Pearl River Channel Improvements Impact Evaluations

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1.0 INTRODUCTION

The Rankin Hinds Pearl River Flood and Drainage Control District prepared an Integrated Draft Feasibility Study and Environmental Impact Statement (FS/EIS) outlining a set of potential strategies to reduce flood risk in the Jackson, MS metropolitan area. This area has been impacted by floods from the Pearl River for more than 100 years, which have disrupted business and industries and threatened residential and public infrastructure. One of the alternatives included in the FS/EIS, identified as Alternative C - Channel Improvements Plan, consists of the excavation and widening of approximately 9.5 miles of the Pearl River from River Mile 284 to River Mile 293.5, and the relocation of an existing weir at approximately River Mile 284.8.

To evaluate the potential impacts of the proposed channel improvements on water quality in the Pearl River, Mendrop Engineering Resources requested that Tetra Tech develop a hydrodynamic and water quality model of the Pearl River that includes Alternative C (Alternative C Model). Tetra Tech developed the Alternative C Model by integrating the proposed changes into an existing hydrodynamic and water quality model of the Pearl River. The existing model was developed in 2018 for the Mississippi Department of Environmental Quality (MDEQ).

MDEQ's model, hereafter identified as Existing Conditions Model, is a dynamic one-dimensional model that simulates hydraulics and water quality in approximately 215 miles of the Pearl River from Jackson, MS, to Bogalusa, LA, from January 1, 2000 through December 31, 2017. MDEQ's Existing Conditions Model was developed using the Environmental Fluid Dynamics Code (EFDC) and Water Quality Analysis Simulation Program (WASP) and simulates hydraulic variables such as flows, water elevations, depths, and velocity, and water quality variables such as temperature, dissolved oxygen (DO), ultimate carbonaceous biochemical oxygen demand (CBODU), total nitrogen (TN), ammonia-nitrogen (NH3-N), nitrate-nitrite (NOX), organic nitrogen (Org-N), total phosphorus (TP), orthophosphate (PO4), organic phosphorus (Org-P), phytoplankton chlorophyll-*a*, and total suspended solids (TSS).

Tetra Tech developed the Alternative C Model by incorporating the proposed Pearl River channel improvements into the Existing Conditions EFDC and WASP Model. The hydrodynamic and water quality results of both models were compared at different locations along the Pearl River to identify the differences and potential changes in water quality caused by the implementation of the Alternative C project.

2.0 MODELING APPROACH

2.1. Pearl River Existing Conditions Model Overview

The Existing Conditions Model was developed for MDEQ as part of ongoing efforts to evaluate nutrient criteria and support the development of total maximum daily loads in the Pearl River (Tetra Tech, 2018). The Existing Conditions Model is a longitudinal one-dimensional model, which means that only longitudinal changes in hydrodynamic and water quality variables are simulated while lateral and vertical changes or gradients are not simulated. The cross section of the river is therefore assumed well mixed vertically and laterally.

The Existing Conditions Model includes the main tributaries and industrial and municipal point sources located between Jackson, MS and Bogalusa, LA. The model routes flow and water quality substances from the upstream boundary at Jackson MS, to the downstream boundary at Bogalusa, LA. Major tributaries and point sources are incorporated in the flow and water quality routing processes. Kinetic transformations including organic matter decay, nutrient speciation, algae primary production, and other biochemical processes are simulated by the model. The model simulations are driven by a combination of observed hydrodynamic and water quality data collected from several agencies and databases including the U.S. Geological Survey (USGS), MDEQ, Louisiana Department of Environmental Quality

(LDEQ), U.S. Environmental Protection Agency (USEPA) Permit Compliance System for National Pollutant Discharge Elimination Systems (NPDES), and USEPA Storage and Retrieval and Water Quality Exchange (STORET).

The Existing Conditions Model was calibrated to reproduce hydraulic and water quality observations collected at several USGS, MDEQ, and Georgia Pacific (GP) monitoring stations located along the river. The calibration period was January 1, 2009 through December 31, 2017. The model was validated to observed data available from January 1, 2001 through December 31, 2008. Calibration/validation variables included: flows, temperature, DO, NH3-N, NOX, Org-N, TP, CBODU, TSS. Some of the most important calibration parameters included model roughness and biokinetic rates controlling CBODU decay, DO consumption, nutrient speciation, phytoplankton growth and nutrient uptake. Further details regarding the Existing Conditions Model can be found in Tetra Tech (2018).

2.2. Alternative C Model Overview

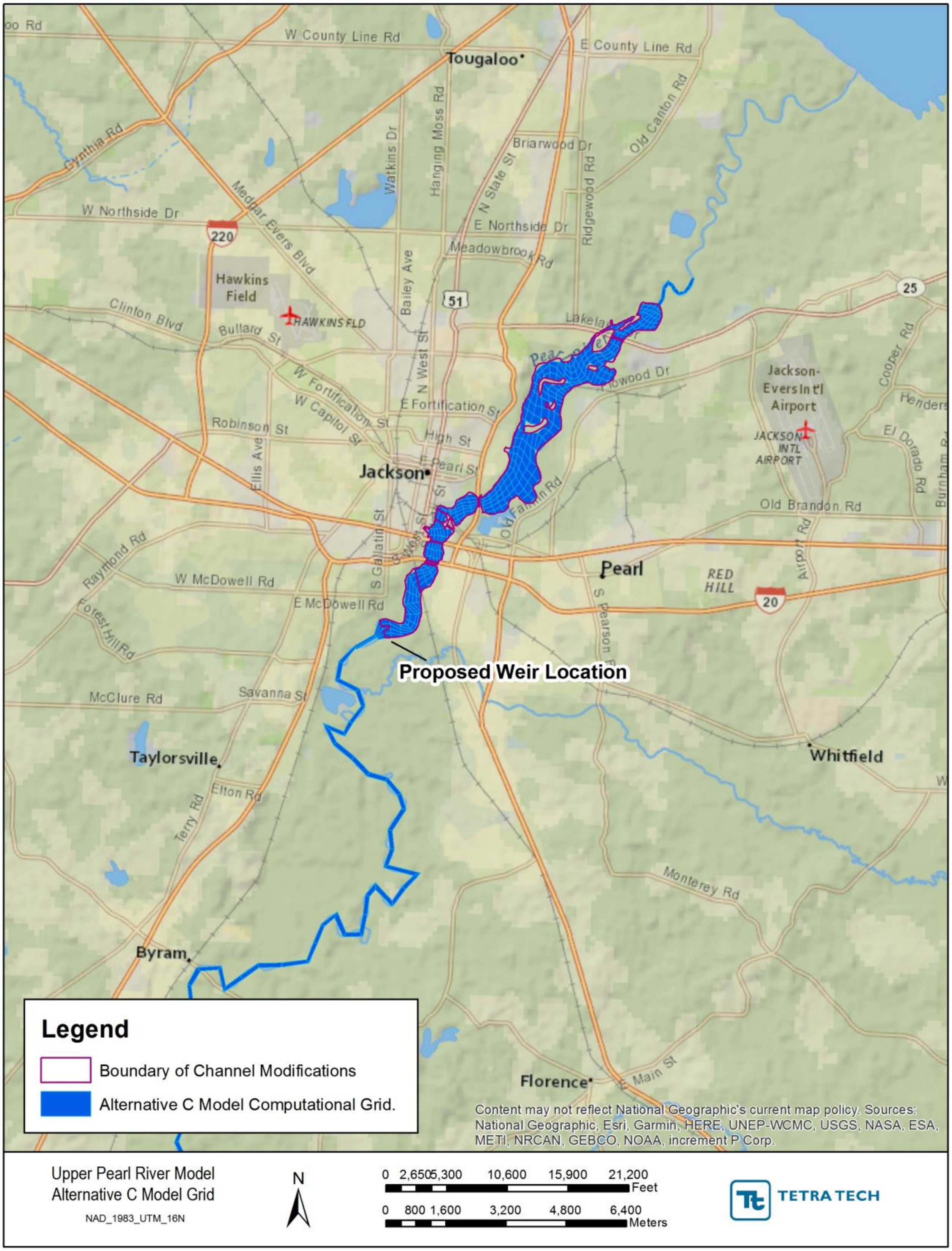
The development of the Alternative C Model was accomplished by incorporating the Alternative C channel modifications, weir structure, and impounded area into the Existing Conditions Model. The Alternative C Model simulates conditions for the period January 1, 2000 through December 31, 2017 and includes:

- A relocated weir structure downstream of Jackson, MS. The structure includes a low flow gate that can be operated during drought periods to maintain minimum flows in downstream areas.
- Longitudinal and lateral grid additions along approximately 9 miles to represent approximately 2,000 acres of impounded area behind the new weir structure. The new model upstream boundary was moved approximately 9 miles from the weir (Figure 1).

Details such as location of the relocated weir downstream of Jackson, MS, area impounded behind the new weir, and bottom elevations of the impounded area were provided by Mendrop Engineering Resources. To represent the impounded area behind the weir structure, 350 new computational grid cells arranged in a two-dimensional mesh of lateral and longitudinal variable resolution were incorporated in the Pearl River EFDC grid. The final computational grid had a total of 957 cells, of which 350 cells were used to represent the two-dimensional impounded waterbody behind the weir (Figure 1), and 607 cells were used to represent the Pearl River channel (Figure 2). The Existing Conditions Model grid and Alternative C Model grid are identical below the weir structure and the only difference between these two grids is the two-dimensional grid added behind the weir to represent the impounded area. The ground elevations assigned to the impounded grid cells behind the weir structure were defined based on cross-sectional geometry data provided by Mendrop Engineering Resources.

In the Alternative C Model, the representation of the weir structure was accomplished by prescribing a rating curve at the location of the structure (Figure 1). The purpose of the rating curve in the model is to control the flow from the impounded region behind the weir to the main Pearl River channel based on changes in water surface elevation behind the weir. The rating curve used in the Alternative C Model was provided by Mendrop Engineering Resources and is presented in Figure 3. In Figure 3, when the water elevations behind the dam exceed the crest elevation (258.1 ft), the rating curve captures free flowing weir flow conditions. When the water elevations fall below the crest elevation, the rating curve captures the operations of an auxiliary low flow gate that can be used to maintain existing minimum flow conditions in the Pearl River.

Finally, boundary conditions including tributary and point source hydraulic and water quality inputs from the Existing Conditions Model were used in the Alternative C Model without any modifications. This way, any potential changes in hydraulic or water quality variables in downstream regions of the model could be related to the proposed channel improvements, weir, and impoundment located in the Jackson area.



Content may not reflect National Geographic's current map policy. Sources: National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO, NOAA, increment P Corp.

Figure 1. Alternative C Model grid representation of impounded area behind weir structure

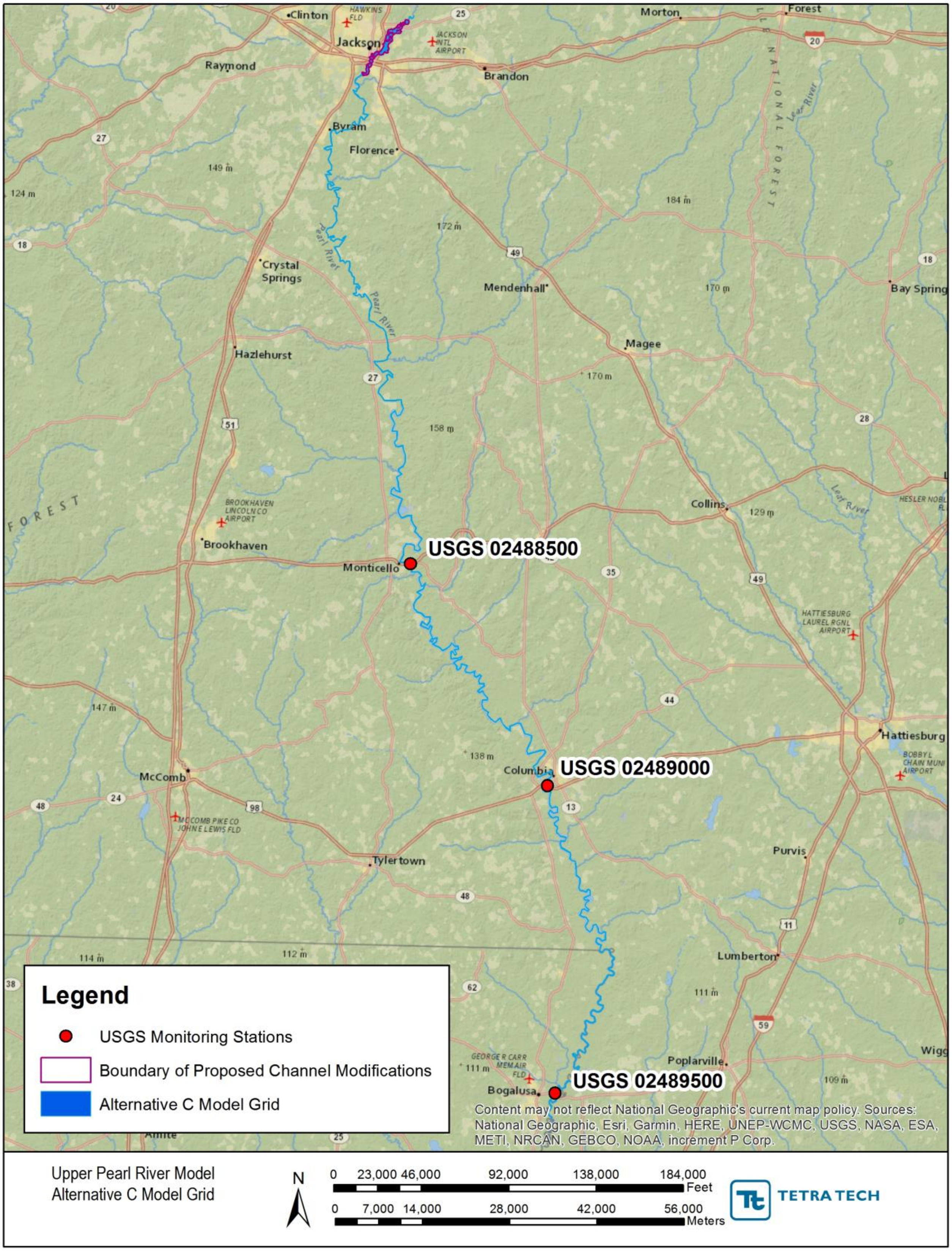
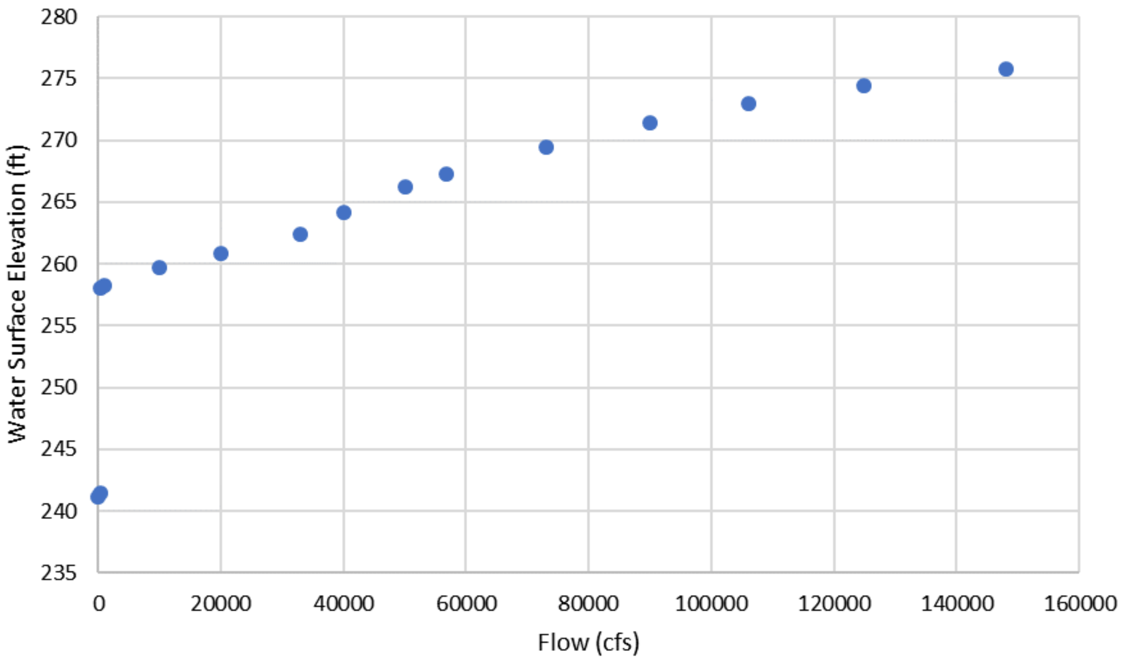


