69.23	91	10	0.42	71.24
1425	12429	O.C. Fisher	59	10	6.10	45.72	-3.12	78	10	90.00	66.51	80	8	0.92	67.24

Table 9-11. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (Continued)

Segment Number	SWQM Station ID	Reservoir Name	**Chlorophyll *a***					**Total Phosphorus**				**Secchi Disk**			
			Rank *	**No. Meas.**	**Mean mg/m^3** **	**TSI Chl *a*** **	**Trend** ***	**Rank**	**No. Meas.**	**Mean mg/m^3**	**TSI TP**	**Rank**	**No. Meas.**	**Mean m**	**TSI SD**
1405	12319	Lake Marble Falls	60	53	7.19	45.73	-0.27	36	50	52.57	55.61	30	57	1.52	55.36
1252	12123	Lake Limestone	61	7	7.48	45.85	-3.71	43	7	45.00	56.74	66	43	0.83	63.85
2116	13019	Choke Canyon	62	6	6.60	46.18	-1.34	61	6	73.33	59.45	4	12	5.11	44.50
1209	11792	Country Club Lake	63	12	11.70	46.61	-----	100	12	836.67	100.50	87	11	0.54	70.12
0209	10138	Pat Mayse	64	7	7.63	46.62	-2.47	48	7	37.86	57.56	39	6	1.29	57.04
0807	10942	Lake Worth	65	4	14.70	46.87	-8.95	67	4	52.50	61.10	75	5	0.73	65.39
0405	10312	Lake Cypress Springs	66	13	6.70	46.97	-1.98	42	13	30.77	56.61	38	15	1.26	56.89
1407	12336	Inks Lake	67	51	8.47	47.26	+0.58	59	47	62.13	59.39	19	57	1.72	52.99
2454	12514	Cox Lake	68	16	11.71	47.35	+0.13	98	15	376.00	87.36	101	17	0.45	83.90
0302	10213	Lake Wright Patman	69	11	10.28	47.53	-2.64	86	11	103.18	70.31	78	11	0.72	66.50
1411	12359	E.V. Spence	70	5	8.96	47.91	-0.06	2	5	15.00	45.37	34	7	1.60	56.39
0817	10981	Navarro Mills	71	6	9.07	48.39	-2.66	71	6	52.50	62.06	88	6	0.50	70.47
2312	13267	Red Bluff	72	18	10.08	48.71	-2.12	18	18	27.78	52.49	57	22	0.91	61.52
0504	10402	Toledo Bend	73	65	7.91	49.11	+0.96	56	55	46.34	58.66	23	119	1.61	53.86
0307	15211	Cooper Lake	74	5	8.81	49.17	-----	81	5	94.00	66.83	90	7	0.52	71.20
0199	10005	Palo Pinto	75	17	10.59	49.38	+1.12	88	17	172.94	73.17	94	18	0.38	75.66
0832	11061	Lake Weatherford	76	6	9.84	49.58	-2.82	55	6	42.50	58.47	73	7	0.73	64.73
0836	15168	Richland-Chambers	77	5	8.22	49.97	-1.67	50	5	44.60	57.61	35	44	1.33	56.51
0512	10458	Lake Fork	78	68	10.26	50.26	+2.22	54	53	45.68	58.40	22	123	1.60	53.70
1434	17020	Lake Bastrop	79	15	12.87	50.80	-----	66	15	52.40	60.65	27	12	1.56	54.28

Table 9-11. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (Continued)

