Mississippi Valley Division,
Regional Planning and Environment Division South

Yazoo Backwater Area Water Management Project

APPENDIX H- Water Quality

November 2024

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From: Kim Caviness <kcaviness@mdeq.ms.gov>
Sent: Thursday, September 5, 2024 5:04 PM
To: Johnson, Brian S CIV USARMY CEMVK (USA)
Subject: [Non-DoD Source] Follow-Up RE: MS Nutrient Criteria Development Efforts

Hi Brian!

Thank you for reaching out regarding your interest in the status of MS's efforts to develop nutrient criteria.

As we discussed on the phone yesterday, the most recent version of Mississippi's Nutrient Criteria Development Plan was released in 2016. MDEQ has continued efforts to collect data and information, develop WQ models, and explore other analytical tools to assist in our evaluation of nutrients and their impacts to our surface waters. MDEQ is currently working with EPA to update this our Nutrient Criteria Development Plan that will include a revised timeline for nutrient criteria in MS waterbodies. The updated plan will hopefully be finalized in early 2025.

Going forward, MS will continue to use a sequenced approach to developing criteria, as discussed in the 2016 document. With this approach MDEQ will establish nutrient criteria for large residence time receiving waters first to ensure protection of downstream uses (as required by the Clean Water Act). While we do not yet have an exact updated timeline, MDEQ plans to develop nutrient criteria for waterbodies in the following order: (1) Lakes and Reservoirs (outside the MS Alluvial Plain), (2) Coastal and Estuarine Waters, (3) Wadeable Streams (outside the MS Alluvial Plain), and (4) Delta Waters (surface waters within the MS Alluvial Plain).

Although MDEQ has multiple ongoing efforts underway to inform the nutrient criteria development process, since the Delta Waters are the last in the sequence of waterbody types, it is anticipated that we are multiple years away from having numeric criteria for Delta Waters that have been formally adopted into MS's Water Quality Standards.

I hope our discussion and this message provides you with the information that you need for your current task. If you need any further information, please do not hesitate to contact me.

Thanks!
KC

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1.1 INTRODUCTION

Across the world as farmers have ramped up production to meet the increasing populations demand for food, water quality has suffered. Most of the major river basins focused on agricultural production, especially, those from the upper Midwest have suffered from degraded water quality conditions for many years due to agricultural runoff. To a lesser extent, the Mississippi Yazoo Basin has experienced a decline in water quality conditions over the last six decades. Many parameters related to nutrients and suspended sediment have been noted in TMDL studies throughout the state by the Mississippi Department of Environmental Quality (MDEQ). However, water quality criteria for some of these parameters are still in development. Many efforts have been made to describe these conditions through the use of numerical models and routine monitoring. These efforts have allowed practitioners to develop a better understanding of the root causes that plague riverine ecosystems. This report will provide insight into the numerical nutrient Spatially Referenced Regression On Watershed (SPARROW) models created for the Mississippi River Valley by the U.S. Geological Survey (USGS) and the sub basins contained within. This will also include a review of the most recent SPARROW model created specifically for the 9 basins in the state of Mississippi which includes the Yazoo Basin. This report will also analyze the water quality data collected from the Yazoo River Basin over the last few decades. The analysis will pay close attention to the depressed levels of dissolved oxygen concentrations observed throughout the basin. The data will also show the trends and current conditions of nutrient concentrations observed in the main stems of the Steele Bayou and Big Sunflower basins. This report will describe the declining river stages observed over the last 90 years in the Yazoo Basin. This appendix will show that baseline water quality conditions in the Yazoo Backwater Area and conditions in the downstream area will not be negatively impacted through the implementation of four proposed alternatives for flood control and water management in the Yazoo Area Basin.

1.2 MDEQ WATER QUALITY STANDARDS

Regulations for Surface Water Quality Criteria for Intrastate, Interstate, and Coastal Waters was adopted by the Mississippi Commission on Environmental Quality June 24, 2021. The water use classification for all perennial surface waters of the Yazoo Backwater Area in the Mississippi water quality regulations is for Fish and Wildlife Support. The designated beneficial use for these waters is Aquatic Life Support, Fish Consumption, and Secondary Contact Recreation (MDEQ 2021). Mississippi's water quality standard for sediment is narrative and reads as follows: "Waters shall be free from materials attributed to municipal, industrial, agricultural or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation or to aquatic life and wildlife or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use" (MDEQ 2021). The following narratives describe the applicable numeric water quality criteria for the Yazoo Basin watershed perennial surface waters:

Dissolved Oxygen: Dissolved oxygen concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l.

pH: The normal pH of the waters shall be 6.0 to 9.0.

Temperature: The maximum water temperature increase above natural temperatures shall not exceed 5°F (2.8°C) in streams, lakes, and reservoirs, nor shall the maximum water temperature exceed 90°F (32.2°C), except that in the Tennessee River, the temperature shall not exceed 86°F (30°C).

Toxic Substances:

Aquatic Life and Human Health Standards (a) Aquatic Life - The concentration of toxic substances in Surface Waters of the State shall not result in chronic or acute toxicity or impairment of the uses of aquatic life. (b) Human Health - The concentration of toxic substances shall not exceed the level necessary to protect human health through exposure routes of fish (and shellfish) tissue consumption, water consumption, or other routes identified as appropriate for the waterbody. Specific criteria subject to surface water classified as those used for Fish and Wildlife Support regulate the following:

Bacteria: Culturable E.coli shall not exceed a geometric mean of 126 per 100 ml over a 30-day period, nor shall the samples examined during a 30-day period exceed 410 per 100 ml more than 10% of the time. There should be a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples.

- **Specific Conductance:** There shall be no substances added to increase the conductivity above 1000 micromhos/cm for freshwater streams.
- **Total Dissolved Solids:** There shall be no substances added to the waters to cause the dissolved solids to exceed 750 mg/l as a monthly average value, nor exceed 1500 mg/l at any time for freshwater streams.

The regulations adopted in 2021 by the Mississippi Commission on Environmental Quality also adopted the following language for the Modified Fish and Wildlife Support Classification and the Drainage Waters Classification.

1.3 MODIFIED FISH AND WILDLIFE SUPPORT

Waters in this classification are intended to support water quality appropriate for a modified population of fish, aquatic life, and wildlife that are limited or substantially degraded due to alternations of the physical habitat, hydrology, or water quality based on one or more 40 CFR 131.10(g) factors. Waters within this classification share the same water quality criteria as Fish and Wildlife waters with the exception of any modified criteria (narrative or numeric) that have been established for a waterbody or waterbody segment. Waters that meet the Modified Fish and Wildlife criteria shall also be suitable for fish consumption and secondary contact recreation. Waters classified as Modified Fish and Wildlife must also protect the attainment of water quality standards within downstream waters. While this classification appears to have applicability to some streams in the lower YBA, none were identified in the 2021 regulations. Future analysis may find this classification to be well suited for the streams and/or basins impacted by this project.

1.4 DRAINAGE WATERS CLASSIFICATION

Waters within this classification are intended strictly for the drainage of agricultural lands, agricultural irrigation, livestock watering, industrial cooling, or process water supplies. Waters classified as Drainage Waters may contain a transient population of aquatic life when there is suitable habitat for survival of aquatic life. However, typical conditions within these waters are not adequate to support the reproductive cycles for fish and other aquatic life. Waters in this classification can include, but are not limited to, wholly artificial canals or ditches, waterbodies or ditches located behind or influenced by a control structure, or waters which are part of a water control or water management system. One or more of the 40 CFR 131.10(g) factors apply to waters in this class. Waters within this classification share the same water quality criteria as Fish and Wildlife waters with the exception of any modified criteria (narrative or numeric) that have been established for a waterbody or waterbody segment. Waters that meet the Drainage Waters criteria shall also be suitable for fish consumption and secondary contact recreation. Waters classified as Drainage Waters must also protect the attainment of water quality standards within downstream waters. While this classification appears to have applicability to those waters impounded by the Steele Bayou and Little Sunflower Outlet Structures, none were identified in the 2021 regulations. Future analysis may find this classification to be well suited for the pooled waters upstream of the Steele Bayou and Little Sunflower River outlet structures.

MDEQ is currently working on the development of additional water quality standards for the state. A telephone conversation (3 September 2024) and subsequent email (5 September 2024) (see Attachment 1) with Ms. Kim Caviness who serves as the Branch Chief for the Office of Water Quality Standards at MDEQ described the recent annual efforts to establish undefined criteria for watersheds in the state. The most recent plan for the development of nutrient criteria (MDEQ, 2016) was not able to reach completion. However, the plan did establish the order in which waterbody types would be addressed in the future. This chronological order is as follows: (1) Lakes and Reservoirs (outside the MS Alluvial Plain), (2) Coastal and Estuarine Waters, (3) Wadable Streams (outside the MS Alluvial Plain), and (4) Delta Waters (surface waters within the MS Alluvial Plain). This schedule would imply that the Yazoo Backwater Area would be the last system to be assessed for nutrient criteria development. There is no projected date for the establishment of Total Suspended Solids (TSS) criteria for surface waters in the state.

1.5 MDEQ TMDL AND 303(D) LISTINGS

The YBWP Area consists of three major basins: Steele Bayou, Deer Creek, and the Big Sunflower River. For the analysis of impaired water bodies, the study area was defined as the extent of the modeled 93-foot pool. As of September 2024, fifteen TMDL have been developed collectively for Deer Creek (3), the Big Sunflower River Basin (1), Steele Bayou (1), Jaynes Bayou (1), Silver Creek (1), Howlett Bayou/Cypress Bayou (1), False River (1), Cypress Lake (1), and the Yazoo River Basin (5) that apply to the Yazoo Backwater study area (Table 1-1). These TMDL include organic enrichment/low dissolved oxygen and nutrients, sediment, and fecal coliform for Deer Creek, organic enrichment, nutrients, and sediment for the Big Sunflower River Basin, sediment for Steele Bayou, total nitrogen and total phosphorus for Jaynes Bayou, total nitrogen and total phosphorus for Silver Creek, biological impairment by toxicity for Howlett/Cypress Bayous, total nitrogen, total phosphorus, and organic enrichment/low dissolved oxygen for False River, total nitrogen and total phosphorus for Cypress Lake, and legacy pesticides, DDT, and toxaphene, sediment, and total nitrogen and total phosphorus for the Yazoo River Basin.

Table 1-1 TMDL Applicable to the Yazoo Backwater Project Area

Water	TMDL	Year
Deer Creek	TMDL for Organic Enrichment/Low DO and Nutrients – Deer Creek	2003
Yazoo River Basin	TMDL for the Legacy Pesticides, DDT and Toxaphene in the Yazoo River Basin	2005
Deer Creek	Sediment TMDL for Deer Creek	2003
Deer Creek	Fecal Coliform TMDL for Deer Creek	2003
Yazoo River Basin	TMDL for the Legacy Pesticides, DDT, and Toxaphene in the Yazoo River Basin	2003
Big Sunflower River	TMDL for Organic Enrichment, Nutrients, and Sediment for the Big Sunflower River	2003
Yazoo River Basin	TMDL Yazoo River Basin Delta Region for Impairment Due to Sediment	2008
Steele Bayou	Sediment TMDL for the Steele Bayou Watershed including Main Canal, Granny Baker Bayou, Granicus Bayou, and Black Bayou	2003
Yazoo River Basin	TMDL Total Nitrogen and Total Phosphorus for Selected Large Rivers in the Delta	2008
Jaynes Bayou	TMDL Total Nitrogen and Total Phosphorus for Jaynes Bayou	2008
Silver Creek	TMDL Total Nitrogen and Total Phosphorus for Silver Creek	2008
Howlett Bayou, Cypress Bayou	TMDL for Biological Impairment by Toxicity or Unknown Pollutants	2003
False River	TMDL Total Nitrogen, Total Phosphorus, and Organic Enrichment/Low Dissolved Oxygen for the False River	2008
Cypress Lake	TMDL Total Nitrogen and Total Phosphorus for Cypress Lake	2008
Yazoo River Basin	TMDL Yazoo River Basin Designated Oxbow Lakes for Sediment	2008

Within the above TMDLs, eighteen impaired segments are located within the modeled 93-foot flood zone (Table 1-2). These segments include reaches on Deer Creek, Big Sunflower River, Big Sunflower Diversion Channel, Steele Bayou, Jaynes Bayou, Silver Creek, Howlett Bayou, Cypress Bayou, False River, Cypress Lake, Holly Bluff Cutoff, and the Yazoo River. Impairments for each listed segment vary and may be due to nutrients, organic enrichments/low dissolved oxygen (DO), DDT and toxaphene, sediment/siltation, pathogens, or biological impairment by unknown pollutants. The TMDL and impaired segments that affect the Yazoo Backwater study area are discussed in the following sections.

Table 1-2 TMDL Segments, Yazoo Backwater Project Area

Name	ID	County	HUC	Cause
Deer Creek	MS403M6	Washington	08030209	DDT, Nutrient Pollution, Organic Enrichment/Low Dissolved Oxygen, Pathogens, Sediment, Toxaphene
Deer Creek	MS406E	Sharkey		DDT, Organic Enrichment/Low Dissolved Oxygen, Sediment, Total Nitrogen, Total Phosphorus, Toxaphene
Deer Creek	MS407M1	Sharkey, Issaquena		DDT, Organic Enrichment/Low Dissolved Oxygen, Total Nitrogen, Total Phosphorus, Toxaphene
Big Sunflower River	MSBIGSUNRM4	Washington, Sharkey, Yazoo	08030207	DDT, Nutrient Pollution, Organic Enrichment/Low Dissolved Oxygen, Sediment, Toxaphene
Big Sunflower River	MSBIGSUNRE	Sharkey, Yazoo, Washington, Humphreys		DDT, Toxaphene
Big Sunflower River	MSBGSND2E	Issaquena, Warren		DDT, Sediment, Toxaphene

Name	ID	County	HUC	Cause
Diversion Channel				
Big Sunflower River Diversion Channel	MSBGND1E	Warren, Issaquena		DDT, Sediment, Toxaphene
Steele Bayou	MS404M3	Washington, Issaquena	08030209	Sediment
Steele Bayou	MS404E	Washington, Issaquena, Sharkey, Warren		DDT, Sediment, Total Nitrogen, Total Phosphorus, Toxaphene
Steele Bayou	MS407S	Issaquena, Sharkey, Warren		DDT, Toxaphene
Jaynes Bayou	MS393E	Sharkey	08030207	DDT, Sediment, Total Nitrogen, Total Phosphorus, Toxaphene
Silver Creek	MS394E	Humphreys, Yazoo	08030207	DDT, Sediment, Total Nitrogen, Total Phosphorus, Toxaphene
Howlett Bayou	MS396M2	Sharkey	08030207	Biological Impairment
Cypress Bayou	MS396M1	Sharkey	08030207	Biological Impairment
False River	MS396E	Sharkey	08030207	DDT, Organic Enrichment/Low Dissolved Oxygen, Sediment, Total Nitrogen, Total Phosphorus, Toxaphene
Cypress Lake	MS407CLE	Issaquena	08030202	DDT, Sediment, Total Nitrogen, Total Phosphorus, Toxaphene

Name	ID	County	HUC	Cause
Holly Bluff Cutoff	MSHBCUTM	Yazoo, Sharkey		DDT, Nutrient Pollution, Organic Enrichment/Low Dissolved Oxygen, Sediment, Toxaphene
Yazoo River	MSYAZR1E	Issaquena, Warren	08030208	DDT, Sediment, Total Nitrogen, Total Phosphorus, Toxaphene

1.6 TMDL FOR ORGANIC ENRICHMENT/LOW DO AND NUTRIENTS FOR DEER CREEK (MDEQ, 2003E)

This TMDL addresses listings from the 1996 Mississippi Section 303(d) list that fall within the Yazoo Backwater study area. These water bodies are listed as either evaluated or monitored for low DO/organic enrichment and nutrients. The water body impacted by the 93-foot Yazoo Backwater pool elevation is identified in Table 1-2. This includes Deer Creek from Arcola to Percy (MS403M6).

Low DO typically occurs during seasonal low-flow, high-temperature periods that occur during the late summer and early fall. Elevated oxygen demand is of primary concern during low-flow periods because the effects of minimum dilution potential and high temperatures combined to produce the worst-case potential effect on water quality. This TMDL states that the water quality standard for dissolved oxygen shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l to support aquatic life. While Mississippi currently does not have standards for allowable nutrient concentrations, it is understood that elevated levels of nutrients may decrease DO concentrations. Therefore, this TMDL developed for DO also addresses the potential impact of elevated nutrients.

The model used in developing this Phase 1 TMDL included both nonpoint and point sources of total ultimate biochemical oxygen demand (TBODu) in the Deer Creek Watershed. This TMDL has been developed as a Phase 1 TMDL because data collected during the critical conditions, that could be used to calibrate the model, are not currently available. TBODu loading from nonpoint sources in the watershed was accounted for by using an estimated background concentration of TBODu in the stream. In addition, the estimated organic loading from direct discharges of wastewater into Deer Creek was included as an additional nonpoint source. There are two NPDES Permitted discharges located in the watershed that are included as point sources in the model. The load and waste load allocations developed for TBODu are equal to the maximum assimilative capacity of Deer Creek, as indicated by predictive modeling. Thus, there is no assimilative capacity for additional TBODu loading in this waterbody segment.

1.7 TMDL FOR THE LEGACY PESTICIDES, DDT, AND TOXAPHENE IN THE YAZOO RIVER BASIN (MDEQ, 2005)

This TMDL addresses listings form the 1996 Mississippi Section 303(d) list that fall within the Yazoo Backwater study area. The water bodies impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. These include Deer Creek from Arcola to Percy (MS403M6), Deer Creek from Smedes to Valley Park (MS407M1), Big Sunflower River from Headwaters at Confluence with Whittaker Bayou to the Yazoo River (MSBIGSUNRE), Big Sunflower River Diversion Channel from HUC Boundary 08030207 to HUC Boundary 08030209 (MSBGSND2E), Big Sunflower River Diversion Channel from HUC Boundary 08030208 to Confluence with Steele Bayou (MSBGSND1E), Steele Bayou Near Issaquena from Black Bayou to the Yazoo River (MS404E), Steele Bayou Near Onward from Highway 1 to the Yazoo River (MS407S), Jaynes Bayou Near Rolling Fork from Headwaters to the Big Sunflower River (MS393E), Silver Creek Near Holly Bluff from Headwaters to the Big Sunflower River (MS394E), False River Near Smedes from Headwaters to the Little Sunflower River (MS396E), Cypress Lake Oxbow Lake Near Valley Park (MS407CLE), and the Yazoo River from Confluence with the Big Sunflower River to Confluence with the Mississippi River (MSYAZR1E). This TMDL is for DDT and toxaphene, which have been found in fish flesh samples.

DDT contamination has been shown to weaken eggshells of certain avian species, such as eagles and pelicans, which can severely impact reproduction rates. The use of DDT was prohibited in the United States in 1973, and toxaphene was banned in 1982. Production of both has ceased in the United States. Unfortunately, degraded metabolites of the parent compound are still present in the Yazoo River Basin. Elevated levels have been found in several fish species, and sediment tests show that the legacy pesticides are still present in the fields and streams. Due to concern about the carcinogenic impact of these pollutants, MDEQ issued a basin-wide fish consumption advisory for 4 species of fish. The good news is that the pesticide levels found in fish are going down. The purpose of this TMDL document is to promote further reduction of the levels found in the aquatic species by promoting best management practices that keep the sediment (and the pesticides) on the fields and out of the streams.

1.8 SEDIMENT TMDL FOR DEER CREEK (MDEQ, 2003B)

This TMDL addresses listings form the 1996 Mississippi Section 303(d) list that fall within the Yazoo Backwater study area. The water bodies impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. These water bodies are listed as either evaluated or monitored for sediment/siltation. This includes Deer Creek from Arcola to Percy (MS403M6).

This TMDL states that the beneficial use of the standard for sediment/siltation includes aquatic life support. Waters shall be free from materials attributable to municipal, industrial, agricultural, or other dischargers producing color, odor, taste, total suspended solids, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses. TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure. In this case, an “other appropriate measure” is used to express the TMDL as the tons of sediment that can be discharged from an acre of a sub watershed during a day(tons/acre/day) at the effective discharge and still attain the applicable water quality standard. This results in a range of acceptable reference yields of 2.4E-03 to 7.3E-03 tons per acre per day at the effective discharge.

1.9 PHASE 1 FECAL COLIFORM TMDL FOR DEER CREEK (MDEQ, 2003A)

This TMDL addresses listings from the 1996 Mississippi Section 303(d) list that falls within the Yazoo Backwater study area. The water bodies impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes Deer Creek from Arcola to Percy (MS403M6).

This TMDL states that the water quality standards for fecal coliform are divided into two time periods. The criteria for the first period, May-October, states that fecal coliform colony counts not to exceed a geometric mean of 200 per 100ml, nor shall more than 10 percent of samples examined during any month exceed a colony count of 400 per 100ml. From November-April the criteria states that fecal coliform colony counts shall not exceed a geometric mean of 2000 per 100 ml, nor shall more than 10 percent of the samples examined during any month exceed a colony count of 4000 per 100 m.

1.10 TMDL FOR THE LEGACY PESTICIDES, DDT, AND TOXAPHENE IN THE YAZOO RIVER BASIN (MDEQ, 2003G)

This TMDL addresses listings from the 1996 and 1998 Mississippi Section 303(d) list that falls within the Yazoo Backwater study area. The water bodies impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes Big Sunflower River near Anguilla from Confluence with Bogue Phalia to mouth at Yazoo River (MSBIGSUNRM4) and Holly Bluff Cutoff near Anguilla from Confluence with Bogue Phalia to mouth at Yazoo River (MSHBCUTM).

DDT and Toxaphene have decades long half-lives rather than most of today’s environmental half-lives of days or weeks. Even after 25 years of little or no use, DDT metabolites are being found that are degraded metabolites of the parent compound. DDT contamination has been linked to problems with the reproduction rates of certain avian species such as eagles and pelicans. The eggs from these and other species were weakened due to contamination and reproduction was severely impacted. The use of DDT was prohibited in the United States in 1973, and toxaphene was banned in 1982. Production of both has ceased in the United States. Unfortunately, the residues of the chemicals are still present in the Yazoo River Basin. Elevated levels have been found in several fish species, and sediment tests show that the legacy pesticides are still present in the fields and streams. Although DDT and toxaphene levels remain a concern in the Mississippi Delta, data indicate a significant decline in levels.

1.11 TMDL FOR ORGANIC ENRICHMENT, NUTRIENTS, AND SEDIMENT FOR THE BIG SUNFLOWER RIVER (MDEQ, 2003F)

This TMDL addresses listings from the 1998 Mississippi Section 303(d) list of impaired water bodies. Two segments within the Yazoo Backwater study area fall within this list and are included in Table 1-2. These include Big Sunflower River near Anguilla from confluence with Bogue Phalia to Yazoo River (MSBIGSUNRM4) and Holly Bluff Cutoff near Anguilla from Chappel Landing to Holly Bluff (MSHBCUTM).

For organic enrichment/low dissolved oxygen and nutrients, the applicable state standard specifies that the dissolved oxygen concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l. Mississippi currently does not have standards for allowable nutrient concentrations, however, since elevated levels of nutrients may cause low levels of dissolved oxygen, the TMDL developed for dissolved oxygen also addresses the potential impact of elevated nutrients in the Big Sunflower River watershed.

This TMDL states that for organic enrichment/dissolved oxygen and nutrients, the DO predicted impairments for the two segments MSBIGSUNRM4 and MSHBCUT resulted in part from hydraulic control structures located within these segments. For example, in MSBIGSUNRM4 a weir located below Highway 12 results in increased predicted depths and decreased velocities (decreased reaeration), and increased retention time (greater impacts of sediment oxygen demand). The combined impact in MSBIGSUNRM4, for the base flow critical condition, was a predicted utilization of approximately 75 % of the available DO deficit in the absence of external TBODu loads, providing little remaining assimilative capacity for those external loads. A weir located in the Holly Bluff Cutoff (MSHBCUT) similarly impacts flows and DO depletions in that segment. Since the utilization of the majority of the available DO deficit results, in part, from the presence of the hydraulic control structures, or man-induced channel modifications, the man-induced channel modifications can be considered a type of pollution. The term pollution is used to describe man-induced activities that may cause a water body to occasionally not attain water quality standards such as weirs and channelization. A pollutant is a particular substance that causes impairment of a water body, such as nutrients or organic material. TMDL development is not required for water bodies impaired due to pollution. It is recommended that the cause of impairment for these segments be reclassified as a pollution cause for this water body.

1.12 TMDL YAZOO RIVER BASIN DELTA REGION FOR IMPAIRMENT DUE TO SEDIMENT (MDEQ, 2008G)

This TMDL addresses listings from the 2006 Mississippi Section 303(d) list of impaired water bodies. Two segments within the Yazoo Backwater study area fall within this list and are included in Table 1-2. These include Deer Creek from Headwaters to Watershed 405 Boundary (MS406E), Big Sunflower River Diversion Channel from HUC Boundary 08030207 to HUC Boundary 08030209 (MSBGSND2E), Big Sunflower River Diversion Channel from HUC Boundary 08030208 to Confluence with Steele Bayou

(MSBGSND1E), Steele Bayou from Black Bayou to the Yazoo River (MS404E), Jaynes Bayou from Headwaters to the Big Sunflower River (MS393E), Silver Creek from Headwaters to the Big Sunflower River (MS394E), False River from Headwaters to the Little Sunflower River (MS396E), and Yazoo River from Confluence with the Big Sunflower River to Confluence with the Mississippi River (MSYAZR1E).

For the water bodies included in this sediment TMDL there is an acceptable range of sediment loadings at the effective discharge of the water body. These ranges were developed from suspended sediment concentration (SSC) data measured at stable streams in the same ecoregion. The target range for the water bodies within the Yazoo Delta is 0.0014 to 0.0045 tons per acre per day at the effective discharge. The effective discharge is the discharge which moves the most sediment or is the channel-forming flow. This discharge has been selected as the critical condition for this TMDL. If the sediment target applicable for sediment in the water body is maintained during critical conditions, then the health of the stream should improve.

1.13 SEDIMENT TMDL FOR THE STEELE BAYOU WATERSHED INCLUDING MAIN CANAL, GRANNY BAKER BAYOU, GRANICUS BAYOU, AND BLACK BAYOU (MDEQ, 2003C)

This TMDL addresses listings from the 1996 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodes impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes Steele Bayou from Silver Lake to Confluence of Mound Bayou near Grace (MS404ME).

The listed segments within the Steele Bayou watershed all lie within the Mississippi Alluvial Plain, Ecoregion 73. TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measure. In this case, an “other appropriate measure” is used to express the TMDL as the tons of sediment that can be discharged from an acre of a sub watershed during a day (tons/acre/day) at the effective discharge and still attain the applicable water quality standard. This results in a range of acceptable reference yields of 2.4E-03 to 7.3E-03 tons per acre per day at the effective discharge. It is expected that all values within this range will result in attainment of water quality standards. The TMDL is expressed at the effective discharge, which is the channel forming flow that moves the most sediment. This TMDL is not applicable on an annual basis, because the effective discharge only occurs statistically once everyone and a half year, not on a daily basis. However, because the effective discharge is the critical condition, compliance with the TMDL at effective discharge will result in the attainment of the water quality standards at all times.

1.14 TMDL TOTAL NITROGEN AND TOTAL PHOSPHORUS FOR SELECTED LARGE RIVERS IN THE DELTA (MDEQ, 2008D)

This TMDL has been developed for selected large rivers in the Delta which were listed in the 2006 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodes impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2.

These include Steele Bayou near Issaquena from Black Bayou to the Yazoo River (MS404E) and the Yazoo River from Confluence with Big Sunflower River to Confluence with Mississippi River (MSYAZR1E).

The water quality criteria for this TMDL states that waters shall be free from materials attributable to municipal, industrial, agricultural, or other dischargers producing color, odor, taste, total suspended solids, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses. This TMDL monitors nutrients found in large rivers in the Delta, specifically total nitrogen and total phosphorus. The total maximum daily load for total nitrogen shall be less than 116,547.8 lbs./day and 17,759.7 lbs/day for total phosphorus.

1.15 TMDL TOTAL NITROGEN AND TOTAL PHOSPHORUS FOR JAYNES BAYOU (MDEQ, 2008C)

This TMDL address listings from the 2006 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodes impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes Jaynes Bayou near Rolling Fork from Headwaters to the Big Sunflower River (MS393E).

Nutrients were addressed through an estimate of a preliminary total phosphorous concentration target and a preliminary total nitrogen concentration target. Based on the estimated existing and target total phosphorous concentrations, this TMDL recommends that these water bodies meet the preliminary target range of 0.16 mg/l. Based on the estimated existing and target total nitrogen concentrations, this TMDL recommends that these water bodies meet the preliminary target range of 1.05 mg/l. This will provide improved water quality for organic enrichment and the support of aquatic life in the water bodies and will result in the attainment of the applicable water quality standards.

1.16 TMDL TOTAL NITROGEN AND TOTAL PHOSPHORUS FOR SILVER CREEK (MDEQ, 2008E)

This TMDL addresses listings from the 1996 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodies impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes Silver Creek near Holly Bluff from Headwaters to the Big Sunflower River (MS394E).

The impaired segment was listed due to evaluating the watershed for potential impairment. Physical, chemical, and/or biological data were collected in Silver Creek in June of 2006 as a part of a fish community monitoring program. These data were evaluated through a stressor identification process that indicated sediment and nutrients were the probable primary stressors.

Nutrients were addressed through an estimate of a preliminary total phosphorous concentration target and a preliminary total nitrogen concentration target. Based on the estimated existing and target total phosphorous concentrations, this TMDL recommends that these water bodies meet the preliminary target range of 0.16 mg/l. Based on the estimated existing and target total nitrogen concentrations, this TMDL recommends that these water bodies to meet the preliminary target range of 1.05 mg/l. This will provide improved water quality for organic enrichment and the support of aquatic life in the water bodies and will result in the attainment of the applicable water quality standards.

1.17 TMDL FOR BIOLOGICAL IMPAIRMENTS BY TOXICITY OR UNKNOWN POLLUTANTS (MDEQ, 2003D)

This TMDL addresses listings from the 1996 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodes impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. These segments include Cypress Bayou near Spanish Fort from Headwaters including parts of Six Mile Bayou and Ten Mile Bayou (MS396M1) and Howlett Bayou near Red Rock from Headwaters to the Little Sunflower River (MS396M2).

MDEQ identified three potential waterbodies in the Yazoo Delta that were thought to be excellent candidates to be reference sites based on the land use. Howlett Bayou, and Cypress Bayou are completely in the Delta National Forest. The National Forest Service utilizes the Howlett Bayou watershed as a primitive campground. Wade Bayou is in the Panther Burn National Wildlife Refuge. In the early 1990s, MDEQ completed sampling at these sites using a screening level biological method. The screening level biological method returned impaired water quality, and the bayous were listed. Biological Impairment indicates impairment for waterbodies in which at least one biological assemblage (fish, macroinvertebrates, or algae) indicates less than full support with moderate modification of the biological community noted. Then it was determined the first biological methods did not provide an accurate measure for the Mississippi Delta. This TMDL was published before more accurate measurements could be made.

1.18 TMDL – TOTAL NITROGEN, TOTAL PHOSPHORUS, AND ORGANIC ENRICHMENT/LOW DISSOLVED OXYGEN FOR THE FALSE RIVER (MDEQ, 2008F)

This TMDL addresses listings from the 2006 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodes impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes False River near Smedes from Headwaters to the Little Sunflower River (MS396E).

Nutrients were addressed through an estimate of a preliminary total phosphorous concentration target and a preliminary total nitrogen concentration target. Based on the estimated existing and target total phosphorous concentrations, this TMDL recommends that these water bodies meet the preliminary target of 0.16 mg/l. Based on the estimated existing and target total nitrogen concentrations, this TMDL recommends that these water bodies meet the preliminary target of 1.05 mg/l. This will provide improved water quality for organic enrichment and the support of aquatic life in the water bodies and will result in the attainment of the applicable water quality standards.

1.19 TMDL – TOTAL NITROGEN AND TOTAL PHOSPHORUS FOR CYPRESS LAKE (MDEQ, 2008B)

This TMDL addresses listings from the 1996 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodies impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes Cypress Lake (MS407CLE).

1.20 TMDL – DESIGNATED OXBOW LAKES FOR SEDIMENT (MDEQ, 2008A)

This TMDL addresses listings from the 1996 Mississippi Section 303(d) List of Impaired Water Bodies. The water bodes impacted by the 93-foot Yazoo Backwater pool elevation are identified in Table 1-2. This includes Cypress Lake (MS407CLE).

Oxbow lakes naturally fill due to sediment deposition overtime. Therefore, sedimentation of an oxbow lake is not an impairment of the use of the water body. For this ecoregion, the targeted sediment yield range for the oxbow tributaries is 0.0004 to 0.0018 tons per acre per day at the effective discharge.

p. Section 303(d) List Impaired Waters Within the Yazoo Backwater Study Area

In addition to the water body segments with completed TMDLs, the Mississippi Department of Environmental Quality compiles a list of additional impaired segments for which effluent limitations are not sufficient to implement one or more applicable water quality standards and for which TMDLs are not yet completed. The current Mississippi 2024 List of Impaired Water Bodies does not currently include any segments within the boundaries of the Yazoo Backwater Pump study area.

SECTION 2 PROJECT IMPACT ON IMPAIRED WATER BODIES

2.1 GENERAL

This section addresses the impacts of the YBWP project on the water quality impairments identified for water bodies within the study area. The four major impairments for this area are sediment, pesticides, nutrients, and low dissolved oxygen/organic enrichment. Overall, the conditions that may result from the implementation of Alternative 2 and Alternative 3 with the required mitigation should help to alleviate impacts to existing water quality conditions within the study area. While the Vicksburg District is aware that the implementation of Alternative 2 and Alternative 3 has the potential to improve water quality concentrations for various parameters, it also understands that the modified water management system is limited in its ability to completely attain the water quality criteria at all times due to the modified landscape in combination with naturally occurring conditions.

2.2 PROJECT IMPACT ON WATER BODIES IMPAIRED BY SEDIMENT

Thirteen segments listed in published TMDLs are impaired due to sediment/siltation (Table 1-2). Immediate impacts relative to the construction of the pump station could experience an increase in sediment loading on the lower segments impaired due to sediment/siltation. Impacts will be minimized through utilization of BMP's outlined in the Stormwater Prevention Plan. In addition, much of the disturbed area related to the construction site (pump pad, inlet channel, outlet channel) will be separated from Steele Bayou and the Yazoo River through the use of coffer dams. This will minimize the interaction of surface waters with run off from the construction site. These impacts will be short term, lasting until construction is completed and new vegetation can be established on disturbed areas.

While the wetland filtering capacity for sediment may be reduced for floodplain areas that are inundated at the 5-year frequency or greater, required mitigation efforts should provide adequate compensation to address these concerns. The initial mitigation analysis detailed in the Mitigation Appendix (??) for reforestation should compensate for water quality impacts. The analysis targeted areas cleared lands at or below the 90.0 feet and 93.0 (NGVD) elevation. For impaired and TMDL waters, the precise location of the reforestation could be important. To reduce impairment, the reforestation needs to be at the source of the impairment for erosion control or downstream or down-gradient of the impairment in order to fully utilize wetland function as described by HGM wetland functional model. Cleared land located above this 5-year flood frequency are up-gradient such that runoff from higher elevation agricultural land often passes through 5- and 2-year land before entering streams. This type of filtering through progressive layers of reforested wetlands maximizes reforestation benefits to water quality. Reforestation should have an impact on erosion prevention and reduced sediment yield in impacted segments within the study area.

Reforesting existing agricultural land would benefit the Yazoo Backwater study area in two ways. Reforestation of agricultural land would remove the land from active farming, thus eliminating or reducing future applications of agricultural chemicals and fertilizers. Reforestation would also stabilize the soil increasing the overall filtering capacity of sediment, phosphorus, and legacy pesticide yield in the lower floodplain.

2.3 PROJECT IMPACT ON WATER BODIES IMPAIRED BY NUTRIENTS

Eleven segments listed in published TMDLs are impaired due to nutrients (Table 1-2). Studies have shown that in-stream nutrient concentrations are highest in the Mississippi Delta during the spring, corresponding to fertilizer application and rain events. Nutrient concentrations are generally at their lowest during the extended low-flow period in the late summer. Removal of TSS and the use of BMPs to keep soil out of Delta streams will also have the effect of reducing concentrations of TP in these water bodies. Nitrogen, on the other hand, is processed microbially in wetlands during the processes of nitrification/denitrification into forms that are less toxic to the aquatic environment or that can be sequestered onto clay soils and temporarily removed from the aquatic environment. Under anaerobic conditions, nitrogen gas can be lost to the atmosphere.

The reforestation component associated with Alternative 2 and Alternative 3 will have the effect of increasing the wetland functions that remove nutrients. Two processes can be used to address the mechanisms used to remove these materials. One is the removal of materials adsorbed onto TSS, such as TP. These materials are removed from waters passing through a wetland by the physical act of settling. The second is the removal of materials such as nitrogen through biological processes. Runoff from agricultural fields can introduce dissolved (nitrogen) and sorbed (phosphorus) nutrients into the aquatic system. This generally occurs during the spring during the period when agricultural lands are being prepared for planting. Wetland processing of nutrients (i.e., the removal of elements and compound's function) also occurs during spring floods when overland flow moves through forested wetlands. In contrast, during the summer when river stages are much lower, nutrients moving into streams could have a more pronounced water quality impact.

2.4 PROJECT IMPACT ON WATER BODIES IMPAIRED BY ORGANIC ENRICHMENT/LOW DO

Within the study area, six impaired segments within published TMDL's were found to be impaired due to organic enrichment/low DO (Table 1-2). The critical period identified for organic enrichment/low DO impairment is low-water, high-temperature periods between August and October when low DO conditions have the greatest potential for adverse effects to aquatic life. While the actual measure of organic enrichment/low DO exceedances is DO concentration, ultimate biochemical oxygen demand (BODu) is the metric used to measure the potential for organic enrichment/low DO. Biochemical oxygen demand measures the oxygen required for the biochemical degradation of organic material, the oxygen used to oxidize inorganic materials such as sulfides and ferrous iron, and the oxygen used to reduce forms of nitrogen.

A project feature that might impact the Yazoo Backwater study area is the increase in the export of organic carbon wetland function as a result of reforestation of cleared land. This wetland function increases in efficiency as forests mature and increases in quantity as the number of forested acres in the flood zone increases. Organic carbon is critical for the health of a water body. It provides the energy source that fuels the lower levels of the food chain. However, assimilation of high organic carbon loads released during the late spring or summer could place DO stress on the system. The impact of organic carbon on the organic enrichment /low DO TMDL is minimized by the fact that organic carbon is rarely released from wetlands during the summer when DO concentrations are most critical. These critical DO concentrations observed in the low flow periods of the year will likely be enhanced by the implementation of the 34 supplemental low flow wells located in the headwaters of the Steele Bayou, Deer Creek, and Big Sunflower River basins. These environmental features will help to maintain base flow in the streams during critical periods minimizing pools and stagnant conditions and allowing for reaeration in the base flow.

2.5 YAZOO BACKWATER AREA AND RECEIVING WATERS

The Yazoo Backwater Area is comprised of three major tributaries: Steele Bayou, Deer Creek, and Big Sunflower River. The Big Sunflower River and its tributaries flow south towards the Little Sunflower River and its either partially diverted out to the Yazoo River through the Little Sunflower Outlet Structure during unusually high flood events or is diverted south to the confluence with Steele Bayou by virtue of the Diversion Channel which connects the two. Deer Creek is also diverted south through the Diversion Channel where it ultimately connects with Steele Bayou. For most hydrologic events and during routine operation, flow is released from the Yazoo Backwater Area through the Steele Bayou Outlet Structure and into the Yazoo River and thence into the Mississippi River.

2.6 WATER QUALILTY CERTIFICATION

The Vicksburg District will pursue a water quality certification with the from MDEQ during the PED phase of this project. The recent 2023 Clean Water Act Section 401 Water Quality Certification Improvement Rule (2023 Rule) provides states with the flexibility to engage with project proponents and federal agencies before the certification process begins. Following the 30-day window of the Pre-filing meeting request, the Vicksburg District will submit a request for certification to MDEQ. From this stage, MDEQ and EPA – Region 4 will collaboratively determine how much time will be needed for review (up to 1-year) unless an automatic extension applies. MDEQ will then make a recommendation to the Mississippi Commission on Environmental Quality on whether the proposed project complies with the water quality standards of the state. The Commission will then determine one of four options: 1) grant certification, 20 grant certification with conditions, 3) deny certification, or 4) expressively waive certification. At this point, the Vicksburg District notify EPA Region 4 of the decision by the state within 5 days. EPA will then have 30 days to consider a “may affect” status for water quality requirements for the state of Louisiana and make the appropriate notifications. Louisianan would then have 60 days to determine whether the discharge will violate its water quality requirements.

2.7 NUTRIENT MODELS (SPARROW)

At the time of writing the Yazoo Backwater Area Reformulation Report of 2007 (YBARR-07), it was assumed that the Yazoo River Basin, like many of the agricultural basins of the Midwest, was a disproportionate contributor of nutrients to the Mississippi River and thus a major contributor to the hypoxic conditions in the Gulf of Mexico. This was primarily due to the close proximity of the Yazoo River to the Gulf of Mexico as well as the level of agricultural activity taking place in the Yazoo River Basin. SPAtially Referenced Regression On Watershed (SPARROW) water quality models were created for the Major River Basins (MRB) (as defined by Goolsby et al. 1999) in the Mississippi and Atchafalaya River Basins (MARB) that lent support to this assessment. Subsequent nutrient data collected from the Yazoo River has shed new light on the false premise that the Basin is a major contributor to the nutrient loading in the Mississippi River and instead it shows that loading from the Yazoo Basin is similar to or below the National Median Concentrations (Coupe 1998).

The depleted dissolved oxygen concentrations (< 2 milligrams per liter (mg/L)) found in the Gulf of Mexico typically referred to as the Hypoxic Zone have long been attributed to the nutrient loading of Nitrogen (N) and Phosphorus (P) from the MARB. Extensive efforts have been made over the last few decades to develop an understanding of where these nutrient loads originate as well as their fate and transport to the Gulf of Mexico.

Several numerical models have been created to help with this determination. Many of the early models utilized multiple-regression techniques related to N and P inputs (Goolsby et al. 1999; David et al. 2010; Jacobson et al. 2011) which pointed to the intensive agricultural regions of the Midwest typically referred to as the Corn Belt. The models showed that the Corn Belt region was responsible for contributing the highest loads and yields to the MARB (Gage 1996). These regression techniques fell short in accounting for downstream transport, long term storage (as found in reservoirs), and permanent removal of nutrients such as denitrification (Robertson et al. 2014).

A national-scale (SPARROW) model was developed to account for these underestimated variables of nutrient fate and transport in the MARB. SPARROW expounded on the simple regression modeling techniques by using a process-based mass-balanced approach with a spatially detailed digital network of streams and reservoirs. This approach allowed for the attenuation of nutrients to be tracked from their application origin to their downstream location (Robertson et al. 2014). Data collected from 425 stream monitoring stations representing relatively large areas from throughout the entire U.S. was used to estimate N and P yields in several of the national-scale models created by Alexander et al. (2008). Long term mean annual nutrient loads were estimated for each monitoring station by combining regularly measured total nutrient concentrations with daily flow measurements for the 1975–1995-time frame. These annual load estimations were used as input for the SPARROW models. The mean annual load for each station was standardized to the 1992 base year (Alexander et al. 2008). The study was able to generate rankings for nutrient flux (contribution) to the Gulf Hypoxic Zone from each state which contributes to the drainage area of the MARB (Alexander et al. 2008).

