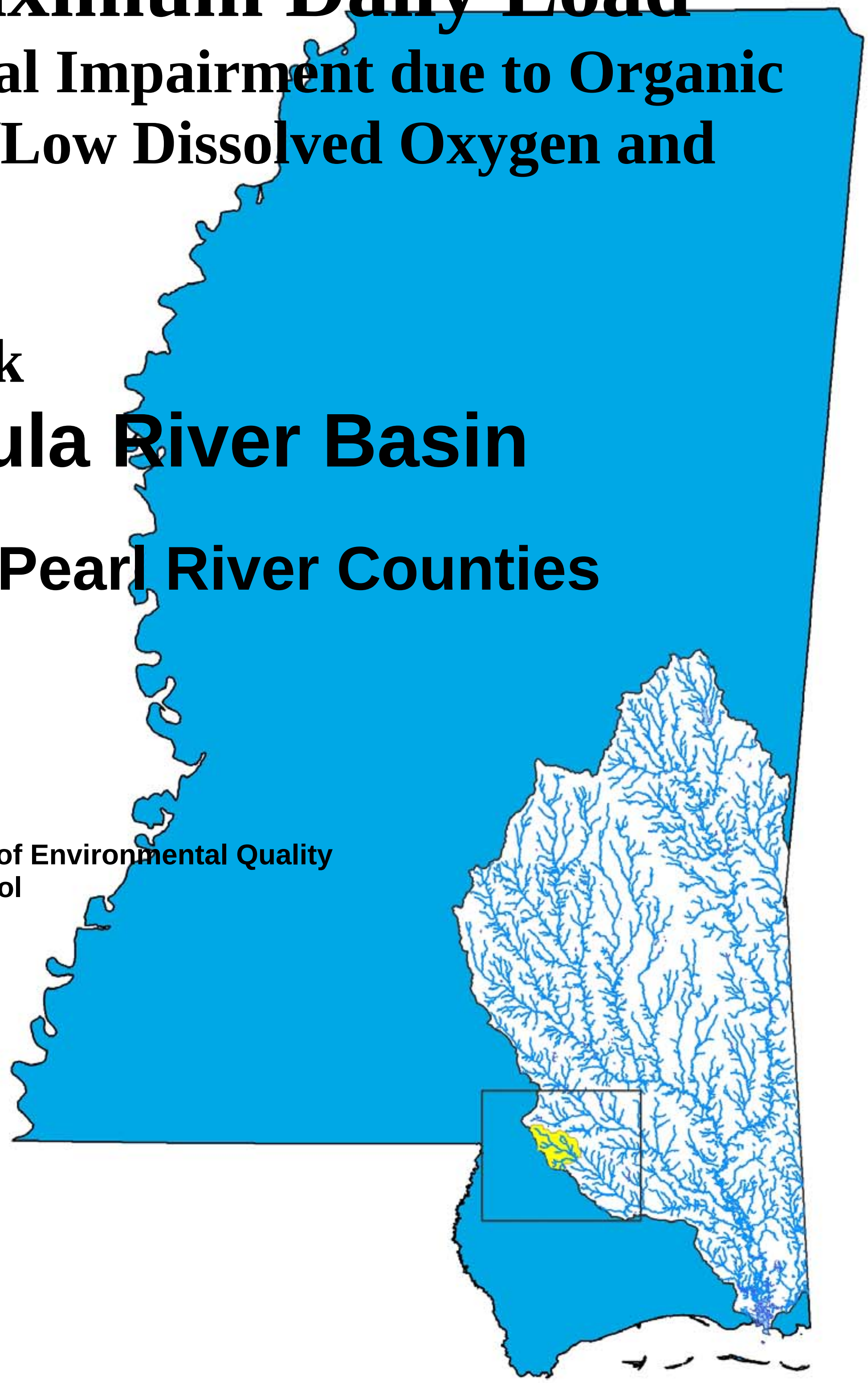
PROPOSED REPORT
June 2005

# Phase 1
# Total Maximum Daily Load
## For Biological Impairment due to Organic Enrichment/Low Dissolved Oxygen and Nutrients

## In Red Creek
# Pascagoula River Basin

## Lamar and Pearl River Counties
## Mississippi

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# FOREWORD

This report has been prepared in accordance with the schedule contained within the federal consent decree dated December 22, 1998. The report contains one or more Total Maximum Daily Loads (TMDLs) for water body segments found on Mississippi's 1996 §303(d) List of Impaired Water bodies. Because of the accelerated schedule required by the consent decree, many of these TMDLs have been prepared out of sequence with the State's rotating basin approach. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

The amount and quality of the data on which this report is based are limited. As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, or changes in landuse within the watershed. In some cases, additional water quality data may indicate that no impairment exists.

**Conversion Factors**

| To convert from | To | Multiply by | To convert from | To | Multiply by |
|---|---|---|---|---|---|
| mile$^2$ | acre | 640 | acre | ft$^2$ | 43560 |
| km$^2$ | acre | 247.1 | days | seconds | 86400 |
| m$^3$ | ft$^3$ | 35.3 | meters | feet | 3.28 |
| ft$^3$ | gallons | 7.48 | ft$^3$ | gallons | 7.48 |
| ft$^3$ | liters | 28.3 | hectares | acres | 2.47 |
| cfs | gal/min | 448.8 | miles | meters | 1609.3 |
| cfs | MGD | 0.646 | tonnes | tons | 1.1 |
| m$^3$ | gallons | 264.2 | µg/l * cfs | gm/day | 2.45 |
| m$^3$ | liters | 1000 | µg/l * MGD | gm/day | 3.79 |

| Fraction | Prefix | Symbol | Multiple | Prefix | Symbol |
|---|---|---|---|---|---|
| $10^{-1}$ | deci | d | 10 | deka | da |
| $10^{-2}$ | centi | c | $10^{2}$ | hecto | h |
| $10^{-3}$ | milli | m | $10^{3}$ | kilo | k |
| $10^{-6}$ | micro | : | $10^{6}$ | mega | M |
| $10^{-9}$ | nano | n | $10^{9}$ | giga | G |
| $10^{-12}$ | pico | p | $10^{12}$ | tera | T |
| $10^{-15}$ | femto | f | $10^{15}$ | peta | P |
| $10^{-18}$ | atto | a | $10^{18}$ | exa | E |

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**i. Listing Information**

| Name | ID | County | HUC | Cause | Mon/Eval |
|---|---|---|---|---|---|
| **Red Creek** | MS102RE | Lamar and Pearl River | 03170007 | Biological Impairment due to Organic Enrichment/Low DO and Nutrients | Monitored |
| Near Lumberton, from headwaters to confluence with Hickory Creek | | | | | |

**ii. Water Quality Standard**

| Parameter | Beneficial use | Water Quality Criteria |
|---|---|---|
| **Dissolved Oxygen** | Aquatic Life Support | DO concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l |
| **Nutrients** | Aquatic Life Support | Waters shall be free from materials attributable to municipal, industrial, agricultural, or other dischargers producing color, odor, taste, total suspended solids, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation, or to aquatic life and wildlife, or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated uses. |

**iii. NPDES Facilities**

| NPDES ID | Facility Name | Permitted Discharge (MGD) | Receiving Water |
|---|---|---|---|
| MS0001678 | Hunt Southland Refining Company, Lumberton Refinery | Report | Unnamed Tributary thence Red Creek |
| MS0020206 | Lumberton POTW | 0.5 | Dry Branch thence Red Creek |

**iv. Phase 1 Total Maximum Daily Load for TBODu**

| WLA (lbs/day) | LA (lbs/day) | MOS (lbs/day) | TMDL (lbs/day) |
|---|---|---|---|
| **384.0** | **255.6** | **3,067.1** | **3,706.7** |

**v. Total Estimated Maximum Daily Load for TP***

| WLA lbs/day | LA lbs/day | MOS lbs/day | TMDL lbs/day |
|---|---|---|---|
| **26.4*** | **31.7 to 64.9*** | **Implicit** | **58.1 to 91.3*** |

* Due to the lack of nutrient water quality criteria these Phase 1 TMDL allocations are estimates based on literature assumptions and projected targets. The State of Mississippi is in the process of developing numeric nutrient criteria in accordance with an EPA approved work plan for nutrient criteria development. This TMDL recommends quarterly monitoring of nutrients for NPDES facilities. MDEQ's calculations of the annual average load indicate that the majority of the estimated nutrient load is from non-point sources. Therefore, the State will focus on striving to attain the goal set by the LA portion of the TMDL.

