Nitrogen and Phosphorus Trends of Long-Term Ambient Water Quality Monitoring Sites in Louisiana

Prepared by

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Table of Contents

List of Tables

List of Figures

Abstract

Long-term and seasonal nutrient trend analyses were conducted for concentrations of total Kjeldahl nitrogen (TKN), nitrate-nitrite (NOx), and total phosphorus (TP) collected from October 1, 1978 through September 30, 2020 at the 21 long-term monitoring sites comprising the Louisiana Department of Environmental Quality's (LDEQ) ambient water quality monitoring network (AWQMN). These sites are located in eleven of the twelve water quality management basins in Louisiana. A censored Seasonal Kendall trend analysis found that TKN was decreasing significantly ($p < 0.05$) overall at 20 of the 21 sites (95%), while no trend was observed at the remaining site at Bayou Lafourche in the Barataria Basin (5%); in the 2015 version of this report all 21 sites were found to be decreasing for TKN. NOx was decreasing overall at 10 sites (48%), and increasing at one site (5%) on the Bogue Chitto River located in the Pearl River Basin, at which NOx was also increasing in the 2015 report. TP was decreasing overall at 11 sites (52%), and increasing at two sites (10%), one each in the Pearl River Basin and Lake Pontchartrain Basin. The increases in TP also mark a change from the 2015 report, as at that time there was no significant trend at these sites. All other overall trends were not statistically significant ($p > 0.05$). Individual seasonal trend analyses showed some statistically significant nutrient concentration increases that were not reflected in the overall trends, primarily during the fall and winter. TKN is generally decreasing in every season; however, in the fall there are 12 sites (57%) for which there is no significant trend. NOx was found to be increasing at the Bogue Chitto River site in the Pearl River Basin in summer, fall, and winter; at the Bayou Lafourche site in the Barataria Basin in fall; and at the Tchefuncte River site in the Lake Pontchartrain Basin in winter. TP was increasing significantly at the Lake Pontchartrain Basin in every season. TP seasonal trends also showed increases in the fall in the Bogue Chitto River, Tchefuncte River, and Tensas River, and increases in winter in the Bogue Chitto River and Tchefuncte River. All other seasonal trends were either decreasing or not statistically significant. Land cover data obtained from the U.S. Department of Agriculture was used to calculate land use type by drainage area, and Kendall rank correlation analyses were conducted to compare median nutrient concentrations to land use and median total suspended solids (TSS) for these watersheds. The results of the correlation analyses found matching significant, positive Kendall's tau values for the relationship between TKN and TSS and TP and TSS ($p < 0.05$), and between TKN and agriculture and TP and agriculture ($p < 0.01$), which support that higher TKN and TP concentrations are associated with increases in agricultural land use, while the finding of significant negative Kendall's tau values between forest cover and TKN and forest cover and TP ($p < 0.01$) suggest higher forest cover is significantly correlated with lower TKN and TP values, all other correlations were not significant. Overall, long-term trends in TKN, NOx, and TP show that nutrient concentrations continue to decrease for the majority of long-term monitoring sites within the state, and that Louisiana continues to make improvements in nutrient management within our water bodies.

1. Background

1.1 Nutrients are Essential to Life

Nitrogen (N) and phosphorus (P) are essential elements of life, as they are core components of cell structure and function, including growth and metabolism (photosynthesis, respiration). In plants, N is primarily used in proteins, nucleic acids and lipoproteins, while P is preferentially utilized in photosynthesis and respiration pathways, nucleic acids, and the phospholipids that comprise cell membranes (LDEQ, 2011). Nucleic acids (DNA and RNA), the information-carrying molecules of cells, are comprised of approximately 39% N and 9% P (Guignard et al., 2017). Because of these critical roles, the availability of environmental N and P are limiting factors in plant growth and function. However, an overabundance of N and P in the environment can lead to eutrophication, defined as excessive plant and/or algal growth as a result of nutrient enrichment (Nixon, 1995; Schindler, 2006). Nutrient pollution, especially of N and P, has become one of the biggest problems facing water quality in the world today (Val H Smith & Schindler, 2009; Val H Smith et al., 1999; USEPA, 2017).

Nitrogen occurs in many forms, but the vast majority is atmospheric nitrogen (see Figure 1). Earth's atmosphere is comprised of about 78% nitrogen, primarily in the form of dinitrogen gas (N_2) which is largely unreactive and not bioavailable. Relatively smaller nitrogen sinks occur in the oceans, rocks, and sediment (Chapin III et al., 2011). The other common forms of nitrogen are the inorganics nitrate/nitrite (NO_3^-/NO_2^-) and ammonium/ammonia (NH_4^+/NH_3), and organic nitrogen ($C\text{-}NH_2$, where C is a complex organic group) (Guignard et al., 2017; Killpack & Buchholz, 1993). The nitrogen cycle describes the process by which nitrogen changes forms and moves between the atmosphere, land, water, and organisms (plants, animals, bacteria) (Chapin III et al., 2011).

The primary environmental source of phosphorus is through weathering of rocks (erosion, leaching, mining), with phosphorus availability becoming limited as rocks age and renewed by continental uplift (Chapin III et al., 2011; Guignard et al., 2017). Like nitrogen, phosphorus in ecosystems is bound to organic matter, and has to be remineralized or dissolved into inorganic orthophosphates by microorganisms (bacteria, fungi) before it can be absorbed by primary producers (Guignard et al., 2017). The primary forms of phosphorus are phosphate and organic-P. Phosphate occurs in various ionic forms depending on pH, including: H_3PO_4 (phosphoric acid), $H_2PO_4^-$ (dihydrogen phosphate), HPO_4^{2-} (hydrogen phosphate), or PO_4^{3-} (phosphate) (see Figure 2).

1.2 Sources of Nutrients in the Environment

N and P enter the environment from a multitude of sources, including runoff and/or leachate from: agriculture, animal feedlots, construction sites, landfills, logging sites, mines, oil fields, pastures, septic tanks, storm sewer outfalls, urban areas, and unsewered industrial sites; wastewater effluent; sanitary and storm sewer overflow; and atmospheric deposition over water (Val H Smith et al., 1999). In addition to inputs from runoff, leachate, and natural sources, humans have greatly altered the nitrogen cycle through the introduction and exponential increase in both fossil fuel combustion and the production of reactive nitrogen for use in agriculture (Galloway et al., 2008). Fertilizer is a substantial source of both N and P. Reactive nitrogen (Nr) creation increased from approximately 15 Tg/yr in 1860 to about 187 Tg/yr in 2005, and is linked to large (20%+) increases in cereals and meat production (Galloway et al., 2008). Nitrogen discharge to rivers increased by 43% from 1970 to 2000, with agriculture contributing about 80% of the human-induced export of N to rivers (Bouwman et al., 2005; Breitburg et al., 2018). This reactive nitrogen is primarily applied in two forms: 1) anhydrous ammonia directly injected into soils or 2) ammonium salts (such as ammonium nitrate) applied to the soil (Reddy and DeLaune, 2008). The ammonium applied to upland soils (i.e., aerobic) can then readily oxidize to nitrate through nitrification. Phosphates are also a primary component in most fertilizers, and thus, nitrate, ammonium, and phosphate are introduced into our waterbodies as runoff from fields and stormwater runoff from urban areas. Animal (e.g., manure) and human waste (from sewage and septic systems) are sources of both inorganic and organic forms of N and P into waterways. As the combustion of fossil fuels continue to increase, currently over 20 million metric tons per year, atmospheric deposition of N into waterbodies is becoming a significant contributor to N pollution (Schlesinger, 1997, Smith, et al., 1999).

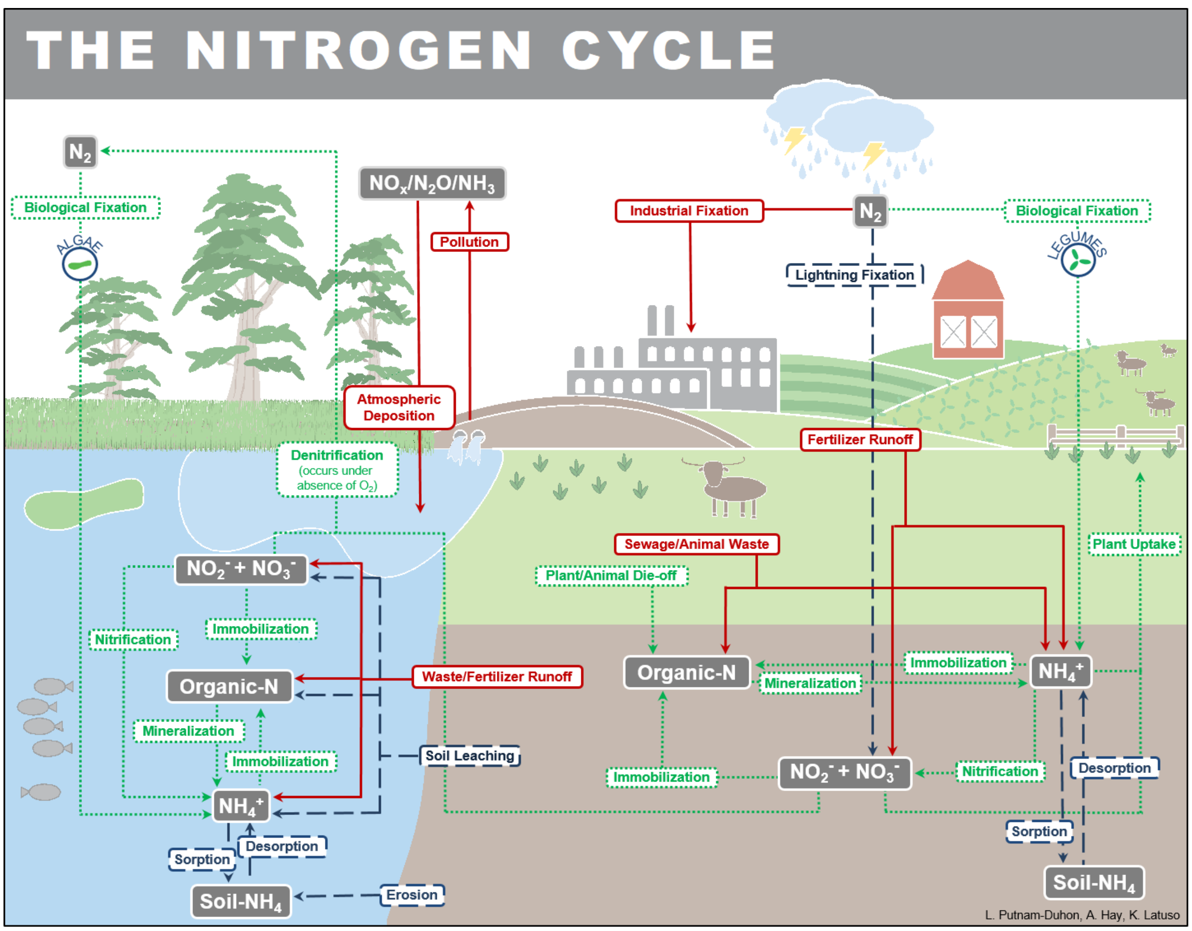


Figure 1. The nitrogen cycle. Anthropogenic inputs are shown in solid red lines; naturally occurring physical and chemical inputs are shown in blue dashed lines; and biological inputs are shown in green dotted lines.

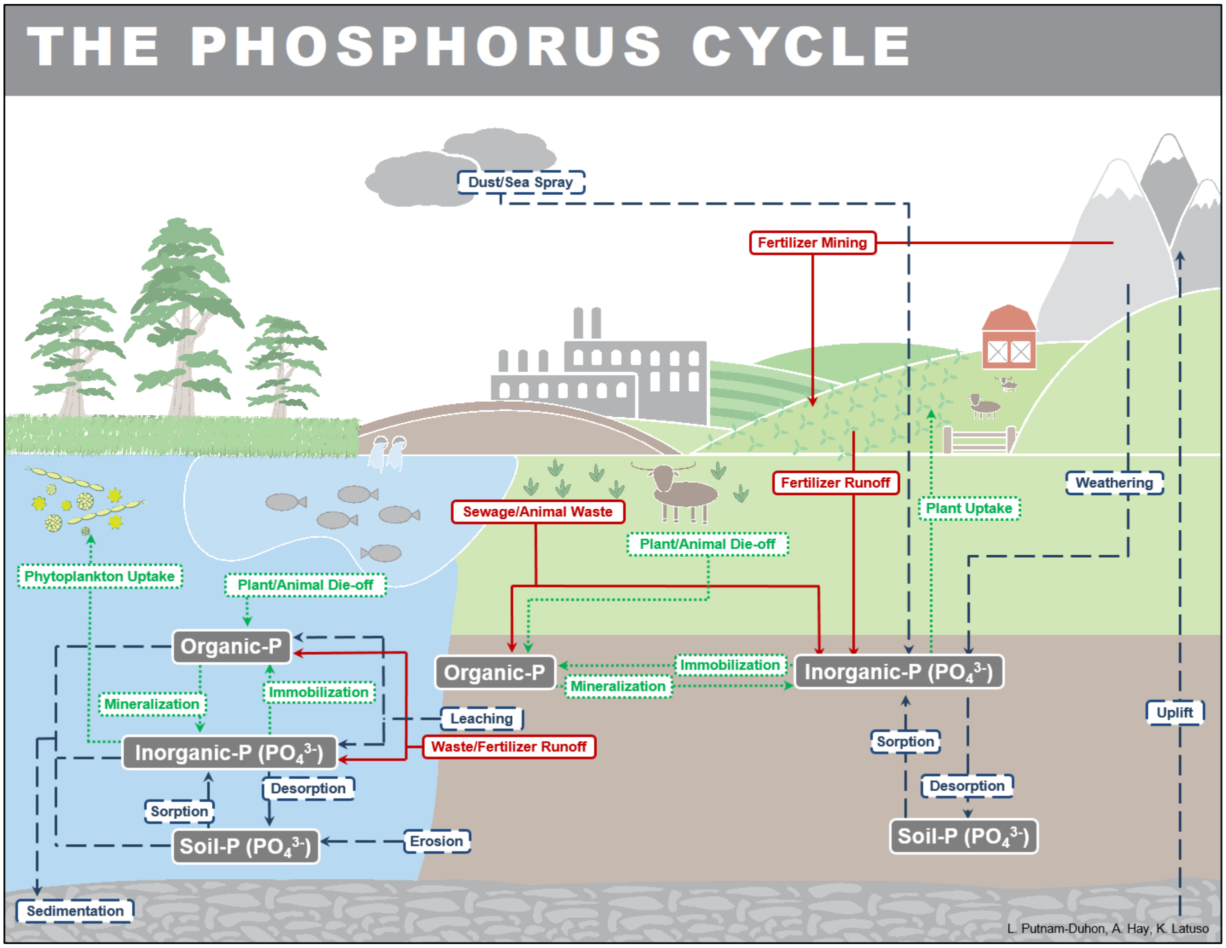


Figure 2. The phosphorus cycle. Anthropogenic inputs are shown in solid red lines; naturally occurring physical and chemical inputs are shown in blue dashed lines; and biological inputs are shown in green dotted lines.

1.3 Effects of Nutrients in Aquatic Ecosystems

Eutrophication is the accumulation of excess nutrients, particularly N and P, in water bodies. Excessive levels of nutrients support excessive algal growth, particularly in warm, slow-moving rivers, shallow lakes, and coastal waters. Algal blooms resulting from eutrophication affect aesthetic water quality (appearance, color, taste, and odor). As algae die and decompose, microorganisms utilize the organic-N and P that are released and, in doing so, consume oxygen. Hypoxia, or “low oxygen,” occurs when dissolved oxygen (DO) levels in the water are depleted to a level that affects critical processes of species in that habitat, this level varies by species but a threshold value of 2 mg/L is generally accepted as the minimum DO concentration necessary for aquatic life to survive and reproduce (Breitburg et al., 2018). Hypoxia can lead to the death of less mobile animals like shellfish and young fish that are dependent upon oxygen for life and are unable to move into healthier waters (Capel et al., 2018; Dubrovsky et al., 2010; Rabalais et al., 2010). Furthermore, depending on the species, harmful algal blooms (HABs) resulting from eutrophication may also produce toxins that are harmful to other organisms and human health (O’Neil et al., 2012; Val H. Smith et al., 2006; Val H Smith & Schindler, 2009; Val H Smith et al., 1999). Cyanobacteria are one such group of HAB-forming phytoplankton, including those in the genera Microcystis and Anabaena, which may produce neurotoxins or hepatotoxins that can be harmful to humans and may kill off smaller aquatic organisms. Cyanobacteria are stimulated by higher temperatures and high nutrient loads, and are well-evolved to remineralize organic P released when other forms of phytoplankton die off and/or are grazed (O'Neil et al., 2012). Toxins released from HABs can move up the food chain as larger animals, like turtles, dolphins, birds, manatees, or larger fish consume the smaller contaminated organisms. Certain forms of nutrients can also cause direct impacts due to toxicity: ammonium is toxic to fish (Eddy, 2005 and references therein) and nitrate and nitrite exposure above the MCL drinking water standard can lead to acquired methemoglobinemia in humans, a blood disorder which results in too little oxygen reaching body cells (Bruning-Fann & Kaneene, 1993; Fan & Steinberg, 1996) Eutrophication can occur naturally, but rates of eutrophication have increased over the last century as a result of human activity (Capel et al., 2018; Chislock et al., 2013; Dubrovsky et al., 2010; Rabalais et al., 2010). Cultural eutrophication, or eutrophication as a result of human activity, is one of the main issues currently affecting a majority of surface waters, and is the primary driver of deoxygenation in coastal waters (Breitburg et al., 2018; Chislock et al., 2013; Val H Smith & Schindler, 2009).

1.4 Louisiana Waters

Due to warm climate and slow-moving waterbodies, Louisiana is especially vulnerable to eutrophication and hypoxia. Low dissolved oxygen continues to be the most frequent suspected cause of impairment for fish and wildlife propagation use in state waters, reported in 235 subsegments in 2020, an increase from 201 in 2018 (LDEQ, 2020). Nutrient load increases can be associated with HABs, as was seen in Lake Pontchartrain after an opening of the Bonnet Carré Spillway in 2008, and again recently in 2019 (Bargu et al., 2011; LDH, 2019).

Ambient surface water quality data is collected by LDEQ monthly at approximately 135 sites statewide within the Ambient Water Quality Monitoring Network (AWQMN), and is used to assess conditions in Louisiana's waterbodies. The AWQMN began monitoring in 1958 and has established over 600 monitoring sites since that time; there are currently just over 480 active monitoring sites. Data is collected on a rotating basis in order to expand the coverage of our monitoring efforts. Twenty-one of the AWQMN sites (located on 16 rivers) are sampled every month of every year to monitor long-term water quality (LDEQ, 2019b).

2. Objective

This report provides a five-year update of the long-term patterns and trends in nutrient concentrations of TKN, NOx, and TP collected at the 21 long-term AWQMN sites in Louisiana surface waters over a period of 42 years from October 1, 1978 through the end of the last completed annual water quality monitoring cycle, or "water-year," on September 30, 2020.

3. Methods

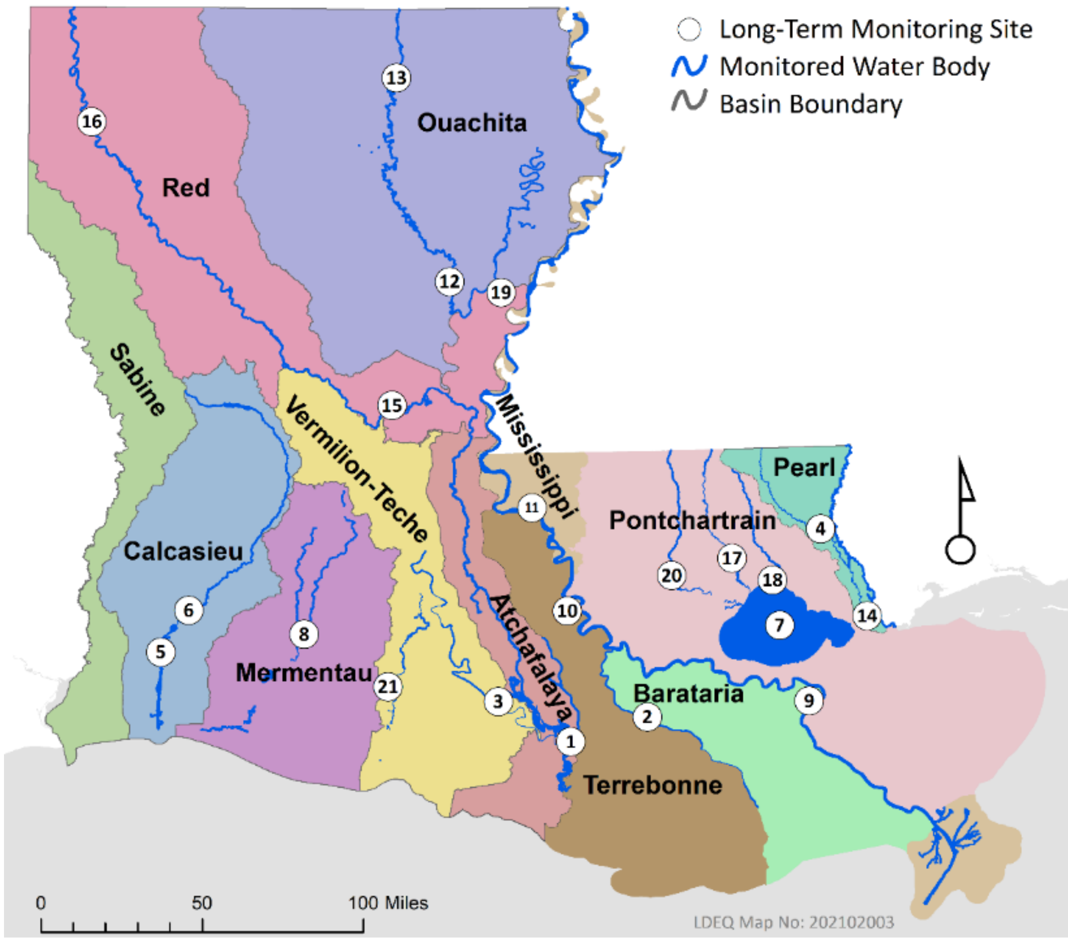
3.1 Nutrient Data Compilation

The 21 AWQMN sites in this study were chosen based on the consistency and timespan of nutrient concentration data available for analysis. These sites are located in eleven of the twelve water quality management basins in Louisiana, as described in *LAC 33:IX.1123.A.1*, which are named for their major waterbodies (11 river systems and one estuarine lake) [Figure 3, (LDEQ, 2021b)]. All TKN, NOx, and TP data for these sites were obtained from the Louisiana Environmental Assessment Utility (LEAU) database and reviewed. Data identified as duplicate samples, samples taken at depths greater than one meter, and those that were flagged for quality assurance/quality control (QA/QC) reasons were removed from the dataset; this resulted in the removal of 950 (3.3%) samples from a total of 28,935. Based on a review of the 99^{th} percentile for each parameter, data over 3.0 mg/L for both TKN (52 out of 8,971 samples) and NOx (22 out of 9,671 samples), and greater than 1.0 mg/L for TP (34 out of 9,343 samples) were considered potential outliers and removed from the analytical dataset. Data with a value below the identified laboratory detection limit (PQL or MDL) were not removed, instead the entire dataset was analyzed using statistical methods designed for left-censored environmental data (Helsel, 2019; Helsel, 2020a; Helsel, 2021). Out of 8,919 TKN samples, 390 (4.37%) were left-censored; out of 9,649 total NOx concentration samples, 735 (7.62%) were left-censored; and out of 9,309 TP samples, 516 (5.54%) were left-censored (Table 1).

In order to examine any influence between nutrients and TSS, TSS data were also obtained and reviewed following the same methodology as above, which resulted in the removal of 92 out of 9,544 samples (0.96%) for QA/QC issues, and 75 of the remaining 9,452 (0.79%) as potential outliers with values greater than 400.0 mg/L. In the TSS data, 576 entries had a PQL that was either zero or blank while the MDL was equal to four; therefore, the censoring threshold values for these data were retained at the more conservative MDL of four. In all other nutrient samples, the PQL and the MDL were equal.

Table 1. Summary of nutrient concentration data for AWQMN long-term sites from Oct. 1, 1978 – Sept. 30, 2020, including: number of samples (n), the number (ncen) and percentage (%cen) of left-censored values, and the minimum (min), maximum (max), and Kaplan-Meier (K-M) median value for each parameter. Total suspended solids (TSS) were included only in the land use correlation analysis.

