Total Maximum Daily Load for Organic Enrichment/Dissolved Oxygen, Nutrients, and Pathogens

Flint Creek Watershed

SEPTEMBER 2003

United States Environmental Protection Agency

Region 4 serving the southeast

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In compliance with the provisions of the Federal Clean Water Act, 33 U.S.C §1251 et. seq., as amended by the Water Quality Act of 1987, P.L. 400-4, the U.S Environmental Protection Agency is hereby establishing Total Maximum Daily Loads (TMDLs) for organic enrichment/dissolved oxygen, nutrients, and pathogens for the Flint Creek watershed in Alabama. Subsequent actions must be consistent with this TMDL.

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James D. Giattina, Director Date
Water Management Division

1.0 Executive Summary

This report presents Total Maximum Daily Loads (TMDLs) for 17 waterbody segments found on Alabama's 1996, 1998, 2000, and 2002 Section 303(d) List of Impaired Waterbodies within the Flint Creek Watershed. Table 1-1 presents the listed segment names along with ID numbers, the designated uses, causes of impairment, the sources of impairment, and the lengths of impairment.

Table 1-1 303(d) Listed Segments within the Flint Creek Watershed

Waterbody Name (ID)	Designated Uses*	Causes of Impairment	Sources of Impairment	Segment Length (mi)
Flint Creek (06030002-330_01)	F&W PWS LWF	OE/DO Nutrients Pathogens Siltation	Municipal Point Sources Nonirrigated Crop prod. Pasture Grazing Int. Animal Feeding Oper. Urban Runoff/Storm Sewers	40.0
Shoal Creek (06030002-330_02)	F&W	OE/DO Pathogens	Urban Runoff/Storm Sewers Agriculture	10.9
Town Branch (06030002-330_03)	F&W	OE/DO	Urban Runoff/Storm Sewers	1.9
Mack Creek (06030002-330_04)	F&W	OE/DO Siltation	Pasture Grazing	5.4
Robinson Creek (06030002-330_05)	F&W	OE/DO Siltation	Agriculture	6.3
Cedar Creek (06030002-330_06)	F&W	OE/DO Pathogens	Agriculture	8.7
East Fork Flint Creek (06030002-330_07)	F&W	OE/DO Pathogens	Unknown Source	14.9
Indian Creek (06030002-330_09)	F&W	OE/DO	Unknown Source	4.2
Crowdabout Creek (06030002-340_01)	F&W	Pathogens OE/DO Siltation	Nonirrigated Crop Production Pasture Grazing Int. Animal Feeding Oper.	15.0
Herrin Creek (06030002-340_02)	F&W	OE/DO Ammonia Nutrients Siltation	Pasture Grazing	6.3
No Business Creek (06030002-350_01)	F&W	OE/DO Pathogens	Nonirrigated Crop Production	6.3
West Flint Creek (06030002-350_02)	F&W	Pathogens OE/DO	Nonirrigated Crop Production Pasture Grazing Int. Animal Feeding Oper.	19.4
Village Branch (06030002-350_03)	F&W	OE/DO	Agriculture	5.7
Big Shoal Creek (06030002-360_01)	F&W	OE/DO	Pasture Grazing	13.3
McDaniel Creek (06030002-360_02)	F&W	OE/DO	Agriculture	3.9
Flat Creek (06030002-360_03)	F&W	OE/DO	Unknown Source	7.3
Elam Creek (06030002-360_04)	F&W	OE/DO	Unknown Source	11.9

Figure 1-1 presents a map of the Flint Creek Watershed with the listed segments identified and the listed parameters. Of these segments, all 17 are listed as impaired for organic enrichment/dissolved oxygen (OE/DO), 1 is listed for nutrients, and 7 for pathogens, for a total of 25 TMDLs.

Within the Flint Creek watershed, three designated uses exist at present, Fish and Wildlife (F&W), Public Water Supply (PWS), and Limited Warmwater Fishery (LWF). Only the mainstem of Flint Creek supports the PWS and LWF classifications and these reaches are shown on Figure 1-1. Based upon the Use Classification Upgrade Report (ADEM, 2001), Flint Creek was upgraded from Agricultural & Industrial Water Supply (A&I) to LWF. This upgrade was effective for point sources January 2003 but prior to this, i.e. for the model period, the A&I criteria were in effect. For the purposes of this TMDL report, the present accepted use classifications are utilized. Table 1-2 presents the water quality criteria for Dissolved Oxygen and Pathogens (Fecal Coliform) for the applicable use classifications within the Flint Creek Watershed.

Table 1-2 Criteria for Dissolved Oxygen and Pathogens for Applicable Designated Use Classifications

Designated Use Classification	DO Criterion	Fecal Coliform Criterion (30-day Geometric Mean)	Fecal Coliform Criterion (Instantaneous)
Public Water Supply (PWS)	5.0 mg/L	1,000 counts/100mL 200 counts/100mL (June-Sept)	2,000
Fish & Wildlife (F&W)	5.0 mg/L	1,000 counts/100mL 200 counts/100mL (June-Sept)	2,000
Limited Warmwater Fishery (LWF)	5.0 mg/L (December through April) 3.0 mg/L (May to November)	1,000 counts/100mL	2,000

The development of targets for the listed segments focused upon dissolved oxygen within the mainstem of the Flint Creek to address the OE/DO issues. The targeted DO criterion for summer low flow conditions is a minimum of 5.0 mg/L in the reaches classified as F&W or PWS, and 3.0 mg/L in the reaches classified as LWF. Additionally, examination of chlorophyll levels in the lower impounded sections helped to assure the system meets designated uses relative to watershed nutrient conditions.

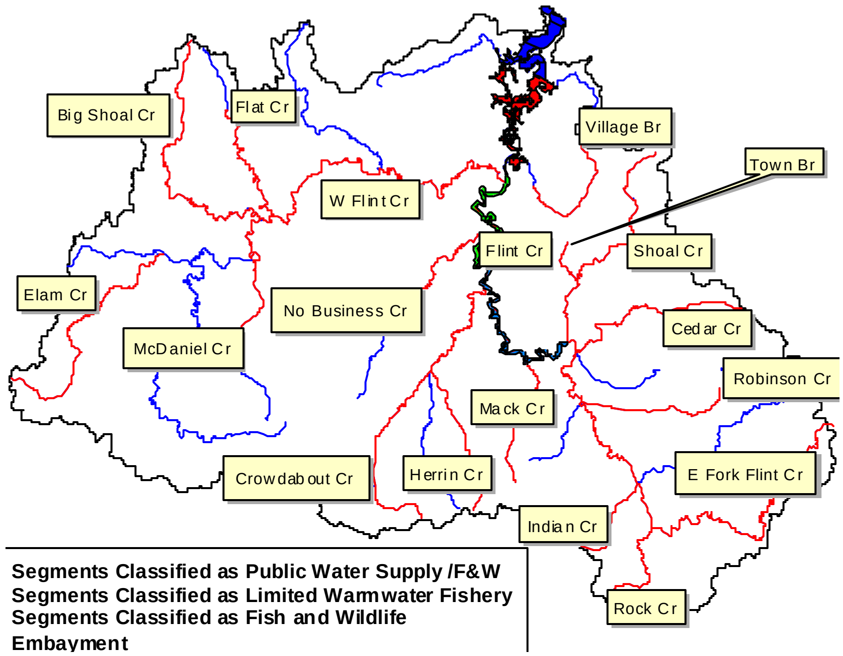


Figure 1-1 303(d) Listed Reaches within the Flint Creek Watershed with Associated Use Classification

Targets for fecal coliform were determined to address the 30-day geometric mean criterion of 200 counts/100mL and 1,000 counts/100mL for the summer and winter periods respectively and the instantaneous criterion of 2,000 counts/100mL. Model simulations then were used to assess the loading, transport, and decay of fecal coliform bacteria associated with agricultural and urban uses and their distribution throughout the system.

A dynamic system of models developed for the Flint Creek watershed was used to evaluate instream concentrations for the parameters of interest. The system consists of an application of the Loading Simulation Program in C++ (LSPC) for the entire watershed that projects instream concentrations due to watershed runoff loadings. In addition, a receiving water hydrodynamic and water quality model was developed for the main stem Flint Creek and specifically within the impounded reaches of Flint Creek to allow for simulation of the instream dissolved oxygen and eutrophication kinetics as well as fecal coliform decay. The instream models are limited to those areas where flow is continuous throughout the year.

This document presents a brief summary of the data analysis and modeling work performed in the development of the TMDLs. Details of model development, calibration and TMDL scenario applications are presented in a report entitled "Development of a

Hydrodynamic and Water Quality Modeling System for the Flint Creek Watershed." This report is hereinafter referred to as the Modeling Report (Tetra Tech, 2003).

2.0 Basis for §303(d) Listing

2.1 Introduction

Section 303(d) of the Clean Water Act (CWA) as amended by the Water Quality Act of 1987 and EPA's Water Quality Planning and Management Regulations [(Title 40 of the Code of Federal Regulations (CFR), Part 130)] require states to identify waterbodies which are not meeting water quality standards applicable to their designated use classifications. The identified waters are prioritized based on severity of pollution with respect to designated use classifications. Total maximum daily loads (TMDLs) for all pollutants causing violation of applicable water quality standards are required to be determined for each identified segment. Such loads are established at levels necessary to implement the applicable water quality standards with seasonal variations and margins of safety. The TMDL process establishes the allowable loading of pollutants, or other quantifiable parameters for a waterbody, based on the relationship between pollution sources and in-stream water quality conditions, so that states can establish water-quality based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

The State of Alabama has identified 17 segments within the Flint Creek Watershed as being impaired. Table 1-1 presents the listed segments along with the parameters listed for each segment. Nine of the listings are reported on the 1996-§303(d) list(s) of impaired waters and the remaining eight were listed on the subsequent 1998-§303(d) list.

On November 5, 2001, EPA proposed TMDLs for waters in the Flint Creek watershed to address impairment from pathogens. Seven stream segments in the Flint Creek watershed had been identified on the State of Alabama's most recent (i.e., 1998 at that time) Section 303(d) list as being impaired due to pathogens including Flint Creek, Shoal Creek, Cedar Creek, E. Fork Flint Creek, Crowdabout Creek, No Business Creek, and West Flint Creek. Based on EPA's water quality modeling analysis used for developing the 2001 proposed TMDLs, EPA determined that 54 segments in the Flint Creek watershed (including several that were identified on the State's 303(d) list) required total maximum daily loads. These 54 segments were determined at the time of the proposal to be water quality limited segments based on a modeling analysis that predicted that load reductions were needed in each of these waters to ensure that water quality standards were attained throughout the watershed. Therefore, TMDLs were proposed in November 2001 for each of these 54 segments.

Based on significant comments received during the public comment period for the proposed TMDLs, EPA is re-proposing TMDLs for the impaired waters using a more rigorous technical analysis and a more sophisticated TMDL approach using all of the available data and information associated with the Flint Creek watershed. Based on the improved analysis and TMDL approach, which is described in detail in this report, EPA determined that the only segments in this watershed that require TMDLs for pathogens are the seven waters that are identified on Alabama’s Section 303(d) list as being impaired for pathogens. Therefore, the re-proposed TMDLs for pathogens address only those seven waters.

The TMDLs developed for the Flint Creek watershed illustrate the steps that can be taken to address a waterbody impaired by OE/DO, Nutrients, Ammonia, and Pathogens (Fecal Coliform). The TMDLs are consistent with a phased approach: estimates are made of needed pollutant reductions, load reduction controls are to be implemented (as many have since the data collection that was used in this analysis), and future water quality is to be monitored for plan effectiveness. Flexibility is built into the plan so that load reduction targets and control actions can be reviewed and updated when further monitoring indicates continuing water quality problems or improvement.

2.2 Problem Definition

The Flint Creek watershed is part of the Tennessee River Basin and has a total drainage area of 455 square miles, covering approximately 291,000 acres. The Flint Creek basin is comprised of four subwatersheds, namely Upper Flint Creek (330), Crowdabout Creek (340), Lower Flint Creek (350), and West Flint Creek (360). These four subwatersheds combined contain approximately 350 miles of perennial streams and over 650 miles of intermittent streams. The majority of the watershed is in Morgan County with portions in Cullman and Lawrence Counties. Flint Creek originates in Cullman County and flows in a northwesterly direction through the western section of Morgan County until it reaches the impounded waters of Wheeler Reservoir on the Tennessee River. Figure 2-1 presents the location of the Flint Creek watershed within the State of Alabama and the Tennessee River Basin. Most of the surface waters within the Flint Creek watershed are designated Fish and Wildlife (F&W) use classification, however, the lower part of Flint Creek is also classified Public Water Supply (PWS), and a 9-mile long central segment is classified Limited Warmwater Fishery (LWF).

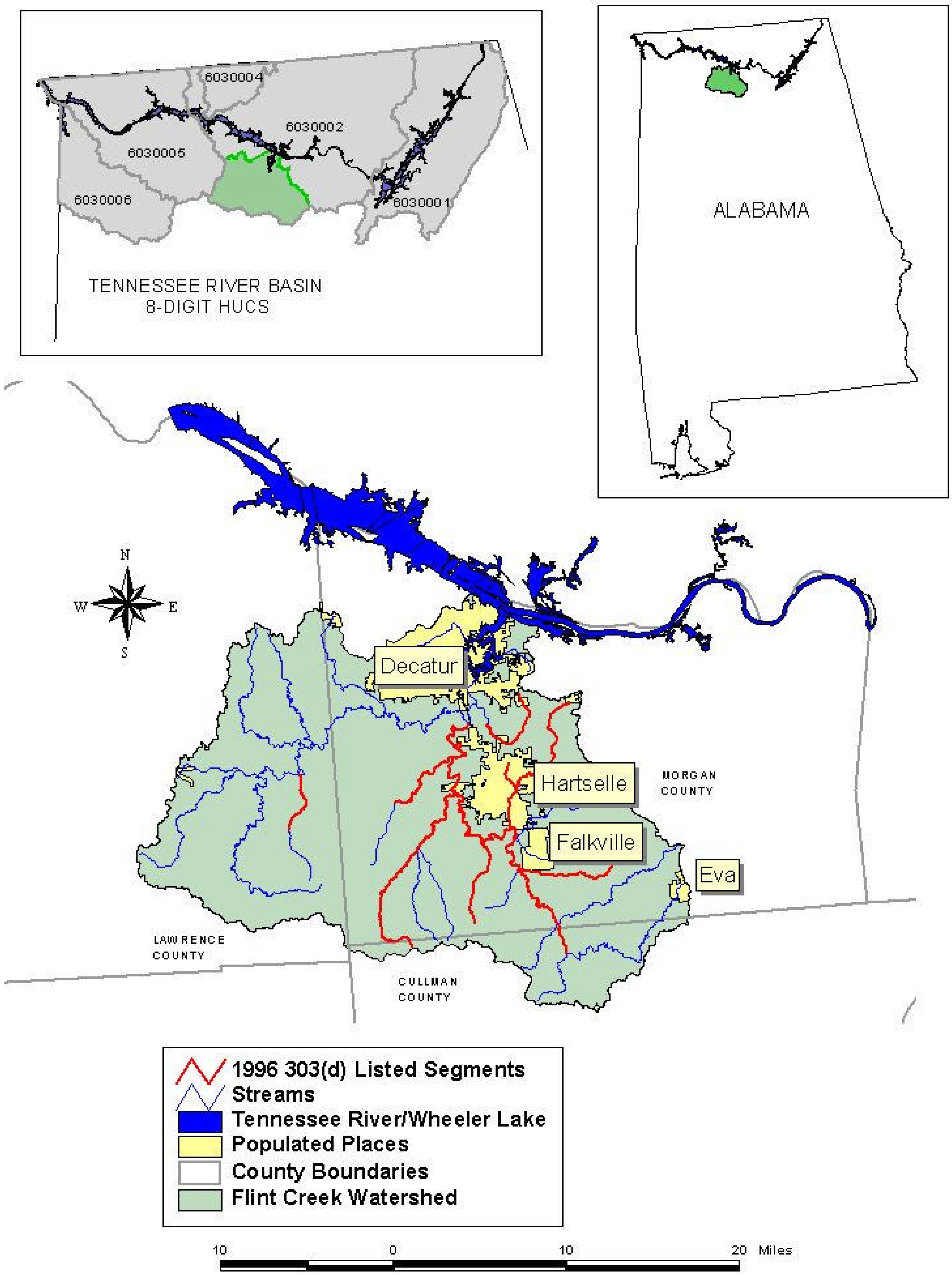


Figure 2-1 Location Map for the Flint Creek Watershed

The overall surface water quality within the Flint Creek watershed has been designated "fair" to "poor." Biological assessments have indicated areas of poor fish health (TVA data reported in ADEM, 1996a) with polluted surface water runoff from agricultural and urban land uses identified as significant problems. Major land uses that impact water quality are agricultural areas within the watershed as well as urban areas around Decatur, Hartselle, and Falkville. Figure 2-2 presents the USGS Multi-Resolution Landuse Classification (MLRC) dataset for the Flint Creek watershed. The dominance of agricultural activities within the watershed can be seen, with 40 percent of the watershed landuse classification related to agriculture.