# EXECUTIVE SUMMARY

This TMDL has been developed for one segment of Red Creek that is on the Mississippi 2002 §303(d) List of Water Bodies as a monitored water body segment due to biological impairment. A Stressor Identification Report which indicates the potential stressors to the water body has been developed for Red Creek. Based on the available information, it was determined that the biological impairment is most likely due to organic enrichment/low dissolved oxygen and nutrients (MDEQ, 2004). The applicable state water quality standard for dissolved oxygen specifies that dissolved oxygen concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l. Ammonia nitrogen levels will also be evaluated in this TMDL using criteria established for ammonia nitrogen toxicity. Additionally, this TMDL will provide an estimate of the total phosphorous (TP) in the stream and a preliminary breakdown of the TP load between point and non-point sources. Currently, Mississippi does not have numeric water quality standards for allowable nutrient concentrations. MDEQ currently has a Nutrient Task Force (NTF) working on the development of numeric criteria for nutrients.

For TMDL development, TP was used as the nutrient of concern because phosphorus is typically the limiting nutrient in most rivers and streams (Thomann and Mueller, 1987). A preliminary analysis of the total phosphorus data measured for non-impaired wadeable streams in the East Bioregion was completed to find a range of appropriate TP loading. The range selected in the East Bioregion is 0.07 to 0.11 mg/L of total phosphorus. MDEQ is presenting this range as a preliminary value for TMDL development which is subject to revision after the development of nutrient criteria, when the work of the NTF is complete. This TMDL has been developed as a Phase 1 TMDL so nutrients may be further evaluated when more data are available and nutrient criteria are developed.

The Red Creek Watershed is located in southeastern Mississippi in HUC 03170007. Red Creek, Photo 1, begins in Lamar County near Lumberton. The river flows for approximately 80 miles in a southeastern direction, from its headwaters to its confluence with Big Black Creek near the Pascagoula River in Jackson County.

**Photo 1. Red Creek at Hwy 11**

The 303(d) segment of Red Creek begins at the headwaters and ends at the confluence with Hickory Creek at the Pearl River County and Forrest County boundary. The total length for segment MS102RE is approximately 16 miles. The location of the watershed is shown in Figure 1.

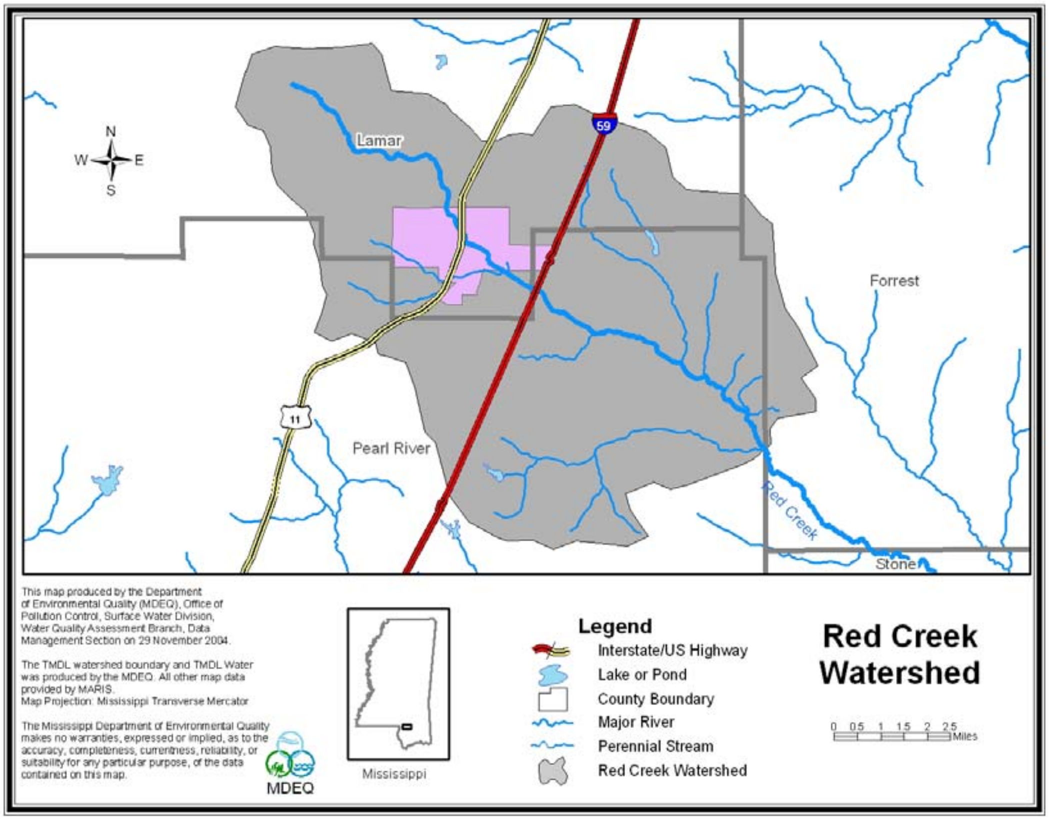



**Figure 1. Red Creek Watershed**

The predictive model used to calculate the dissolved oxygen TMDL is based primarily on assumptions described in MDEQ Regulations. A modified Streeter-Phelps dissolved oxygen sag model was selected as the modeling framework for developing the TMDL allocations for this study. The critical modeling period was determined to occur during the hot, dry summer period. A mass-balance approach was used to ensure that the instream concentration of ammonia nitrogen ($NH_3$-N) did not exceed the water quality criteria. MDEQ also used the mass balance approach to estimate total phosphorous contributions from point and non-point sources.

The TMDL for organic enrichment/low dissolved oxygen was quantified in terms of total ultimate biochemical oxygen demand (TBODu). The model used in developing this TMDL included both non-point and point sources of TBODu in the Red Creek Watershed. TBODu loading from non-point sources and tributaries of Red Creek was accounted for by using an estimated background concentration of TBODu. There are two NPDES permitted discharges located in the watershed that are included as point sources in the model. The model results showed that the predicted dissolved oxygen levels in Red Creek are above water quality standards, and mass balance calculations showed that the levels of $NH_3$-N are below toxicity levels and that the total phosphorous levels are predominantly from non-point sources. Thus, there are no reductions from the current permitted loads required by this TMDL.

# INTRODUCTION

## 1.1 Background

The identification of water bodies not meeting their designated use and the development of total maximum daily loads (TMDLs) for those water bodies are required by §303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA) Water Quality Planning and Management Regulations (40 CFR part 130). The TMDL process is designed to restore and maintain the quality of those impaired water bodies through the establishment of pollutant specific allowable loads. This TMDL has been developed for the evaluated segment, MS102RE, shown in Figure 2.

A segment of Red Creek was originally placed on the §303(d) List based on anecdotal information. Mississippi conducted a survey of district conservationists (DCs) in 1988 and 1989 to find candidate watersheds for future §319 funding opportunities. MDEQ requested each DC identify the watersheds of concern in their county based on available information including land use. Numerous DCs responded to the survey, and MDEQ created Mississippi's §319 List based on these surveys.

In 1992, MDEQ compiled a §303(d) List based, in part, on the §319 List of watersheds of concern. Therefore, water bodies were included on the §303(d) List based on speculation and not water quality monitoring data. MDEQ uses the term "evaluated" to describe these water bodies that were placed on the §303(d) List without monitoring data. At the time, MDEQ considered the evaluated listings from the §319 survey as a placeholder for future monitoring to determine if there was impairment in the watershed. The surveys asked for the presence of agriculture, urban areas, or forestry in the watershed. MDEQ interpreted potential pollutants present on these land uses and listed several broad potential pollutant categories based on the survey results. Every watershed, for which agriculture was checked, was listed for several pollutants, including sediment, pesticides, organic enrichment/low dissolved oxygen, and nutrients. A segment of Red Creek was listed for pesticides, nutrients, siltation, organic enrichment/low dissolved oxygen, and pathogens based on the survey results.

As a result of this listing, Red Creek was monitored in 2001 as part of the Mississippi Benthic Index of Stream Quality (M-BISQ) (MDEQ, 2003). Results of the M-BISQ monitoring and assessment indicated biological impairment at the site. The evaluated (un-monitored) pesticides, nutrients, and siltation causes were subsequently replaced by biological impairment on the Mississippi 2002 Section 303(d) List of Water Bodies due to a failure of this site to meet minimum reference condition criteria for aquatic life use support parameters. Subsequently, a stressor identification report was developed to identify stressors influencing the biological impairment in the Red Creek. The stressor identification report concluded that organic enrichment/low dissolved oxygen and nutrients were the most likely causes of the biological impairment (MDEQ, 2004).

