Prepared in cooperation with Texas Tech University

Spatially Pooled Depth-Dependent Reservoir Storage, Elevation, and Water-Quality Data for Selected Reservoirs in Texas, January 1965–January 2010

Data Series 594

U.S. Department of the Interior
U.S. Geological Survey

Cover. Sanford Dam at Lake Meredith and intake tower complex, October 2009 (photograph by William H. Asquith).

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter(m)
mile (mi)	1.609	mile (mi)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83).

Abbreviations

ADR Annual Water Data Report

NCCWSC National Climate Change and Wildlife Science Center

NWIS National Water Information System

PERL Practical Extraction and Reporting Language

PDF Portable Document File

SQL Structured Query Language

SWQMIS Surface Water Quality Monitoring Information System

TCEQ Texas Commission on Environmental Quality

TPWD Texas Parks and Wildlife Department

TWCR Texas Water Condition Reports

TWDB Texas Water Development Board

USGS United States Geological Survey

VBA Visual Basic for Applications

VBScript Visual Basic Scripting Language

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Abstract

The U.S. Geological Survey (USGS), in cooperation with Texas Tech University, constructed a dataset of selected reservoir storage (daily and instantaneous values), reservoir elevation (daily and instantaneous values), and water-quality data from 59 reservoirs throughout Texas. The period of record for the data is as large as January 1965–January 2010. Data were acquired from existing databases, spreadsheets, delimited text files, and hard-copy reports. The goal was to obtain as much data as possible; therefore, no data acquisition restrictions specifying a particular time window were used. Primary data sources include the USGS National Water Information System, the Texas Commission on Environmental Quality Surface Water-Quality Management Information System, and the Texas Water Development Board monthly Texas Water Condition Reports. Additional water-quality data for six reservoirs were obtained from USGS Texas Annual Water Data Reports. Data were combined from the multiple sources to create as complete a set of properties and constituents as the disparate databases allowed. By devising a unique per-reservoir short name to represent all sites on a reservoir regardless of their source, all sampling sites at a reservoir were spatially pooled by reservoir and temporally combined by date. Reservoir selection was based on various criteria including the availability of water-quality properties and constituents that might affect the trophic status of the reservoir and could also be important for understanding possible effects of climate change in the future. Other considerations in the selection of reservoirs included the general reservoir-specific period of record, the availability of concurrent reservoir storage or elevation data to match with water-quality data, and the availability of sample depth measurements. Additional separate selection criteria included historic information pertaining to blooms of golden algae. Physical properties and constituents were water temperature, reservoir storage, reservoir elevation, specific conductance, dissolved oxygen, pH, unfiltered salinity, unfiltered total nitrogen, filtered total nitrogen, unfiltered nitrate plus nitrite, unfiltered phosphorus, filtered phosphorus, unfiltered carbon, carbon in suspended sediment, total hardness, unfiltered noncarbonate hardness, filtered noncarbonate hardness, unfiltered calcium, filtered calcium, unfiltered magnesium, filtered magnesium, unfiltered sodium, filtered sodium, unfiltered potassium, filtered potassium, filtered chloride, filtered sulfate, unfiltered fluoride, and filtered fluoride. When possible, USGS and Texas Commission on Environmental Quality water-quality properties and constituents were matched using the database parameter codes for individual physical properties and constituents, descriptions of each physical property or constituent, and their reporting units. This report presents a collection of delimited text files of source-aggregated, spatially pooled, depth-dependent, instantaneous water-quality data as well as instantaneous, daily, and monthly storage and elevation reservoir data.

Introduction

Surface-water reservoirs are important sources of water in Texas given the highly variable nature of streamflow in the State (Texas Water Development Board, 2006). Downstream from reservoirs, extremes in the rainfall and runoff process are altered; flood peaks are smaller (Asquith, 2001; Richter and others, 1998), and depending on reservoir-management practices, low flows can be different downstream from dams compared to unregulated flows in the absence of dams (Ward and Stanford, 1995). Alteration of natural flow regimes by the construction of dams can have substantial ecological consequences for fish habitat and overall ecosystem health, but at the same time provide important functions such as managing the flood response of rivers and providing water sources for irrigation, water supply, recreation, and navigation (Fitzhugh and Vogel, 2010). Much of the surface-water supply in Texas, approximately 6.3 million acre-feet, comes from major and minor reservoirs (Texas Water Development Board, 2006). Currently (2011), Texas has 196 major reservoirs that are defined as impoundments with at least 5,000 acre-feet of storage capacity (Texas Water Development Board, 2006). Of the 196 major reservoirs, 175 have a recognized water-supply function. In 2008, irrigation was the largest water use (approximately 10 million acre-feet of water stored in reservoirs was used for irrigation), whereas municipal supply was the second largest water use (approximately 4.2 million acre-feet of water) (Texas Water Development Board, 2010b).

Some researchers have determined that the water resources of Texas might be susceptible to the effects of climate change. Banner and others (2010) discuss some potential effects of climate change in Texas including increased overall temperatures and an overall drier climate, which currently (2011) are expected to reduced the quantity of water resources in Texas. Norwine and John (2007) present discussions on projections of the effects of climate change on south Texas agriculture, ecosystems, and water supply, and Norwine and John conclude that the warming of the Texas climate will likely result in rivers and reservoirs losing larger quantities of water to evaporation. Finally, Solomon and others (2007) prepared climate projections for five regions of the United States and found that the Southwestern United States are currently (2011) expected to experience more extended dry periods between rain events in addition to increased temperatures. In general, increased temperatures and decreased rainfall in Texas and the larger Southwestern United States are expected to result in decreased amounts of surface water available for storage in reservoirs.