Segment Number	SWQM Station ID	Reservoir Name	Chlorophyll *a*					Total Phosphorus				Secchi Disk			
			Rank *	No. Meas.	Mean mg/m^3 **	TSI Chl *a* **	Trend ***	Rank	No. Meas.	Mean mg/m^3	TSI TP	Rank	No. Meas.	Mean m	TSI SD
1222	11935	Proctor Lake	80	14	13.14	51.26	-0.97	82	14	88.21	67.63	83	43	0.59	68.43
1212	11881	Sommerville Lake	81	8	17.39	51.38	+0.01	77	8	77.50	66.27	70	44	0.78	64.28
1012	11342	Lake Conroe	82	14	13.99	51.79	-1.69	58	39	56.41	58.91	61	13	0.88	63.12
1209	11798	Finfeather Lake	83	12	21.35	51.79	-0.61	99	12	679.17	96.53	42	10	1.35	57.56
0815	10979	Bardwell	84	8	11.66	52.27	-0.03	70	8	51.25	62.06	77	8	0.67	66.05
0230	10192	Lake Tanglewood	85	23	18.02	52.42	-0.46	101	23	1126.96	100.67	86	22	0.62	69.07
1253	16247	Sprinfield Lake	86	11	14.75	52.54	-----	92	11	166.36	77.65	97	11	0.26	79.51
0826	16113	Grapevine Lake	87	5	11.24	52.56	+1.10	35	7	34.29	55.30	48	7	1.09	59.51
1210	14238	Lake Mexia	88	19	14.06	52.95	+1.01	94	18	215.56	81.06	96	21	0.28	78.77
2303	13189	Falcon Lake	89	7	11.53	53.10	-1.76	85	8	145.00	70.07	50	7	1.07	59.98
0830	15151	Benbrook Lake	90	6	16.80	54.31	-----	74	6	63.83	63.62	59	49	1.01	61.57
0507	10434	Lake Tawakoni	91	66	19.06	55.29	+1.04	68	52	54.16	61.97	53	120	1.03	60.25
1412	12167	Lake Colorado City	92	5	15.30	56.00	+1.38	45	5	47.00	56.98	56	3	0.98	60.87
1402	17017	Fayette	93	16	22.69	56.43	-----	63	16	69.88	60.03	31	12	1.40	55.54
0803	10899	Lake Livingston	94	52	17.72	56.48	+0.53	89	101	166.19	74.87	76	98	0.76	65.53
1208	11679	Millers Creek	95	4	17.32	56.59	+4.14	39	4	43.75	55.85	51	2	0.75	60.00
0823	11027	Lewisville Lake	96	12	15.52	56.85	+7.37	72	27	80.37	62.22	64	2	0.88	63.71
1242	16781	New Marlin City Lake	97	6	20.12	58.78	-----	91	6	166.67	76.77	95	7	0.33	76.83
1242	16783	Old Marlin City Lake	98	6	32.03	60.73	-----	97	6	221.67	81.74	99	8	0.27	79.89
0809	10944	Eagle Mountain	99	5	24.46	60.98	+7.42	80	5	79.40	66.66	58	39	0.94	61.53

Table 9-11. Trophic Classification of Major Texas Reservoirs Using Carlson's Trophic State Index (Continued)

Segment Number	SWQM Station ID	Reservoir Name	Chlorophyll *a*					Total Phosphorus				Secchi Disk			
			Rank *	**No. Meas.**	**Mean mg/m^3** **	**TSI Chl *a*** **	**Trend** ***	**Rank**	**No. Meas.**	**Mean mg/m^3**	**TSI TP**	**Rank**	**No. Meas.**	**Mean m**	**TSI SD**
0818	16749	Cedar Creek	100	16	26.66	61.22	+8.36	76	16	69.31	65.03	55	17	0.96	60.79
0509	10444	Lake Murvaul	101	6	31.63	64.00	-0.81	79	6	78.33	66.57	74	8	0.71	65.13
0105	10060	Rita Blanca Lake	102	11	196.69	69.48	+1.09	102	12	3062.50	118.27	102	11	0.08	91.78

* Reservoirs are ranked in priority by TSI (Chl)

** The equations for Carlson's TSI (Chl), (TP), and (SD) involve converting each parameter value to its respective natural log (ln). 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.

*** A minus(-) preceding a value in the trend column indicates decreased algal content between the 1998 and 2000 reporting cycles; a plus (+) indicates increased algal content; NC indicates no change in values; a dotted line (-----) indicates absence of comparable data.

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 as to trophic state, priority ranking for restoration is difficult. Carlson's Index is not the same as a water quality index. 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 305(b) assessment and 303(d) list provide a ranking of priorities for protection and restoration for all water bodies including reservoirs.

Texas reservoirs are ranked in Table 9-11 according to Carlson's TSI for chlorophyll *a* as an average calculated from 10 years of SWQM data (September 1991-August 2001). In order to maximize comparability among reservoirs, data from the 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 the CRP. Chlorophyll *a* was given priority as the primary trophic state indicator, because it is best for estimating algal biomass in most reservoirs. A minimum of four chlorophyll *a* measurements and at least two total phosphorus and Secchi disk measurement were required for a reservoir to be included in the ranking. Based on this assessment, nine reservoirs are considered oligotrophic, and 93 reservoirs show signs of eutrophication (Table 9-12). Rankings are also provided for total phosphorus (TP) and Secchi disk transparency (SD). This presentation permits comparison of individual TSI indicators for each reservoir, provides indications of the clearest reservoirs (low TSI SD), and identifies reservoirs with low and high total phosphorus concentrations.