Parameter	n	ncen	%cen	min	max	K-M median
TKN	8919	390	4.37	0.01	3.0	0.72
NOx	9649	735	7.62	0.008	3.0	0.22
TP	9309	516	5.54	0.01	1.0	0.13
TSS	9377	166	1.77	0.40	400.0	25.0



Site Name	Map #	LDEQ Site #	LDEQ Subsegment	LDEQ Basin Name
Atchafalaya River – Morgan City	1	0039	LA010501_00	Atchafalaya River Basin
Bayou Lafourche – Thibodaux	2	0293	LA020401_00	Barataria Basin
Bayou Teche – Adeline	3	0030	LA060401_00	Vermilion-Teche River Basin
Bogue Chitto River – Bush	4	0064	LA090501_00	Pearl River Basin
Calcasieu River – Burton Landing	5	0026	LA030304_00	Calcasieu River Basin
Calcasieu River – Moss Bluff	6	0093	LA030201_00	Calcasieu River Basin
Lake Pontchartrain –Metairie	7	0138	LA041001_00	Lake Pontchartrain Basin
Mermentau River – Mermentau	8	0003	LA050401_00	Mermentau River Basin
Mississippi River – Belle Chasse	9	0051, 0320	LA070301_00	Mississippi River Basin
Mississippi River – Plaquemine	10	0053, 0319	LA070301_00	Mississippi River Basin
Mississippi River – St. Francisville	11	0055, 0318, 4031	LA070201_00	Mississippi River Basin
Ouachita River – Harrisonburg	12	0085	LA080201_00	Ouachita River Basin
Ouachita River – Sterlington	13	0013	LA080101_00	Ouachita River Basin
Pearl River – Slidell	14	0105	LA090202_00	Pearl River Basin
Red River – Marksville	15	0024	LA100201_00	Red River Basin
Red River – Shreveport	16	0120	LA100101_00	Red River Basin
Tangipahoa River –Robert	17	0033	LA040701_00	Lake Pontchartrain Basin
Tchefuncte River – Madisonville	18	0106	LA040802_00	Lake Pontchartrain Basin
Tensas River – Clayton	19	0159	LA081201_00	Ouachita River Basin
Tickfaw River – Springville	20	0116	LA040501_00	Lake Pontchartrain Basin
Vermilion River – Perry	21	0001	LA060802_00	Vermilion-Teche River Basin

Figure 3. The locations of LDEQ's long-term monitoring sites and basins, and a listing of each site's name, map number, LDEQ site number, subsegment, and basin name.

3.2 Watershed Basins and Monitoring Sites

The watershed basins and associated sites discussed in this report are based on the basins described in the LDEQ Water Quality Management Plan [Figure 3, (LDEQ, 2021d)]; only basins surrounding long-term water quality monitoring sites were included. For this report, the Atchafalaya River, Barataria, Terrebonne, and Mississippi River Water Quality Management Basins were combined into one watershed basin due to their interconnectedness (Figure 4). The Calcasieu and Mermentau River Basins were combined into one watershed basin for this report due to their proximity and location in the southwestern part of the state. Hereafter, these watershed basins will be called Mississippi and Calcasieu-Mermentau Basins, respectively. The Sabine River Basin has no long-term monitoring site and was therefore not characterized for this report. A brief description of the watershed basins used in this report follows. Throughout the report, 'watershed basin' or watershed will be used to indicate the river basins contained within the state boundaries of Louisiana, while 'drainage area' will describe the entire basin (including portions outside of Louisiana) that drains into the river at the site indicated.

3.2.1 Red Watershed Basin

The Red River drains approximately 42,374,000 acres (66,209 mi^2) of land, of which 4,966,400 acres (7,760 mi^2) are within Louisiana. The river originates in New Mexico, continuing through Oklahoma, Texas, Arkansas, and Louisiana. It enters Louisiana in the northwestern part of the state and flows southeastward until meeting the Atchafalaya River (LDEQ, 2021d). The major land areas of the Red River Basin within Louisiana are Southern Coastal Plain, Southern Mississippi Valley Alluvium, and a small portion of Southern Mississippi Valley Silty Uplands. The drainage area land use consists of 23.8% forest, 4.5% wetlands, 49.0% grasslands/ pasture, 18.1% agriculture, and 4.4% developed (Appendix A, Figure A. 1). This represents a slight shift toward increased wetlands (+1.5%) and agriculture (+1.1%) and decreased grasslands (-2%) and developed area (-0.6%) when compared to land use estimates in the 2015 long-term trends report. Two long-term monitoring sites are present within the Red Watershed Basin: map number 16 located near Shreveport and map number 15 located near Marksville (Figure 3). Data was collected from July 12, 1981 to December 12, 2019, and October 9, 1978 to August 4, 2020 for the monitoring sites near Shreveport and Marksville, respectively.

3.2.2 Ouachita Watershed Basin

The Ouachita River drains approximately 13,383,000 acres (20,911 mi^2) of land from the states of Arkansas and Louisiana, of which about 6,400,000 acres (10,000 mi^2) are within Louisiana. The watershed basin includes the Ouachita and Tensas Rivers. The Ouachita River enters Louisiana in the northeastern part of the state and flows south where it joins the Tensas River, which begins in northeast Louisiana. The Ouachita Basin primarily consists of rich alluvial plains that support cotton and soybean cultivation, with pine forests in the northwest that are commercially harvested (LDEQ, 2021d). The land use of the drainage area consists of approximately 43.8% (-9.2%) forest, 22.2% wetlands (+6.2%), 9.8% grasslands/pasture (-2.2%), 18.7% agriculture (+4.7%), and 5.5%

developed (-0.5%) (Figure A. 1). Three long-term monitoring sites are present within the Ouachita Watershed Basin: map numbers 12 and 13 are located on the Ouachita River near Harrisonburg and Sterlington, respectively, and map number 19 located on the Tensas River near Clayton (Figure 3). Data collection is from October 10, 1978 to August 4, 2020 for Harrisonburg; October 9, 1978 to September 1, 2020 for Sterlington; and November 16, 1988 to August 4, 2020 for Clayton.

3.2.3. Calcasieu-Mermentau Watershed Basin

The Calcasieu and Mermentau Rivers are located in southwestern Louisiana and are contained entirely within the state, terminating in the Gulf of Mexico. The rivers drain approximately 3,959,000 acres (6,186 mi^2) upstream of the sites shown in Figure 3. Land use of the drainage area consists of 38.9% forest, 18.7% wetlands, 15.9% grasslands/pasture, 18.5% agriculture, and 8.0% developed (Figure A. 1). This is an increase in forest (+8.9%), decrease in wetlands (-2.3%), decrease in grasslands (-8.1%), increase in agriculture (+1.5%), and no change in developed area compared to 2015 land use estimates. Three long-term monitoring sites are present within the watershed basin: map number 6 on the Calcasieu River at Moss Bluff, map number 5 on the Calcasieu River at Burton Landing, and map number 8 on the Mermentau River at Mermentau (Figure 3). Data collection ranges from October 10, 1978 to August 6, 2020 for Moss Bluff, from October 9, 1978 to August 5, 2020 for Burton Landing, and from October 10, 1978 to September 16, 2020 for Mermentau.

3.2.4 Vermilion-Teche Watershed Basin

Both the Vermilion and Teche Rivers comprise the Vermilion-Teche Watershed Basin. The rivers flow through south-central Louisiana and drain approximately 1,558,370 acres (2,435 mi^2). Land use in the drainage area consists of 11.9% forest (+2.9%), 27.2% wetlands (-1.8%), 17.9% grasslands/pasture (-5.1%), 31.9% agriculture (+1.9%), and 11% developed (+1.0%) (Figure A. 1). Two long-term monitoring sites are present within the watershed basin, map number 21 on the Vermilion River at Perry, and map number 3 on Bayou Teche at Adeline (Figure 3). Data collection ranges from October 9, 1978 to September 29, 2020, and from October 10, 1978 to September 28, 2020 for the Vermilion and Teche sites, respectively.

3.2.5 Mississippi Watershed Basin

The Mississippi Watershed Basin drains 796,800,000 acres (1,245,000 mi^2) of land in 31 states and two Canadian provinces, the basin comprises 41% of the contiguous United States (USEPA, 2021). It includes three rivers within Louisiana: the Mississippi River, Atchafalaya River, and Bayou Lafourche. The Atchafalaya currently receives up to 30% of the Mississippi's flow, while nearly all of Bayou Lafourche's flow is received from the Mississippi. The Mississippi River is leveed on both sides from Baton Rouge to its output into coastal waters at Venice, and receives industrial and municipal discharges along this stretch. Land use in the drainage area consists of 22.9% forest (+0.9%), 3.4% wetlands (+0.4%), 36.3% grasslands/pasture (-3.7%), 31.9% agriculture (+2.9%), and 5.2% developed (-0.8%) (Figure A. 1). Five long-term monitoring sites are present within the

Mississippi Watershed Basin: map number 1 located at Morgan City along the Atchafalaya River, map number 2 located at Thibodaux along Bayou Lafourche, and map numbers 9, 10, and 11 located along the Mississippi River at Belle Chasse, Plaquemine, and St. Francisville, respectively (Figure 3). Data collection is from October 11, 1978 to September 28, 2020, February 4, 1991 to September 16, 2020, October 10, 1978 to September 22, 2020, October 9, 1978 to September 9, 2020, and November 13, 1978 to September 15, 2020 for the Atchafalaya, Lafourche, Mississippi-Belle Chasse, Mississippi-Plaquemine, and Mississippi-St. Francisville sites, respectively.

3.2.6 Pontchartrain Watershed Basin

The Tangipahoa, Tchefuncte, and Tickfaw Rivers flow into Lake Pontchartrain, an estuarine lake that is also influenced by waters from the Gulf of Mexico. The three rivers drain part of Mississippi and southeastern Louisiana. The Pontchartrain Watershed Basin is approximately 3,116,000 acres (4,869 mi^2). The land use of the drainage basin consists of 37.7% forest (+13.3%), 28.1% wetlands (-6.9%), 20% grasslands/pasture (-6.0%), 1.3% agriculture (+0.3%) and 12.9% developed (-1.1%). Four long-term monitoring sites are present within the Pontchartrain Watershed Basin: map number 7 located north of Metairie in the middle of Lake Pontchartrain, map number 17 located near Robert along the Tangipahoa River, map number 18 located near Madisonville along the Tchefuncte River, and map number 20 near Springville located along the Tickfaw River. Data collection is from January 13, 1986 to September 17, 2020 for Lake Pontchartrain, October 9, 1978 to September 17, 2020 for the Tangipahoa and Tchefuncte Rivers, and October 9, 1978 to September 1, 2020 for the Tickfaw River.

3.2.7 Pearl Watershed Basin

The Pearl Watershed Basin includes the Bogue Chitto and Pearl Rivers, draining 5,416,000 acres (8,463 mi^2) of land in Louisiana and Mississippi. The basin lies along the southeastern corner of Louisiana. The land use of the drainage basin consists of 53.5% forest (+8.5%), 18.3% wetlands (+3.3%), 18.9% grasslands/pasture (-12.1%), 1.9% agriculture (+0.9%), and 7.2% developed (+0.2%). Two long-term monitoring sites are present within the basin: Map number 4 located near Bush and map number 14 located near Slidell. Data collection ranges from October 9, 1978 to September 9, 2020, and from October 10, 1978 to September 22, 2020 for the Bogue Chitto and Pearl River sites, respectively.

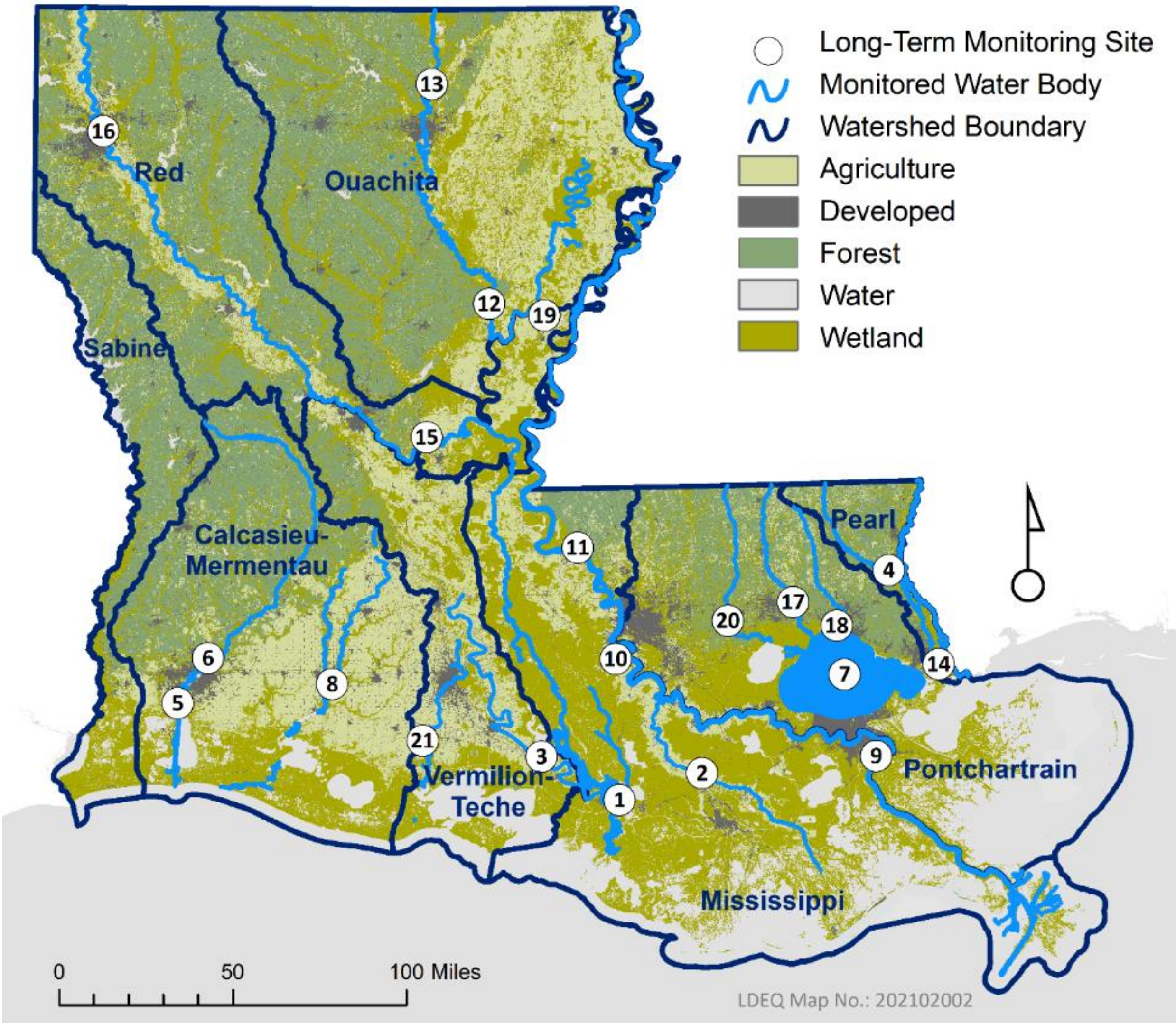


Figure 4. The long-term monitoring stations, general land use, and watersheds used in this report. Forested areas include rangeland, while agriculture areas include cropland and pasture. Wetlands include herbaceous and woody wetlands. Site names and map numbers are as follows: 1) Atchafalaya River-Morgan City; 2) Bayou Lafourche-Thibodaux; 3) Bayou Teche-Adeline; 4) Bogue Chitto River-Bush; 5) Calcasieu River-Burton Landing; 6) Calcasieu River-Moss Bluff; 7) Lake Pontchartrain -Metairie; 8) Mermentau River-Mermentau; 9) Mississippi River-Belle Chasse; 10) Mississippi River-Plaquemine; 11) Mississippi River-St. Francisville; 12) Ouachita River-Harrisonburg; 13) Ouachita River-Sterlington; 14) Pearl River-Slidell; 15) Red River-Marksville; 16) Red River-Shreveport; 17) Tangipahoa River -Robert; 18) Tchefuncte River-Madisonville; 19) Tensas River-Clayton; 20) Tickfaw River-Springville; and 21) Vermilion River-Perry.

3.3 Water Quality Methods

Samples were collected monthly from the 21 AWQMN sites in accordance with the *Standard Operating Procedures for Water Sample Collection, Preservation, Documentation and Shipping* as detailed in the *Quality Assurance Project Plan for the Ambient Water Quality Monitoring Network* (AWQM QAPP) (LDEQ, 2019b; LDEQ, 2019c). A single grab sample was collected from near the center of the main flow and at one-half the total depth of the stream if the stream was less than two meters deep, or at one-meter depth when the stream was over two meters deep. Samples were preserved with H_2SO_4 (pH < 2), kept on ice, and transferred to a laboratory for analysis (LDEQ, 2019b). Total Kjeldahl nitrogen (TKN) was measured using either USEPA Method 351.2, SM4500-NH_3-C, or SM4500-NH_3-D (AWWA, 1999; USEPA, 1993). Nitrate + nitrite (NOx) was measured using USEPA Method 353.2, SM4500-NO_3-E, SM4500-NO_3-F, or Easy 1-R NN (1-Reagent) method (AWWA and APHA, 2005, Chinchilla, 2008, USEPA, 1993). Total P (TP) was measured using USEPA Method 365.4, or SM4500-P-E (AWWA, 2005; USEPA, 1993). Total suspended solids (TSS) were measured using USEPA Method 160.2 or SM2540-D (AWWA, 1999) (USEPA, 1971).

The AWQM QAPP identifies lower reporting limits for NOx, TKN and TP as: 0.05 mg/L for NOx, 0.1 mg/L for TKN, and 0.05 mg/L for TP. Practical Quantitation Levels (PQL) are different from reporting limits, they are set by the laboratory running the analysis, and are defined as the lowest concentration level that can be reliably measured within the limits of the specified laboratory analytical method (Federal Advisory Committee on Detection and Quantitation Approaches and Uses in Clean Water Act Programs, 2007). The PQL depends on many factors, including the sample type, the analytical instruments, and the approved analytical procedure. Because the data collected in this study data back over a period of 42 years from 2020 to 1978, the PQLs recorded with these samples have varied over time. Therefore, solely for the purposes of determining whether a particular sample should be identified as censored (see Section 3.5), each sample result was compared to the PQL recorded with that sample. In samples where the PQL value was missing or erroneously set to zero, the Method Detection Limit (MDL) was used as the censor determinant, as the MDL is more stringent than the PQL with a 99% confidence of correctly identifying the presence of a substance if the concentration is above the MDL. The PQLs recorded for NOx ranged from 0.01 to 0.5 mg/L, the PQLs for TP ranged from 0.02 to 0.4 mg/L, the PQLs for TKN ranged from 0.10 to 0.60 mg/L, and the PQLs for TSS ranged from 0.01 to 20.0 mg/L.

3.4 Land Use Methods

Land use was calculated utilizing the USDA 2020 Crop Data Layer (CDL), Light Detection and Ranging Digital Elevation Model (LiDAR-DEM) and Hydrologic Unit Code (HUC)-8, 10, and 12 layers in ArcGIS 10.5.1 (ESRI, 2017; LOSCO, 2009; USDA-NASS, 2020). Consistent with the 2015 trend analysis, hydrologic units were selected and segmented upstream of each long-term monitoring site with the delineation of each segment and confirmed using LiDAR-DEM to determine drainage areas. The selected hydrologic units were then dissolved to create a single watershed above each site (Figure A. 2). A subset of the CDL was then created for each watershed, and areas for each land use class were calculated by aggregating the land use types from the CDL attribute tables and converting pixels to acreage (NASS USDA, 2020). The sum of all areas was then used to calculate the total drainage area, which was subsequently used to find the relative proportion (as a percentage) for each land use class.

The drainage areas for the following eleven rivers were used for the correlation analysis between land use and nutrients: Bayou Teche, and the Calcasieu, Mermentau, Mississippi, Ouachita, Pearl, Red, Tangipahoa, Tchefuncte, Tensas, and Tickfaw Rivers. Bayou Lafourche and the Atchafalaya River were not included, as they receive the majority of their input from other rivers included in the analysis (e.g., the Atchafalaya River receives water from the Mississippi, Red, and Ouachita Rivers). Similarly, the Bogue Chitto River was not included as it is contained within the Pearl River drainage area. In order to achieve a more independent analysis, the Tickfaw, Tchefuncte, and Tangipahoa Rivers were included individually, as opposed to grouped together within the Pontchartrain Watershed Basin, as Lake Pontchartrain receives some input from the Gulf of Mexico, which would mean potentially including input from the Pearl and Mississippi Rivers. The headwaters of Bayou Teche and the Vermilion River overlap; therefore, these two rivers were combined for this analysis, as it is nearly impossible to tease out the exact land use for each river. Appendix A contains a map illustrating each river's drainage area and lists its land use in detail (Figure A. 2, Table A. 2-A. 4). TSS were also included in the correlation analysis only to determine any influence between TSS and nutrients; TSS trends were not determined as part of this analysis.

3.5 Statistical Analysis

All statistical analyses were performed using R version 4.0.3, the R Commander GUI, and RStudio version 1.3.959 (Fox & Bouchet-Valat, 2020; R Development Core Team, 2020; RStudio, 2021) at an $\alpha = 0.05$. Due to the nature of environmental data, the data were not assumed to be normally distributed, and nonparametric methods were used for analysis, including: Kaplan-Meier descriptive statistics, Kendall's tau correlation analyses, and censored Seasonal Kendall trend analyses. In order to more accurately reflect the data, nutrient concentration data that was reported as below its specified detection limit was included in the analysis as censored data, and a Boolean (TRUE/FALSE) indicator column was added to the dataset using methods described by PracticalStats, LLC in their *Nondetects and Data Analysis* lecture titled "Storing Nondetects in Databases"(Helsel, 2020b). In this method, any nutrient concentration value that fell below the detection limit (PQL or MDL) for that parameter was identified as left-censored and the censor indicator value for that sample was coded as TRUE. The R software statistics packages NADA and NADA2, which are designed to analyze left-censored environmental data, were used to obtain the descriptive statistics and trend analyses in this report, and the Kendall's tau correlation test in R Commander was used to analyze land use correlations (Fox & Bouchet-Valat, 2020; Helsel, 2020a; Lee, 2020; R Development Core Team, 2020).

Table 2. Aggregate Overall Nutrient Long-Term Trend Results by Site from Oct. 1, 1978-Sept. 30, 2020.

	TKN		NOx		TP	
Trend	**Count**	**%**	**Count**	**%**	**Count**	**%**
Increasing	0	0%	1	5%	2	10%
Decreasing	20	95%	10	48%	11	52%
Not significant	1	5%	10	48%	8	38%

4. Results and Discussion

4.1. Nutrient Trends

Out of a total of 63 possible trends (3 nutrient concentrations at each of the 21 long-term monitoring sites), the results of the overall censored Seasonal Kendall test found that 41 (65%) nutrient concentrations were decreasing significantly over time, 3 (5%) were increasing, and 19 (30%) had no significant change ($p > 0.05$) (Table 2). For TKN, concentrations were not increasing significantly at any site overall, concentrations were decreasing significantly at 20 sites (95%), and there was no significant change at one site (5%). For NOx, concentrations were increasing significantly at one site (5%), decreasing significantly at 10 sites (48%), and there was no significant change at ten sites (48%). For TP, concentrations were increasing significantly at 2 sites (10%), decreasing significantly at 11 sites (52%), and there was no significant change at 8 sites (38%) (Table 2). Appendix B provides a table detailing the results of the censored Seasonal Kendall trend analysis for each of the 21 sites within each season individually. Aggregates of the seasonal trends from the censored Seasonal Kendall test from across all long-term monitoring stations are summarized in Table 3 (below). Seasonal trend results show that TP is only increasing at one site (5%) in spring, and NOx and TP are increasing at one site each (5%) in summer. TKN is decreasing at the greatest number of sites, 18 (86%) during the summer, and is not increasing at any site during any season, which is consistent with the overall trend. The spring decreases in NOx at 14 sites (67%) appear to be driving its overall trend, with increases at 2 sites (10%) each in fall and winter. TP is increasing at four sites (19%) during the fall, and three sites (14%) during the winter, which is slightly more than the two sites (10%) reflected in the overall trend. Median values of TKN ranged from 0.42 to 1.08 mg/L, median values of NOx ranged from 0.02 to 1.35 mg/L, and median values of TP ranged from 0.07 to 0.38 mg/L. Appendix C lists the annual median of TKN, NOx, and TP for each site.

Table 3. Aggregate Seasonal Nutrient Long-Term Trend Results by Site from Oct. 1, 1978-Sept. 30, 2020.

Season	Trend	TKN		NOx		TP	
		Count	%	Count	%	Count	%
Spring	Increasing	0	0%	0	0%	1	5%
	Decreasing	16	76%	14	67%	9	43%
	Not significant	5	24%	7	33%	11	52%
Summer	Increasing	0	0%	1	5%	1	5%
	Decreasing	18	86%	4	19%	9	43%
	Not significant	3	14%	16	76%	11	52%
Fall	Increasing	0	0%	2	10%	4	19%
	Decreasing	9	43%	4	19%	5	24%
	Not significant	12	57%	15	71%	12	57%
Winter	Increasing	0	0%	2	10%	3	14%
	Decreasing	17	81%	7	33%	10	48%
	Not significant	4	19%	12	57%	8	38%

Table 4. Minimum, Kaplan-Meier median, maximum, and overall censored Kendall long-term trend results for all nutrients and sites. Decreasing trends (↓) are highlighted in blue, increasing (↑) in red, and insignificant (NS) in gray.