There are no state criteria in Mississippi for nutrients. These criteria are currently being developed by the Mississippi Nutrient Task Force in agreement with EPA Region 4. MDEQ proposed a work plan for nutrient criteria development that has been approved by EPA and is on schedule according to the approved plan in development of nutrient criteria (MDEQ, 2004).

Data have been collected for wadeable streams to be used to calculate the criteria. For this TMDL, MDEQ chose total phosphorus as the limiting nutrient. The management of phosphorus will also control other nutrients. Preliminary analysis of the data reveals that an annual concentration range of 0.07 to 0.11 mg/l is an applicable target for total phosphorus for water bodies located in the East Bioregion. However, MDEQ is presenting this range as a preliminary target value for TMDL development which is subject to revision after the development of nutrient criteria, when the work of the NTF is complete.

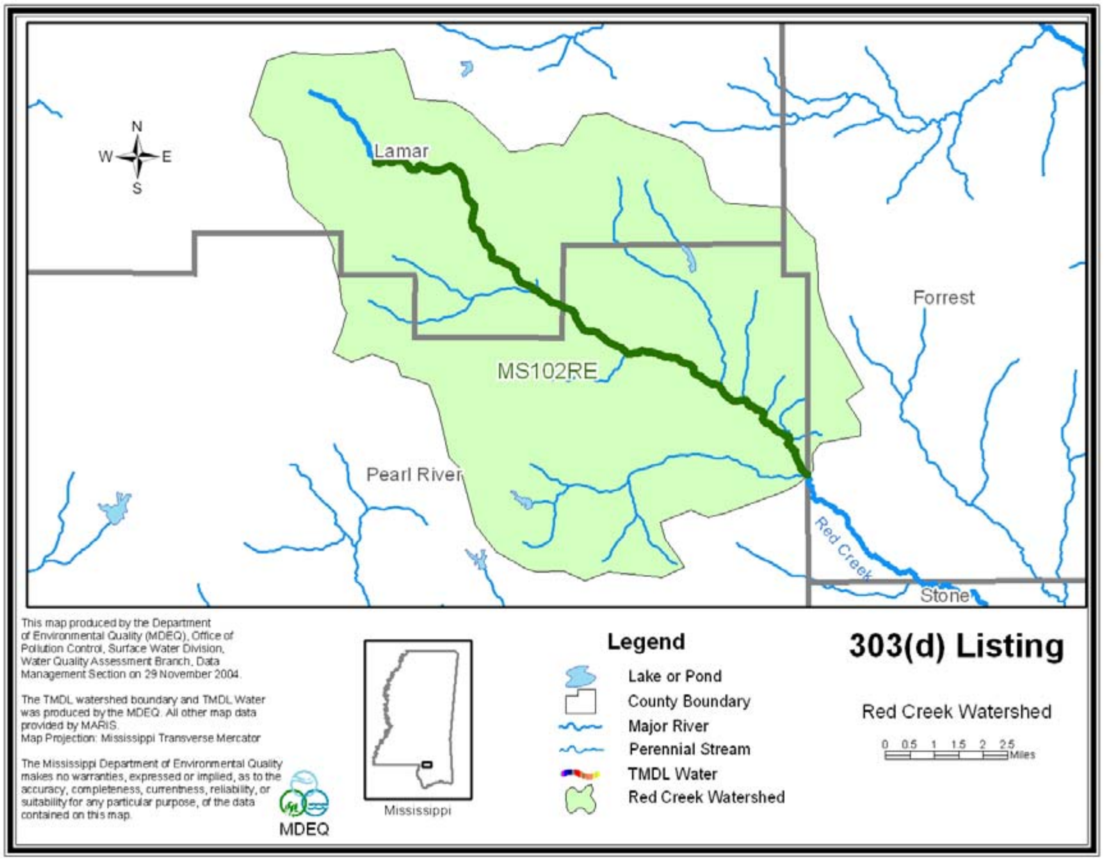



**Figure 2. Red Creek 303(d) Listed Segment**

## 1.2 Applicable Water Body Segment Use

The water use classifications are established by the State of Mississippi in the document *Water Quality Criteria for Intrastate, Interstate and Coastal Waters*. The designated beneficial use for segment, MS102RE, of Red Creek is fish and wildlife support.

## 1.3 Applicable Water Body Segment Standard

The water quality standard applicable to the use of the water body and the pollutant of concern is defined in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters* (MDEQ, 2002). The applicable standard specifies that the dissolved oxygen (DO) concentrations shall be maintained at a daily average of not less than 5.0 mg/l with an instantaneous minimum of not less than 4.0 mg/l. The daily average water quality standard will be used to evaluate impairments and establish this TBODu TMDL.

The water quality standard for ammonia nitrogen toxicity is included in this TMDL. Ammonia nitrogen concentrations can be evaluated using the criteria given in 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014). The maximum allowable instream ammonia nitrogen ($NH_3$-N) concentration at a pH of 7.0 and stream temperature of 26°C is 2.82 mg/l.

Mississippi's NTF is currently developing numeric criteria for nutrients. The current standards only contain a narrative criteria that can be applied to nutrients which states that "Waters shall be free from materials attributable to municipal, industrial, agricultural, or other discharges producing color, odor, taste, total suspended or dissolved solids, sediment, turbidity, or other conditions in such degree as to create a nuisance, render the waters injurious to public health, recreation or to aquatic life and wildlife or adversely affect the palatability of fish, aesthetic quality, or impair the waters for any designated use (MDEQ, 2002)."

In the 1999 Protocol for Developing Nutrient TMDLs, EPA suggests several methods for the development of numeric criteria for nutrients (USEPA, 1999). In accordance with the 1999 Protocol, "The target value for the chosen indicator can be based on: comparison to similar but unimpaired waters; user surveys; empirical data summarized in classification systems; literature values; or best professional judgment." MDEQ believes the most economical and scientifically defensible method for use in Mississippi is a comparison between similar but unimpaired waters within the same region. This method is dependent on adequate data which are being collected in accordance with the EPA approved plan. The initial phase of the data collection process for wadeable streams has been completed. Preliminary analysis of the available data reveals that an annual concentration range of 0.07 to 0.11 mg/l is an applicable TMDL target for total phosphorus for water bodies located in the East Bioregion. However, MDEQ is presenting this as a preliminary target value for TMDL development which will be subject to revision after the development of nutrient criteria, when the work of the NTF is complete.

## 1.4 Selection of a Critical Condition

The critical condition represents the hydrologic and atmospheric conditions in which the pollutants causing impairment of a water body have their greatest potential for adverse effects. Low DO due to elevated nutrient levels typically occurs during seasonal low-flow, high-temperature periods during the late summer and early fall. Elevated oxygen demand and ammonia nitrogen is of primary concern during low-flow periods because the effects of minimum dilution and high temperatures combine to produce the worst-case potential effect on water quality (USEPA, 1997). The flow at critical conditions is typically defined as the 7Q10 flow, which is the lowest flow for seven consecutive days expected during a 10-year period. The 7Q10 flow for Red Creek, 19.3 cfs, was determined based on information given in *Techniques for Estimating 7-Day, 10-Year Low-Flow Characteristics on Streams in Mississippi* (Telis, 1992).

## 1.5 Selection of a TMDL Endpoint

One of the major components of a TMDL is the establishment of instream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. Instream numeric endpoints, therefore, represent the water quality goals that are to be achieved by meeting the load and wasteload allocations specified in the TMDL. The endpoints allow for a comparison between observed instream conditions and conditions that are expected to restore designated uses. The instream DO target for this TMDL is a daily average of not less than 5.0 mg/l. The instream target for ammonia nitrogen is a concentration less than 2.82 mg/l. The instantaneous minimum portion of the DO standard was considered when establishing the instream target for this TMDL. However, it was determined that using the daily average standard with the conservative modeling assumptions would protect the instantaneous minimum standard. The daily average choice is supported by the use of the existing modeling tools in a desktop modeling exercise such as this. More specific modeling and calibration are needed in order to obtain diurnal oxygen levels with any expectation of accuracy. Therefore, based on the limited data available and the relative simplicity of the model, the daily average target is appropriate.