Figure 2. Alternative C Model grid representation of Pearl River channel downstream of weir and monitoring station locations



Note: The rating curve controls the flow through the weir as a function of the forebay water surface elevations.

Figure 3. Rating curve prescribed in the Alternative C Model

3.0 MODELING RESULTS

The Existing Conditions Model and the Alternative C Model were executed to simulate conditions from January 1, 2000 through December 31, 2017, using the period of January 1, 2000 through December 31, 2000 as model spin up period. The hydrodynamic and water quality results of both models after the spin up period were compared to identify the potential impacts of the Alternative C project on regions downstream of the relocated weir structure. The modeling results were compared at three locations with existing USGS monitoring stations: (1) USGS 02488500 Pearl River nr Monticello, MS; (2) USGS 02489000, Pearl River nr Columbia, MS; and (3) USGS 02489500 Pearl River nr Bogalusa, LA (Figure 2). Comparison statistics for the key simulated hydrodynamic and water quality variables are presented in Table 1 through Table 9. The comparison statistics include the mean, median, 5th percentile (5%tile) and 95th percentile (95%tile) values of the time series from January 1, 2001 through December 31, 2017. Graphical comparisons between the Existing Conditions Model and Alternative C Model results are presented in Appendix A.

The hydraulic differences between the Existing Conditions Model results and the Alternative C Model results downstream of the relocated weir at Monticello, Columbia, and Bogalusa were generally less than 5% (Table 1 and Table 2). The differences in simulated 5%tile, mean, and 95%tile flows between the two models were generally minimal. Flows changed by less than 0.5% at most locations with exception of the 5%tile flows simulated at Monticello, which slightly increased by 3% in the Alternative C Model as a result of the low flow gate operations included in the weir rating curve. The impacts of these flow changes on water depths were small. The absolute changes in simulated water depths at Monticello, Columbia, and Bogalusa were usually less than 0.5% with exception of the 5%tile water depths at Monticello which showed a maximum increase of 1.6% in the Alternative C Model.

The simulated impacts of the Alternative C project on downstream flows and depths were small mainly because flows coming from the upstream boundary were able to pass the relocated weir without significant alterations. In addition, by simulating low flow gate operations, low flows were maintained when the water elevations behind the weir dropped below the crest elevation. Upstream of the relocated weir, water depths increased and velocities decreased due to the obstruction caused by the structure.

The impacts of the Alternative C project on water quality were also small in most of the simulated variables with exception of phytoplankton chlorophyll-*a* and CBODU. The variables with the smallest changes from the existing conditions were temperature, DO, TN, and TP. The changes in temperature and DO from the existing conditions generally varied between ±0.5% and ±1.0% respectively. The changes in TN varied between -0.4% and -4.7% and in TP between 0% and -1.5%. Simulated TN and TP concentrations were slightly lower under the Alternative C conditions likely as a result of increased settling of organic particulate nutrients and phytoplankton biomass upstream of the weir. Increased settling of particulate materials in the Alternative C Model are likely caused by lower velocities behind the weir due to the flow obstruction created by the weir structure.

The percent change in phytoplankton chlorophyll-*a* concentrations in the Alternative C project were larger than those described above for nutrients and DO, although the changes in concentrations were small. In general, the simulated 5%tile, mean, and median phytoplankton chlorophyll-*a* concentrations decreased under the Alternative C conditions at Monticello, Columbia, and Bogalusa (Table 7). These results were likely related to increased phytoplankton settling upstream of the weir and also to changes in phytoplankton productivity resulting from changes in depths, residence time, and temperature during non-productive seasons. The maximum reduction in the 5%tile phytoplankton chlorophyll-*a* concentrations, which occur during the winter, was 57% at Monticello. However, the change in the concentration was only 0.32 µg/L, from 0.57 µg/L under existing conditions to 0.25 µg/L under the Alternative C conditions.

Although the 5%tile phytoplankton chlorophyll-*a* concentrations (winter concentrations) decreased under the Alternative C conditions, the 95%tile concentrations, which occur during the summer, exhibited slight increases from the exiting conditions. The highest phytoplankton chlorophyll-*a* values slightly increased during the productive seasons suggesting some enhanced conditions for phytoplankton growth upstream of the weir (Table 7 and Appendix A) likely derived from increased residence. The maximum increase in 95%tile phytoplankton chlorophyll-*a* concentration was 5.1% (Table 7).

Increased residence times behind the relocated weir can have therefore different impacts on phytoplankton chlorophyll-*a* concentrations. In general, low velocities and increased residence times behind the weir tend to increase phytoplankton settling. During the winter, when phytoplankton productivity is typically limited by low sunlight and low temperatures, an increase in settling directly causes a net reduction of phytoplankton chlorophyll-a concentrations. During the summer, when phytoplankton productivity peaks in response to high sunlight and high temperatures, the increased residence time positively impact productivity limiting the impacts of the increased settling. As a result, during summer there is a net increase in summer concentrations.

Simulated TSS concentrations mostly decreased at Monticello, Columbia, and Bogalusa under the Alternative C conditions (Table 8). These changes were also likely caused by increased settling conditions upstream of the weir. The largest reductions in TSS concentrations were simulated at Monticello where concentrations fell between -2.0% and -7.3% from the existing conditions.

The modeling results also showed reductions of CBODU concentrations at Monticello, Columbia, and Bogalusa under the Alternative C conditions. The 5%tile concentrations exhibited the largest reductions (14% - 17% from the existing conditions) while the 95%tile concentrations exhibited the smallest reductions (3% - 5% from the existing conditions). The reductions in CBODU could be associated to increased organic matter processing and decay in the impoundment area resulting from larger residence times behind the weir.

Table 1. Flow summary statistics

	Flow (cfs)							
Location	**Existing Conditions Model**				**Alternative C Model**			
	Mean	**Median**	**5%Tile**	**95%Tile**	**Mean**	**Median**	**5%Tile**	**95%Tile**
Monticello	6,421.5	2,390.7	540.2	25,600.0	6,425.2	2,398.5	557.7	25,556.5
Columbia	7,839.1	3,304.1	1,077.0	29,597.5	7,842.8	3,313.6	1,080.8	29,566.7
Bogalusa	10,947.8	4,972.2	2,011.0	39,504.0	10,951.5	4,973.6	2,003.6	39,590.8

Table 2. Water depth summary statistics

	Depth (ft)							
Location	**Existing Conditions Model**				**Alternative C Model**			
	Mean	**Median**	**5%Tile**	**95%Tile**	**Mean**	**Median**	**5%Tile**	**95%Tile**
Monticello	10.3	7.6	3.7	25.7	10.3	7.6	3.8	25.7
Columbia	12.4	8.8	4.8	30.8	12.4	8.8	4.8	30.9
Bogalusa	15.6	13.1	8.3	30.0	15.6	13.1	8.3	30.0

Table 3. Temperature summary statistics

	Temperature (°F)							
Location	**Existing Conditions Model**				**Alternative C Model**			
	Mean	**Median**	**5%Tile**	**95%Tile**	**Mean**	**Median**	**5%Tile**	**95%Tile**
Monticello	69.2	69.9	48.5	87.7	69.3	70.0	48.3	87.9
Columbia	69.0	69.7	47.8	87.8	69.0	69.8	47.8	87.9
Bogalusa	69.0	70.2	48.0	87.0	69.1	70.2	47.9	87.1

Table 4. DO summary statistics

	Dissolved Oxygen (mg/L)							
Location	**Existing Conditions Model**				**Alternative C Model**			
	Mean	**Median**	**5%Tile**	**95%Tile**	**Mean**	**Median**	**5%Tile**	**95%Tile**
Monticello	8.2	7.9	6.2	10.5	8.2	8.0	6.2	10.6
Columbia	8.2	8.1	5.8	10.6	8.2	8.1	5.9	10.7
Bogalusa	8.4	8.2	6.4	10.7	8.4	8.2	6.4	10.8

Table 5. TN summary statistics

	Total Nitrogen (mg/L)							
Location	**Existing Conditions Model**				**Alternative C Model**			
	Mean	**Median**	**5%Tile**	**95%Tile**	**Mean**	**Median**	**5%Tile**	**95%Tile**
Monticello	1.21	1.05	0.86	2.04	1.18	1.03	0.86	1.95
Columbia	0.88	0.85	0.70	1.16	0.87	0.85	0.67	1.15
Bogalusa	0.64	0.64	0.44	0.83	0.63	0.64	0.42	0.83

Table 6. TP summary statistics

Location	Total Phosphorus (mg/L)							
	Existing Conditions Model				Alternative C Model			
	Mean	Median	5%Tile	95%Tile	Mean	Median	5%Tile	95%Tile
Monticello	0.18	0.15	0.11	0.34	0.18	0.15	0.11	0.34
Columbia	0.12	0.11	0.09	0.18	0.12	0.11	0.09	0.18
Bogalusa	0.09	0.08	0.06	0.12	0.09	0.08	0.06	0.12

Table 7. Phytoplankton chlorophyll-*a* summary statistics

Location	Phytoplankton chlorophyll-*a* (ug/L)							
	Existing Conditions Model				Alternative C Model			
	Mean	Median	5%Tile	95%Tile	Mean	Median	5%Tile	95%Tile
Monticello	11.37	1.24	0.57	51.10	11.32	0.96	0.25	52.70
Columbia	7.93	0.97	0.34	27.24	7.75	0.80	0.20	27.89
Bogalusa	4.10	0.81	0.30	13.04	4.09	0.72	0.24	13.70

Table 8. TSS summary statistics

Location	Total Suspended Solids (mg/L)							
	Existing Conditions Model				Alternative C Model			
	Mean	Median	5%Tile	95%Tile	Mean	Median	5%Tile	95%Tile
Monticello	32.7	29.0	13.5	63.6	31.1	26.9	13.2	62.1
Columbia	24.8	22.5	13.3	42.9	24.3	22.2	12.6	41.3
Bogalusa	18.9	17.2	8.9	35.4	18.6	16.9	8.6	34.9

Table 9. CBODU summary statistics

Location	Biochemical Oxygen Demand (mg/L)							
	Existing Conditions Model				Alternative C Model			
	Mean	Median	5%Tile	95%Tile	Mean	Median	5%Tile	95%Tile
Monticello	12.5	9.8	6.5	24.6	11.4	8.9	5.5	23.3
Columbia	7.6	7.0	5.1	12.2	7.0	6.6	4.2	11.5
Bogalusa	5.0	4.9	3.4	6.9	4.7	4.6	2.9	6.7

4.0 SUMMARY AND CONCLUSIONS

A hydrodynamic and water quality model of the Pearl River was developed to simulate the channel improvements proposed under The Rankin Hinds Pearl River Flood and Drainage Control District, Alternative C plan. The Alternative C Model was developed based on an Existing Conditions Model of the Pearl River available from MDEQ, and was used to identify the potential impacts of the Alternative C project on hydraulics and water quality at Monticello, MS; Columbia, MS; and Bogalusa, LA. The Alternative C Model included:

- A relocated weir structure downstream of Jackson, MS.