In addition to the amount of surface water available for storage in reservoirs, the quality of water stored in reservoirs influences human uses such as fisheries management, recreation, public water supply, and irrigation. The quality of water used for irrigation can influence infiltration and erosion processes in soil (Lentz and others, 1996). Specific conductance is a measure of the ability of water to conduct an electric current and provides an approximation of the dissolved-solids concentration (salinity) in water (Hem, 1985). Water-quality variables such as the amount of salinity and pH can influence plant productivity and affect irrigation equipment (Bauder and others, 2007). Among other factors, fish community composition is associated with differences in water temperature and water quality (Deacon and Mize, 1997). Water temperature, a property inextricably linked to changes in climate, along with other complex and interrelated properties can affect species physiology and biological activities that are dependent on temperature such as the timing and cyclicity (phenology) of fish breeding (Patiño and others, 2003). Higher water temperatures also influence dissolved-oxygen levels; warmer water generally has lower amounts of oxygen compared to cooler water (U.S. Environmental Protection Agency, 2006). Changes in temperature work together with other factors (for example, increases in nutrient concentrations) resulting in increases in algal biomass characteristic of higher trophic states (Carlson, 1977). Naumann (1929) introduced the concept of the trophic states by which lakes are classified as oligotrophic, mesotrophic, eutrophic or hypereutropic depending on the amount of nutrients (Kociolek and Stoermer, 2009). Eutrophication represents a change in the trophic status of a lake or estuary caused by nutrient enrichment that creates conditions conducive to excessive algae growth (Lake Scientist, 2011). Increases in nutrients can affect human usage of water in reservoirs as well as species living within the affected body of water. Excessive nutrient-driven plant growth can affect aquatic species richness by decreasing oxygen levels in water, increasing pH, and also can release toxins that can kill aquatic species (U.S. Environmental Protection Agency, 1999). Golden algae in particular is a growing concern to water-supply and resource managers in Texas because of its production of harmful fish toxins and its potential for enhanced propagation with changing climatic conditions (Texas Parks and Wildlife Department, 2002). Golden algae outbreaks have been documented in Texas since the mid-1980s in the Pecos River and as recently as April 20, 2010, in two north-central Texas reservoirs, Possum Kingdom Reservoir and Lake Whitney (Texas Parks and Wildlife Department, 2010).

Reservoirs have characteristics that have to be accounted for in certain analyses. Reservoir storage refers to the storage volume of a reservoir in acre feet at a given point in time. Reservoir elevation refers to the height in feet of the reservoir water surface. The sample depth of reservoir data is important because, at any given date and at any given location on a reservoir, multiple measurements of the same physical property or constituent might be obtained at varying depths, and each measurement might reflect different concentrations or values. As a result, the term “depth dependent” is used throughout the report in reference to the data described in this report.

The U.S. Geological Survey (USGS), in cooperation with Texas Tech University, constructed a dataset of selected reservoir storage (daily and instantaneous values), reservoir elevation (daily and instantaneous values), and water-quality data from 59 reservoirs throughout Texas. The data described in this report were compiled to partially meet objectives of a larger USGS National Climate Change and Wildlife Science Center (NCCWSC) study to model and predict the influence of climate change on Texas surface waters and their aquatic biotic communities (hereinafter referred to as the NCCWSC study). The goal of the NCCWSC study was to qualitatively and statistically model climate forcing on Texas surface waters and selected aquatic and biotic communities.

One objective of the NCCWSC study was to compile data of observed historical water temperatures and other relevant water-quality data for selected reservoirs with appreciable fishery resources in Texas. This report documents historical water temperatures and other relevant water-quality data for selected reservoirs in Texas for periods of record as large as January 1965–January 2010. Reservoir data from multiple sources were combined to create temporally longer and more complete data records. Using a unique short name for each reservoir, all available data from sampling or monitoring sites (hereinafter referred to as “sites”) were combined regardless of their respective location on the water body. The term “spatially pooled” is used to describe this spatial aggregation of sources. All data from a reservoir regardless of the data source were integrated together into the final data files. The term “source-aggregated” is used to describe this combining of data sources.

Reservoir selection was based on various criteria including the availability of water-quality properties and constituents that might affect the trophic state of the reservoir and could also be important for understanding possible effects of climate change in the future. Other considerations in the selection of reservoirs included the period of record, the availability of concurrent reservoir storage or elevation data to match with water-quality data, and the availability of sample depth measurements. Additional separate selection criteria included historic information pertaining to blooms of golden algae. The data resulting from these efforts are provided as on-line delimited text files of source-aggregated, spatially pooled, depth-dependent, water-quality data as well as instantaneous, daily, and monthly storage and elevation reservoir data and are found in appendixes 1, 2-1 through 2-32, 3-1 through 3-24, and 4-1 through 4-5. Appendix 1 is an information file that discusses the contents of appendixes 2, 3, and 4 as well as provides for reference the associated report title. Appendixes 2-1 through 2-3 contain information pertaining to USGS National Water Information System (NWIS) water-quality data files, and appendixes 2-4 through 2-32 contain spatially pooled depth-dependent water-quality data from USGS NWIS (U.S. Geological Survey, 2010). Appendixes 3-1 through 3-3 contain information pertaining to Texas Commission on Environmental Quality (TCEQ) Surface Water-Quality Monitoring Information System (SWQMIS) water-quality data files, and appendixes 3-4 through 3-24 contain spatially pooled depth-dependent water-quality data from TCEQ SWQMIS (Texas Commission on Environmental Quality, 2010). Appendixes 4-1 through 4-4 contain information pertaining to the storage and elevation data file, and appendix 4-5 contains storage and elevation data compiled from USGS NWIS, TCEQ SWQMIS, and Texas Water Development Board (TWDB) (Texas Water Development Board, 2010a).