Regional SPARROW models were also developed for several of the sub basins in the MARB which utilized refined national geospatial datasets based on land-use conditions and N and P inputs similar to 2002. The regional models also utilized inputs from wastewater treatment plants instead of population-based surrogates to mimic point sources which had been previously used by Alexander et al. (2008). These regional models also employed estimates from long term averages of N and P loads standardized to the 2002 base year from approximately 3,000 sites in the U.S. (Robertson et al. 2014). The collection of these refined regional models was collectively used to create the MARB SPARROW. The output from MARB SPARROW model shed more light on the origin of N and P and a better understanding of their fate and transport to the Gulf of Mexico. The study was able to generate rankings for nutrient flux (contribution) to the Gulf Hypoxic Zone based on the MRB and the contribution of each state to the MARB. The output from the MARB SPARROW was also utilized to generate rankings for nutrient flux to the Gulf of Mexico from each of the HUC8 watersheds incorporated in the models (Robertson et al. 2014).

The output from the national-scale SPARROW models utilized by Alexander et al. (2008) allowed for the ranking of the 30 states considered to be nutrient contributors to the MARB. The state of Mississippi ranked 9th and 8th for total flux of Total Nitrogen (TN) and Total Phosphorus (TP) to the Gulf of Mexico, respectively. This total flux equated to a delivered yield (kg km^{-2} yr^{-1}) of 863.5 and 101.6 for TN and TP, respectively for the state. The state of Illinois was ranked as the highest contributor for total nutrient flux. This equated to a delivered yield (kg km^{-2} yr^{-1}) of 1,734.9 and 117.4 for TN and TP, respectively (Alexander et al. 2008).

The output from the MARB SPARROW model utilized by Robertson et al. (2014) allowed for the ranking of nutrient contribution to the Gulf of Mexico based on MRB regions as well as states in the MARB. Goolsby et al. (1999) classified the MARB into eight MRB to help delineate the origin of nutrient input into the Mississippi River Watershed. The Yazoo Basin was included in one of the southernmost MRB labeled as Lower Mississippi (186,000 km^2) which is largely contained within the states of Mississippi, Arkansas, and Louisiana (Robertson et al. 2014). This region has traditionally been centered on agricultural production due to the high productivity of the deltaic soils and the wet climate. The Lower Mississippi MRB was ranked 6th and 4th in descending order out of the 9 MRB's for delivered TN Load and TP Load (112,000 and 15,700, tons), respectively. When considering Total Delivered Yield of TN and TP, the Lower Mississippi MRB was ranked 4th and 2nd (603 and 84.6, kg/km^2), respectively. For comparison, the MRB labeled as Middle Mississippi which is comprised mostly of the Ohio Valley was ranked as the highest contributor for delivered TN Load and TP load (337,000 and 23,300 tons), respectively. The Middle Mississippi was also ranked as the highest contributor for Total Delivered Yield of TN and TP, (1,230 and 85.0, kg/km^2), respectively (Robertson et al. 2014).

The MARB SPARROW model output ranked the state of Mississippi as 13th and 11th in descending order of the 30 states considered for Delivered Load and Delivered Yield of TN (32,356,714 kg and 568 kg/km^2), respectively. The state of Iowa was the highest contributor for Delivered Load of TN at 203,348,552 kg. The state of Illinois was the highest contributor for Delivered Yield of TN at 1,804 kg/km^2 (Robertson et al. 2014, supplement).

When considering Delivered Load and Delivered Yield of TP, the state of Mississippi was ranked 11th and 2nd (5,244,570 kg and 92.1 kg/km^2), respectively. The state of

Missouri was the highest contributor for Delivered Load of TP at 15,051,168 kg. The state of Illinois was the highest contributor for Delivered Yield of TP at 97.2 kg/km^2 (Robertson et al. 2014, Supplement).

The MARB SPARROW model output ranked the nutrient delivery from 822 HUC8 watersheds that contribute to the Mississippi River. The Steele Bayou HUC8 (08030209) ranked as number 241 and number 303 in descending order for delivered TN Load and TP load (1,910,808 and 145,091 kg), respectively. When considering delivered yield of TN and TP, the Steele Bayou HUC8 (08030209) was ranked #192 and #138 (67.53 and 889.3, kg km^{-2} yr^{-1}), respectively. The Big Sunflower HUC8 (08030207) was ranked as 42nd and 36th in descending order for delivered TN load and TP load (6,230,620 and 556,058 kg), respectively. When considering delivered yield of TN and TP, the Big Sunflower HUC8 (08030207) was ranked number 158 and number 173 (842.6 and 75.2, kg km^{-2} yr^{-1}), respectively. The Lower Yazoo HUC8 (08030208) was ranked as number 508 and number 535 in descending order for delivered TN load and TP load (355,658 and 34,652 kg), respectively. When considering delivered yield of TN and TP, the Lower Yazoo HUC8 (08030208) was ranked number 237 and number 225 (609.0 and 59.3, kg km^{-2} yr^{-1}), respectively. The Upper Yazoo HUC8 (08030208) was ranked as number 144 and 68th in descending order for delivered TN load and TP load (3,149,347 and 448,603 kg), respectively. When considering delivered yield of TN and TP, the Upper Yazoo HUC8 (08030206) was ranked number 201 and 91st (701.8 and 100.0, kg km^{-2} yr^{-1}), respectively (Robertson et al. 2014).

The MARB SPARROW model lends support to the general assertion that nutrients from the State of Mississippi specifically the agricultural regions of the Steele Bayou and Big Sunflower Basins are not the highest contributors to the overall loading of TN to the Gulf of Mexico (Hicks et al. 2017). The national water quality stream assessment published by USGS asserted that the lower concentrations of nitrogen in streams of the Southeast are partly due to the soil and hydrologic characteristics that support greater loss of nitrogen through biological uptake and denitrification before overland flow reaches the streams (Dubrovsky et al. 2010). The Big Sunflower HUC8 sub-basin did rank as 36th for delivered yield for TP which is based on the overall area of the drainage basin. The rankings for TN and TP loads coming from the Big Sunflower HUC8 watershed can be attributed to several factors. The relatively close proximity of the outlet of the Big Sunflower River to the Yazoo River, thence into the Mississippi River, and thence into the Gulf of Mexico, minimizes the available time for in-stream utilization. The slightly higher rankings associated with TP can be partially attributed to the properties associated with the highly erosive Loess soils of which readily bind with the phosphorus present.

The USGS in cooperation with the Mississippi Department of Environmental Quality (MDEQ) developed a state specific SPARROW model for Mississippi which assessed the nutrient status and trends in the surface waters of 9 watersheds for the water years of 2008 – 2018. The model was used to summarize concentrations and estimated loads, yields, and spatial and temporal patterns of TN and TP. One of the included watersheds was the Yazoo Basin. This basin was modeled using 5 USGS National Water-Quality Assessment Project (NAWQA) stations which were located both within and outside of the Yazoo Backwater Area. The first two stations: Little Tallahatchie River at Etta, Ms (station # 07268000) and Yazoo River near Shell Bluff, Ms (station # 07287120) represent the headwater of the Yazoo River outside of the Yazoo Backwater Area. The second two stations: Big Sunflower River at Sunflower, Ms (07288500) and Bogue Phalia near Leland, Ms (Station # 07288650) represent the majority of the drainage area within the Yazoo Backwater Area. The final station: Yazoo River below Steele Bayou near Long Lake, Ms (Station # 07288955) represents the confluence of the stations listed above which accounts for the entire Yazoo Watershed (Hicks et al. 2023).

When compared to the other basins assessed in the model, Hicks et al. 2023 noted that the Yazoo River Basin had the highest median concentration for TN (1.15 mg/L) which showed a high correlation to sites representing predominantly agricultural land use. In contrast, sites modeled representing predominantly forested land use basins were generally very low in TN concentration (less than 1.0 mg/L). The highest annual yield for TN from the state model was estimated at the Bogue Phalia site which yielded 1,014 kilograms per year per square kilometer ([kg/yr.]/km2). Annual TN yields were compared from models with similar timeframes to assess how well the results agreed. Projected yields from the 2012 Regional Scale Calibration SPARROW model were compared with yields computed using the current model to assess variation. The two stations located within the Yazoo Backwater Area (Big Sunflower @ Sunflower and Bogue Phalia near Leland) were estimated to generate 857 and 1,207 TN yield ([kg/yr.]/km2) respectively using the 2012 Regional Scale SPARROW model and 990 and 1,014 TN yield ([kg/yr.]/km2) respectively using the current Mississippi State SPARROW model. This correlates to a 14.4% increase for the Big Sunflower site and a 17.4% decrease for the Bogue Phalia site. Similarly, the estimated yield for TN at the Lower Yazoo River site near Long Lake dropped from 621 to 603 ([kg/yr.]/km2) when comparing the 2012 Regional Scale SPARROW Model to the current Mississippi State SPARROW model representing a decrease of 2.9% (Hicks et al. 2023).

The highest median concentration for TP was found to be at the Big Sunflower Station at Sunflower with a concentration of (0.31 mg/L). This site along with 3 others in the Mississippi Delta: Yazoo Upper, Yazoo Lower, Big Sunflower, and Bogue Phalia all displayed median TP concentrations above 0.1 mg/L. The report noted that this may likely result from naturally high concentrations of phosphorous in the soil (Coupe, 2002) and groundwater (Welch and others, 2009) which could influence surface waters from precipitation runoff as well as agricultural irrigational return water sources from groundwater. In contrast, sites modeled representing forested land use basins were found to be very low at concentration of TP less than 0.02 mg/L. The report attributed this to nutrient uptake and storage from vegetation and minimal phosphorus-based fertilizer application. As with TN, the highest annual yield for TP from the state model was estimated at the Bogue Phalia site which yielded 234 kilograms per year per square kilometer ([kg/yr.]/km2). The two stations located within the Yazoo Backwater

Area (Big Sunflower @ Sunflower and Bogue Phalia near Leland) were estimated to generate 207 and 229 TP yield ([kg/yr.]/km2) respectively using the 2012 Regional Scale SPARROW model and 212 and 234 TN yield ([kg/yr.]/km2) respectively using the current Mississippi State SPARROW model. This correlates to a 2.4% increase for the Big Sunflower site and a 2.0% increase for the Bogue Phalia site. Similarly, the estimated yield for TP at the Lower Yazoo River site near Long Lake dropped from 171 to 165 ([kg/yr.]/km2) when comparing the 2012 Regional Scale SPARROW Model to the current Mississippi State SPARROW model representing a decrease of 3.5% (Hicks et al. 2023).

DISSOLVED OXYGEN AND SUSPENDED SOLIDS

2.8 GENERAL

Dissolved Oxygen (DO) has long served as one of the primary indicators of aquatic health in aquatic ecosystems. Adequate concentrations of DO are vital component to healthy populations of diverse fish species. Low DO conditions can typically be associated with warm climates as well as excessive concentrations of suspended solids which can have a negative influence on the overall population of aquatic communities.

A water quality monitoring program was initiated in 2004 in the Yazoo Backwater Area by the Vicksburg District which extended through 2015. The Steele Bayou Monitoring Program (SBMP) was initially focused on capturing the effectiveness of recently constructed erosion control structures situated along the edge of agricultural fields on top bank of the Steele Bayou Basin (Kilgore et al. 2008, MDEQ 2011). After realizing the extensive value of the program, monitoring quickly expanded to include tributaries in the Big Sunflower Basin (MLB 2023). The similar nature of the Big Sunflower Basin allowed it to serve as a control for the work performed in the Steele Bayou Basin. In addition to monthly grab samples, water quality sondes were utilized to collect hourly, in-situ data for DO, pH, Turbidity, Conductivity, and Temperature. The sondes collected data at four locations in the Steele Bayou Basin: Steele Bayou at Low Water Bridge, Steele Bayou at Grace, Main Canal at Surveillance Station Road, and Black Bayou at Highway 12. This captured conditions in the upper, middle, and lower part of the Steele Bayou Basin. Additionally, one sonde was deployed on the Big Sunflower River for hourly data collection in Anguilla. This site captured conditions in the middle of the Big Sunflower Basin. The sondes were deployed from the bridge decking in corrugated metal pipes or polyvinyl plastic tubes with open bottoms and slots in the side wall. The sondes were suspended into the water approximately two to five feet from the bottom so that the probes would remain inundated during low flow conditions. The grab samples were analyzed for Total Suspended Solids (TSS), Total Dissolved Solids, Total Organic Carbon, Dissolved Organic Carbon, Total Kjeldahl Nitrogen, Nitrate/Nitrite, TN, TP, Total Dissolved Phosphorus, Orthophosphate, Chlorophyll A (CHLOROA), Pheophytin

A, and Biochemical Oxygen Demand. Laboratory analysis was conducted on all the samples according to Environmental Protection Agency (EPA) methods. In addition to the locations previously mentioned, the grab samples were collected from the Big Sunflower River at Holly Bluff, Little Sunflower River at Dummy Line Road, and Steele Bayou on Highway 465 downstream of the Steele Bayou Structure It should be noted that water quality data collected from this last sample location (Steele Bayou on Highway 465 downstream of the Steele Bayou Structure) is limited in its breadth and application for use as a comparative site against the interior of the Yazoo Backwater Area. Samples collected from this site can only be viewed as a representative discharge from the Yazoo Backwater Area when a) the Steele Bayou Outlet Structure is open and flowing and b) when access is available to the Highway 465 bridge. Routine sampling events did occur on days during flood events (lower stage) when the outlet structure gates were closed. Under this condition, a sample collected from this site would represent floodwater from the Yazoo River/Mississippi River and not discharge from the YBA. Also, during many of the flood events during the recorded SBMP collection effort, the road surface of Highway 465 leading to the bridge was inundated and access was not available. This section of Highway 465 that extends from Highway 61 to the bridge is located in an area outside of the protection of the YBA levee system which makes it vulnerable to inundation from the Yazoo River/Mississippi River flooding. For these reasons, routine sampling events at this site were not always collected and thus cannot provide a thorough representation of the YBA throughout the POR for the SBMP. Since its inception, the stations utilized in the SBMP have been helpful in capturing the pooling effects of many backwater flood events in the Yazoo Backwater Area. Figure 2-1 shows the locations of stations previously described which depicts the sub basins and corresponding sample stations in the following colors: Steele Bayou (green), Deer Creek (red), Big Sunflower River (aqua), and Yazoo River (purple) with the Mississippi River captured in the aerial image (west of Steele Bayou). This data shall be made available upon request from USACE Vicksburg District (Hydraulics Branch).

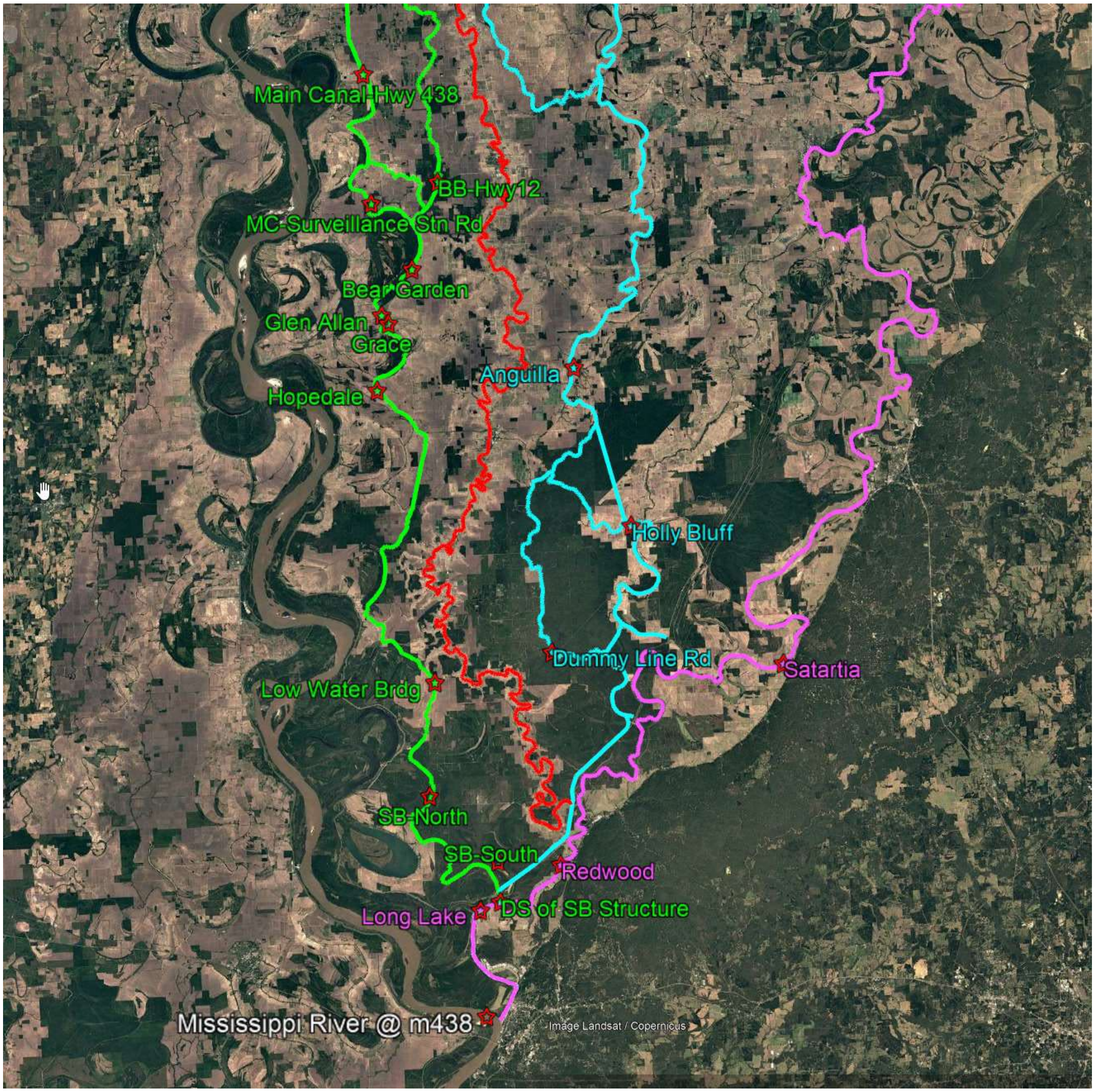

Figure 2-1. SBMP and NWIS stations utilized for deployment of water quality sondes and monthly grab samples.

2.9 YAZOO BACKWATER AREA MANAGEMENT PLAN AND ALTERNATIVES

This appendix will discuss the impacts to water quality resulting from the implementation of four proposed alternatives for flood control and water management in the Yazoo Area Basin. These alternatives are described as follows:

- ALTERNATIVE 1

- No Action

- ALTERNATIVE 2
    - Structural feature:• 25,000 cfs pump station; backwater managed at 90.0 ft during crop season (25Mar-15Oct) and up to 93.0 ft during noncrop season (16Oct-24Mar).
    - Nonstructural feature: • Full utilization of the gate operation of Steele Bayou water control structure to optimize fisheries exchange (75.0 ft) as described in the current water control manual.• Acquisition or floodproofing of residential and commercial properties up to 93.0 ft.

- ALTERNATIVE 3
    - Structural feature: • 25,000 cfs pump station; backwater managed at 90.0 ft during crop season (15Mar-15Oct) and up to 93.0 ft during noncrop season (16Oct-14Mar).
    - Nonstructural feature: • Full utilization of the gate operation of Steele Bayou water control structure to optimize fisheries exchange (75.0 ft) as described in the current water control manual. • Acquisition or floodproofing of residential and commercial properties up to 93.0 ft.

- ALTERNATIVE 4
    - Nonstructural feature: • Acquisition or floodproofing of residential and commercial properties up to 98.2 ft.

The structural feature proposed for flood control and water quality in the Yazoo Area Basin proposed in Alternatives 2 and Alternative 3 include the use of a 25,000-cubic-foot-per-second (cfs) pump station with a seasonal operational pump elevation of 90.0 and 93.0 feet, National Geodetic Vertical Datum (NGVD) in the lower Yazoo Area Basin (Steele Bayou landside). These two alternatives have a 10-day variation in their seasonal pump-on/pump-off restriction. This minor variation will have little impact on the overall influence on water quality resulting from pump usage. As such, the impacts to water quality resulting from Alternatives 2 and Alternative 3 will be viewed as the same for the purposes of this discussion. The implementation of Alternatives 2 and Alternative 3 also include an environmental restoration feature which promotes the construction of 34 independent supplemental low flow groundwater wells along headwater streams of the Big Sunflower, Upper Deer Creek and Steele Bayou Basins. The proposed wells will help alleviate the negative environmental impacts resulting from the observed changes during minimum flow conditions within the three watersheds.

A statistical analysis was generated from the data using SAS Univariate software. The software was used to calculate the daily mean values from the hourly data collected. Mean values were also calculated from the concentrations of Total Suspended Solids (TSS) measured from the grab samples. The mean values were grouped on an annual basis for each available year and subdivided on a monthly basis. This grouping allowed for a more direct comparison of the agricultural growing season and corresponding irrigation typically found in the Yazoo Backwater Area.

Additional water quality data has been collected by the USGS on many of the primary tributaries in the Yazoo Backwater Area stretching back to the 1970's. Information related to TSS concentrations was retrieved from surface water grab samples accessed through USGS's online National Water Information System (NWIS) website. Available data was sorted according to the HUC8 watersheds and analyzed through 2016. The watersheds of interest were the Big Sunflower, Steele Bayou, Upper Yazoo, and the Lower Yazoo which were labeled as BigSun, Steele, UppYaz, and LowYaz respectively. A statistical analysis was generated from the data using SAS Univariate software. The software was able to define values for mean, max, and minimum concentrations of DO and TSS. The statistical output was grouped by month, season, year, and decade. The addition of this data helped to supplement the SBMP data previously mentioned.

2.10 DISSOLVED OXYGEN (TEMPERATURE)

Many of the tributaries in the Yazoo Backwater Area have suffered from depressed DO which impose stressful conditions on the aquatic ecosystem. Lower DO observations start in the spring and extend through the fall months when average temperatures exceed 20 degrees Celsius. These anoxic conditions are exacerbated during extended backwater floods, when runoff is trapped in the basin due to the closure of the Little Sunflower and Steele Bayou Water Control Structures.

Mild winters and hot summers are not uncommon in the Yazoo Basin. The data analyzed from the SBMP shows that mean monthly water temperatures in the Yazoo Basin reach 20 degrees Celsius in April and remain at that temperature or greater until October. Furthermore, temperatures don't fall below 15 degrees Celsius until November (Figure 2-2).

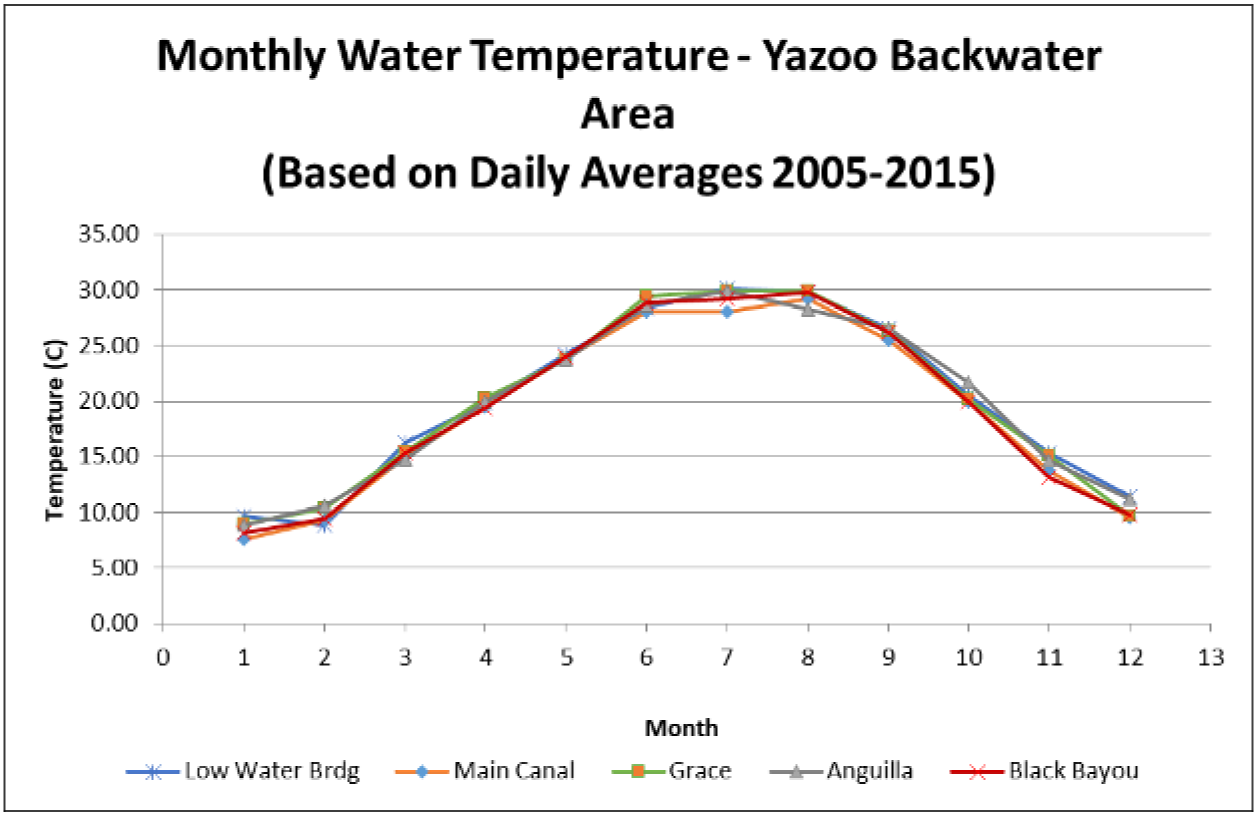

Figure 2-2. SBMP–Monthly Mean Water Temperatures Derived from Daily Means Compiled from Hourly Sonde Data (2–5 feet from bottom).

These warmer conditions have a significant impact on the maximum oxygen concentration that can be dissolved into a stream. Figure 2-3 shows that the DO saturation percentage from the sonde data for the streams monitored in the Steele Bayou Basin (Main Canal, Black Bayou, Grace, Low Water Bridge). The DO saturation rarely reaches 50% from April to November. The sonde data collected from the Big Sunflower River (Anguilla) shows the DO saturation percentage falling below 50% in April and slowly climbing to 60% and 75% in August and October, respectively. The slightly higher DO saturation measurements observed from July to October are likely due the irrigation return flows coming into the Big Sunflower River. This corresponds to the time of intense irrigation from in the Big Sunflower Basin which has a higher percentage of agriculture production than the Steele Bayou Basin.

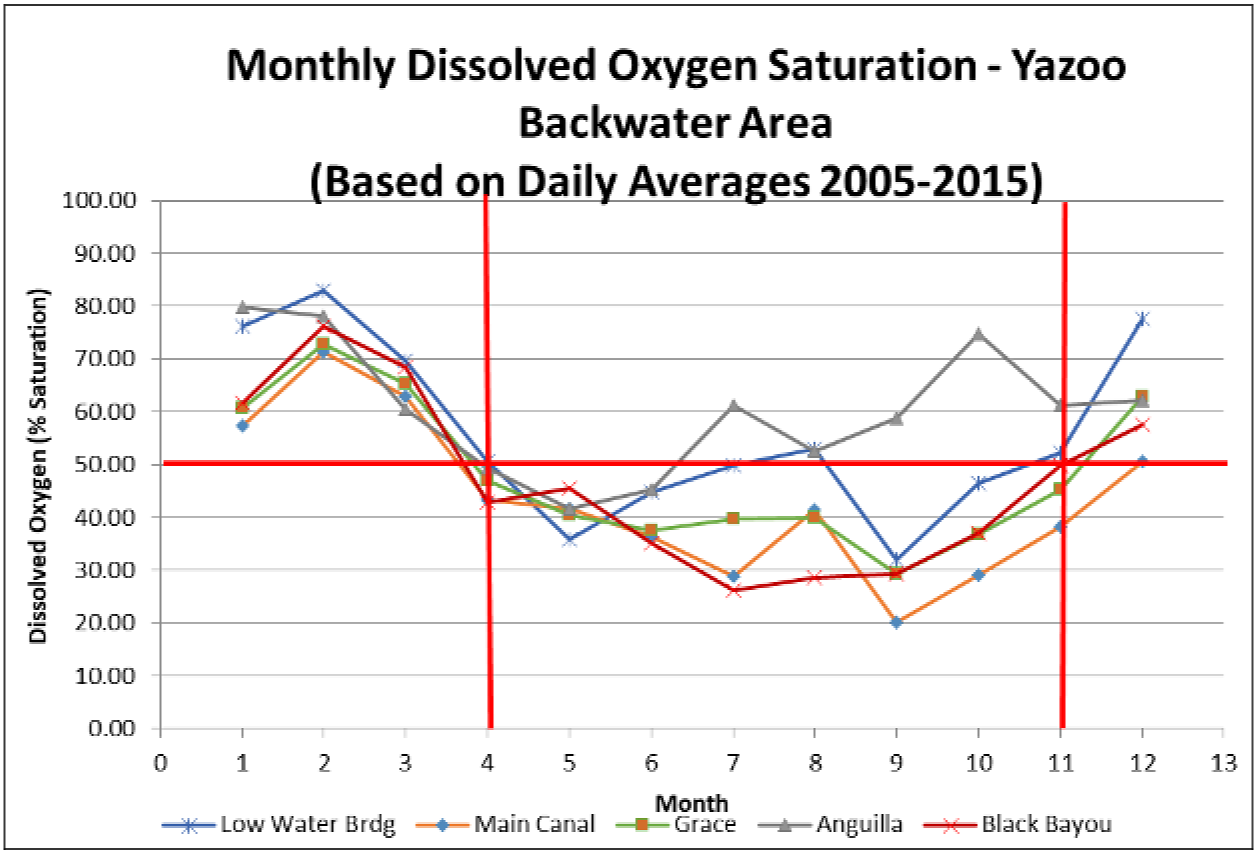

Figure 2-3. SBMP–Monthly Mean of DO Saturation Percentage Derived from Daily Means Compiled from Hourly Sonde Data (2–5 feet from bottom).

The values displayed in Table 2-1 Dissolved Oxygen Saturation Table for Yazoo Backwater Area show saturation potential for DO concentration for freshwater typically found in the Yazoo Basin as temperature increases. When water temperatures reach 20 degrees Celsius, the 50% DO saturation potential falls below 5.00 mg/L.

Table 2-1 Dissolved Oxygen Saturation Table for Yazoo Backwater Area

Temperature (C)	Dissolved Oxygen Concentration (mg/L)	
	100%	50%
15	10.13	5.07
20	9.14	4.57
25	8.30	4.15
30	7.60	3.80

When warm weather is combined with conditions of minimal DO saturation, aquatic life typically suffers from long periods of low DO. Figure 2-4 plots the mean monthly DO concentration (mg/L) observed in the Yazoo Backwater Area. The published Mississippi water quality regulations for DO in streams classified for Fish and Wildlife Support (2021) sets the 1-day average to be 5.0 mg/L which was not met in many of the sampled years. This was typical observed beginning in April and extending through November for the Streams in the Steele Bayou Basin. The minimal DO concentration for streams in the Big Sunflower Basin again started in April and extended through October. These depleted DO conditions for over half of the year in the Yazoo Backwater Area can likely lead to stress on the overall health of the aquatic ecosystem.

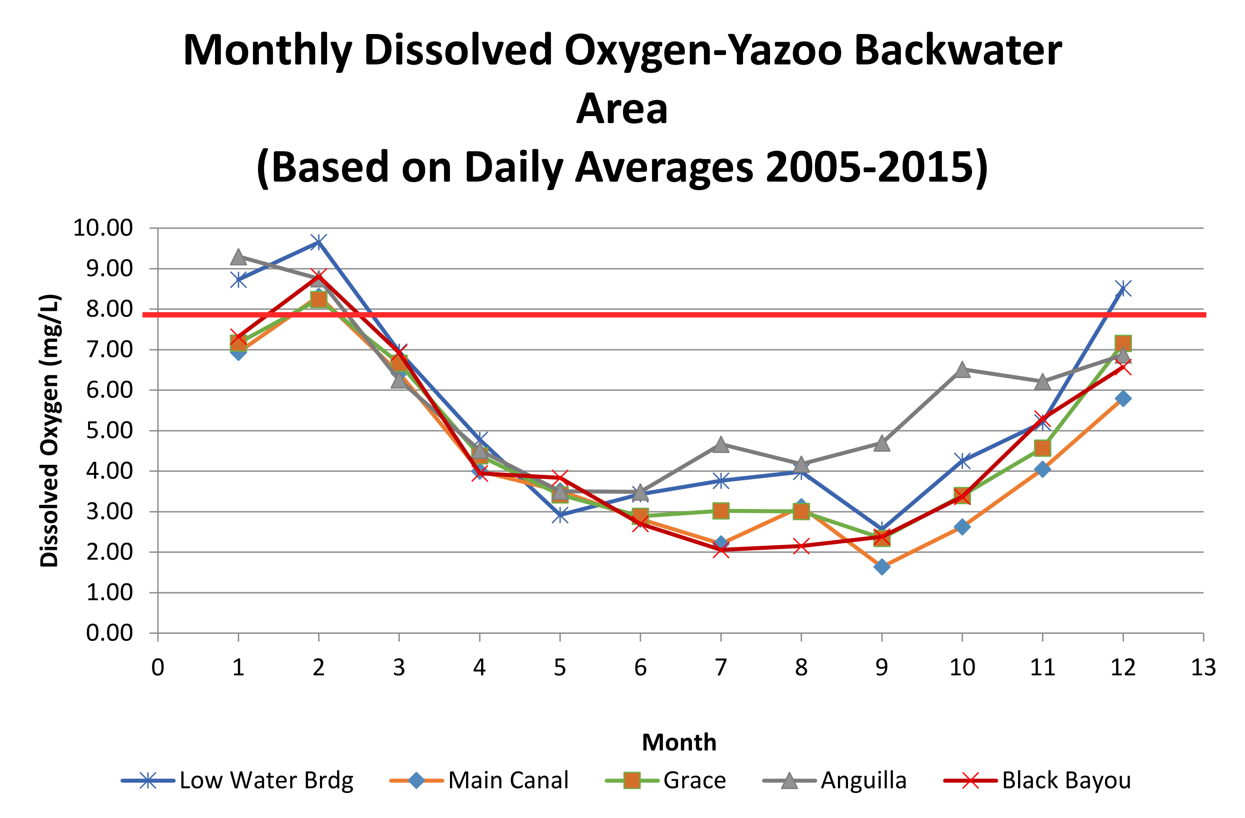

Figure 2-4. SBMP–Monthly Mean DO Concentrations Values Derived from Daily Means Compiled from Hourly Sonde Data (2-5 feet from bottom).

2.11 DISSOLVED OXYGEN (FLOODS)

The SBMP in situ data was used to compile the monthly averages for DO. The hourly in situ data has been displayed in Figure 2-5 using the daily averages. The data has been plotted with the mean daily elevation (NGVD) for Steele Bayou at Grace Gage. The two areas shaded in red highlight the decrease in DO as water levels reach higher stages. These two events coincide with the Yazoo Backwater Area Floods of 2008 and 2009. The two areas shaded in green also highlight the decrease in DO as water levels reach higher stages during a Yazoo headwater flood. The inverse effect can be seen for higher DO concentrations when lower river stages are observed. The red and green shaded areas highlight the similarities in the YBA from backwater floods and headwater floods.

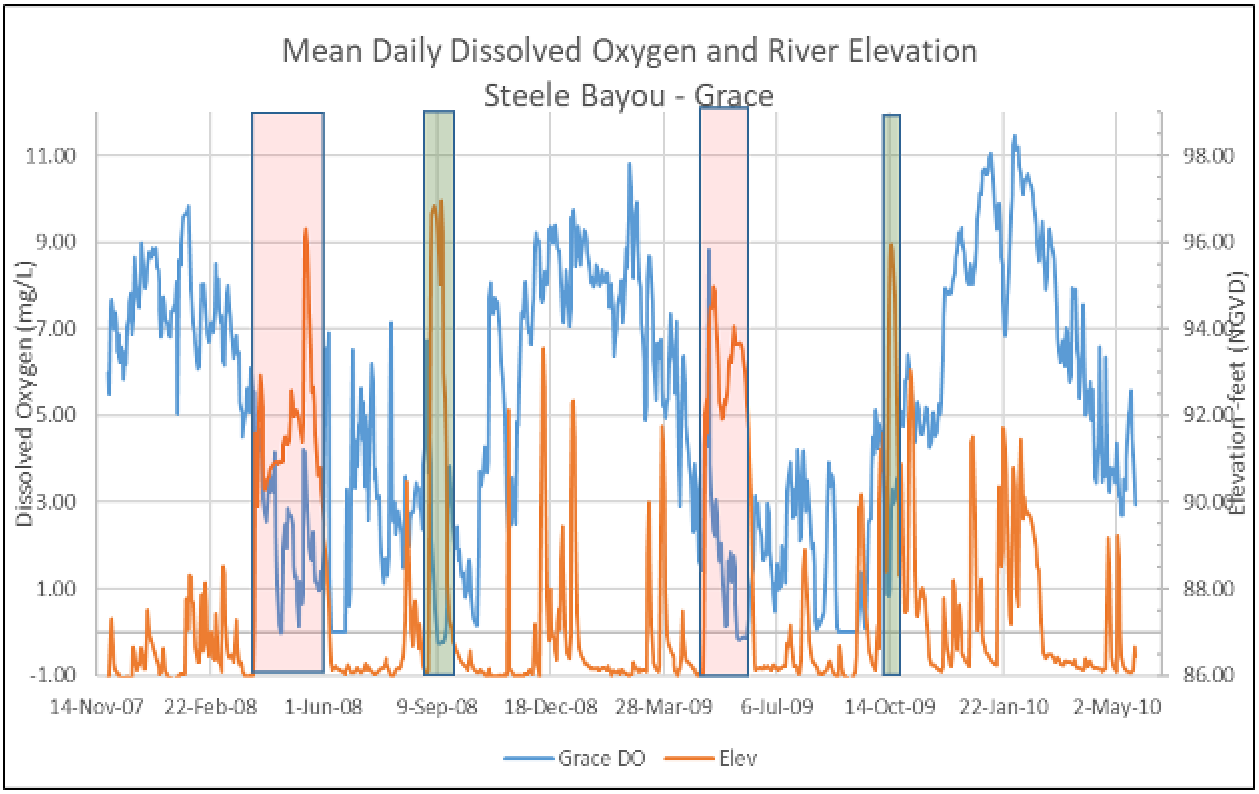

Figure 2-5. SBMP–Daily Mean DO Concentrations (2-5 feet from bottom) and Elevations for Steele Bayou at Grace Gage.

A similar trend as seen in Figure 2-5 can be observed in Figure 2-6 where daily DO concentrations decrease on the Big Sunflower River at Anguilla Gage as river stages increase. The two areas shaded in red highlight the decrease in DO as water levels increase coinciding with the Yazoo Backwater Area Floods of 2008 and 2009. The area shaded in green also corresponds to a decrease in DO as water levels reach higher stages which depicts a headwater event. Likewise, the higher DO concentrations are observed when river stages are low. Figures 2-5 and 2-6 are meant to show inverse relationship of DO with river stage of water column depth during conditions which represent both a headwater flood and a backwater flood.

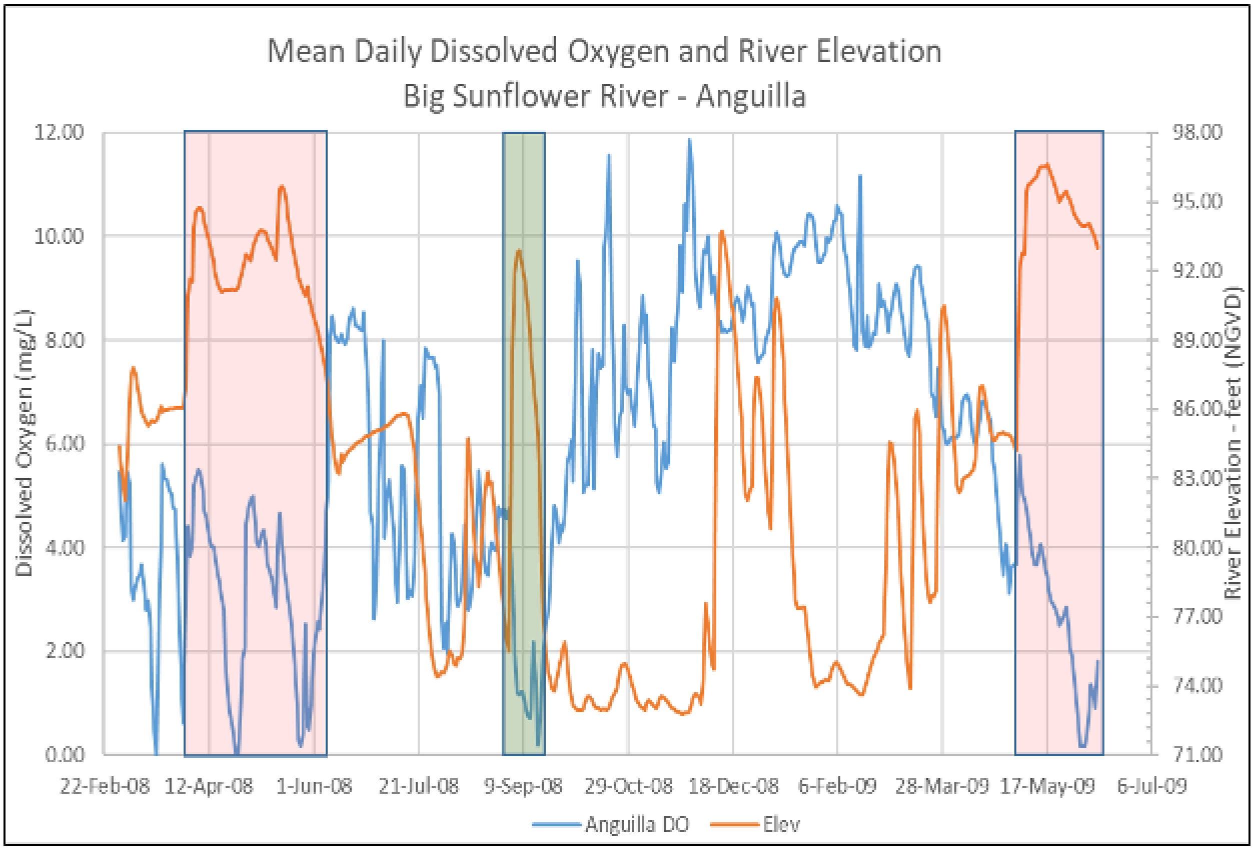

Figure 2-6. SBMP–Daily Mean DO Concentrations (2-5 feet from bottom) and Elevations for the Big Sunflower River at Anguilla Gage.

Data collected from subsequent floods since the YBARR-07 show that long duration floods impose a detrimental impact on the DO levels found in the water column. During the Yazoo Backwater floods of 2011, 2015, and 2019 the Vicksburg District collected water profile data for Dissolved Oxygen and Turbidity throughout the Yazoo Backwater Area.

Figure 2-7 shows how the DO concentration decreases below 5.0 mg/L with depths below 7 and 10 feet at the upper, middle, and lower portions of the Steele Bayou and Big Sunflower Basins. This data was collected during the latter half of the Yazoo Backwater Flood event. It should be noted that this YBA flood event was the third peak for the calendar year 2015 and represents an event when the Steele Bayou Outlet Structure gate was closed but the 25,000 cfs pump station would not have been utilized. The interior stages did not exceed 90.0 feet (NGVD) at the Steele Bayou Structure and would not have triggered a pump operation. Most of the stream locations would have been experiencing low flow conditions minimizing the potential for agitation and re-aeration. The dashed green line represents DO conditions for flood water of the Mississippi River and corresponding Yazoo River into the outlet channel of the Steele Bayou Structure.