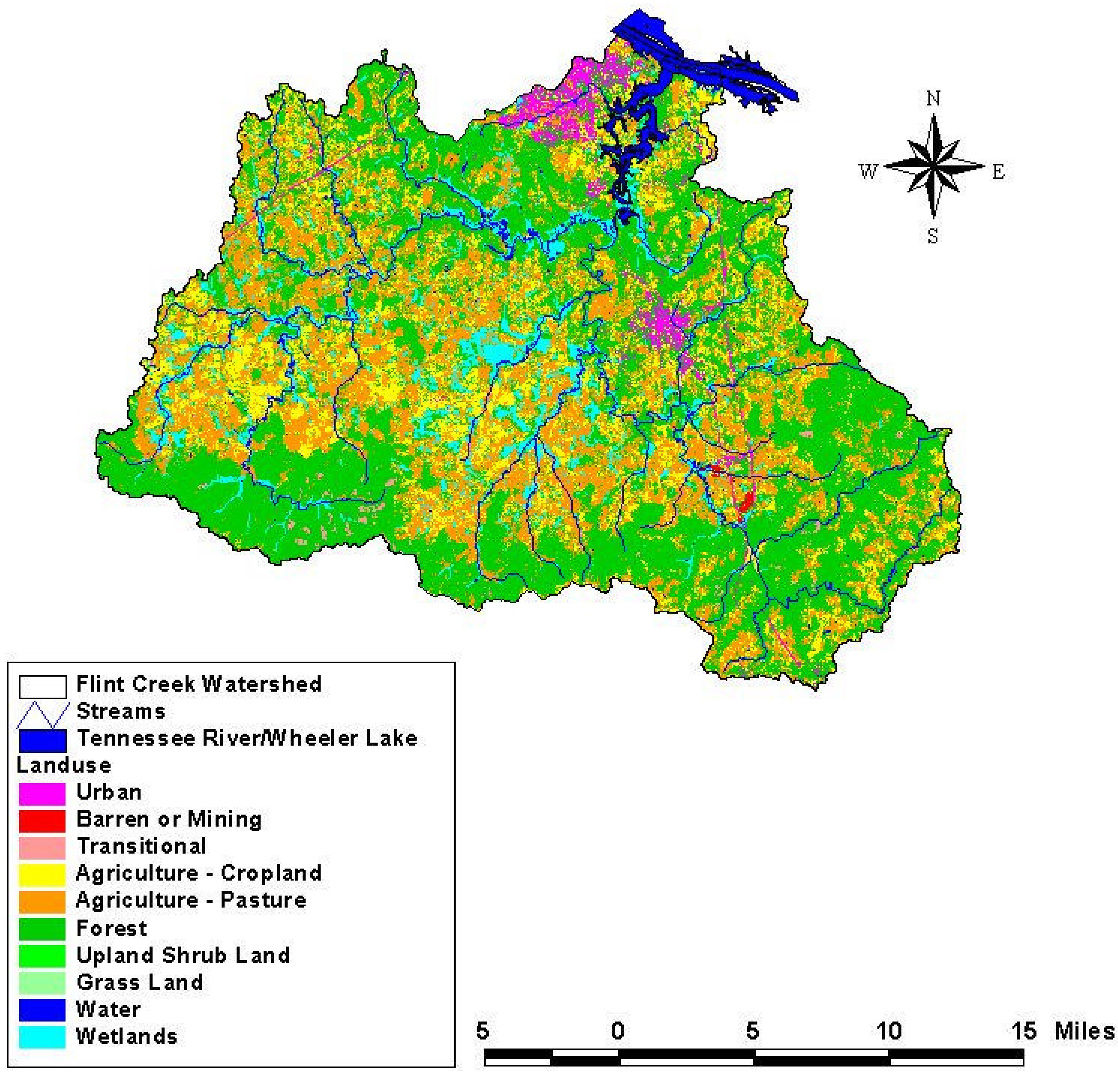


Figure 2-2 Land Use Representation in the Flint Creek Watershed

Table 2-1 presents the results of biological monitoring throughout the listed segments. The data indicate that the health of the system within the listed segments ranges from fair to very poor. The overall cause is attributed to siltation and organic enrichment from urban and agricultural nonpoint sources, with the addition of low dissolved oxygen along specific reaches of the Flint Creek.

Table 2-1 Biological Assessment Results for 303(d) Listed Segments in Flint Creek Watershed (TVA Biological Data for 1994-95 reported in ADEM, 1996)

CU	Waterbody	Bug Health	EPT	Fish Health	IBI	Causes	Sources
1001-12	Flint Creek	Very Poor/Poor	2	Poor	32	Organic Enrichment/Low DO	Ag, Urban NPS and Point Sources
1001-28	Flint Creek	Poor	3	Insufficient Sample		Silt, Organic Enrichment	Ag & Urban NPS
1002-13	West Flint Creek	Poor	3	Poor/Fair	38	Silt, Organic Enrichment	Ag & Urban NPS
1004	Crowdabout Creek	Fair	9	Poor/Fair	36	Silt, Organic Enrichment	Ag & Urban NPS
1005	Mack Creek	Poor	4	Poor	32	Silt, Organic Enrichment	Ag & Urban NPS
1006-U	Shoal Creek	Poor	4	Poor/Fair	36	Silt, Organic Enrichment	Ag & Urban NPS
1007	Cedar Creek	Fair	6	Fair	40	Silt, Organic Enrichment	Ag & Urban NPS
1008	Robinson Creek	Poor/Fair	5	Poor/Fair	38	Silt, Organic Enrichment	Ag & Urban NPS
1010	Indian Creek	Poor/Fair	5	Fair	42	Silt, Organic Enrichment	Ag & Urban NPS
1015	Flat Creek	Fair	9	Poor/Fair	36	Silt, Organic Enrichment	Ag & Urban NPS
1017	McDaniel Creek	Poor/Fair	5	Poor	28	Silt, Organic Enrichment	Ag & Urban NPS
1001-32	Flint Creek	Very Poor	1	Very Poor/Poor	34	Organic Enrichment	Ag, Urban NPS and Point Sources
1003	No Business Creek	Poor/Fair	5	Poor	26	Organic Enrichment	Ag & Urban NPS
1006-L	Shoal Creek	Very Poor	1	Poor	32	Organic Enrichment	Urban NPS
1006-NB	Nasty Branch [Town Branch]	Very Poor	0	Very Poor/Poor	26	Organic Enrichment	Urban NPS
1013	East Fork Flint Creek	Fair	10	Very Poor	22	Organic Enrichment	Ag NPS
1016	Big Shoal Creek	Fair	7	Very Poor	22	Organic Enrichment	Ag NPS
1018	Elam Creek	Fair	8	Very Poor/Poor	24	Organic Enrichment	Ag NPS

Water quality monitoring conducted from 1993 through 1998 (GSA, 1998) indicated periods of time within the watershed (primarily within the mainstem of the Flint Creek) where dissolved oxygen conditions dropped well below the State F&W criterion of 5.0 mg/L, and at times below 3.0 mg/L (LWF areas). These conditions typically occurred during the critical summer months under low flow conditions.

Hydrologic conditions that affect surface water quality include the backwater impacts of Wheeler Lake in the lower Flint Creek embayment and high variability in streamflow, characterized by extreme low flows in summer-fall. Backwater of Wheeler Lake is important at times of low flow because it reduces stream velocities, increases retention time, and reduces stream aeration potential. These combined effects tend to promote accumulation of organic matter, potential growth of algae and macrophytes and low dissolved oxygen levels, and to result in increased biochemical and sediment oxygen demands exerted in the lower segments of Flint Creek and its tributaries. TVA reservoir operations in Wheeler Lake create a typical seasonal pattern in water surface elevation that rises in late spring and summer up to an elevation of 556 feet down to 550 feet during late fall and winter. Figure 2-3 presents the extent of backwater area within the Flint Creek watershed under low flow conditions with the surface elevation at approximately 556 feet.

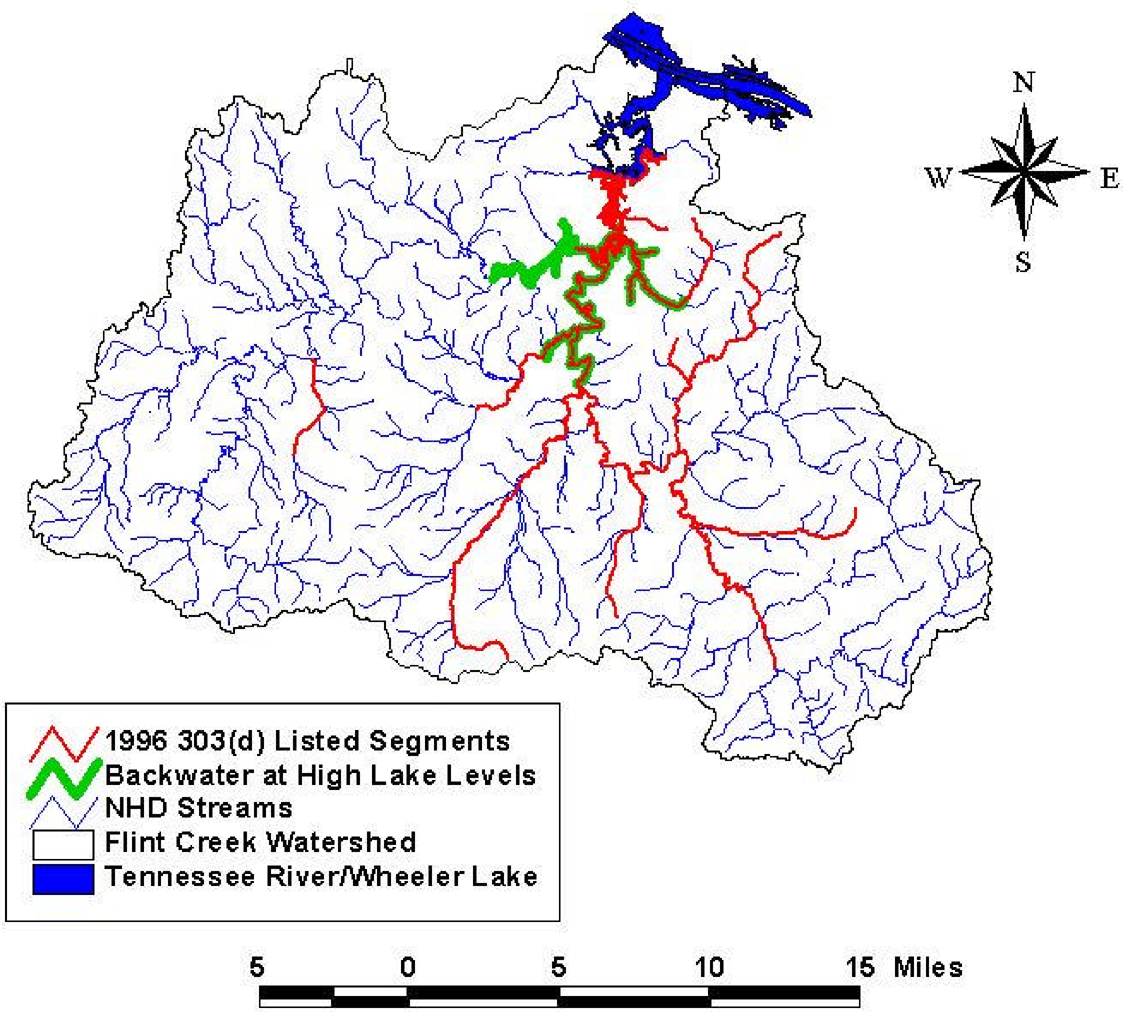


Figure 2-3 Extent of Backwater in Flint Creek and West Flint Creek

The purpose of this TMDL is to establish the acceptable loading of nutrients, organic material, and fecal coliform from all sources, such that the established water quality targets outlined in Section 3.1 are met.

3.0 Technical Basis for TMDL Development

3.1 Water Quality Target Identification

3.1.1. Organic Enrichment/Dissolved Oxygen

Table 2-1 presented the biological assessment data utilized for the listings within the Flint Creek watershed. Siltation and organic enrichment are noted as the primary causes in all of the secondary stream segments and the upstream reaches of Flint Creek. The only segment where low dissolved oxygen is specifically outlined as a cause of impairment is for portions of the mainstem of Flint Creek. However, additional data (GSA, 1998; ADEM, 2001) indicate low dissolved oxygen elsewhere in the watershed during low-flow conditions.

Based upon these data, organic matter loading quantified as instream loadings of biochemical oxygen demand, in addition to total nitrogen and total phosphorus loadings associated with the organic matter, have been utilized as targets for all of the segments other than the portions of the mainstem portion of Flint Creek.

For mainstem portions of Flint Creek, dissolved oxygen was chosen as the target based upon the evaluation of sediment oxygen demand from the accumulation of organic matter, including nutrients. The minimum dissolved oxygen concentration in a stream classified as Fish and Wildlife (and/or Public Water Supply) is 5.0 mg/l, except under extreme natural conditions where a 4.0 mg/L is allowed. For the purpose of this TMDL, a minimum dissolved oxygen level of 5.0 mg/l will be targeted within waters classified as F&W or PWS. The minimum dissolved oxygen concentration in the segment classified as Limited Warmwater Fishery is 3.0 mg/l for the months from May through November and 5.0 mg/L for the period December through April.

3.1.2. Pathogens

A total of seven segments are listed for pathogens, including mainstem Flint Creek, West Flint Creek, Shoal Creek, Cedar Creek, East Fork Flint Creek, Crowdabout Creek, and No Business Creek. In each of these segments a geometric mean and instantaneous water quality target applies. Alabama's water quality criteria regulations (ADEM Admin. Code R. 335-6-10-.09-(5)(e)(7.)) for the F&W and PWS use classifications states:

> *"Bacteria of the fecal coliform group shall not exceed a geometric mean of 1,000/100mL; nor exceed a maximum of 2,000/100mL in any sample. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours. For incidental water contact and recreation during June through September, the bacterial quality of water is acceptable when a sanitary survey by the controlling health authorities reveals no source of dangerous pollution and when the geometric mean fecal coliform organism density does not exceed 100/100mL in coastal waters and 200/100mL in other waters. The geometric*

mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours. When the geometric mean fecal coliform organism density exceeds these levels, the bacterial water quality shall be considered acceptable only if a second detailed sanitary survey and evaluation discloses no significant public health risk in the use of the waters. Waters in the immediate vicinity of discharges of sewage or other wastes likely to contain bacteria harmful to humans, regardless of the degree of treatment afforded these wastes, are not acceptable for swimming or other whole body water-contact sports."