The TMDL for DO will be quantified in terms of organic enrichment. Organic enrichment is measured in terms of total ultimate biochemical oxygen demand (TBODu). TBODu represents the oxygen consumed by microorganisms while stabilizing or degrading carbonaceous and nitrogenous compounds under aerobic conditions over an extended time period. The carbonaceous compounds are referred to as CBODu, and the nitrogenous compounds are referred to as NBODu. TBODu is equal to the sum of NBODu and CBODu, Equation 1.

$$\textbf{TBODu} = \textbf{CBODu} + \textbf{NBODu} \qquad \textbf{(Equation 1)}$$

The TMDL for nutrients will be quantified in terms of an annual average concentration range for TP. TP was used as the nutrient of concern because phosphorus is typically the limiting nutrient in most rivers and streams (Thomann and Mueller, 1987). A preliminary analysis of the total phosphorus data measured for non-impaired wadeable streams in the East Bioregion was completed to transform the narrative criteria for nutrients into a preliminary numeric range for use in TMDL development. Streams were classified as non-impaired based on biological sampling which was conducted as part of Mississippi’s Benthix Index of Stream Quality (MBISQ) project. A non-impaired wadeable stream is one which supports the designated aquatic life use which is defined by the State of Mississippi’s *Water Quality Criteria for Intrastate, Interstate and Coastal Waters* (MDEQ, 2002) and one which also satisfies all other conditions of the narrative criteria. The annual concentration range for this TMDL and all other wadeable streams which are located in the East Bioregion is 0.07 to 0.11 mg/L of total phosphorus. These values may be subject to revision as the nutrient criteria development process continues.

# WATER BODY ASSESSMENT

This TMDL Report includes an analysis of available water quality data and the identification of all known potential pollutant sources in the Red Creek Watershed. The potential point and non-point pollutant sources were characterized by the best available information, monitoring data, and literature values.

## 2.1 Discussion of Instream Water Quality Data

There is a limited amount of data available for the Red Creek Watershed. The most recent data for this segment of Red Creek were collected at a site near Lumberton in the winter of 2001. The sampling was conducted as part of the Mississippi Benthic Index of Stream Quality (M-BISQ), which included chemical, physical, and biological sample collection (MDEQ, 2003). Limited chemical data were also collected near Lumberton, twice in 1997, as part of MDEQ's surface water monitoring program. The available data are given in Table 1.

**Table 1. Available Water Quality Data**

| Station | Location | Date | Time | DO (mg/L) | Total Phosphorus (mg/L) |
|---|---|---|---|---|---|
| 02479180 | HWY 11 | 26-Aug-97 | 15:00 | 8.1 | 0.04 |
| 02479180 | HWY 11 | 15-Dec-97 | 10:35 | 11.6 | 0.04 |

## 2.2 Assessment of Point Sources

An important step in assessing pollutant sources in the Red Creek Watershed is locating the NPDES permitted sources. There are 2 facilities permitted to discharge organic material into Red Creek or its tributaries, which are shown in Table 2. The facilities include a municipal wastewater treatment plant and a refinery. The location of the facilities is shown in Figure 3.

**Table 2. NPDES Permitted Facilities Treatment Types**

| Facility Name | NPDES | Treatment Type |
|---|---|---|
| Hunt Southland Refining Company, Lumberton Refinery | MS0001678 | Dissolved Air Flotation, Activated Sludge, and Aerated Lagoon |
| Lumberton POTW | MS0020206 | Aerated Lagoon |

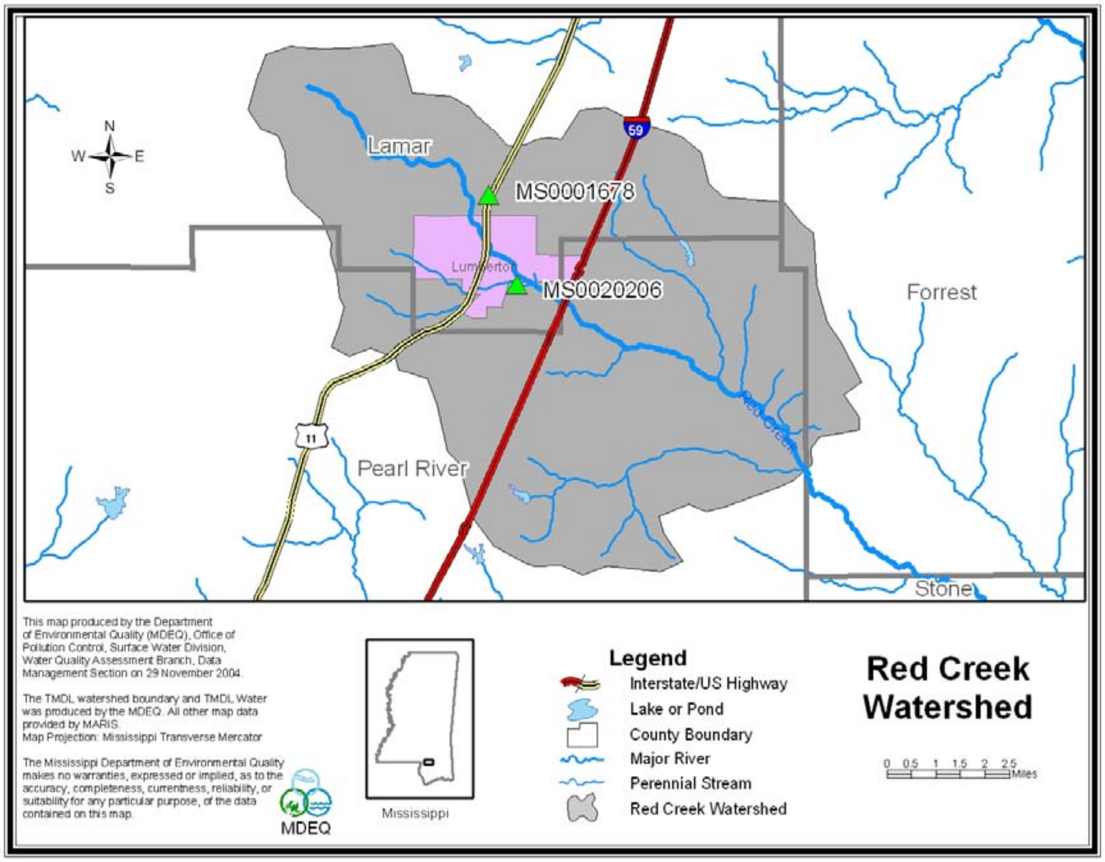



**Figure 3. Point Source Location Map for the Red Creek Watershed**

The Hunt Southland Refining Company has recently made some improvements to their wastewater treatment system. The facility has had a history of noncompliance with several parameters in their permit. In order to improve treatment, the facility installed a dissolved air flotation device and an activated sludge system to treat water coming from the desalter, boiler, cooling, and process draining systems in their plant. This treated water is combined with storm water and other runoff and naturally occurring spring water and further treated in an aerated lagoon before discharge. The improvements made by the Hunt Southland Refining Company are expected to produce better quality effluent than in the past and allow the facility to comply with its NPDES permit.

The current condition of the effluent from each facility was characterized based on all available data including information on each facility's wastewater treatment system, permit limits, and discharge monitoring reports. The permit limits as well as the average flows and $BOD_5$ concentrations, as reported in recent discharge monitoring reports (DMRs) are given in Table 3. Ammonia nitrogen permit limits and monitoring are required for the Hunt Southland Refining Company. The Lumberton POTW does not have a permit limit for $NH_3$-N.

**Table 3. Identified NPDES Permitted Facilities**

| Facility Name | NPDES | Permitted Discharge (MGD) | Actual Average Discharge (MGD) | Permitted Average $BOD_5$ (mg/l) | Actual Average $BOD_5$ (mg/l) | Permitted $NH_3$-N (mg/l) | Actual Average $NH_3$-N (mg/l) |
|---|---|---|---|---|---|---|---|
| Hunt Southland Refining Company, Lumberton Refinery | MS0001678 | Report | 0.097 | 10.0 | 10.3 | 2.0 | 0.8 |
| Lumberton POTW | MS0020206 | 0.5 | 0.27 | 30.0 | 18.9 | -- | -- |

## 2.3 Assessment of Non-Point Sources

Non-point loading of nutrients and organic material in a water body results from the transport of the pollutants into receiving waters by overland surface runoff and groundwater infiltration. Phosphorus is typically seen as the limiting nutrient in most rivers and streams (Thomann and Mueller, 1987). Therefore, this TMDL will address total phosphorus. Phosphorus is primarily transported by runoff when it has been sorbed by eroding sediment. Phosphorous may not be immediately released from sediment and can sometimes reenter the water column from deposited sediment. Most non-point sources of phosphorous will build up and then wash off during rain events. Table 4 presents typical nutrient loading ranges for various land uses.