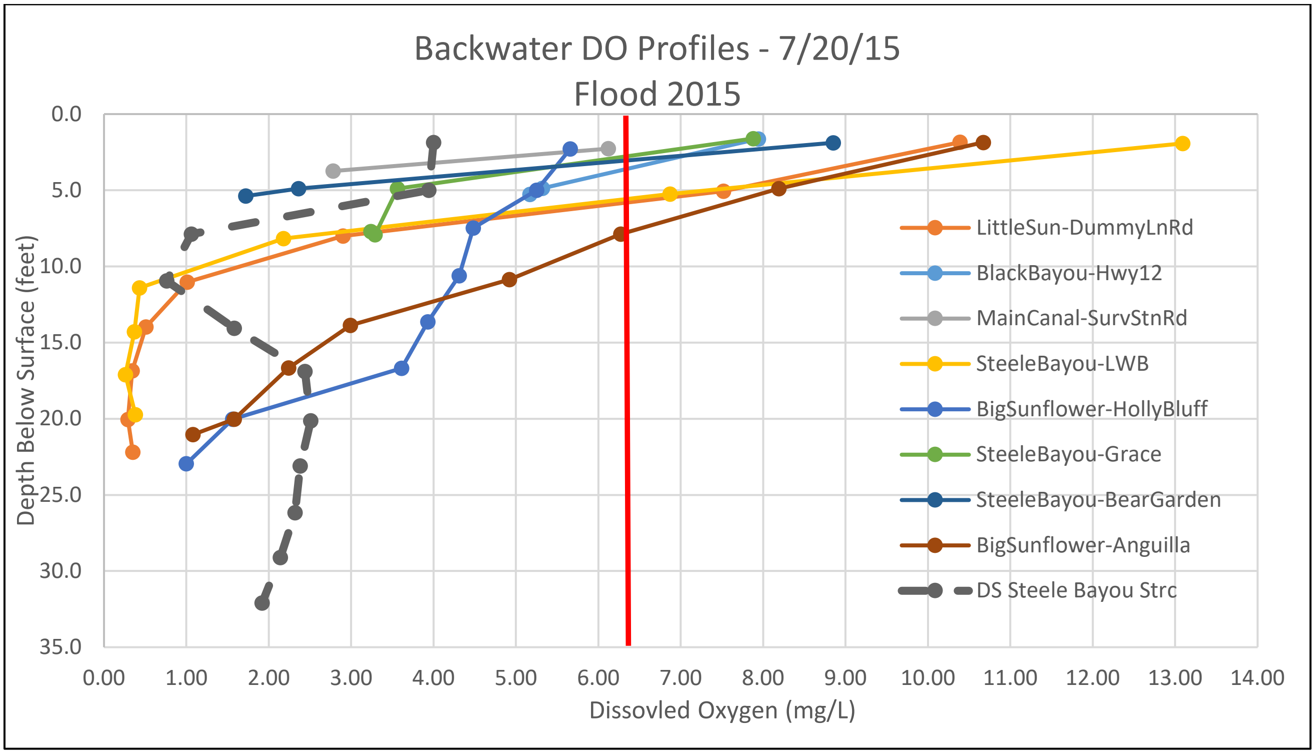

Figure 2-7. DO Water Column Profiles of Streams in the Yazoo Basin taken on July 20, 2015. This data was collected during the third flood of 2015.

The DO profile displayed in Figure 2-8 shows two successive measurements (one week apart) on the Little Sunflower River at Dummy Line Road during the same Backwater Flood event of 2015. A slight reduction of DO concentration can be seen within the top five feet of the water column for the latter measurement. The layer of water at the surface containing a DO concentration above 5.0 mg/L reduces slightly from 7 to 5 feet thick.

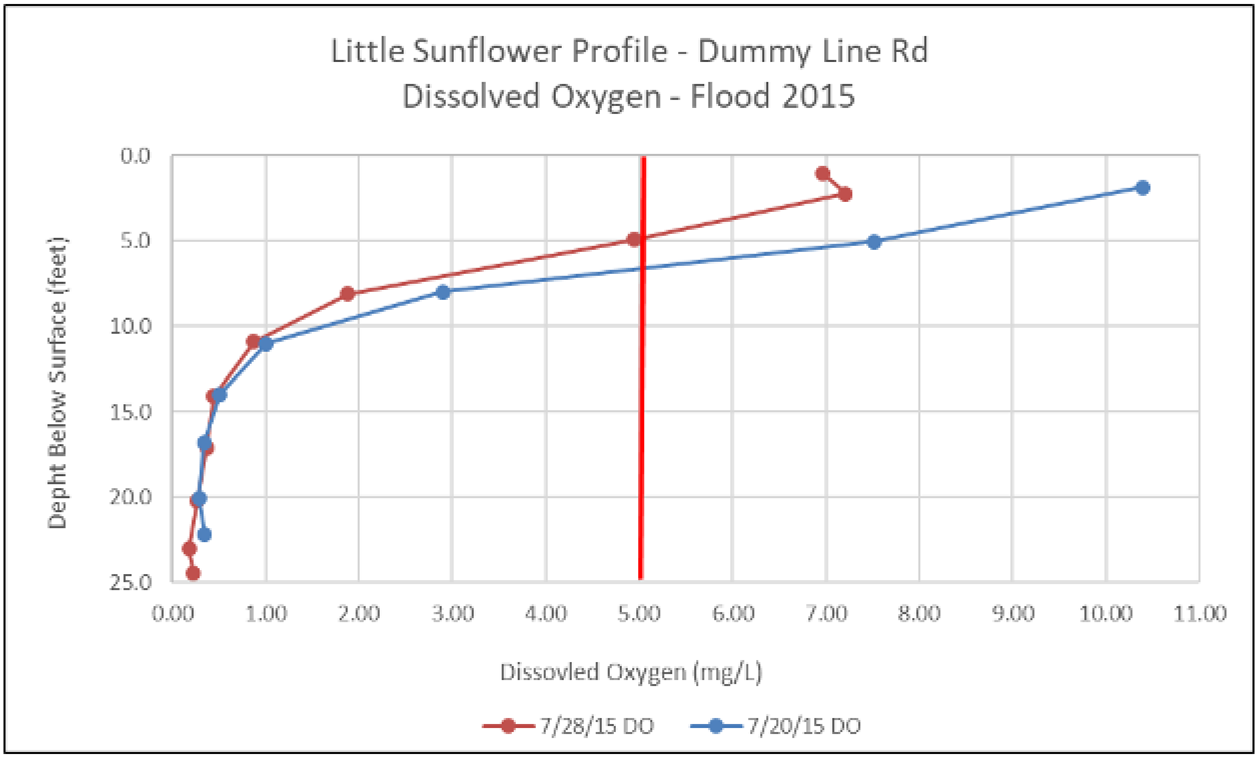

Figure 2-8. DO Water Column Profiles of the Little Sunflower River at Dummy Line Road taken during the Flood of 2015. This data was collected during the third flood of 2015.

Similar DO water column profiles were collected immediately upstream of the Steele Bayou Structure during the Yazoo Backwater Flood of 2019. Figure 2-9 shows reduced concentrations of less than 5.0 mg/L below the upper seven feet of the water column. This is again likely due to the stagnant flow conditions found in the bottom of the Steele Bayou Basin. The slight increase in DO concentration over the two-week time frame is likely due to the effects of primary productivity which will be discussed later in the document.

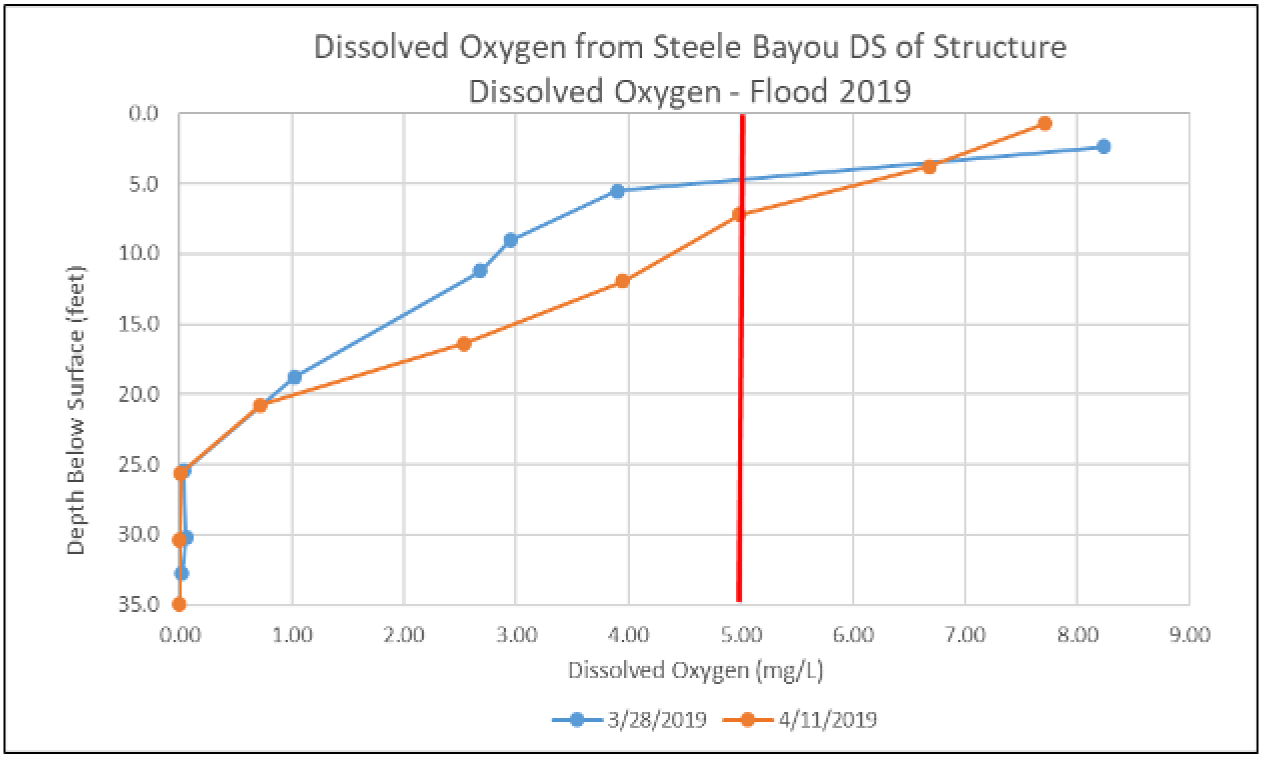

Figure 2-9. DO Water Column Profiles from Steele Bayou Downstream of the Steele Bayou water control structure at Highway 465. This data was collected during the middle of the flood which lasted from 6 June to 8 August.

Low DO concentrations were also observed outside of the Yazoo Backwater Area in the channels of the Big Black River and the Yazoo River as a result of the backwater effects resulting from the high stages of the Mississippi River. Water column profiles were collected on the Big Black River at Highway 61 (approximately 11 miles upstream of confluence with the Mississippi River) and the Yazoo River at Satartia (approximately 53 miles upstream of confluence with the Mississippi River) during the Flood of 2011.

The profiles collected from the Big Black River, which flows directly into the Mississippi River south of Vicksburg, show the effects of the colder water from the Mississippi River moving upstream on the Big Black River as well as the Yazoo River as the flood progresses. These are presented (Figures 2-10 – 2-12 & 2-13) to provide a comparison of the influence of flood events from the Mississippi River on lateral tributaries which experience a backwater condition from higher stages. This differs from the YBA due to the backwater levee system which physically separates the high stages of the Mississippi River water from that of the interior restricting the effects of comixing. The minimal DO concentration at the surface on the 13 May 2011 is representative of the warmer water flowing downstream from the Big Black River as the cooler water from the Mississippi River moves upstream along the bottom (Figure 2-10 and Figure 2-11). This phenomenon is depicted by the wedge shape from the surface to a depth of approximately 10 feet. A similar change in conductivity can be seen on 13 May 2011 where the measurements quickly change from less than 0.10 to greater than 0.25 µS/cm at depths from 5 to 10 feet (Figure 2-12). A similar effect can be seen on 19 May 2011 with the “wedge” moving down deeper in the water column. The last two days of observation show a decrease in the conductivity observed which indicates that mixing of the surface water from the Big Black River, the older Mississippi River water which had previously migrated upstream, and the new Mississippi River water continuing to push its way up the channel.

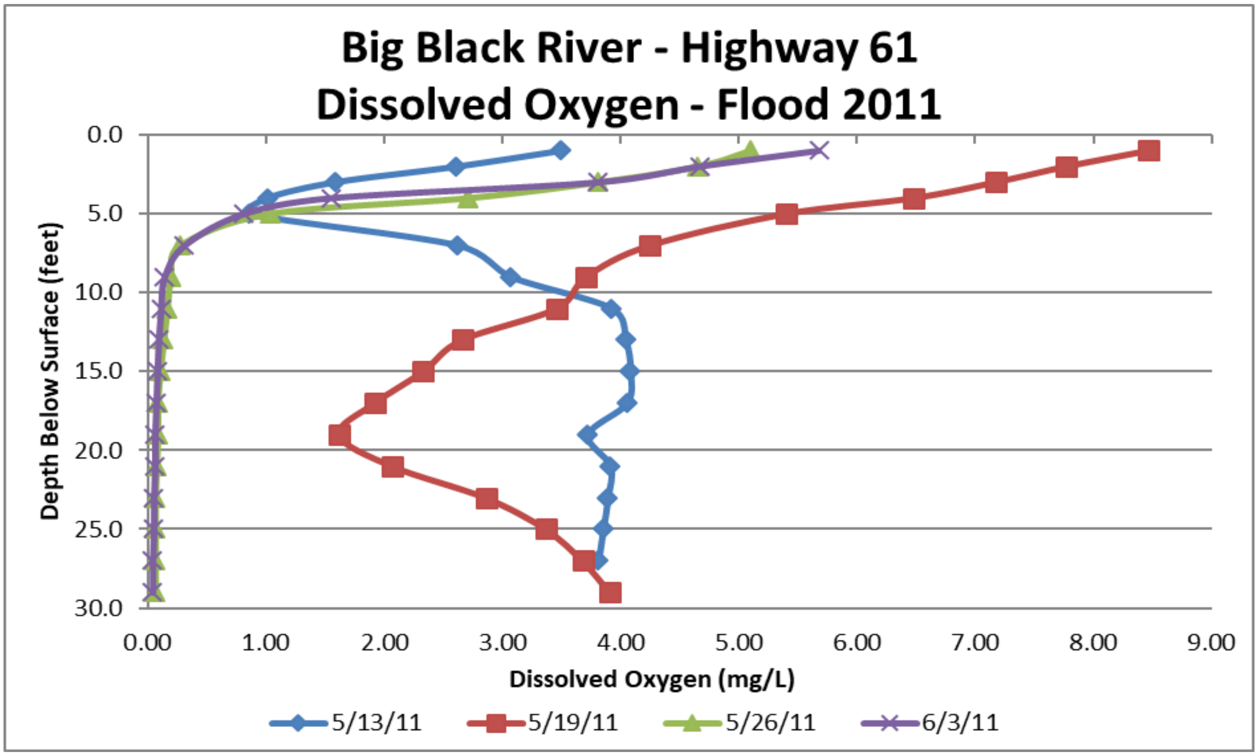

Figure 2-10. Depleted DO Concentrations from the Big Black River at Highway 61 throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

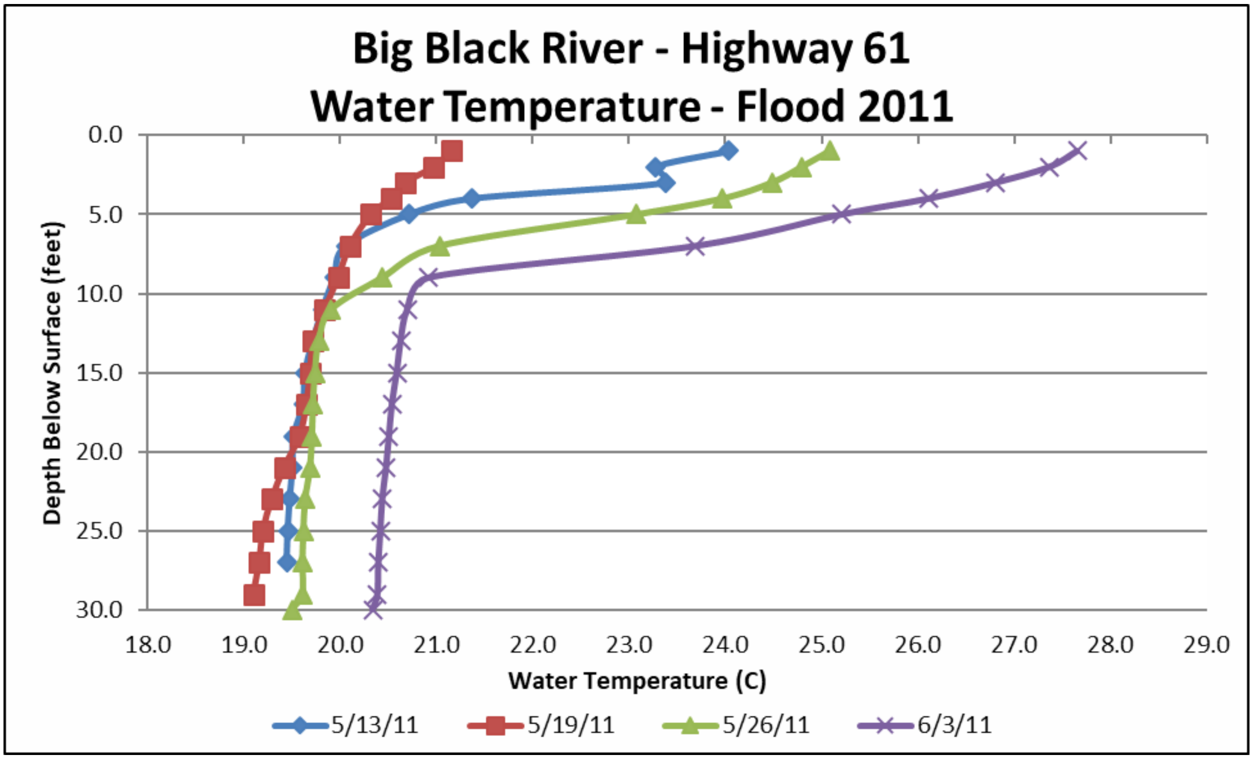

Figure 2-11. Water temperature from the Big Black River at Highway 61 throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

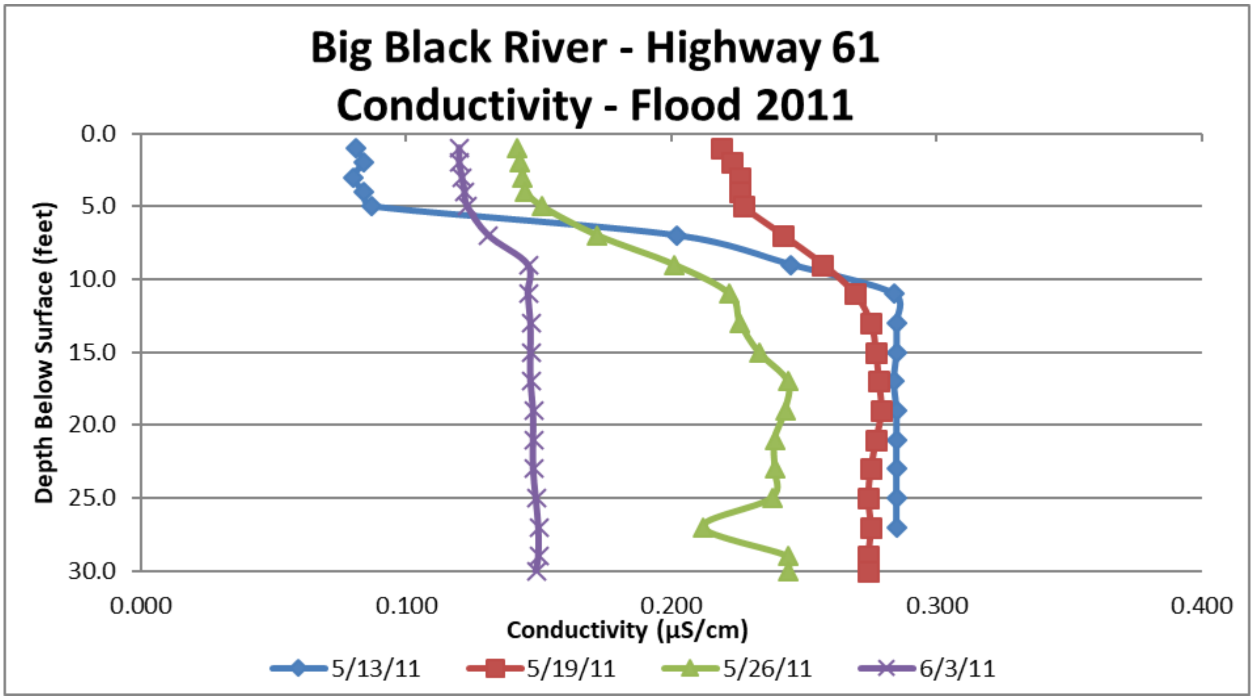

Figure 2-12. Conductivity measurements from the Big Black River at Highway 61 throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

The profile collected from the Yazoo River at Satartia which flows directly into the Mississippi River at Vicksburg shows a pattern similar to the one previously described, which has a slight rise and fall of DO concentration throughout the flood event. A small increase in DO concentration in the surface layer of water (approximately 5 feet) can be seen during the early part of May when the Mississippi River was rising (Figure 2-13). The DO concentration quickly falls out for the latter portion of May and into June as water exchange with the Mississippi River becomes negligible and the flows are held to a minimum.

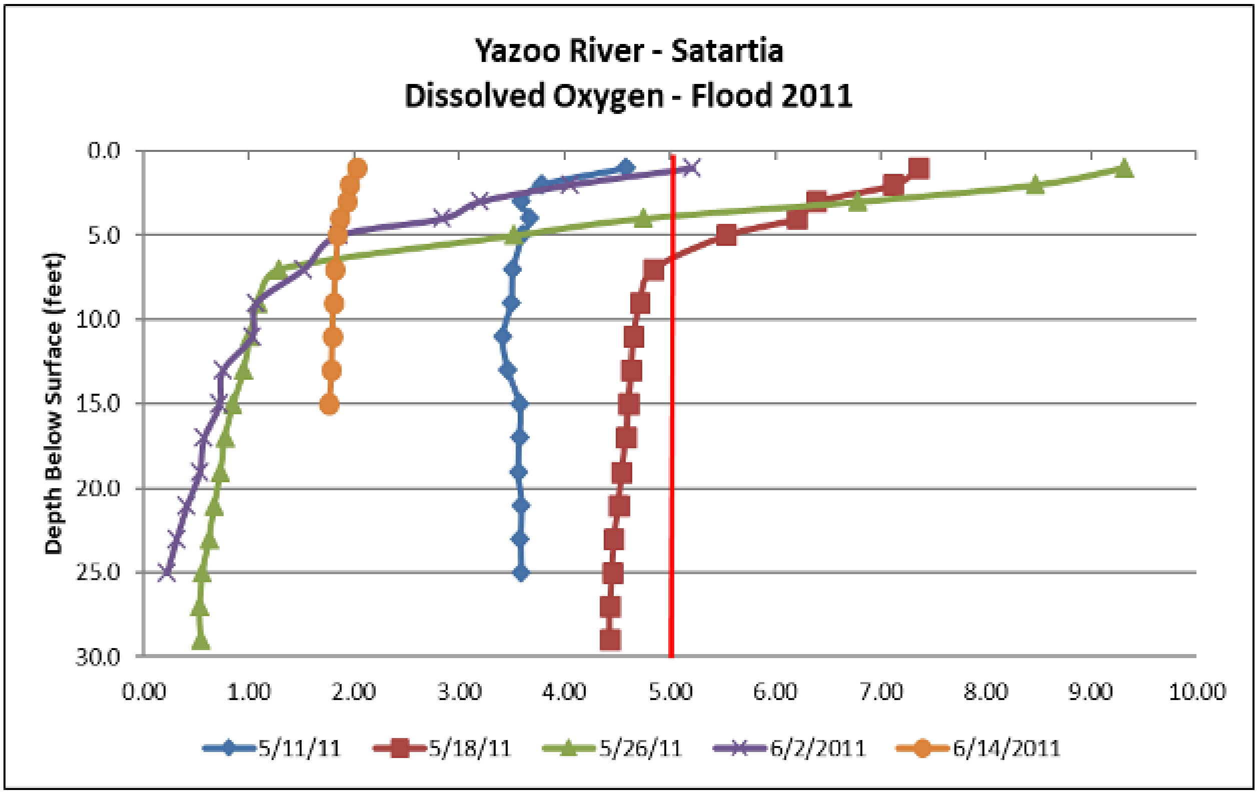

Figure 2-13. Depleted DO Concentrations from the Yazoo River at Satartia throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

During the Flood of 2015, a DO profile was collected on Steele Bayou at Highway 465 downstream of the Steele Bayou water control structure. This location is outside of the bathtub created by the Yazoo Backwater levee and is within 1,500 feet of the confluence with the Yazoo River and approximately nine miles from the Mississippi River. This represents a flood event when the Steele Bayou Outlet Structure gate was closed and not receiving discharge through the gates from the YBA. The graph in Figure 2-14 demonstrates the effects of stagnant conditions on DO when the high stages of the Mississippi River move upstream into its tributaries. Theses profiles were collected towards the latter half of the flood event and show low DO conditions throughout the entire water column.

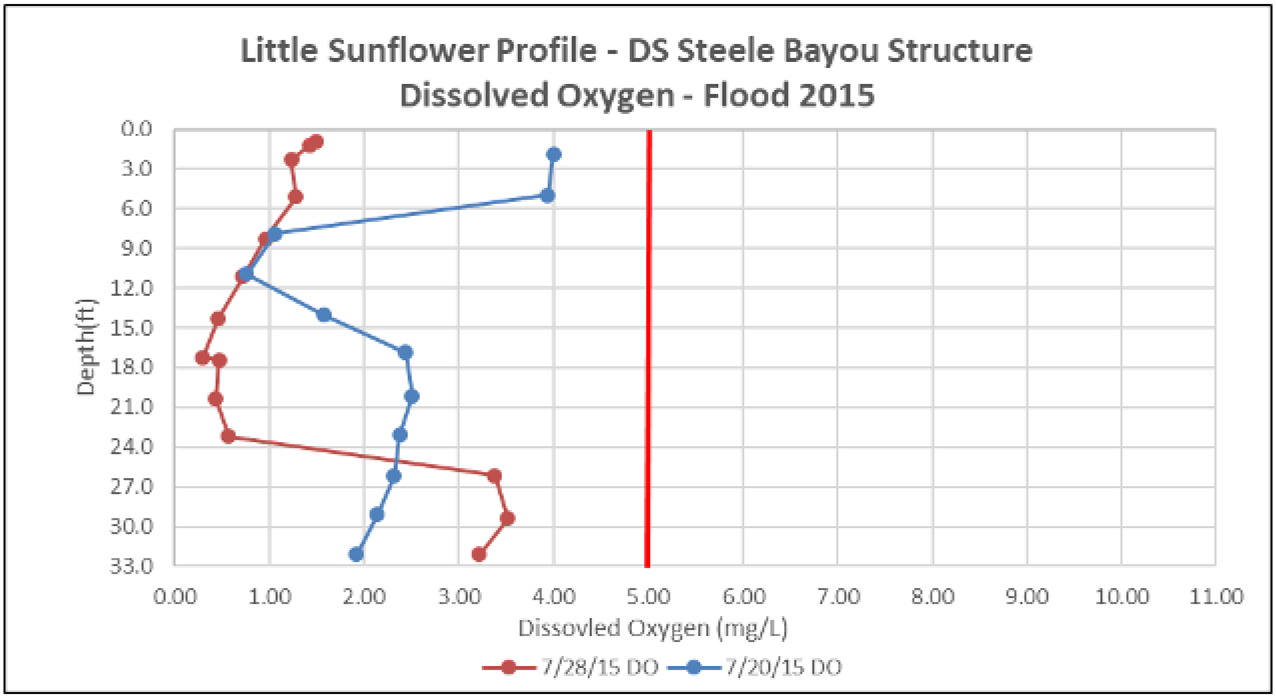

Figure 2-14. DO water column profiles of Steele Bayou at Highway 465 taken during the Flood of 2015. This data was collected during the third flood of 2015.

During the Yazoo Backwater flood of 2019, hourly measurements were collected by water quality sondes in the flooded timber at two locations adjacent to Steele Bayou. The first and northern most site was placed approximately 600 feet west of the Steele Bayou Channel and 14.7 miles upstream of the Steele Bayou water control structure. The second and southern most site was placed approximately 750 feet north of Cypress Bayou, on the eastern side of the Steele Bayou Channel, and at a distance of 3.1 miles upstream of the Steele Bayou water control structure (Figure 2-15). The sondes were suspended from tree limbs to a depth of 3 feet from the bottom. The daily means for DO and depth, plotted in Figure 2-15 shows how the minimal DO concentrations fluctuated during the later weeks of April, and the depth fluctuated during the second Steele Bayou water control structure opening for the 2019 flood (shaded area). It should be noted that the initial water control structure opening is not represented in the time frame in Figure 2-15. During the first week of May, the DO concentrations completely fall to 0.00 mg/L and remain below 0.20 mg/L for the duration of the deployment period until they are retrieved at the end of June. This data further reiterates the depletion of DO in the Yazoo Backwater Area during extended flood events.

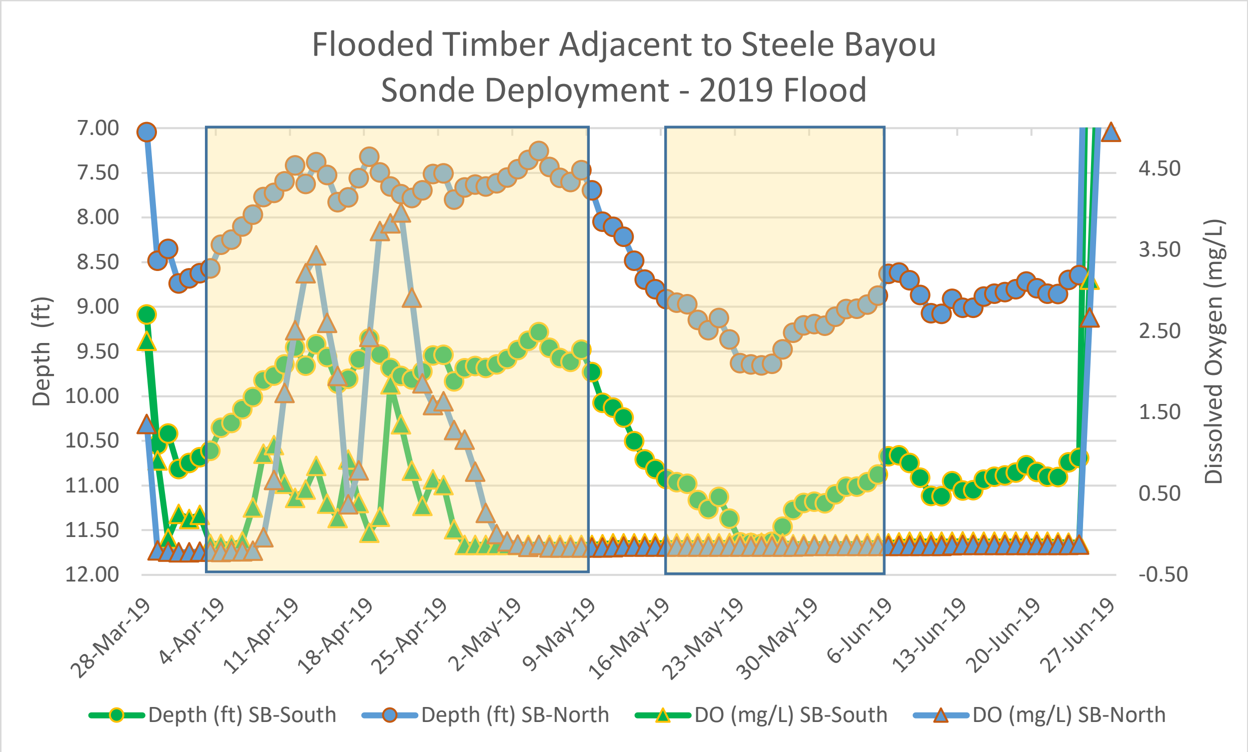

Figure 2-15. Daily mean DO concentrations (3 feet from the bottom) and depth below the surface from sondes deployed in flooded timber adjacent to Steele Bayou during the 2019 flood event: SB-North (above Muddy Bayou water control structure), SB-South (above Steele Bayou water control structure).

During the Yazoo Backwater flood of 2020, multiple measurements were collected by water quality sondes throughout the day from the Steele Bayou and Little Sunflower Channels. The location of the Steele Bayou sonde was located 2.85 miles upstream of the Steele Bayou water control structure labeled Cypress Bayou. This channel location was in close proximity to the sonde deployment utilized during the 2019 Flood. The location of the Little Sunflower sonde was located 6.5 miles upstream of the Little Sunflower water control structure labeled South Greentree. Two sondes were suspended at each location beneath the surface from a floating platform and tethered to a firm location in the channel. The fixed depths of the units were approximately 3.0 feet and 8.0 feet. The daily means for DO observed in the Steele Bayou Channel, plotted in Figure 2-16, show how the minimal DO concentrations fell to below 3.0 mg/L for the first water control structure closure in the month of January and then started to climb again when the Steele Bayou water control structure was opened (yellow shaded area) at the beginning of February. The increase in DO continue through the first week in March where water control structure operations were open but a limited head differential between the stages on Steele Bayou and the Mississippi River were minimal thus minimizing flow out of the basin. The DO concentrations again continued to fall below

5.0 mg/L at the beginning of April when the water control structure was closed again. While the DO concentration at the surface remained at or below 5.0 mg/L, the concentrations measured at the eight-foot depth ranged from 0.5 to 3.6 mg/L for the rest of the flood event.

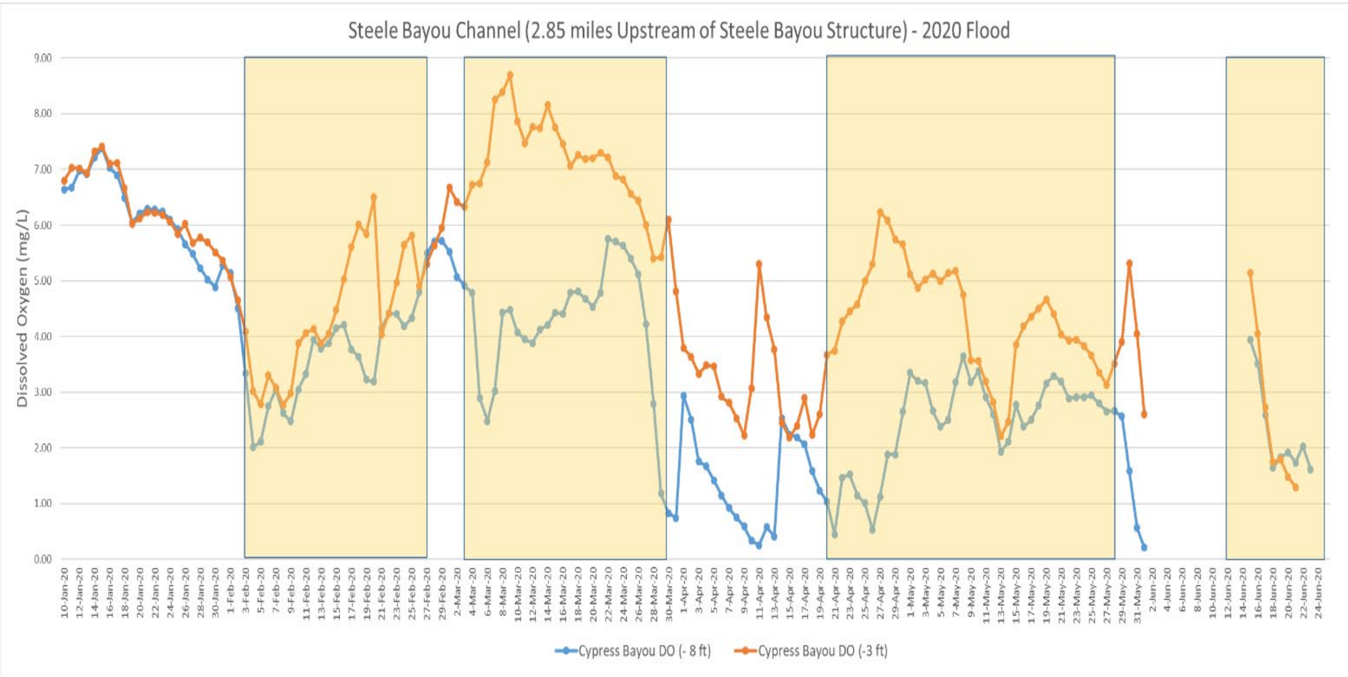

Figure 2-16. Daily mean DO concentrations (3 feet and 8 feet below the surface) from sondes deployed in Steele Bayou Channel during the 2020 flood event (labeled Cypress Bayou, yellow shading – water control strucutre open)

The daily means for DO observed in the Little Sunflower Channel, plotted in Figure 2-17, show how the minimal DO concentrations fell to below 5.0 mg/L for the first water control structure closure in the month of January and then started to climb again when the Steele Bayou water control structure were opened (yellow shaded area) at the beginning of February. The increase in DO continue through the first week in March where water control structure operations were open but a limited head differential between the stages on Steele Bayou and the Mississippi River were minimal thus minimizing flow out of the basin. The DO concentrations on the Little Sunflower River again continued to fall below 4.0 mg/L at the beginning of April when gate operations were closed again. While the DO concentration at the surface remained at or below 4.0 mg/L, the concentrations measured at the 8-foot depth ranged from 0.25 to 3.8 mg/L for the rest of the flood event. The gates at the Little Sunflower water control structure were closed and remained closed for the flood event restricting water release from the Yazoo Basin to the Steele Bayou water control structure. Due to the distance between the Little Sunflower water control structure and the Steele Bayou water control structure, flow was further restricted in the upper basin along with the potential for intermittent re-aeration as can be seen with the second graph. This data further illustrates the condition of low DO in the Yazoo Backwater Area during extended flood events.

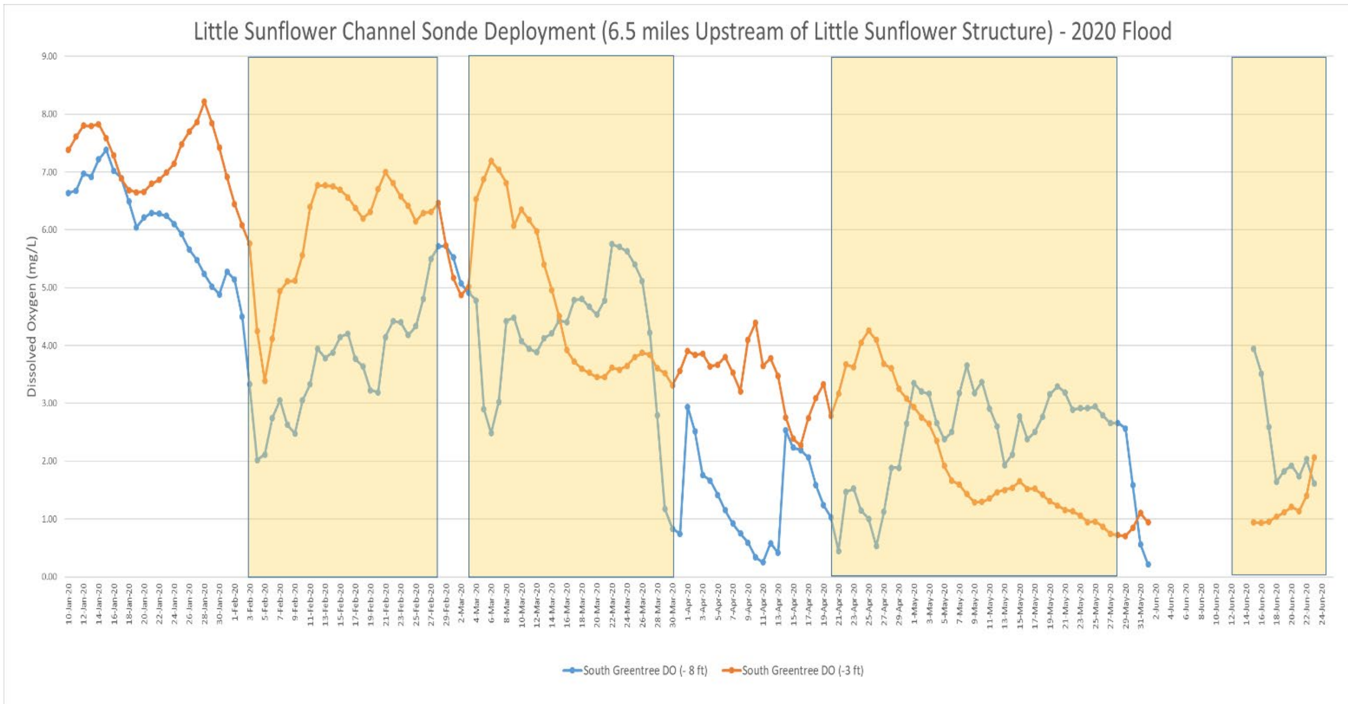

Figure 2-17. Daily mean DO concentrations (3 feet and 8 feet below the surface) from sondes deployed in Little Sunflower Channel during the 2020 flood event (Labeled South Greentree, yellow shading – water control strucutre open)

In 2005 and 2006 the Vicksburg District performed a study on the Little Sunflower River to show the effects of primary productivity on DO in the water column. Water quality profile measurements were collected one day per month from June to October, in the morning and after mid-day. The graph in Figure 2-18 shows how DO concentration increased from 3.0 to 7.0 mg/L from morning to afternoon. The increase in DO is likely due to photosynthesis. Figure 2-19 shows a similar diurnal increase in DO as the day progresses. Both graphs in Figure 2-18 and Figure 2-19 represent the overall higher DO concentrations found in the Little Sunflower during non-flood conditions. These higher concentrations are in stark contrast to the DO conditions found during a flood event.