		Total Kjeldahl Nitrogen (TKN)				Nitrate-Nitrite (NOx)				Total Phosphorous (TP)			
Site	**Map No.**	**Min**	**Median**	**Max**	**Trend**	**Min**	**Median**	**Max**	**Trend**	**Min**	**Median**	**Max**	**Trend**
All Sites		0.01 [a]	0.72	3.00		0.01 [a]	0.22	3.00		0.01 [a]	0.13	1.00	
Atchafalaya	1	0.02 [a]	0.66	1.88	↓	0.01 [a]	0.84	2.38	↓	0.02 [a]	0.17	0.64	↓
Lafourche	2	0.10	0.56	2.80	NS	0.05	1.00	2.54	NS	0.01 [a]	0.15	0.88	NS
Teche	3	0.10	1.02	2.84	↓	0.01 [a]	0.27	2.38	NS	0.03 [a]	0.31	0.90	↓
Bogue Chitto	4	0.02 [a]	0.42	3.00	↓	0.01 [a]	0.28	1.84	↑	0.01 [a]	0.07	0.62	↑
Calcasieu–BL	5	0.02 [a]	0.79	2.82	↓	0.01 [a]	0.13	0.74	↓	0.01 [a]	0.10	0.82	↓
Calcasieu–MB	6	0.02 [a]	0.68	2.72	↓	0.01 [a]	0.06	1.13	↓	0.01 [a]	0.09	0.85	NS
Pontchartrain	7	0.05 [a]	0.46	2.70	↓	0.01 [a]	0.02	1.30	NS	0.01 [a]	0.07	0.73	↑
Mermentau	8	0.10	1.08	2.99	↓	0.01 [a]	0.17	1.13	↓	0.01 [a]	0.24	0.97	↓
Mississippi–BC	9	0.01 [a]	0.68	3.00	↓	0.02 [a]	1.35	2.98	NS	0.01 [a]	0.19	0.88	↓
Mississippi–Pla	10	0.03 [a]	0.76	2.90	↓	0.05	1.30	3.00	NS	0.02 [a]	0.18	0.94	↓
Mississippi–SF	11	0.02 [a]	0.74	2.73	↓	0.02 [a]	1.30	2.94	NS	0.01 [a]	0.19	0.80	↓
Ouachita–H	12	0.02 [a]	0.71	2.71	↓	0.01 [a]	0.14	2.10	↓	0.01 [a]	0.13	0.59	NS
Ouachita–S	13	0.09 [a]	0.68	2.60	↓	0.01 [a]	0.11	2.35	↓	0.01 [a]	0.09	0.76	NS
Pearl	14	0.05 [a]	0.65	2.68	↓	0.01 [a]	0.15	1.80	NS	0.01 [a]	0.10	0.38	NS
Red–M	15	0.06 [a]	0.77	2.91	↓	0.01 [a]	0.16	0.90	NS	0.01 [a]	0.14	0.95	↓
Red–S	16	0.10	0.84	2.33	↓	0.01 [a]	0.09	1.12	↓	0.01 [a]	0.13	0.80	↓
Tangipahoa	17	0.02 [a]	0.44	2.20	↓	0.02 [a]	0.27	0.82	↓	0.01 [a]	0.10	0.72	↓
Tchefuncte	18	0.02 [a]	0.71	2.60	↓	0.01 [a]	0.11	0.62	NS	0.01 [a]	0.10	0.80	NS
Tensas	19	0.02 [a]	0.93	2.70	↓	0.01 [a]	0.26	2.70	NS	0.02 [a]	0.26	0.97	NS
Tickfaw	20	0.01 [a]	0.55	2.40	↓	0.01 [a]	0.20	0.82	↓	0.01 [a]	0.09	0.78	NS
Vermilion	21	0.10	1.05	2.84	↓	0.01 [a]	0.40	1.92	↓	0.05	0.38	1.00	↓

[a] Below lower reporting limit. Current lower reporting limits are 0.1 mg/L for TKN, and 0.05 mg/L for NOx and TP.

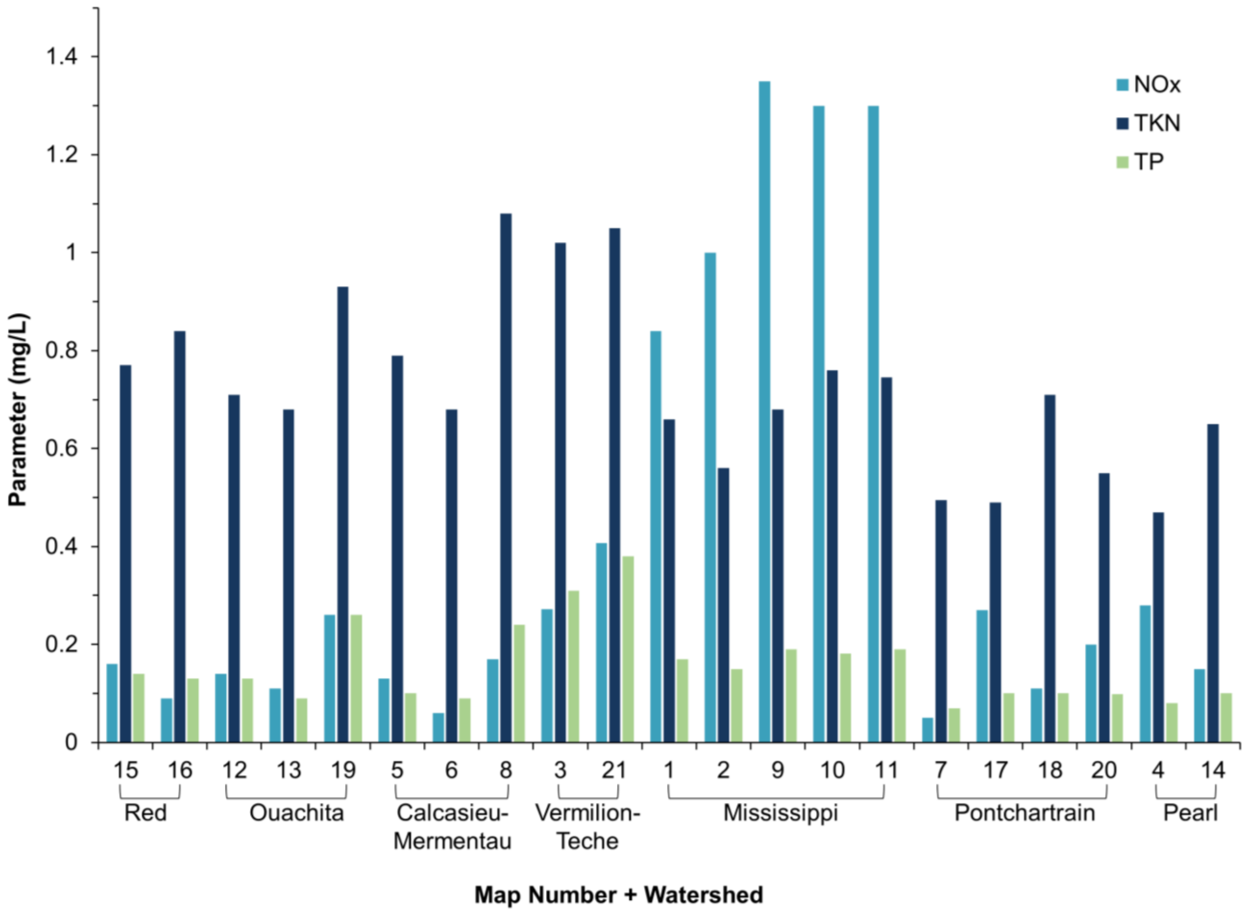


Figure 5. Overall median values at all sites from Oct 1, 1978-Sept. 30, 2020 for concentrations (mg/L) of nitrate-nitrite (NOx), total Kjeldahl nitrogen (TKN), and total phosphorus (TP).

4.1.1 Trends for Red Watershed Basin

TKN values in the Red Watershed ranged from 0.06 to 2.91 mg/L at the Marksville site, and 0.10 to 2.33 mg/L at the Shreveport site (Table 4). NOx values for Marksville ranged from 0.01 to 0.90 mg/L and 0.01 to 1.12 mg/L for Shreveport. TP values for Marksville ranged from 0.01 to 0.95 mg/L and 0.01 to 0.80 mg/L for Shreveport. Overall, the Red River ranks near the middle of the 21 long-term monitoring sites for all nutrients (Figure 6). TKN, NOx, and TP concentrations showed overall significant decreasing trends for the Red River at both sites with the sole exception of NOx at the Marksville site, which had no significant trend (Table 4). Seasonally, TKN was decreasing significantly in every season at Marksville, and was decreasing significantly at every season except winter in Shreveport, where the results were not significant. NOx was decreasing significantly in spring at Marksville and in all seasons at Shreveport; no other seasonal trends for NOx at Marksville were significant. TP was decreasing significantly over every season for both locations (Table B. 1).

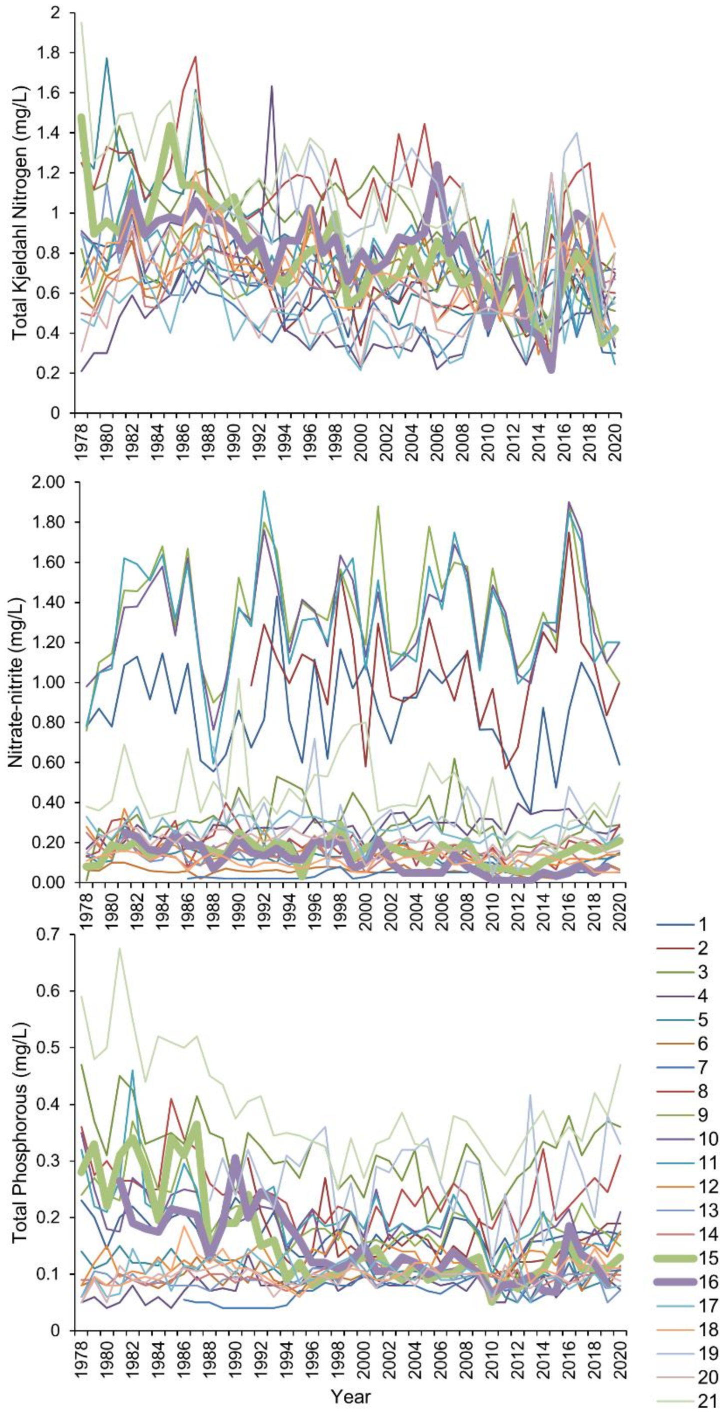


Figure 6. Yearly median total Kjeldahl nitrogen (A), nitrate-nitrite (B), and total phosphorus (C) values from Oct. 1, 1978 through Sept. 30, 2020. The long-term monitoring station at the Red River-Marksville (#15) is highlighted in green and at the Red River-Shreveport (#16) is highlighted in purple.

4.1.2 Trends for Ouachita Watershed Basin

TKN values ranged from 0.02 to 2.71 mg/L, 0.09 to 2.60 mg/L, and 0.02 to 2.70 mg/L for the Harrisonburg, Sterlington, and Tensas sites, respectively. NOx values ranged from 0.01 to 2.10 mg/L, 0.01 to 2.35 mg/L, and 0.01 to 2.70 mg/L for these sites, respectively. TP values ranged from 0.01 to 0.59 mg/L, 0.01 to 0.76 mg/L, and 0.02 to 0.97 mg/L for these sites, respectively. Overall, concentrations of both N forms showed a significant decreasing trend at both Ouachita sites, and while TKN was decreasing significantly at the Tensas site, there was not a significant trend for NOx. There was no significant trend for TP at any of the three sites (Table 4, Figure 7). Seasonally, there is a significant decreasing trend for TKN during the spring and summer at Harrisonburg and in the summer and fall at Sterlington, the rest are not significant. For NOx, concentrations are decreasing significantly at both Ouachita sites except for winter at Harrisonburg, at which there is no trend. For TP, seasonal trends at the Ouachita sites are not significant except for summer at Sterlington where the TP concentration is significantly decreasing. At the Tensas site, TKN is decreasing significantly in every season except fall; there are no significant seasonal trends for NOx; and TP is significantly increasing in fall and winter; all other seasonal trends at this site are not significant (Table B. 1). Looking at annual median nutrient concentrations, TP and TKN values at the Tensas site are ranked higher compared to other sites (Appendix C).

4.1.3 Trends for Calcasieu-Mermentau Watershed Basin

TKN values for the Calcasieu River-Burton Landing, Moss Bluff, and Mermentau sites ranged from 0.02 to 2.82 mg/L, 0.02 to 2.72 mg/L, and 0.10 to 2.99 mg/L. NOx values ranged from 0.01 to 0.74 mg/L at Burton Landing, and 0.01 to 1.13 mg/L at both Moss Bluff and Mermentau. TP values ranged from 0.01 to 0.82 mg/L, 0.01 to 0.85 mg/L, and 0.01 to 0.97 mg/L. Overall nutrient trends for the Calcasieu and Mermentau Rivers are significantly decreasing except for the Moss Bluff site for which there was no significant trend for TP (Table 4, Figure 8). The most marked decrease in TKN appears to be at the Burton Landing site. TP and NOx show a small decrease in concentration over time. The Mermentau has a higher TKN, NOx, and TP concentration than either Calcasieu site, while the more southerly Burton Landing site has a higher TKN, NOx, and TP concentration than the more northern Moss Bluff site. In comparison to the other sites, the Mermentau River ranks near the top for TP and TKN and near the middle for NOx, excluding the Mississippi River. In the Calcasieu River, Moss Bluff ranks near the middle for TKN and the bottom for NOx and TP, while the Burton Landing site ranks in the top third for TKN and the bottom third for NOx and TP (Appendix C).

4.1.4 Trends for Vermilion-Teche Watershed Basin

TKN values for Bayou Teche and Vermilion ranged from 0.10 to 2.84 mg/L at both sites. NOx values ranged from 0.01 to 2.38 mg/L, and 0.01 to 1.92 mg/L, respectively. TP values ranged from 0.03 to 0.90 mg/L and 0.05 to 1.0 mg/L for Bayou Teche and Vermilion (Table 4, Figure 9). For Bayou Teche, overall long-term nutrient concentration trends were significantly decreasing for TKN and TP, and not significant for NOx. Overall, long-term trends for TKN, NOx and TP were all significantly decreasing at the Vermilion site.

Seasonally, TKN was significantly decreasing for all seasons at both the Teche and Vermilion sites. For NOx, seasonal trends were not significant for all seasons at Teche, and was only significant (decreasing) for Vermilion in the spring. For TP, seasonal trends were significantly decreasing for summer and winter, and not significant for spring and fall at the Teche site, and were significantly decreasing for all seasons at the Vermilion site (Table 3). Both the Vermilion and Teche sites are in the top three highest sites for median TKN and TP values, and in the top third of sites for NOx (Appendix C; Figure 9)

4.1.5 Trends for Mississippi Watershed Basin

TKN values for the Atchafalaya River, Bayou Lafourche, Mississippi River – Belle Chasse, Mississippi River – Plaquemine, and Mississippi River—St. Francisville ranged from 0.02 to 1.88 mg/L, 0.10 to 2.80 mg/L, 0.01 to 3.0 mg/L, 0.03 to 2.90 mg/L, and 0.02 to 2.73 mg/L, respectively. NOx values ranged from 0.01 to 2.38 mg/L, 0.05 to 2.54 mg/L, 0.02 to 2.98 mg/L, 0.05 to 3.0 mg/L, and 0.02 to 2.94 mg/L for the Atchafalaya, Lafourche, Belle Chasse, Plaquemine, and St. Francisville, respectively. TP values ranged from 0.02 to 0.64 mg/L, 0.01 to 0.88 mg/L, 0.01 to 0.88 mg/L, 0.02 to 0.94 mg/L, and 0.01 to 0.80 mg/L for the sites, respectively (Table 4, Figure 10). The TKN and TP overall long-term trends are decreasing significantly for all sites except Lafourche, which is not significant for all three nutrient trends. The overall NOx trends are not significant at all sites except for the Atchafalaya site, which is decreasing significantly. The seasonal trends for these five sites are varied. There were significant seasonal decreases in all three nutrients during the spring at the Atchafalaya and all Mississippi River sites, and non-significant trends for all three nutrients at the Lafourche site in spring. The one notable difference between overall and seasonal trends is that at the Lafourche site the seasonal trend for NOx is significantly increasing during the fall, while the overall trend was not significant (Table 3). The median NOx concentrations for the five Mississippi basin sites continued to rank the top five highest in the state, with the three Mississippi River sites the top three. The concentrations ranked near the middle for TKN, and in the top half for TP (Figure 10).

4.1.6 Trends for Pontchartrain Watershed Basin

TKN values for the Lake Pontchartrain, Tangipahoa River, Tchefuncte River, and Tickfaw River sites ranged from 0.05 to 2.70 mg/L, 0.02 to 2.20 mg/L, 0.02 to 2.60 mg/L, and 0.01 to 2.40 mg/L, respectively. NOx values ranged from 0.01 to 1.30 mg/L, 0.02 to 0.82 mg/L, 0.01 to 0.62 mg/L, and 0.01 to 0.82 mg/L for the sites, respectively. TP values ranged from 0.01 to 0.73 mg/L, 0.01 to 0.72 mg/L, 0.01 to 0.80 mg/L, and 0.01 to 0.78 mg/L for the sites (Table 4, Figure 11). The overall long-term trend for TKN is significantly decreasing at all sites. The overall trend for NOx is not significant at Lake Pontchartrain or Tchefuncte, but is significantly decreasing at the Tangipahoa and Tickfaw sites. The overall long-term trend for TP is significantly increasing at Lake Pontchartrain, significantly decreasing at Tangipahoa, and not significant at the Tchefuncte and Tickfaw sites. The seasonal TKN trend for Lake Pontchartrain is decreasing in winter, and not significant for all other seasons; for the remaining three sites, the trend for TKN is decreasing significantly in the spring, summer, and winter, and not significant in the fall. There were no significant seasonal trends for NOx at the Lake Pontchartrain site; and NOx was either decreasing significantly or not significant at the Tangipahoa, Tchefuncte, and Tickfaw sites except in winter at Tchefuncte, which was increasing significantly. The seasonal trends for TP were increasing significantly for all seasons at the Lake Pontchartrain site; decreasing significantly for Tangipahoa in the spring and winter, increasing significantly in the fall at Tchefuncte, and not significant for all seasons at Tickfaw; all other seasonal trends at these were not significant (Table B. 1). Median TKN, NOx, and TP values are all ranked in the bottom half for the Pontchartrain sites. Despite the trends showing significant increases in TP over time for Lake Pontchartrain, the median TP value for Lake Pontchartrain is tied for the lowest of the 21 sites (Table 4).

4.1.7 Trends for Pearl Watershed Basin

TKN values for the Bogue Chitto and Pearl River sites ranged from 0.02 to 3.0 mg/L, and 0.05 to 2.68 mg/L, respectively. NOx values ranged from 0.01 to 1.84 mg/L and 0.01 to 1.80 mg/L for the sites, respectively. TP values ranged from 0.01 to 0.62 mg/L and 0.01 to 0.38 mg/L for the sites, respectively (Table 4, Figure 12). The overall long-term TKN trend was decreasing significantly at both the Bogue Chitto and Pearl sites. The overall long-term trends for both NOx and TP were increasing significantly at the Bogue Chitto site and not significant at the Pearl site. The long-term seasonal trends for TKN were decreasing significantly for both the Bogue Chitto and Pearl sites during the summer and winter, no other seasonal trends for TKN were significant at either site. For NOx, the seasonal trends were increasing significantly for summer, fall and winter at the Bogue Chitto site, and not significant for spring at Bogue Chitto and for all seasons at the Pearl site. For TP, the seasonal trends were increasing significantly at the Bogue Chitto site during fall and winter, and not significant for spring and summer; no seasonal trends were significant for TP at the Pearl site (Table B. 1). Median TKN is ranked the lowest of all 21 long-term sites for the Bogue Chitto and ranked in the bottom third for the Pearl. Median NOx is in the top third for the Bogue Chitto and near the middle for the Pearl. Median TP is tied for lowest of 21 for the Bogue Chitto and in the bottom third for the Pearl.

4.1.8 Discussion of Trends

For the most part, nutrient concentrations of nitrogen and phosphorus in major water bodies of Louisiana are generally decreasing. In the Lake Pontchartrain and Bogue Chitto sites, where trends show overall increases in TP, or NOx and TP, respectively, the overall nutrient concentrations are ranked at the mid-to-low end among long-term monitoring sites and are still generally low, still further evaluation in these areas may be warranted. A number of regulations have been passed over the last fifty years that have helped drive the reduction in nutrient concentrations and overall water quality improvements in Louisiana. The biggest driver of these improvements is the federal Clean Water Act (CWA), passed in 1972, that allows implementation of both nonpoint source and point source programs to protect and restore water quality. Though long-term nutrient data availability begins in 1978, the reduction of nutrients in Louisiana waters can still be observed, especially for TKN and TP (Figure 7 to Figure 12, and Appendix C). The CWA

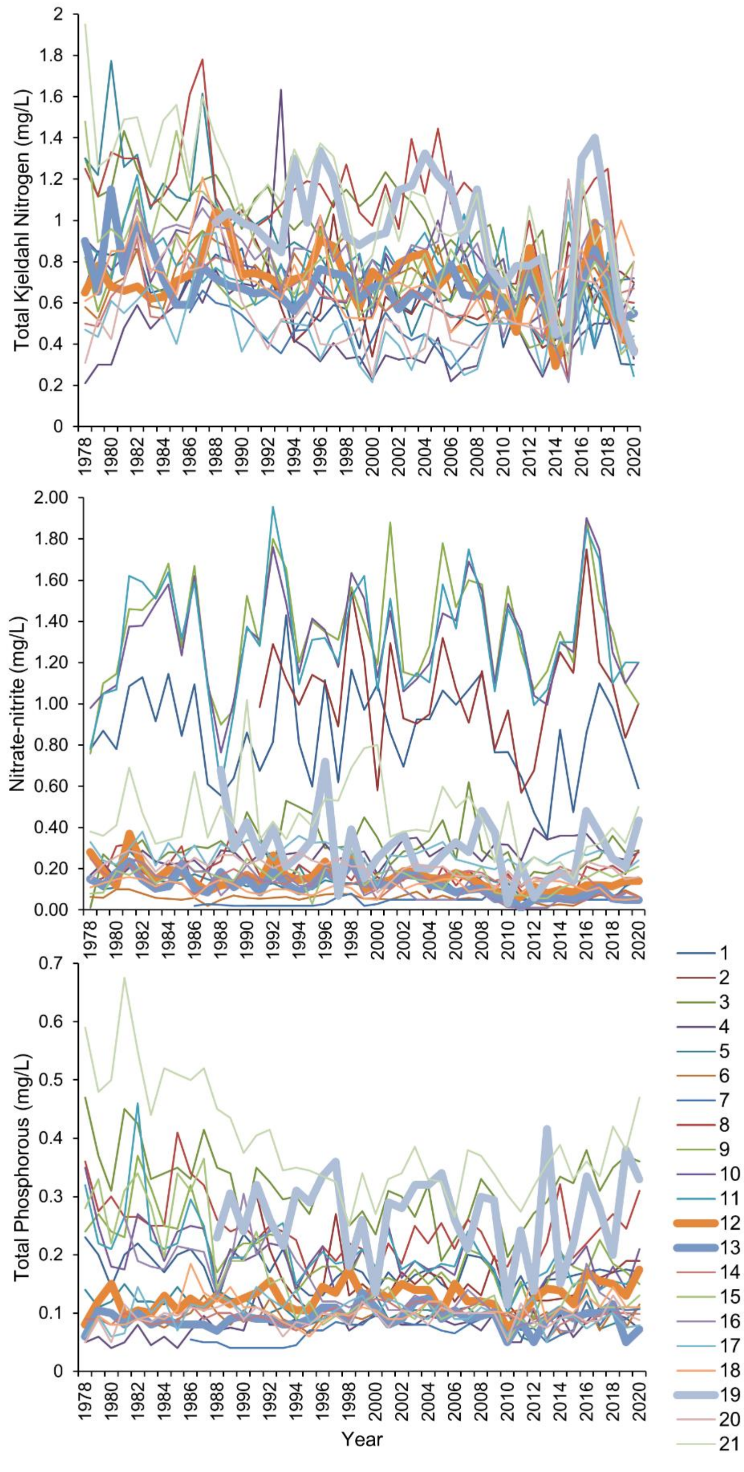


Figure 7. Yearly median values of total Kjeldahl nitrogen (A), nitrate-nitrite nitrogen (B), and total phosphorous (C) from Oct. 1, 1978 through Sept. 30, 2020. Ouachita River-Harrisonburg (#12) is highlighted in orange, Ouachita River-Sterlington (#13) is in light blue, and Tensas River (#19) is in dark blue.