Purpose and Scope

This report describes selected reservoir storage (daily and instantaneous values), reservoir elevation (daily and instantaneous values), and water-quality data that were compiled from 59 reservoirs across Texas on the basis of meeting specific data-selection criteria. The period of record for the data is as large as January 1965–January 2010. The data sources and selection criteria are described along with methods used to compile and format the data. The format for the on-line data files also is discussed in the context of the anticipated use of the data in the R environment for statistical computing (R Development Core Team, 2009).

Study Area

Texas is approximately 7 percent of the total land and water area of the United States (Texas Almanac, 2010). Climatological conditions are diverse; the average annual precipitation during 1961–90 ranged from more than 60 inches in southeastern Texas to about 10 inches in southwestern Texas (U.S. Geological Survey, 2005).

The climate of Texas is highly variable, ranging from flood to drought conditions yearly in much of the State (Bomar, 1979; Carr, 1967). Scientists at the National Oceanic and Atmospheric Administration reported that droughts in Texas during 1985–2000 were more frequent and lasted longer compared to droughts in surrounding States (National Oceanic and Atmospheric Administration, 2001). Weather extremes in Texas are common because its location enables the influence of four principle air masses (Frontier Associates LLC, 2008). Two of these air masses—the “continental tropical air mass” from the Pacific Ocean to the west and the “maritime tropical air mass,” which originates in the Gulf of Mexico—typically are characterized as warm and moist. The two cold and dry air masses are the “maritime polar air mass” from the northwest and the “continental polar air mass” from the north. In addition, Texas’ proximity to the Gulf of Mexico subjects the State to tropical depressions, tropical storms, and hurricanes during the summer and early fall. Consequently, the general climate of Texas is often described as varied (Bomar, 1994; Texas Almanac, 2010). Bomar (1994) provides a review of Texas weather and climate and details historically important rainfall and resulting floods, the characteristics of the atmosphere, general weather, meteorology concepts, and weather statistics for Texas. An additional resource for Texas climate and physiographic information including characteristic climatic patterns, geographic distribution of precipitation, and characteristic annual temperatures is provided by Carr (1967).

Methods

Source Data Acquisition

Available original (raw) data from various sources were compiled using Visual Basic scripts and Microsoft Access. A single-purpose program was written in the Visual Basic for Applications (VBA) language to download and compile instantaneous water-quality, daily and instantaneous reservoir storage, and daily and instantaneous reservoir elevation data from the publicly accessible USGS NWIS database. Daily data are summarized values representing a given day and can represent values such as mean, median, maximum, minimum, or other derived values. Microsoft Access was the application environment used to run VBA programs mentioned. Microsoft Access is a relational database application that provides a convenient environment for data manipulation with VBA and Structured Query Language (SQL) (Microsoft, 2010). An initial list of approximately 2,070 sites classified as USGS NWIS site type “lake” in Texas was compiled from the NWIS database. The associated data were downloaded from the USGS NWIS web site in the form of delimited text files by reading into the VBA program the list of Texas sites identifiers. Using the site identifier as a component of the uniform resource locator, the VBA program would query the USGS NWIS web site to retrieve the data for each site. Water-quality data contained in hard-copy USGS Texas Annual Water Data Reports (ADRs) also were identified and manually recovered as described in the Annual Water Data Report Data Recovery section of this report.

In addition to the data obtained from USGS NWIS, data were compiled from databases maintained by TCEQ and TWDB. An initial list of about 1,400 TCEQ reservoir sites and their data were downloaded from the TCEQ SWQMIS database in delimited text files and processed into a relational database format using a VBA program. The TWDB is responsible for monitoring water conditions and storage capacities of 109 major reservoirs in Texas (Texas Water Development Board, 2010a). The TWDB has surveyed 77 of the 109 major reservoirs since 1990. In November 2007, an additional 32 reservoirs were added to the survey list. All monthly storage data for the 109 reservoirs contained in the “Texas Water Conditions Reports,” hereinafter referred to as TWDB data, were obtained in a delimited file format directly from TWDB staff (Dale Crockett, Texas Water Development Board, written commun., 2010) and were processed using a Visual Basic Scripting Language (VBScript) program. The USGS NWIS and TCEQ SWQMIS data contained potentially one or more sites per reservoir; whereas, each reservoir that TWDB monitors has only one TWDB site.

Source Data Assessment

Computer tools, including Practical Extraction and Reporting Language (PERL) and VBA programs as well as SQL, were used to assess all data. Primary reservoir selection criteria included the presence of water-quality properties and constituents related to trophic state and climate, length of period of sample record, the overlap of reservoir storage or elevation with water-quality data, and the presence of sample depth measurements. An approximate 10-year period of data record for samples with a sample count threshold of roughly 40 for the period was used as a starting point for site data evaluation. The focus on water-quality properties and constituents related to trophic state and climate relates to one of the objectives of the NCCWSC study. The related objective of the NCCWSC study is to complete regional statistical analyses of physical properties and constituents in reservoirs to identify those that might potentially change in response to long-term changes in atmospheric temperature, or could be used to study the effects of climate change on Texas surface waters and the aquatic biotic communities of Texas surface waters (Reynaldo Patiño, USGS Texas Cooperative Fish and Wildlife Research Unit, written commun., 2010) A list of reservoirs having known or suspected golden algae blooms over the past approximately 20 years (1985–present) was provided by the Texas Parks and Wildlife Department (TPWD) to Texas Tech University partners and USGS (Bob Betsill, Texas Parks and Wildlife Department, written commun., 2010). The TPWD list of reservoirs was used as separate criteria whereby if a reservoir met the primary selection criteria it would be included in the final list of reservoirs even if it was not on the TPWD reservoir list. If a reservoir on the TPWD list had available data but did not meet the primary reservoir selection criteria, it was still included in the final list of reservoirs. Physical properties and constituents were water temperature, reservoir storage, reservoir elevation, specific conductance, dissolved oxygen, pH, unfiltered salinity, unfiltered total nitrogen, filtered total nitrogen, unfiltered nitrate plus nitrite, unfiltered phosphorus, filtered phosphorus, unfiltered carbon, carbon in suspended sediment, total hardness, unfiltered noncarbonate hardness, filtered noncarbonate hardness, unfiltered calcium, filtered calcium, unfiltered magnesium, filtered magnesium, unfiltered sodium, filtered sodium, unfiltered potassium, filtered potassium, filtered chloride, filtered sulfate, unfiltered fluoride, and filtered fluoride. Table 1 lists the physical properties and constituents that were compiled, as well as the USGS NWIS parameter code for each type of data; the source of the data also is noted.