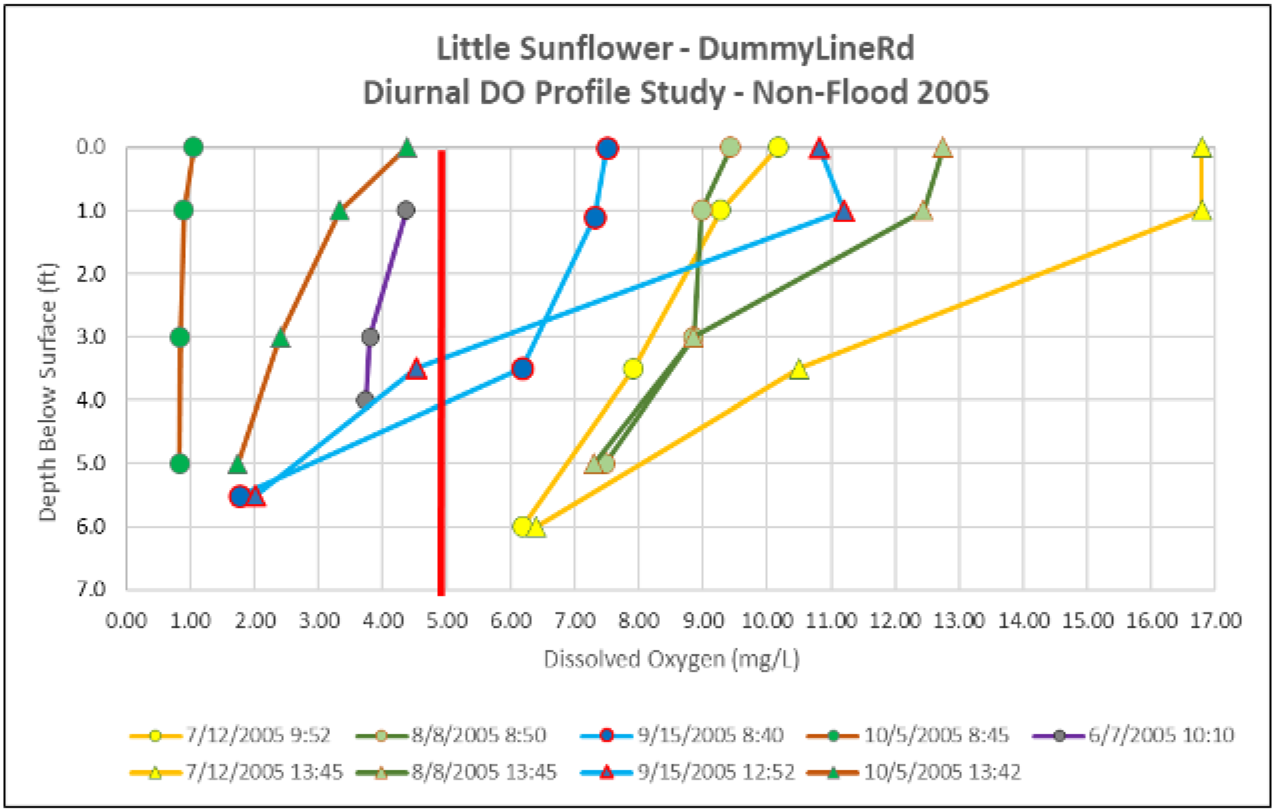

Figure 2-18. Diurnal Patterns for DO observe over a four-month period on the Little Sunflower River.

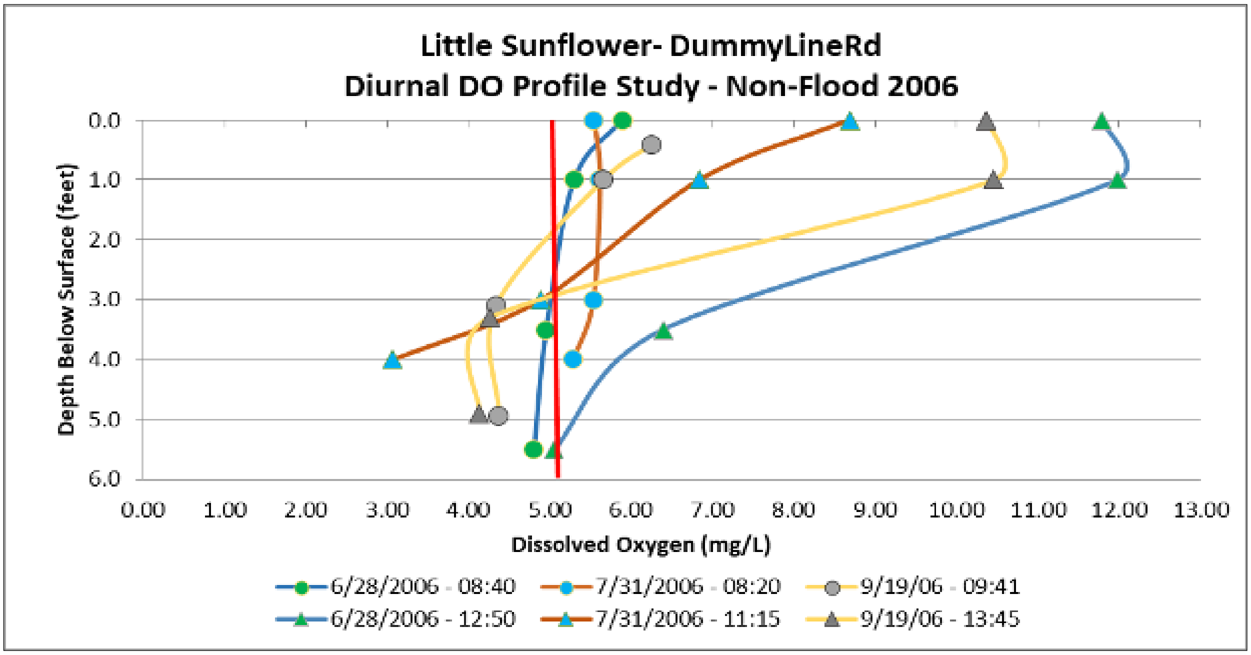

Figure 2-19. Diurnal Patterns for DO observe over a four-month period on the Little Sunflower River.

The low DO concentrations found in the Yazoo Basin have been associated with many corresponding factors. Warm water temperatures in excess of 20 degrees Celsius observed from the months of April to the fall months of October and November show a reduced concentration of DO. Low DO concentrations have also been observed during periods when the Steele Bayou and Little Sunflower water control structures are closed. One of the eight HGM functions, used to evaluate wetlands, is the export of nutrients and carbon. This "export of nutrients and carbon," can generally be assimilated in a flowing stream, but it becomes a burden during extended flood events. During these periods, backwater pools are created with higher-than-normal depths for extended periods. These extended periods of stagnant water limit the ability for re-aeration through agitation. For the first few weeks of a typical backwater flood, water depth and temperature stratification slow the process of diffusion limiting the principal mechanism for oxygen transfer into the water column from the surface. This condition compounded with the increase Biochemical Oxygen Demand (BOD) exerted by the organic matter (leaf litter) on the unmixed water closer to the forest floor allows for severe DO depletion (Delaune, R.D. et al. 1993).

The environmental restoration feature associated with Alternative 2 and Alternative 3 promotes the construction of the supplemental low flow groundwater wells located at the headwaters of the Steele Bayou and Big Sunflower basins is expected to provide a positive benefit to the overall low DO and minimal base flow conditions observed during the critical months. These warmer months typically coincide with the low flow periods in the primary tributaries of the two basins. The supplemental water provided to increase base flow should stimulate re-aeration through agitation minimizing the presence of stagnant intermittent pools along the channels.

The 25,000 cfs pump station feature included in Alternative 2 and Alternative 3 of the Yazoo Area Backwater Plan reduce the flood impacts on the area by moving water over the backwater levee into the Yazoo River. The construction of this pump station will help increase DO in the water column by minimizing the overall depth of a flood event and improving diffusion from the surface water of the interior backwater. The combination of these effects should have an overall benefit to DO in the Yazoo Backwater Area during extended flood events. Sediment disturbance during construction of the Yazoo Backwater Pump station may cause temporary increases in turbidity and nutrient levels. Temporary decreases in light penetration from localized increases in turbidity could cause reductions in photosynthesis. This could result in temporary, localized decreases in DO concentrations. Such increases would be of short duration. The DO and nutrient levels should return to preconstruction concentrations once the turbidity clears, and photosynthesis rates return to normal. The full utilization of the gate operation up to 75.0 (NGVD) Steele Bayou – Landside of the water control structure will also have a positive benefit on water exchange between the Yazoo River surface water and the Yazoo Backwater interior pool. This effect will allow the exchange of riverine water which is subject to greater reaeration potential and high DO concentrations, with interior backwater which has historically suffered from low DO. This will also translate to greater fisheries exchange between the two basins. The agitation generated by the pump activity in the outlet channel should have a positive effect on reaeration of discharge from interior TBA pool. However, a similar condition has been observed during the initial stages of a gate opening at the Steele Bayou Structure during a flood event.

In Alternative 4 the acquisition or floodproofing of residential and commercial properties up to 98.2 ft could subject the Yazoo Basin to sediment disturbance during construction activities which may cause temporary increases in turbidity and nutrient levels. In the No Action alternative provided in Alternative 1, the existing conditions observed in the Yazoo Backwater would continue to prevail during flood events. This would include depressed DO concentrations throughout much of the water column in the lower basin and stressed aquatic habitat.

2.12 SUSPENDED SOLIDS

Suspended solids have been observed to preclude the transmission of light through the water column in the Yazoo Backwater Area. This limited light can significantly restrict the growth of phytoplankton in the water column thus inhibiting the primary productivity. The Vicksburg District collected turbidity and DO profile measurements from the water column during the Backwater Flood of 2011 over a five-week period from 11 May to 14 June. The following graphs will display comparisons between the decrease in turbidity and the presumed increase in light transmission at the surface. This greater light transmission translates to a positive effect on photosynthetic activity and the production of chlorophyll A which has a positive effect on DO in the water column. The following DO graphs are used as a surrogate to the show the impacts of turbidity changes over time during a flood event. The data will also show how DO concentrations decreased with depth as described in the previous section.

The Low Water Bridge station is situated in the lower portion of the Yazoo Backwater Area. The graph in Figure 2-20 for the Steele Bayou Channel at Low Water Bridge shows a distinct decline in DO concentration as the depth increases during the Yazoo Backwater Flood of 2011. During the 2011 Flood Event, this location experienced the effects of “Backwater” flooding as a result of the closure of the Steele Bayou water control structure. This backwater flooding created pooling which restricts re-aeration due to increased depth. The highest DO levels are just below the surface and are at or below 5 mg/L for the first four weeks of the flood event. Surface DO concentrations eventually increased as the flood event progressed.

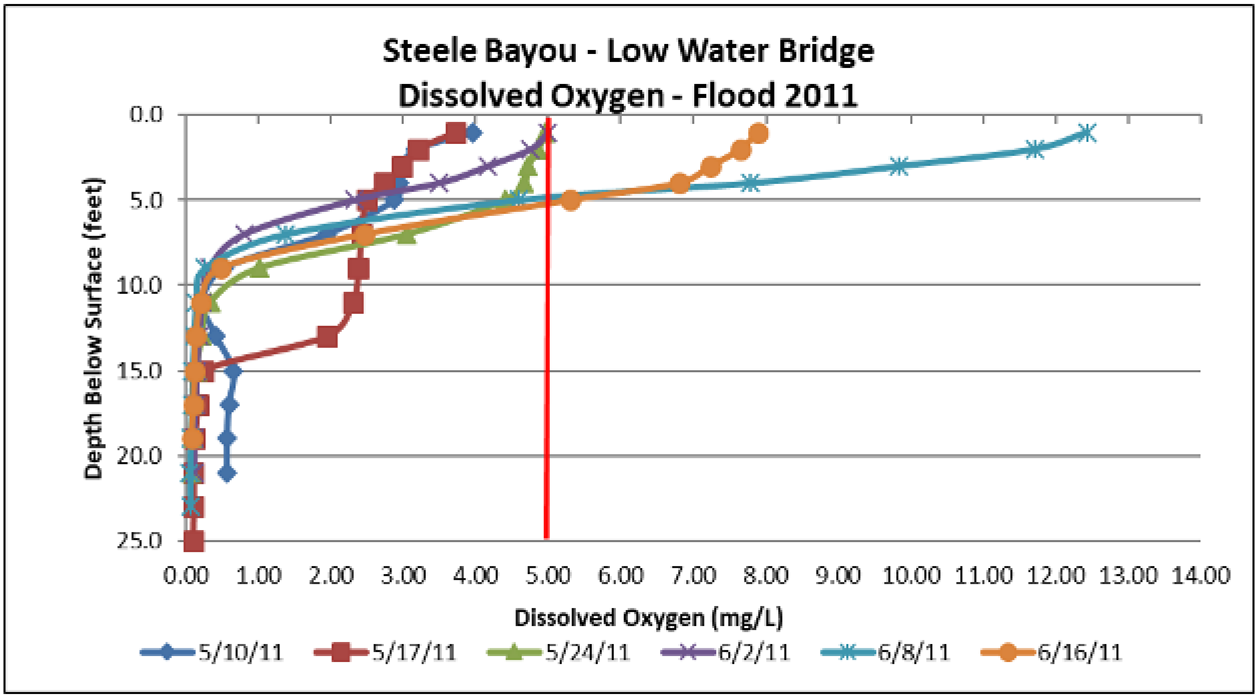

Figure 2-20. Depleted DO concentrations from the Steele Bayou Channel at Low Water Bridge throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

The graph shown in Figure 2-21 shows the reduction of turbidity concentrations from over 150 to less than 10 nephelometric turbidity units (NTU) as the flood event progressed. The backwater pooling effect provides optimal conditions for settling. This settling of solids from the water column over the first few weeks of the flood allowed for better light transmission and consequently increased primary productivity. The production of oxygen from an increase in phytoplankton activity, along with the diffusion of oxygen from the surface, increased DO concentrations in the surface layer during the latter weeks of the flood event. ChloroA concentrations are considered a direct indicator of primary productivity. Laboratory analysis from the grab samples collected on 10 May and 8 June from Steele Bayou at Low Water Bridge during the flood event revealed ChloroA concentrations to be less than 5.0 and 23.9 mg/m^3. The increase in ChloroA agrees well with the decrease in turbidity.

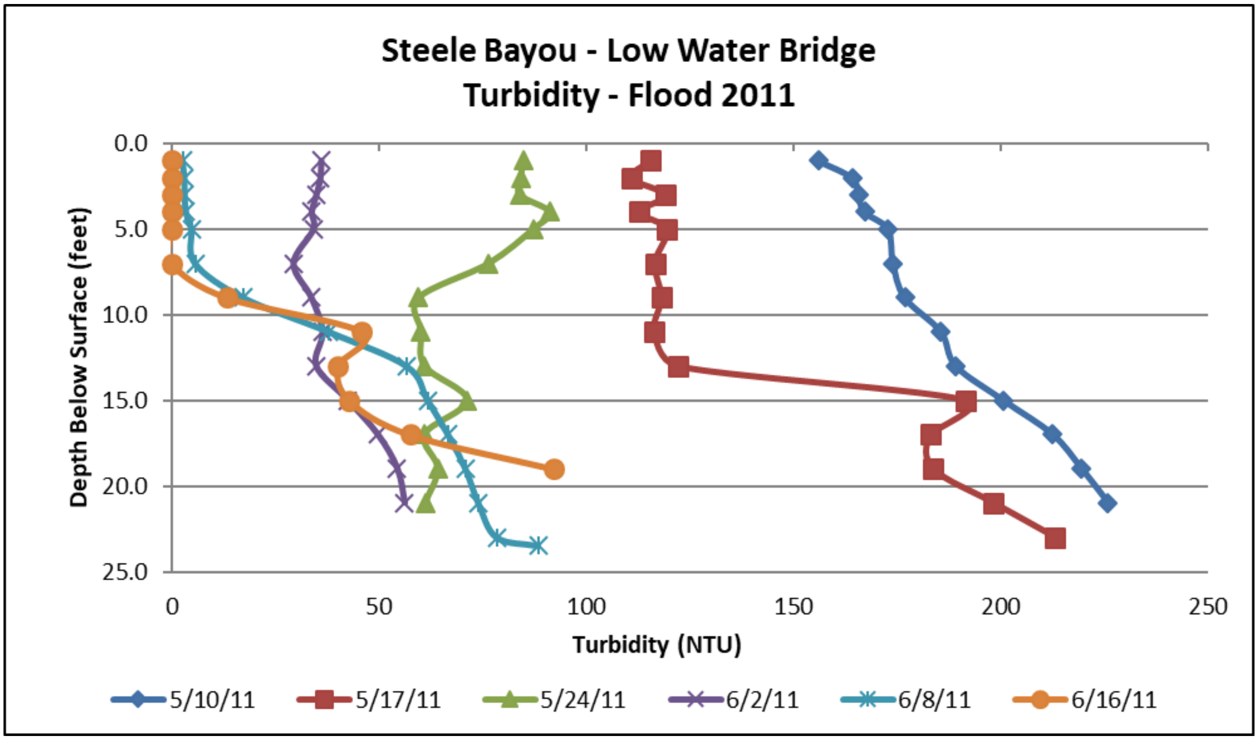

Figure 2-21. Turbidity concentrations from the Steele Bayou Channel at Low Water Bridge throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

The data shows a similar trend for depressed DO conditions at the Steele Bayou at Grace station which experienced inundation from backwater during the May to June time frame. After the turbidity concentrations decreased to less than 50 NTU's, DO concentrations responded accordingly in the surface layer.

The Little Sunflower Channel at Dummy Line Road is situated in the lower portion of the Yazoo Backwater Area. The Dummy Line Road Bridge is located adjacent to the Delta National Forest and approximately seven miles from the Big Sunflower River. Most of the drainage to this site is forested. Similar to the conditions found at Low Water Bridge, turbidity decreased in the water column as the event progressed (Figure 2-22). However, only minimal increases in DO were observed at the Dummy Line Road Station throughout the entire monitoring period (Figure 2-23). The concentrations for ChloroA collected on 10 May and 8 June at this station were both found to be less than 5.0 mg/m^3. Turbidity values at this location did not decline as rapidly as the other stations. As such, increased levels of photosynthetic activity were not measured in the second grab sample.

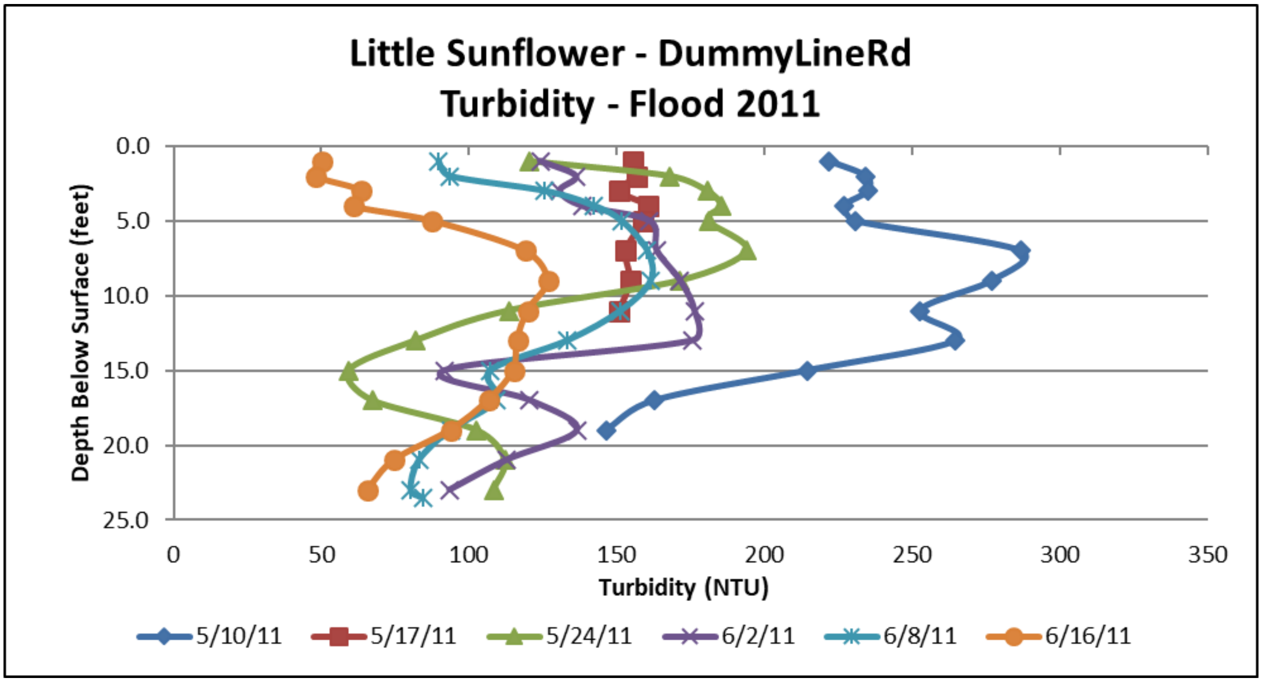

Figure 2-22. Turbidity concentrations from the Little Sunflower Channel at Dummy Line Road within Delta National Forest throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

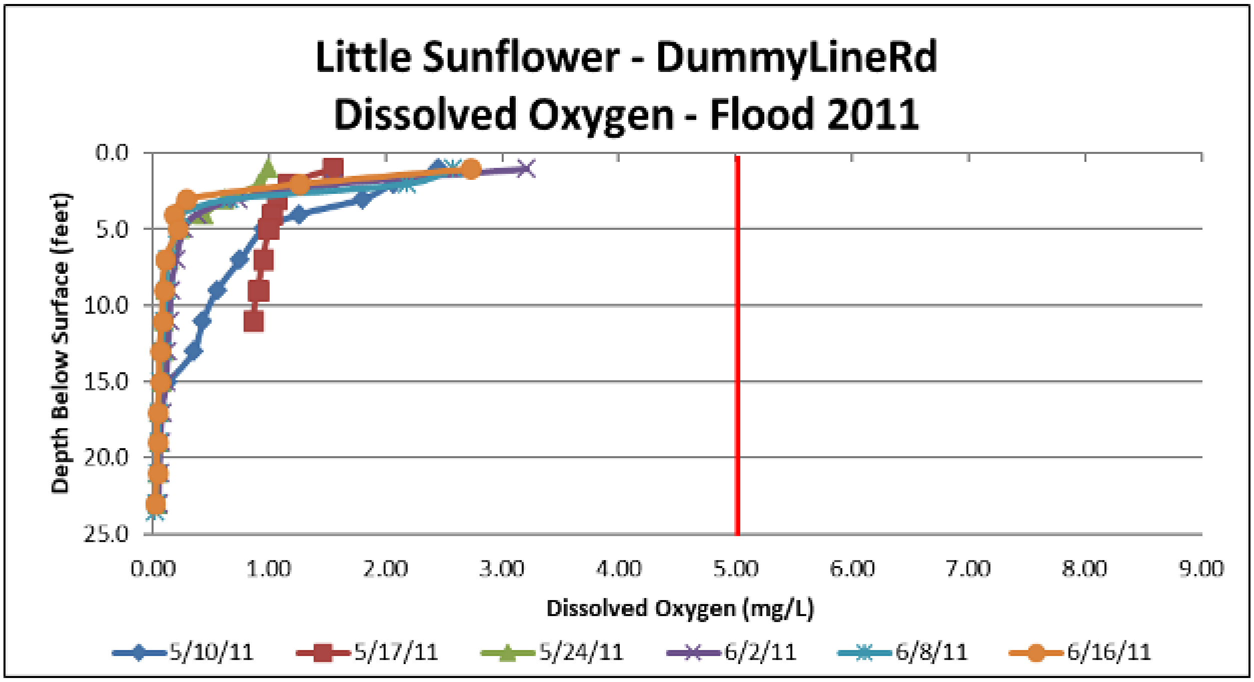

Figure 2-23. Depleted DO concentrations from the Little Sunflower Channel at Dummy Line Road within Delta National Forest throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

The Big Sunflower River experienced the same effects of depressed DO for the first few weeks of the monitoring period. The DO concentration at the Anguilla Station was less than 5.0 mg/L at the surface and decreased rapidly for the month of May (Figure 2-24). Turbidity decreased from 300 to less than 50 NTU's over the same time frame (Figure 2-25). Dissolved oxygen conditions responded accordingly in the surface layer for the month of June.

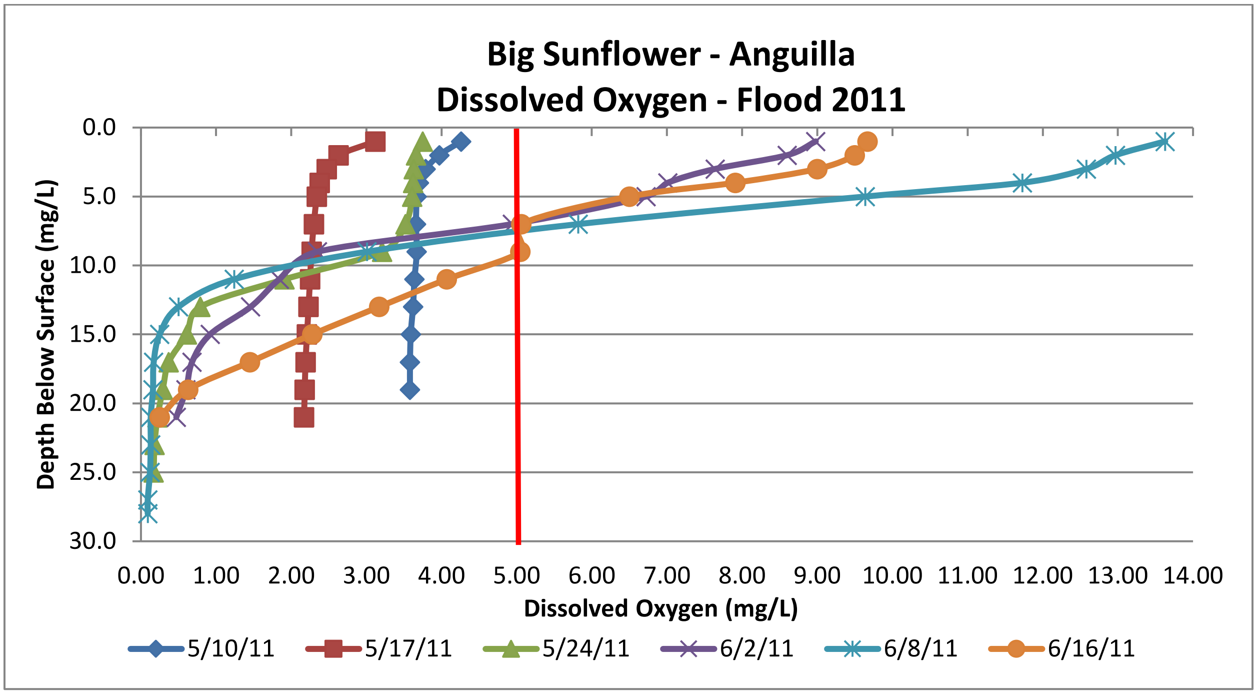

Figure 2-24. Depleted DO concentrations from the Big Sunflower River at Anguilla throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

The grab samples collected on 10 May and 8 June from the Big Sunflower River at Anguilla showed a similar response of ChloroA to turbidity. ChloroA was measured to be less than 5.0 and 22.7 mg/m^3, respectively. These measurements indicate an inverse relationship between turbidity and photosynthetic activity. As previously noted, during periods when backwater pools grow deeper and sustain prolonged periods of stagnation, suspended solids have an opportunity to settle out of the water column. This corresponds to increased light transmission through the surface layer and the increased production of algal productivity. As a result, DO concentrations begin to recover within the first 5 to 10 feet of surface. Furthermore, this condition may be exacerbated in the flood pool by the nutrient availability from the upper watershed. This may in turn exhibit greater extremes of high and low DO concentrations in the diurnal regime.

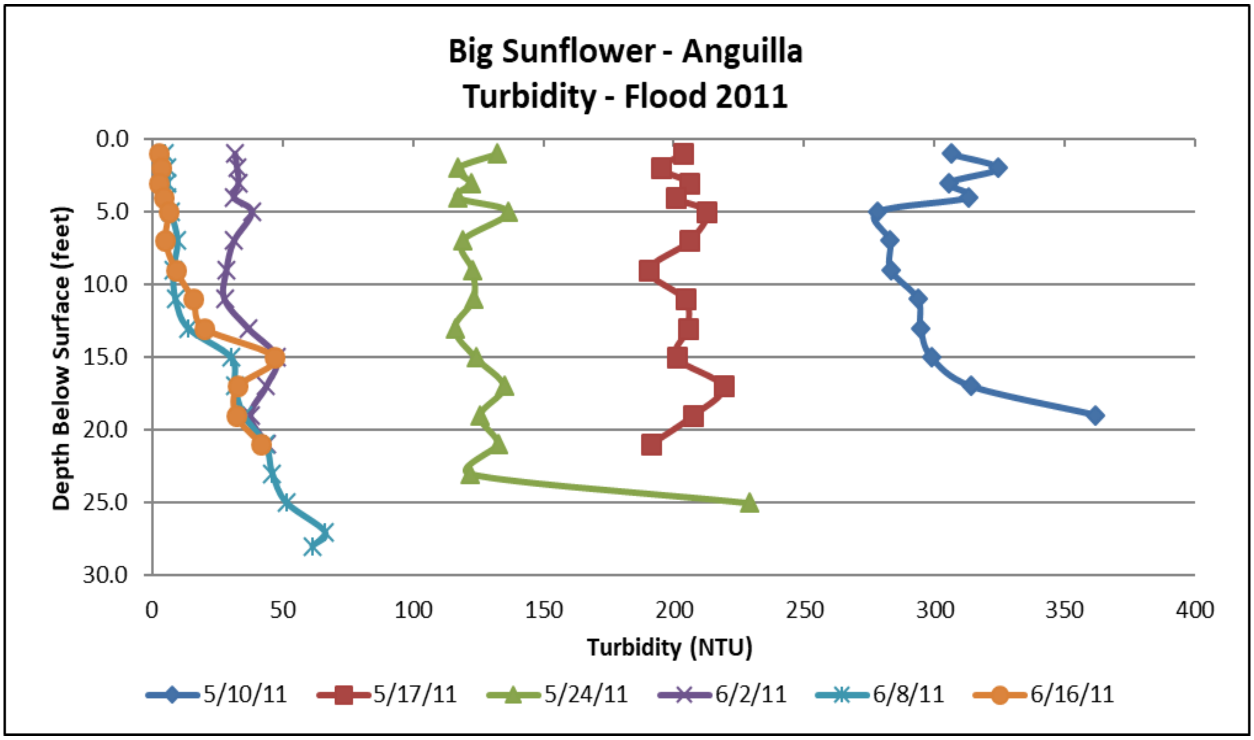

Figure 2-25. Turbidity concentrations from the Big Sunflower River at Anguilla throughout the 2011 Flood. This data was collected during the peak of the flood which lasted from 8 March to 20 July.

The Turbidity graphs from the Flood of 2011 displayed in Figure 2-21, Figure 2-22, and Figure 2-25 show the concentration decreasing at an average rate of 50 NTU's per week for the first three weeks of monitoring. This appears to slow down at a minimal concentration of 50 NTU. This corresponds to the initial period of a typical flood before the pump station would initiate pumping. For the larger flood events which correspond to a longer detention time, the operation of the Yazoo Backwater Pump station proposed in Alternative 2 and Alternative 3 when compared to No Action Alternative and Alternative 4 would slightly reduce the overall settling time for suspended solids in the basin. During the 2013 and 2018 event, this reduction in settling time was calculated to be approximately 2 weeks. The reduction in settling time for the front end of the 2019 event would have approached approximately 5 weeks. This reduced residence time in the pooled area may have a temporary impact on sediment delivery downstream of the structure. These comparisons are explained in detail later in this report.

In the 1990s, high suspended solids were observed throughout the Steele Bayou Basin. The same problems were noted in the Big Sunflower Basin. The high sediment loading was coupled with the intense agricultural production of the two basins as well as the high erosive potential of the deltaic soils. During post-harvest when farmers plow and re-dress their fields in preparation for the next spring, intense runoff or "first flush" rainfall events (typical of the tropical storm season) can contribute episodic erosion events to the watershed. These events have been observed to be a major contributor of the overall suspended solids problem in the Yazoo Basin. The reduction of floodplain inundation for the larger flood events that exceed the 5-year frequency may correspond to a decrease in sediment attenuation in the YBA. These trends shall be monitored in a post project setting as prescribed through the adaptive management schedule and the MOA's coupled to this project.

The bar graph displayed in Figure 2-26 shows the average annual TSS concentrations found in the Steele Bayou Basin. The data collected from the SBMP shows how the concentrations were reduced by approximately 50% from the early 1990's to the early 2000's from concentrations in excess of 200 mg/L to average concentrations of 100 mg/L. The concentrations were observed to increase the first few years of the 2010 decade, peaking in 2013 (likely due to the heavy precipitation associated with the Backwater Flood Event of 2013). A slight decrease was observed from 2013 to 2015. This most recent downward trend of TSS was likely the response from the installation of the last 50 Steele Bayou erosion control structures and related sediment reduction projects implemented in the agricultural community. (Kilgore et al. 2008, MDEQ 2011).

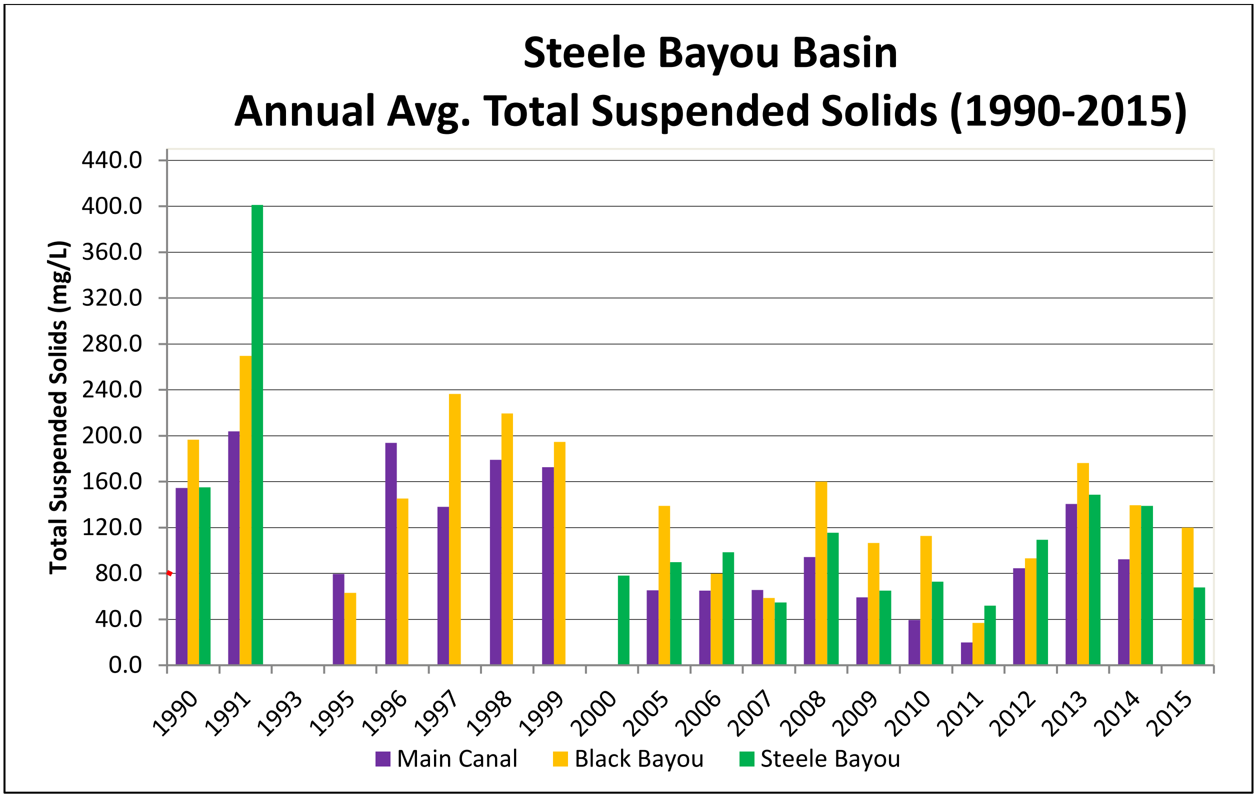

Figure 2-26. Average Annual TSS Concentration for the Steele Bayou Basin from SBMP.

The bar graph displayed in Figure 2-27 shows a similar increase in TSS concentration in the Big Sunflower Basin from the first few years of the decade starting in 2011 and peaking in 2014. The target concentration appears to be approximately 140 mg/L-TSS below the most recent average annual peak observed for the Big Sunflower Basin in 2014. It should be noted that the construction for the first Big Sunflower Erosion Control Structures began in 2016. The effectiveness of these structures is not reflected in the graph. A reduction in suspended sediment concentrations in the Big Sunflower Basin is expected in the subsequent years.

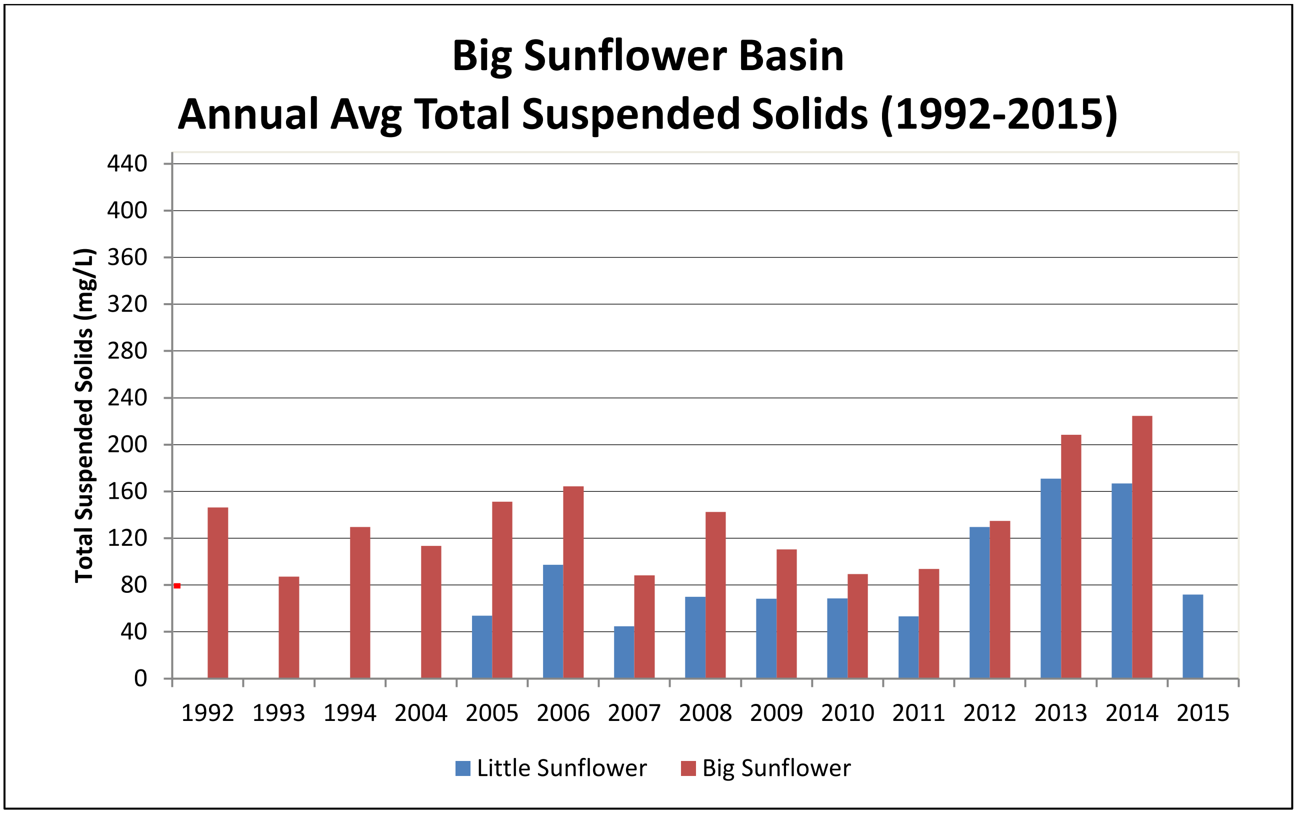

Figure 2-27. Average Annual TSS Concentration for the Big Sunflower Basin from SBMP.

The minimal DO concentrations observed in the main stems of the Steele Bayou, Upper Deer Creek and Big Sunflower Basin have been observed during the warmer months of the last ten years. These depressed conditions which have been defined by the EPA to be less than 5.0 mg/L in warm water streams have been shown to extend for over six months. The pools created in the lower portion of the basins during backwater flood events minimize the capacity for re-aeration of the water. This can further exacerbate a minimal DO problem especially in the deeper pools that last for multiple months. The data does support the re-emergence of DO in the surface layers of the flood pools by virtue of primary productivity. However, these conditions typically develop during a backwater flood after weeks of stagnant conditions when suspended solids have had a chance to fall out of the water column. The algae present is allowed to flourish from greater transmission of sunlight due to increased water clarity. This phenomenon can provide little influence on the health of the system since it comes after such an extended period of depressed DO or hypoxic conditions when fish and other aquatic species have either left the system or died.

The Vicksburg District initiated a program in 2004 to mitigate the impacts of increased sediment loading that had resulted in part from the increased agricultural land use within the Steele Bayou Basin. The Vicksburg District partnered with Delta Wildlife, Mississippi Levee Board, Natural Resources Conservation Service, Ducks Unlimited, and MDEQ to implement a program that would employ drop pipe inlet structures to help reduce the erosive effects of run-off from agricultural fields (Kilgore et al. 2008, MDEQ 2011). The runoff was found to be associated with increased levels of sediment /siltation and nutrients in the watershed. The aim of this program was to install approximately 100 drop pipe structures at the edge-of-field in order to reduce sediment loading into the watershed. This program was implemented alongside additional conservation farming practices and monitored to track effectiveness.

In the early part of the 2000 decade, the U.S. Department of Agriculture (USDA) started promoting the Educational Quality through Innovative Partnerships (EQUIP) Program to the agricultural community in the Yazoo Delta which educated farmers about the overall benefits of best management practices (BMP's) for row-crop production. These practices included the resurfacing of agricultural fields through land leveling to slopes typically less than 0.5% and the construction of pads/pipes around the perimeter of agricultural fields. The EQUIP Program also promoted the use of surge valves, deficit irrigation techniques, vegetative buffer strips, and moisture meters to optimize use of water applied through irrigation.

The water management BMP's act to slow the rate of runoff reducing siltation. The goal of the BMP's is to reduce the overall volume of irrigation water needed for efficient agricultural production and has had a favorable impact on the water quality in the Yazoo Basin. This was documented by the USGS - Steele Bayou 319 success story for sediment reduction from edge of field structures (Hickes et al. 2011, MLB 2023). In this program, researchers demonstrate how these sediment reduction structures located in stream inlets at edge-of-field minimize the movement of valuable topsoil from the field into adjacent water bodies. These sediment reduction structures consequently reduce the amount of bound phosphorus that can enter the system and eventually the Mississippi River. The combination of these practices has been instrumental to slowing the rate of runoff and helping control the loading of sediment and nutrients into the Yazoo Watershed.

The data also shows that an overall decrease in TSS has been observed in the Steele Bayou Basin. The concentrations were reduced by approximately by 50% from the early 1990's to the early 2000's from concentrations in excess of 200 mg/L to average concentrations of 100 mg/L. These reductions are a result of the structures built by the

Steele Bayou Erosion Control Program as well as the BMP's implemented by the farming community through the EQUIP Program. Similar reductions in TSS concentrations are expected from the construction of future erosion control structures built in the Big Sunflower Basin.

In summary, the data shows that turbidity is greatest during the first few weeks of a Yazoo Backwater Flood. As the backwater pools grow deeper and sustain prolonged periods of stagnation, the suspended solids have an opportunity to settle out of the water column. This process makes way for increased light transmission through the surface layer and the increased production of phytoplankton. As a result, DO concentrations appear to recover within the first 5 to 10 feet from the surface. The implementation of the 25,000 cfs pumps in Alternative 2 or Alternative 3 will result in the reduction of wetland area available for settling of sediment during large flood events which exceed the 5-year frequency in the YBA. The trends shall be monitored in the post project phase of Alternative 2 or Alternative 3 through the adaptive management structure which could encourage more of the agricultural BMP that have been initiated in the YBA. The required mitigation efforts associated with these alternatives will help to offset soil runoff into the surface waters. Acreage will be removed from cultivation through the required mitigation plans. The proposed strategy will seek to acquire acreage below 90.0 feet and 93.0 feet elevation for tree planting and reestablishment of bottomland hardwood forests. Alternative 2 and Alternative 3 have current mitigation acreage requirements of 7,650 ac and 5,722 ac, respectively which should serve to benefit water quality in the Yazoo Backwater Area.