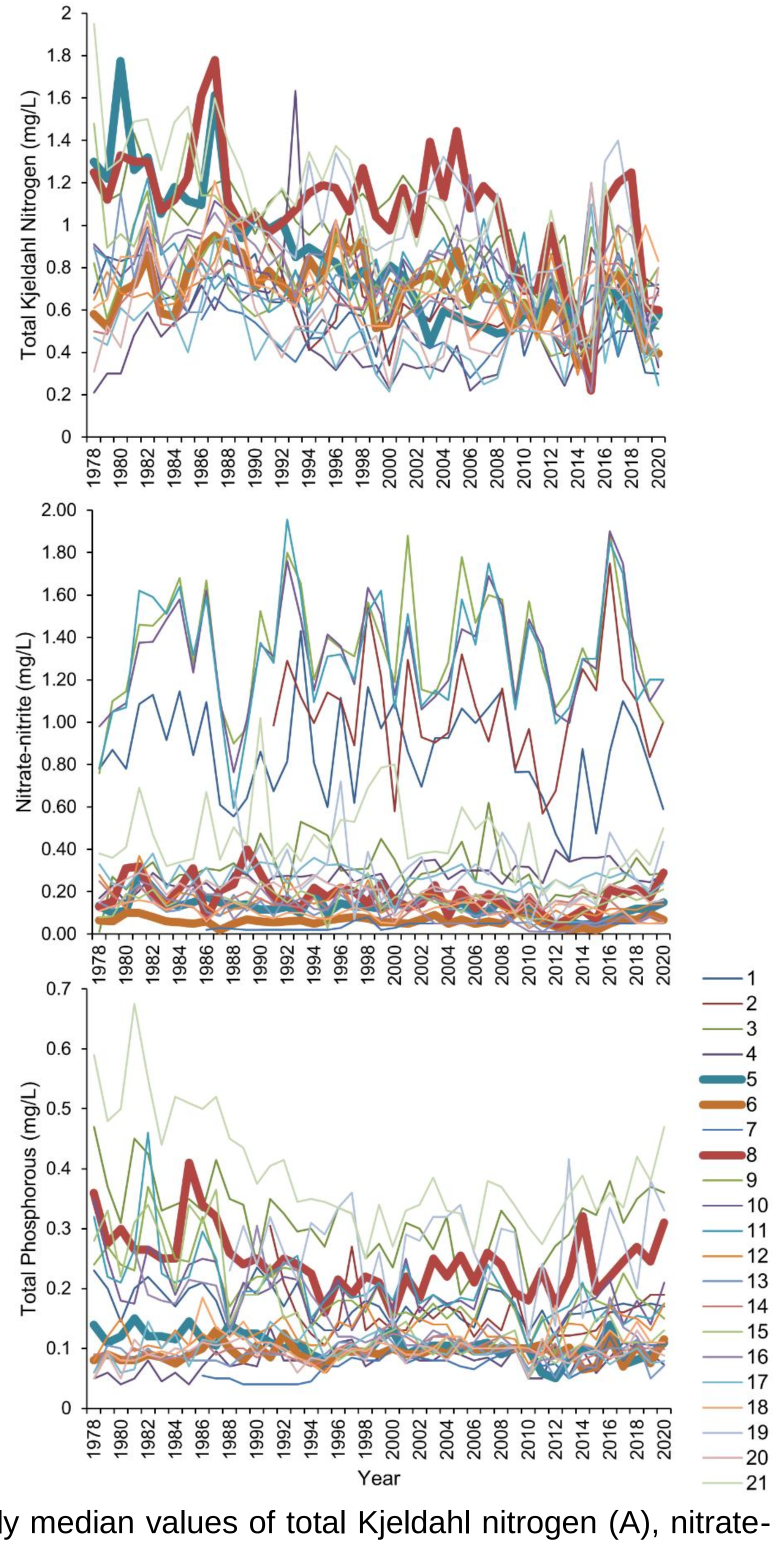


Figure 8. Yearly median values of total Kjeldahl nitrogen (A), nitrate-nitrite nitrogen (B), and total phosphorous (C) from Oct. 1, 1978 through Sept. 30, 2020. Calcasieu River-Burton Landing (#5) is highlighted in blue, Calcasieu River – Moss Bluff (#6) is in orange, and Mermentau River (#8) is in red.

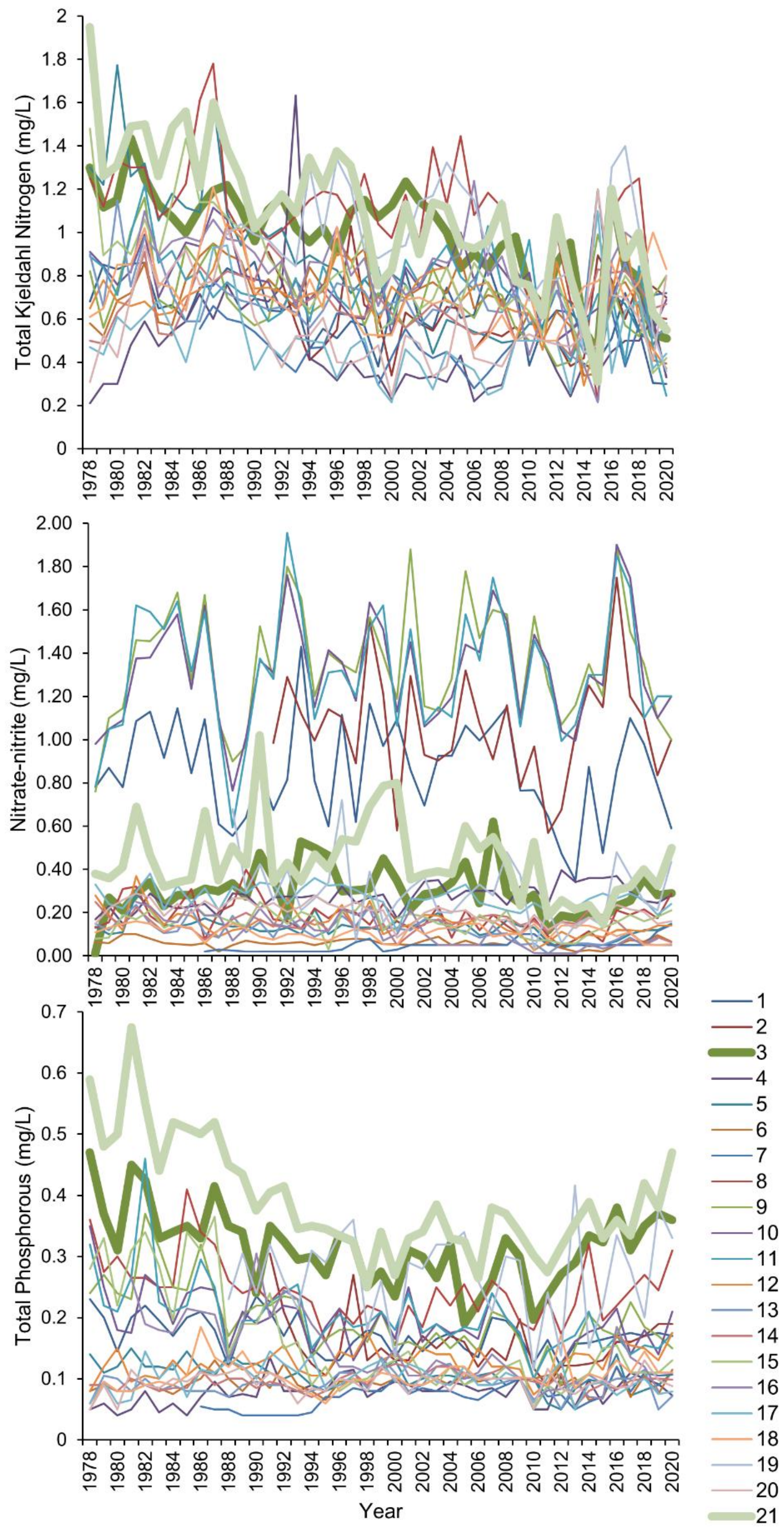


Figure 9. Yearly median values of total Kjeldahl nitrogen (A), nitrate-nitrite nitrogen (B), and total phosphorous (C) from Oct. 1, 1978 through Sept. 30, 2020. Bayou Teche (#3) is highlighted in dark green and Vermilion River (#21) is in light green.

requires point source dischargers to meet specific effluent limits through the National Pollutant Discharge Elimination System (NPDES). Since 1996, Louisiana has been delegated by the USEPA to administer the NPDES under their own program, the Louisiana Pollutant Discharge Elimination System (LPDES). All point source pollutant dischargers are required to obtain a permit from LDEQ under the LPDES program under either Industrial or Municipal & General Water Permits depending on facility type (LDEQ, 2021c).

The CWA also created an avenue to provide funding to assist in the building of publicly owned treatment works (POTWs). It requires POTWs to reach their effluent limits based on secondary treatment of wastewater. Secondary treatment leads to a substantial reduction in the amount of organic matter in wastewater, and subsequently of nutrients, since two major components of organic matter are N and P. Requiring point source dischargers and POTWs to treat their effluents prior to discharging into waterbodies has resulted in a reduction in the load of many pollutants, including nutrients (USEPA, 2000). However, the USEPA *National Water Quality Inventory: Report to Congress* continues to list municipal discharges and sewage as a probable source for the top causes of pollution associated with impairment for assessed bays and estuaries by square miles (USEPA, 2009; USEPA, 2017). As POTWs age, facilities require upgrades to continue proper treatment. Processing wastewater beyond secondary treatment is needed to provide further reduction of nutrients (USEPA, 2009).

Nonpoint sources encompass the other main source of nutrients, including agriculture, urban runoff/stormwater, and atmospheric deposition. In the national water quality report to Congress, these three sources are consistently listed among the top ten sources of impairment for water bodies (USEPA, 2009, 2017). In 1987, amendments to the CWA established Section 319, which has provided grant money for states to develop and implement nonpoint source management programs since 1990 ("Section 319 Nonpoint Source Management Program," 2010). As management programs have been introduced and conservation practices implemented, the nutrient load from fertilizers has decreased.

LDEQ's *Nonpoint Source Annual Report* estimated that in 2019, program efforts resulted in an estimated annual reduction of 23,809 pounds of N and 4,646 pounds of P from nonpoint sources to Louisiana water bodies. In 2019, CWA Section 319 funds were utilized to conduct 19 public education and outreach events, and to complete reconnaissance surveys, monitor water quality, continue managing existing watershed implementation plans, and develop three new watershed implementation plans (LDEQ, 2019a). Collaboratively, these programs have identified the Lake Pontchartrain Basin, the Mermentau River Basin, the Vermilion-Teche River Basin, the Mississippi River Basin, the Ouachita River Basin, and the Terrebonne Basin as priority watersheds for nutrient reduction and management strategy implementation (LNRMS Team, 2020).

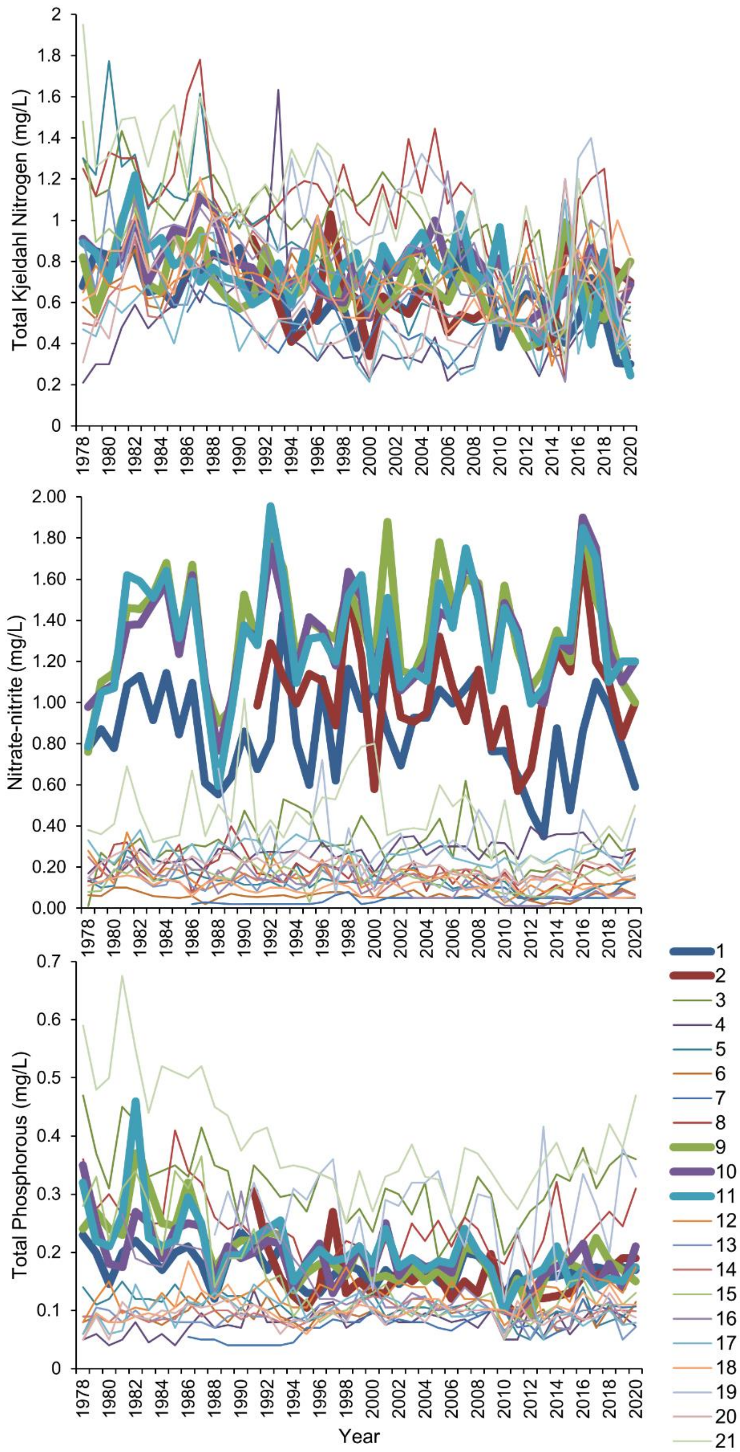


Figure 10. Yearly median values of total Kjeldahl nitrogen (A), nitrate-nitrite nitrogen (B), and total phosphorous (C) from Oct. 1, 1978 through Sept. 30, 2020. Atchafalaya River (#1) is highlighted in dark blue, Bayou Lafourche (#2) is in red, Mississippi River-Belle Chasse (#9) is in green, Mississippi River-Plaquemine (#10) is in purple, and Mississippi River-St. Francisville (#11) is in teal.

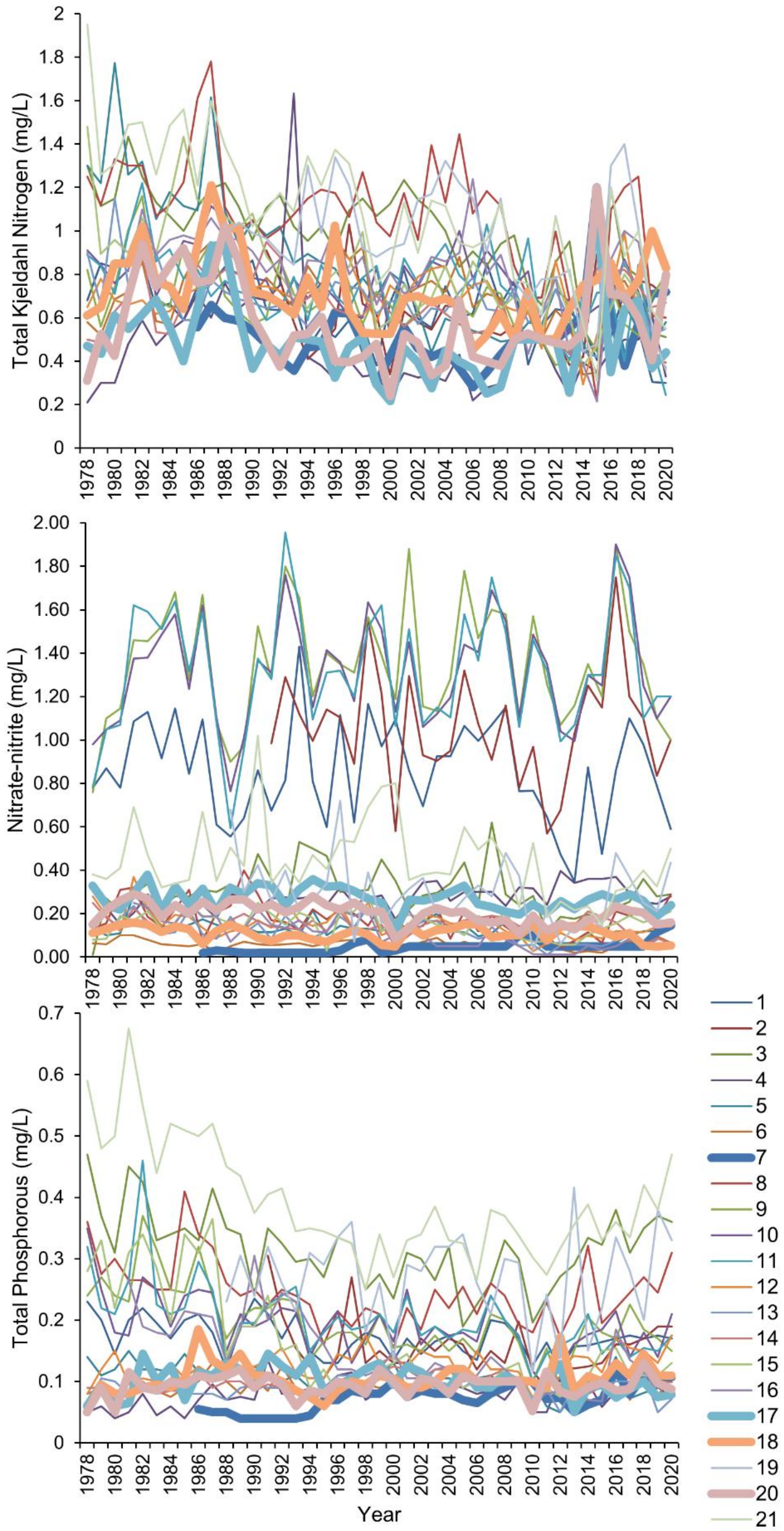


Figure 11. Yearly median values of total Kjeldahl nitrogen (A), nitrate-nitrite nitrogen (B), and total phosphorous (C) from Oct. 1, 1978 through Sept. 30, 2020. Lake Pontchartrain (#7) is highlighted in dark blue, Tangipahoa River (#17) in light blue, Tchefuncte River (#18) in orange, and Tickfaw River (#20) in light red.

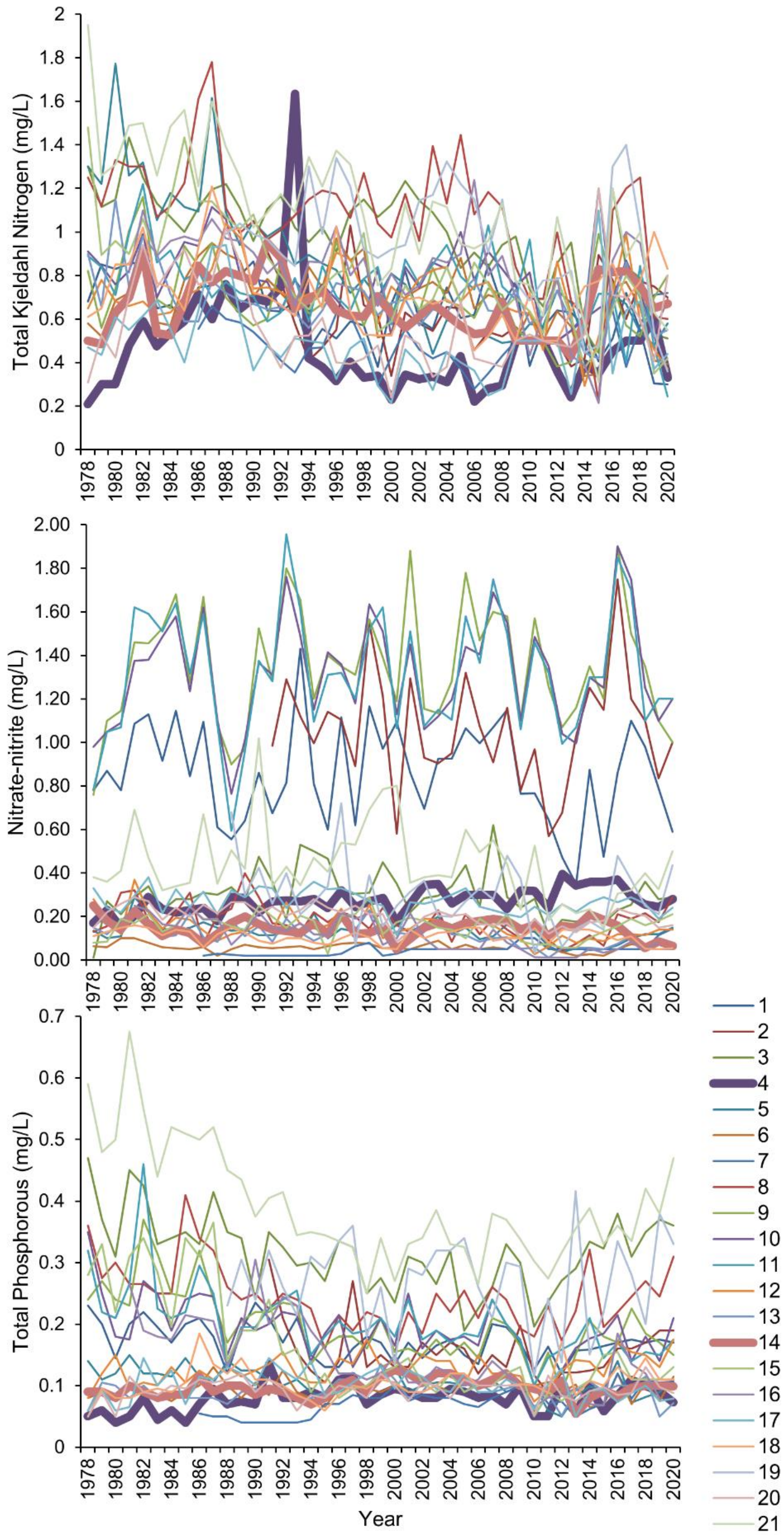


Figure 12. Yearly median values of total Kjeldahl nitrogen (A), nitrate-nitrite nitrogen (B), and total phosphorous (C) from Oct. 1, 1978 through Sept. 30, 2020. Bogue Chitto River (#4) is highlighted in purple and Pearl River (#14) in pink.

4.2 Land Use Correlation

The results of the nonparametric Kendall’s tau correlation analyses are found in Table 5 (below). Kaplan-Meier median concentrations (from 2000-2020, Appendix C) for each nutrient were tested for correlation with TSS and with each aggregate land use category. Significant positive Kendall’s tau correlations were found between both TKN and TSS and TP and TSS, and also between TKN and agriculture and TP and agriculture, supporting that nutrient concentrations increase as agricultural land use increases and as the level of TSS concentrations increase. Significant negative Kendall’s tau values for the correlation between TKN and forest cover and TP and forest cover support that as forest cover increases, nutrient concentrations decrease. Agriculture is often associated with higher amounts of soil erosion (Capel et al., 2018; Howarth et al., 2002), thus the strong positive correlation between TP, TKN, TSS, and agriculture is not surprising. Similarly, forest cover is often associated with reduced erosion; multiple watershed studies show runoff from forested watersheds carries less sediment and tends to conserve nutrients as compared to cultivated watersheds (Howarth et al., 2002; Mello et al., 2018).

Briefly, recall the drainage areas used for the land use analysis included only the area draining into the southernmost monitoring site located on each river, (see Sections 3.2 and 3.4 for a more detailed description). The drainage areas (Figure A. 2) for the Mermentau, Vermilion-Teche, Tensas, Mississippi, and Red River sites have the highest occurrence of agriculture, while the drainage areas of the Ouachita, Calcasieu, Pearl, Tchefuncte, Tickfaw, and Tangipahoa sites have the highest occurrence of forest. Grasslands make up a large portion of the Red, Mississippi, and Tangipahoa drainage areas. The percentage of developed area for all watersheds is small. Wetlands have the smallest representation in the Red and Mississippi drainage areas (Figure 14**)**.