- The excavation and widening of approximately 9.5 miles of the Pearl River from River Mile 284 to River Mile 293.5.

The Existing Conditions Model and the Alternative C Model were executed to simulate hydrodynamics and water quality in the Pearl River during the period January 1, 2000 through December 31, 2017. The results of both models were then compared to identify the potential impacts of the Alternative C project on flows, water depths, temperature, DO, nutrients, phytoplankton chlorophyll-*a*, TSS and CBODU downstream of the project. The comparison between the Alternative C Model results and the Existing Conditions Model results at Monticello, Columbia, and Bogalusa indicated that:

- The differences in average, median and 95%tile flows and depths were usually less than 0.5%. At Monticello, the 5%tile flows slightly increased by 3%, and the 5%tile depths increased by 1.6% in the Alternative C Model. The slight increases were caused by flow operations incorporated in the model to preserve flow conditions under drought periods.
- The differences in average, median, 5%tile and 95% temperature varied between ±0.5%. These changes usually represented only a difference of ±0.1 °F in simulated temperatures.
- The differences in average, median, 5%tile and 95% DO concentrations varied between ±1.0%.
- Simulated TN slightly decreased in the Alternative C Model likely in response to an increase in settling of organic particulate nutrients and phytoplankton biomass upstream of the relocated weir. The differences in average, median, 5%tile and 95% TN varied between -0.4% and -4.7%.
- Simulated TP slightly decreased in the Alternative C Model likely in response to an increase in settling of organic particulate nutrients and phytoplankton biomass upstream of the relocated weir. The differences in average, median, 5%tile and 95%tile TP varied between 0% and -1.5%
- The simulated 5%tile, mean, and median phytoplankton chlorophyll-*a* concentrations decreased in the Alternative C model likely in response to changes in phytoplankton productivity and increased settling of phytoplankton biomass upstream of the relocated weir. The 5%tile concentration at Monticello exhibited the largest reduction from 0.57 µg/L under Existing Conditions to 0.25 µg/L under the Alternative C conditions.
- The simulated 95%tile phytoplankton chlorophyll-*a* concentrations slightly increased in the Alternative C Model likely in response to changes in phytoplankton productivity upstream of the weir. The 95%tile concentration at Bogalusa exhibited the largest increase in phytoplankton from 13.04 µg/L under Existing Conditions to 13.7 µg/L under the Alternative C conditions. This change represented an increase of 5.1%.
- Simulated TSS concentrations decreased under in the Alternative C Model likely in response to an increase in settling upstream of the relocated weir. The differences in average, median, 5%tile and 95% TSS concentrations varied between -2.0% and -7.3%.
- Simulated CBODU concentrations decreased under in the Alternative C Model likely in response to an increase in organic matter processing and decay, and increased settling of organics upstream of the relocated weir. The 5%tile concentrations exhibited the largest reductions (14% to 17% from the existing conditions) while the 95%tile concentrations exhibited the smallest reductions (3% to 5% from the existing conditions).

5.0 REFERENCES

Tetra Tech (2018). Hydrodynamics and Water Quality Modeling Report for the Upper Pearl River Watershed, Mississippi. Prepared for GP Monticello LLC.

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APPENDIX A GRAPHICAL COMPARISONS OF SIMULATED HYDRODYNAMIC AND WATER QUALITY VARIABLES