**Table 4. Nutrient Loadings for Various Land Uses**

| Landuse | Total Phosphorus [lb/acre-y] | | | Total Nitrogen [lb/acre-y] | | |
|---|---|---|---|---|---|---|
| | Minimum | Maximum | Median | Minimum | Maximum | Median |
| Roadway | 0.53 | 1.34 | 0.98 | 1.2 | 3.1 | 2.1 |
| Commercial | 0.61 | 0.81 | 0.71 | 1.4 | 7.8 | 4.6 |
| Single Family-Low Density | 0.41 | 0.57 | 0.49 | 2.9 | 4.2 | 3.6 |
| Single Family-High Density | 0.48 | 0.68 | 0.58 | 3.6 | 5.0 | 5.2 |
| Multifamily Residential | 0.53 | 0.72 | 0.62 | 4.2 | 5.9 | 5.0 |
| Forest | 0.09 | 0.12 | 0.10 | 1.0 | 2.5 | 1.8 |
| Grass | 0.01 | 0.22 | 0.12 | 1.1 | 6.3 | 3.7 |
| Pasture | 0.01 | 0.22 | 0.12 | 1.1 | 6.3 | 3.7 |

Source: Horner et al., 1994 in Protocol for Developing Nutrient TMDLs (USEPA 1999)

Non-point pollution sources of concern are storm drainage from urban areas including the City of Lumberton. Other landuse activities within the drainage basin, such as agriculture, and urbanization also contribute to non-point source loading. Overland surface runoff and groundwater infiltration results in the transport of TBODu and nutrients into receiving waters.

The drainage area of Red Creek is 50,393 acres (78.8 square miles). The watershed contains many different landuse types, including urban, forest, cropland, pasture, scrub/barren, water, and wetlands. The landuse information given below is based on data collected by the State of Mississippi's Automated Resource Information System (MARIS) in 1997. This data set is based on Landsat Thematic Mapper digital images taken between 1992 and 1993. Forest and pasture are the dominant landuses within the watershed. The landuse distribution is shown in Table 5 and Figure 4.

**Table 5. Landuse Distribution, Red Creek Watershed**

| | Urban | Forest | Cropland | Pasture | Scrub/ Barren | Water | Wetlands | Total |
|---|---|---|---|---|---|---|---|---|
| Area (acres) | 1,294 | 19,923 | 1,211 | 12,814 | 11,095 | 341 | 3,715 | 50,393 |
| Percentage | 2.6 | 39.5 | 2.4 | 25.3 | 22.0 | 0.7 | 7.4 | 100.0% |

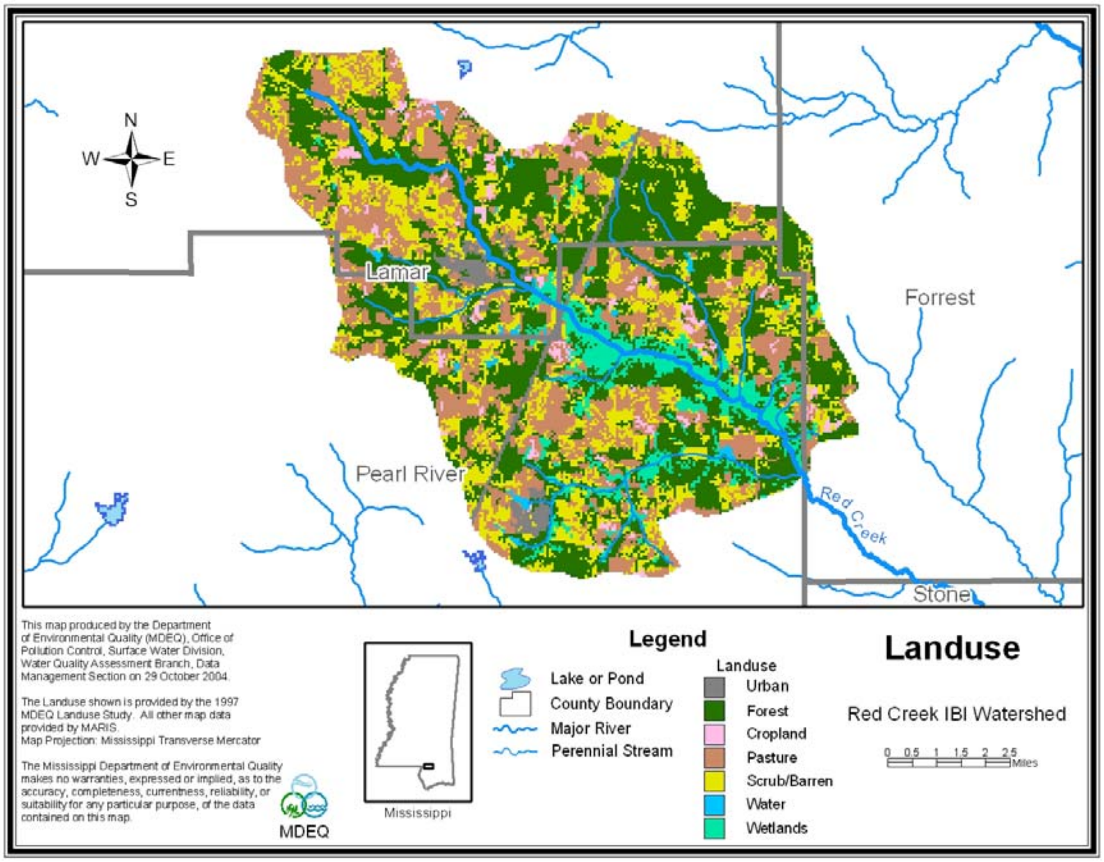



**Figure 4. Landuse Distribution for the Red Creek Watershed**

# MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between the instream water quality target and the source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a range of techniques, from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain water body responses to flow and loading conditions. In this section, the selection of the modeling tools, setup, and model application are discussed.

## 3.1 Modeling Framework Selection

A mathematical model, STeady Riverine Environmental Assessment Model (STREAM), for DO distribution in freshwater streams was used for developing the TMDL. STREAM is an updated version of the AWFWUL1 model, which had been used by MDEQ for many years. The use of AWFWUL1 is promulgated in the *Wastewater Regulations for National Pollutant Discharge Elimination System (NPDES) Permits, Underground Injection Control (UIC) Permits, State Permits, Water Quality Based Effluent Limitations and Water Quality Certification* (MDEQ, 1994). This model has been approved by EPA and has been used extensively at MDEQ. A key reason for using the STREAM model in TMDL development is its ability to assess instream water quality conditions in response to point and non-point source loadings.

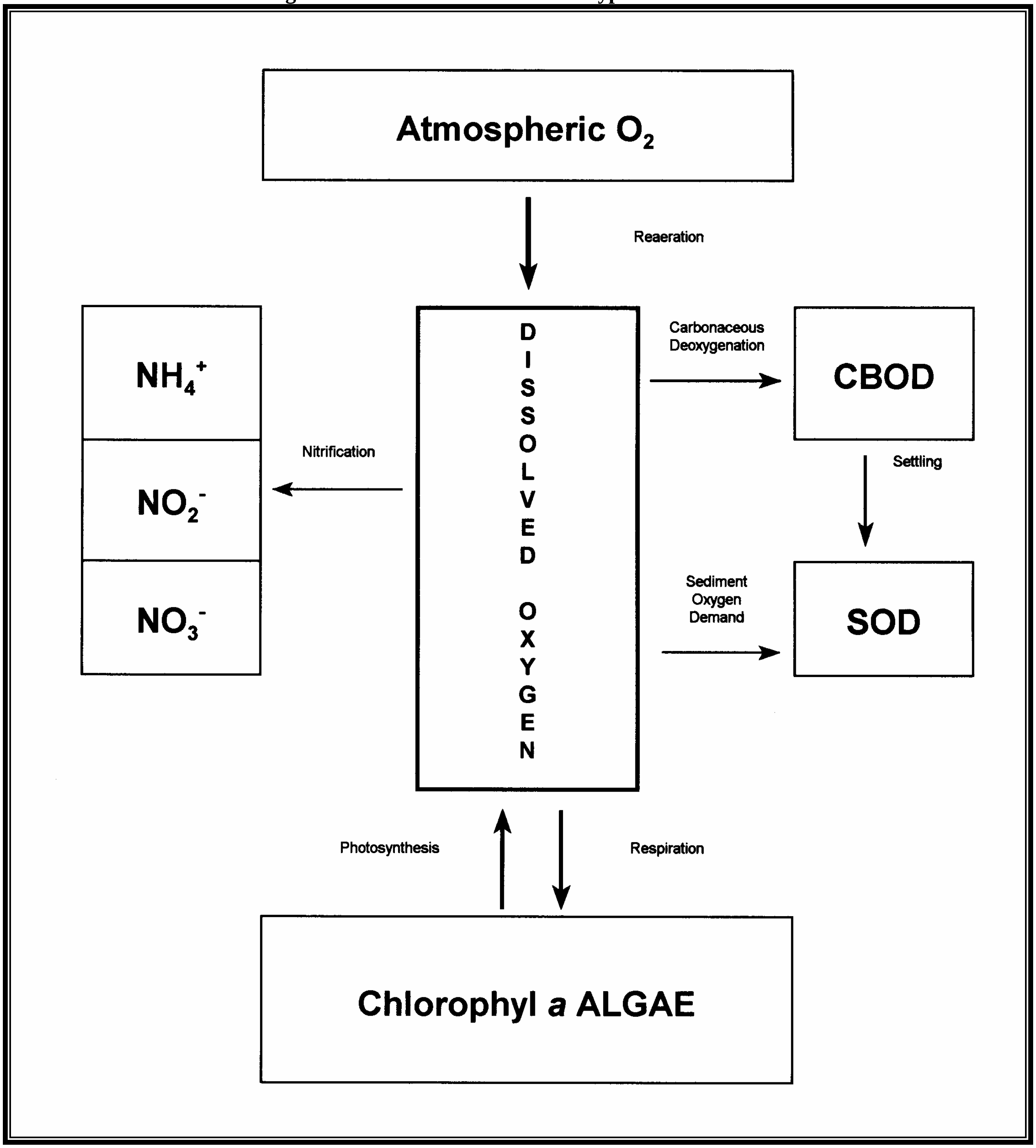
STREAM is a steady-state, daily average computer model that utilizes a modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification, reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 5 shows how these processes are related in a typical DO model. Reaction rates for the instream processes are input by the user and corrected for temperature by the model. The model output includes water quality conditions in each computational element for DO, CBODu, and $NH_3$-N concentrations. The hydrological processes simulated by the model include stream velocity and flow from point sources and spatially distributed inputs.