The most recent USEPA report on “The Quality of Our Nation’s Waters” identified the top three causes of pollution linked to the impaired rivers and streams studied across the country as pathogens, sediment, and nutrients including phosphorus and nitrogen. Agricultural activities have been identified as one of the top three sources of these water body impairments, and are linked to high nutrient values, as well as herbicides, pesticides and fecal bacteria pollution (USEPA, 2017). The LDEQ 2020 Integrated Report identified Agriculture as the third largest suspected source of impairment of Louisiana rivers and streams by size (2,644 river miles), after Source Unknown (4,961 miles) and Natural Sources (3,209 miles) (LDEQ, 2020). The correlation analysis between nutrients and land use presented in this report supports the linkage between agriculture and nutrients, as higher concentrations of TP and TKN are significantly correlated to the presence of agriculture within the state.

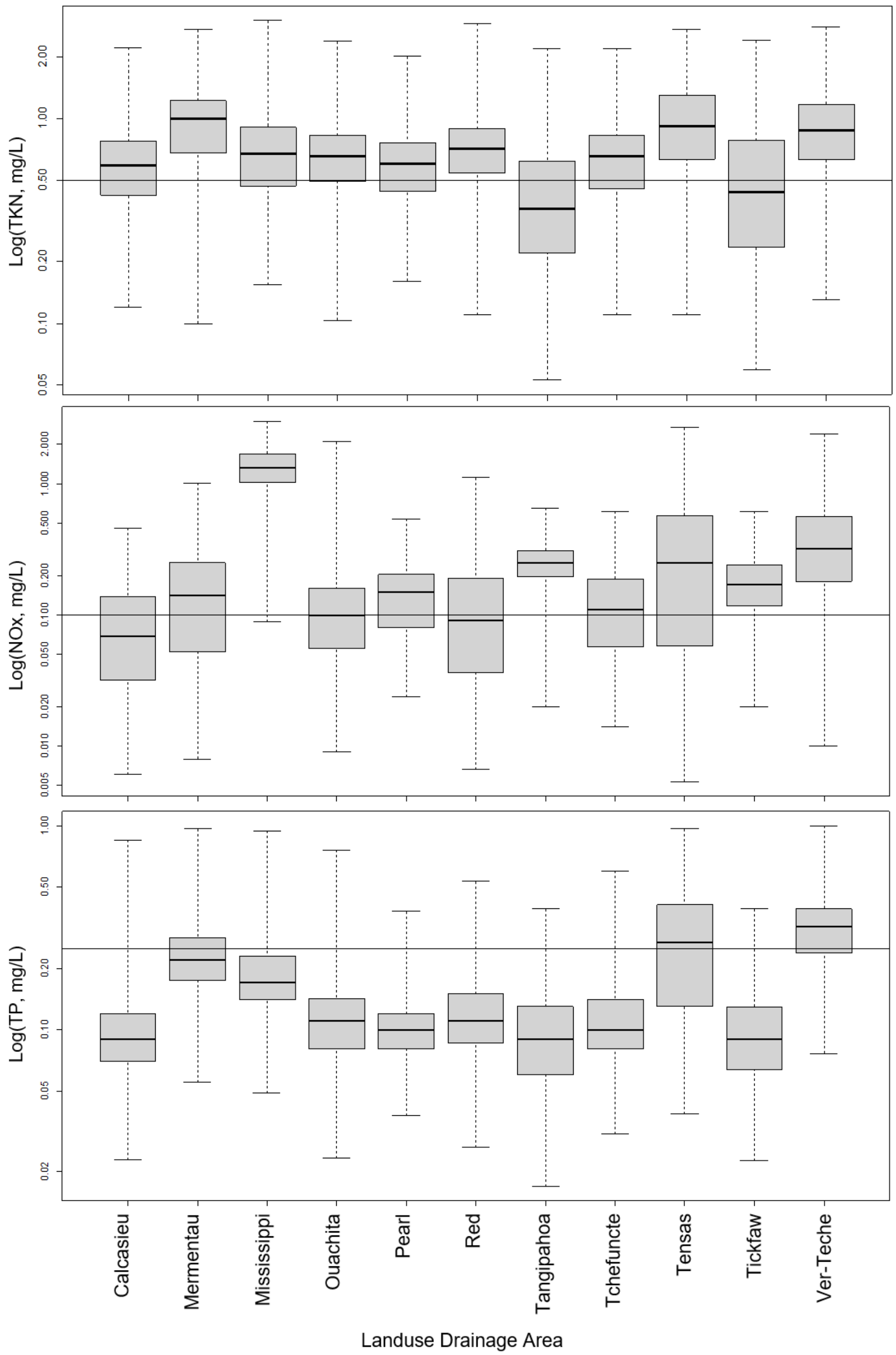


Figure 13. Censored boxplots of logs for TKN, NOx, and TP results from 2000-2020, for drainage areas used in land use correlations. Log scale shown to improve visibility of differences in median values. Gray horizontal lines represent the highest censoring detection limit for each nutrient.

Table 5. Correlation results of Kendall's rank correlation tau analysis comparing nutrients (TKN, NOx, and TP), to total suspended solids (TSS) and land use. Significant results (at $p \leq 0.05$) are highlighted in yellow for positive correlation and green for negative correlation. Agriculture was divided into three categories to find the individual significance of these components.

		TKN	NOx	TP
TSS	tau	*0.463*	0.330	*0.539*
	p-val	*0.050*	0.160	*0.026*
Wetlands	tau	0.183	0.164	0.229
	p-val	0.435	0.542	0.342
Forest	tau	*-0.624*	-0.345	*-0.686*
	p-val	*0.008*	0.165	*0.004*
Developed	tau	-0.110	-0.164	-0.076
	p-val	0.639	0.542	0.751
Agriculture	tau	*0.661*	0.200	*0.686*
	p-val	*0.005*	0.445	*0.004*
Grasslands	tau	-0.220	0.091	-0.229
	p-val	0.349	0.761	0.342

		TKN	NOx	TP
Non N-fixer	tau	*0.514*	0.200	*0.610*
	p-val	*0.029*	0.445	*0.011*
N-fixer	tau	0.404	0.164	*0.534*
	p-val	0.086	0.542	*0.027*
Rice/Aqua	*tau*	*0.477*	0.018	*0.496*
	p-val	*0.042*	1.000	*0.039*

The Ouachita and Calcasieu-Mermentau drainage areas are good examples of the relationship between nutrients and land use. Both drainage areas have a greater acreage of agriculture occurring primarily near one river within the watershed, which are separated out in the landuse watersheds (the Tensas River in the Ouachita Basin and Mermentau River in the Mermentau Basin, Figure 14). The Tensas and Mermentau Rivers, which have the highest agricultural land use percentages, also have higher TP and TKN concentrations than the Calcasieu and Ouachita Rivers (Figure 13, Figure 14, Table A.1). The Tensas and Mermentau have the highest two median TKN concentrations, and second and third highest TP concentrations (after Vermilion-Teche), while these concentrations are noticeably lower for both nutrients in the Calcasieu and Ouachita. When agriculture was further broken down by crop type (e.g., N-fixer, non N-fixer, and rice and/or aquaculture), all three crop types were significantly correlated with higher TP values; non N-fixers and rice/aquaculture were significantly correlated with higher TKN concentrations, but N-fixers were not (Table 5). Nitrogen fixing crops, such as soybeans, are able to obtain their own N from the atmosphere through the biological process of N fixation that occurs in root nodules. *Rhizobia*, specialist bacteria that live in these nodules, are the organisms responsible for fixing atmospheric N, converting N_2 to NH_4^+. Because these plants are able to utilize their symbiotic relationship with *Rhizobia* to fix their own N, less N, if any, is needed from fertilizer applied to these crops (Havlin et al., 2005; Padgett et al., 2019). The 2015 trends report found a significant correlation between N-fixing crops and TKN, which was not found in this study. The change in significance might be explained by the generally decreasing trends in TKN concentration, and might also be affected by the incorporation of censored data in the analysis. As N-fixing crops require no or decreased N application, this lack of correlation is a more expected result.

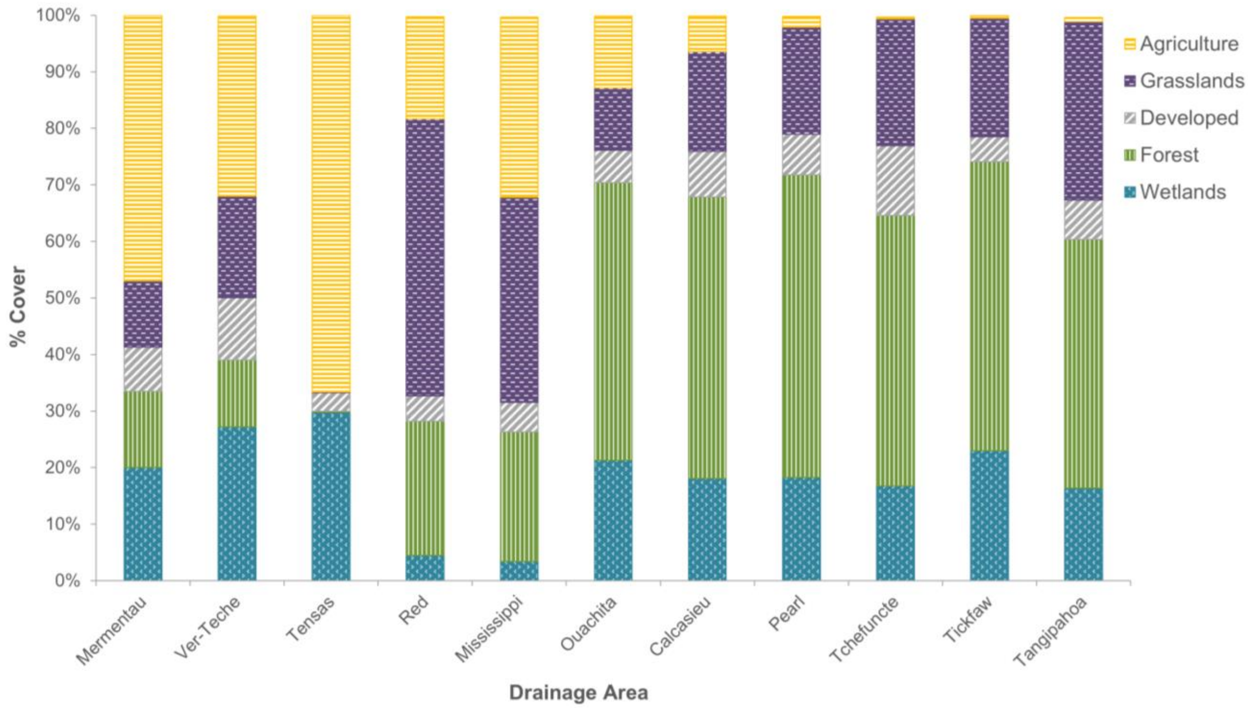


Figure 14. Percent cover of each major land use class for the major drainage areas within Louisiana. The Vermilion-Teche drainage area is abbreviated as Ver-Teche.

The Vermilion-Teche and Tensas drainage areas have very similar TKN median values from 2000 to 2020 (Figure 13, Table A. 1), but the amount of agriculture occurring is over double in the Tensas drainage area compared to the Vermilion-Teche (Figure 14, Table A.1). The 2020 USDA Cropland Data layer identified the Tensas as having over 66% agricultural land cover, predominantly of non N-fixing crops, while the Vermilion-Teche (32% agricultural land cover) is about even between N-fixing and non N-fixing crops (Figure 15). The drainage area with the highest TKN value (Mermentau, median TKN = 0.99 mg/L) also has the highest rice production (29% land cover). Rice is grown in flooded soils, which typically equates to anaerobic (no oxygen) conditions. Under anaerobic conditions, NOx will be converted to N_2 via denitrification and be lost to the atmosphere. In order for rice to receive any N from fertilizer, it must be in the form of NH_4^+, which could be contributing to the higher TKN values found in the Mermentau watershed.

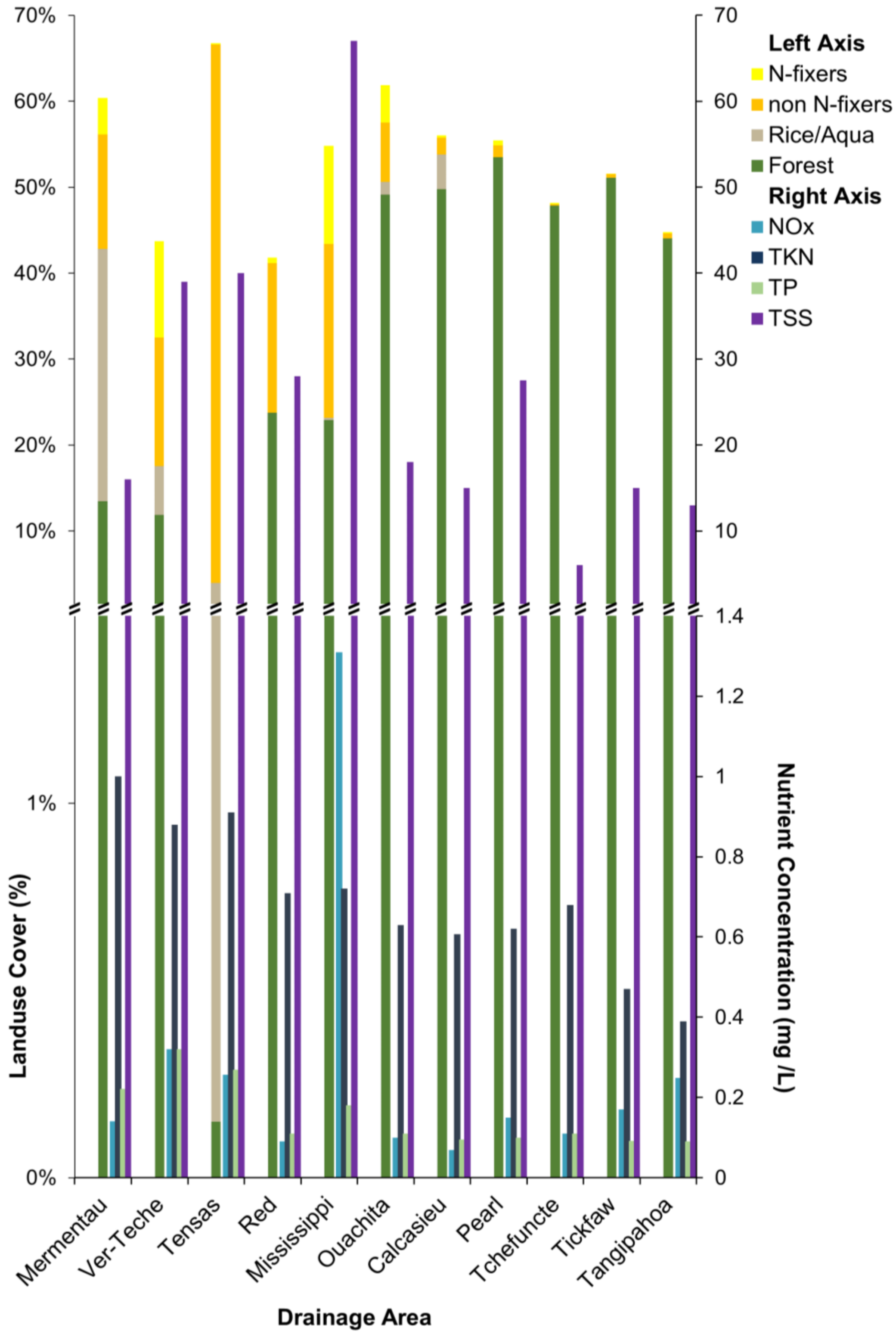


Figure 15. Comparison of median NOx, TP, and TKN concentrations from 2000 to 2020 to median TSS concentrations from 2000 to 2020 (right axis) and to percent cover of significant land use classes for each watershed used in the correlation analyses (left axis).

The correlation analysis also shows forested areas are associated with lower TKN and lower TP concentrations. The sites located in drainage areas with the highest proportion of forest cover (Pearl, Tickfaw, Calcasieu, Ouachita, Tchefuncte, and Tangipahoa) have the six lowest median TKN (0.37 to 0.65 mg/L) and median TP (0.09 to 0.11 mg/L) values, whereas the sites located in the drainage areas with highest agricultural land use (Tensas, Mermentau, Mississippi, Vermilion-Teche, and Red) have the five highest median TKN and TP values, and in some cases nearly double the amount of TKN (0.67 to 0.99 mg/L) and TP (0.11 to 0.32 mg/L) (Table A. 1, Figure 13). The reduced soil erosion that occurs in forested ecosystems likely contributes to the lower TKN concentrations, but trees are also known to provide a sink for N (Goodale et al., 2002; Nadelhoffer et al., 1984). Forested watersheds are also known to conserve P through reduced soil erosion, and therefore reduced transport of soil-bound P into waterbodies (Howarth et al., 2002, and references therein). Though a higher TP is significantly correlated with the presence of agriculture, four out of the five sites in drainage areas with the highest agricultural land use (Mermentau, Mississippi, Vermilion-Teche, and Red) show an overall decreasing trend for TP, whereas three out of the six sites in drainage areas with the greatest proportion of forest cover (Ouachita, Tickfaw, and Tchefuncte) showed no overall trend for TP, and the Tchefuncte showed significant seasonal increases in TP during the fall and winter (Figure 14, Table 4, Table B. 1). Accordingly, even though TP concentrations are higher in surface waters where agriculture is a major land use in the drainage area, there has been progress in decreasing the amount of TP entering our waterbodies.

NOx shows no significant correlation to either TSS or to any land use type. This could be due to the confounding influence of atmospheric deposition, which is becoming an important pathway for entry of NOx into water bodies. Atmospheric deposition is listed as one of the three most common probable sources of pollution associated with impairment in rivers and streams; lakes, ponds, and reservoirs; and bays and estuaries by the EPA (USEPA, 2017). Deposition could also be contributing to the higher NOx concentration in the Calcasieu River at Burton Landing in comparison to the site further upstream at Moss Bluff. There are few agricultural sources of N between Moss Bluff (map number 6) and Burton Landing (map number 5) on the Calcasieu River, which points to atmospheric deposition, stormwater/urban runoff, or point sources as a source of the increase. Most of the development in the Calcasieu watershed is located between the Moss Bluff and Burton Landing sites around the City of Lake Charles, which contains about 8% developed land. The Air Permits Division at LDEQ maintains an emission inventory of actual criteria and toxic air pollutant emissions in the Emissions Reporting and Inventory Center (ERIC), which was used to investigate the atmospheric deposition of NOx. Using data from LDEQ's ERIC database for the past five years, the mean NOx emitted from 2016 to 2020 was calculated for a radius of 50,000 m from a point halfway between the Moss Bluff and Burton Landing sites on the Calcasieu River (LDEQ, 2021a). The mean NOx emissions for the Lake Charles area was 19,147 tons, down from an average of 23,054 tons in 2009-2013. Additionally, two models created to pinpoint sources of N pollution (the SPAtially Referenced Regressions On Watersheds (SPARROW) and Nutrient Export from WatershedS (NEWS) models) show atmospheric deposition as a primary source of N in the southwestern part of Louisiana, further supporting deposition as the primary source of increased NOx for the Lake Charles area along the Calcasieu River (McCrackin et al., 2013).

Significant increasing trends were found at the Bogue Chitto River site for NOx and TP, seasonal analysis found that these increases for NOx are occurring in summer, fall, and winter; and for TP in fall and winter. The reasons for this may warrant further evaluation. The Bogue Chitto, which is contained within the Pearl Watershed (Figure A. 2), has very similar land use to the Calcasieu. The Bogue Chitto drainage area is primarily forest (53%), woody wetlands (12%), grassland/pasture (20%), and shrubland (6%). Less than 2% of land use is related to agriculture and only 7% is developed (Appendix A). However, the mean NOx emissions, obtained using the same method as for the Calcasieu from a 50,000 m radius around the long-term monitoring station at the Pearl River near Bush (map number 4), was only 2,594 tons of NOx, which is also a decrease from an average of 3,993 tons in 2009-2013. Therefore, atmospheric deposition of NOx is not likely to be a large contributor. Potential sources of nutrient increases could result from failures of municipal wastewater treatment plants, leakage from off-site sewage treatment, or runoff from animal manure activities; however, in these scenarios, TKN would also be expected to increase and TKN is not changing significantly except during winter, where TKN is significantly decreasing. Additional studies are needed to investigate potential sources, but would be warranted in order to target the specific causes of the NOx and TP increases.

Further review and research may be warranted to explain the water quality improvements realized through implementation of water quality programs, and best management and conservation practices. Speciation of TKN and TP may help narrow down specific sources of N or P. Both TKN and TP consist of an organic and inorganic form: TKN of organic-N and ammonium (NH_4^+) and TP of organic-P and phosphate (PO_3^{4-}). Similarly, water samples collected are unfiltered (particulate, sorbed to soil) as opposed to filtered (dissolved, bioavailable). Knowledge of the proportion of organic versus inorganic or dissolved versus particulate could point to potential nutrient sources, such as manure (higher organic proportion) or soil runoff (more particulate than dissolved). In addition, exploration of seasonal water temperature variations and its impact, if any, on water quality in Louisiana may be warranted to further understanding of seasonal increases of TKN and TP found in a few long-term sites in fall and winter. Further studies may be useful to determine the sources of nutrients in order to achieve continued water quality improvement in our waters.

5. Conclusion

Louisiana continues to make improvements in nutrient management within our water bodies. Long-term trends in NOx, TKN, and TP show that overall, nutrient concentrations continue to decrease for the majority of long-term monitoring sites within the state. While the state has made great progress in managing nutrients, continued programs targeting best management and conservation practices to agricultural areas in the state may further the nutrient management effort in Louisiana. Participation by all watershed stakeholders is needed from state and local governments, industry, and the public to continue to achieve reductions of nutrients. Work has already begun on implementation strategies for nutrient management. Together with the Coastal Protection and Restoration Authority of Louisiana (CPRA), the Governor's Office of Coastal Activities (GOCA), the Louisiana Department of Agriculture and Forestry (LDAF), the Louisiana Department of Natural Resources (LDNR), and the Louisiana State University Agricultural Center, LDEQ formed the Louisiana Nutrient Reduction and Management Strategy Interagency Team. This Interagency Team has been implementing a Nutrient Reduction and Management Strategy since 2014 to address water quality and manage nutrients in our waters through a variety of avenues including nonpoint source, point source, and coastal protection and restoration management (LNRMS Team, 2020). The nutrient trend analyses presented in this report help document observed nutrient trends in Louisiana water bodies and identify areas where current strategies are either working or need improvement.

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Appendix A: Detailed Land Use Information

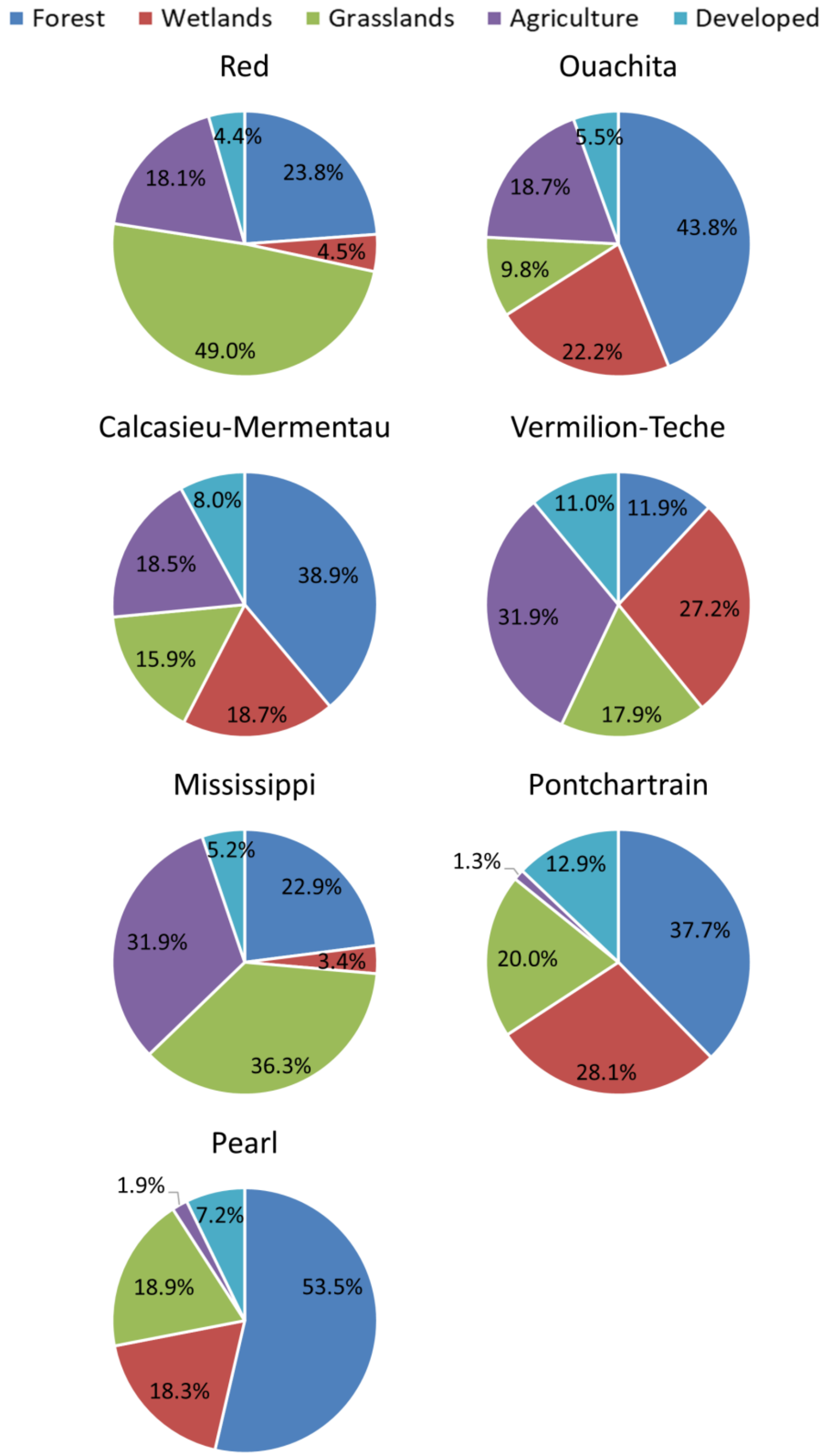

Figure A. 1. Consolidated percent land use for the drainage areas described in this report.