Table 9-12. Number of Texas Reservoirs Assessed in Each Trophic Class

Trophic Class	**TSI (Chl *a*) Index Range**	**Number of Reservoirs**
Oligotrophic	0 - 35	9
Mesotrophic	> 35-45	47
Eutrophic	> 45-55	34
Hypereutrophic	> 55	12

Reservoirs with the clearest water (highest Secchi disk transparency) occur primarily in the central portion of the state and are listed in descending order are: Lake Travis (Segment 1404), Canyon Lake (Segment 1805), Amistad Reservoir (Segment 2305), Choke Canyon (Segment 2116), and Stillhouse Hollow (Segment 1216). Reservoirs with the poorest light transparency (lowest Secchi disk transparency) listed in descending order are: Rita Blanca Lake (Segment 0105), Cox Lake (in Segment 2454), Lake Kickapoo (Segment 0213), Old Marlin City Lake (Segment 1242), and Lake Texana (Segment 1604).

Reservoirs with the lowest total phosphorus concentrations listed in descending order are: Lake Georgetown (Segment 1249), E.V. Spence (Segment 1411), Greenbelt (Segment 0223), Lake Coleman (Segment 1419), and Lake Mackenzie (Segment 0228). Reservoirs enriched with the highest total phosphorus concentrations listed in descending order are: Rita Blanca Lake (Segment 0105), Lake Tanglewood (Segment 0230), Country Club Lake (Segment 1209), Finfeather Lake (Segment 1209), and Cox Lake (Segment 2454).

Water Quality Trends in Reservoirs

Carlson's TSI Chl *a* values for 109 reservoirs from the 2000 and 2002 reporting cycles were compared to indicate temporal trends (Table 9-11). Insufficient data for one of the reporting periods were available for only nine reservoirs to allow computation of trends. The period of record for the 2000 reporting cycle was September 1989-August 1998; for 2002, the period of record was September 1991-August 2001. Overall, TSI Chl *a* values, which estimate the amount of algal biomass, indicate improvement (decrease in values) in 63 of 93 (68%) reservoirs. Increases in algal biomass (increase in TSI Chl *a* values) are indicated in 20 of 93 (32%) reservoirs. The TSI Chl *a* values were remarkably stable among the 93 reservoirs between the two reporting cycles, with 33 of 93 (52%) changing by 1 unit or less. In 20 of 63 (32%) reservoirs, the TSI Chl *a* values changed by 3 units or more.

Reservoirs that improved the most, as shown by substantial decreasing TSI Chl *a* values, are Lake Worth (Segment 0807), Lake Corpus Christi (Segment 2103), Lake Palo Pinto (Segment 1230), Lake Palestine (Segment 0605), and B.A. Steinhagen (Segment 0603)(Table 9-11). Reservoirs with the largest trends for increasing algal content (substantial positive TSI Chl *a* values) are Cedar Creek (Segment 0818), Eagle Mountain (Segment 0809), Lake Lewisville (Segment 0823), Lake L.B.J. (Segment 1406), and Millers Creek (Segment 1208). These changes are for a two-year period and may not represent longer term trends.

Reservoir Control Programs

Texas employs several reservoir pollution control procedures to ensure high-quality water for recreational, domestic, and industrial uses. Surface water quality standards have been adopted for significant reservoirs throughout the state. The standards establish designated uses for classified segments and presumed uses for unclassified 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. TMDLs are conducted to determine the assimilative capacity of the segment and to determine discharge treatment levels and nonpoint source loads necessary to meet the criteria. These treatment levels are then required when issuing wastewater permits to dischargers. In some cases, TMDLs may recommend no discharge of wastewater. 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. Each major reservoir is routinely monitored to assess the overall condition of the water body and determine short- or long-term water quality trends. The Carlson's Trophic State Index is used to score reservoirs according to trophic conditions based on Secchi disk transparency, total phosphorus levels, and chlorophyll *a* levels. Reservoirs with nonsupported uses are placed on the State of Texas 303(d) List.

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 BOD_5 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: §§311.31-311.36.

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 BOD_5, 15 mg/L TSS, and 3 mg/L NH_3-N as a 30-day average. All wastewater effluents disposed of on land shall meet an effluent quality of 20 mg/L BOD_5 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 dual-feed 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, which means 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 BOD_5, and filtration is required to supplement suspended solids removal by January 1, 1993.

In addition to water quality monitoring and creation of rules to regulate the permitting of wastewater discharges to reservoirs, the TCEQ maintains an extensive inspection program of wastewater treatment facilities. When permit limitations are not being met, the appropriate enforcement action is pursued.

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.