Unique short names for each reservoir were created to facilitate fuzzy or partial name matching; the matching was done using keyword searches on the USGS NWIS and TCEQ SWQMIS datasets automated through VBA and PERL programs. Fuzzy keyword searches to discern matches to a pattern of characters within strings of characters when the overall string might differ were used (Ji and others, 2009). A fuzzy keyword approach allows for a wider set of results to be obtained with the knowledge that all results likely will not serve the intended purpose. Results that do not serve the intent of the search are considered false positives. All sites on a given reservoir were identified and spatially pooled by assigning them a reservoir short name. To clarify, data from all sites at a single reservoir were combined such that data from any data source were associated only with the reservoir and not the physical site locations. The headers of the USGS NWIS delimited text files were inspected for the site name using a single-use program written in PERL, whereas the TCEQ SWQMIS data were searched using a VBA program that analyzed the site-description field. Searchable short names also were devised for the TPWD list of reservoirs so that those reservoirs of interest could be taken into account during the overall data-assessment process.

Results of the fuzzy keyword search were screened manually to remove false positives where a reservoir short name might match, for example, part of another site’s descriptive name field that did not pertain to the actual name of the reservoir. For example, there are about 24 unique water-quality sites for Lake Whitney, Tex.; two of these are: “USGS 08092500 Whitney Lake near Whitney, Tex.” and “USGS 315203097222601 Whitney Lake Site AC near Whitney, Tex.” With this example reservoir, the short name “Whitney” would identify and return any occurrence of the character string “Whitney” in a site name along with the associated site identifier. A reservoir tracking table (not shown here) along with the types of data provided by each source on each reservoir was used to track the iterative assessment process for narrowing down the possible reservoirs. Table 2 lists the final product of that tracking table. The approximate locations and spatial distribution of the selected reservoir locations across Texas are shown in figure 1. Table 2 also lists the label numbers, reservoir names, and short names that are shown in figure 1.

TCEQ SWQMIS and TWDB data were assessed to identify an initial list of more than 100 candidate reservoirs. Because the TWDB data contained only storage and elevation, the absence of USGS NWIS or TCEQ SWQMIS water-quality data on reservoirs with TWDB data would eliminate those reservoirs from the TWDB reservoir list. An approach similar

Table 1. Physical properties or constituents for which data were compiled from selected reservoirs in Texas, 1965–2010.

[USGS, U.S. Geological Survey; NWIS, National Water Information System (U.S. Geological Survey, 2011); TCEQ, Texas Commission on Environmental Quality (Texas Commission on Environmental Quality, 2010); TWDB, Texas Water Development Board (Texas Water Development Board, 2010a)]

Description of physical propery or constituent	USGS NWIS parameter code	Data sources
Temperature, water, degrees Celsius	00010	USGS NWIS, TCEQ
Reservoir storage, acre-feet	00054	USGS NWIS, TCEQ, TWDB
Reservoir elevation, feet	00062	USGS NWIS, TCEQ
Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius	00095	USGS NWIS, TCEQ
Dissolved oxygen, water, unfiltered, milligrams per liter	00300	USGS NWIS, TCEQ
pH, water, unfiltered, field, standard units	00400	USGS NWIS, TCEQ
Salinity, water, unfiltered, parts per thousand	00480	USGS NWIS, TCEQ
Total nitrogen, water, unfiltered, milligrams per liter	00600	USGS NWIS, TCEQ
Total nitrogen, water, filtered, milligrams per liter	00602	USGS NWIS
Nitrate plus nitrite, water, unfiltered, milligrams per liter as nitrogen	00630	USGS NWIS, TCEQ
Phosphorus, water, unfiltered, milligrams per liter as phosphorus	00665	USGS NWIS, TCEQ
Phosphorus, water, filtered, milligrams per liter as phosphorus	00666	USGS NWIS, TCEQ
Carbon (inorganic plus organic), water, unfiltered, milligrams per liter	00690	USGS NWIS
Carbon (inorganic plus organic), suspended sediment, total, milligrams per liter	00694	USGS NWIS
Hardness, water, milligrams per liter as calcium carbonate	00900	USGS NWIS, TCEQ
Noncarbonate hardness, water, unfiltered, field, milligrams per liter as calcium carbonate	00902	USGS NWIS
Noncarbonate hardness, water, filtered, field, milligrams per liter as calcium carbonate	00904	USGS NWIS
Calcium, water, unfiltered, milligrams per liter as calcium carbonate	00910	USGS NWIS, TCEQ
Calcium, water, filtered, milligrams per liter	00915	USGS NWIS, TCEQ
Magnesium, water, filtered, milligrams per liter	00925	USGS NWIS, TCEQ
Magnesium, water, unfiltered, recoverable, milligrams per liter	00927	USGS NWIS, TCEQ
Sodium, water, unfiltered, recoverable, milligrams per liter	00929	USGS NWIS, TCEQ
Sodium, water, filtered, milligrams per liter	00930	USGS NWIS, TCEQ
Potassium, water, filtered, milligrams per liter	00935	USGS NWIS, TCEQ
Potassium, water, unfiltered, recoverable, milligrams per liter	00937	USGS NWIS, TCEQ
Chloride, water, filtered, milligrams per liter	00940	USGS NWIS, TCEQ
Sulfate, water, filtered, milligrams per liter	00945	USGS NWIS, TCEQ
Fluoride, water, filtered, milligrams per liter	00950	USGS NWIS, TCEQ
Fluoride, water, unfiltered, milligrams per liter	00951	USGS NWIS, TCEQ
Total nitrogen (nitrate + nitrite + ammonia + organic-N), water, filtered, analytically determined, milligrams per liter	62854	USGS NWIS
Total nitrogen (nitrate + nitrite + ammonia + organic-N), water, unfiltered, analytically determined, milligrams per liter	62855	USGS NWIS

Table 2. Selected Texas reservoirs for which water-quality, reservoir storage, or reservoir elevation data were compiled, and identification of reservoirs with suspected historical golden algae blooms.