Table A. 1. Median water quality parameter values from 2000 to 2020 and major land use classes for each drainage area used in nonparametric Kendall's tau correlation analyses. Agriculture is shown both aggregate and separated into three categories (rice/aquaculture, N-fixing crops, and non N-fixing crops) for further analysis.

	Water Quality Parameter				Land Use							
	TKN	NO_X	TP	TSS	Wetlands	Forest	Developed	Grasslands	Agriculture	Rice/Aqua	N-fixer	non N-fixer
Drainage Area	mg/L				% cover							
Calcasieu	0.59	0.07	0.09	15.00	18%	50%	8%	18%	6%	4%	0%	2%
Mermentau	0.99	0.14	0.22	16.00	20%	13%	8%	12%	47%	29%	4%	13%
Mississippi	0.67	1.32	0.17	67.00	3%	23%	5%	36%	32%	0%	11%	20%
Ouachita	0.65	0.10	0.11	18.00	21%	49%	6%	11%	13%	1%	4%	7%
Pearl	0.60	0.15	0.10	27.00	18%	53%	7%	19%	2%	—	1%	1%
Red	0.71	0.09	0.11	27.50	4%	24%	4%	49%	18%	0%	1%	17%
Tangipahoa	0.37	0.25	0.09	13.00	16%	44%	7%	32%	1%	—	0%	1%
Tchefuncte	0.65	0.11	0.10	6.00	17%	48%	12%	22%	0%	—	0%	0%
Tensas	0.91	0.25	0.27	39.00	30%	0%	3%	0%	67%	4%	0%	63%
Tickfaw	0.45	0.17	0.09	15.00	23%	51%	4%	21%	0%	—	0%	0%
Ver-Teche	0.88	0.32	0.32	38.00	27%	12%	11%	18%	32%	6%	11%	15%

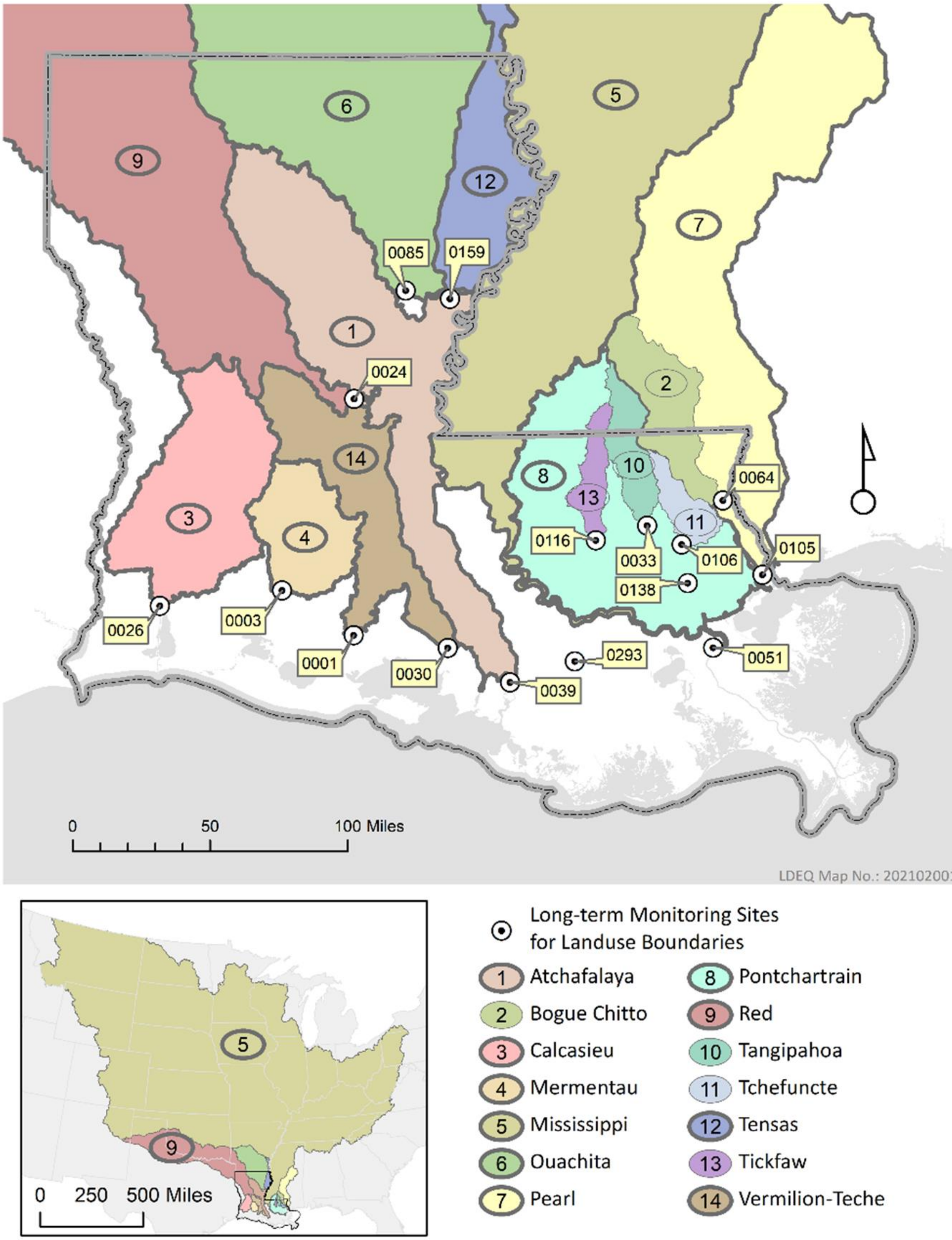

Figure A. 2. Map of the drainage areas used in land use category calculations.

Table A. 2. Land use by % cover and total acres for the Mississippi, Red, Ouachita, Tensas, and Calcasieu River drainage areas. The Atchafalaya River basin only consists of land not included in other basins. Blank cells represent no data.

Land use	Mississippi		Red		Ouachita		Tensas		Atchafalaya		Calcasieu	
	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres
Barren	0.30%	2,149,753	0.27%	112,533	0.12%	13,759	0.03%	476	0.22%	7,913	0.16%	3,384
Barren	0.30%	2,149,753	0.27%	112,533	0.12%	13,759	0.03%	476	0.22%	7,913	0.16%	3,384
Forest (total)	22.91%	163,712,306	23.75%	10,025,907	49.14%	5,841,427	0.15%	2,209	30.76%	1,099,777	49.79%	1,028,244
Deciduous Forest	16.46%	117,604,633	9.82%	4,143,641	7.50%	892,103	0.01%	195	1.46%	52,290	0.27%	5,494
Evergreen Forest	4.07%	29,056,141	10.53%	4,442,852	37.50%	4,457,764	0.12%	1,750	29.00%	1,036,675	49.01%	1,012,193
Mixed Forest	2.39%	17,051,532	3.41%	1,439,415	4.13%	491,560	0.02%	264	0.30%	10,812	0.51%	10,557
Wetlands (total)	3.41%	24,374,079	4.46%	1,884,129	21.27%	2,528,236	29.81%	440,274	42.77%	1,529,223	18.10%	373,894
Herbaceous Wetlands	1.33%	9,530,473	0.17%	69,911	0.60%	71,501	3.93%	58,065	1.57%	56,175	0.47%	9,620
Woody Wetlands	2.08%	14,843,605	4.30%	1,814,218	20.67%	2,456,735	25.88%	382,208	41.20%	1,473,048	17.64%	364,274
Developed (total)	5.19%	37,104,990	4.44%	1,872,775	5.73%	680,649	3.28%	48,409	4.26%	152,325	8.04%	165,988
Developed/High Intensity	0.20%	1,408,554	0.14%	58,699	0.13%	15,390	0.03%	490	0.05%	1,954	0.41%	8,448
Developed/Low Intensity	1.40%	9,982,636	1.15%	484,442	1.99%	237,111	0.57%	8,385	1.15%	41,170	3.98%	82,243
Developed/Med Intensity	0.52%	3,747,453	0.34%	142,499	0.40%	47,474	0.14%	2,116	0.17%	6,057	0.77%	15,864
Developed/Open Space	3.07%	21,966,347	2.81%	1,187,135	3.20%	380,674	2.53%	37,417	2.89%	103,144	2.88%	59,433
Grasslands (total)	36.27%	259,114,493	49.00%	20,685,013	11.04%	1,312,355	0.11%	1,617	7.84%	280,448	17.66%	364,679
Grassland/Pasture	26.71%	190,836,638	30.63%	12,930,290	6.83%	812,502	0.07%	1,028	3.23%	115,411	9.28%	191,724
Shrubland	9.56%	68,277,855	18.37%	7,754,723	4.20%	499,853	0.04%	589	4.62%	165,037	8.37%	172,955
Agriculture: N-fixers (total)	11.42%	81,591,373	0.64%	269,593	4.31%	512,404	0.19%	2,846	8.03%	287,121	0.26%	5,465
Alfalfa	1.61%	11,499,215	0.25%	105,532	0.00%	18	0.01%	98				
Clover/Wildflowers	0.01%	51,353	0.00%	285	0.00%	6	0.00%	1	0.03%	910		
Dbl Crop Barley/Soybeans	0.00%	9,765										
Dbl Crop Corn/Soybeans	0.00%	145	0.00%	54	0.00%	1	0.00%	8	0.01%	200	0.00%	
Dbl Crop Soybeans/Cotton	0.00%	145										
Dbl Crop Soybeans/Oats	0.00%	4,101	0.00%	21	0.01%	1,228	0.03%	390	0.00%	7		
Dbl Crop WinWht/Soy	0.30%	2,113,975	0.02%	9,063	0.02%	2,455	0.13%	1,878	0.05%	1,864	0.01%	196
Dry Beans	0.08%	569,744			0.00%	41	0.00%	0				

Land use	Mississippi		Red		Ouachita		Tensas		Atchafalaya		Calcasieu	
	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres
Peanuts	0.01%	47,446	0.03%	12,065	0.02%	2,332	0.03%	466	0.00%	1		
Peas	0.13%	928,725	0.01%	2,788	0.00%	194	0.00%	5	0.00%	6	0.00%	1
Soybeans	9.29%	66,366,760	0.33%	139,708	4.26%	506,131			7.95%	284,133	0.26%	5,268
Vetch			0.00%	77								
Rice/Aquaculture (total)	0.23%	1,625,548	0.03%	11,062	1.46%	173,733	3.82%	56,392	0.93%	33,149	3.99%	82,493
Aquaculture	0.00%	11,607	0.00%	834	0.01%	873	0.04%	544	0.15%	5,187	2.00%	41,280
Rice	0.23%	1,613,941	0.02%	10,227	1.45%	172,861	3.78%	55,848	0.78%	27,962	2.00%	41,213
Agriculture: non N-fixers (total)	20.26%	144,780,381	17.41%	7,349,796	6.95%	825,639	62.61%	924,592	5.18%	185,117	1.99%	41,012
Alfalfa									0.00%	63		
Apples	0.00%	8,786										
Asparagus	0.00%	0										
Barley	0.17%	1,213,469	0.04%	18,673								
Blueberries	0.00%	85	0.00%	76	0.00%	8			0.00%	0	0.00%	
Broccoli	0.00%	0										
Buckwheat	0.00%	19,424	0.00%	104								
Cabbage	0.00%	1,982	0.00%	0			0.00%	0				
Camelina	0.00%	220										
Canola	0.09%	676,952	0.00%	342								
Cantaloupes	0.00%	614										
Carrots	0.00%	1,077										
Cherries	0.00%	479										
Chick Peas	0.02%	109,337										
Christmas Trees	0.00%	8,852	0.00%	3								
Citrus	0.00%	0	0.00%	5								
Corn	10.54%	75,278,956	0.55%	230,644	2.51%	298,628	12.46%	183,991	1.59%	56,834	0.04%	862
Cotton	0.30%	2,109,080	3.16%	1,333,793	1.12%	133,657	5.81%	85,777	0.56%	20,086	0.00%	22
Cranberries	0.00%	314										
Cucumbers	0.00%	1,151	0.00%	0								
Dbl Crop Barley/Corn	0.00%	3,437	0.00%	60								
Dbl Crop Oats/Corn	0.00%	2,540	0.00%	708	0.00%	119						
Dbl Crop Triticale/Corn	0.00%	20,264	0.00%	241								
Dbl Crop WinWht/Corn	0.01%	73,773	0.01%	4,024	0.00%	11	0.00%	0	0.00%	1	0.00%	1
Dbl Crop WinWht/Cotton	0.00%	12,172	0.08%	35,313	0.00%	5	0.00%	20	0.00%	2		
Dbl Crop WinWht/Sorghum	0.02%	139,942	0.05%	21,295								

Land use	Mississippi		Red		Ouachita		Tensas		Atchafalaya		Calcasieu	
	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres
Dry Beans			0.00%	1,645								
Durum Wheat	0.18%	1,258,572	0.00%	252								
Eggplants	0.00%	4										
Fallow/Idle Cropland	1.83%	13,074,071	1.54%	651,192	2.08%	246,776	4.77%	70,373	1.19%	42,381	1.43%	29,612
Flaxseed	0.03%	233,193										
Gourds	0.00%	6										
Grapes	0.00%	1,179	0.00%	27								
Greens	0.00%	436	0.00%	7	0.00%	51	0.00%	1				
Herbs	0.01%	71,482	0.10%	44,112	0.00%	218	0.00%	1				
Hops	0.00%	127										
Lentils	0.06%	416,713										
Millet	0.12%	844,582	0.02%	9,913	0.00%	88	0.02%	334	0.01%	455		
Mint	0.00%	11,377										
Misc Vegs & Fruits	0.00%	411										
Mustard	0.01%	64,606										
Oats	0.14%	1,034,293	0.06%	25,223	0.00%	462	0.04%	559	0.00%	21	0.00%	1
Olives			0.00%	1								
Onions	0.00%	1,757	0.00%	1								
Other Crops	0.01%	49,662	0.02%	6,474	0.00%	72	0.00%	1				
Other Hay/Non Alfalfa	2.31%	16,516,827	1.39%	587,016	0.87%	103,852	0.70%	10,370	0.42%	15,138	0.44%	9,069
Other Small Grains	0.00%	8,145										
Other Tree Crops	0.00%	109										
Peaches	0.00%	,848	0.00%	75	0.00%	2	0.00%	0	0.00%	3		
Peanuts												
Pears	0.00%	4										
Peas												
Pecans	0.01%	40,088	0.06%	23,222	0.05%	5,649	0.29%	4,348	0.06%	2,065	0.01%	155
Peppers	0.00%	482	0.00%	16								
Perennial Ice/Snow	0.00%	12,828										
Pistachios	0.00%	89										
Plums	0.00%	44										
Pop or Orn Corn	0.02%	172,990										
Potatoes	0.02%	136,388	0.00%	848								

Land use	Mississippi		Red		Ouachita		Tensas		Atchafalaya		Calcasieu	
	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres	%Cover	Acres
Pumpkins	0.00%	20,064	0.00%	53	0.00%	2						
Radishes	0.00%	1,515										
Rape Seed	0.00%	0										
Rye	0.06%	420,596	0.14%	59,121	0.00%	190			0.00%	2		
Safflower	0.01%	83,591	0.00%	86								
Sod/Grass Seed	0.02%	107,985	0.06%	25,262	0.01%	1,514	0.00%	26	0.00%	4	0.03%	573
Sorghum	0.63%	4,531,634	1.41%	597,085	0.01%	1,621	0.13%	1,926	0.04%	1,514	0.01%	113
Soybeans							37.69%	556,590				
Speltz	0.00%	1,040										
Spring Wheat	1.16%	8,323,184	0.00%	105								
Squash	0.00%	558			0.00%	2						
Strawberries	0.00%	127										
Sugarbeets	0.04%	265,035										
Sugarcane	0.00%	11,693	0.00%	40	0.00%	125	0.01%	132	1.25%	44,613	0.02%	484
Sunflower	0.17%	1,196,786	0.00%	1,958	0.00%	32	0.00%	57	0.00%	1		
Sweet Corn	0.02%	135,989	0.00%	41	0.00%	66	0.00%	0	0.00%	2		
Sweet Potatoes	0.00%	30,835	0.00%	28	0.01%	1,294	0.23%	3,414	0.00%	171		
Switchgrass	0.00%	4,426	0.00%	894								
Tobacco	0.00%	24,470										
Tomatoes	0.00%	2,695	0.00%	0	0.00%	448						
Triticale	0.05%	356,740	0.17%	73,378								
Turnips	0.00%	14										
Vetch	0.00%	799										
Walnuts	0.00%	2,300										
Watermelons	0.00%	2,863	0.00%	43	0.00%	188	0.00%	2				
Winter Wheat	2.19%	15,620,223	8.52%	3,596,398	0.26%	30,557	0.45%	6,668	0.05%	1,762	0.01%	119

Table A. 3. Land use by % cover and total acres for the Mermentau, Vermilion and Bayou Teche, Pearl, Bogue Chitto River, and Lake Pontchartrain drainage areas. Blank cells represent no data.

Land use	Mermentau		Vermilion-Teche		Pearl		Bogue Chitto		Pontchartrain	
	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres
Barren	0.03%	236	0.15%	2,336	0.17%	9,439	0.47%	3,534	0.35%	10,759
Barren	0.03%	236	0.15%	2,336	0.17%	9,439	0.47%	3,534	0.35%	10,759
Forest (total)	13.45%	119,318	11.87%	184,372	53.50%	2,893,322	52.83%	397,236	34.76%	1,077,059
Deciduous Forest	0.13%	1,157	0.29%	4,438	2.15%	116,232	0.86%	6,487	0.53%	16,441
Evergreen Forest	12.71%	112,758	10.94%	169,909	33.13%	1,791,598	37.97%	285,520	30.70%	951,203
Mixed Forest	0.61%	5,403	0.65%	10,025	18.22%	985,492	14.00%	105,229	3.53%	109,415
Wetlands (total)	20.05%	177,871	27.19%	22,177	18.25%	987,090	11.96%	89,915	30.89%	957,151
Herbaceous Wetlands	0.17%	1,522	0.57%	8,803	0.36%	19,721	0.19%	1,395	3.87%	119,761
Woody Wetlands	19.88%	176,349	26.62%	413,374	17.89%	967,369	11.77%	88,520	27.03%	837,390
Developed (total)	7.78%	69,054	11.00%	170,786	7.23%	391,181	6.73%	50,584	14.37%	445,349
Developed/High Intensity	0.14%	1,216	0.42%	6,484	0.19%	10,381	0.10%	763	0.96%	29,614
Developed/Low Intensity	5.00%	44,384	5.50%	85,342	1.70%	91,969	1.57%	11,839	5.12%	158,670
Developed/Med Intensity	0.42%	3,712	0.86%	13,326	0.61%	33,086	0.35%	2,598	2.32%	72,020
Developed/Open Space	2.23%	19,742	4.23%	65,634	4.73%	255,745	4.71%	35,383	5.97%	185,045
Grasslands (total)	11.74%	104,163	17.94%	278,519	18.91%	1,022,847	26.18%	196,864	18.11%	61,228
Grassland/Pasture	10.58%	93,887	16.87%	261,899	14.43%	780,631	19.89%	149,572	12.04%	372,980
Shrubland	1.16%	10,276	1.07%	16,619	4.48%	242,215	6.29%	47,292	6.08%	188,248
Agriculture: N-fixers (total)	4.28%	38,002	11.19%	173,821	0.57%	30,720	0.42%	3,156	0.27%	8,362
Alfalfa										
Clover/Wildflowers	0.00%	2	0.00%	61						
Dbl Crop Barley/Soybeans										
Dbl Crop Corn/Soybeans			0.00%	1	0.01%	306	0.04%	299	0.00%	105
Dbl Crop Soybeans/Cotton										
Dbl Crop Soybeans/Oats	0.00%	0	0.00%	5	0.00%	220	0.03%	188	0.01%	286
Dbl Crop WinWht/Soybeans	0.00%	29	0.13%	2,075	0.01%	485	0.01%	56	0.01%	210
Dry Beans										

Land use	Mermentau		Vermilion-Teche		Pearl		Bogue Chitto		Pontchartrain	
	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres
Peanuts			0.00%	0	0.01%	782			0.00%	10
Peas			0.00%	1	0.00%	44			0.00%	0
Soybeans	4.28%	37,970	11.06%	171,677	0.53%	28,883	0.35%	2,613	0.25%	7,750
Vetch										
Rice/Aquaculture (total)	29.37%	260,555	5.65%	87,755	0.00%	65	0.00%	5	0.01%	247
Aquaculture	13.30%	118,001	2.27%	35,205	0.00%	50	0.00%	1	0.00%	154
Rice	16.07%	142,554	3.38%	52,551	0.00%	15	0.00%	4	0.00%	93
Agriculture: non N-fixers (total)	13.30%	118,040	15.01%	233,139	1.36%	73,475	1.41%	10,586	1.23%	38,013
Alfalfa										
Apples										
Asparagus										
Barley										
Blueberries					0.00%	36			0.00%	1
Broccoli										
Buckwheat										
Cabbage					0.00%	6	0.00%	6	0.00%	22
Camelina										
Canola										
Cantaloupes										
Carrots										
Cherries										
Chick Peas										
Christmas Trees										
Citrus										
Corn	0.12%	1,072	1.61%	24,954	0.28%	15,303	0.56%	4,182	0.14%	4,453
Cotton	0.00%	16	0.33%	5,081	0.10%	5,675	0.02%	115	0.00%	80
Cranberries										
Cucumbers					0.00%	4				
Dbl Crop Barley/Corn										
Dbl Crop Oats/Corn										
Dbl Crop Triticale/Corn										
Dbl Crop WinWht/Corn					0.00%	6	0.00%	1	0.00%	2
Dbl Crop WinWht/Cotton			0.00%	0	0.00%	4	0.00%	1	0.00%	4
Dbl Crop WinWht/Sorghum										

Land use	Mermentau		Vermilion-Teche		Pearl		Bogue Chitto		Pontchartrain	
	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres
Dry Beans										
Durum Wheat										
Eggplants										
Fallow/Idle Cropland	11.09%	98,422	2.51%	38,922	0.07%	3,525	0.01%	113	0.20%	6,295
Flaxseed										
Gourds										
Grapes										
Greens										
Herbs										
Hops										
Lentils										
Millet	0.01%	127	0.00%	6	0.00%	41	0.00%	14	0.00%	63
Mint										
Misc Vegs & Fruits					0.00%	1				
Mustard										
Oats	0.00%	0	0.00%	2	0.00%	70	0.00%	7	0.00%	2
Olives										
Onions										
Other Crops	0.00%	1	0.00%	38	0.00%	1			0.00%	2
Other Hay/Non Alfalfa	1.15%	10,241	1.22%	18,964	0.86%	46,732	0.78%	5,840	0.31%	9,757
Other Small Grains										
Other Tree Crops										
Peaches										
Peanuts							0.00%	22		
Pears										
Peas							0.00%	3		
Pecans	0.01%	117	0.08%	1,313	0.00%	41	0.00%	2	0.00%	18
Peppers					0.00%	1				
Perennial Ice/Snow										
Pistachios										
Plums										
Pop or Orn Corn										
Potatoes										

Land use	Mermentau		Vermilion-Teche		Pearl		Bogue Chitto		Pontchartrain	
	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres	% Cover	Acres
Pumpkins					0.00%	6			0.00%	0
Radishes										
Rape Seed										
Rye			0.00%	0						
Safflower										
Sod/Grass Seed	0.01%	68	0.01%	110	0.02%	1,169	0.00%	19	0.00%	24
Sorghum	0.00%	10	0.15%	2,327	0.01%	436	0.01%	100	0.00%	37
Soybeans										
Speltz										
Spring Wheat										
Squash										
Strawberries					0.00%	2	0.00%	2	0.00%	89
Sugarbeets										
Sugarcane	0.89%	7,869	8.82%	136,967	0.00%	19	0.00%	17	0.55%	17,104
Sunflower			0.00%	1	0.00%	2			0.00%	0
Sweet Corn					0.00%	4			0.00%	34
Sweet Potatoes	0.00%	39	0.10%	1,540	0.00%	98	0.00%	5	0.00%	5
Switchgrass					0.00%	1				
Tobacco										
Tomatoes										
Triticale										
Turnips										
Vetch										
Walnuts										
Watermelons					0.00%	29	0.00%	0		
Winter Wheat	0.01%	58	0.19%	2,914	0.00%	264	0.02%	139	0.00%	22

Table A. 4. Land use by % cover and total acres for the Tangipahoa, Tchefuncte, and Tickfaw River drainage areas. Blank cells represent no data.