A.1 WATER DEPTH

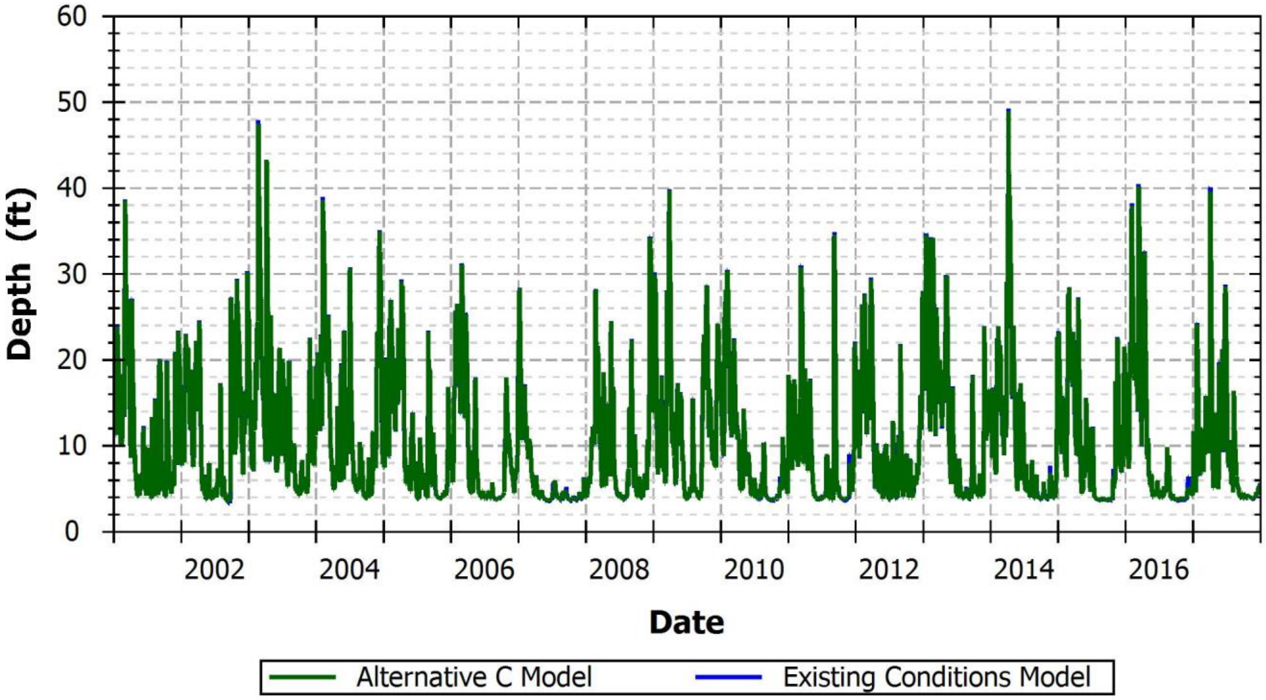

Figure A-1. Simulated water depth at Monticello

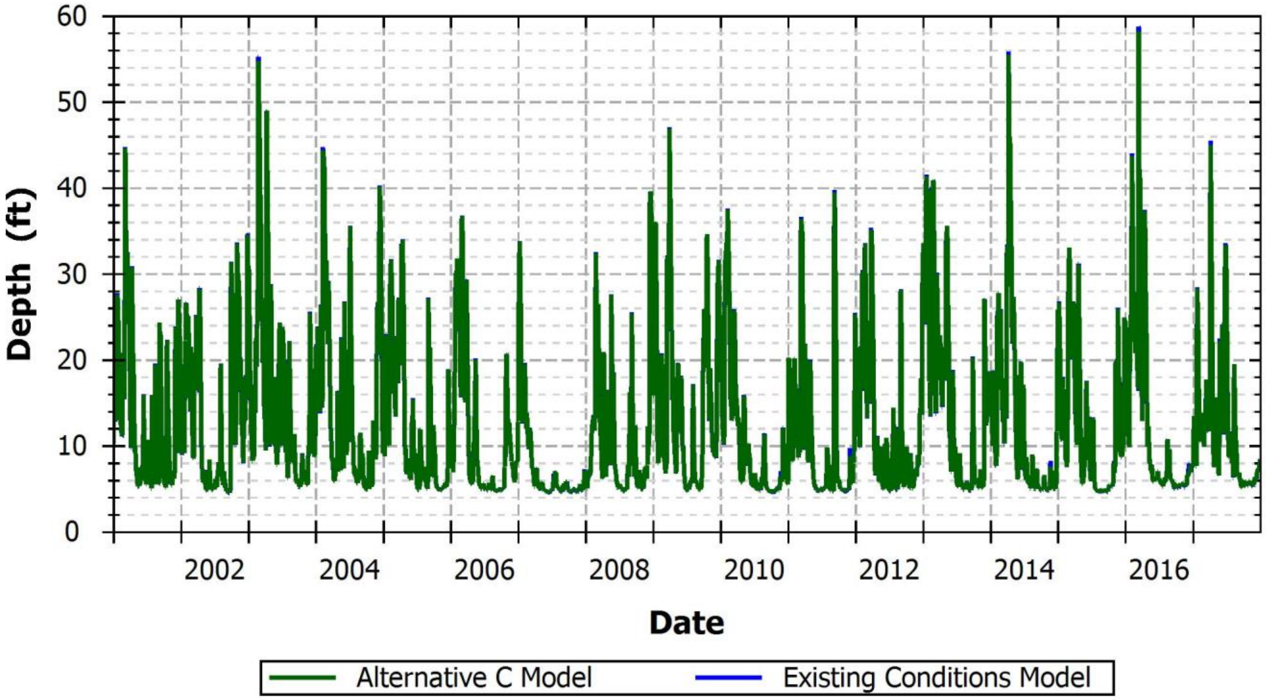

Figure A-2. Simulated water depth at Columbia

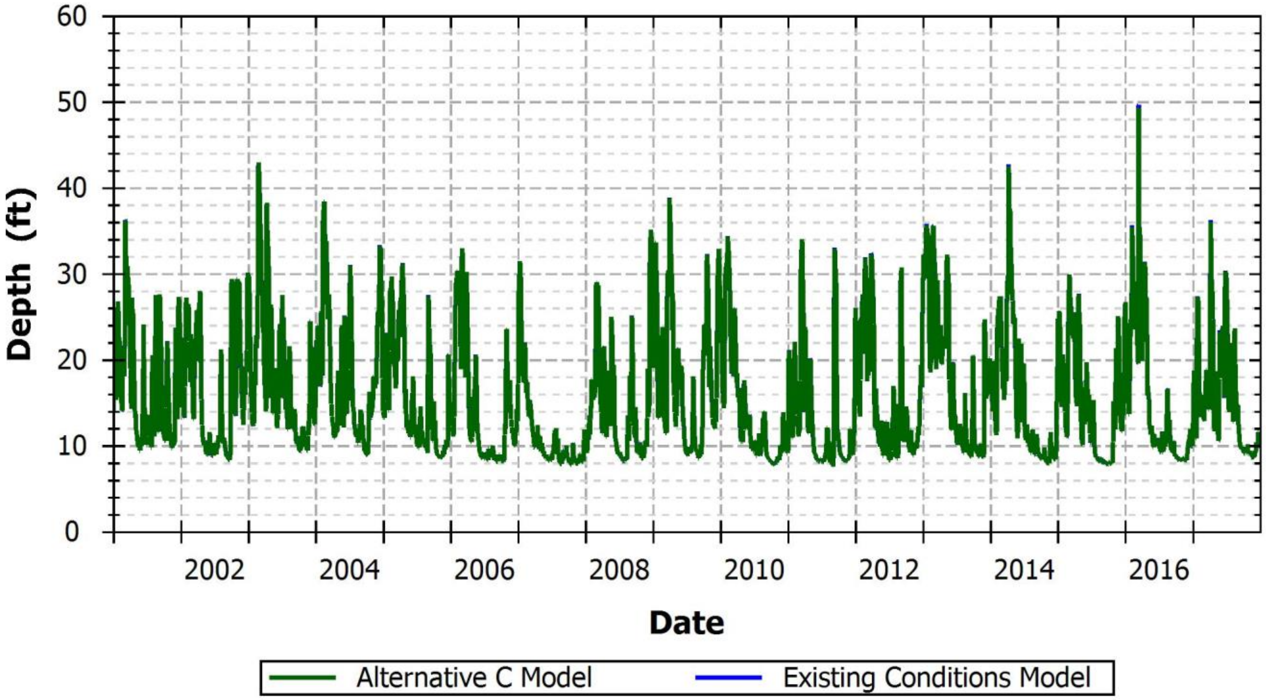

Figure A-3. Simulated water depth at Bogalusa

A.2 FLOW

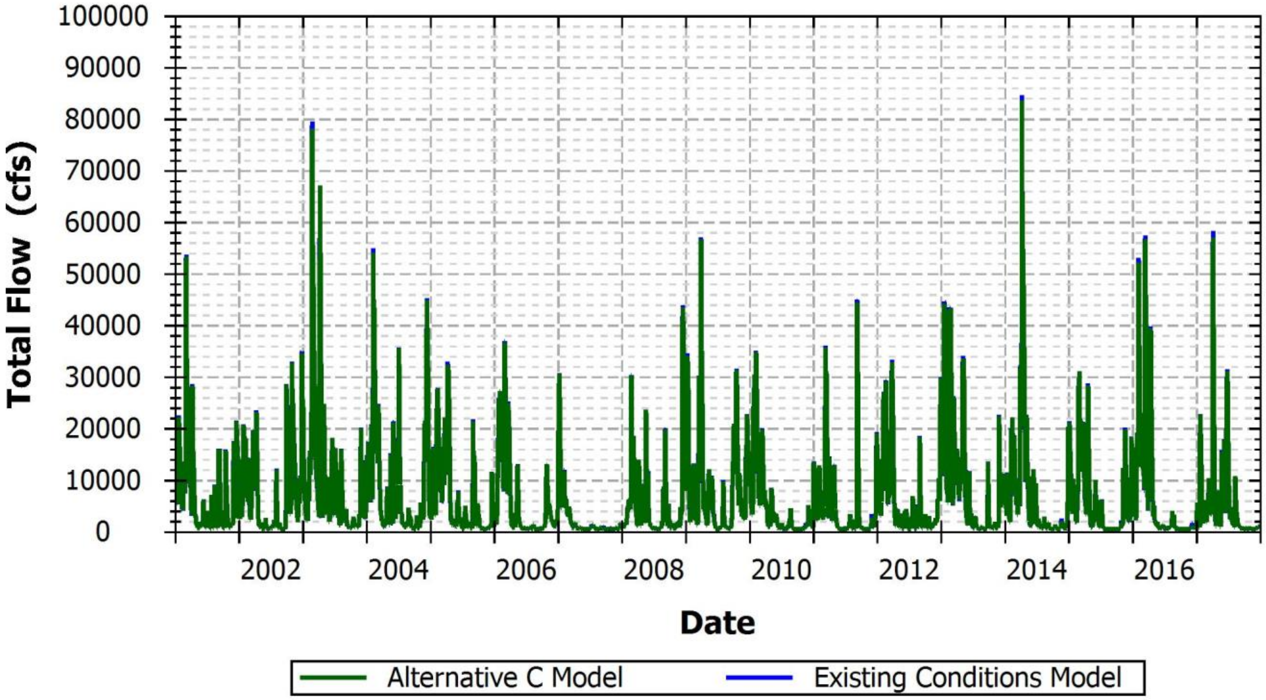

Figure A-4. Simulated flow at Monticello

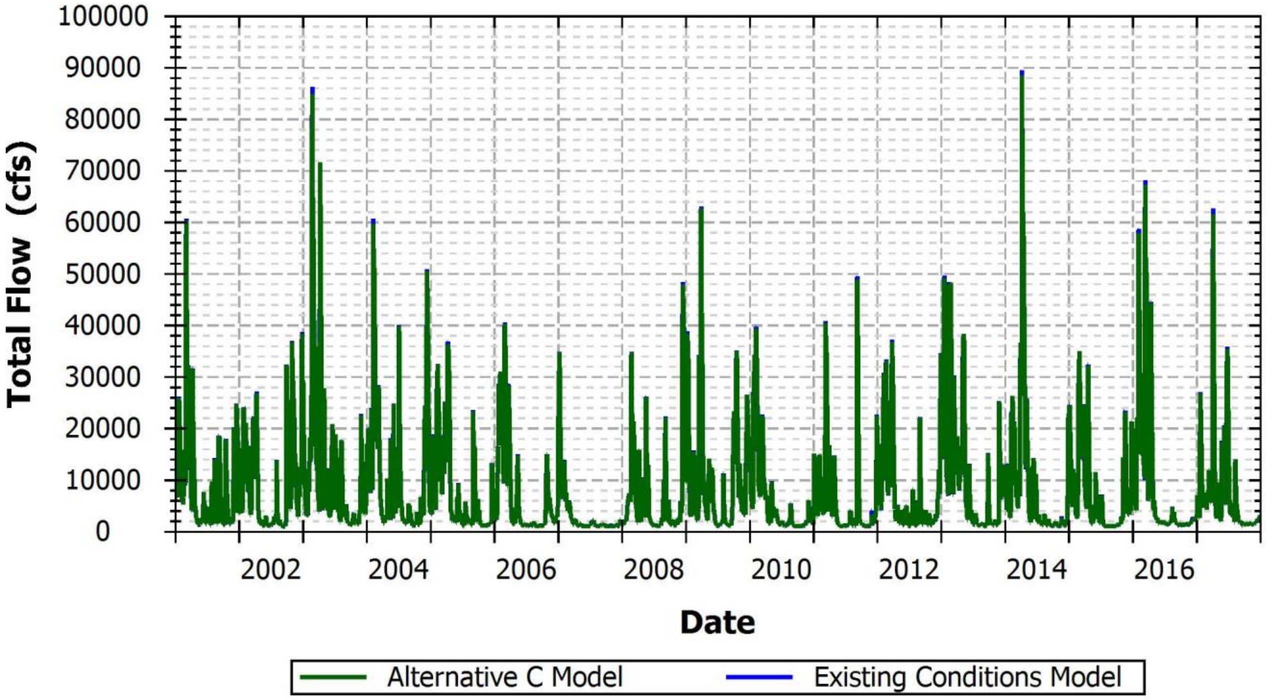

Figure A-5. Simulated flow at Columbia

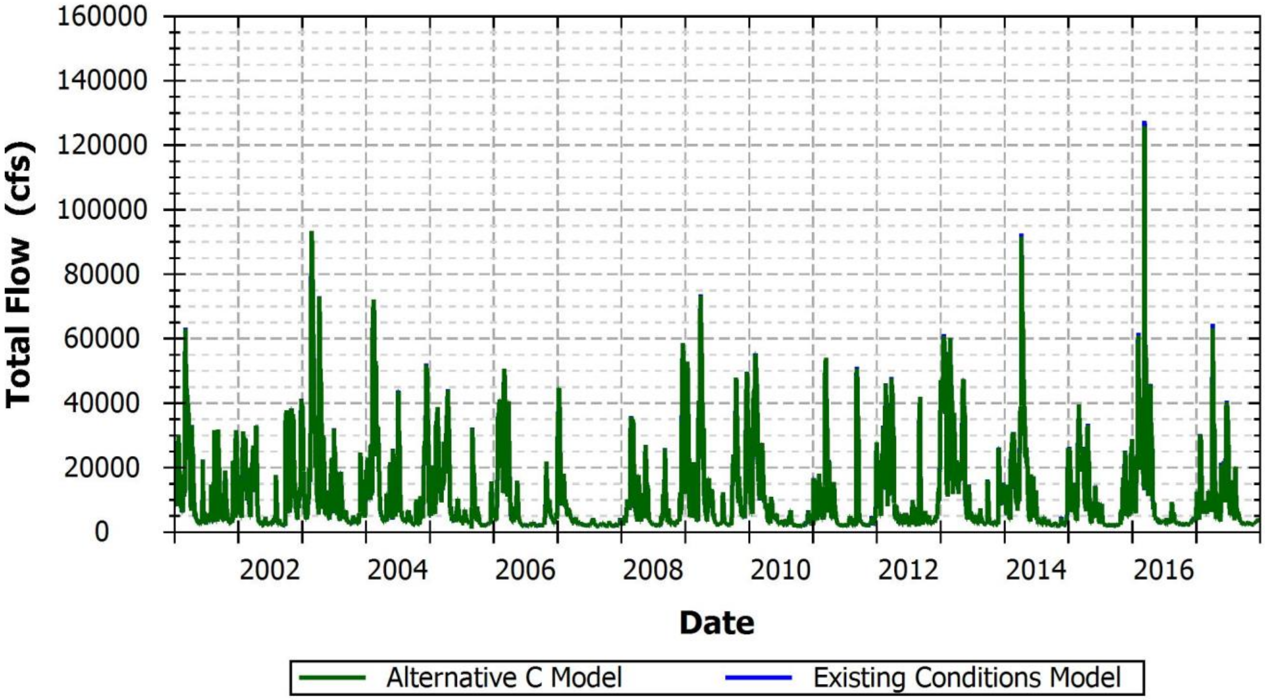