SECTION 3 NUTRIENTS

3.1 GENERAL

As previously described in Sections 1 and 2 extensive efforts have been made by the Vicksburg District through the SBMP to collect water quality nutrient data throughout the Yazoo Backwater Area since the writing of the YBARR-07. A statistical analysis was generated from both of the data sets using SAS Univariate software. The software was used to calculate mean values from the concentrations generated from the monthly surface water grab samples. The mean values for TN and TP were grouped on an annual basis for each available year and subdivided on a monthly basis. This grouping allowed for a better comparison of the agricultural growing season and corresponding irrigation period typically found in the Yazoo Basin. The subsequent data collection efforts conducted over the last decade lends new insight to the overall trends for nutrient found throughout the Steele Bayou and Big Sunflower Basins.

Additional water quality data has been collected by the USGS on many of the primary tributaries in the Yazoo Backwater Area stretching back to the 1970's. Information related to TN and TP concentrations was retrieved from surface water grab samples accessed through USGS's online NWIS website. Available data was sorted according to the HUC8 watersheds and analyzed through 2016. The watersheds of interest were the Big Sunflower, Steele Bayou, Upper Yazoo, and the Lower Yazoo which were labeled as BigSun, Steele, UppYaz, and LowYaz respectively. A statistical analysis was generated from the data using SAS Univariate software. The software was able to define values for mean, max, and minimum for the following nutrient concentrations: TN and TP. The statistical data generated for the nutrient parameters was grouped into decade time frames starting with 1970 and continuing through 2010. The combination of these two data sets help to supplement the SBM Data used to describe the overall water quality health of the Yazoo Backwater Area. Lastly, water quality criteria standards for TN and TP have not been defined by the Mississippi Commission on Environmental Quality for the state of Mississippi. To supplement, the National Median concentration given for TP and TN categorized for agricultural regions was identified on many of the graphs throughout this section as a reference for comparison (Dubrovsky et al. 2010).

3.2 PHOSPHORUS

Phosphorus is an essential plant nutrient, and it has long been amended to soils to increase crop productivity. Residual phosphorus that is not utilized in the uptake for plant growth is typically bound to the soil particles. Runoff during precipitation events, brings these soil particles and their attached phosphorus molecules to the stream where the heavier soil particles settle out and the lighter clay particles slowly migrate downstream. The graph in Figure 3-1 shows a distinct relationship between the monthly averages of suspended solids and phosphorus concentrations found in the Steele Bayou Basin. The concentration for the two constituents appears to decrease from an approximate average peak of 0.33 and 150.00 mg/L for TP and TSS, respectively in the winter when conditions are wet. The concentrations reach an approximate low during the dry summer months of 0.17 and 40.0 for TP and TSS, respectively. Many of the acres utilized for agricultural production in the Steele Bayou Basin in the 1980's and 1990's has since been reforested through the Wetland Reserve Program and Conservation Reserve Program administered by the USDA. While these programs are not directly tied to the implementation of this project, they will likely continue throughout the YBA subject to the funding discretion of Congress.

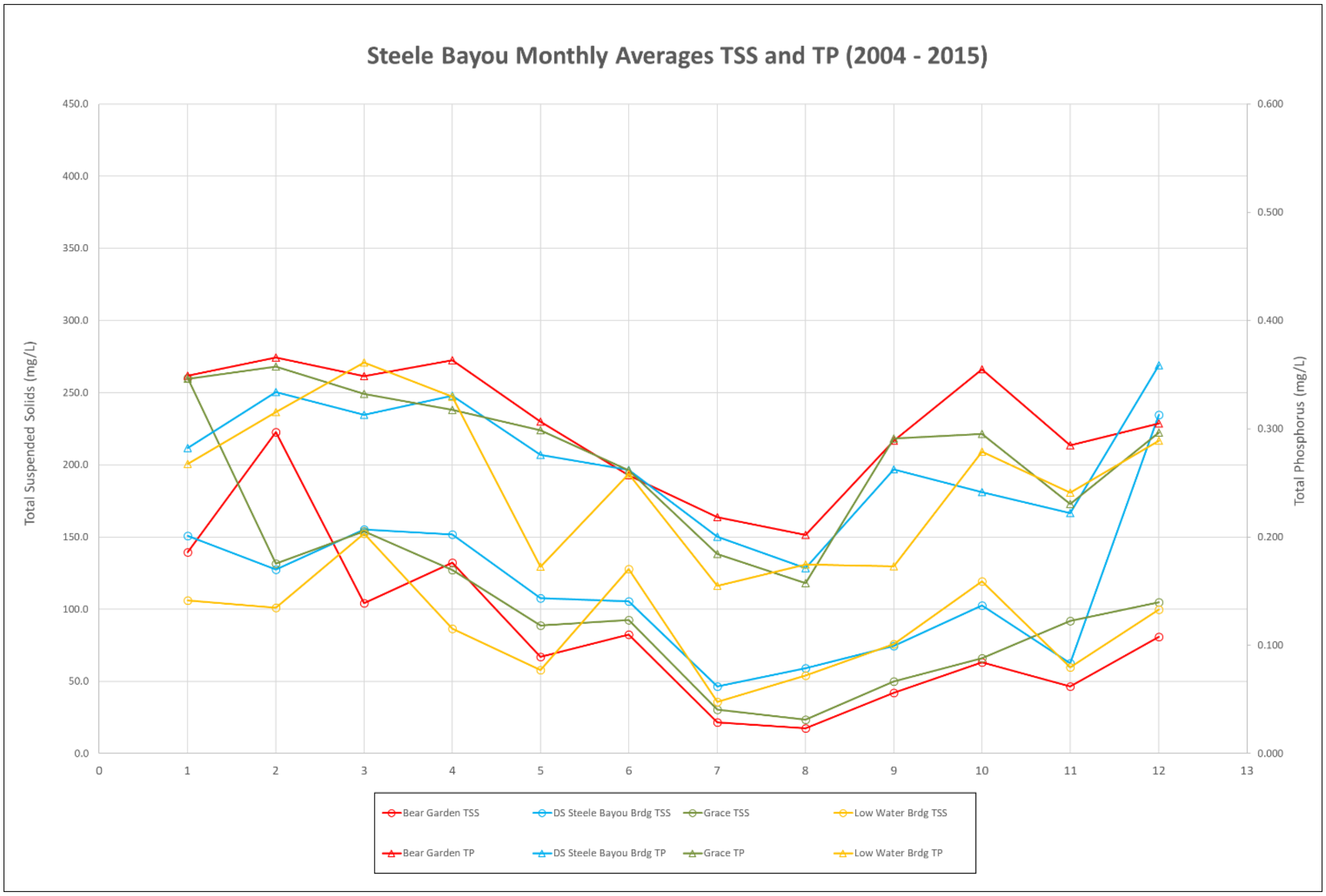

Figure 3-1. Average Concentrations for TSS and TP found in the Steele Bayou Basin grouped by month from data collected by the SBMP.

The link between TP and TSS was more pronounced in the Big Sunflower Basin where agricultural activity is more prevalent. The graph in Figure 3-2 shows the concentrations for the two constituents on the Big Sunflower River appear to decrease at a greater rate from an approximate average peak of 0.47 and 400.00 mg/L for TP and TSS, respectively in the winter when conditions are wet. The concentrations reach an approximate low during the dry summer months of 0.17 and 50.0 for TP and TSS, respectively. The link between the two constituents is not quite as clear for the data collected on the Little Sunflower River. This is likely due to the reduction in farm acres found in the Little Sunflower drainage basin as opposed to the Big Sunflower drainage basin.

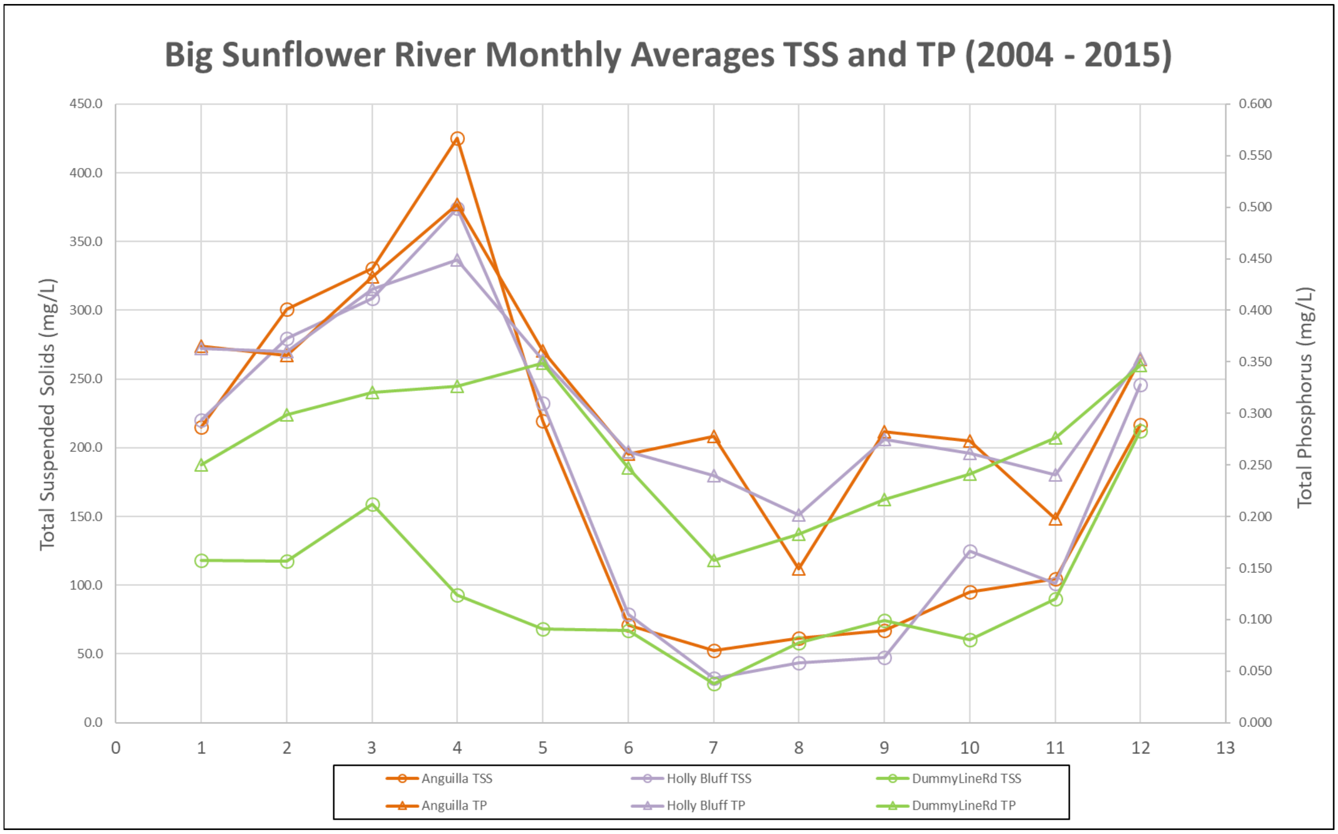

Figure 3-2. Average Concentrations for TSS and TP found in the Big Sunflower Basin grouped by month from data collected by the SBMP

The annual mean TP concentrations in the Steele Bayou Basin showed a decrease from the early 1990's of a concentration of 0.50 mg/L to the end of the decade of around 0.25 mg/L (Figure 3-3). The concentrations peaked again to 0.40 mg/L in the first decade following 2000 until falling back down to around 0.16 mg/L. Concentrations climbed again slightly to a value of 0.25 mg/L in 2015. This concentration agrees with the median stream TP concentration of 0.25 mg/L which was published by USGS from multiple streams situated in agricultural areas from the U.S. Median values were given for TP and TN in the Circular 1350, Nutrients in the Nation's Streams and Groundwater, 1992 – 2004. These trends can partially be attributed to the BMP's encouraged by MDEQ, NRCS, and YMD to the agricultural community which include the installation of sediment reduction structures (edge of filed drop pipe), pads and pipes, and land leveling (MDEQ 2011).

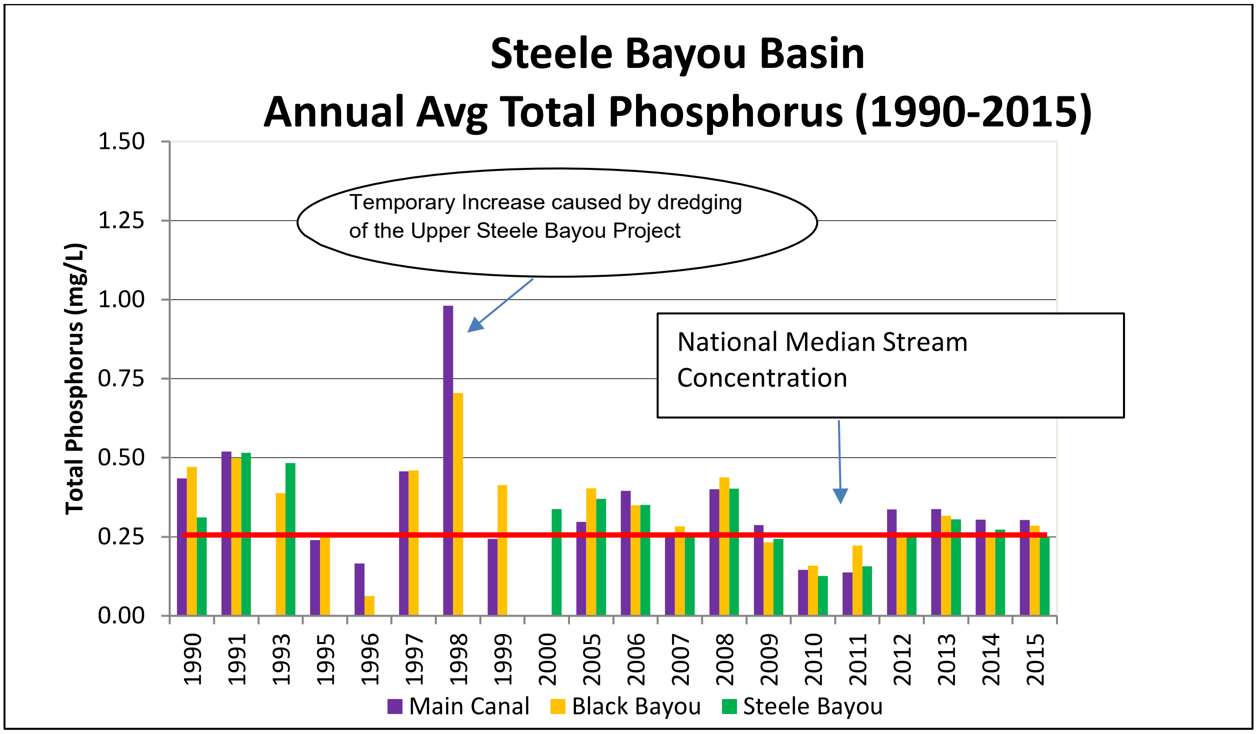

Figure 3-3. Average Annual TP Concentration for the Steele Bayou Basin from SBMP.

A similar pattern was observed in the Big Sunflower Basin for annual mean concentrations of TP as was described for the Steele Bayou Basin with lower peak values for the last two decades (Figure 3-4). The concentration in 1992 climbed from 0.18 to 0.445 mg/L in 2006. In 2010 the mean fell to 0.17 mg/L and then climbed back to 0.30 in 2014. Overall, the TP concentrations for both basins are in close agreement with the median value of 0.25 mg/L-TP published by USGS.

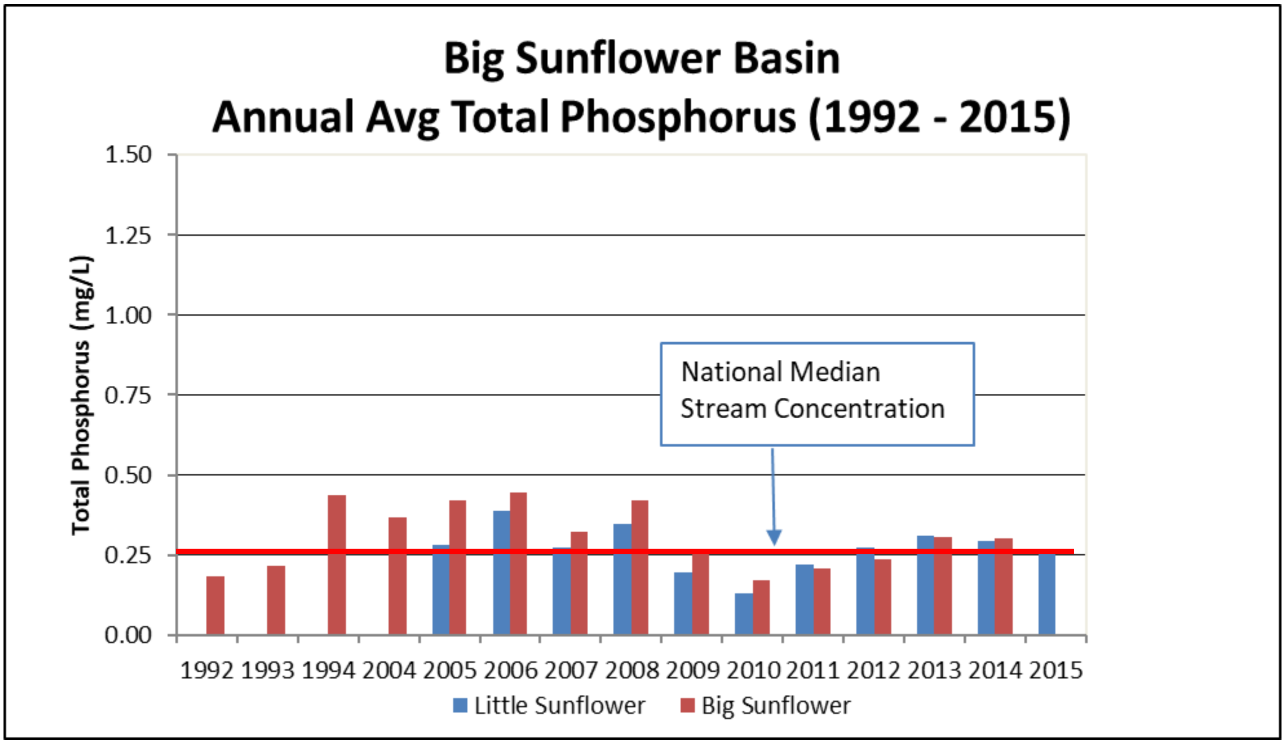

Figure 3-4. Average Annual TP Concentration for the Big Sunflower Basin from SBMP.

The bar graph displayed in Figure 3-5 shows the trends for long term TP monitoring in the Yazoo Basin. The graph presents the data from the NWIS and SBMP data sets for comparison of mean TP concentration by decade. A rise and fall of approximately 0.10 mg/L-TP can be seen from the SBMP data in the Big Sunflower Basin from the decades of 1990 to 2010. During the same time frame, TP fell approximately 0.20 mg/L-TP in the Steele Bayou Basin. Extreme discrepancies were noted between the NWIS and the SBMP data for the 2010 decade. Further study revealed that many of the measurements recorded for the NWIS data set in the Yazoo Basin appeared to show bias to hourly measurements from in-stream and edge-of-field storm water runoff studies. These collection efforts appeared to skew the mean values when compared to the monthly sampling efforts conducted in the SBMP. The phosphorus concentration for the 2010 decade appears to remain at approximately 0.25 mg/L-TP as it traveled from the Big Sunflower and Steele Bayou Watersheds to the Lower Yazoo Watershed. This analysis takes advantage of data collected from both programs.

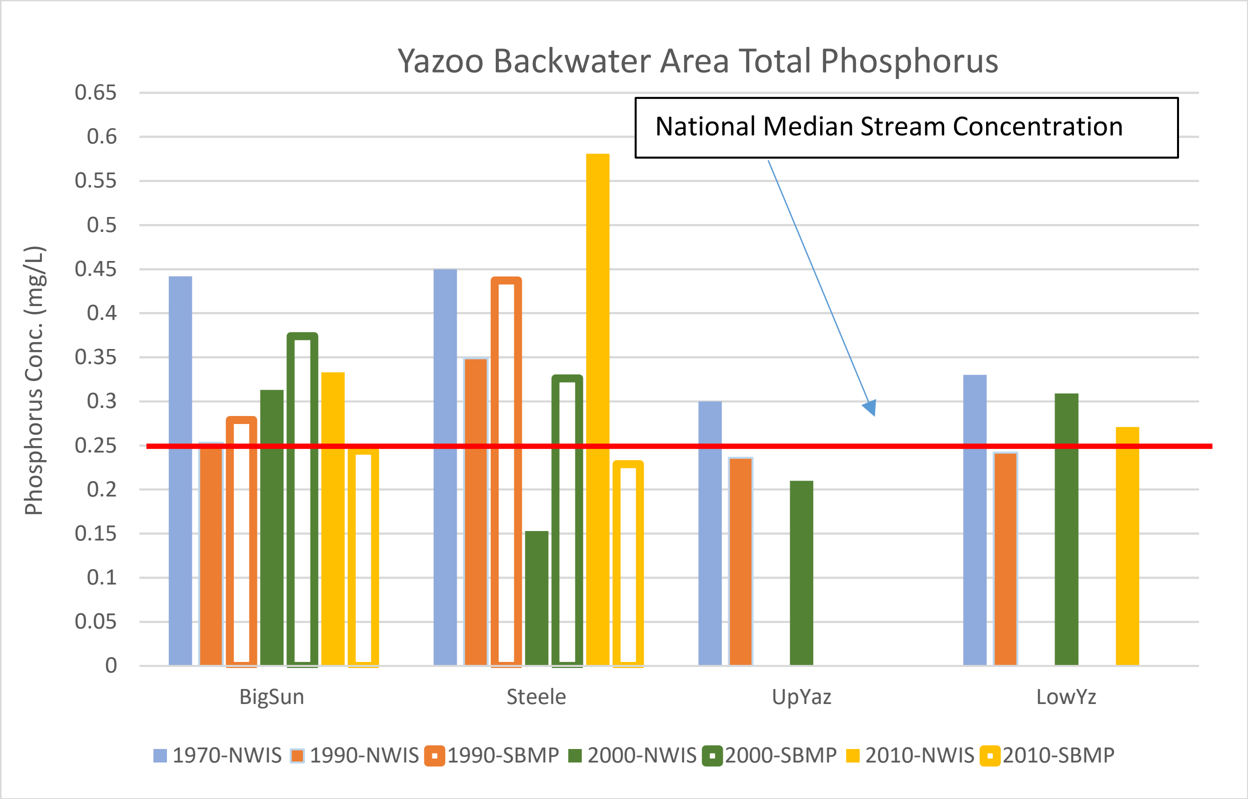

Figure 3-5. Mean Concentrations for TP found within the Big Sunflower, Steele Bayou, Upper Yazoo and Lower Yazoo HUC 8 Watersheds from NWIS and SBMP databases.

The concentrations for TP observed in both the Steele Bayou and Little Sunflower Basins increased from the decade starting in 2000 to the following 2010 decade. However, the TP concentrations observed in the Lower Yazoo Basin at Long Lake were observed to be lower. The Long Lake location represents the most downstream point in the Yazoo River before it enters the Mississippi River. The reduction of TP concentration as water moved from the upper to lower reaches of the Steele Bayou and Bid Sunflower Basins could be attributed to stream utilization, bound to sediment particles and removed from the system by virtue of deposition, or diluted by downstream inflow.

The implementation of the 25,000 cfs pumps in Alternative 2 or Alternative 3 will result in the reduction of wetland area available for settling of sediment and corresponding phosphorus concentrations during large flood events which exceed the 5-year frequency in the YBA. This reduction of wetland area is not believed to have a significant impact on sediment and TP delivered from the YBA to the Mississippi River. These sediment and phosphorus delivery trends shall be monitored in the post project phase of Alternative 2 or Alternative 3 through the adaptive management structure which could promote agricultural BMPs to mitigate these impacts. The required mitigation efforts associated with these alternatives will help to offset soil runoff as well as phosphorus contribution into the surface waters. Cumulative cultivation acreage will be reduced in the YBA through the required mitigation plans. The proposed strategy will seek to acquire acreage below 90.0 feet and 93.0 feet elevation for tree planting and reestablishment of bottomland hardwood forests. Alternative 2 and Alternative 3 have current mitigation acreage requirements of 7,650 ac and 5,722 ac, respectively which should serve to benefit the phosphorus loading in the Yazoo Backwater Area. This reduction in cultivation acreage will be proportional to an increase in forested wetland acreage which will help compensate for sediment and phosphorus retention that may be lost for backwater flooding in wooded areas that exceed the 5-year frequency.

3.3 NITROGEN

The increased use of nitrogen amendments for enhanced agricultural yields has been fully utilized in the Yazoo Basin over the past few decades. This practice has become more prevalent over the last 20 years when the dominant crop shifted from cotton to corn and soybeans. This shift marked a drastic increase in the amount of nitrogen needed to optimize production. The demand for nitrogen fertilizers has almost doubled.

The TN concentrations in the Steele Bayou Basin follow a cyclical pattern similar to that observed for TP. The peak was observed to come during the spring months at a value of approximately 2.25 mg/L and then recede in the early fall to a value of approximately 1.00 mg/L (Figure 3-6). The National Median concentration given for TN concentrations categorized for agricultural regions was 3.8 mg/L (Dubrovsky et al. 2010). The monthly average mean concentrations for TN in the Steele Bayou Basin were approximately 2.0 mg/L-TN below the national median value (Figure 3-6).

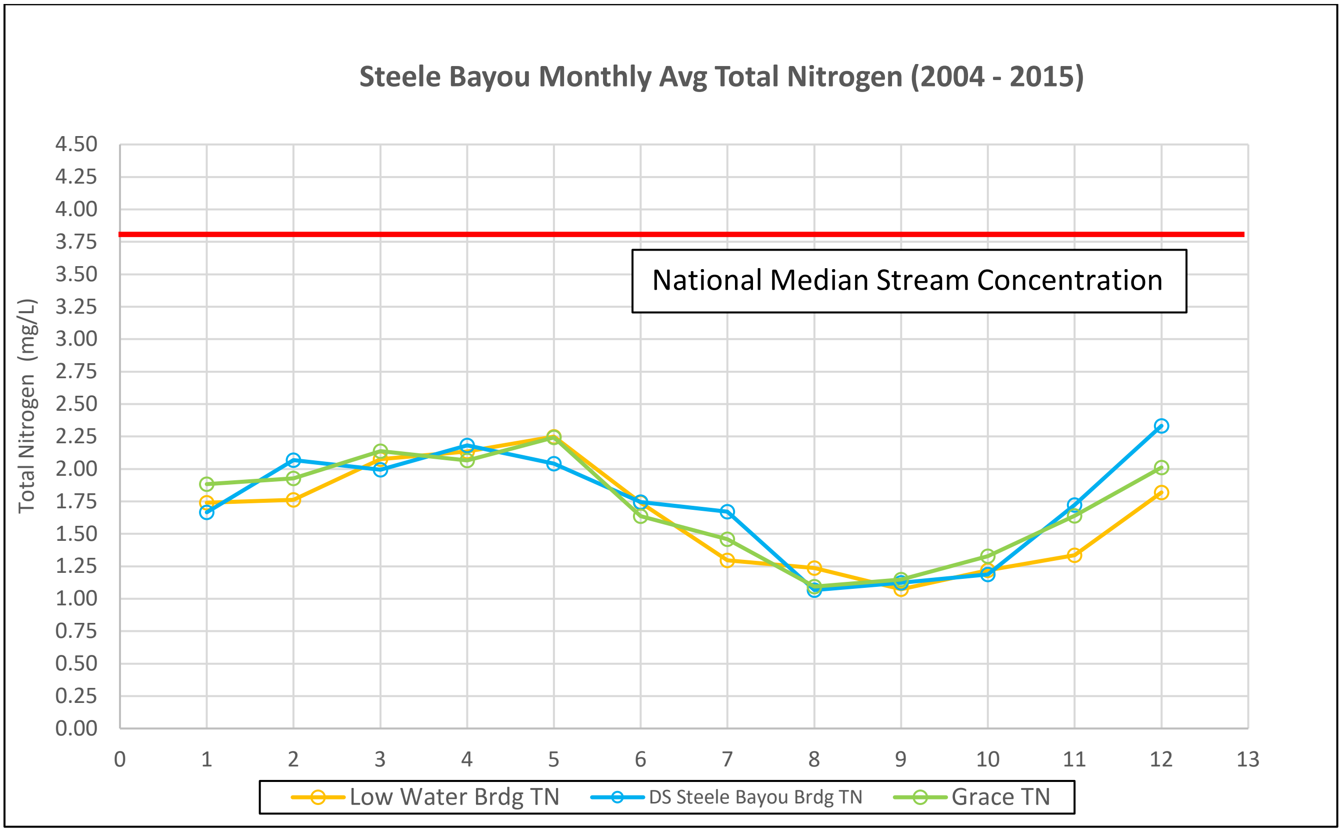

Figure 3-6. Average Concentrations for TN found in the Steele Bayou Basin grouped by month–SBMP Data.

The annual trend over the last two decades of record for the Steele Bayou Basin shows an approximate high and low of 2.00 and 1.00 mg/L, respectively (Figure 3-7).

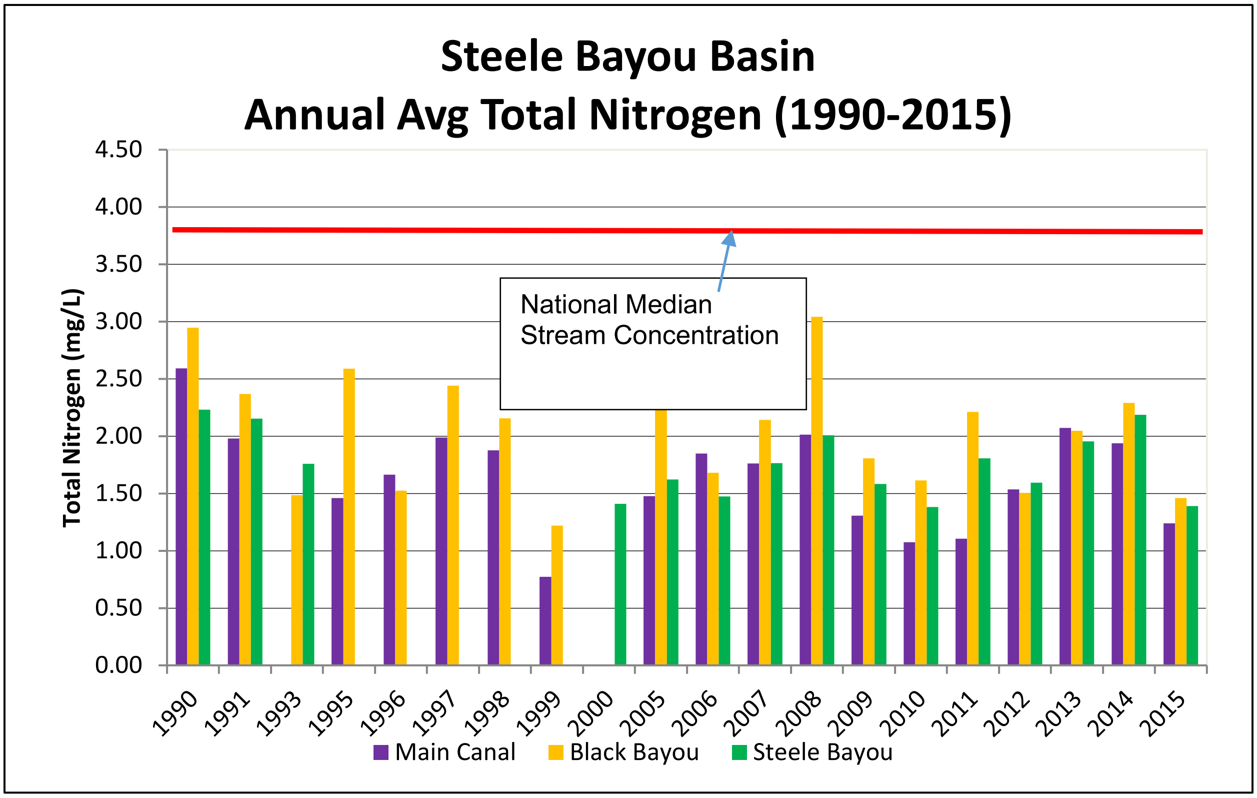

Figure 3-7. Average Annual TN Concentration for the Steele Bayou Basin from SBMP.

The TN concentrations in the Big Sunflower Basin follow the same annual cyclical pattern as previously mentioned with greater amplitudes of the high and low with approximate values of 4.00 and 1.25 mg/L, respectively (Figure 3-8). These larger peaks observed in April and May approach the national median concentration for TN published by the USGS (Dubrovsky et al. 2010). These high values can be attributed to the increase agricultural production found in the Big Sunflower Basin. The lower peak and valley value associated with the Dummy Line Road input are attributed to values from the Little Sunflower River which receives runoff from a disproportionately smaller area invested in agriculture.

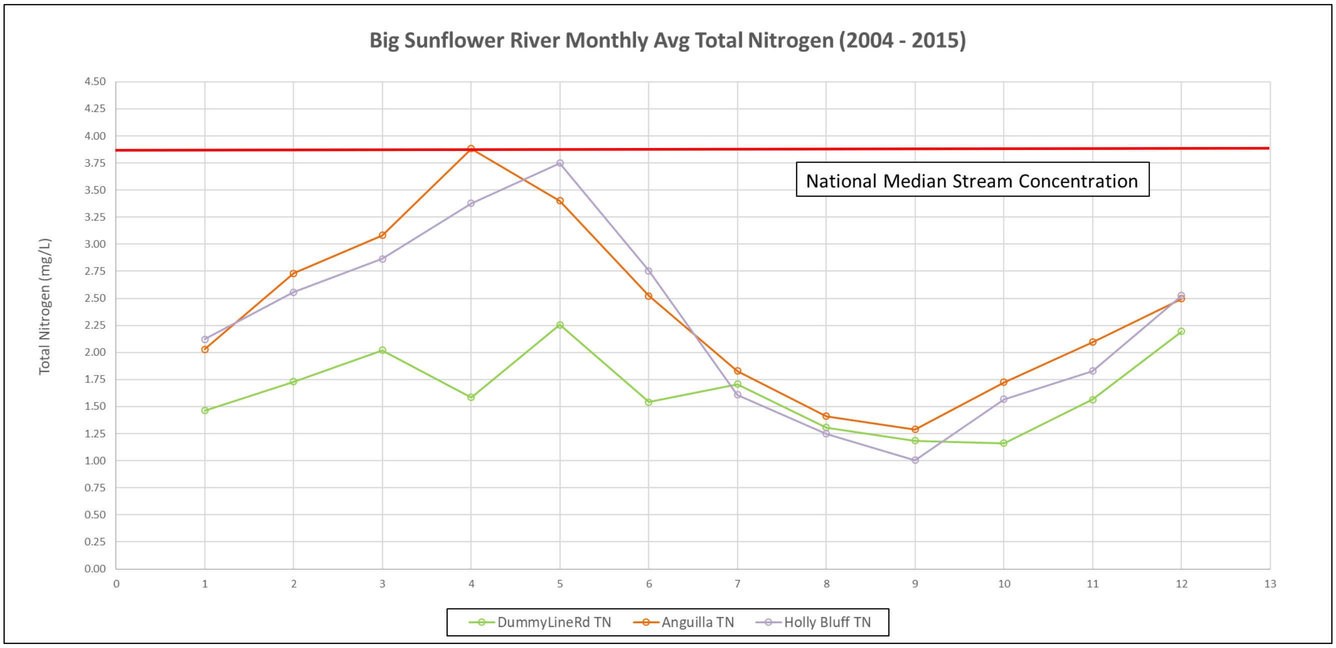

Figure 3-8. Average Concentrations for TN found in the Big Sunflower Basin grouped by month–SBMP Data.

The annual trend over the last two decades of record for the Big Sunflower Basin shows an approximate high and low of 2.50 and 2.00 mg/L, respectively (Figure 3-9). These values register far below the national median concentration published by USGS (Dubrovsky et al. 2010).

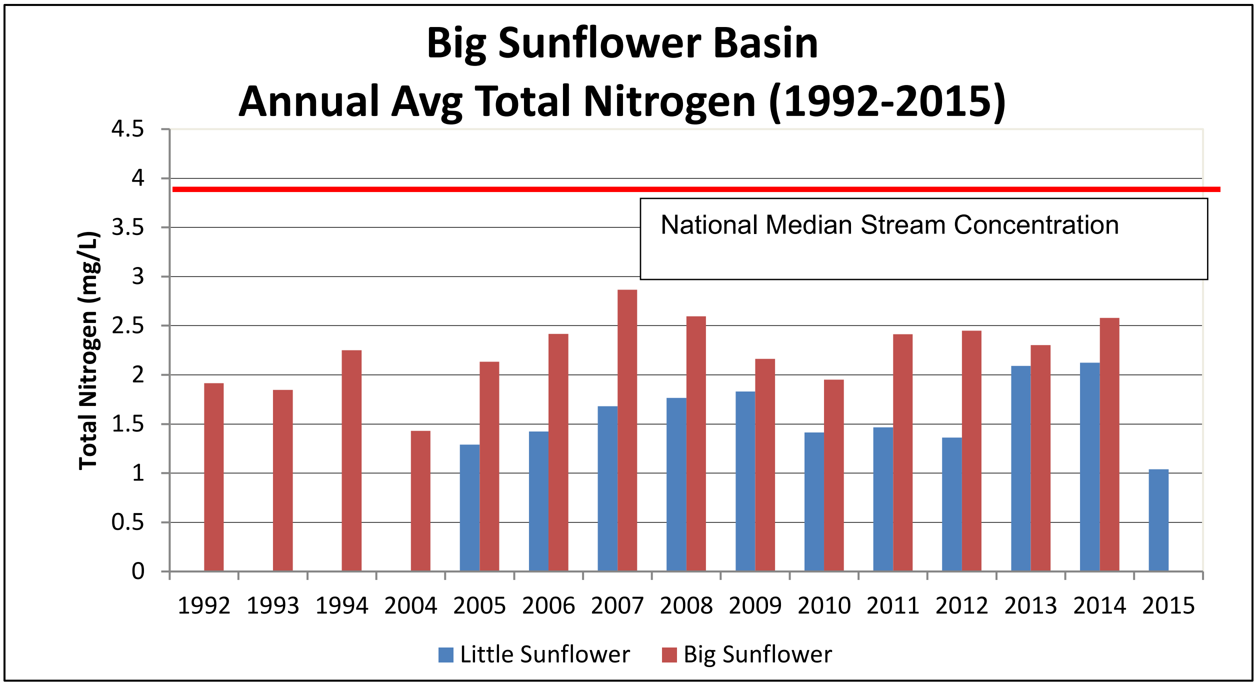

Figure 3-9. Average Annual TN Concentration for the Big Sunflower Basin from SBMP.

The bar graph displayed in Figure 3-10 shows the trends for long term TN monitoring in the Yazoo Basin. The graph presents the data from the NWIS and SBMP data sets for comparison of mean TN concentrations by decade. A slight increase of TN can be seen from the SBMP data in the Big Sunflower Basin from the decades of 1990 to 2010 while concentrations fell in the Steele Bayou Basin over the same time frame. In the 2010 decade, concentrations for TN from the Big Sunflower Basin were approximately 1.0 mg/L higher in the SBMP data. The inverse was observed for the Steele Bayou Basin where the average TN from the SBMP data set was approximately 1.5 mg/L lower than the NWIS data. It should be noted that measurements recorded for the NWIS data set in the Yazoo Basin appeared to show bias to hourly measurements from in-stream and edge-of-field storm water runoff studies. The nitrogen concentration for the extended time frame was reduced as it traveled from the Big Sunflower, Steele Bayou, and Upper Yazoo Watersheds to the Lower Yazoo Watershed. The overall trend for all the sub basins in the Yazoo Backwater Area appears to be far less than the national median concentration for TN published by the USGS (Dubrovsky et al., 2010).

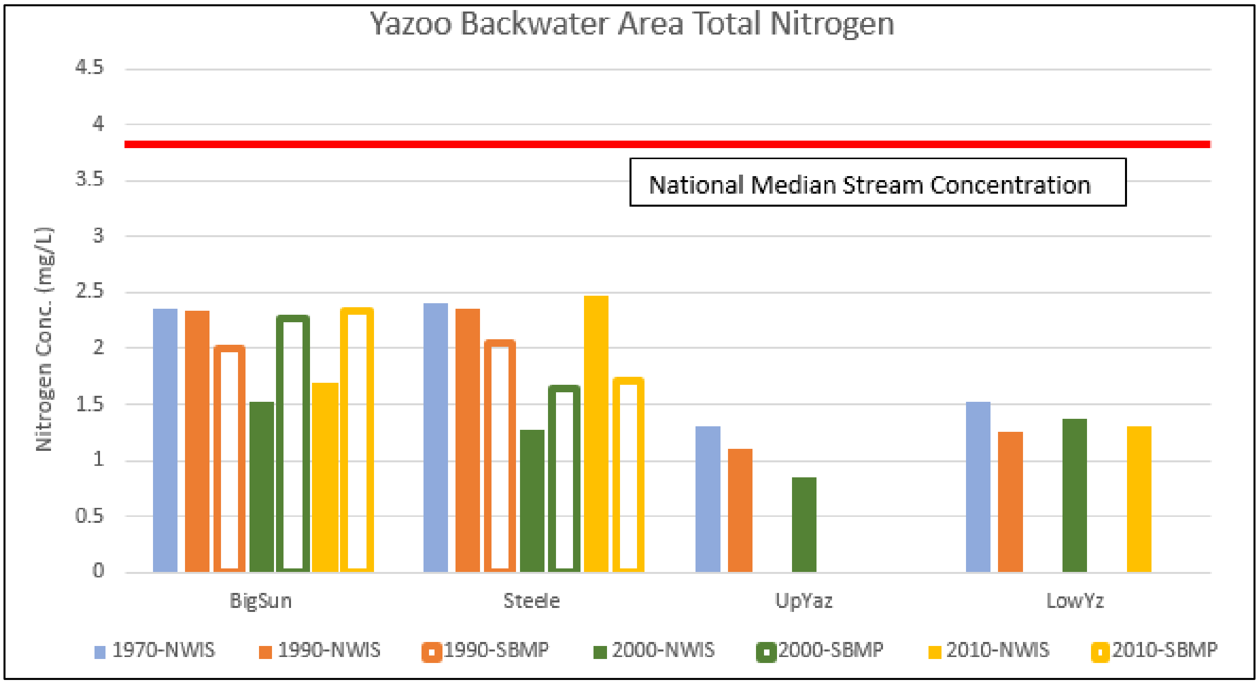

Figure 3-10. Mean Concentrations for TN found within the Big Sunflower, Steele Bayou, Upper Yazoo and Lower Yazoo HUC 8 Watersheds from data collected from NWIS and SBMP databases.

The implementation of the 25,000 cfs pumps in Alternative 2 or Alternative 3 will result in the reduction of wetland area available for nitrogen uptake during large flood events which exceed the 5-year frequency in the YBA. This reduction of wetland area is not believed to have a significant impact on TN delivered from the YBA to the Mississippi River. These nitrogen delivery trends shall be monitored in the post project phase of Alternative 2 or Alternative 3 through the adaptive management structure. The required mitigation efforts associated with these alternatives will help to offset the nitrogen utilization function in the YBA by first reducing the cumulative cultivation acreage in the YBA and proportionally reestablishing trees in areas below 90.0 feet and 93.0 feet elevation. Alternative 2 and Alternative 3 have current mitigation acreage requirements of 7,650 ac and 5,722 ac, respectively which should serve to benefit the nutrient loading concerns for the Yazoo Backwater Area for backwater flooding in wooded areas that exceed the 5-year frequency.