The model was set up to calculate reaeration within each reach using the Tsivoglou formulation. The Tsivoglou formulation calculates the reaeration rate, $K_a$ (day$^{-1}$ base *e*), within each reach according to Equation 2.

$$\mathbf{K_a = C*S*U} \qquad \textbf{(Equation 2)}$$

C is the escape coefficient, U is the reach velocity in mile/day, and S is the average reach slope in ft/mile. The value of the escape coefficient is assumed to be 0.11 for stream reaches with flows less than 10 cfs and 0.0597 for stream reaches with flows greater than 10 cfs. Reach velocities were calculated using an equation based on flow and slope. Slopes for Red Creek range from 20 to 4 ft/mile.

**Figure 5. Instream Processes in a Typical DO Model**




## 3.2 Model Setup

The model for Red Creek was developed beginning with its headwaters north of Lumberton, MS to its confluence with Hickory Creek. This model includes two tributaries; Dry Creek and an unnamed tributary. Dry Creek carries effluent from the Lumberton POTW. The Hunt Southland Refining Company discharges into the unnamed tributary. Figure 6 shows the model setup for Red Creek. The locations of the confluence of point sources and significant tributaries are shown. Arrows represent the direction of flow in each segment. The numbers on the figure represent approximate river miles (RM). River miles are assigned to water bodies with the highest number at the upstream point and decreasing in the downstream direction to zero at the mouth.

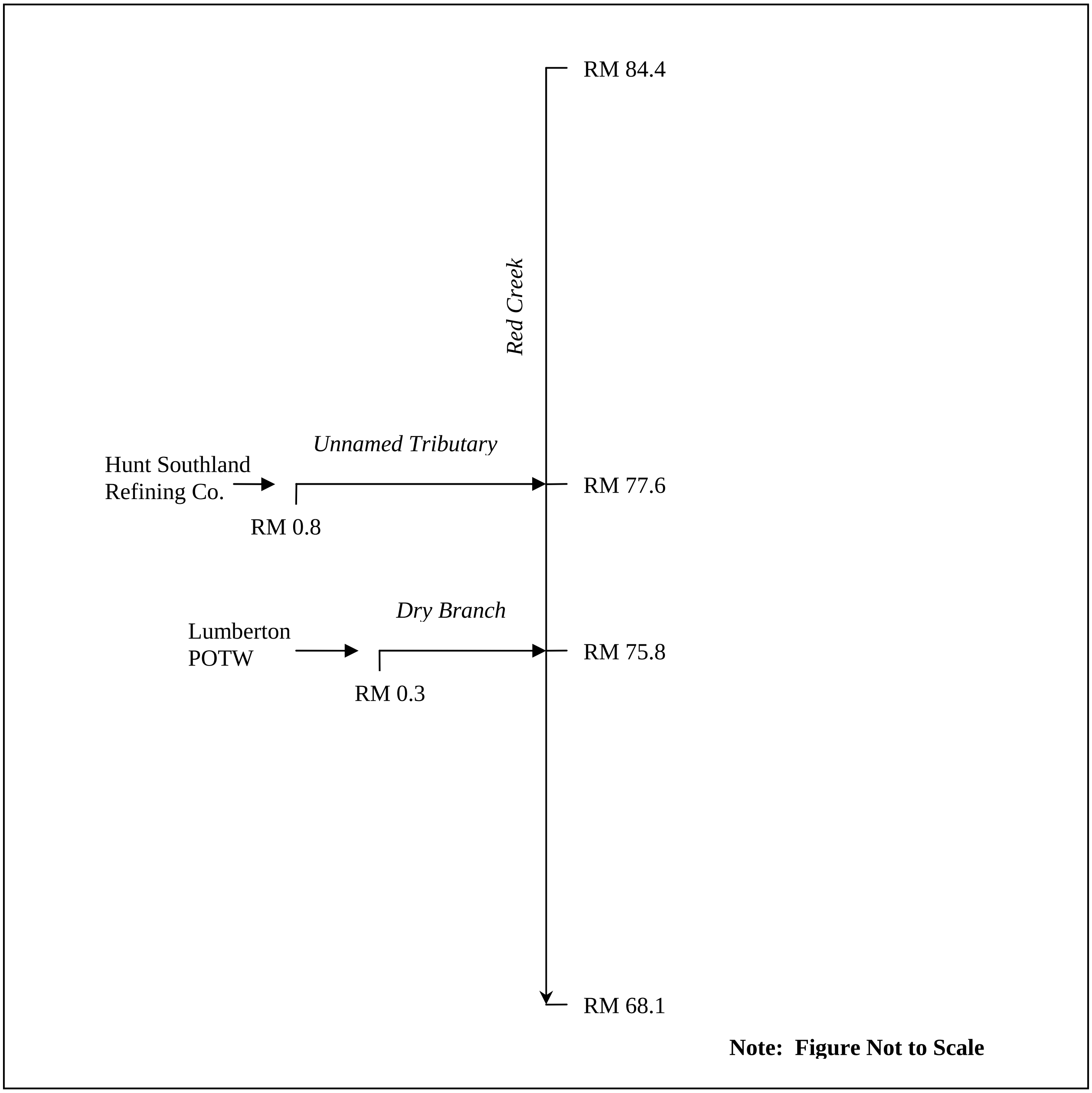



**Figure 6. Red Creek Model Setup**

The modeled water body is divided into reaches for modeling purposes. Reach divisions are made at locations where there is a significant change in hydrological and water quality characteristics, such as the confluence of a point source or tributary. Within each reach, the modeled segments are divided into computational elements of 0.1 mile. The simulated hydrological and water quality characteristics are calculated and output by the model for each computational element.

The STREAM model was setup to simulate flow and temperature conditions, which were determined to be the critical condition for this TMDL. The temperature used in the model varies with flow. In accordance with MDEQ regulations, the temperature is set to 26°C for flows less than 50 cfs. The headwater instream DO is assumed to be 85% of saturation at the stream temperature. The instream CBODu decay rate is dependent on temperature, according to Equation 3.

$$\mathbf{K_{d(T)} = K_{d(20°C)}(1.047)^{T-20}} \qquad \textbf{(Equation 3)}$$

Where $K_d$ is the CBODu decay rate and T is the assumed instream temperature. The assumptions regarding the instream temperatures, background DO saturation, and CBODu decay rate are required by the *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). Also based on MDEQ Regulations, the rates for photosynthesis, respiration, and sediment oxygen demand were set to zero because data for these model parameters were not available.

## 3.3 Source Representation

Both point and non-point sources were represented in the model. The loads from NPDES permitted sources and tributaries were added as direct inputs into the appropriate location as a flow in MGD and concentrations of $CBOD_5$ and ammonia nitrogen in mg/L. Spatially distributed loads, which represent non-point sources of flow, $CBOD_5$, and ammonia nitrogen were distributed evenly into each computational element of Red Creek.