Figure A-6. Simulated flow at Bogalusa

A.3 TEMPERATURE

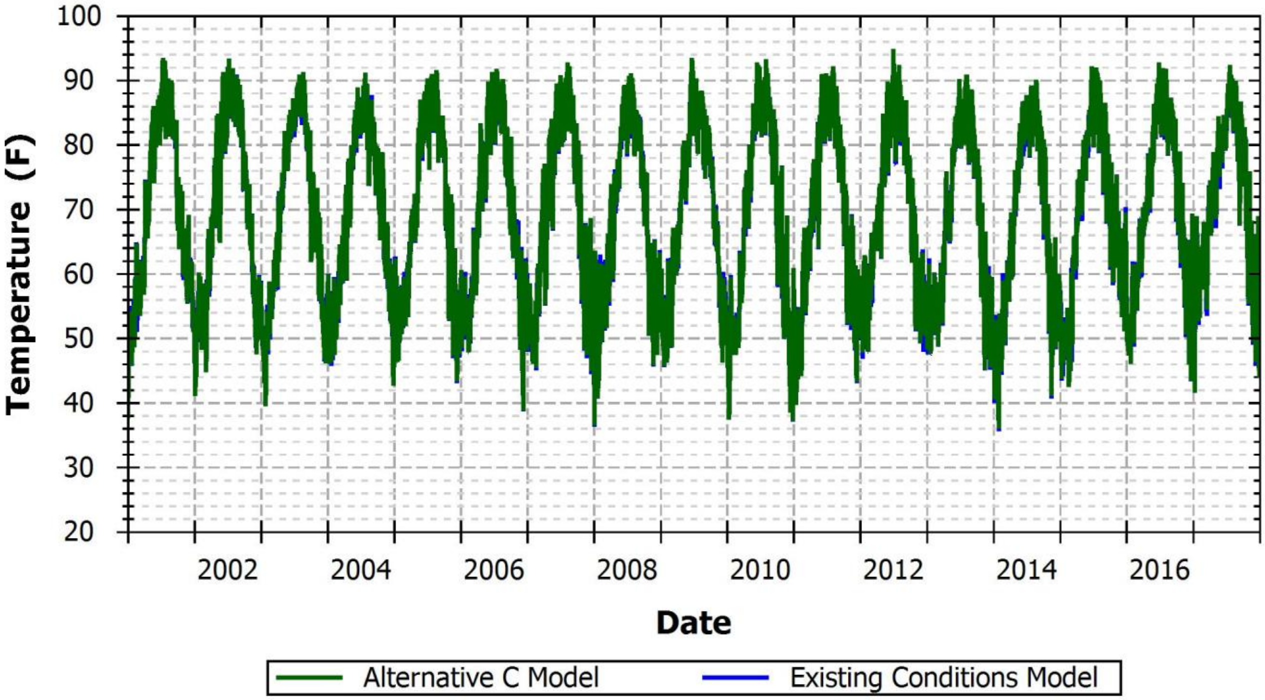

Figure A-7. Simulated temperature at Monticello

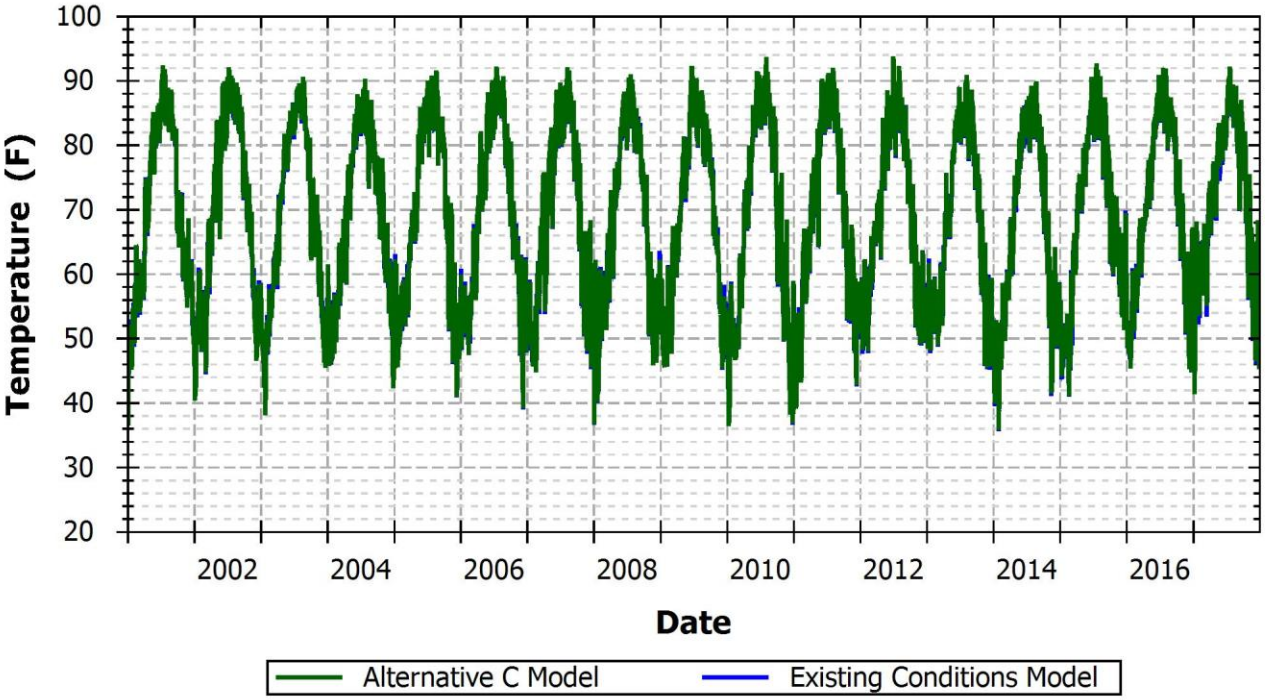

Figure A-8. Simulated temperature at Columbia

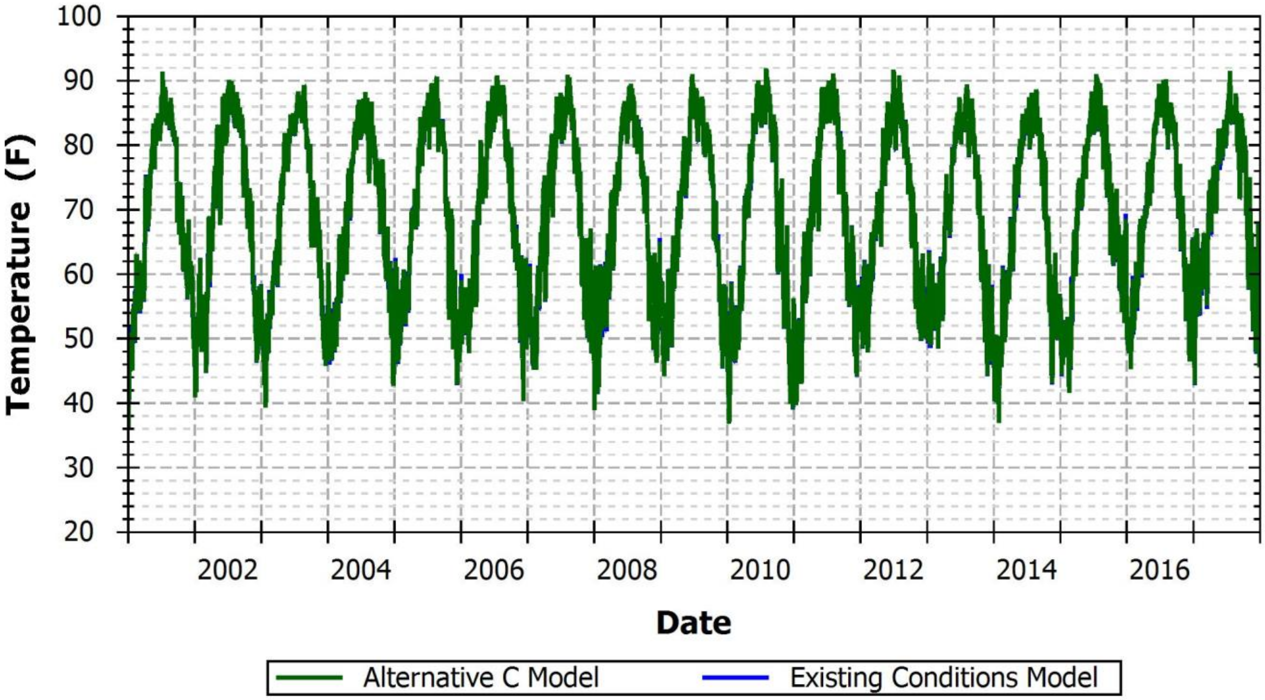

Figure A-9. Simulated temperature at Bogalusa

A.4 DISSOLVED OXYGEN

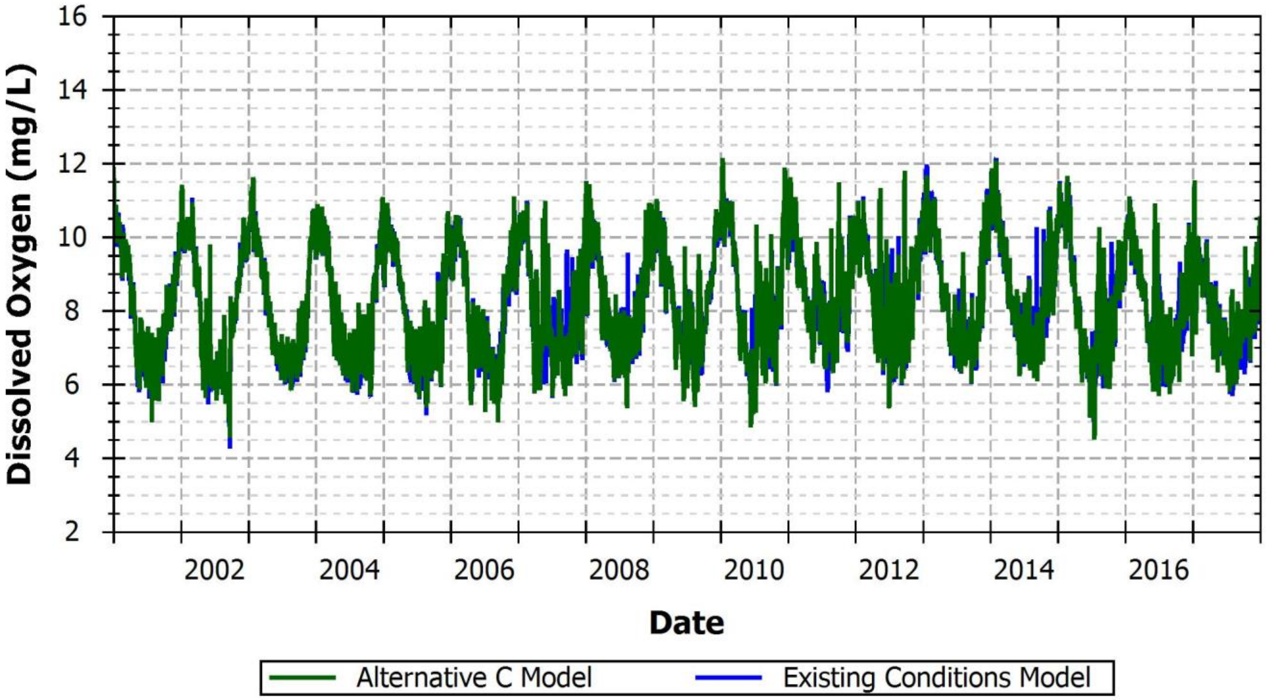

Figure A-10. Simulated DO at Monticello

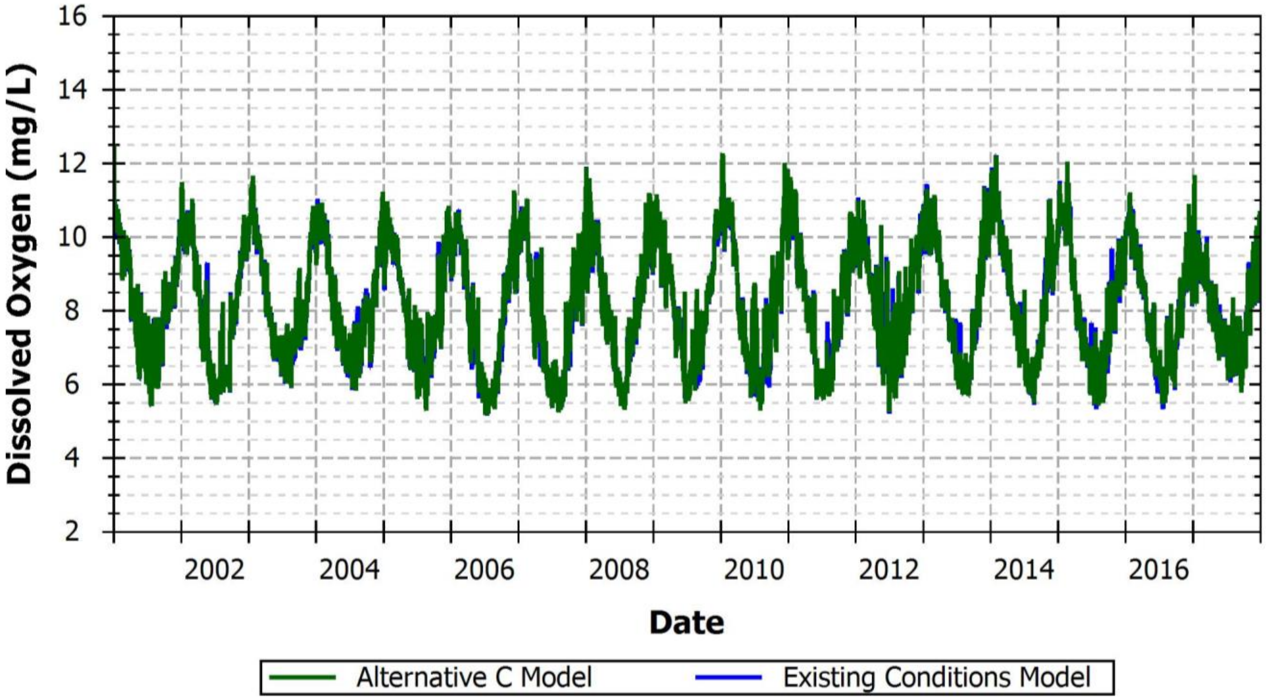

Figure A-11. Simulated DO at Columbia