SECTION 4 DOWNSTREAM WATER QUALITY IMPACTS

Implementation of Alternative 2 or Alternative 3 which utilize a 25,000 cfs pump station in the Yazoo Backwater will not likely result in a significant change to the total loading of TN and TP to the Mississippi River. This can also be said for the impacts to temperature and DO. The timing of the delivery of nutrient loading to the Mississippi River will be extended on the front end of the flood event by a few weeks; however, the overall mass should remain the same. Implementation of No Action Alternative and Alternative 4 which do not utilize a pump feature, have a similar effect of nutrient loading to the Yazoo River/Mississippi River from the backwater pool at the end of a flood event. Currently, when flood conditions recede allowing the Steele Bayou and Little Sunflower structures to be opened, backwater is routed to the same downstream destination as would be experienced using a pump station. The overall mass loading to the Mississippi River for the four alternatives should remain unchanged. In an effort to compare similar terms, flow data derived only from the model output was analyzed to make calculations for the contribution of nutrients and dissolved oxygen from the Yazoo Backwater Area to the Mississippi River. These comparisons primarily included current output conditions which employ the use of the Steele Bayou and Little Sunflower Outlet Structures alone and modeled output conditions generated from Alternative 2 conditions which implement the defined pumping sequence. The pump station modeled conditions which employed the use of 22 individual pumps at 1,167 cfs, in which any number of pump units could be used at one time, up to a maximum output flow rate of 25,000 cfs from the pump station, as described in Alternative 2. Alternative 2 was chosen for this analysis instead of Alternative 3 as a more conservative estimate. This alternative demonstrated a greater change from the current baseline outlet gate operation of the two structures by operating the proposed pumps for a 10 day increase in the crop season.

Given the scale and complexity of the HEC-RAS model used to describe the 25,000 cfs pump station during applicable flood events, certain caveats were utilized in the model. Immediate turn-off/turn-on of the pump station was not sequential with gate operation, and thus it can be seen to exhibit some overlapping flow through the pump station and the gate. The inclusion of pump operation into the 2-D model required a forced boundary condition on the outside boundaries. This condition inaccurately created minor values of negative flow in the model which are typically found towards the end of a flood event. A multiple of an equidistant unit of pumps approximating 25,000 cfs was used based on available pump curve data for existing pump units (1,167 cfs per pump unit). The closest approximation to the proposed pump station was a collection of 22 of these existing pump units, totaling 25,674 cfs, which slightly exceeds 25,000 cfs. This condition shall be refined to a maximum flow of 25,000 cfs during the design phase. These initial modeling limitations may require additional analysis during the design phase of the project.

Temperature (NWIS data parameter code: # P 00010), discharge (# P 00061), dissolved oxygen (# P 00300), total suspended solids (# P 00530), total nitrogen (# P 00600), and phosphorous (# P 00665) were used in the analysis of the data to make comparisons between the Yazoo Backwater Area and the Mississippi River for concentrations, loading, and their proportional relationships.

The analysis used water quality parameter data collected from USGS NWIS website. For the Mississippi River, a dataset was provided for samples taken at Station 322023090544500, which is located on the Mississippi River at River Mile 438, just upstream of the confluence of the Yazoo and Mississippi Rivers. For the Yazoo River, a water quality dataset was provided for samples taken at Station 7288955, which is located at Long Lake, on the short portion of the Yazoo River that connects the Steele Bayou structure to the Mississippi River. The samples were collected in both datasets for the period from April 2008 through February 2024.

The analysis also used data collected through routine monitoring implemented by U.S. Army Corps of Engineers (Corps) Vicksburg District employees as part of the Steele Bayou Monitoring Program (SBMP). This dataset included data from three sampling sites located in the lower watersheds of Steele Bayou and Big Sunflower River within the Yazoo Backwater Area. Dummy Line Road sampling site was used to collect data from Little Sunflower River, and data from this location were available for analysis from June 2004 through January 2016. Holly Bluff sampling site was used to collect data from Big Sunflower River, and data from this location were available for analysis from April 2004 through January 2016. Low Water Bridge sampling site was used to collect data from Steele Bayou, and data from this location were available for analysis from April 2006 through January 2016. It should be noted that due to the limitation of data availability, the 2018 and 2019 flood events include monthly average concentration data for the given parameters that were from a period of record outside these two flood events.

All sample values from both sources were screened for a depth (NWIS data parameter code: # P 00003) which would be representative of surface water quality conditions. The USGS data were filtered to include only readings taken at a depth of 1 foot or less. The SBMP data were filtered to include only surface level readings, which are limited to a maximum depth of 1 meter.

To normalize for number of samples taken on the same day, a daily average of readings was taken for each of the constituents of concern per sampling location. These daily constituent averages were then grouped by month, and a monthly average (mAvg) was calculated, allowing for the observation of trends throughout a year for water quality.

For the three Yazoo Backwater Area sampling sites, the calculated mAvg for each site was then used in a weighted average formula based on contribution to the drainage basin for each of the tributaries, resulting in one mAvg to be representative of the Yazoo Backwater Area water quality. The weights assigned to each tributary are 2.6% Little Sunflower River at Dummy Line Road, 80.5% Big Sunflower River at Holly Bluff, and 16.8% Steele Bayou at Low Water Bridge. These total to a tenth of a percent less than 100%, an error that is the result of rounding to the ten-thousandths place during the calculation.

The mAvg results for the three water bodies are shown in *Table 4-1* through *Table 4-3*. Direct comparisons were made between the same analyzed constituent for each water body in *Figure 4-1* through *Figure 4-6*.

Table 4-1 Mississippi River mAvg calculation results for each of the constituents

Mississippi River -- RM 438

Month	mAvg Temperature (C)	mAvg Discharge (cfs)	mAvg DO (mg/L)	mAvg TN (mg/L)	mAvg TP (mg/L)
1	5.79	823066.67	11.77	2.02	0.28
2	6.06	754937.50	12.19	1.83	0.20
3	10.08	1010551.72	10.51	2.04	0.25
4	15.53	1012233.33	9.08	2.14	0.22
5	20.56	1126787.88	7.30	2.22	0.22
6	26.18	890535.71	6.55	2.49	0.24
7	28.93	722384.62	6.28	2.53	0.25
8	28.84	492428.57	6.72	1.85	0.21
9	27.73	570666.67	6.85	1.90	0.37
10	20.94	394705.88	8.24	1.56	0.22
11	#N/A	#N/A	#N/A	#N/A	#N/A
12	9.50	499812.50	10.98	1.79	0.19

Table 4-2 Yazoo River mAvg calculation results for each of the constituents

Yazoo River -- Long Lake

Month	mAvg Temperature (C)	mAvg Discharge (cfs)	mAvg DO (mg/L)	mAvg TSS (mg/L)	mAvg TN (mg/L)	mAvg TP (mg/L)
1	8.44	25252.83	9.98	231.00	1.39	0.33
2	9.64	28371.27	9.74	152.50	1.51	0.35
3	14.08	26053.62	7.94	48.00	1.31	0.30
4	18.68	30671.74	6.03	16.00	1.39	0.32

5	24.06	14442.76	5.56	86.50	1.48	0.26
6	28.22	20332.03	4.31	36.00	1.41	0.26
7	30.12	13605.88	4.66	31.00	1.19	0.20
8	30.33	12683.52	5.70	53.00	1.05	0.23
9	27.52	11032.05	6.13	54.50	0.91	0.28
10	21.82	13022.22	6.81	115.00	1.07	0.36
11	15.27	14598.21	8.45	316.50	1.02	0.30
12	10.88	16502.70	9.49	169.00	1.30	0.29

Table 4-3 Backwater Area mAvg calculated results for each of the constituents

Backwater Area

Month	mAvg Temperature (C)	mAvg DO (mg/L)	mAvg TSS (mg/L)	mAvg TN (mg/L)	mAvg TP (mg/L)
1	8.40	9.03	171.02	2.04	0.34
2	9.80	8.74	135.62	2.40	0.35
3	15.77	7.02	211.55	2.71	0.41
4	20.59	4.73	230.11	3.12	0.43
5	23.60	4.45	109.30	3.43	0.32
6	28.32	4.52	146.32	2.62	0.26
7	30.63	5.59	64.26	1.55	0.22
8	29.48	5.57	64.20	1.25	0.20
9	26.11	5.77	86.83	1.02	0.26
10	20.87	5.53	123.60	1.49	0.26
11	14.41	7.42	75.68	1.75	0.24
12	11.50	8.41	184.35	2.39	0.34

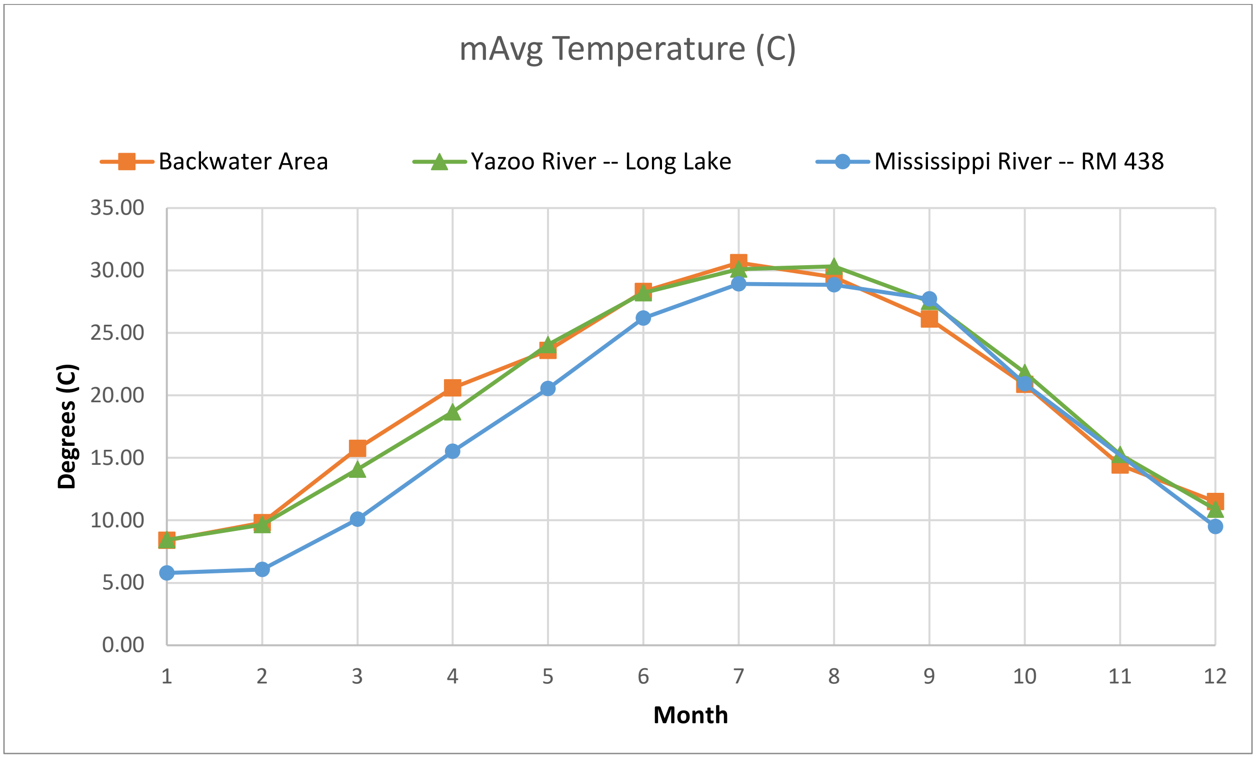

Figure 4-1 Comparing mAvg temperature between water bodies measured in degrees Celsius

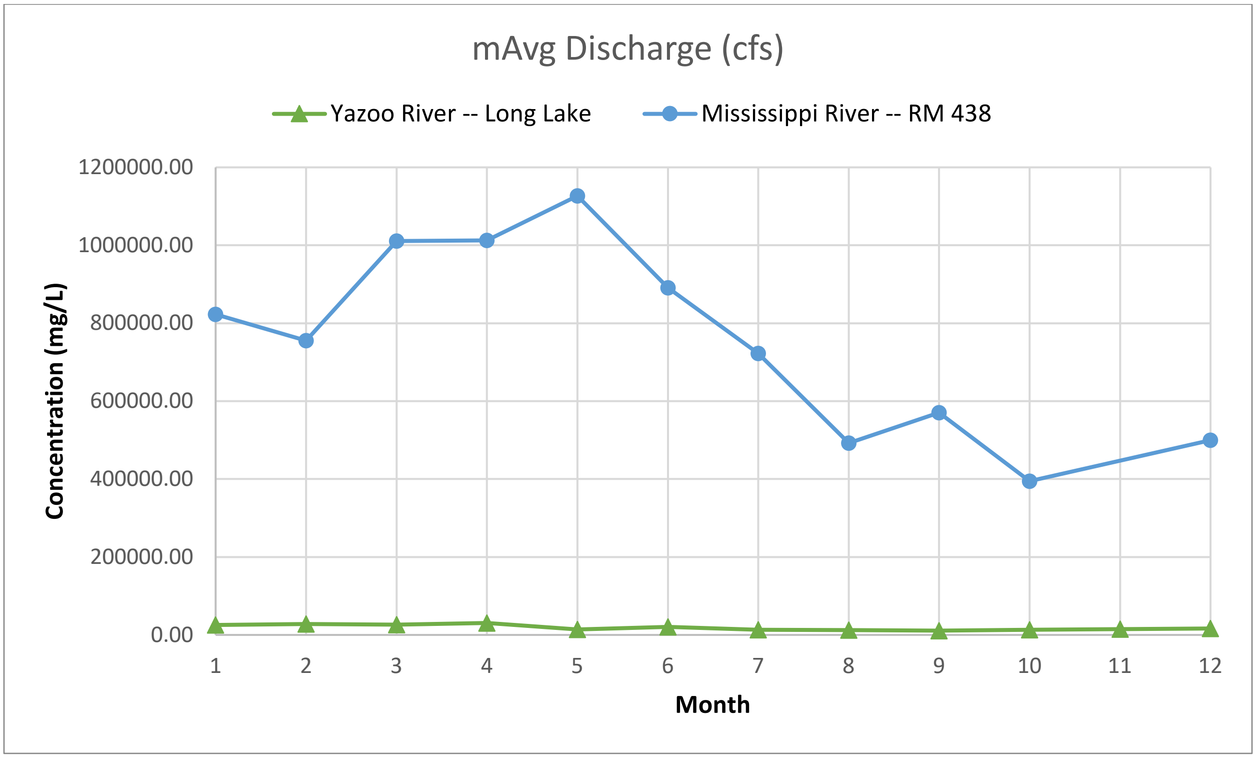

Figure 4-2 Comparing mAvg discharge measured in cubic feet per second

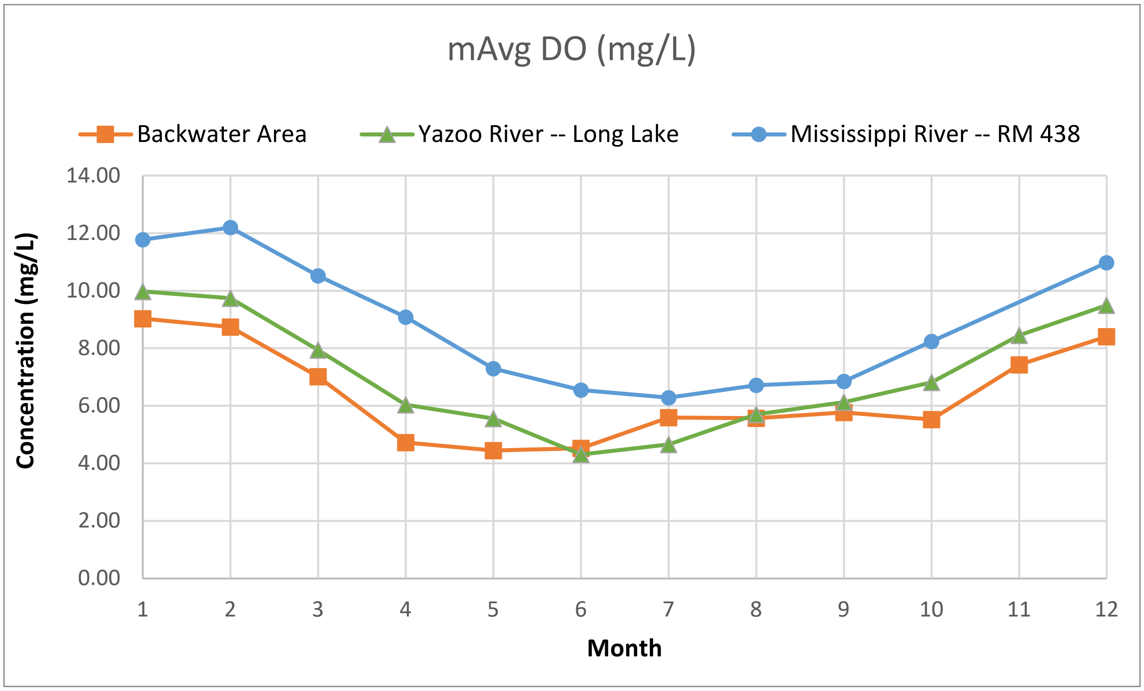

Figure 4-3 Comparing mAvg dissolved oxygen concentrations measured in milligrams

per liter

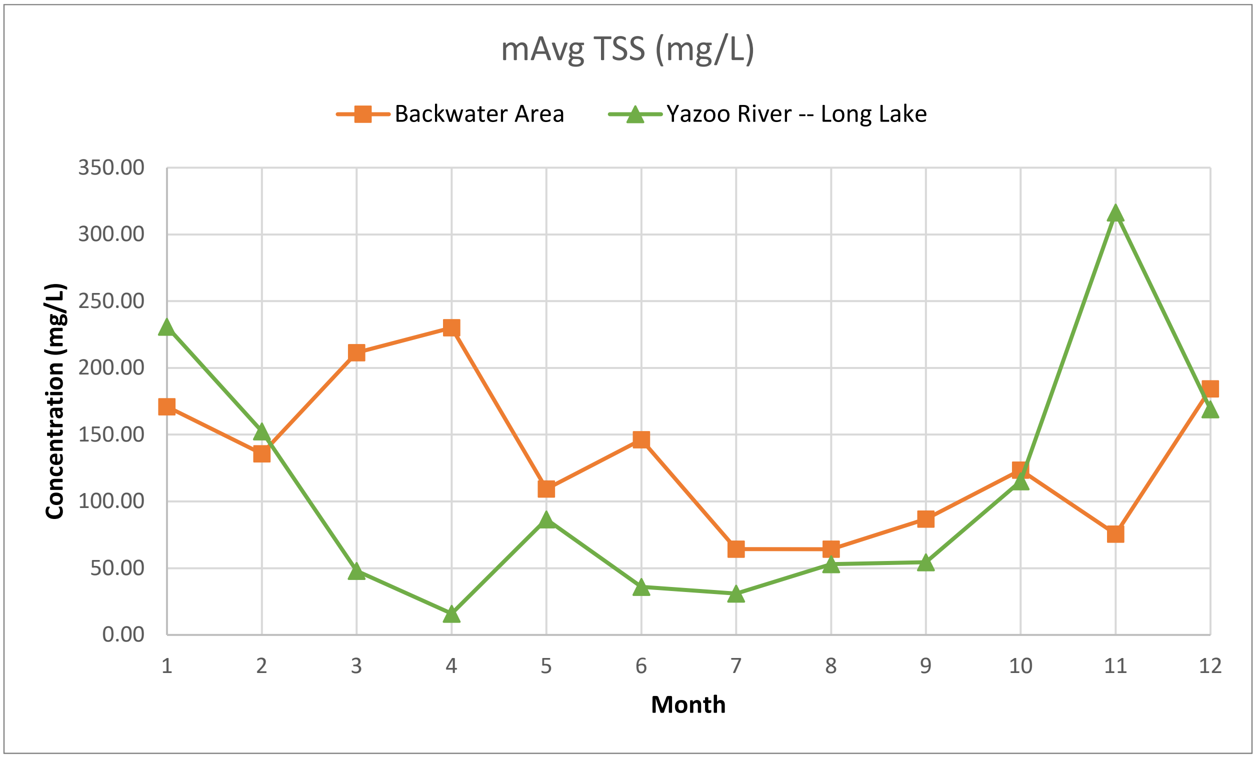

Figure 4-4 Comparing mAvg total suspended solid concentrations measured in milligrams per liter

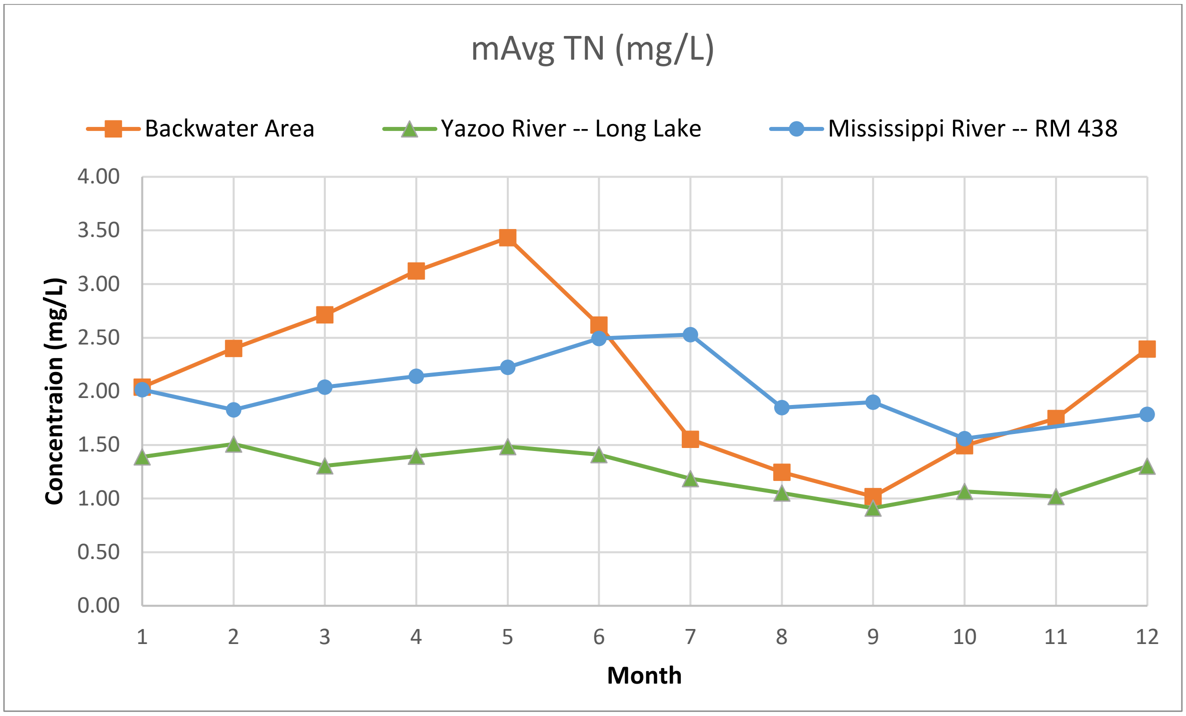

Figure 4-5 Comparing mAvg total nitrogen concentrations measured in milligrams per liter

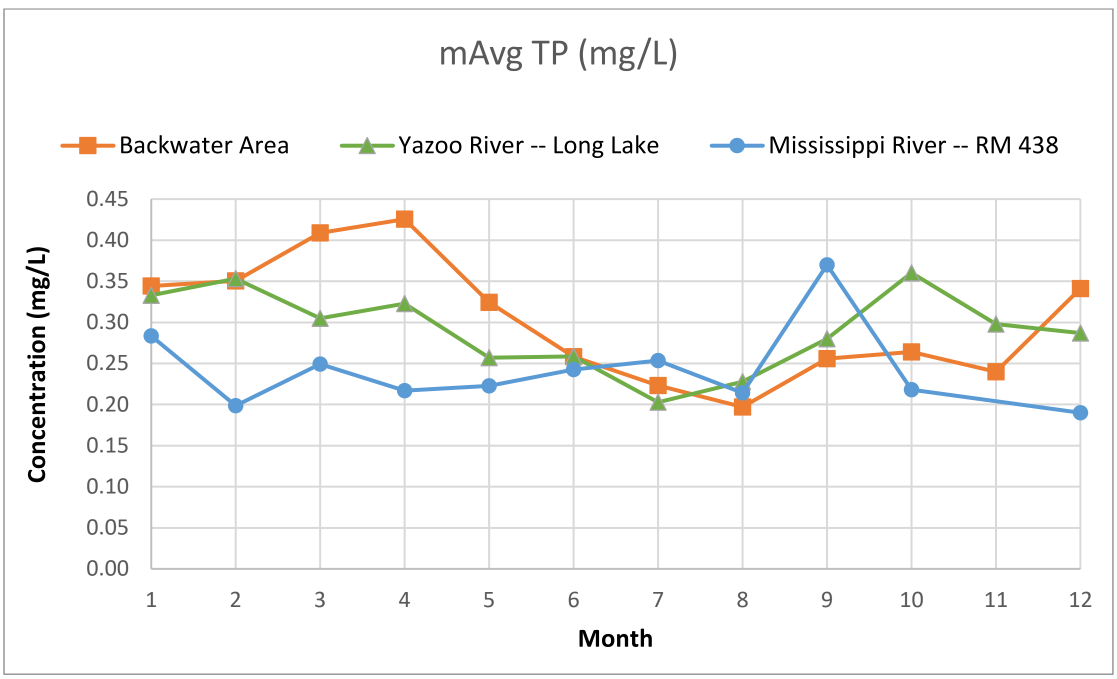

Figure 4-6 Comparing mAvg total phosphorous concentrations measured in milligrams per liter

The temperature trends of the Mississippi River are closely correlated to those of the Backwater Area and Yazoo River – Long Lake (*Figure 4-1*). Mississippi River discharge is significantly greater than that of the Yazoo River – Long Lake. While dissolved oxygen (DO) mAvg values show correlation across water bodies, the other three constituents—total suspended solids (TSS), total nitrogen (TN), and phosphorous (TP)—do not follow a similarly tight trend. Although the water body with the highest mAvg concentration does change from month to month, the concentrations of each do follow a similar trend within the range of concentrations for the other two.

Water samples were not recorded during the month of November for the Mississippi River at the filtered depth in the period of record used for this analysis; therefore, the table shows an N/A where that month's averaged data would be. Total suspended solids were not recorded for the Mississippi River at the filtered depth in the period of record used for this analysis; therefore, they were not included in the above plot showing the concentrations for the Backwater Area and the Yazoo River. Discharge for the Backwater Area was not included in the above plot showing the Yazoo River and the Mississippi River. This is because the Backwater Area discharge of concern is that through the Steele Bayou structure, either through the existing gate or through the pumps. The flow through the structure will be considered in this analysis.

The Corps collects water quality samples immediately downstream of the Steele Bayou control structure on Highway 465. It should be noted that water quality data collected from this sample location is limited in its breadth and application for use as a comparative site against the interior of the Yazoo Backwater Area. Samples collected from this site can only be viewed as a representative discharge from the Yazoo Backwater Area when a) the Steele Bayou Outlet Structure is open and flowing and b) when access is available to the Highway 465 bridge. Routine sampling events did occur when the outlet structure gates were closed. Under this condition, a sample collected from this site would represent floodwater coming back up the Yazoo River from the Mississippi River and not discharge from the Yazoo Backwater Area. Also, during many of the flood events during the recorded SBMP collection effort, the road surface of Highway 465 leading to the bridge was inundated and access was not available. This section of Highway 465 that extends from Highway 61 to the bridge is located in an area outside of the protection of the Yazoo Backwater Area levee system which makes it vulnerable to inundation from the Yazoo River and Mississippi River flooding. For these reasons, routine sampling events at this site were not always collected and thus cannot provide a thorough representation of the Yazoo Backwater Area throughout the period of record for the SBMP.

Modeled flows through the Steele Bayou control structure show flows generated by the pumps when required criteria are met, as prescribed in Alternative 2. However, under current conditions, flow passes through the Steele Bayou structure by means of the existing gate. Water Management staff of the Corps' Vicksburg District provided the formula used to determine the existing Steele Bayou rating curve, which allows for calculation of flow through the structure at given head differentials.

Two flow versions were generated for three flood events, totaling six structure flow events in total. These were "pump alternative" (PA) and "without pump" (WOP) for the flood events in 2013, 2018, and 2019. The PA versions show a combined timeline of flow through the Steele Bayou structure by means of the pumps and by means of the gate. The WOP versions show flow through the Steele Bayou structure only by means of the existing gate. Flood events from 2013, 2018, and 2019 were chosen because they are representative of the historical range of flood events at the Vicksburg gage for 1.3 MMCFS, 1.7 MMCFS, and 1.8 MMCFS, respectively. The 2019 flood event had the second greatest flow reading at the Vicksburg gage over the entire period of record, less than only the 2011 event. However, the 2019 flood event caused the greatest length of impact on the Yazoo Backwater Area by requiring the Steele Bayou structure be closed, and so it was selected to represent a high flow reading on the Mississippi River.

During the 2013 flood event (Figure 4-7), the modeled pump station operation would have begun on May 15, 2013, 12 days and 16 hours prior to when the Steele Bayou Control Structure gates actually opened on May 27, 2013. During the 2018 flood event (Figure 4-8), the modeled pump station operation would have begun on March 9, 2018, 16 days and 9 hours prior to when the Steele Bayou Control Structure gates actually opened on March 25, 2018. During the 2019 flood event (Figure 4-9), the modeled pump station operation would have begun on February 24, 2019, 36 days and 11 hours prior to when the Steele Bayou Control Structure gates actually opened on April 1, 2019.

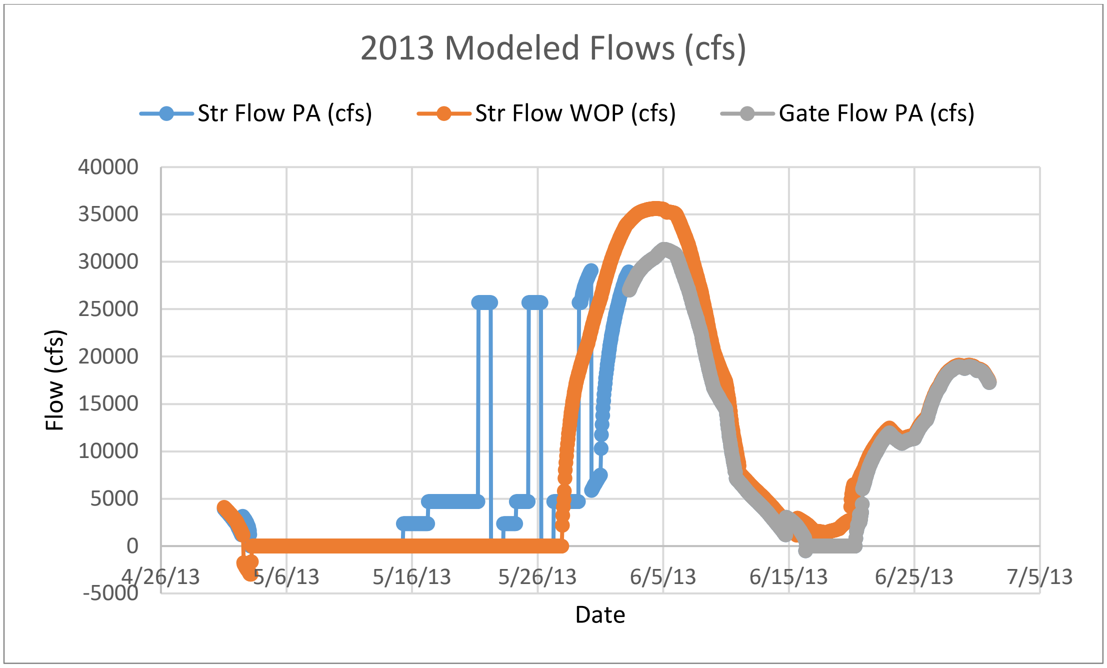

Figure 4-7 Steele Bayou PA and WOP flows; Yazoo River mAvg discharge (2013)

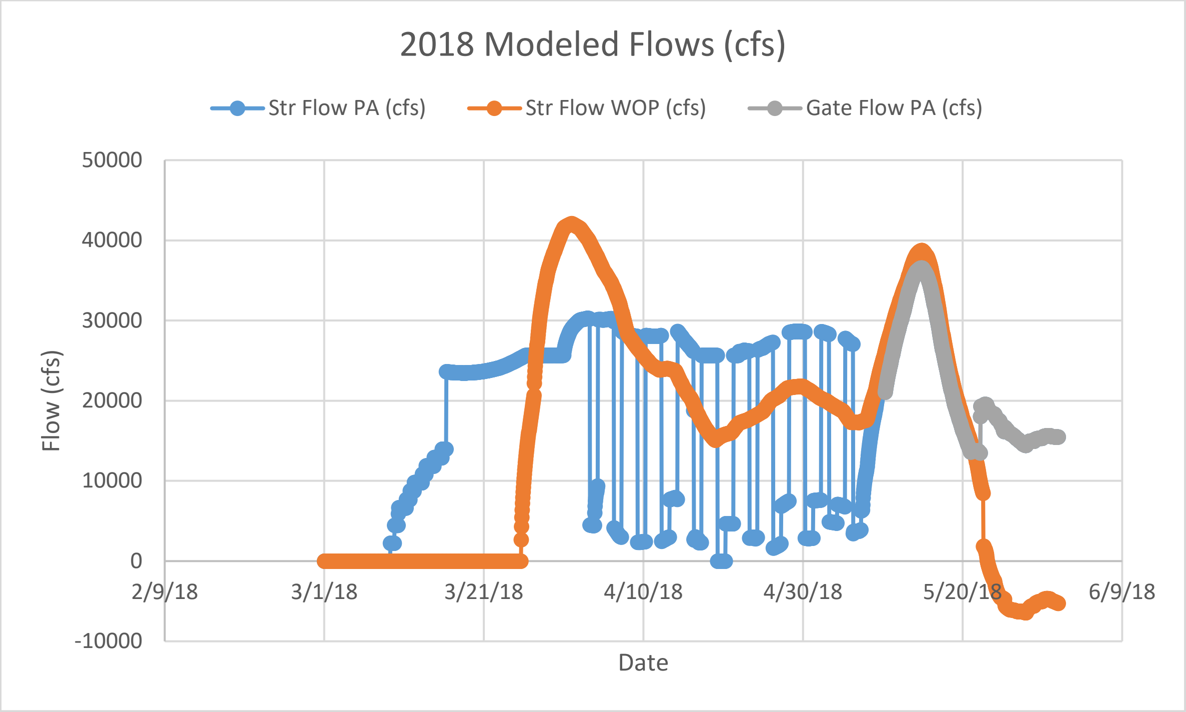

Figure 4-8 Steele Bayou PA and WOP flows; Yazoo River mAvg discharge (2018)

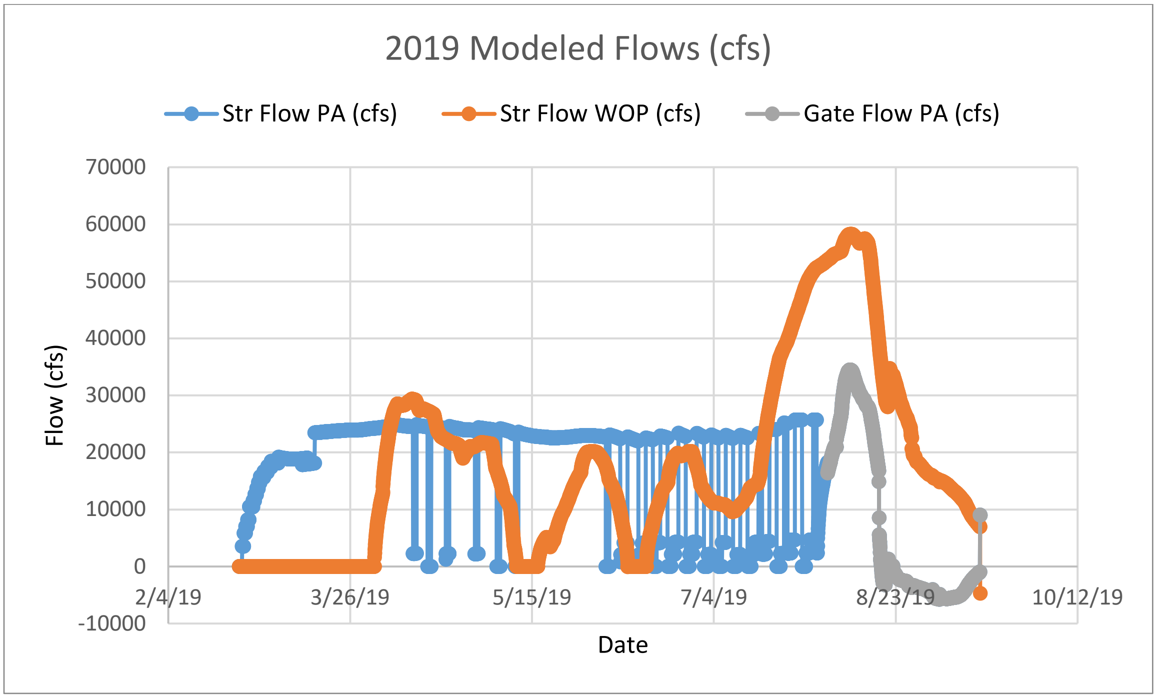

Figure 4-9 Steele Bayou PA and WOP flows; Yazoo River mAvg discharge (2019)

Load (kg/day) of dissolved oxygen, total nitrogen, and total phosphorous were calculated by multiplying mAvg concentration (mg/L) of the Backwater Area by modeled flow (cfs) through the pump station and the control gate in the PA version or through only the control gate in the WOP version, and applying conversion factors (L/cf, kg/mg, s/day). This was done for both versions of structure flow (PA and WOP) and for the three considered flood events (2013, 2018, 2019). Load of DO, TN, and TP was also calculated for the Mississippi River with the same method. The load of each flow version and flood event was divided by the corresponding load in the Mississippi River and multiplied by 100% as a calculation of the relative effect the Backwater Area water quality has on the Mississippi River.

For the 2013 flood event, DO load during the PA version reaches a maximum of 319,941 kg/day while in pump operation and 346,406 kg/day after transitioning to gate flow; DO loading during the WOP version reaches a maximum of 394,115 kg/day (Figure 4-10). The maximum percent loading to the Mississippi River of DO during the 2013 flood event was 1.5% during PA version with pump operating, 2.0% during PA version with gate only, and 2.3% during WOP version (Figure 4-11). TN load during the PA version reaches a maximum of 244,058 kg/day while in pump operation and 200,431 kg/day after transitioning to gate flow; TN loading during the WOP version reaches a maximum of 256,658 kg/day (Figure 4-12). The maximum percent loading to the Mississippi River of TN during the 2013 flood event was 3.1% during both the PA version with pump operating and the PA version with gate only, and 3.7% during WOP version (Figure 4-13). TP load during the PA version reaches a maximum of 23,079 kg/day while in pump operation and 19,788 kg/day after transitioning to gate flow; TP loading during the WOP version reaches a maximum of 24,270 kg/day (Figure 4-14). The maximum percent loading to the Mississippi River of TP during the 2013 flood event was 3.0% during PA version with pump operating, 3.2% during PA version with gate only, and 3.6% during WOP version (Figure 4-15).