Based upon the ADEM's water quality criteria for fecal coliform, an instantaneous maximum of 2000 counts/100mL was established as the target. Additionally, maximum 30-day geometric means of 1,000 counts/100mL and 200 counts/100mL for winter months and June through September respectively were established for all waters, except for waters classified as LWF. The maximum 30-day geometric mean for waters classified as LWF is 1,000 counts/100mL year-round.

3.2 Source Assessment

3.2.1. Organic Enrichment/Dissolved Oxygen

Both point and non-point sources may contribute to organic enrichment within a given waterbody. Potential sources of organic loading are numerous and often occur in combination. In rural areas, storm runoff from row crops, livestock pastures, animal waste application sites, and feedlots can transport significant loads of organic material. Nationwide, poorly- treated municipal wastewater comprises a major source of organic matter to rivers and streams. Urban stormwater runoff, failing septic systems, sanitary sewer overflows, and combined sewer overflows can be significant sources of organic loading.

Potential sources of organic loading in the watershed were identified based on an evaluation of land use/cover information on watershed activities and aerial surveys (S&WCD 1995). The source assessment was used as the basis of development of the model and ultimate analysis of the TMDL allocations. The organic and nutrient loading within the watershed included representation of both point and non-point sources.

Point Sources in the Flint Creek Watershed

ADEM maintains a database of current NPDES permits and GIS files that locate each permitted outfall. This database includes municipal, semi-public/private, industrial, mining, industrial stormwater, and concentrated animal feeding operations (CAFO) permits. Table 3-1, below, shows the NPDES-permitted point sources in the watershed that discharge into the Flint Creek watershed. Figure 3-1 shows the location of each facility.

Table 3-1 NPDES Permitted Discharges in the Flint Creek Watershed

POTW	County	Permit	Design Flow (MGD)	CBOD summer (mg/l)	CBOD winter (mg/l)	NH3 summer (mg/l)	NH3 winter (mg/l)	DO (mg/l)
Hartselle	Morgan	AL0054674	2.7	8	30	1	2.5	7
--under LWF requirements	Morgan	*AL0054674*	*2.7*	*8*	*14*	*1*	*2*	*7*
Falkville HCR Lagoon	Morgan	AL0021113	0.275	30	30	NL	NL	NL
Ala Sheriffs Boys Ranch	Morgan	AL0059552	0.013	4	7	1.2	2.1	5
Danville High School	Morgan	AL0051870	0.026	5	25	1	11.9	5
Speake Schools	Lawrence	AL0043028	0.0175	10	30	1.2	2.1	6
E. Lawrence Schools	Lawrence	AL0054879	0.025	10	25	1.2	2.1	5
Vinemont School	Cullman	AL0051128	0.025	25	25	1.4	2.1	6

The two most significant point sources within the Flint Creek Watershed are the Falkville and Hartselle discharges. The Hartselle municipal wastewater treatment facility, operating under NPDES permit AL0054674, is the largest point source in the Flint Creek watershed, discharging into Shoal Creek approximately 0.45 miles from the confluence with Flint Creek. According to plant engineer Wayne Roberson, in times of drought, the plant discharge comprises the majority of the streamflow in Shoal Creek. Hartselle is permitted to discharge an average of 2.7 MGD with different permit limits for BOD and ammonia in summer (May-November) and winter (December-April). According to monthly average discharge monitoring reports (DMRs), historical discharge has varied in the range from 0.79 to 4.84 MGD in the years 1993-April 2001, with a median monthly average discharge of 1.88 MGD, approximately 70 percent of its design limits.

The Falkville 275,000 gallon municipal wastewater lagoon, operating under NPDES permit AL0021113, discharges directly to Flint Creek with a permitted flow defined by the regression equation:

Discharge (MGD) = [0.0857 x Streamflow (cfs)] – 2.143

Falkville's permit is a specialized one. It utilizes what is referred to as a Hydrograph Controlled Release (HCR) lagoon system. This type of permit allows wastewater discharges that are proportional to the streamflow. There is usually a minimum streamflow specified in the permit below which no discharge is allowed. Minimum streamflow of Flint Creek for Falkville to discharge is 25 cfs. According to Chris Lovelace of the Town of Falkville, the lagoon requires only one or two discharges annually. In a recent recorded discharge on October 5, 2001, a sample was taken as part of the permit renewal process. The sample contained concentrations of 38.3 mg/l BOD5 and 6.38 mg/l ammonia.

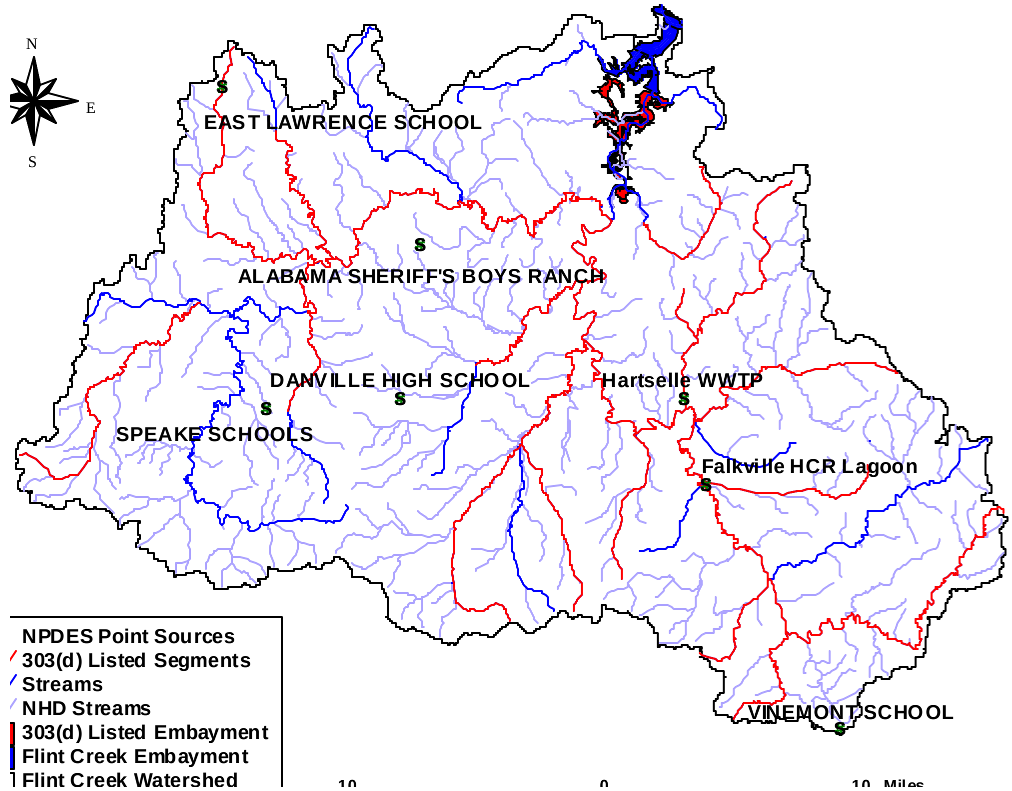


Figure 3-1 Point Source Discharges in the Flint Creek Watershed

Non-Point Sources in the Flint Creek Watershed

Shown in Table 3-2 is a summary of land usage in the Flint Creek watershed. A land use map of the watershed is presented in Figure 2-2. Figure 3-2 presents a pie chart depicting the overall land use distribution. The predominant land uses within the watershed are forest and agriculture. Their respective percentages of the total watershed are 46% and 40% respectively.

Table 3-2 Land Use Distribution within the Flint Creek Watershed

Landuse	Acres	Percentages
Urban	7545	2.5%
Barren/Mining	323	0.1%
Transitional	1154	0.4%
Agricultural - Cropland	41495	13.7%
Agricultural - Pasture	79765	26.3%
Forest	139423	46.0%
Water	4322	1.4%
Wetlands	21477	7.1%
Total	303049	100%

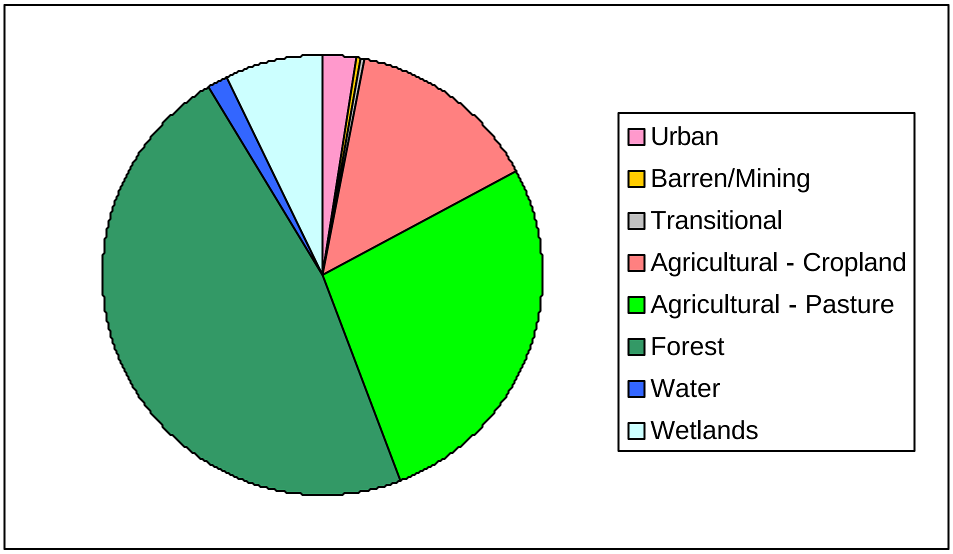


Figure 3-2 Land Use Distribution within Flint Creek Watershed

Each land use has the potential to contribute to the organic loading in the watershed due to organic material on the land surface that potentially can be washed off into the receiving waters of the watershed. Specific information on agricultural and management activities and watershed characteristics were obtained from reports published by the Morgan County Soil and Water Conservation District (S&WCD 1995).

The major sources of organic enrichment from non-point sources within the Flint Creek watershed are nutrients and organic material from agricultural and urban lands and direct discharge to streams due to cattle. Other non-point source contributions could be failing septic systems and urban runoff. Compared to other land uses, organic enrichment from forested land is normally considered to be minimal. This is because forested land tends to serve as a good filter, thus preventing excessive amounts of pollutant loads, such as sediment and organic matter, from entering the stream. Runoff from pastures, animal operations, improper land application of animal wastes, and animals with access to streams are all mechanisms that can introduce organic loading to water bodies.

3.2.2. Pathogens

Fecal coliform loadings also result from both point and nonpoint sources. A point source can be defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source contributions can typically be attributed to municipal wastewater facilities, illicit discharges, and leaking sewers in urban areas.

Municipal wastewater treatment facilities are permitted through the NPDES process administered by ADEM. Larger treatment facilities have chlorination systems that remove fecal coliform bacteria in the effluent before it is discharged. The treatment facilities treat human waste received from the collection system and then discharge their effluent into a nearby stream.

In urban settings, sewer lines can typically run parallel to the stream in the floodplain. If there is a leaking sewer line, high concentrations of fecal coliform can flow into the stream or leach into the groundwater. Illicit discharges are facilities that are currently discharging fecal coliform bacteria when they are not permitted or they are violating their defined permit limit by exceeding the fecal coliform concentration.

Nonpoint sources of fecal coliform bacteria do not have one discharge point, but rather, occur over the entire length of a stream or waterbody. On the land surface, fecal coliform bacteria accumulates over time in the soil and then is washed off during rain events. As the runoff transports the sediment over the land surface, more fecal coliform bacteria is collected and carried to the stream. At the same time as the accumulation of fecal coliform bacteria is occurring, the bacteria is also dying and decaying. Therefore, there is some net loading into the stream that is dictated by the watershed hydrology. The nonpoint sources of fecal coliform can be quantified from the following list of contributors:

- Livestock grazing
- Manure application to row crops and/or pasture
- Confined Animal Feeding Operations (CAFOs)
- Animals having direct access to streams
- Wildlife in agricultural and forested areas
- Urban runoff
- Failing septic systems in rural areas
- Leaking sewers lines in urban areas

Agricultural animals are a potential source of several types of fecal coliform loading to streams in the Flint Creek watershed. Livestock data are reported by county and published by the USDA in the Census of Agriculture (USDA, 1997). The available livestock data include population estimates for beef cows, dairy cows, hogs, and poultry (chickens). In addition, TVA aerial surveys and animal counts within the Flint Creek watershed in cooperation with the Morgan County Soil and Water Conservation District were published as part of the Flint Creek Watershed Project (S&WCD 1995).

Agricultural livestock and other unconfined animals (i.e., deer and other wildlife) also often have direct access to streams that pass through pastures. When cattle are not excluded from access to stream reaches, they represent a major potential source of direct fecal coliform loading to the stream. To account for the potential influence of cattle loads deposited directly in stream reaches within the watersheds, fecal coliform loads from cattle in streams can be calculated as a direct source into the stream.

Wildlife deposit feces onto land surfaces where it can be transported during storm events to nearby streams. Wildlife deposits can be from a wide range of species in Alabama, but common wildlife includes deer, raccoons, and waterfowl.

Fecal coliform loading from urban areas is potentially attributable to multiple sources including storm water runoff, illicit discharges of wastewater, runoff from improper disposal of waste materials, failing septic systems, and domestic animals. Septic systems are common in unincorporated portions of watersheds and may be direct or indirect sources of bacterial pollution via ground and surface waters. Onsite septic systems have the potential to deliver fecal coliform bacteria loads to surface waters due to system failure and malfunction.

Point Sources of Pathogens in the Flint Creek Watershed

The details of the point sources contributing to the Flint Creek watershed were described in Section 3.2.1. Seven permitted wastewater facilities in the Flint Creek watershed are included as potential sources of fecal coliform to the watershed. For the purpose of this study, it was assumed that these are discharging fecal coliform at a maximum of 200 counts per 100 milliliters.

Non-Point Sources of Pathogens in the Flint Creek Watershed

Historically in the Flint Creek watershed, agricultural runoff from pasture has contributed increased fecal coliform loads to a water body when farm management practices allowed animal waste to be washed into the stream, increasing instream fecal coliform levels. Animal counts were determined by TVA aerial surveys in cooperation with the Morgan County Soil and Water Conservation District (S&WCD, 1995). Pasture landuse areas and livestock densities for each subwatershed were used to estimate the potential fecal coliform loading. Further details are described in the Modeling Report (Tetra Tech, 2003).

Septic systems are common in unincorporated portions of the Flint Creek watershed and may be direct or indirect sources of bacterial pollution via ground and surface waters. A high percentage of residents in the watershed rely on septic systems for wastewater treatment. Septic systems have the potential to deliver fecal coliform bacteria loads to surface waters due to system failure and malfunction. To estimate this potential loading, it was necessary to evaluate where septic tanks are located and estimate what proportion of septic systems may be malfunctioning.

The number of septic systems in the Flint Creek watershed was calculated from Census data (U.S. Census Bureau, 1990). The density of septic systems (number per acre) was determined for each subbasin within the Flint Creek watershed based on Census tract GIS shapefiles. After estimating the number of septic systems per subwatershed, the potential number of failing systems per subbasin was determined in order to calculate bacteria loading. Additional details on the use of septic system data in development of the fecal coliform loads is presented in the Modeling Report (Tetra Tech, 2003).

Wildlife is another potential source of fecal coliform loading to receiving waterbodies. For TMDL development purposes, the deer population was assumed to represent the wildlife contribution, since population data for other wildlife species in the watershed was not readily available. It is assumed that deer habitat within the watershed includes forest, cropland, pasture, and wetlands. Typical estimates of the distribution of white-tailed deer within the region were provided by the Alabama Department of Conservation, Division of Wildlife and Freshwater Fisheries (2000).