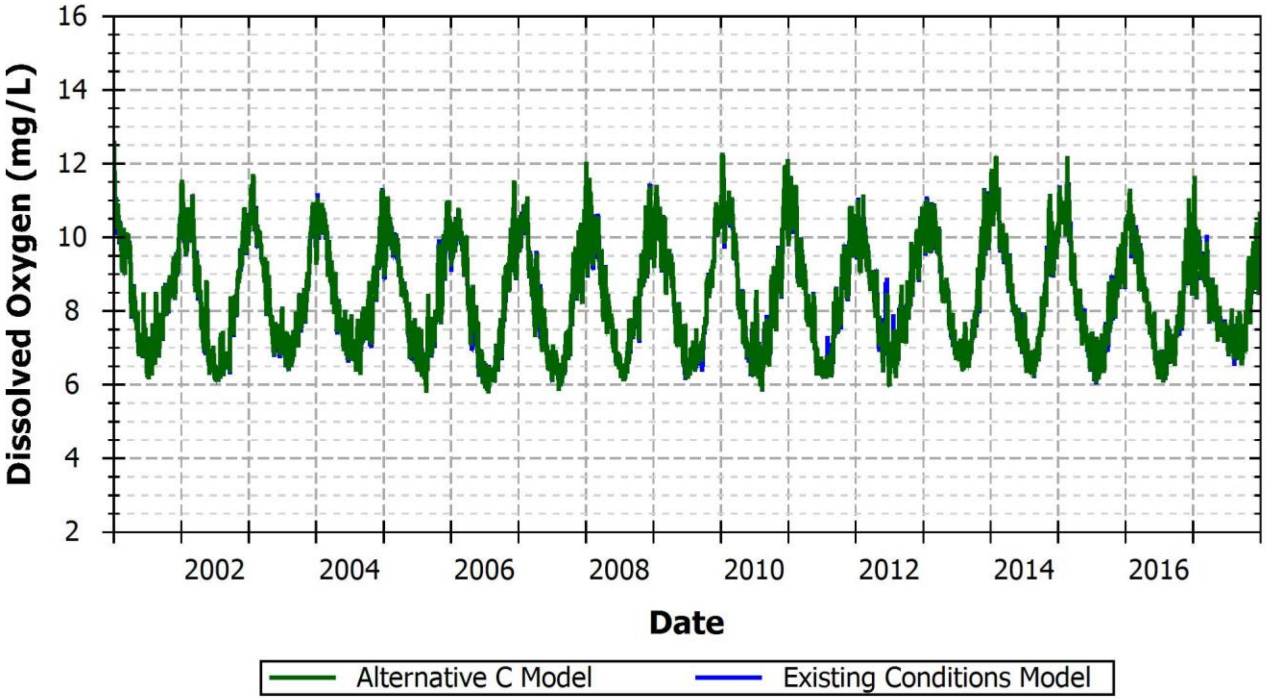

Figure A-12. Simulated DO at Bogalusa

A.5 TOTAL NITROGEN

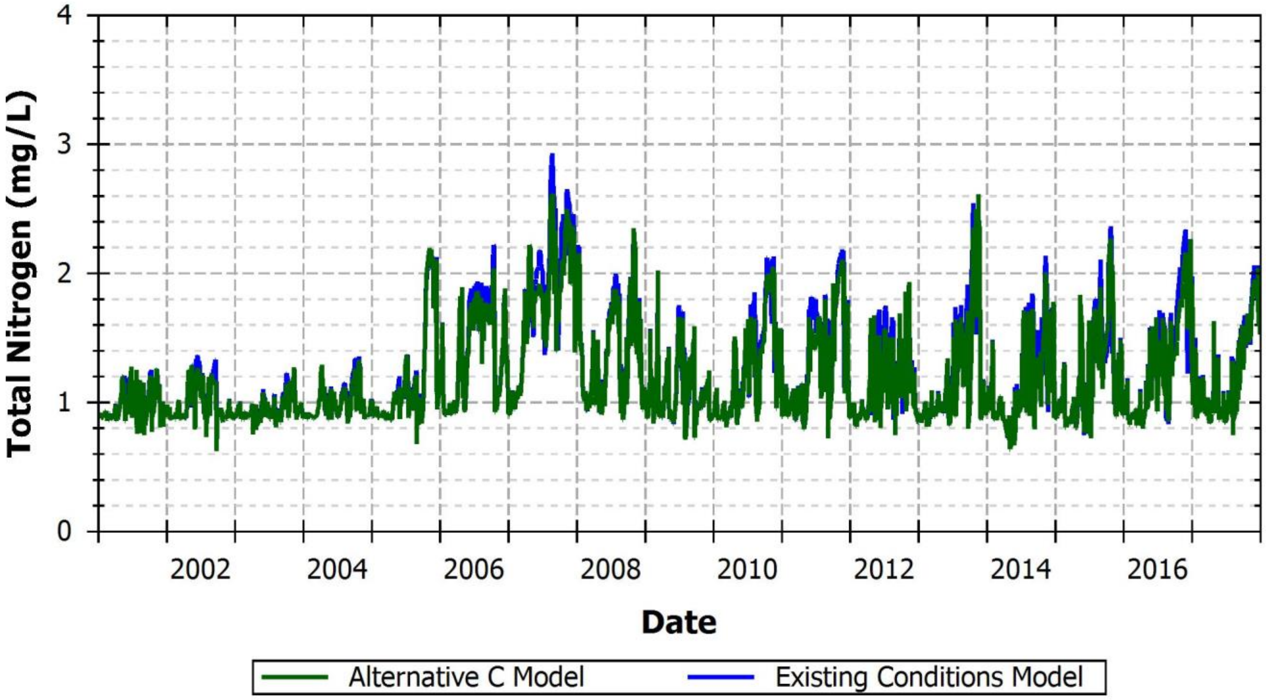

Figure A-13. Simulated TN at Monticello

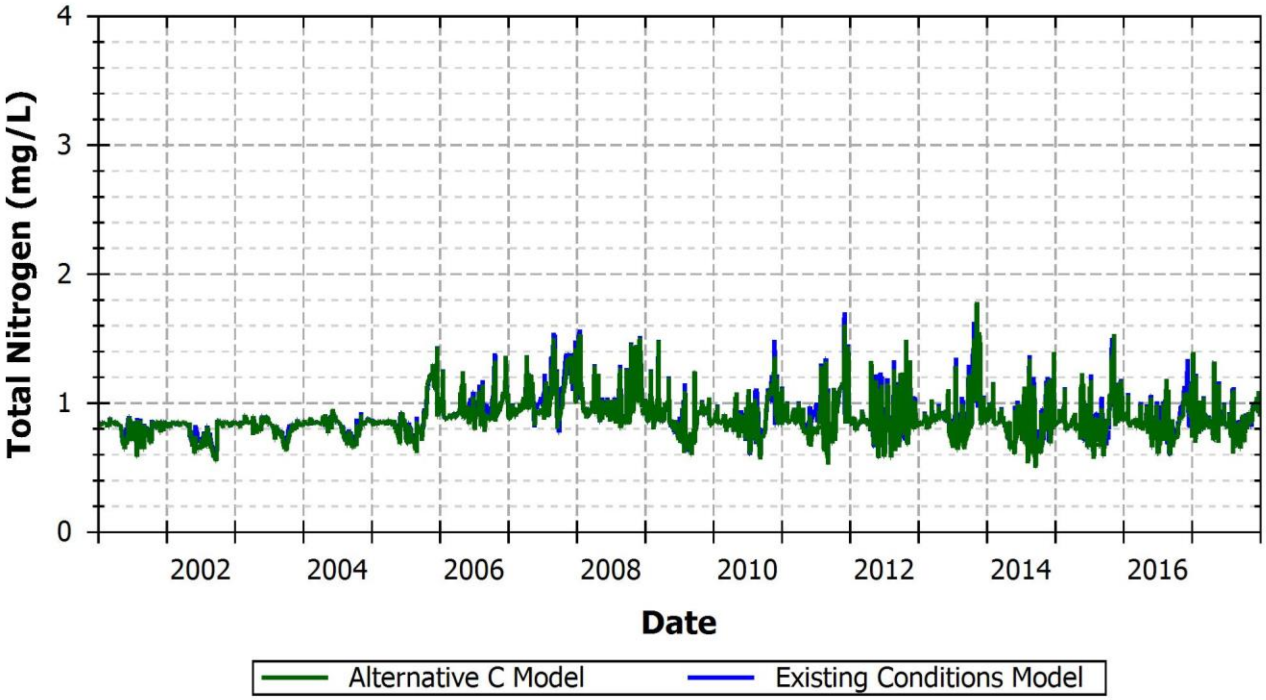

Figure A-14. Simulated TN at Columbia

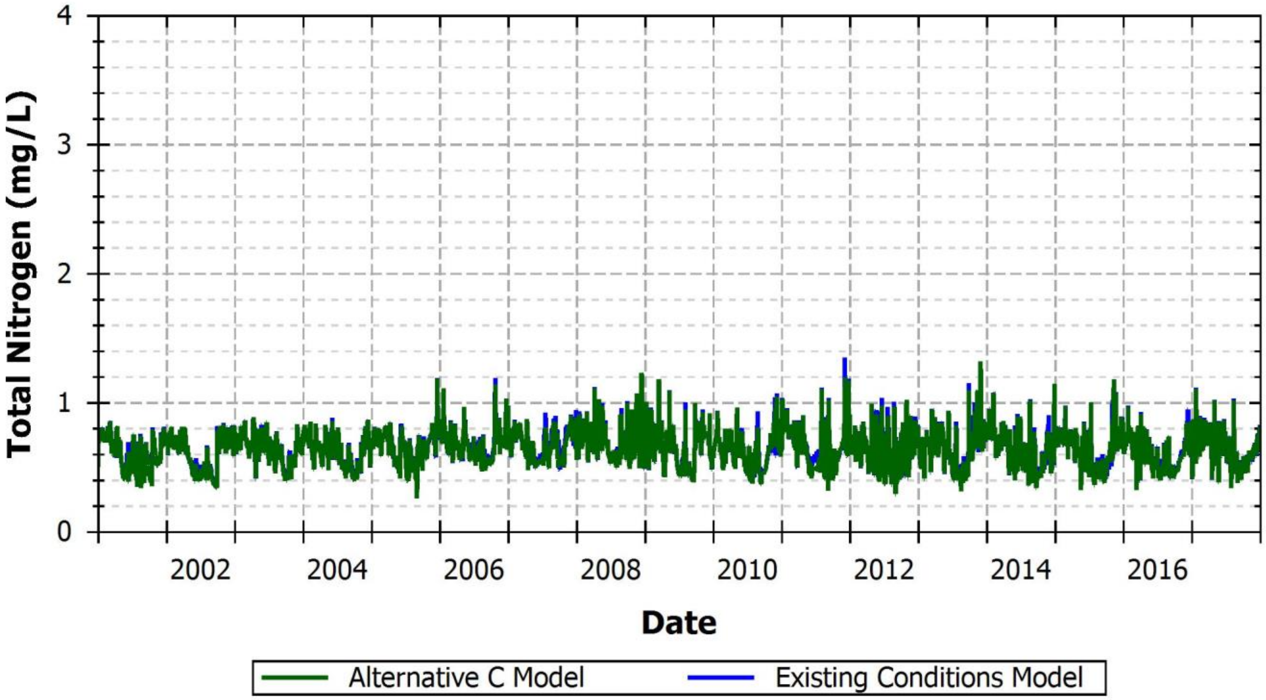

Figure A-15. Simulated TN at Bogalusa

A.6 TOTAL PHOSPHORUS

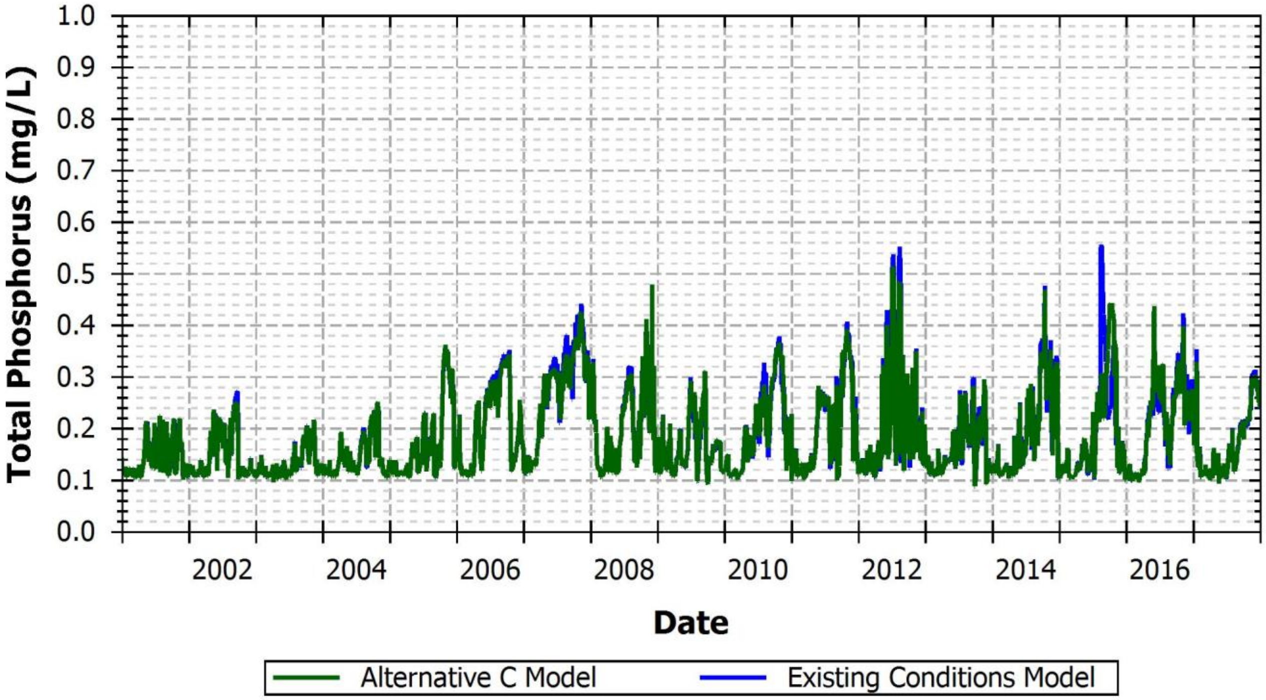

Figure A-16. Simulated TP at Monticello

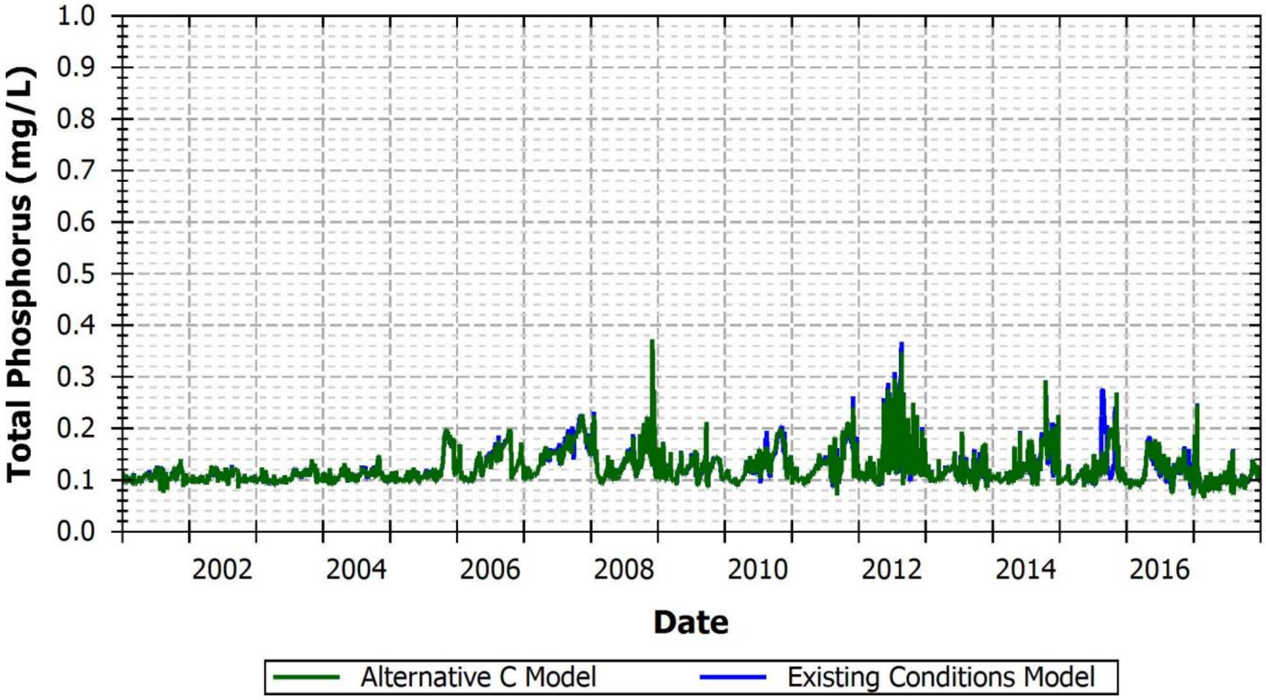

Figure A-17. Simulated TP at Columbia