[U.S. Geological Survey, USGS; NWIS, National Water Information System; ADR, Annual data report; TCEQ, Texas Commission on Environmental Quality; TWDB, Texas Water Development Board; TPWD, Texas Parks and Wildlife Department; STOR, reservoir storage; DELEV, daily reservoir elevation; ELEV, reservoir elevation; QW, water quality; MSTOR, monthly reservoir storage; --, not available; DSTOR, daily reservoir storage]

Map identifier (figure 1)	Reservoir name	Reservoir short name	Major river basin	USGS NWIS data	USGS ADR data	TCEQ data	TWDB data	X indicates reservoir is on TPWD list of reservoirs with suspected historical golden algae blooms
1	Belton Lake	Belton	Brazos	STOR, DELEV, ELEV	--	QW	MSTOR	--
2	Buffalo Springs Lake	Buffalo Springs	Brazos	QW	--	QW	--	X
3	Lake Georgetown	Georgetown	Brazos	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
4	Granger Lake	Granger	Brazos	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
5	Hubbard Creek Reservoir	HubbardCk	Brazos	QW, DSTOR, DELEV, STOR, ELEV	--	QW, STOR	MSTOR	--
6	Lake Limestone	Limestone	Brazos	DSTOR, DELEV, STOR, ELEV	QW	QW	MSTOR	--
7	Lake Granbury	LkGranbury	Brazos	QW, DSTOR, DELEV, STOR, ELEV	QW	QW	MSTOR	X
8	Possum Kingdom Lake	Possum Kingdom	Brazos	QW, DSTOR, DELEV, STOR, ELEV	QW	QW, ELEV	MSTOR	X
9	Proctor Lake	Proctor	Brazos	STOR, DELEV, ELEV	--	QW	MSTOR	--
10	Lake Ransom Canyon	Ransom	Brazos	--	--	QW	--	X
11	Somerville Lake	Somerville	Brazos	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
12	Stillhouse Hollow Lake	Stillhouse	Brazos	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
13	Lake Sweetwater	Sweetwater	Brazos	QW	--	QW	--	X
14	Lake Waco	Waco	Brazos	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
15	White River Lake	White	Brazos	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
16	Lake Whitney	Whitney	Brazos	QW	--	QW	MSTOR	X
17	Lake Meredith	Meredith	Canadian	QW, STOR, DELEV, ELEV	--	QW, ELEV	MSTOR	X
18	Lake Buchanan	Buchanan	Colorado	--	--	QW, ELEV	MSTOR	--
19	O.H. Ivie Reservoir	Ivie	Colorado	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	X
20	Lake Colorado City	LkColoradoCity	Colorado	QW, DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	X
21	E.V. Spence Reservoir	Spence	Colorado	QW, DSTOR, DELEV, STOR, ELEV	QW	QW, ELEV	MSTOR	X
22	Lake J. B. Thomas	Thomas	Colorado	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
23	Lake Travis	Travis	Colorado	STOR	--	QW, ELEV	MSTOR	--
24	Twin Buttes Reservoir	TwinButtes	Colorado	DSTOR, DELEV, STOR	--	QW, STOR, ELEV	MSTOR	--
25	Lake Cypress Springs	Cypress	Cypress	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
26	Lake O the Pines	Pines	Cypress	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
27	Canyon Lake	Canyon	Guadalupe	STOR, DELEV, ELEV	--	QW	MSTOR	--
28	Lake Texana	Texana	Lavaca	QW, STOR, DELEV, ELEV	--	QW, STOR	MSTOR	--
29	Lake Palestine	Palestine	Neches	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--

Table 2. Selected Texas reservoirs for which water-quality, reservoir storage, or reservoir elevation data were compiled, and identification of reservoirs with suspected historical golden algae blooms.—Continued

[U.S. Geological Survey, USGS; NWIS, National Water Information System; ADR, Annual data report; TCEQ, Texas Commission on Environmental Quality; TWDB, Texas Water Development Board; TPWD, Texas Parks and Wildlife Department; STOR, reservoir storage; DELEV, daily reservoir elevation; ELEV, reservoir elevation; QW, water quality; MSTOR, monthly reservoir storage; --, not available; DSTOR, daily reservoir storage]