A Soil and Water Conservation watershed assessment provided information stating that livestock access to streams is a concern in the Flint Creek watershed. When cattle are not denied access to stream reaches, they represent a major potential source of direct fecal coliform loading to the stream. To account for the potential influence of fecal coliform loads deposited directly in stream reaches within the watersheds, fecal coliform loads from cattle in streams were calculated and characterized as a direct source of loading to the stream segments.

3.3 Linking Numeric Water Quality Targets

EPA regulations define loading, or assimilative capacity, as the greatest amount of loading that a waterbody can receive without violating water quality standards (40 CFR Part 130.2(f)). The following outlines how for each parameter the water quality targets defined earlier were linked to the potential pollutant sources to determine TMDLs for the listed segments.

3.3.1 Organic Enrichment/Dissolved Oxygen

Section 3.1.1 identified water quality targets to be used in determining the TMDLs for the segments listed for OE/DO. These targets are organic matter as BOD concentrations, and criteria for minimum dissolved oxygen concentrations.

A watershed model was developed which simulated nutrient and organic loads throughout the watershed. The model provided simulations of the instream nutrient concentrations over a six year period enable the assessment of nutrient impacts on dissolved oxygen in Flint Creek.

An instream hydrodynamic and water quality model was developed which allowed dynamic simulation of the nutrients and organic material in those reaches where flow is continuous or impounded due to the effects of Wheeler Reservoir. The receiving water models provided simulations of the instream nutrient concentrations for simulation of the full eutrophication cycle including nutrients, BOD, dissolved oxygen, and chlorophyll-*a*. Using the dissolved oxygen (DO) water quality criteria of 5.0 mg/l in F&W and 3.0 mg/l in the LWF reaches, a TMDL model analysis was performed on mainstem Flint Creek through a critical summer period along with a winter period to determine the loading capacity for the watershed. This was accomplished through a dynamic simulation aimed at meeting the dissolved oxygen target limits by varying source contributions, either point or nonpoint. In the case of the nonpoint source loads, the simulations reflect the effects of NPS loads on sediment oxygen demand. These loads were for the 1994 simulation year that represented a typical critical condition year. The final acceptable simulation represented the TMDL (and loading capacity of the waterbody).

The linkage between the nonpoint-source loading model developed for the Flint Creek watershed and the instream dissolved oxygen simulations was achieved by identification of impacted and evaluation of sediment oxygen demand (SOD) in the system that allows DO criteria to be achieved in the critical conditions.

For this loading condition, a 1.5 gmO_2/m^2/day SOD value was assigned and the dissolved oxygen profile under critical conditions was developed for comparison with the impacted conditions. The TMDL was then determined as that percent reduction in organic matter load between the existing conditions and the SOD conditions that satisfy the water quality targets listed above throughout the year.

3.3.2 Pathogens

Section 3.1.1 identified two water quality targets to be used in determining the TMDLs for the segments listed for fecal coliform. These targets are 30-day geometric means of 200 counts/100mL and 1000 counts/100mL for the summer and winter periods respectively, as well as an instantaneous value of 2000 counts/100mL. Time series of instream fecal coliform concentrations were then simulated from 1993 to 1998 using both the system of models described in Section 4.

3.4 Data Availability and Analysis

A wide range of data and information were used to characterize the watershed and the instream conditions. The categories of data used include physiographic data that describe the physical conditions of the watershed and environmental monitoring data that identify potential pollutant sources and their contribution, and in-stream water quality monitoring data. A detailed summary of the environmental data used in the development of the model and the assessment of conditions along the listed reaches is presented within the Modeling Report (Tetra Tech, 2003).

4.0 Model Development

Establishing the relationship between in-stream water quality and source loading is an important component of TMDL development. It allows the determination of the relative contribution of sources to total pollutant loading and the evaluation of potential changes to water quality resulting from implementation of various management options. This relationship can be developed using a variety of techniques ranging from qualitative assumptions based on scientific principles to numerical computer modeling. In this section, the numerical modeling techniques developed to simulate the loading of organic material, nutrients, and pathogens and the resulting in-stream response are summarized.

For development of the Flint Creek Watershed TMDLs, a system of models were developed to allow the determination of the watershed loads to the listed reaches, the instream flow and transport within the listed reaches, and the instream response of critical water quality parameters. The system of models included the following:

- Loading Simulation Program in C++ (LSPC) – used to quantify the loads of organic material, nutrients, and fecal coliform to the listed reaches and to project instream concentrations within secondary stream segments.
- Environmental Fluid Dynamics Code (EFDC) – to simulate the flow and transport of material within the primary branches of the Flint and West Flint Creek listed reaches where flow is continuous throughout the year.
- Water Quality Analysis and Simulation Program (WASP) – to simulate the instream response of critical water quality parameters to the watershed loads where flow is continuous throughout the year.

The following presents general descriptions of each of the models along with brief discussions of the model calibrations and applications. A complete discussion of the development, calibration, and application of the models is presented in a separate modeling report (Tetra Tech, 2003).

4.1 Watershed Model

For the determination of the watershed loads to the receiving waters, hydrologic response and pollutant loading model calibrations were performed. The first step is the calibration of the hydrologic response of the watershed to rainfall and background source flows. During periods of precipitation, the rainfall will govern hydrology and subsequent loads of organic material, nutrients, and fecal coliform. During dry periods, past events and their associated storage and background inflows will govern the system hydrology. In each case there is a subsequent load to the listed waters that must be carried forward to the instream modeling. Loads washed into the system will pass through and/or react during dry periods if the loads still remain in the water column. In addition, build up of organic material in the listed reaches from past events can create increased sediment oxygen demand that exerts itself during low flow periods. In each case, the development of a TMDL that accounts for the nonpoint source impacts upon the system requires the use of a watershed model.

4.1.1. Watershed Hydrology Model

Based on the considerations described above, analysis of the monitoring data, review of the literature, and past modeling experience, the Loading Simulation Program C++ (LSPC) was used to represent the source-response linkage in the Flint Creek watershed. LSPC is a comprehensive data management and modeling system that is capable of representing loading from nonpoint and point sources found in the Flint Creek watershed and simulating in-stream processes. LSPC is based on the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and fecal coliform modeling.

LSPC was configured for the Flint Creek watershed to simulate the watershed as a series of the hydrologically connected subwatersheds that contribute loads to various lengths of the listed reaches. To represent watershed loadings and resulting concentrations of nutrients, biochemical oxygen demand, and fecal coliform to the stream segments, the watershed was divided into 58 subwatersheds. These subwatersheds represent hydrologic boundaries. Figure 4-1 presents the subwatershed delineation used in the LSPC model application to the Flint Creek Watershed. The delineation was based on elevation data (7.5 minute Digital Elevation Model [DEM] from USGS), stream connectivity (from the National Hydrography Dataset stream coverage), and the locations of monitoring stations.

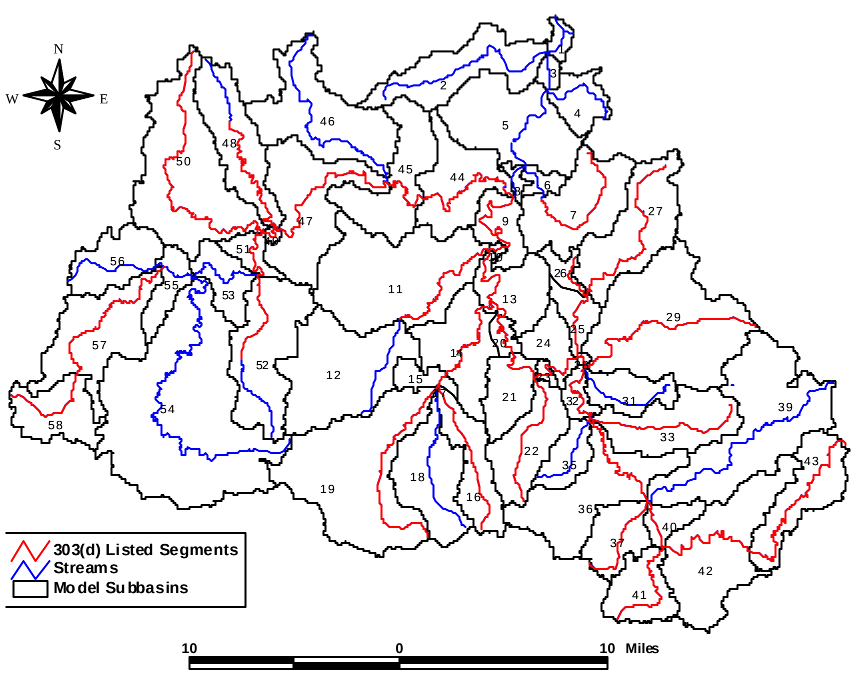


Figure 4-1 Subwatershed Delineation for Flint Creek Watershed

The hydrology of the LSPC model was calibrated at two USGS monitoring stations. USGS03576500 is located in the upper mainstem reaches of Flint Creek and USGS03577000 is located in the upper reaches of the West Flint Creek as shown in Figure 4-2. The hydrology calibration was performed prior to water quality calibration and involved adjustment of the model parameters used to represent the hydrologic cycle until acceptable agreement was achieved between simulated flows and historic stream flow data measured at gages for the same period of time. Model parameters adjusted include: evapotranspiration, infiltration, upper and lower zone storage, groundwater storage, recession, losses to the deep groundwater system, and interflow discharge. Modeled flow was compared to continuous flow data at both USGS flow gages. In addition, the model was validated to instantaneous flow measurements from 1993 through 1998 at the same two locations. Modeled flow was also compared to flow observations available at each of the other GSA sampling stations. Figure 4-3 shows the calibration of the LSPC hydrology model at USGS03576500. For a more detailed discussion on the hydrologic model calibration and validation, see the modeling report (Tetra Tech, 2003).

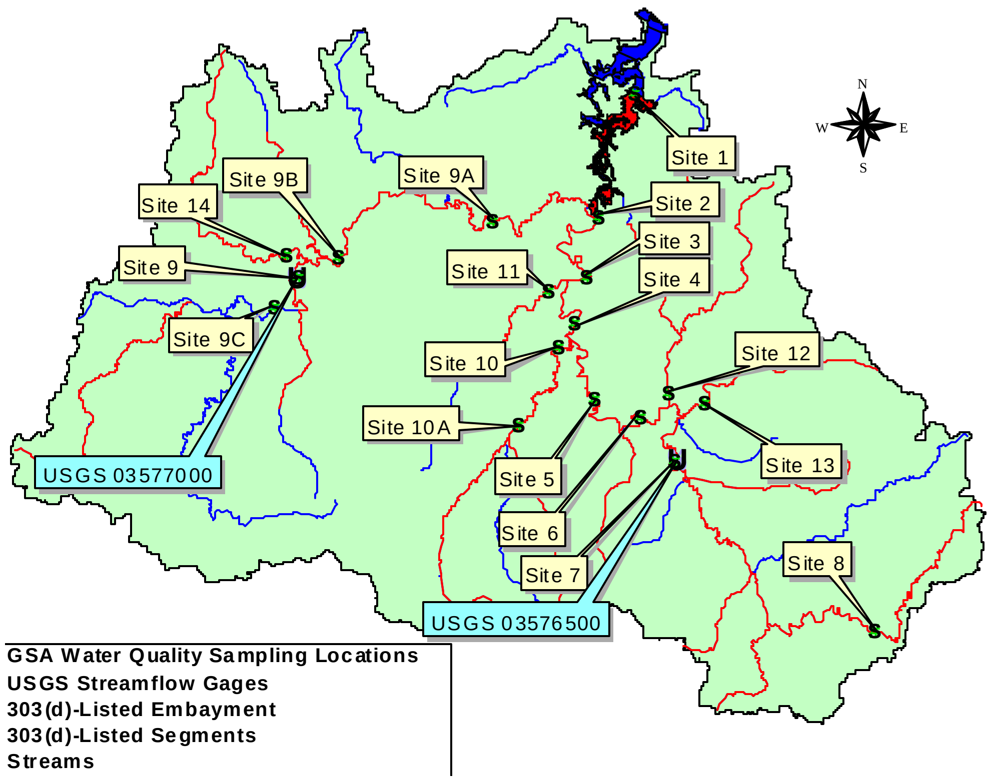


Figure 4-2 Location of USGS Flow Gauges and GSA Sampling Stations

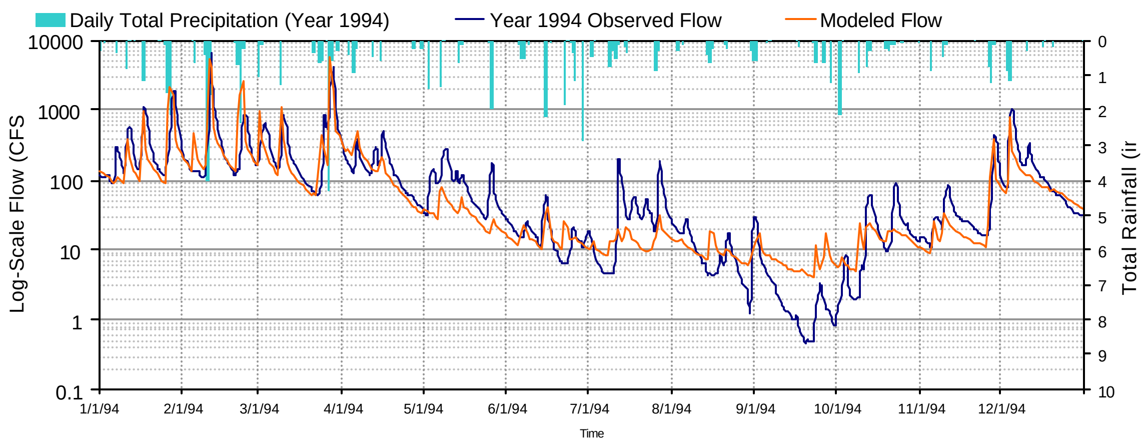


Figure 4-3 Comparison of Simulated and Measured Flow at USGS 03576500 for 1994

4.1.2. Watershed Water Quality Model

LSPC was also used to simulate the contribution of nutrients, CBOD, and fecal coliform from adjacent drainage areas and minor wastewater treatment facilities. The LSPC water quality model is critical for the development of TMDLs in the Flint Creek watershed for the following two reasons: a) simulate the time varying nature of deposition on land surfaces and transport to receiving waters; and b) incorporate seasonal effects on the production, fate and transport of nutrients, CBOD, and fecal coliform.

In addition to LSPC, the Region IV Watershed Characterization System (WCS) was used to display, analyze, and compile available information to support water quality model simulations. Results of the WCS characterization are input to a spreadsheet developed by Tetra Tech, Inc. called the Fecal Coliform Loading Estimation Spreadsheet (FCLES). The spreadsheet is used to estimate modeling parameters associated with nutrient, CBOD, and fecal buildup and washoff loading rates. The spreadsheet is also used to estimate direct sources of loading to water bodies from leaking/failing septic systems and animals having access to streams, in particular grazing beef cattle. Information from the WCS and spreadsheet tool were used as input for the LSPC model.

For modeling purposes, the nutrient, CBOD, and fecal coliform sources are represented by the following components:

- runoff loads from land uses (build-up and washoff due to runoff),
- direct source loads from cattle in the streams and failing septic systems, and
- permitted point source discharges to streams simulated within LSPC.

Typically, nonpoint sources are characterized by buildup and washoff processes: they contribute material to the land surface, where they accumulate and are available for runoff during storm events. These nonpoint sources can be represented in the model as land-based runoff from the land use categories to account for their contribution to form loading within the watersheds. Accumulation rates (number per acre per day) can be calculated for each land use based on all sources contributing nutrients, CBOD, and fecal coliform to the surface of the land. For this study, where specific sources were identified as contributing to a land use, accumulation rates were calculated. For example, grazing livestock and wildlife are specific sources contributing to land uses within the watershed. The land uses that experience accumulation due to livestock and wildlife include:

- Cropland (livestock and wildlife),
- Forest (wildlife),
- Pasture (livestock and wildlife), and
- Wetlands (wildlife).