Land use	**Tangipahoa**		**Tchefuncte**		**Tickfaw**	
	% Cover	**Acres**	**% Cover**	**Acres**	**% Cover**	**Acres**
Barren	0.39%	1,591	0.36%	906	0.09%	234
Barren	0.39%	1,591	0.36%	906	0.09%	234
Forest (total)	44.05%	181,140	47.87%	121,646	51.10%	129,482
Deciduous Forest	0.48%	1,959	0.02%	44	0.34%	850
Evergreen Forest	37.91%	155,894	47.73%	121,282	48.96%	124,068
Mixed Forest	5.66%	23,287	0.13%	319	1.80%	4,565
Wetlands (total)	16.36%	67,288	16.74%	42,532	22.99%	58,248
Herbaceous Wetlands	0.21%	859	0.31%	776	0.23%	576
Woody Wetlands	16.15%	66,429	16.43%	41,755	22.76%	57,671
Developed (total)	6.92%	28,459	12.36%	31,405	4.46%	11,311
Developed/High Intensity	0.15%	596	0.34%	852	0.03%	66
Developed/Low Intensity	1.79%	7,353	2.55%	6,478	0.96%	2,421
Developed/Med Intensity	0.47%	1,930	1.22%	3,090	0.10%	249
Developed/Open Space	4.52%	18,579	8.26%	20,984	3.38%	8,575
Grasslands (total)	31.53%	129,672	22.38%	56,866	20.91%	52,988
Grassland/Pasture	22.88%	94,081	15.17%	38,558	11.78%	29,863
Shrubland	8.66%	35,591	7.20%	18,308	9.13%	23,125
Agriculture: N-fixers (total)	0.16%	671	0.14%	344	0.05%	131
Alfalfa						
Clover/Wildflowers						
Dbl Crop Barley/Soybeans						
Dbl Crop Corn/Soybeans	0.02%	96	0.00%	6		
Dbl Crop Soybeans/Cotton						
Dbl Crop Soybeans/Oats	0.05%	188	0.03%	72	0.00%	8
Dbl Crop WinWht/Soybeans	0.01%	36	0.03%	75	0.00%	3

Land use	Tangipahoa		Tchefuncte		Tickfaw	
	% Cover	Acres	% Cover	Acres	% Cover	Acres
Dry Beans						
Peanuts	0.00%	5			0.00%	0
Peas	0.00%	0				
Soybeans	0.08%	346	0.08%	192	0.05%	120
Vetch						
Rice/Aquaculture (total)	0.00%	3	0.00%	1	0.00%	5
Aquaculture	0.00%	1	0.00%	0	0.00%	2
Rice	0.00%	2	0.00%	0	0.00%	3
Agriculture: non N-fixers (total)	0.58%	2,375	0.16%	407	0.40%	1,014
Alfalfa						
Apples						
Asparagus						
Barley						
Blueberries	0.00%	1				
Broccoli						
Buckwheat						
Cabbage	0.00%	4				
Camelina						
Canola						
Cantaloupes						
Carrots						
Cherries						
Chick Peas						
Christmas Trees						
Citrus						
Corn	0.25%	1,011	0.09%	219	0.09%	230
Cotton	0.01%	30	0.00%	1	0.00%	5
Cranberries						
Cucumbers						
Dbl Crop Barley/Corn						
Dbl Crop Oats/Corn						
Dbl Crop Triticale/Corn						
Dbl Crop WinWht/Corn	0.00%	0			0.00%	0
Dbl Crop WinWht/Cotton	0.00%	0	0.00%	4	0.00%	0

Land use	Tangipahoa		Tchefuncte		Tickfaw	
	% Cover	Acres	% Cover	Acres	% Cover	Acres
Dbl Crop WinWht/Sorghum						
Dry Beans						
Durum Wheat						
Eggplants						
Fallow/Idle Cropland	0.01%	56	0.00%	8	0.01%	24
Flaxseed						
Gourds						
Grapes						
Greens						
Herbs						
Hops						
Lentils						
Millet	0.01%	31	0.00%	6	0.00%	1
Mint						
Misc Vegs & Fruits						
Mustard						
Oats						
Olives						
Onions						
Other Crops						
Other Hay/Non Alfalfa	0.29%	1,178	0.06%	147	0.28%	722
Other Small Grains						
Other Tree Crops						
Peaches						
Peanuts						
Pears						
Peas						
Pecans	0.00%		0.00%	1	0.00%	1
Peppers						
Perennial Ice/Snow						
Pistachios						
Plums						
Pop or Orn Corn						
Potatoes						
Pumpkins	0.00%	0				
Radishes						

Land use	Tangipahoa		Tchefuncte		Tickfaw	
	% Cover	Acres	% Cover	Acres	% Cover	Acres
Rape Seed						
Rye						
Safflower						
Sod/Grass Seed	0.00%	0				
Sorghum	0.00%	7	0.01%	14	0.00%	1
Soybeans						
Speltz						
Spring Wheat						
Squash						
Strawberries	0.00%	13			0.00%	1
Sugarbeets						
Sugarcane	0.01%	36	0.00%	8	0.01%	27
Sunflower						
Sweet Corn						
Sweet Potatoes	0.00%	1				
Switchgrass						
Tobacco						
Tomatoes						
Triticale						
Turnips						
Vetch						
Walnuts						
Watermelons						
Winter Wheat	0.00%	5			0.00%	2

Appendix B: Detailed Results of Seasonal Kendall Permutation Test on Left-Censored Data

Table B. 1. Results of left-censored nonparametric Seasonal Kendall trend test for AWQMN long-term sites using the censeaken command from the NADA2 package in R, including the number of values (n), Kendall's tau value, significance (p), Theil-Sen slope, and trend direction. Significant results ($p < 0.05$) are shown in red italics. Decreasing trends (↓) are highlighted in blue, increasing (↑) in red, and insignificant (NS) in gray.

			Total Kjeldahl Nitrogen (TKN)					Nitrite + Nitrate (NOx)					Total Phosphorus (TP)				
Site Name	**Map#**	**Season**	**n**	**tau**	**pval**	**slope**	**trend**	**n**	**tau**	**pval**	**slope**	**trend**	**n**	**tau**	**pval**	**slope**	**trend**
Atchafalaya	1	Spring	112	-0.20	*0.00*	-0.01	↓	118	-0.21	*0.00*	-0.01	↓	115	-0.24	*0.00*	0.00	↓
		Summer	108	-0.27	*0.00*	-0.01	↓	110	0.04	0.56	0.00	NS	108	-0.08	0.21	0.00	NS
		Fall	103	-0.20	*0.00*	-0.01	↓	112	-0.10	0.11	0.00	NS	108	0.07	0.27	0.00	NS
		Winter	101	-0.15	*0.03*	-0.01	↓	105	0.01	0.90	0.00	NS	102	-0.11	0.10	0.00	NS
Lafourche	2	Spring	66	0.00	0.97	0.00	NS	76	-0.12	0.14	-0.01	NS	70	0.02	0.82	0.00	NS
		Summer	75	-0.08	0.34	0.00	NS	85	0.03	0.72	0.00	NS	83	-0.04	0.63	0.00	NS
		Fall	56	-0.06	0.50	0.00	NS	68	0.19	*0.02*	0.01	↑	63	0.02	0.82	0.00	NS
		Winter	70	-0.03	0.76	0.00	NS	81	0.03	0.74	0.00	NS	78	0.05	0.56	0.00	NS
Teche	3	Spring	123	-0.24	*0.00*	-0.01	↓	128	0.00	0.99	0.00	NS	126	-0.11	0.07	0.00	NS
		Summer	124	-0.31	*0.00*	-0.01	↓	128	-0.03	0.59	0.00	NS	125	-0.14	*0.02*	0.00	↓
		Fall	116	-0.27	*0.00*	-0.01	↓	123	0.00	1.00	0.00	NS	120	-0.07	0.29	0.00	NS
		Winter	118	-0.33	*0.00*	-0.02	↓	120	0.03	0.58	0.00	NS	118	-0.23	*0.00*	0.00	↓
Bogue Chitto	4	Spring	107	-0.12	0.07	-0.01	NS	115	0.09	0.16	0.00	NS	108	0.00	0.99	0.00	NS
		Summer	105	-0.16	*0.01*	-0.01	↓	115	0.15	*0.02*	0.00	↑	113	0.07	0.26	0.00	NS
		Fall	93	-0.13	0.07	0.00	NS	107	0.38	*0.00*	0.01	↑	95	0.20	*0.00*	0.00	↑
		Winter	104	-0.17	*0.01*	-0.01	↓	116	0.26	*0.00*	0.00	↑	112	0.15	*0.02*	0.00	↑

			Total Kjeldahl Nitrogen (TKN)					Nitrite + Nitrate (NOx)					Total Phosphorus (TP)				
Site Name	**Map#**	**Season**	**n**	**tau**	**pval**	**slope**	**trend**	**n**	**tau**	**pval**	**slope**	**trend**	**n**	**tau**	**pval**	**slope**	**trend**
Calcasieu–BL	5	Spring	122	-0.40	*0.00*	-0.02	↓	126	-0.24	*0.00*	0.00	↓	124	-0.13	*0.03*	0.00	↓
		Summer	114	-0.47	*0.00*	-0.02	↓	122	-0.19	*0.00*	0.00	↓	117	-0.18	*0.00*	0.00	↓
		Fall	114	-0.41	*0.00*	-0.02	↓	117	-0.10	0.13	0.00	NS	116	-0.27	*0.00*	0.00	↓
		Winter	115	-0.51	*0.00*	-0.02	↓	119	-0.17	*0.01*	0.00	↓	117	-0.29	*0.00*	0.00	↓
Calcasieu–MB	6	Spring	122	-0.21	*0.00*	-0.01	↓	125	-0.20	*0.00*	0.00	↓	124	0.01	0.85	0.00	NS
		Summer	116	-0.20	*0.00*	-0.01	↓	123	-0.08	0.21	0.00	NS	120	0.05	0.44	0.00	NS
		Fall	112	-0.15	*0.02*	0.00	↓	117	-0.08	0.19	0.00	NS	114	-0.07	0.24	0.00	NS
		Winter	117	-0.18	*0.00*	-0.01	↓	121	-0.15	*0.01*	0.00	↓	119	-0.05	0.41	0.00	NS
Pontchartrain	7	Spring	95	-0.11	0.12	0.00	NS	103	-0.02	0.76	0.00	NS	104	0.15	*0.02*	0.00	↑
		Summer	94	-0.07	0.34	0.00	NS	107	0.03	0.60	0.00	NS	101	0.14	*0.03*	0.00	↑
		Fall	80	0.07	0.36	0.00	NS	97	-0.03	0.68	0.00	NS	93	0.22	*0.00*	0.00	↑
		Winter	95	-0.14	*0.05*	-0.01	↓	103	0.07	0.30	0.00	NS	97	0.31	*0.00*	0.00	↑
Mermentau	8	Spring	114	-0.33	*0.00*	-0.02	↓	128	-0.10	0.11	0.00	NS	125	-0.09	0.16	0.00	NS
		Summer	117	-0.14	*0.02*	-0.01	↓	126	-0.12	0.05	0.00	NS	122	-0.07	0.25	0.00	NS
		Fall	115	-0.13	*0.04*	0.00	↓	122	-0.25	*0.00*	0.00	↓	118	-0.06	0.37	0.00	NS
		Winter	116	-0.32	*0.00*	-0.02	↓	120	-0.21	*0.00*	0.00	↓	120	-0.24	*0.00*	0.00	↓
Mississippi–BC	9	Spring	119	-0.20	*0.00*	-0.01	↓	127	-0.19	*0.00*	-0.01	↓	125	-0.30	*0.00*	0.00	↓
		Summer	111	-0.17	*0.01*	-0.01	↓	124	0.07	0.27	0.00	NS	118	-0.26	*0.00*	0.00	↓
		Fall	102	-0.10	0.15	0.00	NS	118	0.00	0.95	0.00	NS	109	-0.16	*0.01*	0.00	↓
		Winter	108	-0.21	*0.00*	-0.01	↓	120	0.01	0.94	0.00	NS	117	-0.21	*0.00*	0.00	↓
Mississippi–Pla	10	Spring	118	-0.22	*0.00*	-0.01	↓	128	-0.14	*0.02*	-0.01	↓	121	-0.22	*0.00*	0.00	↓
		Summer	105	-0.16	*0.01*	-0.01	↓	125	0.07	0.27	0.00	NS	115	-0.19	*0.00*	0.00	↓
		Fall	104	-0.01	0.92	0.00	NS	121	-0.02	0.71	0.00	NS	108	0.00	0.98	0.00	NS
		Winter	112	-0.25	*0.00*	-0.01	↓	124	0.02	0.72	0.00	NS	114	-0.22	*0.00*	0.00	↓

			Total Kjeldahl Nitrogen (TKN)					Nitrite + Nitrate (NOx)					Total Phosphorus (TP)				
Site Name	**Map#**	**Season**	**n**	**tau**	**pval**	**slope**	**trend**	**n**	**tau**	**pval**	**slope**	**trend**	**n**	**tau**	**pval**	**slope**	**trend**
Mississippi–SF	11	Spring	115	-0.22	*0.00*	-0.01	↓	124	-0.17	*0.01*	-0.01	↓	120	-0.27	*0.00*	0.00	↓
		Summer	111	-0.10	0.11	0.00	NS	133	0.08	0.19	0.01	NS	122	-0.13	*0.04*	0.00	↓
		Fall	101	-0.07	0.27	0.00	NS	118	-0.01	0.84	0.00	NS	105	-0.09	0.20	0.00	NS
		Winter	107	-0.22	*0.00*	-0.01	↓	119	0.06	0.33	0.00	NS	112	-0.26	*0.00*	0.00	↓
Ouachita–H	12	Spring	123	-0.14	*0.02*	0.00	↓	127	-0.18	*0.00*	0.00	↓	122	0.07	0.28	0.00	NS
		Summer	119	-0.20	*0.00*	-0.01	↓	124	-0.18	*0.00*	0.00	↓	120	-0.06	0.32	0.00	NS
		Fall	110	-0.07	0.29	0.00	NS	120	-0.37	*0.00*	-0.01	↓	114	0.06	0.36	0.00	NS
		Winter	119	-0.08	0.20	0.00	NS	123	-0.05	0.43	0.00	NS	118	0.10	0.12	0.00	NS
Ouachita–S	13	Spring	113	-0.10	0.10	0.00	NS	125	-0.18	*0.00*	0.00	↓	126	0.08	0.17	0.00	NS
		Summer	107	-0.24	*0.00*	-0.01	↓	129	-0.41	*0.00*	-0.01	↓	125	-0.12	*0.04*	0.00	↓
		Fall	100	-0.18	*0.01*	0.00	↓	119	-0.38	*0.00*	0.00	↓	114	0.06	0.33	0.00	NS
		Winter	102	-0.13	0.06	0.00	NS	120	-0.19	*0.00*	0.00	↓	117	-0.10	0.10	0.00	NS
Pearl	14	Spring	115	-0.11	0.07	0.00	NS	124	-0.10	0.10	0.00	NS	117	-0.01	0.91	0.00	NS
		Summer	113	-0.15	*0.02*	0.00	↓	123	-0.06	0.31	0.00	NS	122	0.06	0.35	0.00	NS
		Fall	107	-0.09	0.17	0.00	NS	121	0.03	0.67	0.00	NS	113	0.04	0.57	0.00	NS
		Winter	110	-0.15	*0.02*	-0.01	↓	120	0.02	0.71	0.00	NS	116	0.04	0.53	0.00	NS
Red–M	15	Spring	115	-0.32	*0.00*	-0.01	↓	119	-0.15	*0.02*	0.00	↓	116	-0.34	*0.00*	0.00	↓
		Summer	116	-0.49	*0.00*	-0.02	↓	120	-0.05	0.43	0.00	NS	115	-0.38	*0.00*	0.00	↓
		Fall	112	-0.29	*0.00*	-0.01	↓	120	0.04	0.52	0.00	NS	115	-0.25	*0.00*	0.00	↓
		Winter	116	-0.35	*0.00*	-0.01	↓	117	-0.08	0.21	0.00	NS	116	-0.35	*0.00*	0.00	↓
Red–S	16	Spring	102	-0.21	*0.00*	-0.01	↓	102	-0.29	*0.00*	-0.01	↓	100	-0.21	*0.00*	0.00	↓
		Summer	101	-0.22	*0.00*	-0.01	↓	102	-0.30	*0.00*	-0.01	↓	98	-0.30	*0.00*	0.00	↓
		Fall	98	-0.17	*0.02*	-0.01	↓	105	-0.29	*0.00*	-0.01	↓	101	-0.22	*0.00*	0.00	↓
		Winter	100	-0.09	0.16	0.00	NS	101	-0.33	*0.00*	-0.01	↓	100	-0.32	*0.00*	0.00	↓

			Total Kjeldahl Nitrogen (TKN)					Nitrite + Nitrate (NOx)					Total Phosphorus (TP)				
Site Name	Map#	Season	n	tau	pval	slope	trend	n	tau	pval	slope	trend	n	tau	pval	slope	trend
Tangipahoa	17	Spring	121	-0.17	*0.01*	-0.01	↓	129	-0.16	*0.01*	0.00	↓	127	-0.20	*0.00*	0.00	↓
		Summer	113	-0.24	*0.00*	-0.01	↓	125	-0.02	0.78	0.00	NS	121	-0.12	0.05	0.00	NS
		Fall	109	-0.10	0.13	0.00	NS	121	0.07	0.26	0.00	NS	117	-0.01	0.92	0.00	NS
		Winter	115	-0.21	*0.00*	-0.01	↓	125	-0.31	*0.00*	0.00	↓	121	-0.18	*0.00*	0.00	↓
Tchefuncte	18	Spring	110	-0.14	*0.03*	-0.01	↓	117	-0.13	*0.03*	0.00	↓	118	-0.08	0.18	0.00	NS
		Summer	98	-0.17	*0.01*	-0.01	↓	112	-0.06	0.34	0.00	NS	105	0.04	0.53	0.00	NS
		Fall	95	-0.08	0.24	0.00	NS	114	-0.03	0.67	0.00	NS	107	0.14	*0.03*	0.00	↑
		Winter	103	-0.27	*0.00*	-0.01	↓	110	0.15	*0.02*	0.00	↑	104	0.13	0.06	0.00	NS
Tensas	19	Spring	77	-0.22	*0.01*	-0.02	↓	75	-0.08	0.30	-0.01	NS	76	-0.01	0.91	0.00	NS
		Summer	87	-0.29	*0.00*	-0.02	↓	85	-0.05	0.52	0.00	NS	88	-0.10	0.18	0.00	NS
		Fall	71	0.01	0.91	0.00	NS	77	0.05	0.54	0.00	NS	76	0.20	*0.01*	0.00	↑
		Winter	85	-0.15	*0.05*	-0.02	↓	85	-0.09	0.20	0.00	NS	85	0.15	*0.05*	0.00	↑
Tickfaw	20	Spring	115	-0.24	*0.00*	-0.01	↓	121	-0.28	*0.00*	0.00	↓	116	-0.07	0.28	0.00	NS
		Summer	98	-0.16	*0.02*	-0.01	↓	109	-0.12	0.06	0.00	NS	106	-0.03	0.61	0.00	NS
		Fall	101	-0.02	0.75	0.00	NS	114	0.12	0.07	0.00	NS	109	0.08	0.20	0.00	NS
		Winter	102	-0.20	*0.00*	-0.01	↓	109	-0.29	*0.00*	0.00	↓	105	-0.10	0.13	0.00	NS
Vermilion	21	Spring	121	-0.44	*0.00*	-0.03	↓	127	-0.12	*0.05*	0.00	↓	125	-0.27	*0.00*	0.00	↓
		Summer	118	-0.27	*0.00*	-0.01	↓	126	-0.05	0.44	0.00	NS	123	-0.15	*0.01*	0.00	↓
		Fall	115	-0.30	*0.00*	-0.01	↓	123	-0.10	0.09	0.00	NS	118	-0.14	*0.03*	0.00	↓
		Winter	115	-0.36	*0.00*	-0.02	↓	120	-0.05	0.40	0.00	NS	116	-0.31	*0.00*	-0.01	↓

Appendix C: Annual Nutrient Medians for Each Site

Table C.1. Annual medians of total Kjeldahl nitrogen (TKN), total phosphorus (TP), and nitrate-nitrite(NOx) from Oct. 1, 1978 through Sept. 30, 2020 for the Atchafalaya, Bayou Lafourche, Bayou Teche, Bogue Chitto, Calcasieu and Pontchartrain Basins. TKN, NOx, and TP are presented in mg/L. Blanks indicate no data.

	Atchafalaya			Lafourche			Teche			Bogue Chitto			Calcasieu-BL			Calcasieu-MB			Pontchartrain		
Year	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP
1978	0.68	0.78	0.23				1.30	0.01[a]	0.47	0.21	0.17	0.05	1.30	0.14	0.14	0.58	0.07	0.08			
1979	0.85	0.87	0.20				1.12	0.27	0.37	0.30	0.23	0.06	1.22	0.10	0.11	0.52	0.06	0.09			
1980	0.83	0.78	0.15				1.15	0.21	0.31	0.30	0.15	0.04[a]	1.78	0.11	0.12	0.69	0.10	0.08			
1981	0.86	1.09	0.20				1.44	0.29	0.45	0.48	0.21	0.05	1.26	0.29	0.15	0.72	0.10	0.08			
1982	0.86	1.13	0.22				1.25	0.34	0.43	0.59	0.29	0.08	1.32	0.22	0.12	0.86	0.08	0.09			
1983	0.65	0.92	0.20				1.13	0.23	0.33	0.48	0.24	0.05	1.06	0.15	0.12	0.59	0.06	0.09			
1984	0.67	1.15	0.17				1.07	0.28	0.34	0.54	0.22	0.06	1.18	0.14	0.12	0.57	0.06	0.08			
1985	0.59	0.85	0.20				1.00	0.28	0.35	0.59	0.23	0.04[a]	1.12	0.15	0.15	0.78	0.05	0.09			
1986	0.75	1.10	0.21				1.11	0.31	0.33	0.72	0.24	0.07	1.10	0.18	0.12	0.89	0.06	0.10	0.56	0.02[a]	0.06
1987	0.76	0.61	0.18				1.20	0.30	0.42	0.60	0.18	0.10	1.62	0.15	0.11	0.95	0.02[a]	0.13	0.66	0.03[a]	0.05
1988	0.84	0.56	0.12				1.22	0.34	0.35	0.76	0.29	0.07	1.09	0.14	0.14	0.90	0.05	0.10	0.60	0.03[a]	0.05
1989	0.80	0.64	0.19				1.11	0.28	0.34	0.65	0.29	0.08	0.94	0.14	0.13	0.87	0.07	0.08	0.59	0.02[a]	0.04[a]
1990	0.87	0.86	0.24				0.96	0.48	0.24	0.70	0.22	0.07	1.05	0.12	0.13	0.71	0.06	0.11	0.54	0.02[a]	0.04[a]
1991	0.64	0.68	0.21	0.91	0.99	0.31	1.11	0.36	0.35	0.68	0.27	0.14	0.98	0.12	0.11	0.79	0.06	0.09	0.48	0.02[a]	0.04[a]
1992	0.64	0.82	0.17	0.78	1.29	0.21	1.17	0.19	0.33	0.75	0.28	0.08	1.02	0.13	0.10	0.72	0.06	0.13	0.41	0.02[a]	0.04[a]
1993	0.68	1.43	0.21	0.58	1.12	0.16	1.02	0.53	0.30	1.64	0.27	0.08	0.85	0.10	0.11	0.65	0.07	0.09	0.36	0.02[a]	0.04[a]
1994	0.46	0.81	0.15	0.41	1.00	0.13	0.96	0.50	0.30	0.42	0.28	0.09	0.90	0.22	0.09	0.84	0.05	0.08	0.47	0.02[a]	0.05
1995	0.56	0.60	0.13	0.47	1.14	0.11	1.02	0.47	0.27	0.38	0.24	0.08	0.86	0.10	0.08	0.75	0.07	0.07	0.47	0.02[a]	0.07
1996	0.51	1.12	0.13	0.55	1.11	0.14	0.91	0.30	0.34	0.32	0.32	0.11	0.83	0.15	0.09	0.97	0.08	0.10	0.63	0.03[a]	0.07
1997	0.59	0.62	0.16	1.03	0.89	0.27	1.10	0.31	0.33	0.41	0.25	0.12	0.72	0.13	0.10	0.87	0.08	0.10	0.62	0.07	0.09

[a] Below lower reporting limit. The lower reporting limit for TKN is 0.1 mg/L, for NOx is 0.05 mg/L, and for TP is 0.05 mg/L.