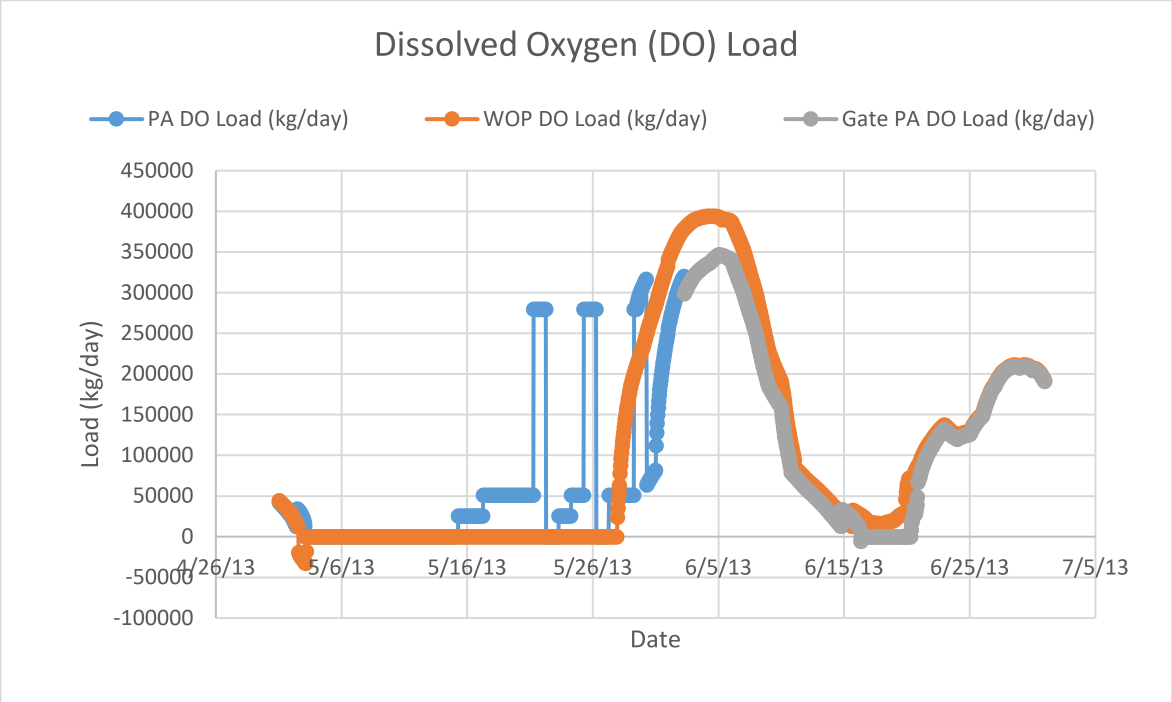

Figure 4-10 Dissolved oxygen load for PA and WOP (2013)

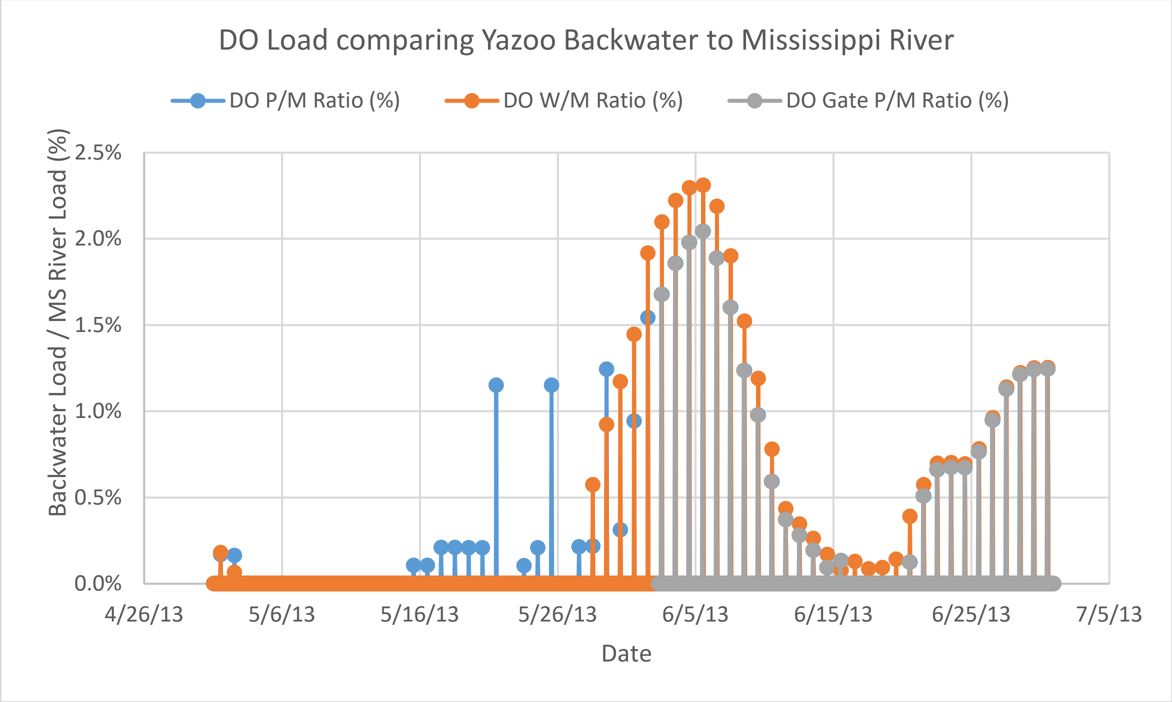

Figure 4-11 Dissolved oxygen percent load from Steele Bayou structure to Mississippi River (2013)

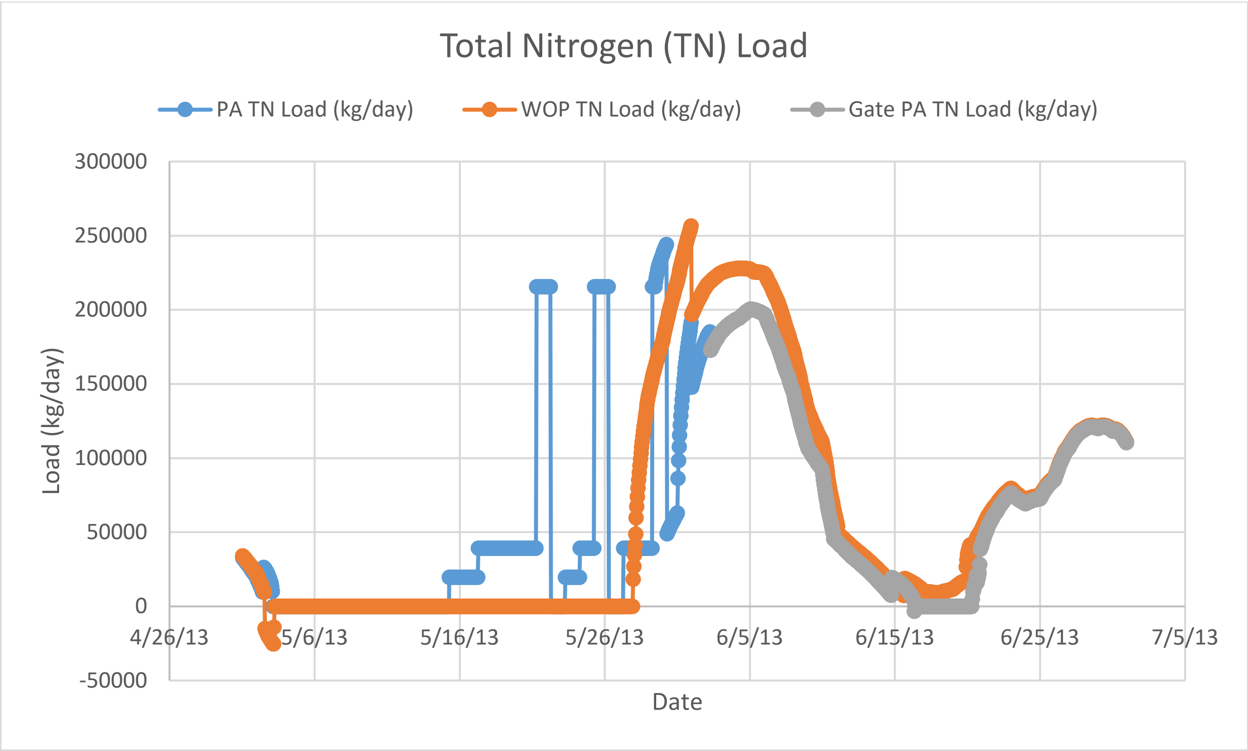

Figure 4-12 Total nitrogen load for PA and WOP (2013)

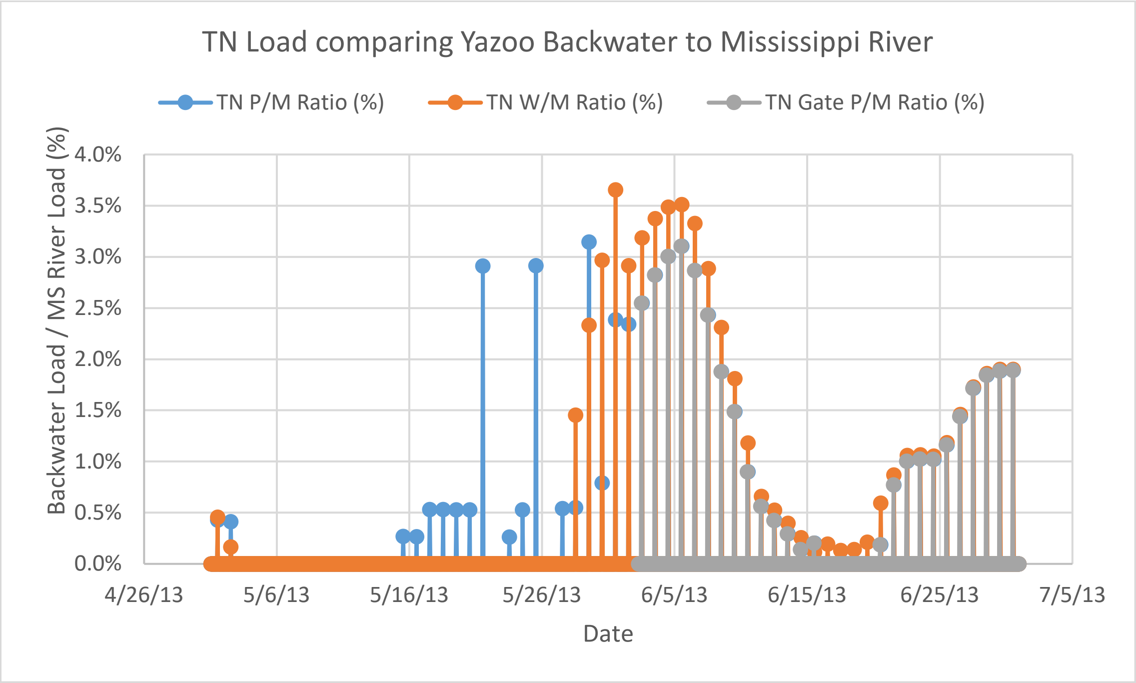

Figure 4-13 Total nitrogen percent load from Steele Bayou structure to Mississippi

River (2013)

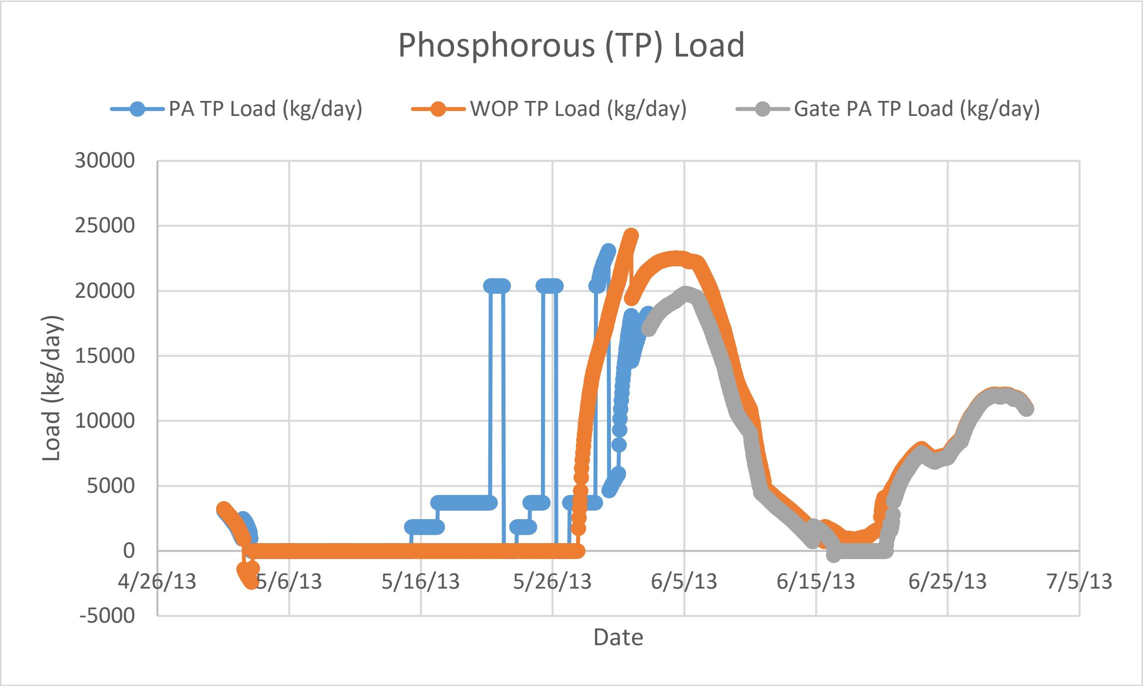

Figure 4-14 Total phosphorous load for PA and WOP (2013)

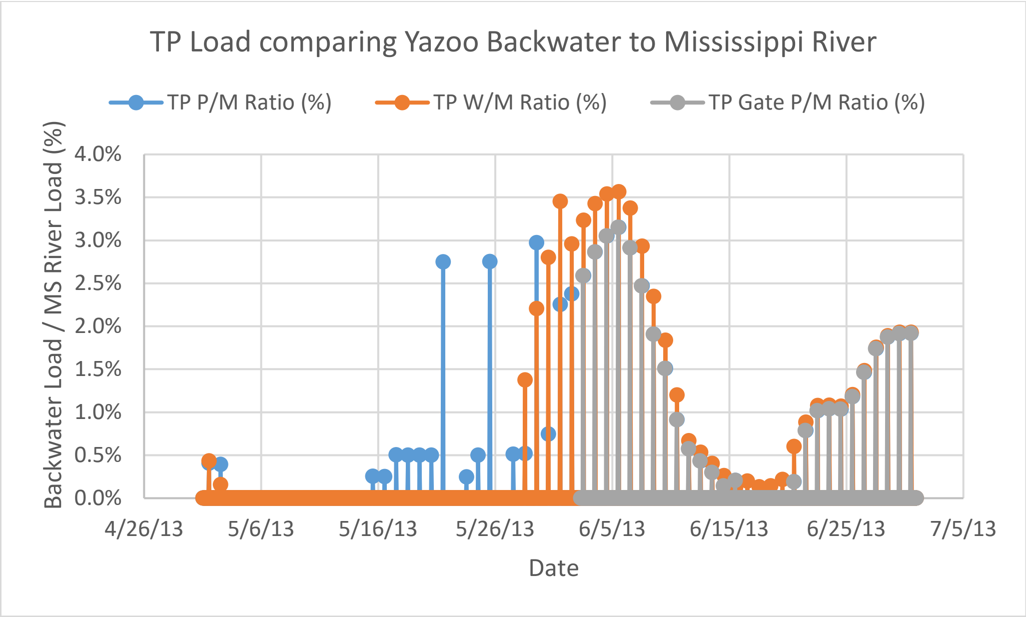

Figure 4-15 Total phosphorous percent load from Steele Bayou structure to Mississippi River (2013)

Plots displaying DO, TN, and TP loading (Figure 4-10, Figure 4-12, and Figure 4-14) resemble the flow plot displayed for the flood event of 2013 (Figure 4-7). The observable sharp change in the plot between labeled dates 5/26/13 and 6/5/13 occurs with the change in mAvg concentration of the parameter, which corresponds with the change in the month. While loading was computed using average concentrations for each parameter from the respective month, flow through the structure in both versions was computed using hourly data. This creates a consistent plot per month but results in noticeable changes in the plot when the month changes. The mAvg concentration used for the calculation can be found in the beginning of this section.

The blue line of the plot is the PA version, and the “columns” of blue demonstrate instances where the pumps reach a maximum flow of 25,000 cfs. It should be noted that the pump station was modeled for full utilization (25,000 cfs) for the date range when peaks are occurring on the blue PA plot. Some plots (e.g. Figure 4-14) appear to show an increase in loading when the pumps are at maximum flow. The change in mAvg concentration from month to month, as described above with the sharp change on the orange WOP plot, provides context for this appearance. While it is not quite as apparent on the blue PA plot as it is on the orange WOP plot, the sharp monthly average change does occur, resulting in less loading with the drop in mAvg concentration.

The changes in the plot resulting from comparisons of mAvg concentrations with hourly flows were found to be similar to the plots comparing load from the Backwater with load in the Mississippi River (Figure 4-11, Figure 4-13, and Figure 4-15). This is largely due to the availability of daily flow data for the Mississippi River. These daily flow values result in what appear to be a striped plot.

For the 2018 flood event, DO load during the PA version reaches a maximum of 496,919 kg/day while in pump operation and 397,822 kg/day after transitioning to gate flow; DO loading during the WOP version reaches a maximum of 722,184 kg/day (Figure 4-16). The maximum percent loading to the Mississippi River of DO during the 2018 flood event was 1.6% during PA version with pump operating, 2.3% during PA version with gate only, and 2.4% during WOP version (Figure 4-17). TN load during the PA version reaches a maximum of 240,196 kg/day while in pump operation and 306,850 kg/day after transitioning to gate flow; TN loading during the WOP version reaches a maximum of 325,125 kg/day (Figure 4-18). The maximum percent loading to the Mississippi River of TN during the 2018 flood event was 3.7% during the PA version with pump operating, 5.8% during the PA version with gate only, and 6.2% during WOP version (Figure 4-19). TP load during the PA version reaches a maximum of 31,533 kg/day while in pump operation and 29,017 kg/day after transitioning to gate flow; TP loading during the WOP version reaches a maximum of 43,814 kg/day (Figure 4-20). The maximum percent loading to the Mississippi River of TP during the 2018 flood event was 5.0% during PA version with pump operating, 5.5% during PA version with gate only, and 7.0% during WOP version (Figure 4-21).

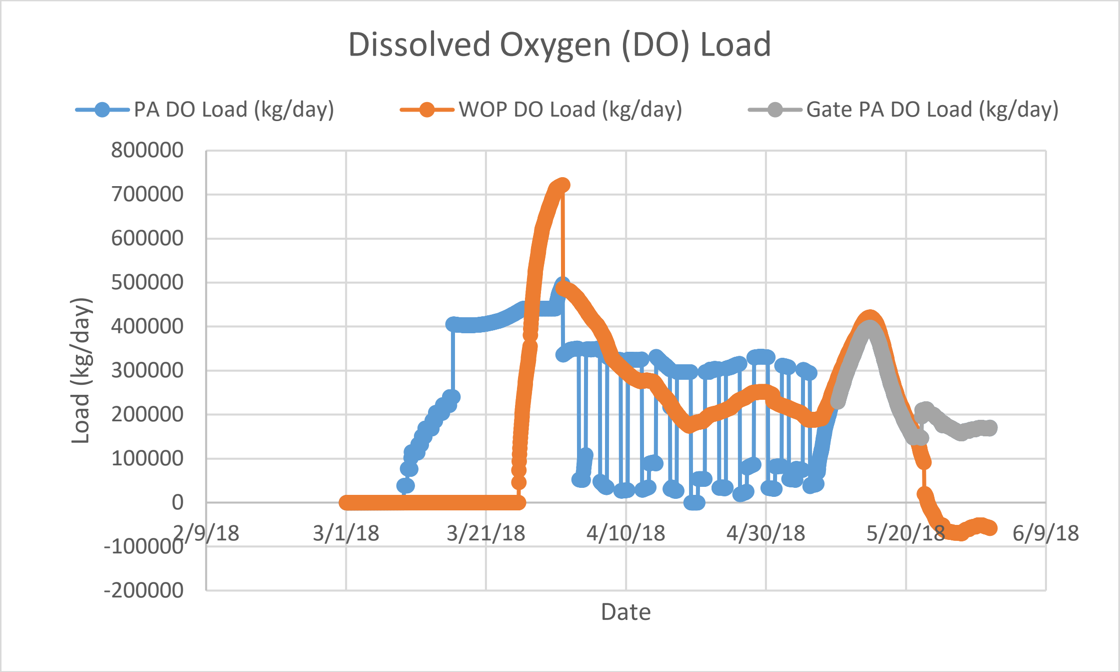

Figure 4-16 Dissolved oxygen load for PA and WOP (2018)

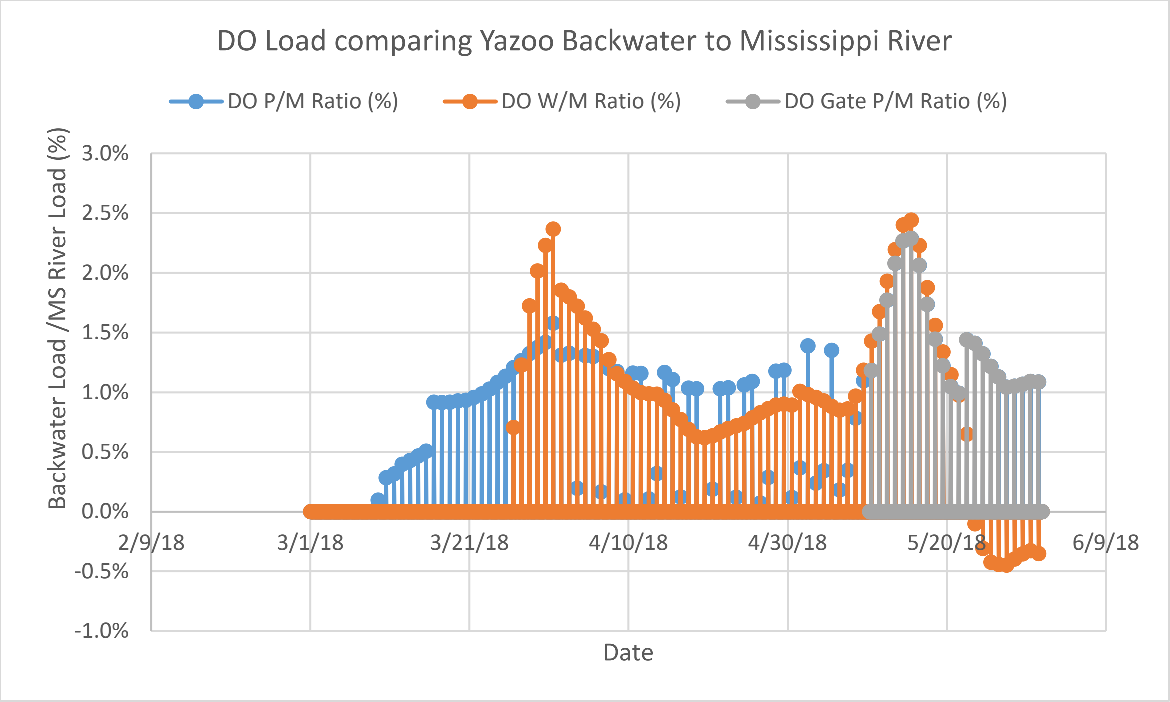

Figure 4-17 Dissolved oxygen percent load from Steele Bayou structure to Mississippi River (2018)

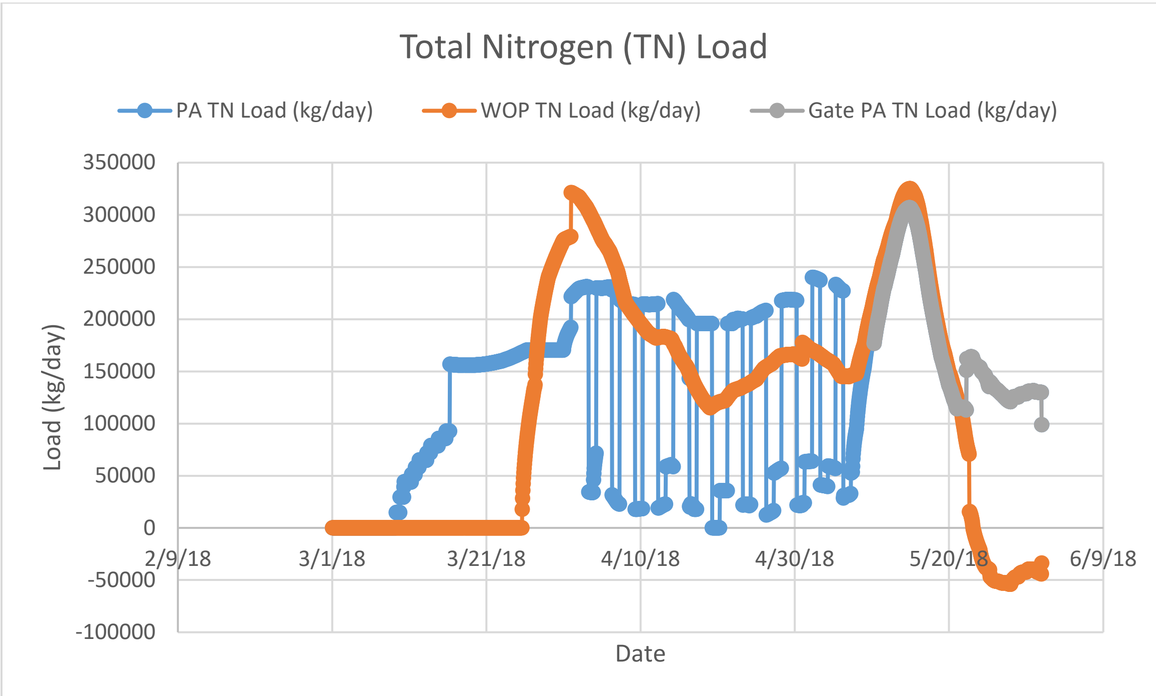

Figure 4-18 Total nitrogen load for PA and WOP (2018)

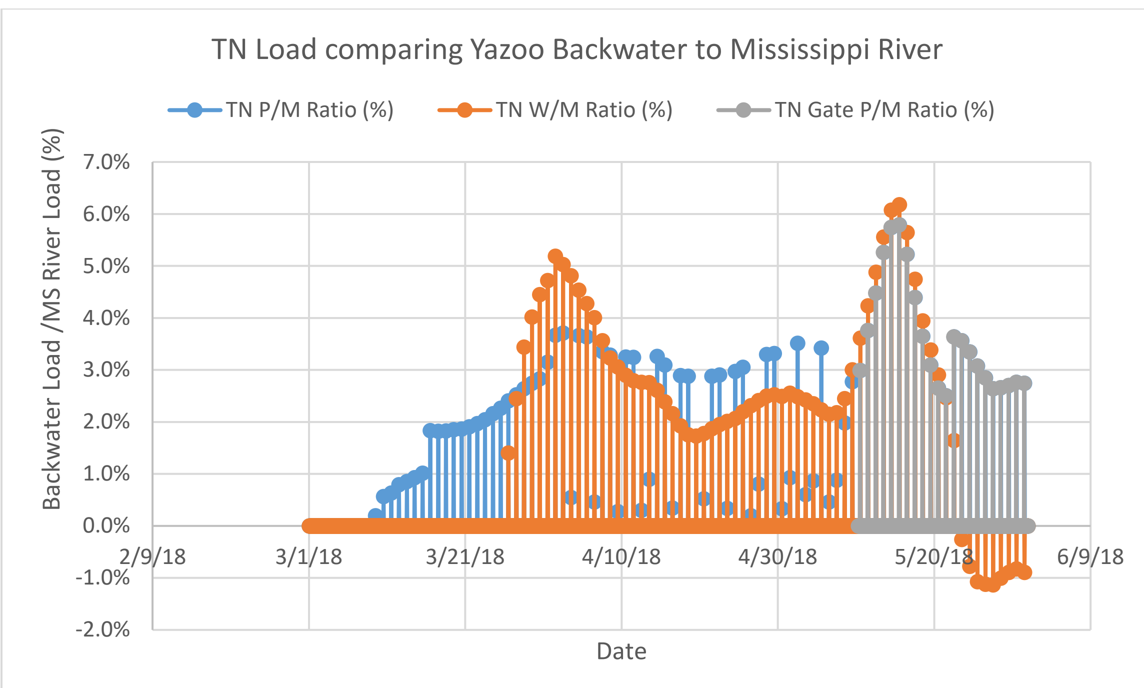

Figure 4-19 Total nitrogen percent load from Steele Bayou structure to Mississippi River (2018)

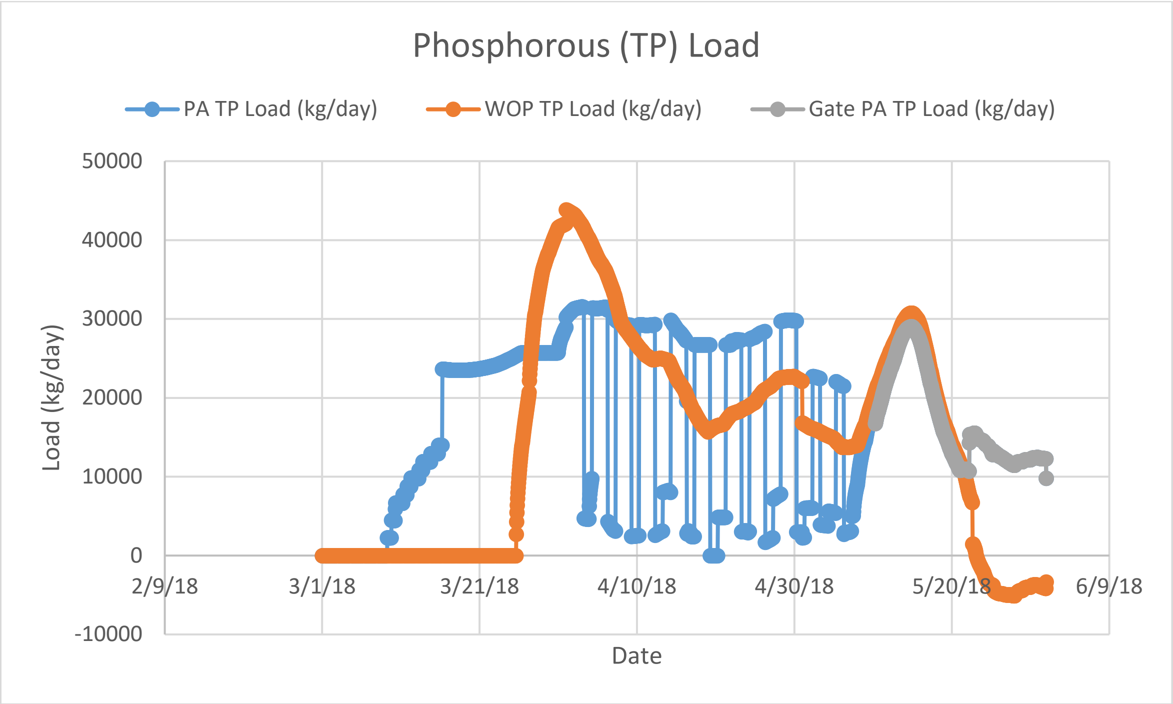

Figure 4-20 Total phosphorous load for PA and WOP (2018)

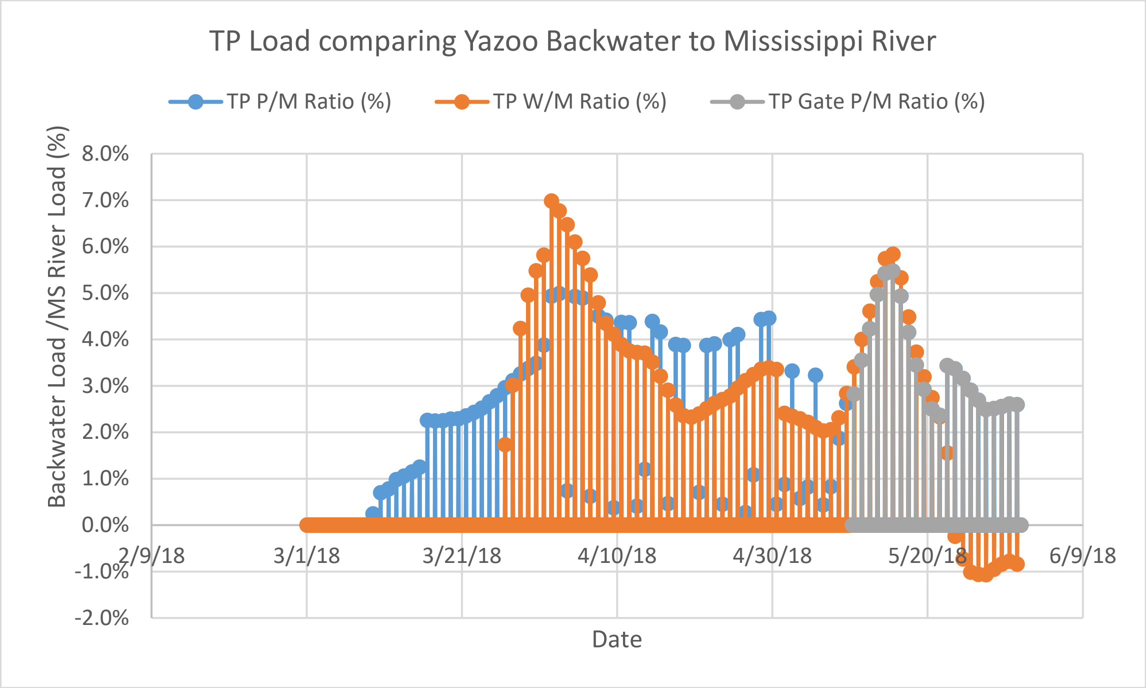

Figure 4-21 Total phosphorous percent load from Steele Bayou structure to Mississippi River (2018)

Plots displaying DO, TN, and TP loading (Figure 4-16, Figure 4-18, and Figure 4-20) resemble the flow plot displayed for the flood event of 2018 (Figure 4-8). The observable sharp change in the plot between labeled dates 3/21/18 and 4/10/18 occurs with the change in mAvg concentration of the parameter, which corresponds with the change in the month. While loading was computed using average concentrations for each parameter from the respective month, flow through the structure in both versions was computed using hourly data. This creates a consistent plot per month but results in noticeable changes in the plot when the month changes. The mAvg concentration used for the calculation can be found in the beginning of this section.

The changes in the plot resulting from comparisons of mAvg concentrations with hourly flows were found to be similar to the plots comparing load from the Backwater with load in the Mississippi River (Figure 4-17, Figure 4-19, and Figure 4-21). This is largely due to the availability of daily flow data for the Mississippi River. These daily flow values result in what appear to be a striped plot.

For the 2019 flood event, DO load during the PA version reaches a maximum of 415,129 kg/day while in pump operation and 469,534 kg/day after transitioning to gate flow; DO loading during the WOP version reaches a maximum of 793,955 kg/day (Figure 4-22). The maximum percent loading to the Mississippi River of DO during the 2019 flood event was 1.9% during PA version with pump operating, 3.1% during PA version with gate only, and 5.8% during WOP version (Figure 4-23). TN load during the PA version reaches a maximum of 203,621 kg/day while in pump operation and 104,967 kg/day after transitioning to gate flow; TN loading during the WOP version reaches a maximum of 223,993 kg/day (Figure 4-24). The maximum percent loading to the Mississippi River of TN during the 2019 flood event was 2.5% during both the PA version with pump operating and the PA version with gate only, and 4.7% during WOP version (Figure 4-25). TP load during the PA version reaches a maximum of 25,956 kg/day while in pump operation and 16,608 kg/day after transitioning to gate flow; TP loading during the WOP version reaches a maximum of 30,541 kg/day (Figure 4-26). The maximum percent loading to the Mississippi River of TP during the 2019 flood event was 3.4% during both the PA version with pump operating and the PA version with gate only, and 6.4% during WOP version (Figure 4-27).

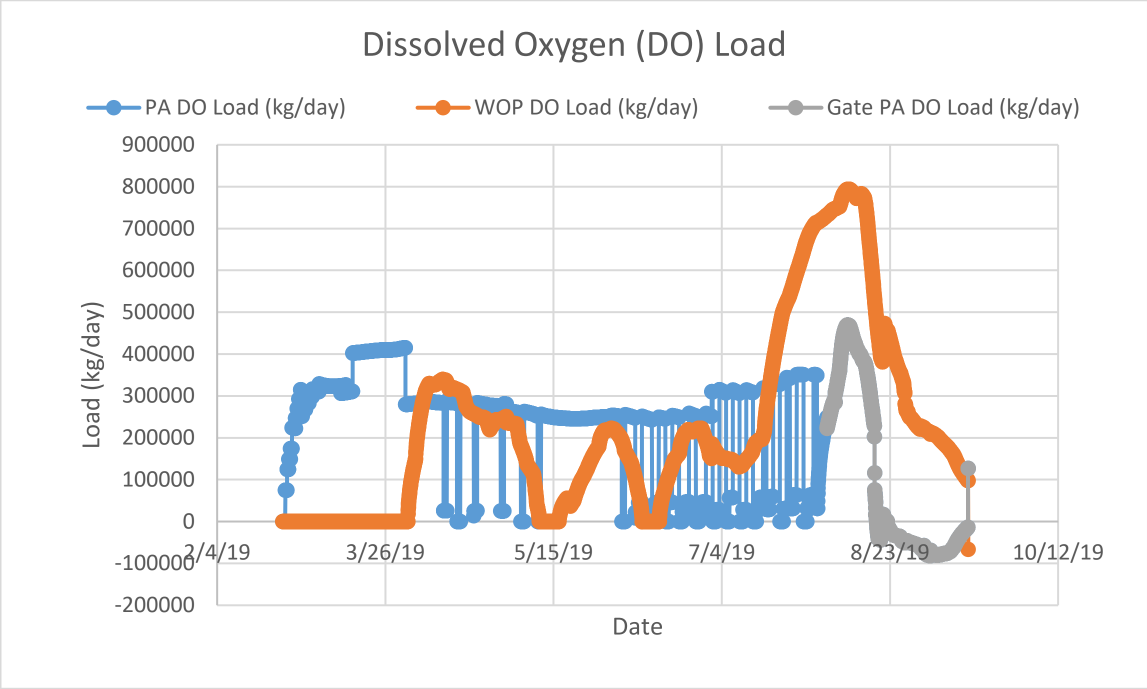

Figure 4-22 Dissolved oxygen load for PA and WOP (2019)

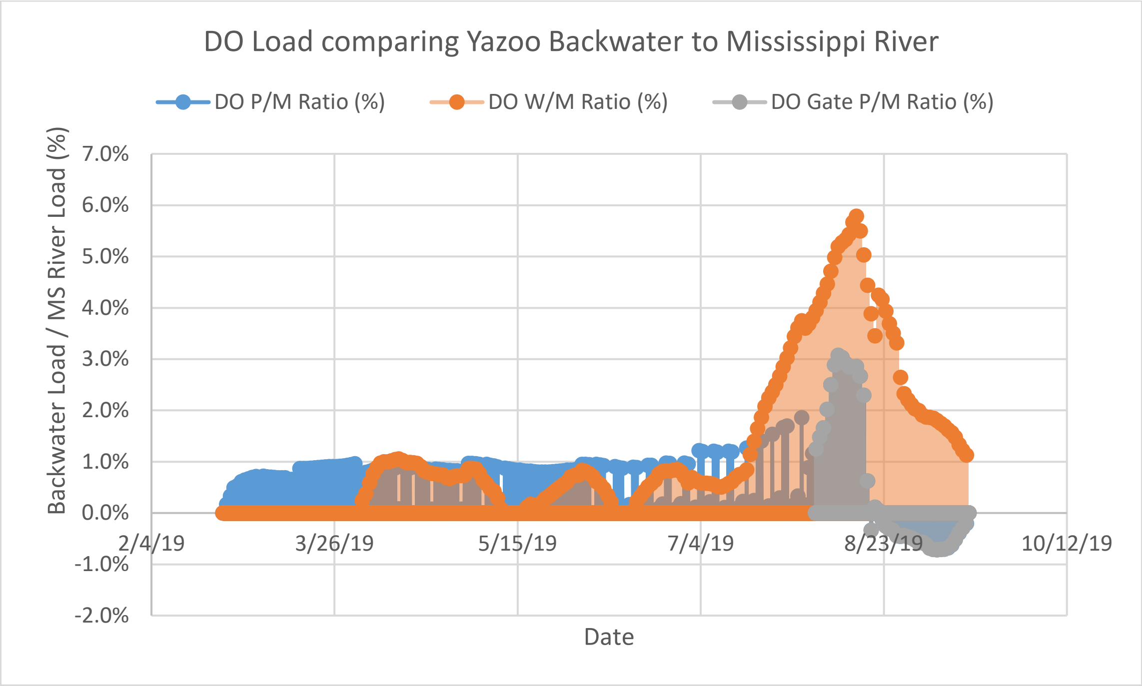

Figure 4-23 Dissolved oxygen percent load from Steele Bayou structure to Mississippi River (2019)

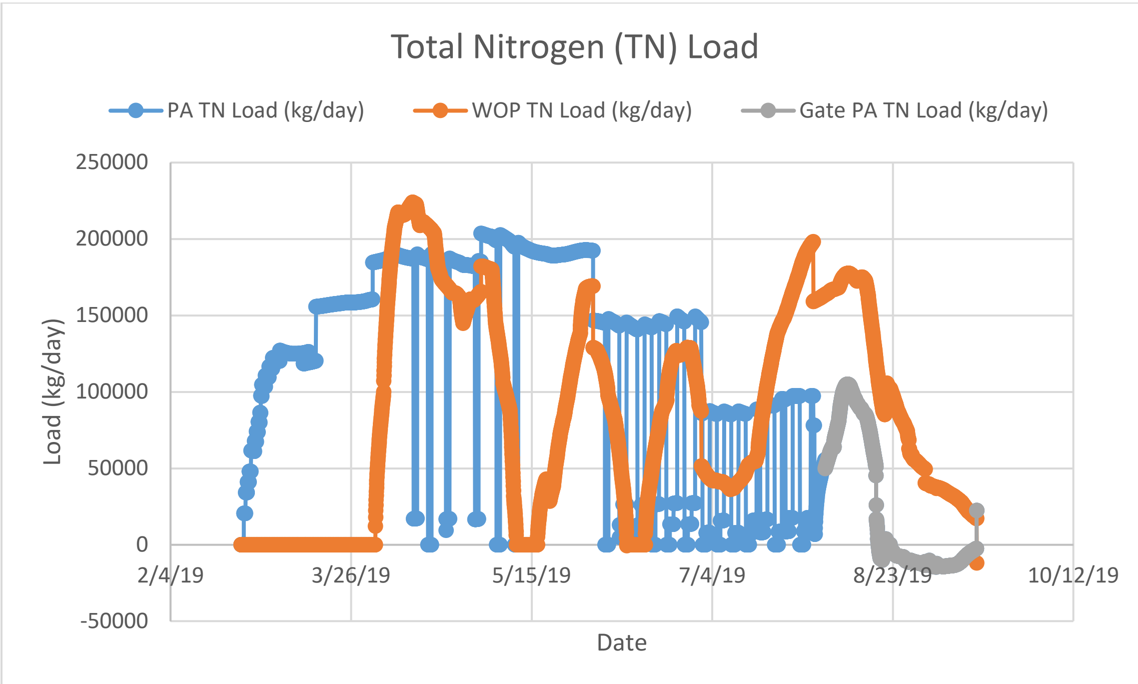

Figure 4-24 Total nitrogen load for PA and WOP (2019)

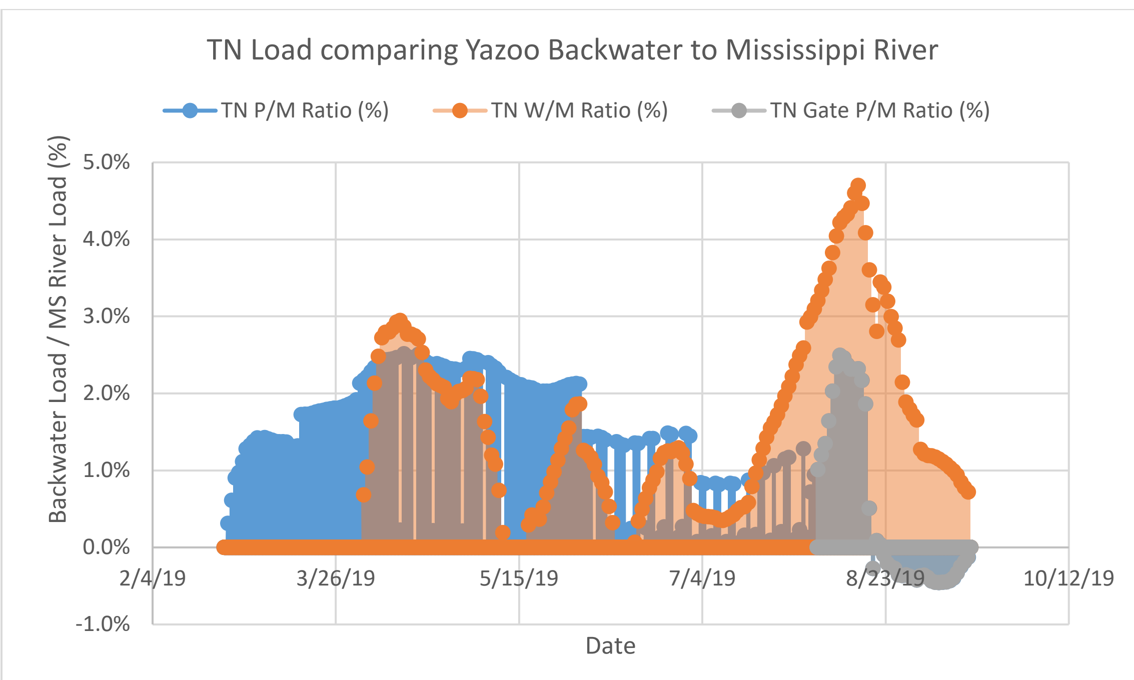

Figure 4-25 Total nitrogen percent load from Steele Bayou structure to Mississippi River (2019)

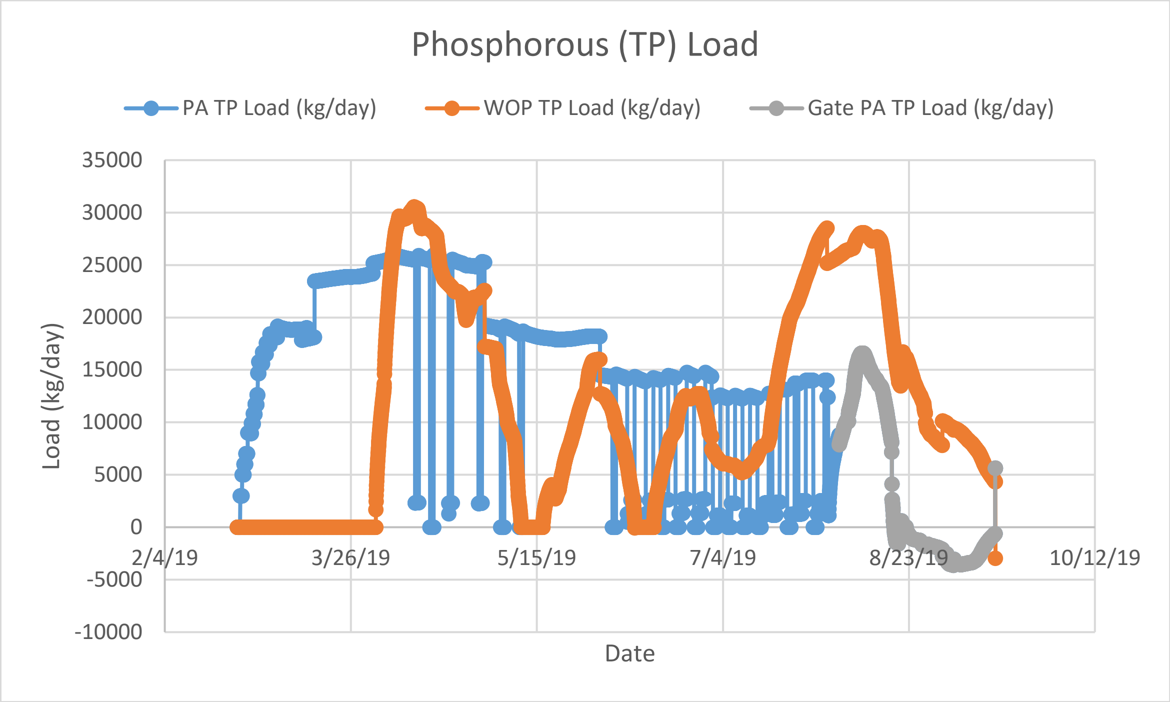

Figure 4-26 Total phosphorous load for PA and WOP (2019)

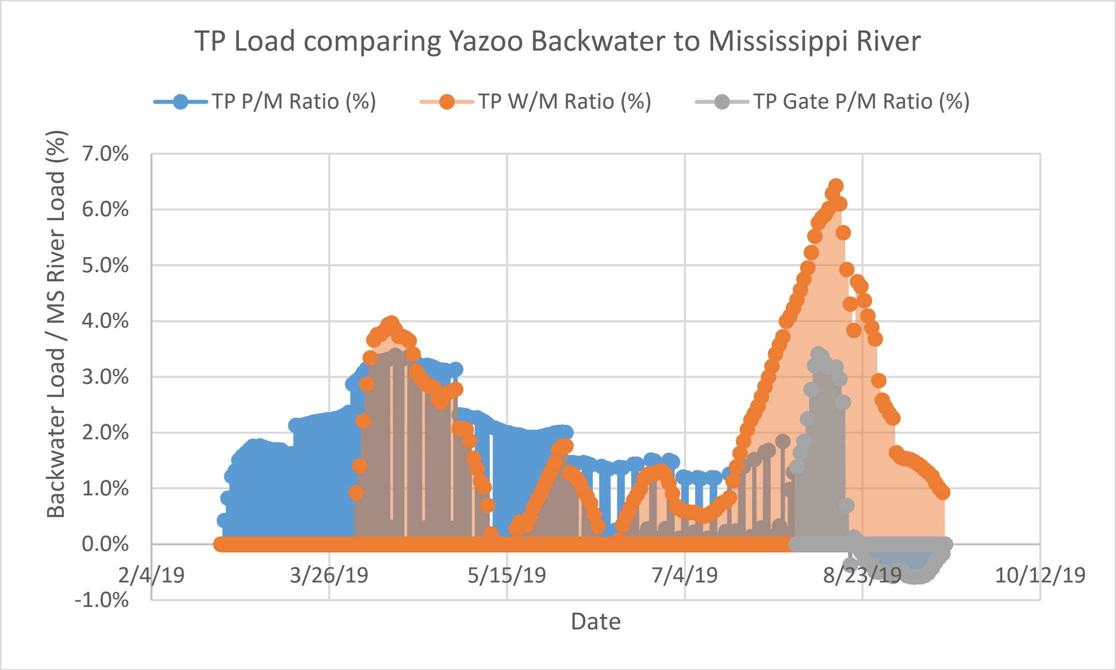

Figure 4-27 Total phosphorous percent load from Steele Bayou structure to Mississippi River (2019)

Plots displaying DO, TN, and TP loading (Figure 4-22, Figure 4-24, and Figure 4-26) resemble the flow plot displayed for the flood event of 2019 (Figure 4-9). The observable sharp change in the plot between labeled dates 7/4/19 and 8/23/19 occurs with the change in mAvg concentration of the parameter, which corresponds with the change in the month. While loading was computed using average concentrations for each parameter from the respective month, flow through the structure in both versions was computed using hourly data. This creates a consistent plot per month but results in noticeable changes in the plot when the month changes. The mAvg concentration used for the calculation can be found in the beginning of this section.