Accumulation rates can be derived using the distribution of animals by land use and using typical production rates for different animal types. The nutrient, CBOD, and fecal coliform accumulation rates for pasturelands is the sum of the individual accumulation rates due to contributions from grazing livestock, the application of manure (dairy cows and chickens), and wildlife. The nutrient, CBOD and fecal coliform accumulation rates for cropland is the sum of the individual accumulation rates due to contributions from grazing livestock, the application of manure (hogs and chickens), and wildlife.

The estimated number of livestock animals in the Flint Creek watershed is discussed in detail within the Modeling Report (Tetra Tech, 2003). For modeling purposes, it was assumed that dairy cows are confined most of the time and that their waste is applied to pasture land. Beef cattle were assumed to have access to streams and were considered to be a direct nonpoint source of nutrients to the stream reaches. Chicken waste was assumed to be applied to pasture and hog waste was assumed to be applied to cropland.

Literature values for typical nutrient, CBOD, and fecal coliform accumulation rates were used for the urban land uses. The literature value used for urban land uses is the median default value for commercial land (Horner, 1992). The value used for barren and strip mining land uses was half of the urban value. The value used for harvested wood land use was the same value as forest.

Wildlife is another potential source of nutrients, CBOD, and fecal coliform to receiving waters. For modeling purposes, the deer population was assumed to represent the wildlife contribution, since population data for other wildlife species in the watershed was not readily available. It was assumed that deer habitat within the watershed includes forest, cropland, pasture, and wetlands. Typical estimates for the distribution of white-tailed deer within the region were provided by the Alabama Department of Conservation, Division of Wildlife and Freshwater Fisheries (2000). The provided density (deer per square mile) was applied to deer habitat areas within the watershed to estimate population counts by subwatershed. The Flint Creek watershed typically has 15 or less deer per square mile. An average density of 7.5 deer per square mile was applied to forest, pasture, and cropland while a density of 15 deer per square mile was applied to wetland areas.

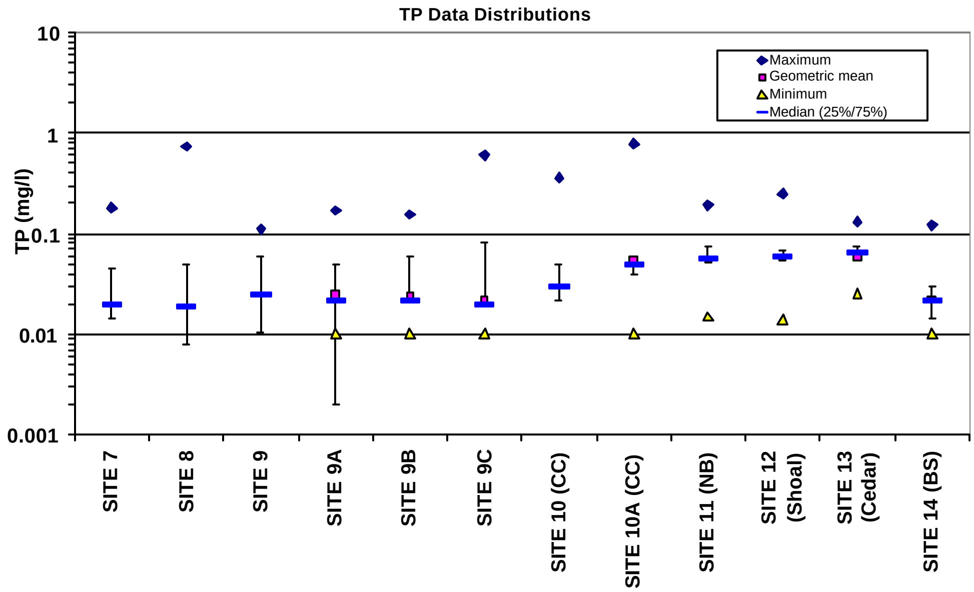
Cattle depositing manure directly into stream reaches represents a direct nonpoint source of nutrients, CBOD, and fecal coliform. The number of cattle producing and depositing waste in streams in the watershed at any give time were determined from cattle count numbers provided by the Tennessee Valley Authority (TVA). The percentage of cattle adjacent and non-adjacent to the stream reaches was determined for each subwatershed based on information provided in the *Flint Creek Watershed Project: Flint Creek Pollutant Loading Estimates* (S&WCD, 1995). It was assumed that 10 percent of the beef cattle have access to the stream, three percent are actually in the stream, and one percentof the cattle are depositing waste directly in the stream. The cattle were simulated in the model as direct sources of nutrients, CBOD, and fecal coliform loads, with a representative flow rate (cubic feet per second) and load (counts per hour). The representative load was calculated based on the number of cows in the stream and the production rate for cows. The flow was estimated based on the number of cows in the stream, the manure production rate of cows (ASAE, 1998) and the approximate density of cow manure.

Failing septic systems represent a nonpoint source that can contribute nutrients, CBOD, and fecal coliform to receiving waterbodies through surface or subsurface malfunctions. The estimated number of septic systems and the percent failure rate were provided by the SWCA Database. To provide for a margin of safety accounting for the uncertainty of the number, location, and behavior (e.g., surface vs. subsurface breakouts; proximity to stream) of the failing systems, failing septic systems are represented in the model as direct sources to the stream reaches. Contributions from failing septic system discharges are included in the model with a representative flow and concentration, which were quantified based on the following information:

- Number of failing septic systems in each subwatershed.
- Estimated population served by the septic systems (an average of 2.5 people per household, obtained from 2000 Bureau of the Census data).
- An average daily discharge of 70 gallons/person/day (Horsley & Witten, 1996).
- Septic effluent concentration of 220 mg/l of CBOD5, 15 mg/L organic nitrogen, 25 mg/L ammonia, 3 mg/L organic phosphorus, and 5 mg/L inorganic phosphorus, and 1 x 10^5 counts/100mL fecal coliform (Metcalf and Eddy, 1991).
- Assumed delivery ratio for direct discharge.

Following hydrology calibration, the water quality constituents were calibrated. Modeled versus observed in-stream concentrations for all of the nutrient species, the CBOD, and fecal coliform were directly compared during model calibration. The water quality calibration consisted of executing the watershed model, comparing water quality time series output to available water quality observation data, and adjusting water quality parameters within a reasonable range.

The time period of the model simulation was from 1993 through 1998. This time period was selected based on the availability and relevance of the observed data to the current conditions in the watershed. For each water quality sampling site, model results were plotted against the respective observed data to assess the model's response to spatial variation of loading sources. Figure 4-4 shows a data to model comparison of the longitudinal total phosphorus distributions as simulated by the LSPC watershed model for 1993 through 1998. Figure 4-5 shows a similar plot for fecal coliform comparison. A detailed discussion of the results of the water quality calibrations along with all assumptions utilized for each of the listed pollutants are presented in the Modeling Report (Tetra Tech, 2003).



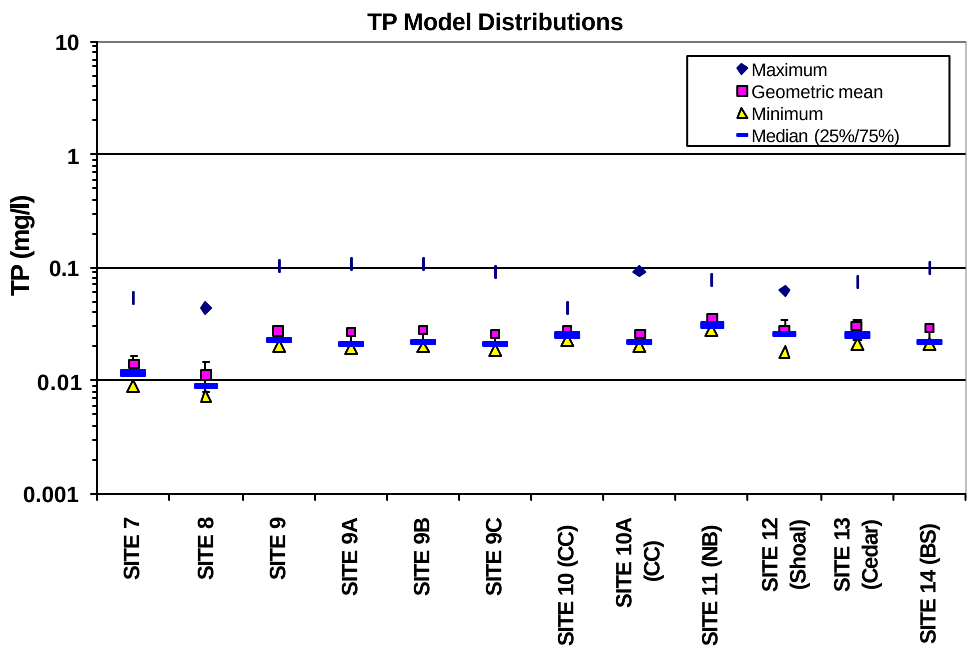
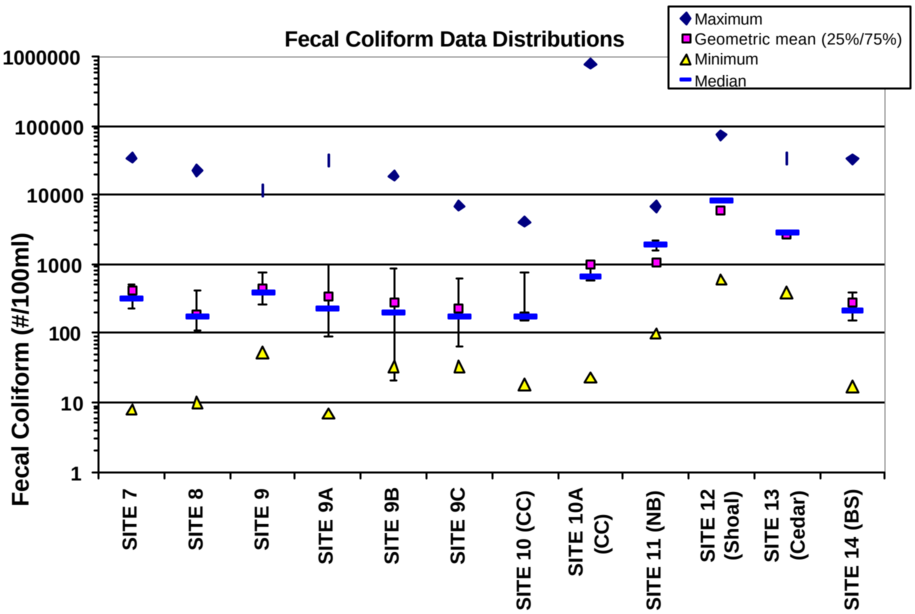


Figure 4-4 1993-1998 LSPC Watershed Model versus Total Phosphorus Data



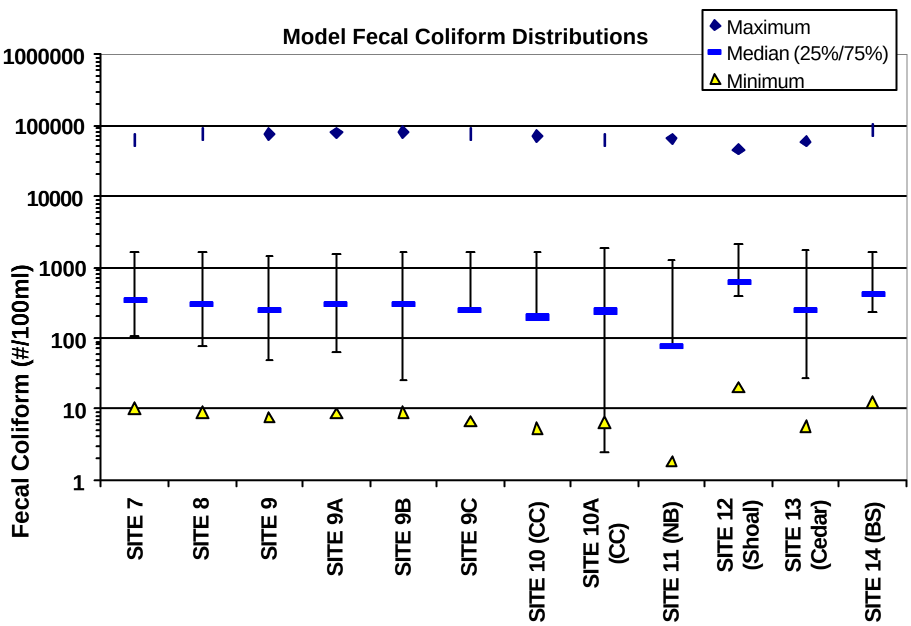


Figure 4-5 1993-1998 LSPC Watershed Model versus Fecal Coliform Data

For fecal coliform, the instantaneous criterion of 2000 counts/100mL was used. A full 6-year simulation was run applying reductions until the target of 2000 counts/100mL was met at all times. Figure 4-6 presents an example plot of a fecal simulation with the existing load, the instantaneous target and the time series of fecal coliform under the revised loading condition. As Crowdabout Creek is within a primarily rural area, the load reductions come from the following sources:

- Direct loading from cattle with access to streams,
- Buildup and runoff of loadings from pasture lands, and
- Loading from failing septic systems.

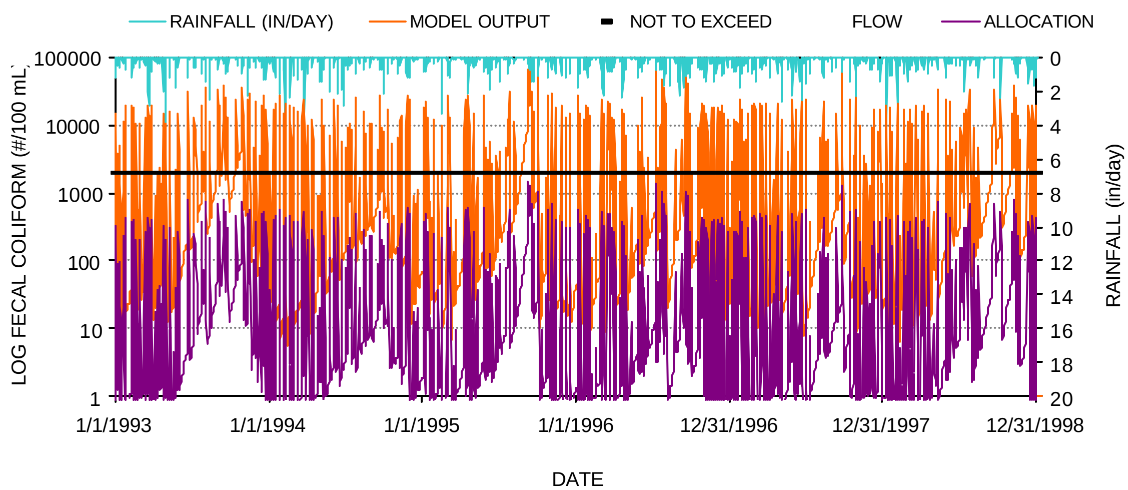


Figure 4-6 Existing Condition and Allocation Condition Runs for Crowdabout Creek for the Instantaneous Fecal Coliform Criterion.

For the geometric mean criterion, the time series output was filtered to provide a running 30-day geometric mean over the period of simulation. The results are then evaluated against the criteria that vary seasonally, i.e. 200 counts/100mL during the summer months and 1,000 counts/100mL during the winter months. Figure 4-7 presents a plot of the geometric mean evaluation with the fecal coliform criteria shown by season.