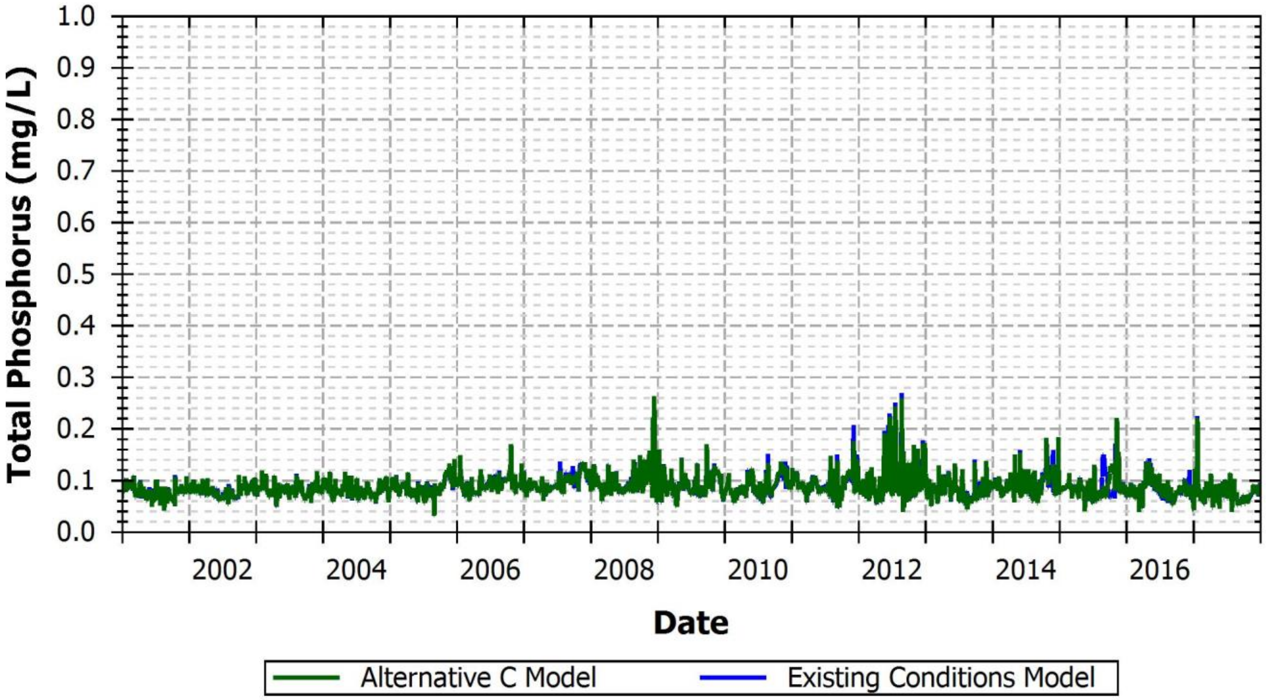

Figure A-18. Simulated TP at Bogalusa

A.7 PHYTOPLANKTON CHLOROPHYLL *A*

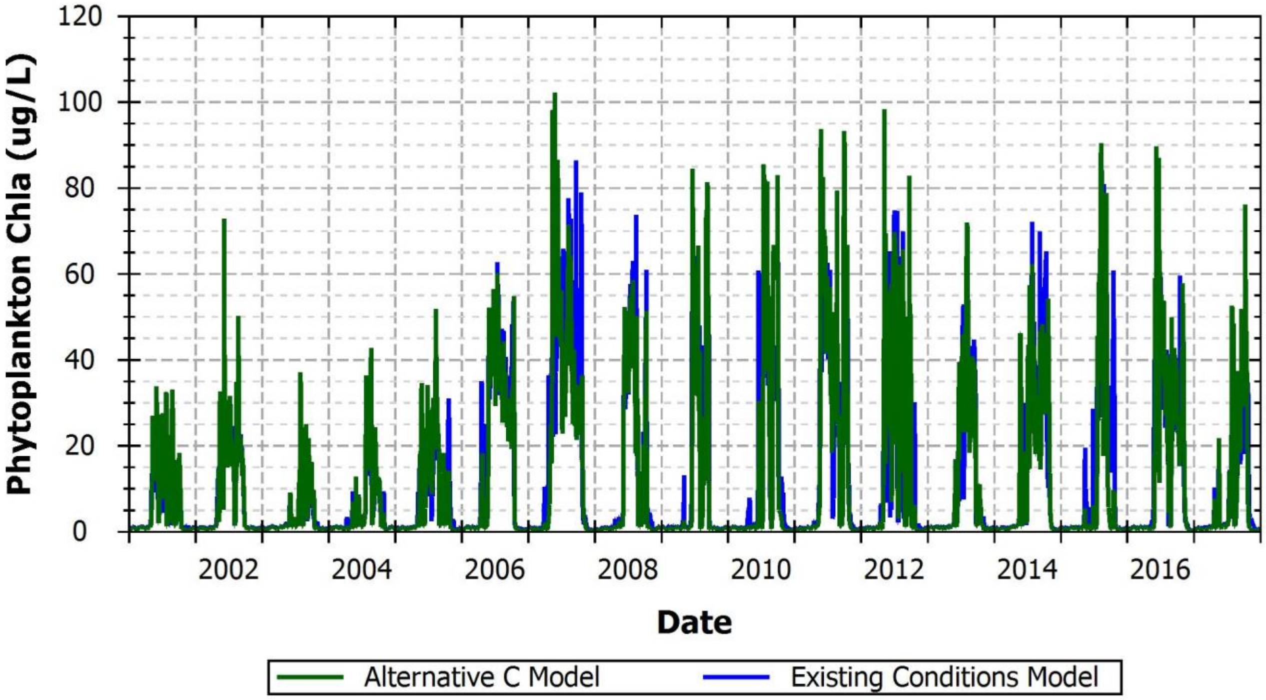

Figure A-19. Simulated phytoplankton chlorophyll-*a* at Monticello

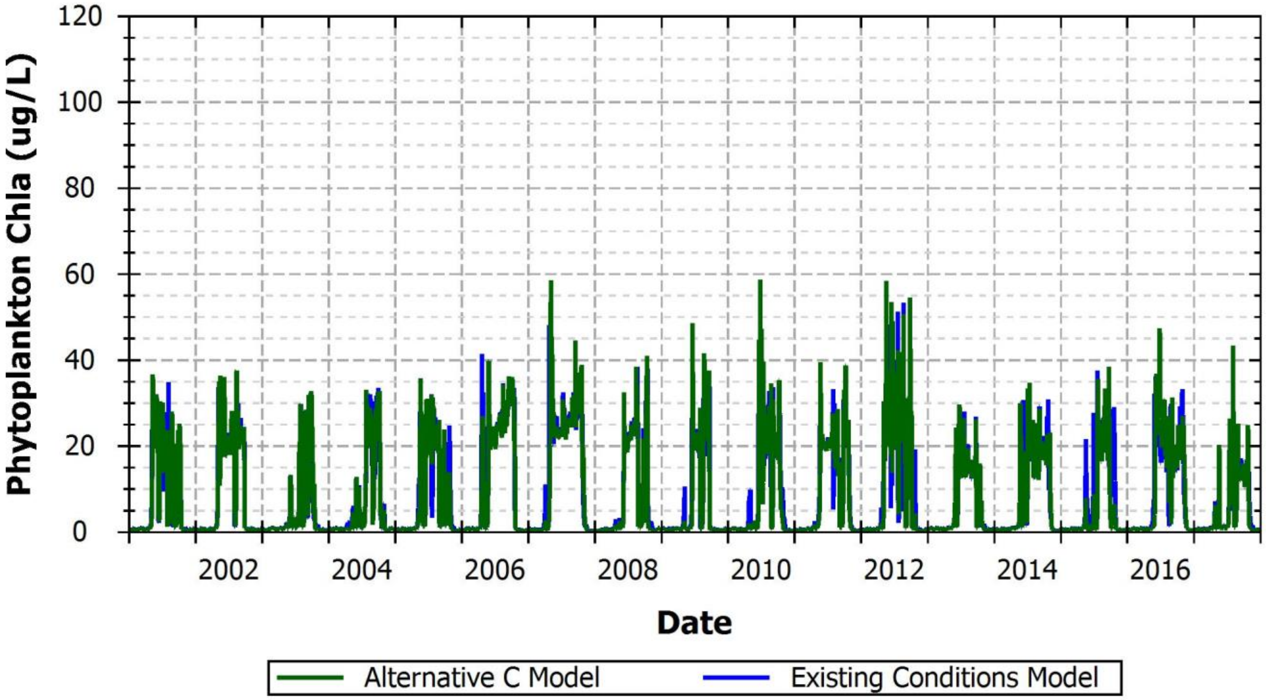

Figure A-20. Simulated phytoplankton chlorophyll-*a* at Columbia

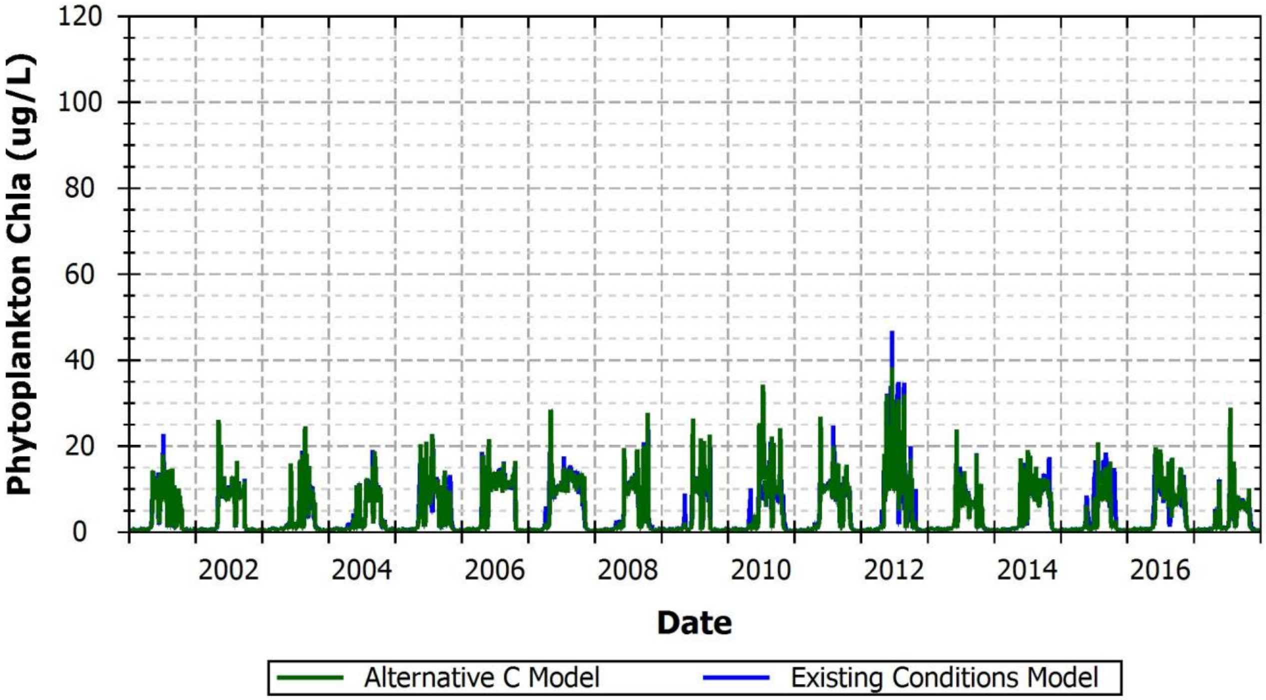

Figure A-21. Simulated phytoplankton chlorophyll-*a* at Bogalusa

A.8 TOTAL SUSPENDED SOLIDS

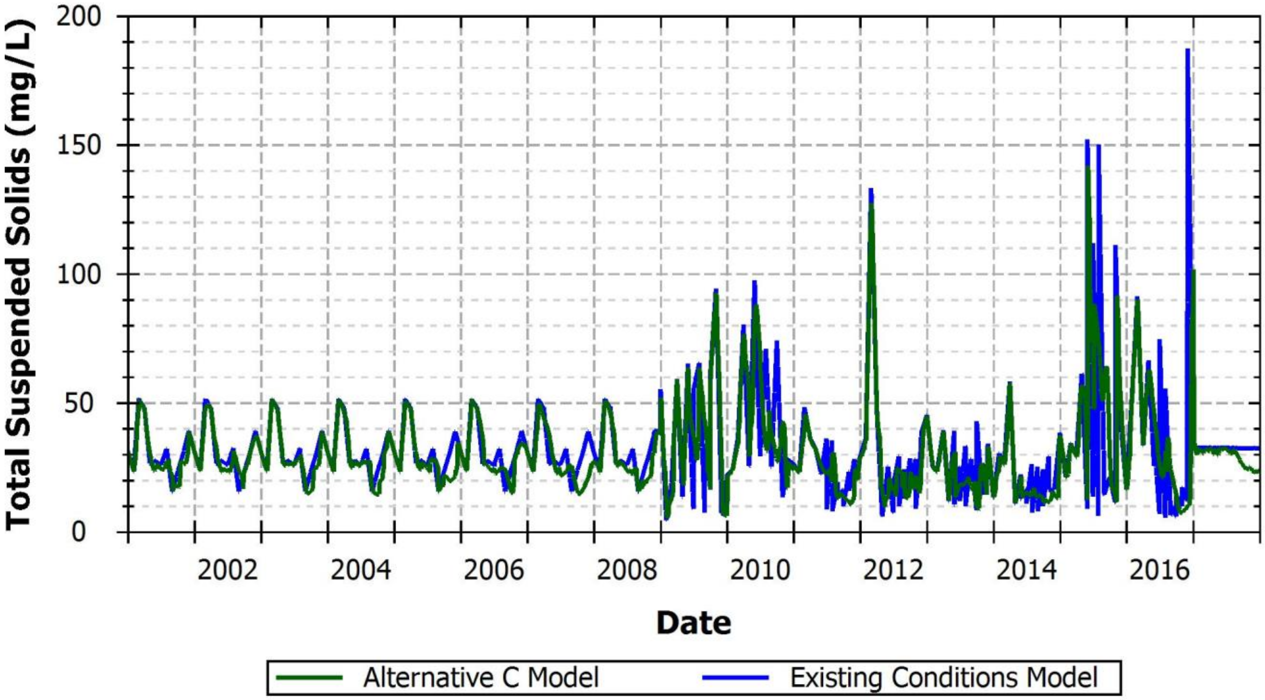