Map identifier (figure 1)	Reservoir name	Reservoir short name	Major river basin	USGS NWIS data	USGS ADR data	TCEQ data	TWDB data	X indicates reservoir is on TPWD list of reservoirs with suspected historical golden algae blooms
30	Sam Rayburn Reservoir	Rayburn	Neches	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
31	Choke Canyon Reservoir	Choke	Nueces	DSTOR, DELEV, STOR, ELEV	--	QW, STOR	MSTOR	--
32	Corpus Christi Reservoir	Corpus	Nueces	DSTOR, DELEV, STOR, ELEV	--	QW, STOR, ELEV	MSTOR	--
33	Baylor Lake	Baylor	Red	--	--	QW	--	X
34	Lake Childress	Childress	Red	--	--	QW	--	X
35	Diversion Lake	Diversion	Red	--	--	QW	--	X
36	Greenbelt Lake	Greenbelt	Red	DSTOR, DELEV, STOR	--	QW	MSTOR	--
37	Lake Kemp	Kemp	Red	QW	--	QW	--	--
38	Mackenzie Reservoir	MacKenzie	Red	STOR, DELEV, ELEV	--	QW	MSTOR	--
39	Moss Creek Lake	Moss	Red	QW	--	--	--	X
40	Lake Texoma	Texoma	Red	QW	--	QW	--	X
41	Red Bluff Reservoir	RedBluff	Rio Grande	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	X
42	Lake Tawakoni	Tawakoni	Sabine	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
43	Toledo Bend Reservoir	Toledo	Sabine	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
44	Medina Lake	Medina	San Antonio	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
45	Lake Houston	Houston	San Jacinto	DSTOR, STOR	--	QW, STOR	MSTOR	--
46	Lake Conroe	LkConroe	San Jacinto	QW, DSTOR, DELEV, STOR, ELEV	--	QW, STOR	MSTOR	--
47	Wright Patman Lake	Patman	Sulphur	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
48	Lake Arlington	Arlington	Trinity	QW, DSTOR, DELEV, STOR, ELEV	--	--	--	--
49	Bardwell Lake	Bardwell	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW, STOR, ELEV	MSTOR	--
50	Benbrook Lake	Benbrook	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
51	Lake Bridgeport	Bridgeport	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
52	Eagle Mountain Lake	Eagle	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
53	Joe Pool Lake	JoePool	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW, STOR	MSTOR	--
54	Lewisville Lake	Lewisville	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
55	Lake Livingston	Livingston	Trinity	QW, DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
56	Navarro Mills Lake	Navarro	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW, ELEV	MSTOR	--
57	Lake Ray Hubbard,	RayHubbard	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
58	Richland-Chambers Reservoir	Richland-Chambers	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--
59	Lake Ray Roberts	Roberts	Trinity	DSTOR, DELEV, STOR, ELEV	--	QW	MSTOR	--

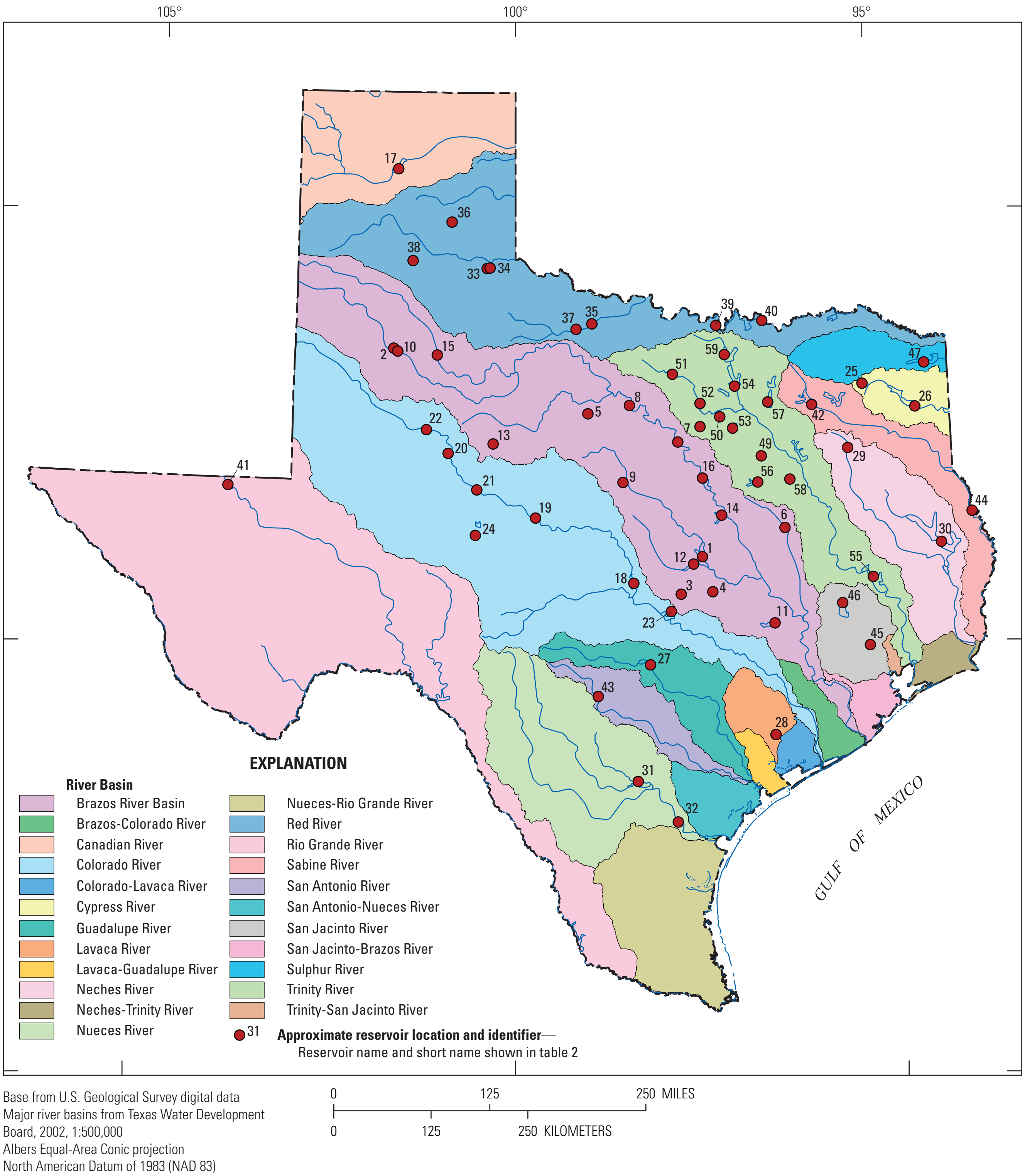

Figure 1. Approximate locations of selected Texas reservoirs for which storage, elevation, and water-quality data were compiled, 1965–2010. The major basin extents are only shown for Texas.