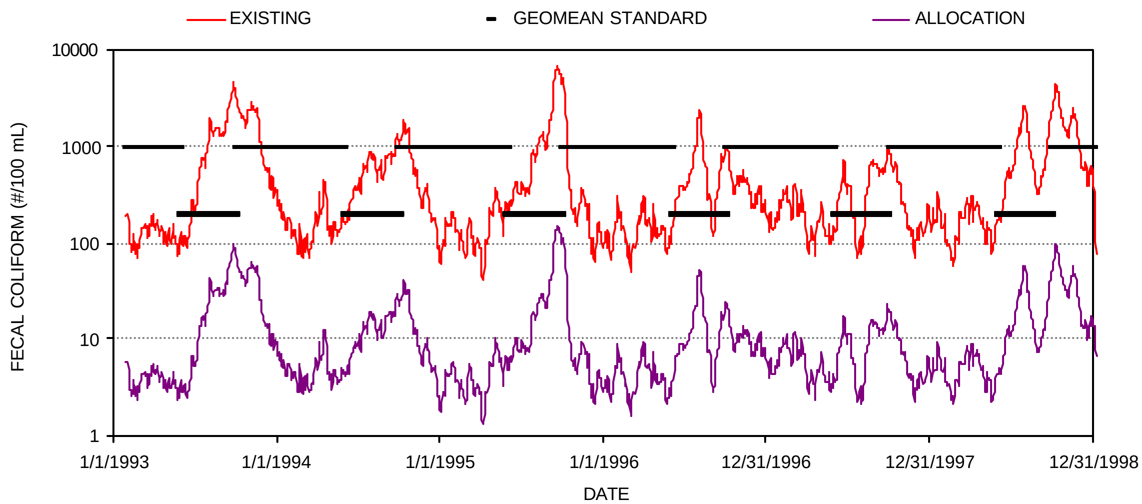


Figure 4-7 Existing Condition and Allocation Condition Runs for Crowdabout Creek for the 30-day Geometric Mean Fecal Coliform Criteria.

4.2 Receiving Water Models

Section 4.1 presented the watershed model utilized to develop the time dependant overland flows and pollutant concentrations to be input to the receiving water models. The receiving water models take the pollutant loads from the watershed model and provide for the transport and transformation of the material as it moves through the mainstem of Flint Creek. The smaller, upstream point sources were included in the LSPC watershed model. The two major point source discharges, Hartselle WWTP and Falkville HCR Lagoon, are included directly in the receiving water models. In the case of nutrients and organic material, the models provide for the oxidation, nitrification, uptake through photosynthesis, and other processes, and simulates the instream dissolved oxygen concentrations. In the case of fecal coliform, the receiving water models provide for instream decay using first order processes. Additionally, the instream models provide for the balance in the water column between oxygen depletion due to the processes described above, sediment oxygen demand, and reaeration across the water surface. These processes act on the water as it moves through the system under the simulated flow and transport.

4.2.1. Hydrodynamic Model (EFDC)

In order to simulate the flow and transport within the listed reaches, a hydrodynamic model which simulates the flow, velocity, and transport was developed. The Environmental Fluid Dynamics Code (EFDC) model was utilized with a two-dimensional simulation grid within the lower reaches of Flint Creek. This area is primarily a backwater area of Wheeler Lake. Within the upper portions of the Flint Creek and West Flint Creek, the grid was reduced to one dimension.

EFDC is a general-purpose modeling package for simulating dynamic advection and dispersion in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands and nearshore-to-shelf-scale coastal regions. The EFDC model was originally developed at the Virginia Institute of Marine Science for estuarine and coastal applications and is considered public domain software. The EFDC code has been extensively tested and documented.

EFDC solves the hydrodynamic continuity, momentum, and transport equations. In addition, it allows for specification of time variable water surface elevation at the downstream boundary, i.e. allowing a time dependent Lake Wheeler water surface elevation as the downstream boundary of the Flint Creek simulations. Specific details on the model equations, solution techniques and assumptions can be found in Hamrick (1996).

Inputs to the EFDC Flint Creek and West Flint Creek hydrodynamic model include the following:

- Model grid and geometry,
- Lake Wheeler water surface elevation,
- Meteorological data from Huntsville, AL, and
- Flows at headwaters and distributed flows from watershed.

The model grid was developed based upon the shorelines from USGS Topographic Maps, measured cross-sectional information from ADEM, elevation data (7.5 minute Digital Elevation Model [DEM] from USGS), and stream connectivity (from the National Hydrography Dataset stream coverage). Figure 4-8 presents a schematic of the EFDC model grid with the two-dimensional area in the embayment and 1-dimensional segments in the riverine areas. The grid covers the mainstem Flint Creek, West Flint Creek, and the impounded portion of No Business Creek.

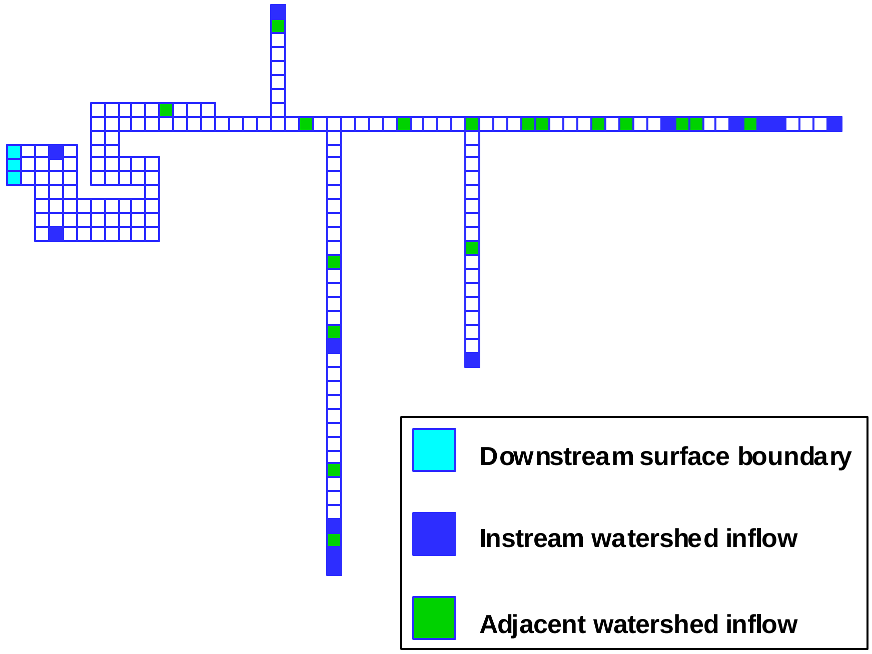


Figure 4-8 Schematic of EFDC Hydrodynamic Model Grid

The lower boundary of the model grid is at the mouth of Flint Creek to Lake Wheeler. The lake level fluctuates seasonally based upon prescribed lake management practices. The lake levels fluctuate between 550 and 556 feet NGVD with low lake levels from November through March and high lake levels from March through October. The degree of backwater in the system during the summer months when the lake level is maintained near 556 feet can be critical. During this period, backwater in the system reaches over 20 miles upstream.

Flow inputs to the system come at headwaters of the reaches within the model, as well as distributed flows representing tributary inflow and direct overland flow from adjacent catchments. Headwater flows are derived from the LSPC model output at the "pour point" of subwatersheds that discharge to the headwaters of the various simulated reaches.

EFDC was used to simulate the dynamic transport and decay of fecal coliform concentrations in the lower Flint and West Flint Creeks based on the watershed inputs.

Further information about the EFDC application and calibration is detailed in the modeling report (Tetra Tech, 2003).

4.2.2. Water Quality Model (WASP)

In order to simulate the temporal and spatial concentrations of nutrients, BOD, dissolved oxygen, and chlorophyll-*a*, a water quality model was utilized which simulates the full eutrophication kinetics including phosphorus and nitrogen cycling, oxidation of organic material, sediment oxygen demand, and reaeration across the water surface. The WASP model was configured with a two-dimensional simulation grid identical to that developed for EFDC. Within the upper portions of Flint Creek and West Flint Creek, a one-dimensional application of the WASP model was applied.

For simulation of the water quality, the EFDC model was externally linked to the Water Quality Analysis Simulation Program (WASP) through a hydrodynamic forcing file that contains the flows, volumes, and exchange coefficients between adjacent cells. WASP 6.1, an enhancement of the original WASP model (Di Toro et al., 1983; Connolly and Winfield, 1984; Ambrose, R.B. et al., 1988), is a dynamic compartment model for aquatic systems, including both the water column and the underlying benthos. The time varying processes of advection, dispersion, point and diffuse mass loading, and boundary exchange are represented in the basic program.

Water quality processes are represented in special kinetic subroutines that are either chosen from a library or written by the user. WASP is structured to permit easy substitution of kinetic subroutines into the overall package to form problem-specific models. WASP permits the modeler to structure one, two, and three-dimensional models; allows the specification of time-variable exchange coefficients, advective flows, waste loads and water quality boundary conditions; and permits tailored structuring of the kinetic processes, all within the larger modeling framework without having to write or rewrite large sections of computer code.

For the Flint Creek watershed simulations, the WASP model was run under full eutrophication kinetics with the following state variables simulated:

- Dissolved oxygen (DO),
- Ultimate Carbonaceous Biochemical Oxygen Demand (CBODU),
- Ammonia as Nitrogen (NH_3-N),
- Nitrate/Nitrite as N (NO_3NO_2-N),
- Organic Nitrogen (ON),
- Organic Phosphorus (OP),
- Ortho-Phosphorus (PO_4-P), and
- Chlorophyll-a.

In order to perform the full eutrophication simulations the following general input conditions were required.

- Boundary flows and concentrations for all 8 state variables where flow enters the model,
- Spatial distribution of Sediment Oxygen Demand,
- Spatial distribution of reaeration,
- Flows and concentrations for point source discharges within the receiving water domain,
- Meteorological inputs, and
- Model input coefficients.

Boundary flows and concentrations were derived from the LSPC simulations described in Section 4.1.2. The boundary conditions utilized in the simulations are presented in detail in the modeling report.

Sediment Oxygen Demand measurements were taken at various locations throughout the system (EPA 1996). These values were utilized to develop the Sediment Oxygen Demand throughout the system with average values used in the model.

For the Flint Creek modeling only two of the permitted point source discharges were input directly into the receiving water models (EFDC/WASP). The remaining five point source discharges were loaded into the subwatersheds within the LSPC model and therefore reach the receiving water models through the flow and concentration boundary condition inputs.

Meteorological data used in the WASP model were measured at the Huntsville, AL weather station. For the WASP model, hourly weather data is utilized for the inputs.

Figure 4-9 shows a dissolved oxygen calibration plot at Site 3 on Flint Creek. This is the area where the lowest dissolved oxygen (DO) sag usually occurs.

The WASP model input coefficients reflect the best available literature values, and where available (i.e. CBOD decay rate) site-specific values are utilized. The best fit between the WASP model simulations and the measured data was obtained by variation of critical parameters within the range of acceptable literature values. Where site-specific measured values are used, no adjustment of those coefficients is made. A full detailed discussion of the WASP model inputs, assumptions and calibration is presented in the Modeling Report (Tetra Tech, 2003).

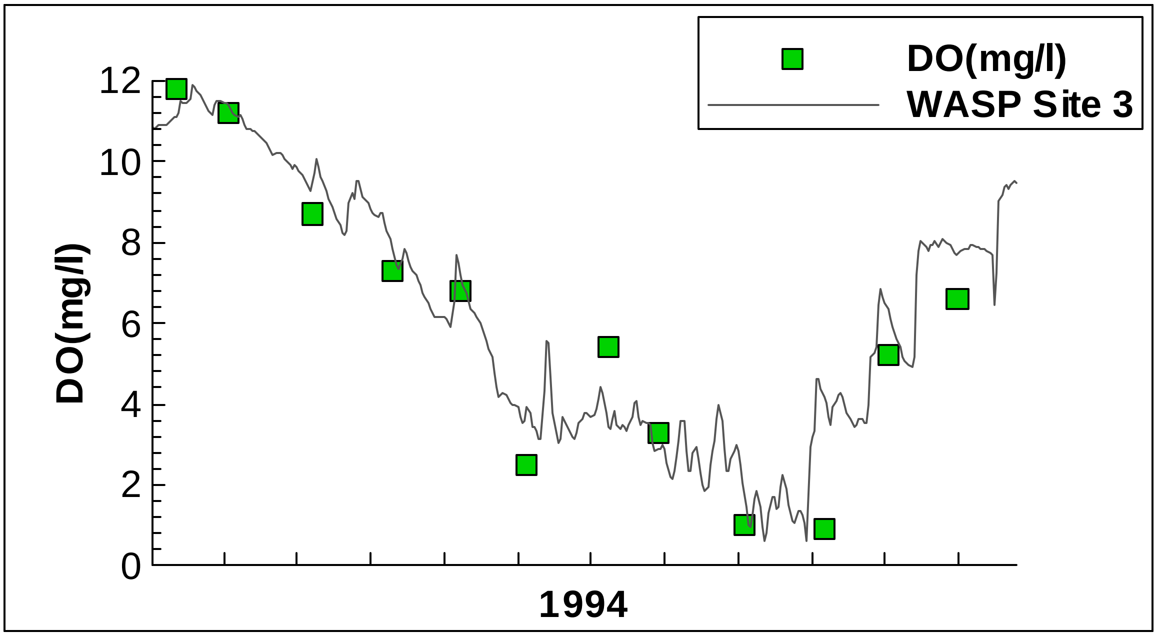


Figure 4-9 1994 Dissolved Oxygen WASP Calibration at Site 3 (Low Point of DO Sag)

5.0 TMDL Development

This section presents the TMDLs developed for OE/DO and Fecal Coliform for the Flint Creek watershed. Nutrients were evaluated and addressed with the OE/DO TMDLs, therefore separate TMDLs for nutrients were not necessary. A TMDL is the total amount of a pollutant load that can be assimilated by the receiving water while still achieving water quality criteria, in this case Alabama's water quality criteria for aquatic life. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are comprised of the sum of individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this definition is denoted by the following equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

In order to develop the TMDL, the following steps will be defined:

- TMDL Endpoints,
- Baseline Conditions,
- Critical Conditions,
- TMDL Scenarios,
- Load Reductions,
- Margin of Safety, and
- Seasonal Variation.

5.1 TMDL Endpoints

The TMDL endpoints represent the in-stream water quality targets used in quantifying the load reduction necessary to attain water quality standards. The TMDL endpoints can be a combination of water quality criteria, both numeric and narrative, and surrogate parameters that would ensure the criteria are being met. The following presents the endpoints used for each of the parameters simulated.

5.1.1. OE/DO and Nutrients

The dissolved oxygen criteria were used as the endpoint for developing the TMDLs. The F&W stream segments must meet a 5.0 mg/L minimum and the LWF stream segment on Flint Creek must meet a 3.0 mg/L in the summer period. The organic enrichment and nutrient components of the TMDL are considered in the dissolved oxygen target.

Since DO concentrations in Flint Creek at low flow are dominated by the effects of sediment oxygen demand, SOD was used as a surrogate parameter to ensure that the dissolved oxygen criteria would be met. The WASP model showed the sensitivity of

SOD on the dissolved oxygen concentrations due to the low flows and shallow depths exhibited in the watershed. The WASP model was used to determine an appropriate SOD target that would maintain the 3.0 mg/L for the LWF segment and 5.0 mg/L in the lower F&W segment. The model demonstrated that SOD at 1.5 g O_2/m^2/day would be sufficient to meet DO criteria, a reduction from measured SOD of 3.3 g O_2/m^2/day measured in Flint Creek (EPA, 1996).