Figure A-22. Simulated TSS at Monticello

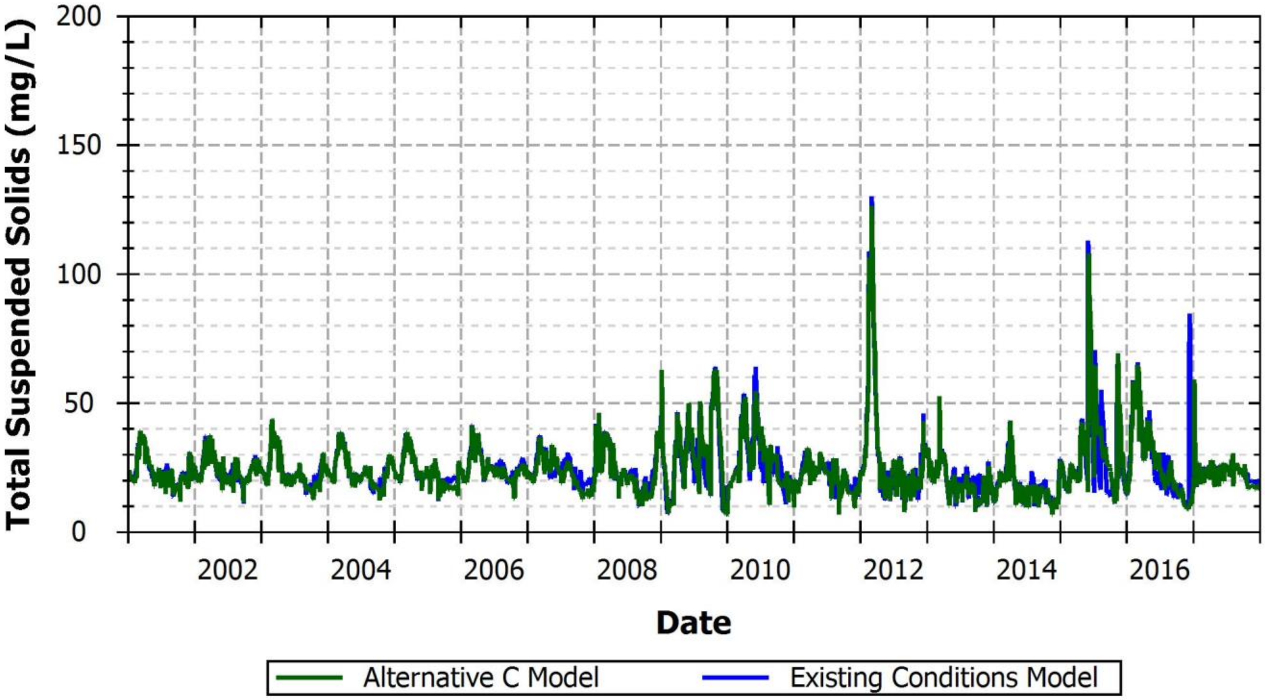

Figure A-23. Simulated TSS at Columbia

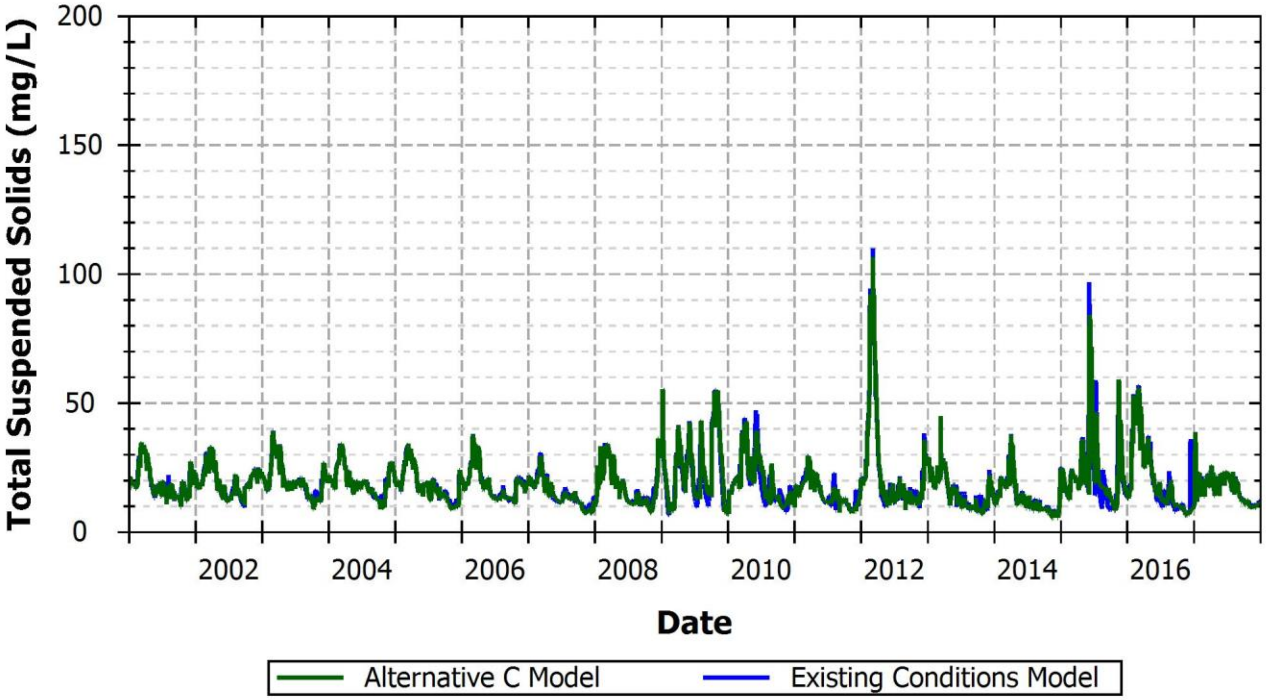

Figure A-24. Simulated TSS at Bogalusa

A.9 BIOCHEMICAL OXYGEN DEMAND

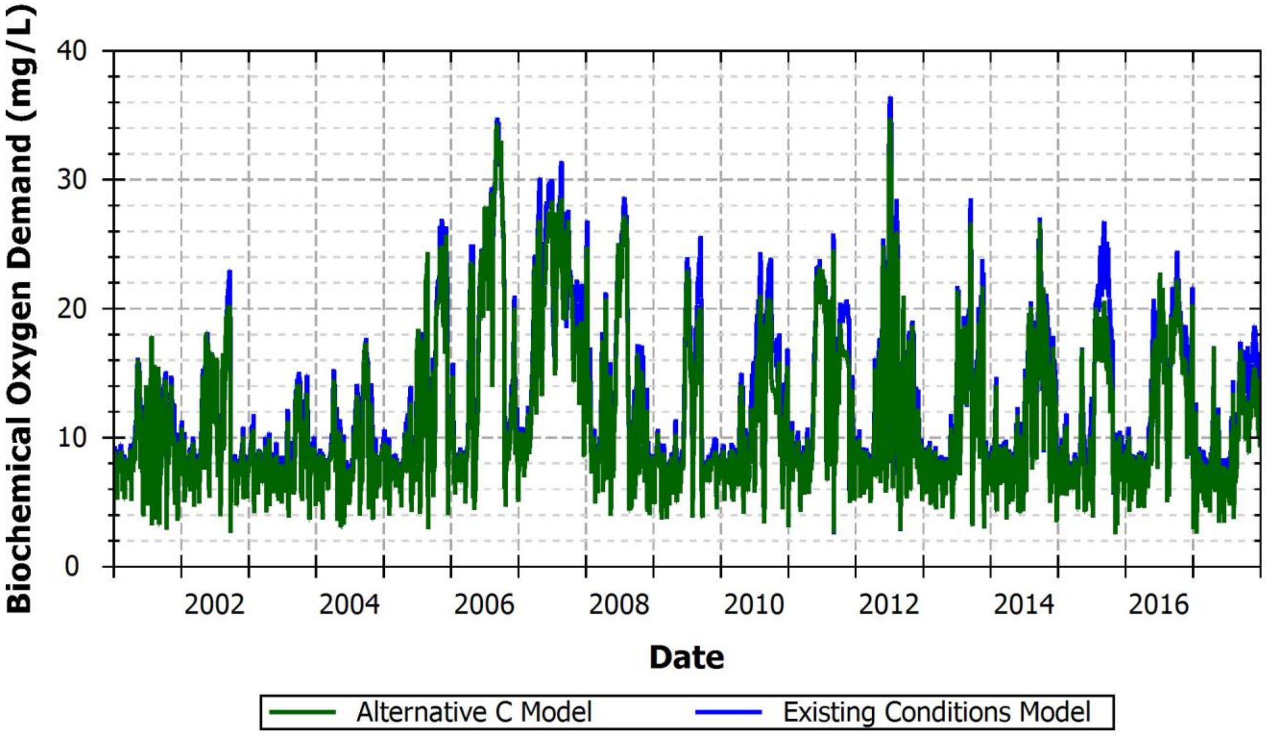

Figure A-25. Simulated CBODU at Monticello

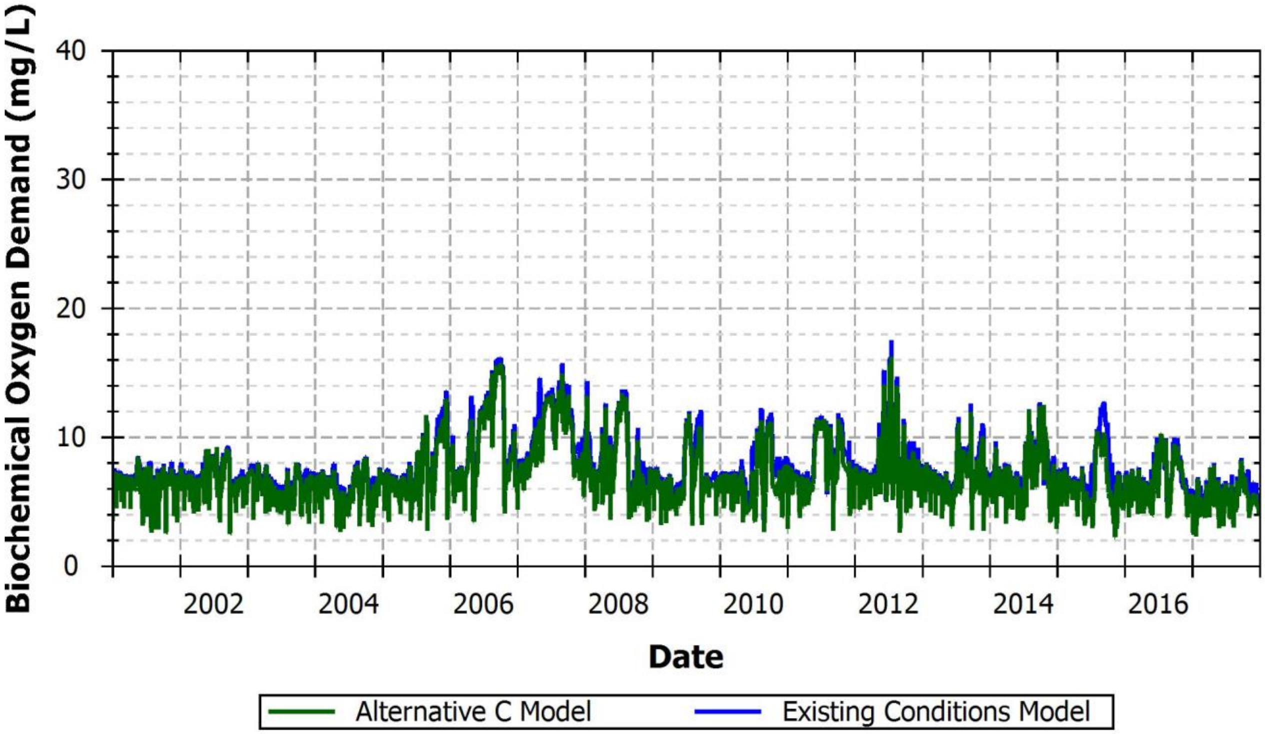

Figure A-26. Simulated CBODU at Columbia

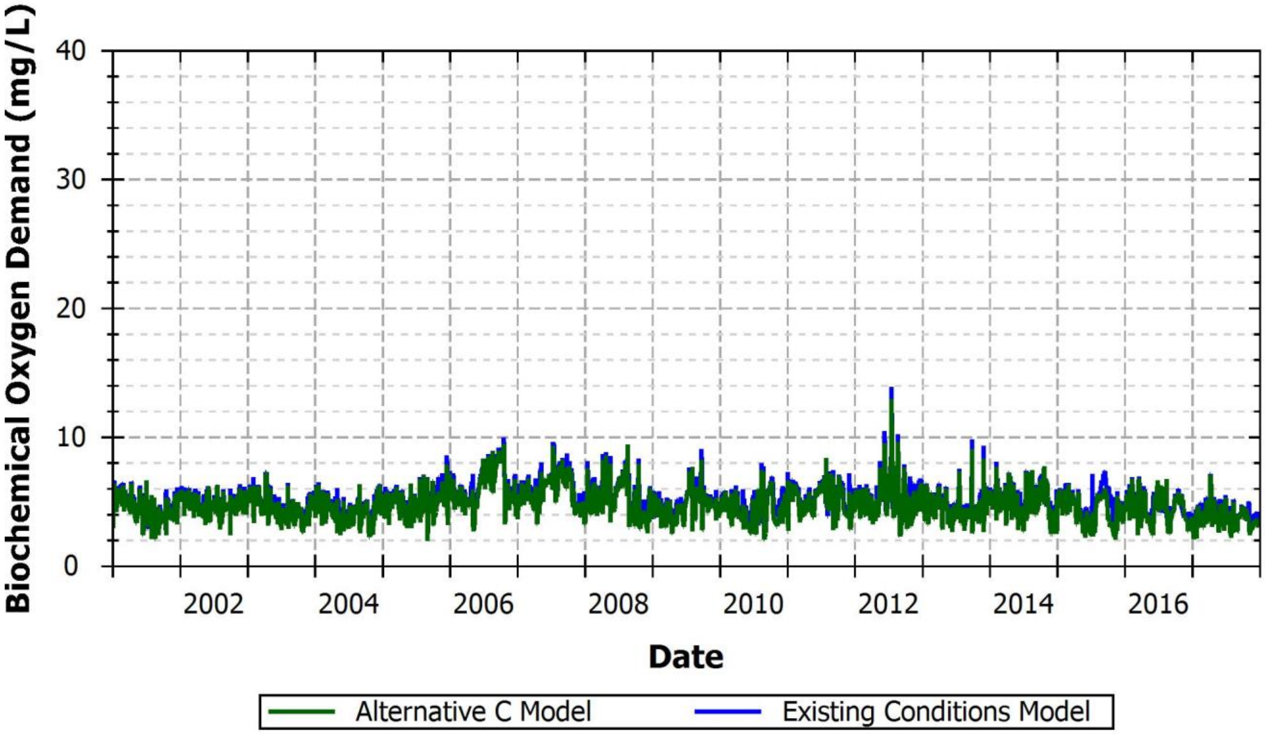

Figure A-27. Simulated CBODU at Bogalusa