Organic material discharged to a stream from an NPDES permitted point source is typically quantified as 5-day biochemical oxygen demand ($BOD_5$). $BOD_5$ is a measure of the oxidation of carbonaceous and nitrogenous material over a 5-day incubation period. However, oxidation of nitrogenous material, called nitrification, usually does not take place within the 5-day period because the bacteria that are responsible for nitrification are normally not present in large numbers and have slow reproduction rates (Metcalf and Eddy, 1991). Thus, $BOD_5$ is generally considered equal to $CBOD_5$. Because permits for point source facilities are written in terms of $BOD_5$ while TMDLs are typically developed using CBODu, a ratio between the two terms is needed, Equation 4.

$$\mathbf{CBODu = CBOD_5 * Ratio} \qquad \textbf{(Equation 4)}$$

The CBODu to $CBOD_5$ ratios are given in *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). These values are recommended for use by MDEQ regulations when actual field data are not available. The value of the ratio depends on the treatment type of wastewater. For secondary treatment systems (conventional and aerated lagoons), this ratio is 1.5. A CBODu to $CBOD_5$ ratio of 1.5 is appropriate for both of the facilities discharging into Red Creek.

In order to convert the ammonia nitrogen ($NH_3$-N) loads to an oxygen demand, a factor of 4.57 pounds of oxygen per pound of ammonia nitrogen ($NH_3$-N) oxidized to nitrate nitrogen ($NO_3$-N) was used. Using this factor is a conservative modeling assumption because it assumes that all of the ammonia is converted to nitrate through nitrification. The oxygen demand caused by nitrification of ammonia is equal to the NBODu load. The sum of CBODu and NBODu is equal to the point source load of TBODu. The maximum permitted loads of TBODu from each of the existing point sources are given in Table 6. The Hunt Southland Refining Company does not have a maximum permitted flow. Instead, this facility is required to report their flow on a monthly basis. The maximum flow for this facility given in Table 6 is based on the maximum flow measured during a 19 month period (January 2003 through July 2004).

The average flows and $BOD_5$ and $NH_3$-N concentrations for both facilities are given in Table 7. The average flow and $BOD_5$ and $NH_3$-N concentrations for Hunt Southland Refining Company were calculated as the average of the monthly average flows and concentrations reported during this same time period. The 19 month period is assumed to be representative of the current operation of the facility. The averages for the Lumberton POTW were also based on recent DMR data. Note that the permitted $CBOD_5$ concentrations are greater than the concentrations, as reported in the DMR data for the Lumberton POTW. Because the Lumberton POTW is not required to report values for ammonia nitrogen an assumed value of 2.0 mg/L was used to calculate the NBODu load for this facility.

**Table 6. Point Sources, Maximum Permitted Loads**

| Facility | Flow (MGD) | $CBOD_5$ (mg/l) | $NH_3$-N (mg/L) | $CBOD_u$:$CBOD_5$ Ratio | CBODu (lbs/day) | $NH_3$-N (lbs/day) | NBODu (lbs/day) | TBODu (lbs/day) |
|---|---|---|---|---|---|---|---|---|
| Hunt Southland Refining Company, Lumberton Refinery | *0.786* | 10.0 | 2.00 | 1.5 | 98.3 | 13.1 | 59.9 | 158.2 |
| Lumberton POTW | 0.500 | 30.0 | ***2.00* | 1.5 | 187.7 | 8.3 | 38.1 | 225.8 |
| | | | | | **286.0** | **21.5** | **98.0** | **384.0** |

*Value based on the maximum flow reported in DMR data
**Assumed value

**Table 7. Point Sources, Loads Based on Averages of DMR Data**

| Facility | Flow (MGD) | $CBOD_5$ (mg/l) | $NH_3$-N (mg/L) | $CBOD_u$:$CBOD_5$ Ratio | CBODu (lbs/day) | $NH_3$-N (lbs/day) | NBODu (lbs/day) | TBODu (lbs/day) |
|---|---|---|---|---|---|---|---|---|
| Hunt Southland Refining Company, Lumberton Refinery | **0.097* | 10.3 | 0.81 | 1.5 | 12.5 | 0.7 | 3.0 | 15.5 |
| Lumberton POTW | 0.270 | 18.9 | ***2.00* | 1.5 | 63.8 | 4.5 | 20.6 | 84.4 |
| | | | | | **76.3** | **5.2** | **23.5** | **99.9** |

*Assumed value based on average flow reported in DMR Data
**Assumed value

Direct measurements of background concentrations of CBODu and $NH_3$-N were not available for Red Creek. Because there were no data available, the background concentrations of CBODu and $NH_3$-N were estimated based on *Empirical Stream Model Assumptions for Conventional Pollutants and Conventional Water Quality Models* (MDEQ, 1994). According to these regulations, the background concentrations used in modeling are CBODu = 2.0 mg/L and $NH_3$-N = 0.1 mg/l. The background concentrations were used to establish the headwater conditions for Red Creek. They were also used as estimates of the CBODu and $NH_3$-N concentrations in water entering the water body through non-point sources,

The non-point source flows were estimated based on USGS data. The 7Q10 flow condition for Red Creek at Vestry (02479300) is 108 cfs, with a drainage area of 441 square miles (Telis, 1992). This flow monitoring station is located on Red Creek downstream of the modeled segment. To estimate the amount of flow in Red Creek within the segment, a drainage area ratio was calculated using the flow gage (108 cfs/441 square miles = 0.245 cfs/square mile). The ratio was then multiplied by the drainage area of the modeled segment, 78.8 square miles (0.245 cfs/square mile * 78.8 square miles = 19.3 cfs). Thus, the total amount of non-point source flow in the segment at 7Q10 conditions was estimated to be 19.3 cfs. This flow was assumed to be evenly distributed into each modeled reach of Red Creek and tributaries of Red Creek. The flows were multiplied by the background concentrations of CBODu and $NH_3$-N to calculate the non-point source loads going into the water body, Table 8.

**Table 8. Non-point Source Loads Input into the Model**

| Reach | Flow (cfs) | CBODu (mg/L) | CBODu (lbs/day) | $NH_3$-N (mg/l) | NBODu (lbs/day) | TBODu (lbs/day) |
|---|---|---|---|---|---|---|
| Unnamed Tributary (RM 0.8 – 0.0) | 0.9 | 2.0 | 9.7 | 0.1 | 2.2 | 11.9 |
| Dry Branch (RM 0.3 – 0.0) | 0.3 | 2.0 | 3.2 | 0.1 | 0.7 | 4.0 |
| Red Creek (RM 84.4 – 82.7) | 1.9 | 2.0 | 20.5 | 0.1 | 4.7 | 25.2 |
| Red Creek (RM 82.7 -79.0) | 4.1 | 2.0 | 44.2 | 0.1 | 10.1 | 54.3 |
| Red Creek (RM 79.0 – 77.6) | 1.6 | 2.0 | 17.2 | 0.1 | 3.9 | 21.2 |
| Red Creek (RM 77.6 – 75.8) | 2.0 | 2.0 | 21.6 | 0.1 | 4.9 | 26.5 |
| Red Creek (RM 75.8 – 74.8) | 1.1 | 2.0 | 11.9 | 0.1 | 2.7 | 14.6 |
| Red Creek (RM 74.8 - 71.6) | 3.5 | 2.0 | 37.7 | 0.1 | 8.6 | 46.4 |
| Red Creek (RM 71.6 – 68.1) | 3.9 | 2.0 | 42.0 | 0.1 | 9.6 | 51.6 |
| | **19.3** | | **208.1** | | **47.5** | **255.6** |

## 3.4 Model Results

Once the model setup was complete, the model was used to predict water quality conditions in Red Creek. The model was first run under baseline conditions. Under baseline conditions, the loads from NPDES permitted point sources were set at their average loads as determined from the discharge monitoring reports. Thus, baseline model runs reflect the current condition of the water body. The baseline condition model was run again with the permits set at the maximum loads allowed in the NPDES permits. Model runs with permits at both average loads and maximum permitted loads showed that the water quality standard for dissolved oxygen was not violated at any point in Red Creek. Finally, the maximum allowable load was determined by increasing the non-point source loads. The model was run using a trial-and-error process to determine the maximum TBODu loads that would not violate water quality standards for DO. These model results are called the maximum load scenario.