5.1.2. Pathogens

The TMDL endpoint for the pathogen TMDLs was the water quality criteria summarized as follows:

- LWF: 2,000 counts/100mL (instantaneous maximum)
  1,000 counts/100mL (30-day geometric mean)
- PWS: 2,000 counts/100mL (instantaneous maximum)
  1,000 counts/100mL (October through May 30-day geometric mean)
  200 counts/100mL (June through September 30-day geometric mean)
- FW: 2,000 counts/100mL (instantaneous maximum)
  1,000 counts/100mL (October through May 30-day geometric mean)
  200 counts/100mL (June through September 30-day geometric mean)

5.2 Baseline Conditions

The calibrated model provided the basis for performing the allocation analysis. The first step in the analysis involves simulation of baseline conditions. Baseline conditions represent existing nonpoint source loading conditions and permitted point source discharge conditions. The existing load for the listed segment is represented as the sum of the daily discharge load of the direct nonpoint sources, the point sources loads, and the daily load indirectly going to surface waters from all land uses (e.g., surface runoff) for 1994. The baseline conditions allow for an evaluation of in-stream water quality under critical conditions.

The model was run for baseline conditions from 1993-1998. Predicted instream concentrations of dissolved oxygen for the listed waterbodies and their tributaries were compared directly to the TMDL endpoints. This comparison allowed evaluation of the expected magnitude and frequency of exceedance under a range of hydrologic and environmental conditions, including dry periods, wet periods, and more typical periods. Calibration plots of 1993 through 1998 are shown in Section 4 and also in the modeling report (Tetra Tech, 2003).

5.2.1. OE/DO and Nutrients

The baseline nutrient and CBOD loads were established for all of the listed segments and are shown in Table 5-1. These loads were developed from a combination of the LSPC watershed model and the WASP water quality model. The LSPC loads were generated from six years (1993-1998) of model output and an average was calculated. The WASP loads were generated from two years (1993-1994) of model output and an average was calculated. All of the loads were simulated at the downstream of each listed segment to calculate a total existing load.

Table 5-1 Baseline (Existing) Loads for the Impaired Segments

	6-yr Existing Annual Loads (lb/yr)			6-yr Median Concentrations (mg/l)		
Impaired Segments	**CBODU**	**TN**	**TP**	**CBODU**	**TN**	**TP**
Flint Creek*	2,420,538	1,306,392	47,381	1.8	1.5	0.068
Shoal Creek	160,266	66,755	3,655	2.1	0.9	0.041
Town Branch	30,700	7,076	509	4.2	1.0	0.048
Mack Creek	63,739	38,142	1,577	1.8	1.0	0.040
Robinson Creek	82,793	42,606	2,287	1.6	0.9	0.035
Crowdabout Creek	799,229	224,175	9,721	2.5	1.0	0.038
No Business Creek*	605,860	192,529	6,229	2.8	1.3	0.048
Village Branch	65,436	36,916	2,504	1.3	0.8	0.026
McDaniel Creek	284,027	64,349	2,371	3.3	1.1	0.043
Cedar Creek	188,545	101,469	4,369	1.8	1.0	0.040
E. Fork Flint Creek	157,033	94,488	3,837	1.4	1.0	0.044
Indian Creek	44,612	18,857	1,334	1.4	0.8	0.029
Herrin Creek	32,940	35,267	1,775	2.1	1.0	0.045
West Flint Creek*	1,582,442	792,016	26,924	1.8	1.3	0.050
Big Shoal Creek	209,519	106,869	3,586	2.2	1.0	0.054
Elam Creek	283,654	85,928	4,451	2.6	1.0	0.036
Flat Creek	90,521	50,256	1,840	2.1	1.1	0.048

*WASP results for 2-yr average 1993-1994

Note: Flint Creek loads include all tributaries less instream decay

5.2.2. Pathogens

The fecal coliform baseline load was simulated for all six years (1993 through 1998) with the LSPC watershed model and the EFDC model. Table 5-2 shows a comparison of measured data maximums, model output results, and fecal coliform criteria for GSA sampling sites.

Table 5-2 Summary of Fecal Coliform Comparison for Baseline Conditions

303(d)-Listed Stream Segment	GSA Data Site	Data Maximum (#/100ml)	Applicable Water Quality Model	Model Maximum (#/100ml)	Instant-aneous Criterion (#/100ml)	Model Geometric Mean Maximum (#/100ml)	Geometric Mean Criterion (#/100ml)
Flint Creek	Site 1	6,000	EFDC (1994)	17,800	2,000	812	1000/200
Flint Creek	Site 2	20,000	EFDC (1994)	17,600	2,000	1,075	1000/200
Flint Creek	Site 3	6,200	EFDC (1994)	23,800	2,000	1,690	1000/200
Flint Creek	Site 4	56,000	EFDC (1994)	28,000	2,000	3,500	1000/200
Flint Creek	Site 5	35,000	EFDC (1994)	29,700	2,000	3,465	1,000
Flint Creek	Site 6	104,000	EFDC (1994)	31,300	2,000	4,320	1,000
Flint Creek	Site 7	35,000	LSPC (6-yr)	88,400	2,000	4,900	1000/200
West Flint Creek	Site 9A	32,000	EFDC (1994)	20,200	2,000	1,250	1000/200
E.Fork Flint Creek	Site 8	23,000	LSPC (6-yr)	68,200	2,000	4,200	1000/200
Crowdabout Creek	Site 10A	800,000	LSPC (6-yr)	68,300	2,000	4,600	1000/200
No Business Creek	Site 11	6,900	LSPC (6-yr)	78,400	2,000	4,700	1000/200
Shoal Creek	Site 12	74,000	LSPC (6-yr)	102,000	2,000	14,700	1000/200
Cedar Creek	Site 13	34,000	LSPC (6-yr)	92,700	2,000	10,600	1000/200

5.3 Critical Conditions

5.3.1 OE/DO and Nutrients

For the mainstem Flint Creek and West Flint Creek, data analysis showed that the critical condition for dissolved oxygen is the summer low flow, high temperature periods. The dissolved oxygen conditions within the Flint Creek watershed corresponds to summer periods of low flow, where Lake Wheeler levels create significant backwatering up the Flint Creek and the West Flint Creek. For the purpose of this TMDL, a low-flow year with high temperatures (1994) was utilized for the purpose of determining the TMDL to represent the worst-case conditions. The simulations were performed with time dependant daily fluctuations of Lake Wheeler water surface elevation, simulated inflows from the LSPC model with simulated concentrations of the eight state variables, measured meteorological conditions, and measured sediment oxygen demand. Nutrient enrichment of the lower reaches and the associated chlorophyll-a increases also coincide with the low flow summer period and is simulated with the models.

5.3.2 Pathogens

For fecal coliform two criteria must be met to ensure that the waterbody is meeting its designated uses. One is a geometric mean (30-day) that comes in to play during the low flow summer months. The critical condition therefore is a low flow summer period that was simulated for 1994. The second is an instantaneous criterion that normally applies during storm event conditions. For the evaluation of the instantaneous criterion simulations over the 6-year period encompass sufficient conditions to fully reflect the critical periods.

5.4 TMDL Scenarios for OE/DO and Nutrients

The WASP model was used to run the following scenarios to achieve a dissolved oxygen endpoint that meets the 5.0 and 3.0 mg/L criteria:

- Critical conditions with existing permit limits and watershed loads,
- Critical conditions with proposed TP limits on major point sources and existing SOD (3.3 gO_2/m^2/day), and
- Critical conditions with proposed TP limits on major point sources and reduced SOD (1.5 gO_2/m^2/day).

After extensive model runs and nutrient reduction scenarios, it was evident that the dissolved oxygen concentrations in the downstream segments of the Flint Creek and even in the embayment were controlled by flow, velocity and reaeration, water temperature, and sediment oxygen demand (SOD). Currently, the WASP model does not have a sediment diagenesis algorithm to simulate SOD processes. It is an input into the model, rather than using deterministic methods to predict SOD based on instream loads and settling rates. To accomplish this relationship, another model was used to establish a link between instream loads of CBODU, TN, and TP versus SOD.

An SOD model developed by Quantitative Environmental Analysis (QEA) and modified by Dr. James Martin at Mississippi State University (MSU) was implemented to determine the relative change in SOD by reducing the watershed load.

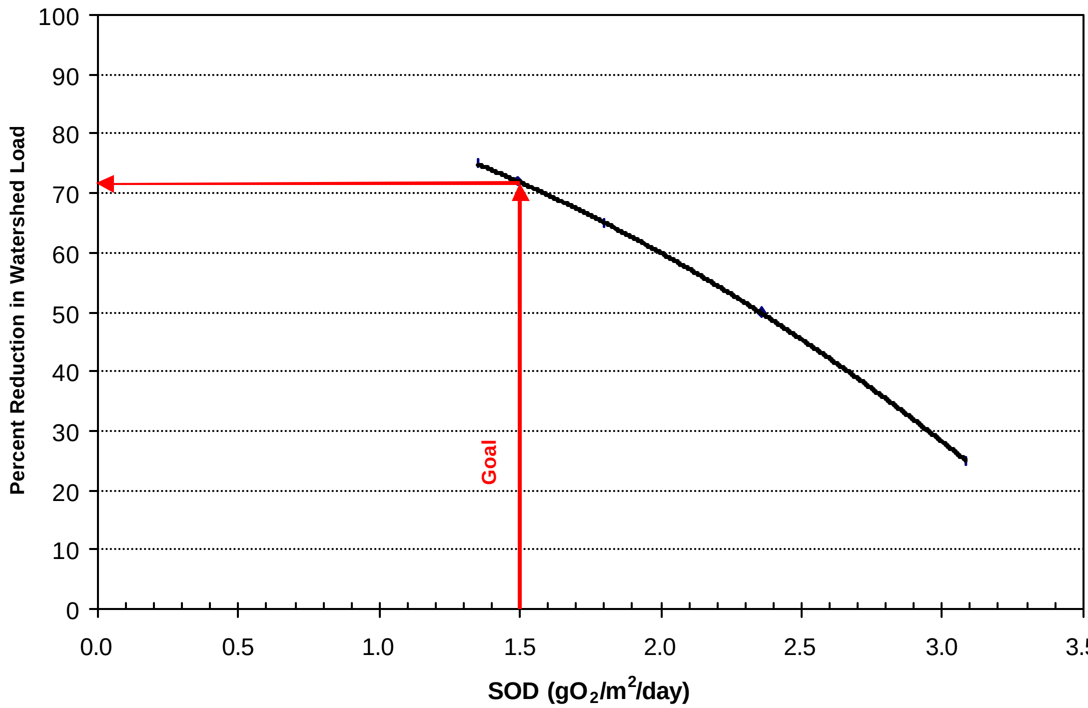


Figure 5-1 SOD Model Predicted Relationship between Percent Reduction of Watershed Load and SOD

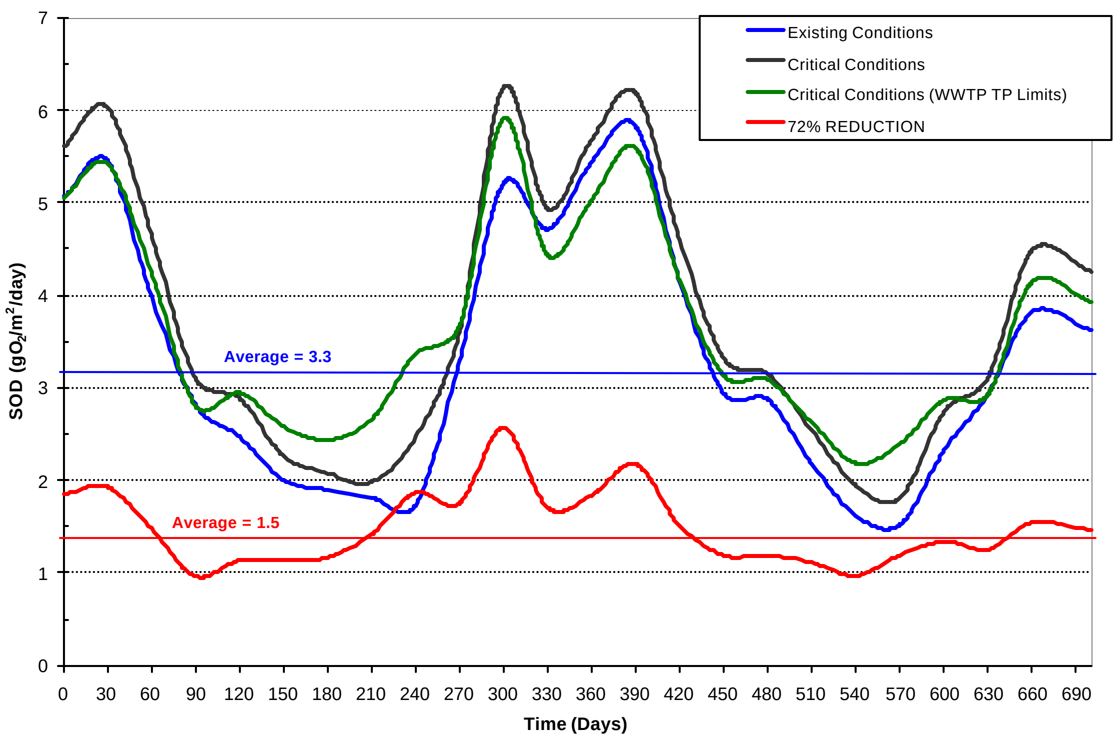


Figure 5-2 SOD Reduction Scenarios

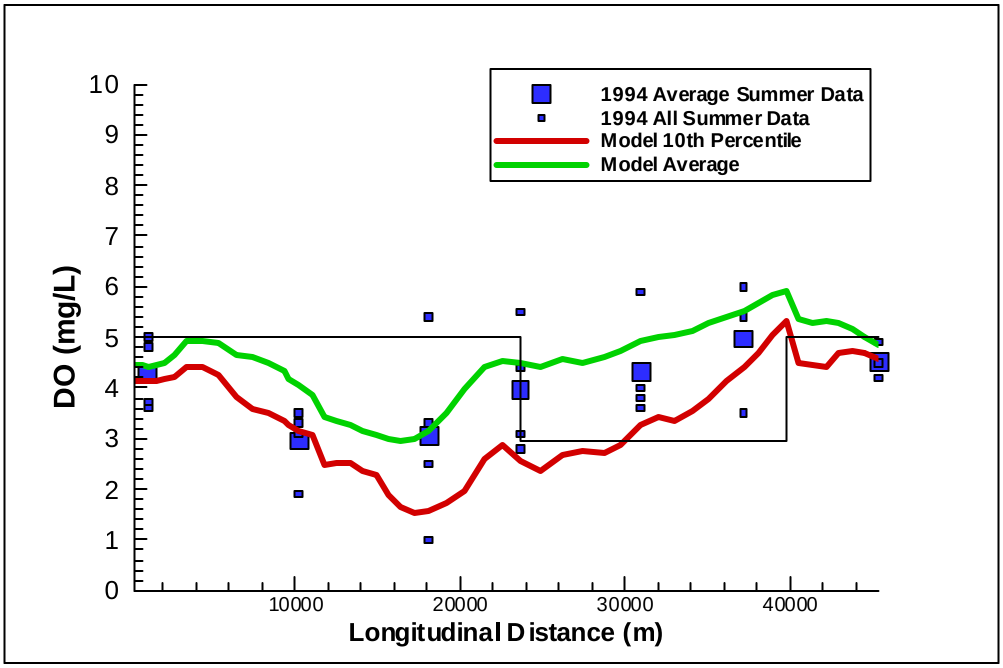


Figure 5-3 Longitudinal Comparison of Simulated and Measured Dissolved Oxygen for June-September 1994

In order to determine the conditions necessary to meet the DO targets, the WASP model was run with all point sources at their existing permit limits for BOD, NH3, and DO; and maximum design flows. The Falkville lagoon was characterized by the scenario where the lagoon fills at the designated design flow and discharges according to the HCR regression equation and low-flow limitations. Further details are described in the Modeling Report (Tetra Tech, 2003).