Year	Atchafalaya			Lafourche			Teche			Bogue Chitto			Calcasieu-BL			Calcasieu-MB			Pontchartrain		
	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP
1998	0.57	1.17	0.18	0.67	1.55	0.13	1.15	0.31	0.25	0.33	0.27	0.07	0.79	0.13	0.09	0.93	0.08	0.10	0.48	0.08	0.08
1999	0.38	0.97	0.17	0.62	1.22	0.15	1.07	0.45	0.28	0.34	0.29	0.09	0.70	0.12	0.12	0.52	0.06	0.09	0.30	0.02[a]	0.08
2000	0.67	1.10	0.14	0.34	0.58	0.13	1.13	0.35	0.24	0.23	0.18	0.10	0.81	0.16	0.13	0.54	0.06	0.10	0.43	0.03[a]	0.10
2001	0.82	0.86	0.17	0.63	1.30	0.13	1.24	0.22	0.31	0.35	0.26	0.09	0.76	0.13	0.09	0.70	0.05	0.09	0.56	0.05	0.08
2002	0.60	0.70	0.15	0.58	0.93	0.17	1.15	0.29	0.30	0.33	0.35	0.08	0.64	0.17	0.10	0.74	0.07	0.09	0.46	0.05	0.09
2003	0.56	0.93	0.17	0.55	0.91	0.15	1.09	0.30	0.27	0.34	0.35	0.08	0.44	0.20	0.11	0.77	0.09	0.10	0.42	0.05	0.08
2004	0.75	0.93	0.18	0.66	0.95	0.17	1.00	0.34	0.32	0.31	0.26	0.10	0.60	0.12	0.11	0.72	0.05	0.09	0.45	0.05	0.08
2005	0.61	1.07	0.15	0.65	1.32	0.16	0.84	0.44	0.19	0.43	0.30	0.09	0.57	0.15	0.10	0.88	0.07	0.11	0.37	0.05	0.07
2006	0.62	1.00	0.14	0.46	1.08	0.12	0.91	0.25	0.23	0.22	0.30	0.08	0.54	0.10	0.11	0.65	0.05	0.10	0.28	0.05	0.07
2007	0.85	1.07	0.20	0.54	0.91	0.15	0.84	0.62	0.26	0.28	0.30	0.09	0.52	0.11	0.11	0.71	0.06	0.10	0.35	0.05	0.08
2008	0.66	1.15	0.20	0.52	1.16	0.13	0.94	0.29	0.33	0.30	0.24	0.07	0.49	0.17	0.09	0.69	0.05	0.10	0.43	0.05	0.09
2009	0.77	0.76	0.17	0.57	0.78	0.20	0.98	0.24	0.30	0.50	0.32	0.10	0.50	0.14	0.10	0.50	0.10	0.10	0.50	0.10	0.10
2010	0.38	0.77	0.13	0.50	0.97	0.12	0.74	0.28	0.20	0.50	0.32	0.05	0.58	0.13	0.10	0.63	0.10	0.10	0.50	0.10	0.10
2011	0.56	0.64	0.16	0.50	0.57	0.09	0.66	0.12	0.24	0.50	0.24	0.05	0.57	0.07	0.06	0.50	0.05	0.11	0.50	0.05	0.07
2012	0.64	0.47	0.12	0.50	0.68	0.12	0.86	0.19	0.27	0.36	0.40	0.10	0.73	0.04[a]	0.05	0.64	0.04[a]	0.09	0.50	0.05	0.07
2013	0.63	0.35	0.16	0.38	1.03	0.12	0.95	0.18	0.29	0.24	0.34	0.06	0.68	0.06	0.08	0.57	0.02[a]	0.10	0.55	0.05	0.05
2014	0.56	0.88	0.16	0.42	1.25	0.13	0.55	0.20	0.33	0.40	0.36	0.10	0.49	0.05	0.10	0.34	0.03[a]	0.07	0.62	0.05	0.06
2015	0.41	0.48	0.16	0.90	1.15	0.13	0.45	0.17	0.32	0.35	0.36	0.06	0.34	0.05	0.09	0.35	0.02[a]	0.07	1.20	0.05	0.07
2016	0.51	0.86	0.17	0.78	1.75	0.16	1.20	0.23	0.38	0.45	0.37	0.08	0.71	0.07	0.14	0.74	0.05	0.12	0.64	0.05	0.12
2017	0.72	1.10	0.18	0.60	1.20	0.16	0.84	0.26	0.31	0.50	0.30	0.11	0.67	0.10	0.07	0.77	0.07	0.07	0.38	0.05	0.08
2018	0.55	0.98	0.17	0.78	1.10	0.17	0.79	0.36	0.35	0.50	0.26	0.10	0.54	0.12	0.08	0.66	0.07	0.11	0.57	0.05	0.11
2019	0.31	0.79	0.18	0.75	0.84	0.19	0.53	0.28	0.37	0.61	0.25	0.09	0.48	0.12	0.09	0.41	0.10	0.08	0.71	0.12	0.11
2020	0.30	0.59	0.17	0.70	1.00	0.19	0.51	0.29	0.36	0.33	0.28	0.07	0.58	0.15	0.11	0.40	0.07	0.12	0.72	0.15	0.11

[a] Below lower reporting limit. The lower reporting limit for TKN is 0.1 mg/L, for NOx is 0.05 mg/L, and for TP is 0.05 mg/L.

Table C.2. Annual medians of total Kjeldahl nitrogen (TKN), total phosphorus (TP), and nitrate-nitrite (NOx) from 1978 to 2020 for the Mermentau, Mississippi, Ouachita, and Pearl River Basins. TKN, NOx, and TP are presented in mg/L. Blanks indicate no data.

	Mermentau			Mississippi-BC			Mississippi-Pla			Mississippi-SF			Ouachita-H			Ouachita-S			Pearl		
Year	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP
1978	1.25	0.13	0.36	0.82	0.76	0.24	0.91	0.98	0.35	0.89	0.79	0.32	0.65	0.28	0.08	0.90	0.15	0.06	0.50	0.25	0.09
1979	1.12	0.16	0.28	0.56	1.10	0.27	0.85	1.05	0.25	0.84	1.05	0.22	0.78	0.19	0.12	0.66	0.12	0.11	0.49	0.18	0.09
1980	1.33	0.31	0.30	0.74	1.15	0.24	0.76	1.09	0.18	0.71	1.07	0.21	0.68	0.12	0.15	1.15	0.18	0.10	0.63	0.14	0.08
1981	1.30	0.32	0.27	1.01	1.46	0.23	0.82	1.38	0.18	0.99	1.62	0.27	0.66	0.37	0.10	0.75	0.24	0.08	0.70	0.23	0.10
1982	1.30	0.19	0.27	1.16	1.46	0.37	0.99	1.38	0.27	1.22	1.59	0.46	0.68	0.22	0.11	0.98	0.15	0.10	0.91	0.17	0.09
1983	1.07	0.14	0.25	0.69	1.53	0.32	0.70	1.49	0.25	0.86	1.51	0.23	0.62	0.15	0.10	0.90	0.11	0.08	0.54	0.11	0.08
1984	1.12	0.22	0.25	0.65	1.68	0.25	0.83	1.58	0.19	0.92	1.64	0.21	0.63	0.20	0.13	0.72	0.12	0.09	0.53	0.14	0.09
1985	1.23	0.31	0.41	0.94	1.28	0.25	0.96	1.24	0.24	0.78	1.32	0.22	0.71	0.19	0.11	0.59	0.22	0.08	0.68	0.13	0.09
1986	1.61	0.08	0.34	0.85	1.67	0.32	0.94	1.62	0.25	0.82	1.59	0.30	0.74	0.14	0.13	0.59	0.11	0.08	0.85	0.08	0.12
1987	1.78	0.21	0.32	0.95	1.08	0.24	1.12	1.11	0.25	0.70	1.08	0.25	0.83	0.09	0.11	0.78	0.09	0.08	0.77	0.12	0.09
1988	1.11	0.24	0.26	0.70	0.90	0.17	1.06	0.77	0.15	0.77	0.60	0.13	1.04	0.12	0.13	0.72	0.19	0.07	0.82	0.17	0.10
1989	1.00	0.40	0.24	0.63	0.97	0.21	0.81	1.01	0.21	0.72	0.96	0.20	0.98	0.13	0.12	0.69	0.11	0.09	0.80	0.20	0.10
1990	1.05	0.29	0.25	0.57	1.53	0.22	0.79	1.37	0.19	0.71	1.38	0.20	0.74	0.17	0.13	0.67	0.16	0.10	0.78	0.17	0.09
1991	0.97	0.17	0.23	0.60	1.28	0.22	0.77	1.31	0.20	0.59	1.28	0.23	0.75	0.14	0.14	0.65	0.09	0.09	0.95	0.14	0.10
1992	1.01	0.16	0.25	0.87	1.80	0.24	0.64	1.76	0.22	0.63	1.96	0.24	0.73	0.27	0.16	0.66	0.19	0.09	0.88	0.14	0.09
1993	1.08	0.13	0.24	0.71	1.66	0.23	0.78	1.49	0.22	0.79	1.61	0.26	0.69	0.17	0.12	0.63	0.13	0.08	0.65	0.13	0.08
1994	1.15	0.22	0.23	0.63	1.20	0.14	0.69	1.15	0.14	0.59	1.10	0.15	0.72	0.15	0.11	0.56	0.09	0.08	0.69	0.17	0.07
1995	1.19	0.18	0.16	0.67	1.40	0.17	0.76	1.42	0.19	0.85	1.31	0.18	0.73	0.16	0.11	0.64	0.12	0.09	0.73	0.12	0.08
1996	1.18	0.22	0.22	0.96	1.35	0.18	0.69	1.36	0.22	0.71	1.32	0.21	0.91	0.24	0.15	0.77	0.19	0.11	0.64	0.21	0.10
1997	1.07	0.20	0.19	0.76	1.31	0.18	0.61	1.18	0.13	0.64	1.20	0.19	0.88	0.13	0.14	0.75	0.14	0.11	0.62	0.12	0.11

	Mermentau			Mississippi-BC			Mississippi-Pla			Mississippi-SF			Ouachita-H			Ouachita-S			Pearl		
Year	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP
1998	1.27	0.15	0.22	0.57	1.57	0.16	0.60	1.64	0.17	0.79	1.52	0.19	0.72	0.26	0.18	0.73	0.23	0.09	0.61	0.13	0.09
1999	1.04	0.24	0.21	0.72	1.39	0.21	0.83	1.51	0.21	0.84	1.62	0.21	0.58	0.10	0.13	0.62	0.13	0.14	0.71	0.15	0.12
2000	0.98	0.16	0.16	0.66	1.19	0.16	0.53	1.13	0.17	0.58	1.07	0.18	0.75	0.13	0.14	0.68	0.13	0.11	0.63	0.05	0.13
2001	1.18	0.13	0.22	0.56	1.88	0.16	0.84	1.45	0.25	0.88	1.51	0.24	0.69	0.15	0.13	0.69	0.12	0.08	0.56	0.10	0.12
2002	0.96	0.15	0.19	0.63	1.16	0.15	0.75	1.06	0.16	0.76	1.08	0.18	0.79	0.19	0.15	0.57	0.17	0.09	0.61	0.15	0.11
2003	1.40	0.23	0.25	0.84	1.14	0.18	0.86	1.12	0.19	0.85	1.15	0.19	0.83	0.19	0.14	0.65	0.17	0.12	0.67	0.17	0.12
2004	1.13	0.09	0.22	0.68	1.28	0.15	0.83	1.20	0.18	0.94	1.11	0.17	0.84	0.16	0.14	0.63	0.12	0.13	0.62	0.15	0.12
2005	1.45	0.21	0.26	0.66	1.78	0.17	1.00	1.44	0.18	0.80	1.58	0.19	0.68	0.15	0.10	0.72	0.12	0.09	0.57	0.17	0.11
2006	1.08	0.12	0.21	0.61	1.47	0.15	0.78	1.41	0.17	0.74	1.37	0.18	0.75	0.18	0.15	0.79	0.09	0.11	0.53	0.18	0.10
2007	1.19	0.19	0.26	0.74	1.60	0.21	0.91	1.69	0.24	1.03	1.75	0.24	0.77	0.16	0.12	0.64	0.10	0.09	0.54	0.19	0.11
2008	1.12	0.14	0.24	0.71	1.58	0.20	0.83	1.55	0.20	0.75	1.50	0.20	0.66	0.12	0.12	0.63	0.11	0.10	0.68	0.18	0.12
2009	0.84	0.10	0.19	0.56	1.11	0.16	0.75	1.10	0.18	0.69	1.06	0.17	0.64	0.10	0.12	0.74	0.05	0.10	0.50	0.14	0.10
2010	0.69	0.17	0.18	0.50	1.57	0.10	0.81	1.49	0.10	0.97	1.46	0.10	0.63	0.03[a]	0.07	0.58	0.06	0.05	0.50	0.16	0.10
2011	0.69	0.09	0.23	0.50	1.26	0.15	0.50	1.35	0.09	0.50	1.32	0.15	0.46	0.06	0.09	0.61	0.01[a]	0.09	0.50	0.11	0.09
2012	1.00	0.04[a]	0.17	0.38	1.07	0.09	0.50	1.04	0.13	0.50	0.99	0.16	0.87	0.11	0.13	0.73	0.05	0.05	0.50	0.16	0.11
2013	0.68	0.08	0.22	0.40	1.16	0.15	0.54	1.00	0.16	0.41	1.07	0.17	0.62	0.08	0.14	0.59	0.06	0.09	0.43	0.15	0.05
2014	0.61	0.11	0.32	0.63	1.35	0.21	0.60	1.30	0.18	0.55	1.30	0.21	0.29	0.10	0.14	0.45	0.06	0.11	0.60	0.21	0.08
2015	0.22	0.07	0.20	0.99	1.20	0.18	0.65	1.25	0.19	0.72	1.30	0.15	0.52	0.09	0.12	0.42	0.05	0.09	0.83	0.19	0.09
2016	1.10	0.21	0.22	0.76	1.90	0.17	0.69	1.90	0.22	0.72	1.85	0.17	0.72	0.12	0.17	0.67	0.08	0.10	0.82	0.16	0.08
2017	1.20	0.19	0.25	0.57	1.50	0.23	0.87	1.75	0.14	0.40	1.70	0.14	0.99	0.12	0.16	0.86	0.11	0.10	0.82	0.10	0.10
2018	1.25	0.22	0.27	0.52	1.35	0.19	0.72	1.25	0.18	0.85	1.10	0.16	0.59	0.12	0.15	0.70	0.06	0.12	0.75	0.06	0.10
2019	0.61	0.18	0.25	0.70	1.10	0.17	0.54	1.10	0.14	0.48	1.20	0.15	0.46	0.14	0.13	0.52	0.05	0.05	0.65	0.09	0.10
2020	0.60	0.29	0.31	0.80	1.00	0.15	0.69	1.20	0.21	0.25	1.20	0.18	0.37	0.14	0.18	0.55	0.05	0.07	0.67	0.06	0.10

[a] Below lower reporting limit. The lower reporting limit for TKN is 0.1 mg/L, for NOx is 0.05 mg/L, and for TP is 0.05 mg/L.

Table C.3. Annual medians of total Kjeldahl nitrogen (TKN), total phosphorus (TP), and nitrate-nitrite(NOx) from 1978 to 2020 for the Red, Tangipahoa, Tchefuncte, Tensas, Tickfaw, and Vermilion River Basins. TKN, NOx, and TP are presented in mg/L. Blanks indicate no data.

	Red-M			Red-S			Tangipahoa			Tchefuncte			Tensas			Tickfaw			Vermilion		
Year	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP
1978	1.48	0.08	0.28				0.47	0.33	0.06	0.61	0.11	0.05				0.31	0.15	0.05	1.95	0.38	0.59
1979	0.90	0.09	0.33				0.44	0.24	0.10	0.65	0.13	0.10				0.53	0.22	0.09	1.26	0.36	0.48
1980	0.96	0.19	0.22				0.61	0.22	0.06	0.85	0.15	0.08				0.43	0.26	0.05	1.31	0.41	0.50
1981	0.90	0.17	0.31	0.82	0.25	0.27	0.55	0.30	0.07	0.85	0.16	0.08				0.71	0.29	0.12	1.49	0.69	0.68
1982	1.06	0.21	0.34	1.10	0.23	0.19	0.62	0.38	0.15	1.02	0.15	0.09				0.94	0.27	0.09	1.50	0.47	0.55
1983	0.90	0.13	0.29	0.89	0.17	0.18	0.69	0.22	0.10	0.77	0.12	0.10				0.75	0.19	0.09	1.26	0.32	0.44
1984	1.14	0.16	0.20	0.96	0.16	0.18	0.56	0.33	0.13	0.75	0.14	0.09				0.84	0.24	0.10	1.49	0.34	0.52
1985	1.44	0.25	0.34	0.98	0.25	0.22	0.40	0.25	0.07	0.64	0.13	0.11				0.92	0.20	0.10	1.56	0.36	0.51
1986	1.14	0.19	0.31	0.96	0.19	0.21	0.64	0.32	0.12	0.93	0.06	0.19				0.76	0.26	0.11	1.21	0.67	0.50
1987	1.14	0.18	0.37	1.06	0.19	0.21	0.93	0.21	0.11	1.21	0.12	0.14				0.78	0.22	0.11	1.60	0.35	0.52
1988	1.07	0.16	0.14	0.97	0.07	0.13	0.94	0.32	0.13	1.01	0.15	0.12	0.99	0.68	0.23	1.02	0.27	0.11	1.39	0.51	0.45
1989	1.02	0.14	0.19	0.96	0.13	0.19	0.62	0.29	0.12	1.02	0.13	0.15	1.04	0.30	0.31	0.86	0.27	0.12	1.25	0.42	0.44
1990	1.08	0.25	0.19	0.91	0.22	0.31	0.37	0.34	0.10	0.72	0.09	0.11	0.99	0.43	0.24	0.61	0.22	0.09	1.02	1.02	0.38
1991	0.89	0.20	0.24	0.81	0.15	0.20	0.48	0.33	0.15	0.71	0.08	0.11	0.97	0.26	0.32	0.50	0.25	0.11	1.09	0.34	0.41
1992	0.80	0.15	0.15	0.87	0.14	0.25	0.43	0.24	0.13	0.67	0.10	0.10	0.90	0.40	0.26	0.38	0.21	0.10	1.18	0.43	0.42
1993	0.71	0.21	0.16	0.66	0.17	0.23	0.51	0.31	0.11	0.62	0.10	0.09	0.85	0.21	0.22	0.52	0.23	0.06	1.09	0.35	0.35
1994	0.65	0.18	0.09	0.87	0.12	0.19	0.50	0.36	0.14	0.79	0.08	0.08	1.30	0.27	0.31	0.53	0.28	0.09	1.35	0.47	0.35
1995	0.75	0.03[a]	0.12	0.86	0.12	0.16	0.49	0.33	0.09	0.65	0.07	0.06	0.99	0.34	0.29	0.61	0.24	0.08	1.21	0.41	0.35
1996	0.81	0.21	0.08	1.03	0.22	0.12	0.33	0.33	0.09	1.03	0.10	0.09	1.34	0.72	0.34	0.40	0.22	0.10	1.38	0.54	0.34
1997	0.84	0.21	0.10	0.80	0.19	0.12	0.47	0.31	0.11	0.64	0.13	0.10	1.21	0.07	0.36	0.40	0.25	0.10	1.31	0.53	0.33

[a] Below lower reporting limit. The lower reporting limit for TKN is 0.1 mg/L, for NOx is 0.05 mg/L, and for TP is 0.05 mg/L.

	Red-M			Red-S			Tangipahoa			Tchefuncte			Tensas			Tickfaw			Vermilion		
Year	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP	TKN	NOx	TP
1998	1.00	0.29	0.10	0.88	0.22	0.11	0.51	0.27	0.12	0.53	0.11	0.10	0.92	0.39	0.18	0.42	0.21	0.08	1.07	0.69	0.25
1999	0.54	0.12	0.12	0.66	0.07	0.12	0.30	0.25	0.13	0.53	0.06	0.11	0.88	0.16	0.26	0.48	0.21	0.12	0.76	0.79	0.34
2000	0.59	0.18	0.13	0.81	0.10	0.15	0.22	0.12	0.10	0.53	0.05	0.11	0.92	0.25	0.14	0.24	0.09	0.10	0.83	0.80	0.27
2001	0.76	0.20	0.15	0.71	0.22	0.11	0.46	0.27	0.13	0.69	0.14	0.09	0.94	0.32	0.29	0.53	0.14	0.08	1.13	0.36	0.33
2002	0.65	0.18	0.11	0.76	0.10	0.11	0.40	0.26	0.12	0.70	0.10	0.09	1.15	0.37	0.28	0.49	0.20	0.11	0.90	0.38	0.34
2003	0.69	0.15	0.09	0.88	0.05	0.13	0.28	0.28	0.10	0.67	0.13	0.10	1.17	0.21	0.32	0.34	0.23	0.10	1.14	0.39	0.39
2004	0.84	0.14	0.12	0.86	0.05	0.12	0.45	0.30	0.09	0.69	0.13	0.12	1.33	0.20	0.32	0.38	0.21	0.08	1.12	0.38	0.33
2005	0.68	0.10	0.09	0.90	0.05	0.10	0.40	0.33	0.12	0.65	0.15	0.12	1.22	0.27	0.34	0.68	0.21	0.11	0.95	0.60	0.33
2006	0.86	0.19	0.10	1.24	0.05	0.11	0.37	0.25	0.09	0.46	0.15	0.10	1.15	0.33	0.26	0.42	0.17	0.10	0.93	0.50	0.27
2007	0.76	0.15	0.10	0.80	0.14	0.14	0.25	0.23	0.09	0.52	0.09	0.10	0.91	0.28	0.21	0.40	0.16	0.10	0.96	0.55	0.38
2008	0.64	0.21	0.12	0.89	0.08	0.12	0.28	0.21	0.11	0.62	0.10	0.10	1.15	0.48	0.30	0.38	0.17	0.10	1.13	0.44	0.37
2009	0.70	0.09	0.13	0.70	0.05	0.10	0.50	0.20	0.10	0.50	0.10	0.10	0.77	0.38	0.29	0.50	0.11	0.10	0.78	0.23	0.34
2010	0.63	0.07	0.05	0.43	0.01[a]	0.07	0.50	0.24	0.06	0.72	0.15	0.10	0.68	0.03[a]	0.11	0.53	0.19	0.05	0.76	0.53	0.30
2011	0.54	0.07	0.09	0.62	0.01[a]	0.08	0.50	0.21	0.10	0.50	0.08	0.09	0.78	0.22	0.24	0.50	0.12	0.12	0.61	0.18	0.27
2012	0.79	0.06	0.08	0.79	0.01[a]	0.08	0.50	0.26	0.13	0.50	0.14	0.17	0.78	0.06	0.14	0.48	0.16	0.08	1.07	0.26	0.32
2013	0.61	0.06	0.09	0.43	0.01[a]	0.10	0.26	0.22	0.05	0.64	0.14	0.08	0.82	0.15	0.42	0.47	0.13	0.08	0.79	0.22	0.36
2014	0.38	0.10	0.11	0.39	0.05	0.07	0.61	0.26	0.09	0.75	0.14	0.11	0.45	0.18	0.15	0.53	0.17	0.09	0.58	0.23	0.39
2015	0.47	0.13	0.15	0.22	0.03[a]	0.07	1.10	0.29	0.09	0.78	0.12	0.10	0.48	0.14	0.22	1.20	0.18	0.10	0.31	0.15	0.33
2016	0.65	0.16	0.16	0.87	0.05	0.19	0.35	0.27	0.07	0.86	0.09	0.13	1.30	0.48	0.34	0.71	0.24	0.09	1.20	0.31	0.36
2017	0.80	0.19	0.11	1.00	0.09	0.14	0.64	0.29	0.09	0.69	0.11	0.11	1.40	0.37	0.28	0.70	0.22	0.09	0.89	0.32	0.34
2018	0.71	0.16	0.11	0.95	0.05	0.12	0.68	0.26	0.10	0.77	0.05	0.15	1.02	0.25	0.20	0.60	0.21	0.13	1.00	0.40	0.42
2019	0.35	0.18	0.11	0.63	0.08	0.08	0.37	0.19	0.08	1.00	0.05	0.11	0.54	0.21	0.38	0.41	0.15	0.10	0.63	0.33	0.38
2020	0.42	0.21	0.13				0.44	0.24	0.08	0.83	0.05	0.11	0.36	0.44	0.33	0.80	0.16	0.09	0.55	0.50	0.47

[a] Below lower reporting limit. The lower reporting limit for TKN is 0.1 mg/L, for NOx is 0.05 mg/L, and for TP is 0.05 mg/L.