to that used for the USGS NWIS data was used to associate TCEQ sites with their associated reservoir-by-reservoir short names. Care was taken to ensure that any reservoir short names devised from the USGS NWIS data assessment process matched reservoir short names devised for the TCEQ and TWDB assessment process. When possible, USGS NWIS and TCEQ water-quality properties and constituents were matched using the database parameter codes for individual physical properties and constituents, description of the physical property or constituent, and reporting units. TCEQ SWQMIS data were temporally assessed by using a VBA program and SQL to generate sample counts per site as well as the earliest and most recent sample dates associated with a site to gage length of the overall sample period. TCEQ SWQMIS data also were assessed by using a VBA program and SQL along with the TWDB candidate reservoir list to determine reservoir overlap between the two datasets. Of the 109 total reservoirs for which TWDB data were available, 49 of the 59 final selected reservoirs were determined to be usable based on the concurrent assessment of USGS NWIS and TCEQ SWQMIS data (table 2). A total of 199 sites in USGS NWIS (including NWIS water-quality sample and NWIS storage or elevation daily data sites) representing 54 of the 59 selected reservoirs (table 2) were identified as relevant using the fuzzy site name match and site screening processes. A total of 331 TCEQ sites from 57 reservoirs (table 2) were identified as containing the desired data. The data files associated with this report provide detailed USGS NWIS, TCEQ, and TWDB site record information for the selected sites located on the selected reservoirs.

The USGS annually publishes data for each water year in a report series known as the Annual Water Data Report (ADR). A water year is the 12-month period from October 1 through September 30. It is designated by the calendar year in which it ends. Thus, the period October 1, 1964, through September 30, 1965, is called “water year 1965.” The ADR reports serve as archival products and provide supplemental access to current and historical water data contained in the USGS NWIS database. Data from selected reservoir sites published in the USGS Texas Water Science Center ADR for 1965 through 2005 (U.S. Geological Survey, 1966–2006a; 1966–2006b; 1966–2006c) were compiled for this report. All ADR data from water years 2006 and later are digitally available from the USGS NWIS database. Reservoir elevation, storage, and water quality are included in these published data. All 123 ADR volumes for Texas containing data from water years 1965–2005 were manually searched to identify reservoirs with at least 10 years of record. Qualifying reservoirs were identified and the pages containing those data were flagged for additional assessment. To ensure data were representative of most of the water year, only sites with temperature and reservoir storage data distributed over at least 3 quarters of a year (4 months per quarter) were included. The pages from reports containing these data were scanned into portable document files (PDFs). A minimum of 3 quarters was used as criteria similar to that used for assessment of the USGS NWIS and TCEQ SWQMIS data. The ADR pages flagged for additional assessment were compared with digital USGS NWIS data to determine if the data were already available in USGS NWIS so as to avoid data duplication. Data from seven sites at four reservoirs were found that were not in the USGS NWIS, and these sites were entered into an Access database.

Final Data Format for and Assembly of Spatially Pooled, Depth-Dependent Reservoir Water-Quality, Storage, and Elevation Data

A final compiled data format was designed and implemented using a combination of additional VBA and PERL programs as well as extensive post-processing using the R environment (R Development Core Team, 2009). The goal was to combine several data sources and all sites at a given reservoir in a format that captured the depth-dependent characteristics of reservoir water-quality data. A data file format of space character-delimited text files was used. Ancillary information files such as the lists of data source sites were delimited using the pipe character “|”. The final data files were structured so that all sample values were represented with file “header” information including the reservoir short name, information describing the physical property or constituent and its associated database parameter code, sample value depth, mean, standard deviation, and count representing the number of sample values used in computation of the mean and standard deviation values for each physical property or constituent. The data were not screened on the basis of sample depth. The data were output with one water-quality physical property or constituent per text file, and all storage and elevation data were combined in a single text file. All temperature values in Fahrenheit were converted to Celsius. All sample depth measurements in meters were converted to feet.

The records of all selected physical properties and constituents from all sites from which data were compiled for a given reservoir were loaded into computer memory to create “data ensembles.” Each data ensemble consisted of a sequence of physical properties and constituents for a given sample depth for a specific date and time (table 1). If a sample depth was missing for a given ensemble, a sample depth of zero was assigned because none of the source data contain a sample depth of zero. The time stamp (hours, minutes, seconds) was removed but dates (month, day, year) were kept. All TWDB data were “snapped” to the end date of the month with which the monthly storage value was associated. For example, a December 2010 monthly storage value would be assigned a date of 12/31/2010. All data for a given sample depth for each reservoir, sample collection date, and for each physical property or constituent were placed into temporary data arrays in computer memory, and the mean, standard deviation, and sample size of each physical property or constituent were computed. Calculation of the mean for multiple data values on a sample collection date and standard deviation numerically constitutes the spatial pooling and temporal combining of multiple sites at a single reservoir by data type for a given date for a physical property or constituent.

The complete range of dates for all properties or constituents was determined to standardize data records for each reservoir and sample depth so that a data file for any property or constituent contained the same dates and the same number of lines whether or not a sample value was available as compared with other property or constituent data files. If a given physical property or constituent was sampled on a given date, every record for every physical property or constituent would have entry for that date. If a physical property or constituent was not measured in particular sample, a missing data identifier denoted by “NA” was used. This complete date range approach was used to ensure that the output files for each physical property or constituent have precisely the same number of record entries although the absolute counts of data by physical property or constituent differ for each reservoir. This processing ensured the data files were consistent with the rectangular data structure used by most spreadsheets and statistical processing software.