The changes in the plot resulting from comparisons of mAvg concentrations with hourly flows were found to be similar to the plots comparing load from the Backwater with load in the Mississippi River (Figure 4-23, Figure 4-25, and Figure 4-27). This is largely due to the availability of daily flow data for the Mississippi River. These daily flow values result in what appear to be a translucent plot, as compared to the striped plots for the 2013 and 2018 comparisons. The striping becomes less visible in the 2019 plot because of the length of the flood event—since so many more days, and thereby data, are included in a plot of the same dimensions, the lines become less distinct and instead appear as a translucent shading of orange.

These plots have been generated to show the proportional relationship of water, oxygen, and nutrients delivered from the Backwater Area to the Mississippi river both in current conditions through the Steele Bayou gate and in modeled conditions with the proposed 25,000 cfs pump station.

The evidence suggests the greatest difference between the two versions of flow conditions exists on the front of the event. The 2018 flood event plots demonstrate a condition representative of a “plug flow” at the opening of the Steele Bayou structure from the Backwater Area into the downstream portion of the Yazoo River and the Mississippi River. The metered operation of the pump station shows varied flows for the PA version; however, the flow through the gate at this time in the WOP version suggests similar overall structure flow from Steele Bayou in this time window of the flood event. Utilization of the pump station appears to facilitate a more uniform delivery of loading for DO, TN, TP and presumably sediment (not analyzed) over a range of flood events on the Mississippi River which should be assimilated into the system more efficiently. For the overall event, once the gates are opened in both the PA version and the WOP version, the flows begin to converge, and little difference is observed between the two versions. All data aggregation, filtration, and computation were conducted in Microsoft Excel for this

SECTION 5 LOW FLOW

5.1 GENERAL

In the early part of the twentieth century, flow in the rivers and streams of the Yazoo Basin remained in contact with the surficial aquifer. This connection allowed for water movement from the stream to the aquifer during periods of heavy rainfall and water movement from the aquifer to the stream during the dry periods of the year. The later condition describes what is traditionally referred to as environmental flow or base flow. Environmental flows or base flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems, and the human livelihoods and well-being that depend on these ecosystems. Environmental flow in a stream can significantly influence the overall potential for aquatic health since the availability of adequate water supply is necessary for aquatic habitat. These flows help to maintain the channel geometry allowing for suspension of sediments along the thalweg as well as providing an adequate wetted perimeter for bottom dwelling species like mussels which are prevalent in the two basins. Adequate environmental flow also helps to mitigate the oxygen dynamics in a stream by providing an adequate supply of DO to support both the needs of aquatic organisms as well as the demands imposed by sediment (SOD). However, when the surficial aquifer is heavily utilized for irrigation or some other consumptive use, the water level in the aquifer can fall below the stream bed, and the stream will no longer receive environmental or base flow from the aquifer.

5.2 HISTORICAL LOW FLOW

The main tributaries of the Steele Bayou and Big Sunflower Basins have suffered from decreasing annual minimum flows over the last 50 years. The station located on the Big Sunflower River at Sunflower; Mississippi represents a key position in one of the Yazoo Basin's major rivers to describe the historical decline in minimal flows over most of the last century. The graph in Figure 5-1 below shows that the minimum flow was around 200 cubic feet per second (cfs) in the 1930s through the 1940s, but that minimum flow diminished to just under 100 cfs during the next three decades. By the 1980s and 1990s the minimum flow (1% duration) had diminished by 90% to around 20 cfs, from the initial flow measurements taken in the mid 1930's.

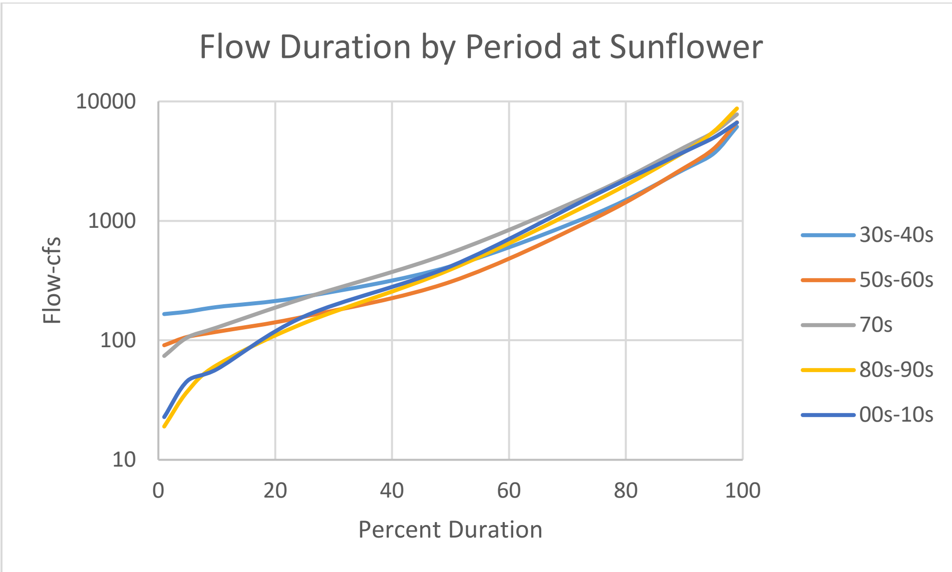

Figure 5-1. Flow Duration by Period in the Big Sunflower River at Sunflower, Mississippi

The historical flow depletion observed for each of the four seasons is explained in more detail in the Engineering Appendix, Low Flow in Delta Streams of this report. The analysis from this section explains how the fall months have been observed to experience the most restrictive flows of which coincide with the season which receives the least precipitation. The median flow representing the fall months in the periods from 1980 to 1999 and the period from 2000 to 2019 were observed to be 102 and 106 cfs, respectively. These median flow values were substantially less than the median flow values observed in the fall months from the 1930's to the 1970's which ranged from 153 to 225 cfs. These minimal stream conditions for the fall months are further reiterated by reporting the 1% flow of only 10 cfs for the 1980's and 1990's which had declined from 160 cfs for the 1930's and 1940's, 90 cfs for the 1950' and 1960's, and 71 cfs for the 1970's. The most recent period of 2000 to 2019 saw a slight increase for the 1% flow for the fall months to 18 cfs but still falls far below the historical base flows observed in the early part of the 19th century.

During the summer months, the more recent decades show a slight increase in observed flow. This increase is due to irrigation return flow. The median flows were 287 cfs for the 1930' and 1940's, 202 cfs for the 1950's and 1960's, 458 cfs for the 1970's, 440 cfs for the 1980' and 1990's, and 370 cfs for the 2000's and 2010's. The increase in minimal flows in the summer months for the recent periods can be attributed to the increasing use of irrigation in the Yazoo Basin largely starting in the 1970's. The widespread use of this fundamental agricultural practice has added to cumulative stream flows by virtue of irrigation runoff.

Recent attempts have been made to supplement base flow conditions in the Yazoo Basin. In 2005 and 2006 the Yazoo Mississippi Delta Joint Water Management District installed 11 low flow groundwater wells in northwest Caohoma County (MDEQ 2011). This effort was designed for flow augmentation of 35 to 50 cfs to the upper watershed of the Big Sunflower River Basin. This flow represents the 5% duration of the 2000's (Figure 4-2). The operation of these augmentation efforts has been hampered since their inception due to flow path restrictions from the wells to the channel of the Big Sunflower River minimizing the full potential of the project in the basin.

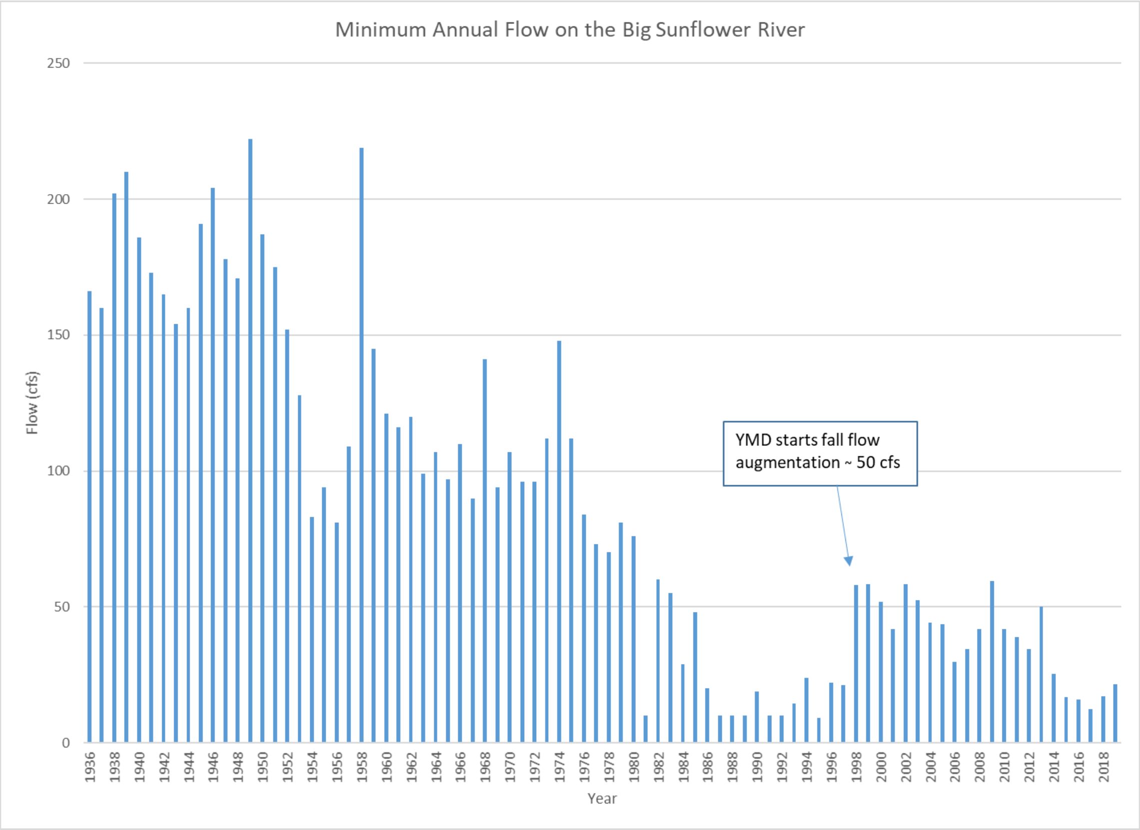

Figure 5-2. Annual Minimum Flow of the Big Sunflower River at Sunflower, Mississippi from 1936 to 2008.

5.3 SUPPLEMENTAL LOW FLOW GROUNDWATER WELL SITES

The environmental feature associated with Alternative 2 and Alternative 3 promotes the construction of 34 supplemental low flow groundwater well sites in the headwaters of the Big Sunflower, the Upper Deer Creek, and the Steele Bayou basins. Early uses of flow augmentation were to improve water quality or to improve water quantity to ensure the water quality was maintained. The Federal Water Pollution Control Agency, in Atlanta, GA contracted with the University of Florida (Final Report to Southeast Region, FWPCA, Sep 1969, A Model For Quantifying Flow Augmentation Benefits; Pyatt et al.

1969) to examine the cost benefit of augmenting flow compared to the increased costs of wastewater treatment. One of the EPA first reports dealt with flow augmentation, "Water Quality Control Though Flow Augmentation" (Heidelberg College, Biology Department 1971). Again, the emphasis of the study was improving water quality. The use of flow augmentation to improve water quality and aquatic health is explained in greater detail in the Engineering Appendix – Low Flow in Delta Streams.

The objective of the supplemental low flow groundwater well environmental restoration component of the project is to establish environmental flow or base flows for the region which will mimic flows observed in the mid-20th century found in the Yazoo Basin. The implementation of the supplement low flow groundwater well sites will ideally supplement existing flows to a rate of 0.1 to 0.2 cfs per square mile for the applicable watersheds. This goal of 0.1 to 0.2 cfs per square mile was an initial target based on historical flow data from within the YBA. A more robust discussion on the historical base flow in the YBA can be found in the Engineering Appendix – Low Flow in Delta Streams. Further studies shall be conducted through the implementation phase to refine these values as described in the Adaptive Management phase associated with the respective alternative. This projected per square mile flow rate will support year-round channel geomorphology conditions, provide the necessary water quality conditions for aquatic life, and help to supplement adequate inundation for mussel beds found in the Big Sunflower River basin. This environmental feature would be administered through the monitoring and adaptive management phase of Alternative 2, Alternative 3, or Alternative 4. It would be implemented in an iterative process working to refine benefits to the surface waters of the Yazoo Basin.

The proposed locations of the 34 supplemental low flow groundwater well sites were based on two criteria: the wells were within 30,000 feet of the Mississippi River channel and the wells reside on the landside of the Yazoo Backwater levee. The first condition was set to insure adequate groundwater supply from annual recharge from the Mississippi River. The potential for annual recharge of the alluvial aquifer from the Mississippi River is proportionally greater for water bearing strata closer to the channel. Significant drawdown of the alluvial aquifer has been primarily concentrated in the Sunflower and LeFlore counties. The supplemental low flow gourndwater wells have been located in areas that have not demonstrated long term decline in the water table. This natural phnomenon is explained in greater detail in the Engineering Appendix: Well Field Augmentation. The second condition was set to insure supplemental flows were going to areas with strong mussel bed populations that have been plagued with inadequate minimum flows. Each well site will mimic a common design capable of delivering a maximum of 5.0 cfs during low flow periods. The pump for each well site will be situated on the top bank of headwater stream with a pipe discharging water onto a splash pad which will then flow down a constructed re-aeration trough to the channel. The cooler temperature regime typically associated with groundwater will also have a positive effect on the DO saturation when mixed with warmer surface waters.

The water extracted from the MRVA is known to have higher levels of iron concentrations. Currently there are more than 20,000 wells in use for agricultural irrigation in the Yazoo Backwater Area. While the operation of these irrigation wells has had a significant contribution to Yazoo Basin via irrigation return flow, the surface water quality has not experienced a noticeable change. The ferrous iron pumped by each supplemental low flow groundwater well will likely precipitate in the reaeration trough adjacent to the channel and should not have an adverse effect on stream water quality (may improve by removal of phosphorus). The clean groundwater taken from the MRVA has been found to be free of harmful contaminates and should have a positive impact on the overall water quality in the Yazoo Basin.

The period for critical flows in the YBA and corresponding use of the supplemental low flow wells comes after the agricultural growing season and notable decline in stream stages resulting from diminished irrigation return flow. The supplemental flow delivered to the streams should not be viewed as a water source for irrigation (via surface water) to nearby farming operations which could hamper the overall benefits to the project. The operational plan for the supplemental low flow groundwater wells will be structured based on adaptive management strategies tailored for low flow conditions when irrigation return flows have ceased. Depth transducers will be installed in each sub-basin, and pumping will be initiated or halted based on observed water surface elevations. Minimum flow targets will be established for downstream locations, and the number of wells operated will vary so target flows are achieved. The wells will not be operated during major flood events.

The three primary basins that will be supplemented by these well sites are: The Steele Bayou Basin, the Upper Deer Creek Basin, and the Big Sunflower Basin. The Big Sunflower includes the Harris Bayou, Hushpuckena River, and Bogue Phalia sub-basins. The number of well sites and cumulative additional flow each basin is set to receive is as follows: Steele Bayou - 8 well sites (40 cfs), Upper Deer Creek - 5 well sites (25 cfs), and Big Sunflower - 21 well sites (105 cfs). A map depicting the locations of the proposed well locations along with the tributaries they will support is shown in Figure 5-3, Figure 5-4, and Figure 5-5. Coordinates for each of the proposed wells is given in Table 5-1. It should be noted that each well site may move up to 1,000 feet up or down stream and/or to the opposing bank from the proposed locations. These relocations could result from unforeseen limitations with HTRW, cultural artifacts, power availability, or unwilling landowners.

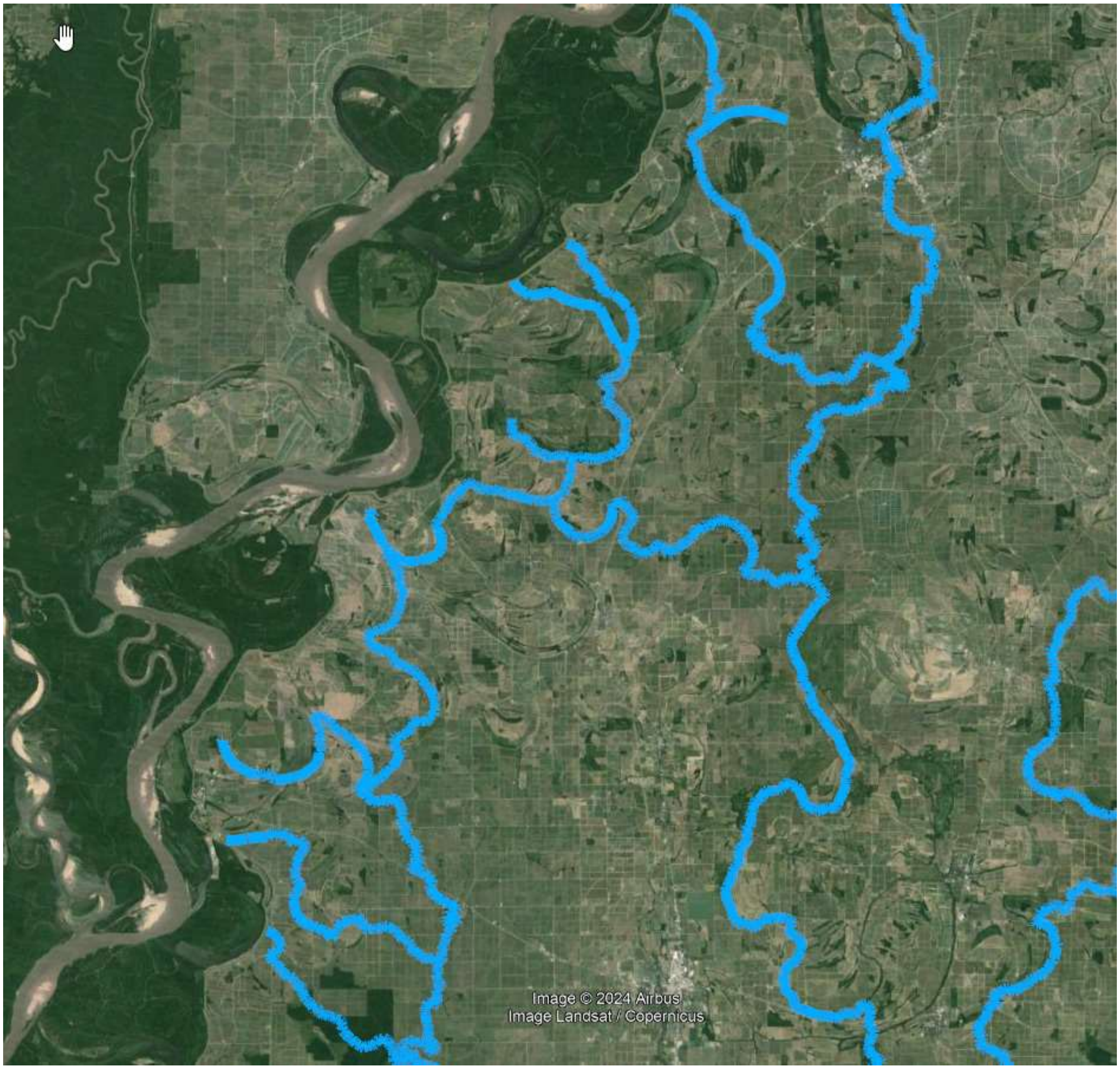

Figure 5-3. Map of the proposed 21 well sites for the Big Sunflower Basin along with the tributaries that will be supplemented.

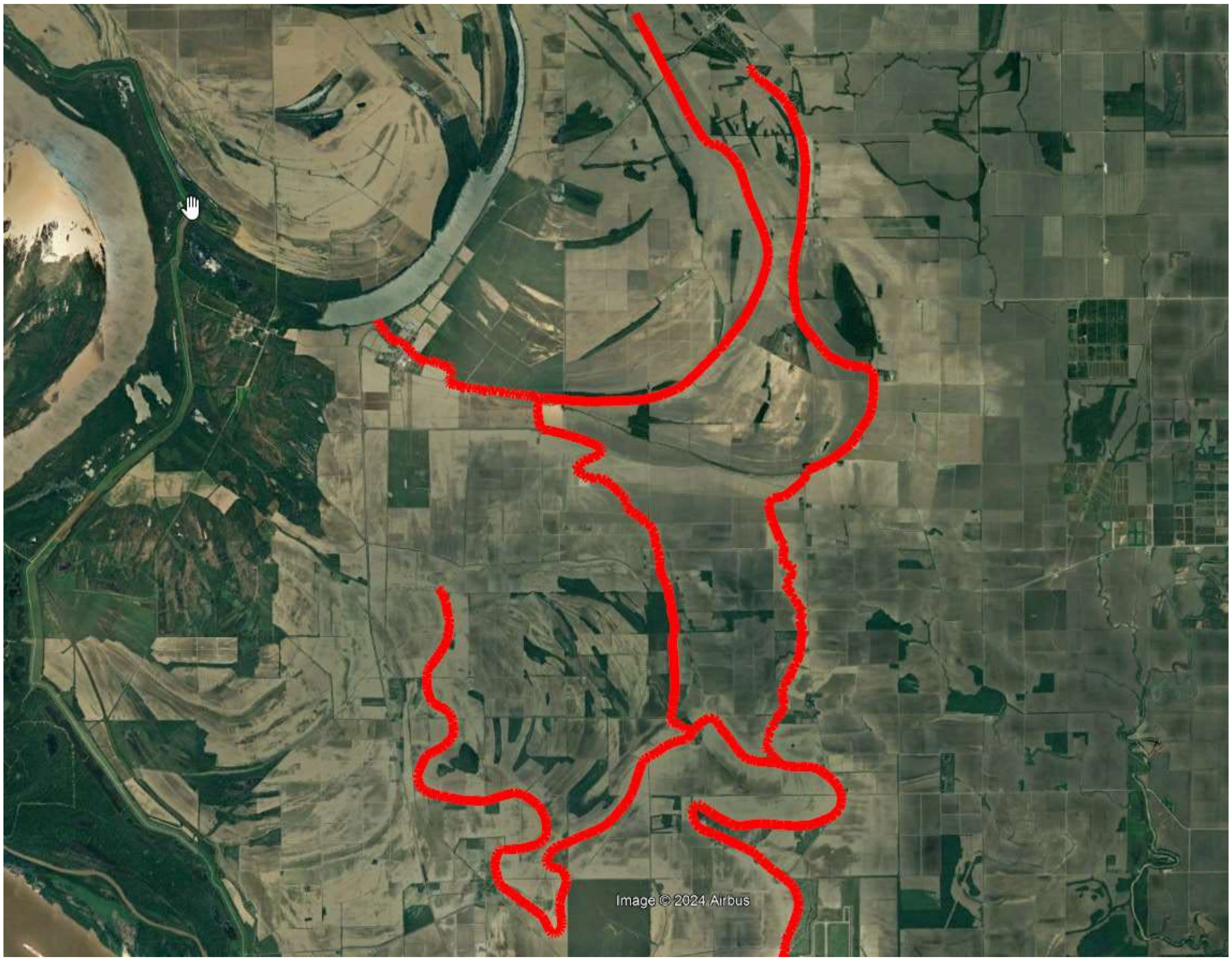

Figure 5-4. Map of the proposed 5 well sites for the Upper Deer Creek Basin along with the tributaries that will be supplemented.

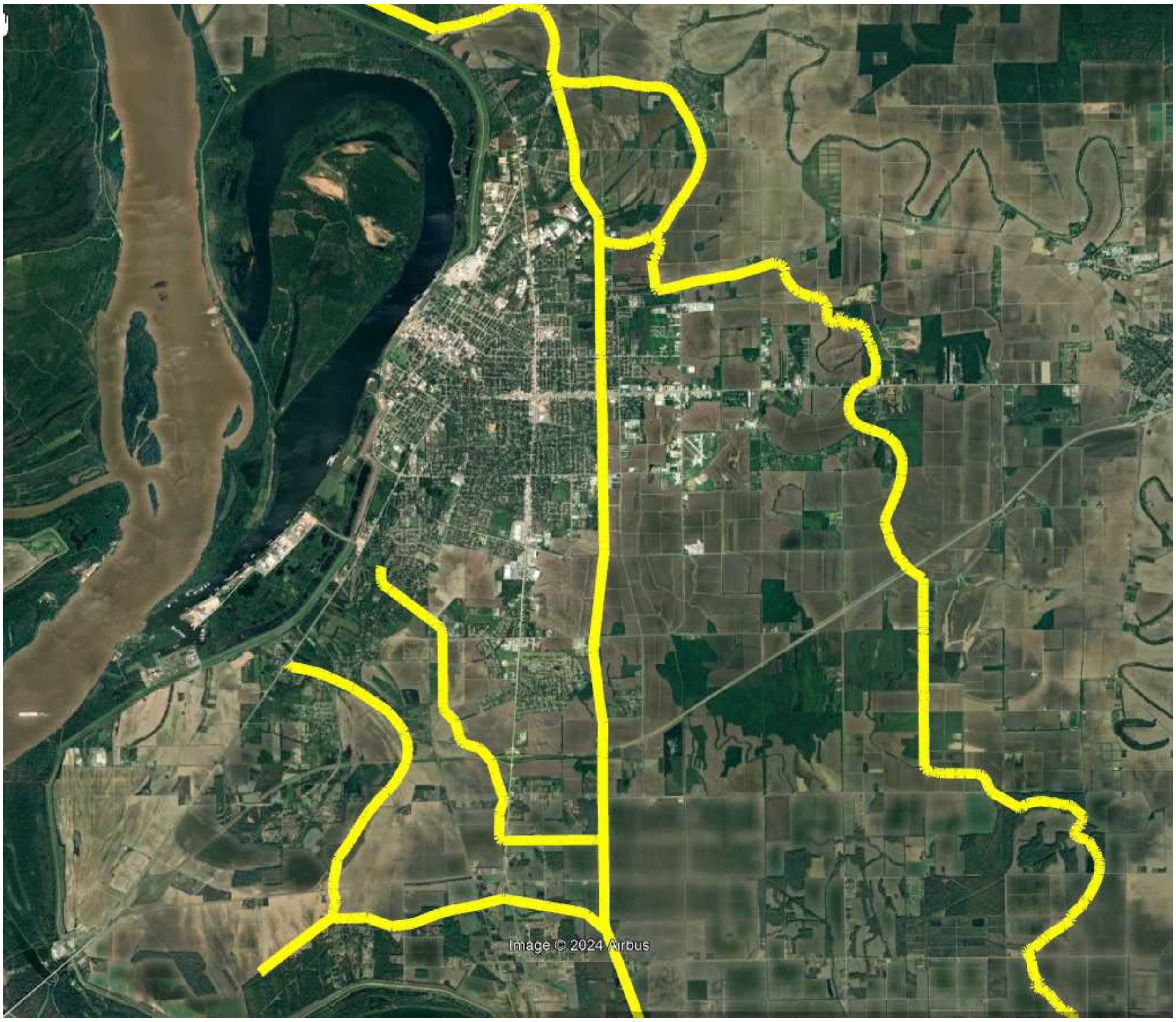

Figure 5-5. Map of the proposed 8 well sites for the Steele Bayou Basin along with the tributaries that will be supplemented.

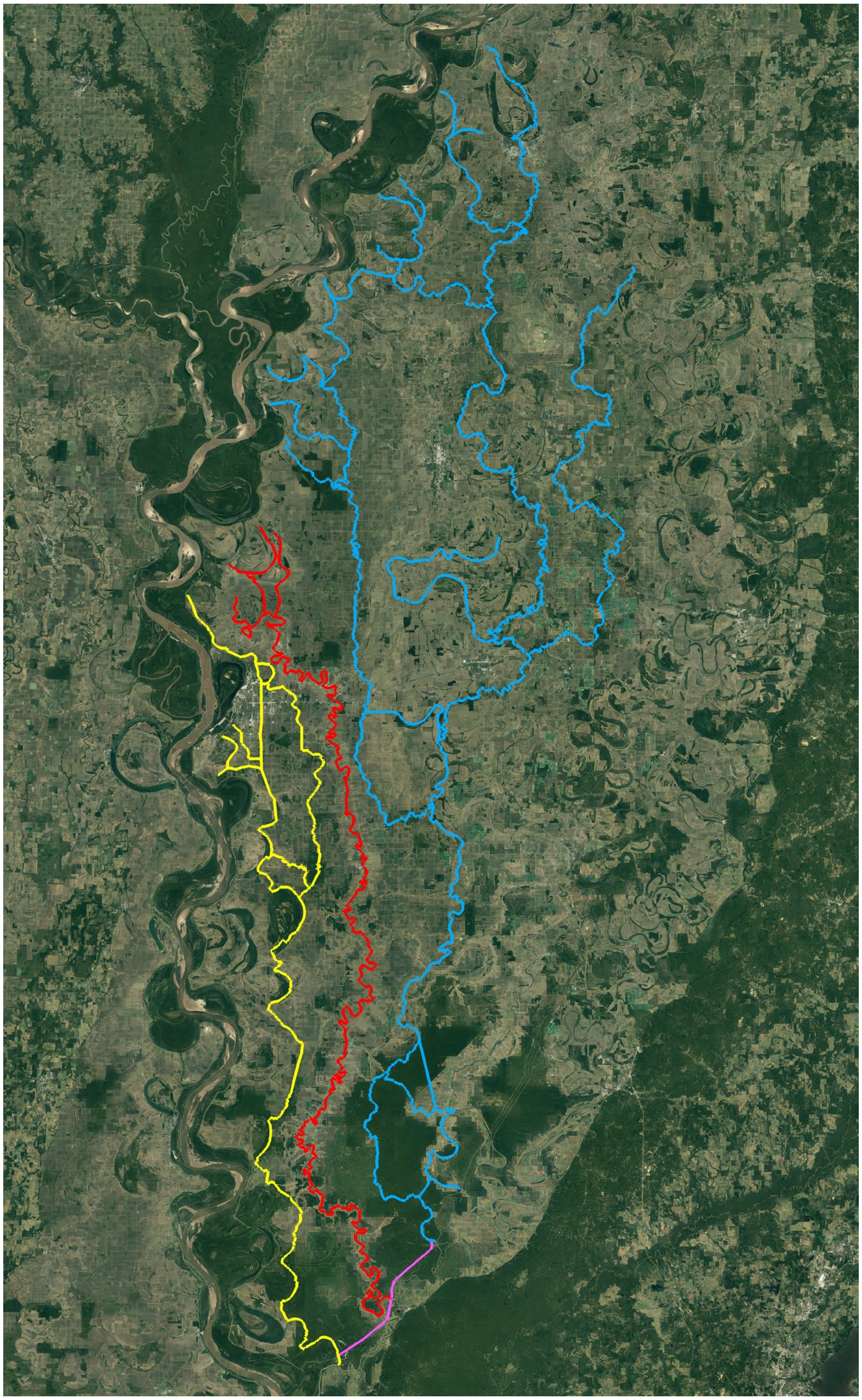

Figure 5-6. Location of the Well Sites for the Yazoo Backwater Area Water Management Project.

Table 5-1 Location and acres associated with Well Sites described for the Yazoo Area Backwater Project

YBW FEATURES						
County	**Site Name**	**Water Body**	**Latitude**	**Longitude**	**Area (Acres)**	Access Road acres
Coahoma	YBP-HB-RB-1	Ritchies Bayou			1.25	0.01
Coahoma	YBP-HB-RB-2	Ritchies Bayou			1.25	0.47
Coahoma	YBP-HB-RB-3	Ritchies Bayou			0.75	0.52
Coahoma	YBP-HB-HB-4	Harris Bayou			1.00	0.40
Coahoma	YBP-HB-HB-5	Harris Bayou			0.75	0.38
Coahoma	YBP-HB-HB-6	Harris Bayou			0.50	
Coahoma	YBP-HP-HP-7	Hushpuckena River			0.75	0.05
Coahoma	YBP-HP-HP-8	Hushpuckena River			1.00	0.21
Coahoma	YBP-HP-MS-10	McNeil Slough			1.00	
Bolivar	YBP-HP-SB-12	Upper Stokes Bayou			1.25	0.13
Bolivar	YBP-HP-EB-13	Edwards Bayou			0.75	
Bolivar	YBP-BP-BP-14	Bogue Phalia			0.50	0.03
Bolivar	YBP-BP-BP-15	Bogue Phalia			1.25	0.95
Bolivar	YBP-BP-BP-16	Bogue Phalia			1.00	0.03
Bolivar	YBP-BP-LB-18	Lane Bayou			1.25	0.14
Bolivar	YBP-BP-LB-19	Lane Bayou			0.75	0.42
Bolivar	YBP-BP-LB-20	Lane Bayou			1.25	0.32
Bolivar	YBP-BP-LB-22	Laban Bayou			1.00	0.15
Bolivar	YBP-BP-LB-23	Laban Bayou			0.75	0.09
Bolivar	YBP-BP-LB-24	Laban Bayou			1.25	0.12
Bolivar	YBP-BP-SB-26	Lower Stokes Bayou			0.50	2.02
Bolivar	YBP-DC-SB-27	Straight Bayou			1.00	0.23

Bolivar	YBP-DC-BB-28	Browns Bayou			0.75	0.25
Bolivar	YBP-DC-DC-29	Deer Creek			0.75	1.69
Bolivar	YBP-DC-DC-30	Deer Creek			0.75	0.04
Washington	YBP-DC-WB-32	Williams Bayou			0.75	0.06
Washington	YBP-MC-MC-33b	Main Canal			1.00	0.05
Washington	YBP-BB-HB-34	Horshoe Bayou			0.75	1.72
Washington	YBP-BB-HB-35	Horshoe Bayou			1.00	0.29
Washington	YBP-MC-No8-39	Ditch No8			0.75	0.03
Washington	YBP-MC-No6-40	Ditch No6			0.75	0.61
Washington	YBP-MC-No8-41	Ditch No8			0.75	0.45
Washington	YBP-MC-No9-43	Ditch No9			0.75	0.22
Washington	YBP-MC-No6-44	Ditch No6			1.25	0.11

Please note that these locations are based on preliminary assessments and may move up to 1,000 feet up or down stream and/or to the opposite bank at final design. (At the time of public notice of the DEIS, the supplemental well locations were not a fee title possession by USACE and could not be displayed.)

SECTION 6 CONCLUSION

The mean concentrations observed for nitrogen and phosphorus coming from the Yazoo Backwater Area fall far below the concentrations estimated out of the Midwest Tributaries as detailed in the MARB SPARROW model. The Yazoo Backwater Area does not contribute a disproportionate load of nitrogen to the Gulf of Mexico and is generally in line with its proportionate contribution of phosphorus to the Gulf hypoxic zone. The extensive erosion control measures employed by the Vicksburg District and its Federal, State and local sponsors have made significant strides to control the nutrient contributions from the Yazoo Basin to the Gulf Hypoxic Zone. The features associated with Alternative 2 and Alternative 3 will account for a small increase in total loading of TN and TP to the Mississippi River. However, Alternative 1 (No Action) and Alternative 4 exert similar increases of these nutrients to the Mississippi River. The timing of the nutrient loading to the Mississippi River will be by a few weeks on the front end of a given flood event however the overall mass should be similar.

Implementation of the features associated with Alternative 2 and Alternative 3 can significantly enhance the overall water quality in the Yazoo Backwater Area. Construction of the 25,000 cfs Backwater Pump station may provide a slight benefit to

DO in the water column by minimizing the overall depth of a flood event thus improving diffusion from the surface water. As the backwater pools grow deeper and sustain prolonged periods of stagnation, the suspended solids have an opportunity to settle out of the water column. This process makes way for increased light transmission through the surface layer and the increased production of algal growth. As a result, DO concentrations begin to recover within the first 5 to 10 feet of surface. This condition may be exacerbated in the flood pool by the nutrient availability from the upper watershed, which may in turn exhibit greater extremes of high and low DO concentrations in the diurnal regime. This turnaround typically comes too late to provide habitat for aquatic species because they have either left the region or died from the extended period of poor conditions. The construction of the pump feature associated with Alternative 2 and Alternative 3 would slightly reduce the overall settling time for suspended solids in the basin when compared to No Action Alternative and Alternative 4 but not before much of the settling had taken place. The reduced time frame should have a minimal impact on DO contributions from primary productivity. The construction of the pump feature associated with Alternative 2 and Alternative 3 would reduce this extended period of poor DO conditions. The combination of these effects should have an overall benefit to DO in the Yazoo Backwater Area during extended flood events.

In Alternative 4 the implementation of floodproofing of residential and commercial properties up to 98.2 ft could subject the Yazoo Basin to sediment disturbance during construction activities which may cause temporary increases in turbidity and nutrient levels. In the No Action Alternative as well as in Alternative 4, the existing conditions observed in the Yazoo Backwater would continue to prevail during flood events. This would include depressed DO concentrations throughout much of the water column in the lower basin and restricted fisheries habitat.

The environmental restoration feature associated with this project includes the construction of supplemental low flow groundwater well sites built in the headwaters of the two basins. These wells will help to supplement needed base flow in the major arteries of the systems allowing for year-round in-channel habitat during critical low flow periods. These well sites will provide a positive benefit to the overall low DO conditions observed during the warmer months. These warmer months typically coincide with the low flow periods in the primary tributaries of the two basins. The supplemental water provided should stimulate re-aeration through agitation minimizing the presence of stagnant intermittent pools in the channels. Water from the well sites will likely decrease the ambient temperature of the streams and have a positive effect on DO saturation which would be beneficial to aquatic life.

The implementation of the 25,000 cfs Pump Station described in Alternative 2 and Alternative 3 may encourage some farmers to invest more resources into their operations for enhanced productivity of existing cultivated acres. The potential impacts from these efforts will largely be offset by the acreage removed from cultivation activities through the required mitigation plans. The proposed strategy will seek to acquire acreage below 90.0 feet and 93.0 feet elevation for tree planting and reestablishment of bottomland hardwood forests. Alternative 2 and Alternative 3 have current mitigation acreage requirements of 7,650 ac and 5,722 ac, respectively, which should serve to benefit water quality in the Yazoo Backwater surface waters.

Section 4.0 Downstream Water Quality Impacts describes the minimal impacts of DO, TN, TP, and sediment that are contributed to the Yazoo River and Mississippi River system from discharge of the Yazoo Backwater Area. The section provides comparisons of the implementation of Alternative 2 and the use of the pump station with the current conditions which employ the use of the Steele Bayou and Little Sunflower Outlet Structures only. The two scenarios compare the transfer of water from the YBA downstream to the Mississippi River. The analysis, which was calculated from the model output during a range of Mississippi River flood events (flood years 2013, 2018, and 2019) shows a slight decrease in peak loadings for the subject parameters relative to the Mississippi River when the pump station (Alternative 2) was utilized. In the pump alternative (PA) version analyzed above, increases in loading to the Mississippi River from the Yazoo Backwater Area (YBA) of dissolved oxygen (DO), total nitrogen (TN), and phosphorous (TP) peak at a range of 1.5-3.1%, 2.5-5.8%, and 3.0-5.5%, respectively. Alternately, in the without pump (WOP) version analyzed above, increases in loading to the Mississippi River from the YBA of DO, TN, and TP peak at a range of 2.3-5.8%, 3.7-6.2%, and 3.6-7.0%, respectively. By comparison, the PA version delivers a smaller percentage increase of DO, TN, and TP of peak loading to the existing capacity in the Mississippi River as calculated during the labeled flood events. Since the overall mass of TN and TP remains unchanged in the YBA, the reduction in peak loading is accomplished by extending the flood event from 2 to 5 weeks on the leading edge of a given flood event. With current conditions, loading is delivered to the Mississippi River in a “plug flow” style. The pump creates both more time to distribute load to the Mississippi River and more consistent flow from the Backwater Area to the Mississippi River.

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