The WASP model was found not to be sensitive to instream BOD concentrations; rather, the SOD dominates the oxygen balance of the system. SOD was reduced to 1.5 gO_2/m^2/day in order to achieve the DO targets of 3.0 mg/L in the LWF segment and 5.0 in the F&W segment. 10^{th} percentile WASP model results for the critical period are shown in Figure 5-5.

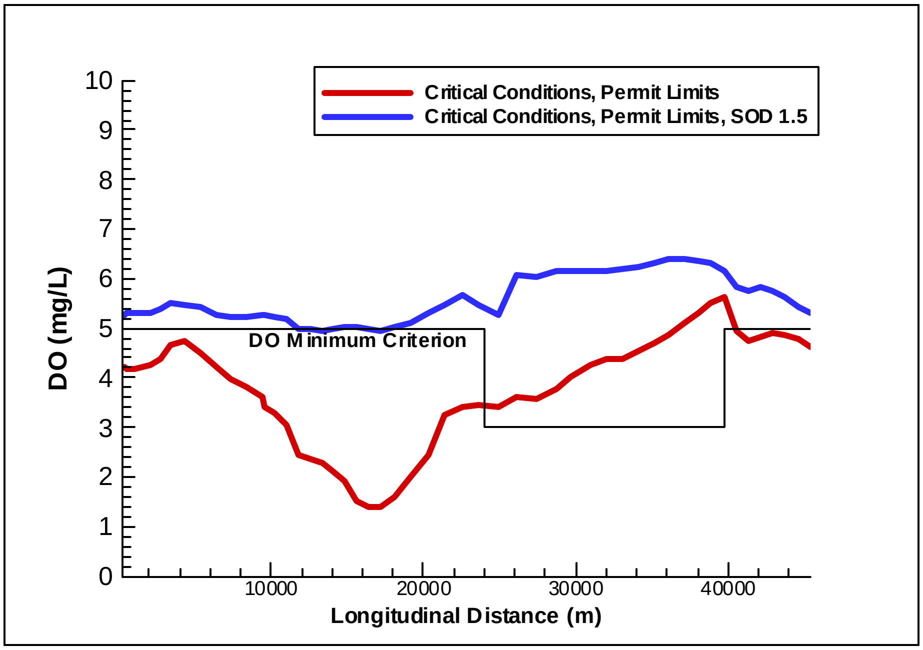


Figure 5-4 Model Dissolved Oxygen, 10th percentile May-November 1993-1994

5.4.1 TMDL for OE/DO - Flint Creek and West Flint Creek Segment

The point source loads in consideration were the two majors including Hartselle WWTP and Falkville Lagoon discharging to Flint Creek segment 06030002-330_01, and five minor point sources discharging to tributaries. The nutrient TMDL for this segment is TP load of 19,321 lb/yr and TN load of 315,216 lb/day and the BODU load for the OE/DO TMDL is 703,283 lb/yr. Table 5-3 shows the proposed Wasteload Allocations based on the existing permit limits and assumed nutrient concentrations.

Table 5-3 Wasteload Allocations for NPDES Point Sources

Permittee/NPDES	Season	Permit Flow (MGD)	CBOD5 permit (mg/l)	NH3 permit (mg/l)	TN- assumed (mg/l)	TP- assumed (mg/l)	CBODU (mg/l)	CBODU (lb/yr)	TN (lb/yr)	TP (lb/yr)
Hartselle	SUMMER	2.7	8.0	1.0	5.0	1.0	17.2	70,150	20,392	4,078
AL0054674	WINTER	2.7	14.0	2.0	5.0	1.0	30.1	122,763	20,392	4,078
Falkville AL0021113	ANNUAL	0.275	30	20.0	23.0	4.5	64.5	26,793	9,554	1,869
Ala Sheriffs Boys Ranch	SUMMER	0.013	4.0	1.2	12.2	3.0	8.6	172	244	60
AL0059552	WINTER	0.013	7.0	4.1	15.1	3.0	15.1	296	297	59
Danville High School	SUMMER	0.026	5.0	1.0	12.0	3.0	10.8	429	479	120
AL0051870	WINTER	0.026	25.0	1.9	22.9	3.0	53.8	2,111	899	118
Speake Schools	SUMMER	0.0175	10.0	1.2	12.2	3.0	21.5	578	328	81
AL0043028	WINTER	0.0175	30.0	2.1	13.1	3.0	64.5	1,705	346	79
E. Lawrence Schools	SUMMER	0.025	10.0	1.2	12.2	3.0	21.5	825	468	115
AL0054870	WINTER	0.025	25.0	2.1	13.1	3.0	53.8	2,030	495	113
Vinemont School	SUMMER	0.025	25.0	1.4	12.4	3.0	53.8	2,063	476	115
AL0051128	WINTER	0.025	25.0	2.1	13.1	3.0	53.8	2,030	495	113

5.4.2 TMDL Nonpoint Source Load Reductions

For OE/DO, nutrients, and CBOD, the load reductions were derived from the SOD model. The SOD model concluded that a 72% reduction in the total carbon (or CBODU) load must be achieved to meet the dissolved oxygen criterion applicable to lower Flint Creek. This corresponds to a 79% reduction in the nonpoint source load for the entire watershed with existing wasteload allocations. Table 5-4 illustrates the nonpoint source reductions and the resultant TMDLs needed to meet the DO criterion. For nutrients, every segment except Flint Creek, the existing 6-year average nonpoint source loads are equal to the TMDL. Despite impairment by dissolved oxygen, nutrient loading itself does not appear to be causing impairment. This shall be investigated further by ADEM through follow-up monitoring and evaluation.

Table 5-4 TMDL for OE/DO Impaired Stream Segments

	LA (lb/yr)			WLA (lb/yr)			TMDL (lb/yr)		
Impaired Segments	**CBODU**	**TN**	**TP**	**CBODU**	**TN**	**TP**	**CBODU**	**TN**	**TP**
Flint Creek*	471,338	260,269	8,321	231,945	54,947	11,000	703,283	315,216	19,321
Shoal Creek	33,135	13,801	756	192,913	40,867	8,157	226,047	54,668	8,913
Town Branch	6,347	1,463	105	0	0	0	6,347	1,463	105
Mack Creek	13,178	7,886	326	0	0	0	13,178	7,886	326
Robinson Creek	17,117	8,809	473	0	0	0	17,117	8,809	473
Crowdabout Creek	165,238	46,348	2,010	0	0	0	165,238	46,348	2,010
No Business Creek*	124,557	39,515	1,239	2,540	1,378	238	127,097	40,893	1,477
Village Branch	13,529	7,632	518	0	0	0	13,529	7,632	518
McDaniel Creek	58,722	13,304	490	0	0	0	58,722	13,304	490
Cedar Creek	38,981	20,978	903	0	0	0	38,981	20,978	903
E. Fork Flint Creek	31,620	19,334	746	4,093	971	228	35,713	20,305	974
Indian Creek	9,223	3,899	276	0	0	0	9,223	3,899	276
Herrin Creek	6,810	7,291	367	0	0	0	6,810	7,291	367
West Flint Creek*	325,848	163,257	5,459	5,605	2,177	507	331,453	165,434	5,966
Big Shoal Creek	43,317	22,095	741	0	0	0	43,317	22,095	741
Elam Creek	58,645	17,765	920	0	0	0	58,645	17,765	920
Flat Creek	18,715	10,390	380	0	0	0	18,715	10,390	380

5.4.3 Stormwater (MS4) Point Source Load Reductions

The municipal separate stormwater sewer system (MS4) that must be addressed in the TMDL process includes areas within the boundary of the Decatur 1990 Urban Area designated by ADEM as a Phase II MS4.

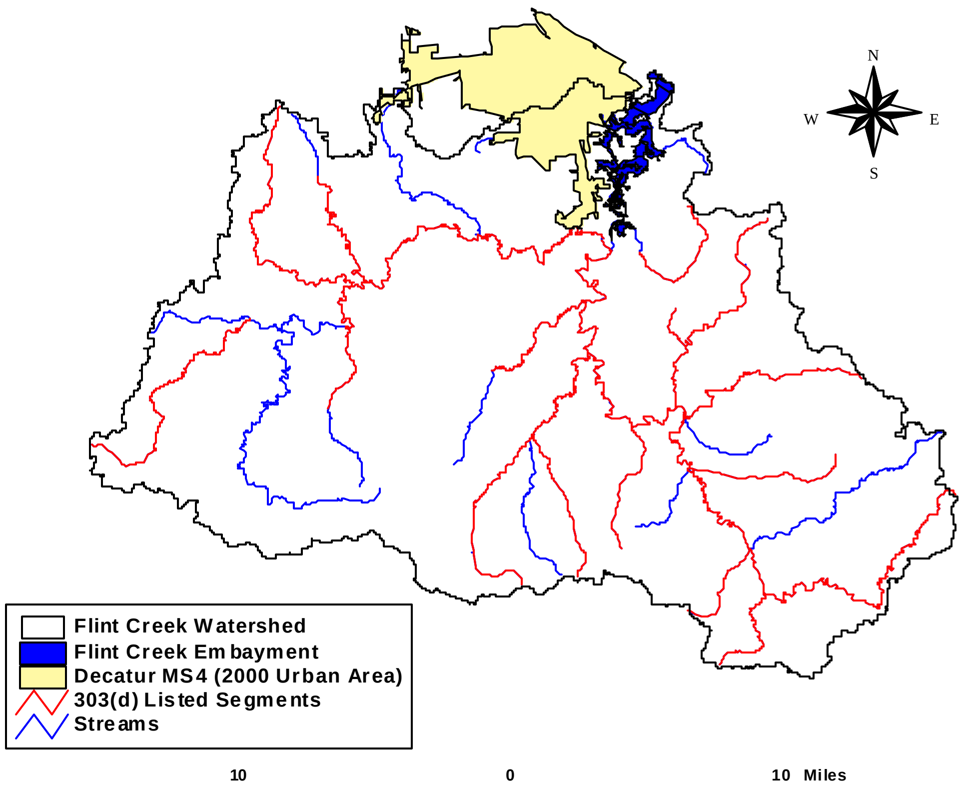


Figure 5-5 MS4 Boundaries Pertinent to Flint Creek Watershed TMDL Development

5.5 TMDL Scenarios for Pathogens

Pathogen TMDLs in the Flint Creek watershed were developed using a combination of the LSPC watershed model and EFDC instream model to dynamically simulate bacteria runoff, transport and decay as a result of rain events and steady discharge from continuous sources. Estimates of animal densities in model subbasins were developed using animal counts and cattle proximity to streams documented by S&WCD (1995), septic system densities recorded in the 1990 Census, and typical bacteria count characteristics of septic and animal waste discharges.

Extremely high fecal coliform counts were recorded frequently in all seven pathogen-listed streams in the Flint Creek watershed, apparently caused by runoff from urban and agricultural land uses, as well as persistent dry-weather sources comprised of cattle with access to streams and potentially failing onsite septic systems. The models were calibrated to measured data to capture seasonal and wet/dry weather trends and magnitudes of runoff concentration peaks.

To meet ADEM's instantaneous and geometric mean pathogens criteria, bacteria loading reductions were applied to the 5 tributary segments considered in the LSPC model. These reductions were applied as a percentage decrease in the land-based runoff sources (urban, pasture land uses) as well as the steady sources (cattle in streams, failing septic systems) until both the instantaneous and seasonal 30-day geometric mean criteria were complied with for the simulated years 1993-1998. In general, steady sources were more of an influence in dry periods and required reductions to meet the geometric mean criterion, while land-based sources influenced runoff peak concentrations and required reductions to meet the instantaneous criterion.

All point sources were assumed to be in compliance with continuous discharge limits of 200 counts/100ml. After the tributary reductions were made, fecal coliform bacteria loading sources were reduced in the remaining watershed contributing to Flint and West Flint Creeks. Reductions for the overall watershed were 97.5 percent to meet water quality criteria, for both land-based and steady sources.

TMDLs were calculated as the 30-day total fecal coliform load in each listed segment, for the period of time when the model calculated 30-day geometric mean was greatest after the necessary reductions were made. MS4 areas are required to make the same reductions as neighboring land uses. Table 5-5 shows the results of the fecal coliform load reductions.

Table 5-5 Fecal Coliform TMDLs and Percent Reductions for Listed Segments

Listed Segment	TMDL	WLAs		LAs		Effective Instream Fecal Coliform Concentration
		WWTFs*	MS4s	Precipitation-Induced Nonpoint Sources	Other Direct Sources (Instream Cattle, Septics, SSOs)	
	(counts/30 day)	(counts/30 day)	(% reduction)	(% reduction)	(% reduction)	(% reduction)
Flint Creek at AL67	4.6E+13	7.0E+11	97.5	97.5	97.5	97.6%
W. Flint Creek	1.5E+13	1.3E+10	97.5	97.5	97.5	97.7%
Shoal Creek	2.6E+12	6.1E+11	---	98.5	99.85	98.2%
Cedar Creek	6.1E+12	---	---	98.4	98.2	98.5%
E. Fork Flint Creek	1.6E+12	5.7E+09	---	97.0	97.5	96.9%
Crowdabout Creek	1.2E+13	---	---	97.0	97.5	97.0%
No Business Creek	1.1E+13	5.9E+09	---	97.5	97.5	97.4%

*Assumed to discharge max 200 #/100ml at permitted flow.

5.6 Margin of Safety

There are two methods for incorporating a MOS in the analysis: a) by implicitly incorporating the MOS using conservative model assumptions to develop allocations; or b) by explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations. The following outlines the MOS issues relative to the TMDL parameters.

The margin of safety was addressed implicitly with modeling assumptions:

- Conservative decay rate for fecal coliform - 0.5 day-First-order decay rate;
- Fecal coliform reductions base on simulated 30-day period rather than instantaneous;
- Six-year simulations for fecal coliform models;
- Two-year simulations for dissolved oxygen.

5.7 Seasonal Variation

Seasonal variation is considered in the development of the TMDL because the allocation runs are performed over an entire calendar year. The model simulates the response of the nutrients, dissolved oxygen, and fecal coliform under various hydrologic, meteorological and loading conditions, thus fully evaluating the potential seasonal variations. In the months of November through March, when the LWF classification goes from a 3.0 mg/L to a 5.0 mg/L, the allocations are evaluated based upon meeting a 5.0 mg/L condition throughout the system.

6.0 Follow Up Monitoring

ADEM has adopted a basin approach to water quality management; an approach that divides Alabama's fourteen major river basins into five groups. Each year, the ADEM water quality resources are concentrated in one of the basin groups. One goal is to continue to monitor §303(d) listed waters. This monitoring will occur in each basin according to the schedule in Table 6-1. The Flint Creek watershed is located in the Tennessee River basin.

Table 6-1 Monitoring schedule for Alabama River Basins

River Basin Group	Scheduled Year
Cahaba / Black Warrior	2002
Tennessee	2003
Choctawhatchee / Chipola / Perdido-Escambia / Chattahoochee	2004
Tallapoosa / Alabama / Coosa	2005
Escatawpa / Upper Tombigbee / Lower Tombigbee / Mobile	2006

Monitoring will help further characterize water quality conditions resulting from implementation of the TMDL via best management practices in the watershed. Furthermore, follow-up monitoring will document the algal conditions in the Flint Creek embayment resulting from the existing nutrient loadings.

It is thought that a decade of nonpoint source pollution prevention administered by the Morgan County Soil and Water Conservation District should have a beneficial effect on water quality in the Flint Creek watershed. Follow-up monitoring will serve to document water quality trends and current conditions since the intensive watershed survey in the years 1993-1998.

7.0 Public Participation

A thirty-day public notice will be provided for this TMDL. During this time, copies of this TMDL will be available upon request, and the public will be invited to provide comments on the TMDL.

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