Date information was compiled in a standard (MM/DD/YYYY) format to facilitate temporal analysis. In addition, all conventional sample dates were formatted to contain leading zeros in cases where the month or day digit was a single digit. For example, a date of 1/1/2005 would be formatted in the final data file as 01/01/2005.

An epoch date, or reference date, was calculated to allow record sorting for the entire dataset period; the conventional date format was retained. The epoch origin date used was 01/01/1900, so for any given sample value, the epoch date for that sample would be the number of days after 01/01/1900 that the sample was taken. For example, a sample collected on 01/30/1967 would have an epoch date of 24,500. A Julian date, or days-into-the-year, also was calculated as the number of days into a calendar year that a sample was taken; the Julian date facilitates the sorting of all sample results for a given year and computations involving radians, such as trigonometric functions, which are a consideration when analyzing cyclical patterns (periodicity) of water-quality properties and constituents. Leap years were accounted for in the assignment of epoch and Julian dates. In the convention for Julian dates used in this report, Julian dates lag the calendar date by a value of one in order to represent the number of completed days into a given calendar year; for example, a sample collected on 01/30/1967 is assigned a Julian date of 29.

Spatially Pooled Depth-Dependent Reservoir Storage, Elevation, and Water-Quality Data

Reservoir storage, elevation, and water-quality data compiled from 59 reservoirs in Texas listed in table 2 are provided in appendixes 1, 2-1 through 2-32, 3-1 through 3-24, and 4-1 through 4-5. Appendix 1 is an information file that discusses the contents of appendixes 2, 3, and 4 as well as provides for reference the associated report title. Appendixes 2-1 through 2-3 contain information pertaining to USGS NWIS water-quality data files, and appendixes 2-4 through 2-32 contain 342,577 records of spatially pooled depth-dependent water-quality data from USGS NWIS that comprise 29 properties and constituents (table 1) from 54 of the 59 reservoirs listed in table 2. Appendixes 3-1 through 3-3 contain information pertaining to TCEQ SWQMIS water-quality data files, and appendixes 3-4 through 3-24 contain 1,981,749 records of spatially pooled depth-dependent water-quality data from TCEQ SWQMIS that comprise 21 properties and constituents (table 1) from 57 of the 59 reservoirs listed in table 2. Appendixes 4-1 through 4-4 contain information pertaining to the storage and elevation data file, and appendix 4-5 contains storage and elevation data compiled from USGS NWIS, TCEQ SWQMIS, and TWDB. USGS NWIS contained 1,412,577 records of daily or instantaneous reservoir storage or elevation data from 48 of the 59 reservoirs listed in table 2. TCEQ SWQMIS contained 1,253 records of reservoir storage or elevation data from 28 of the 59 reservoirs listed in table 2. TWDB contained 11,172 records of monthly reservoir storage data for 49 of the 59 reservoirs listed in table 2.

Summary

The U.S. Geological Survey (USGS), in cooperation with Texas Tech University, constructed a dataset of selected reservoir storage (daily and instantaneous values), reservoir elevation (daily and instantaneous), and water-quality data from 59 reservoirs throughout Texas. The data described in this report were compiled to partially meet objectives of a larger USGS National Climate Change and Wildlife Science Center study titled “Modeling and Predicting the Influence of Climate Change on Texas Surface Waters and their Aquatic Biotic Communities,” hereinafter referred to as the NCCWSC study. One objective of the NCCWSC study was to compile data of observed historical water temperatures and other relevant water-quality information for selected reservoirs with appreciable fisheries resources in Texas. This report documents historical water temperatures and other relevant water-quality data for selected reservoirs in Texas with periods of record as large as January 1965–January 2010.

Reservoir data from multiple sources were combined to create temporally longer and more complete data records. Existing reservoir storage, elevation, and water-quality data were assembled from databases, delimited text files, spreadsheets, and published USGS reports. Primary data sources include the USGS National Water Information System (NWIS), the Texas Commission on Environmental Quality (TCEQ) Surface Water-Quality Management Information System (SWQMIS), and the Texas Water Development Board (TWDB) monthly Texas Water Condition Reports. Additional data sources included USGS Annual Water Data Reports containing data that do not currently (2011) reside in the USGS NWIS database. Data from the multiple sources were assessed and processed to compile the data documented by this report. Source data were combined to create temporally longer and more complete sets of properties and constituents. All available sites occurring at a reservoir were spatially pooled by devising a unique abbreviated name or short name per reservoir. Reservoir selection was based on various criteria including the availability of water-quality properties and constituents that might affect the trophic status of the reservoir and also could be important for understanding possible effects of climate change. Other considerations in the selection of reservoirs included the period of record, the availability of concurrent reservoir storage or elevation data to match with water-quality data, and the availability of sample depth measurements. Additional separate selection criteria included historic information pertaining to blooms of golden algae. Physical properties and constituents were water temperature, reservoir storage, reservoir elevation, specific conductance, dissolved oxygen, pH, unfiltered salinity, unfiltered total nitrogen, filtered total nitrogen, unfiltered nitrate plus nitrite, unfiltered phosphorus, filtered phosphorus, unfiltered carbon, carbon in suspended sediment, total hardness, unfiltered noncarbonate hardness, filtered noncarbonate hardness, unfiltered calcium, filtered calcium, unfiltered magnesium, filtered magnesium, unfiltered sodium, filtered sodium, unfiltered potassium, filtered potassium, filtered chloride, filtered sulfate, unfiltered fluoride, and filtered fluoride. When possible, USGS NWIS and TCEQ SWQMIS water-quality properties and constituents were matched using the database parameter codes for individual physical properties and constituents, description of the physical property or constituent, and their reporting units. This report presents a collection of delimited text files of source-aggregated, spatially pooled, depth-dependent, instantaneous water-quality data as well as instantaneous, daily, and monthly storage and elevation reservoir data.

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