### 3.4.1 Baseline Model Results

The baseline model results are shown in Figures 7 and 8. Figure 7 shows the modeled daily average DO with the NPDES permits at their current loads based on average DMR data, Table 7. The figure shows the daily average instream DO concentrations, beginning with river mile 84.4 and ending with river mile 68.1 in Red Creek. As shown, the model predicts that the DO stays above the standard of 5.0 mg/l. Baseline model output for ammonia nitrogen is shown in Figure 8. Ammonia nitrogen levels are below the water quality standard of 2.82 mg/l.

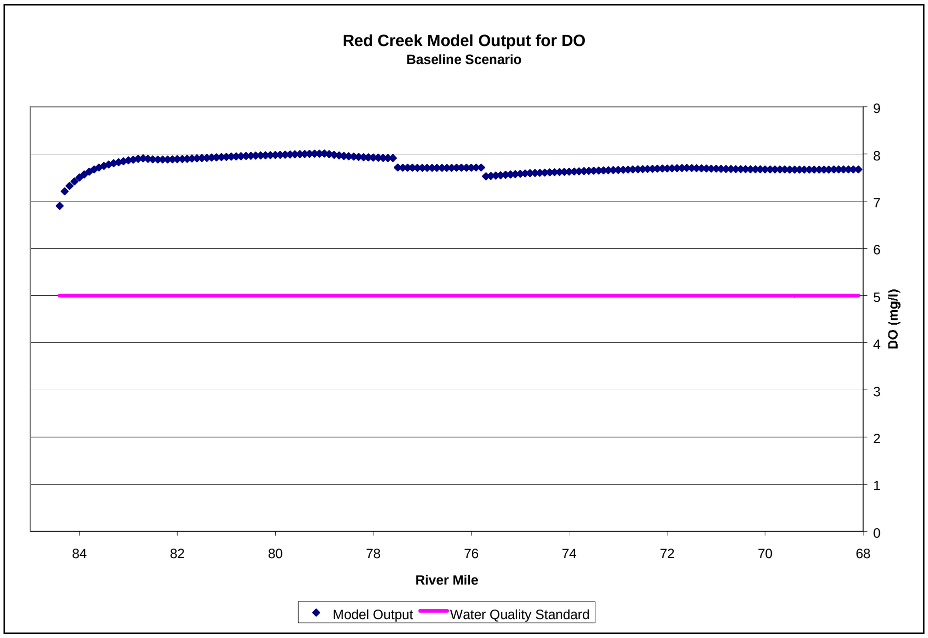



**Figure 7. Baseline Model Output for DO in Red Creek**

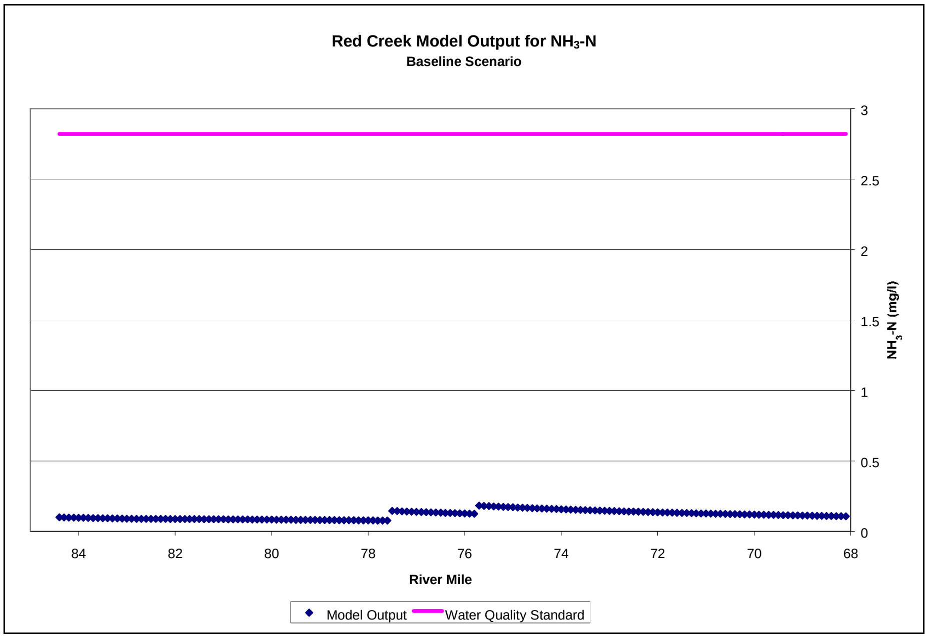



**Figure 8. Baseline Model Output for $NH_3$-N in Red Creek**

### 3.4.2 Model Results at NPDES Permit Limits

A second model run was completed in order to predict the dissolved oxygen in Red Creek if the NPDES permits were discharging at their maximum permit limits, Table 6. The results of this model run are shown in Figure 9. The red line on the graph represents the daily average DO water quality standard of 5.0 mg/l. As shown, the modeled DO stays above the daily average standard. The permitted load is within the assimilative capacity of the water body. The water body has remaining assimilative capacity beyond the permitted loading. Thus, this TMDL does not limit future growth in this area.

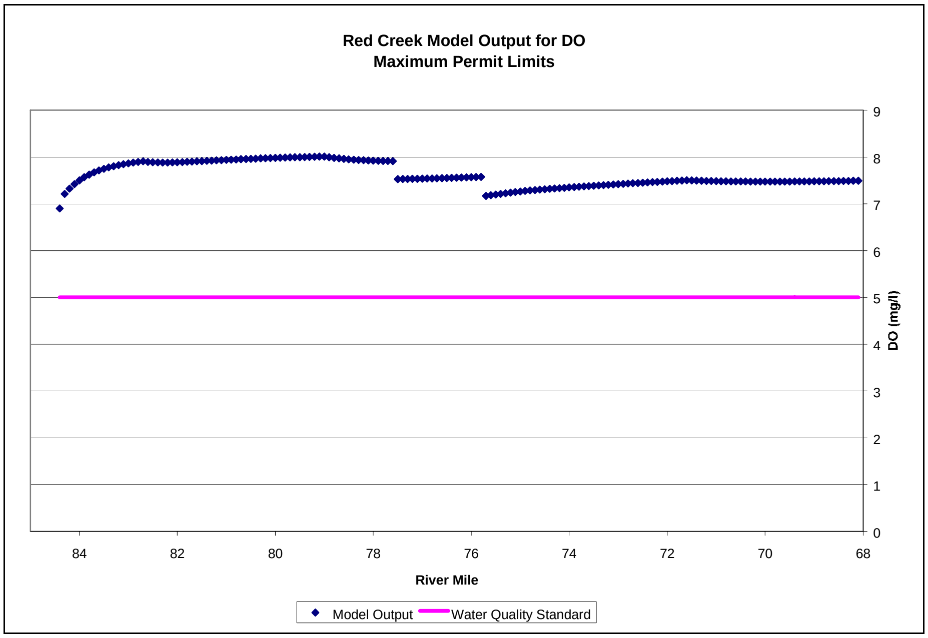



**Figure 9. Model Output for Red Creek at Permitted Loads**

### 3.4.3 Maximum Load Scenario

Calculating the maximum allowable load of TBODu involved increasing the non-point loads and running the model using a trial-and-error process until the modeled DO was just above 5.0 mg/l. The maximum loads from the point sources were not increased. However, the baseline non-point source loads were increased by a factor of 13. The increased non-point source loads are shown in Table 9. The increased loads were used to develop the allowable maximum daily load for Red Creek. The difference between the baseline and maximum non-point source loads will be used to calculate the margin of safety. The model output for DO with the increased loads is shown in Figure 10.

**Table 9. Non-point Source Loads Input into the Model, Maximum Load Scenario**

| Reach | Flow (cfs) | $CBOD_u$ (mg/L) | CBODu (lbs/day) | $NH_3$-N (mg/l) | NBODu (lbs/day) | TBODu (lbs/day) |
|---|---|---|---|---|---|---|
| Unnamed Tributary (RM 0.8 – 0.0) | 0.9 | 2 | 126.1 | 0.1 | 28.8 | 154.9 |
| Dry Branch (RM 0.3 – 0.0) | 0.3 | 2 | 42.0 | 0.1 | 9.6 | 51.6 |
| Red Creek (RM 84.4 – 82.7) | 1.9 | 2 | 266.3 | 0.1 | 60.8 | 327.1 |
| Red Creek (RM 82.7 -79.0) | 4.1 | 2 | 574.6 | 0.1 | 131.3 | 705.9 |
| Red Creek (RM 79.0 – 77.6) | 1.6 | 2 | 224.2 | 0.1 | 51.2 | 275.5 |
| Red Creek (RM 77.6 – 75.8) | 2 | 2 | 280.3 | 0.1 | 64.0 | 344.3 |
| Red Creek (RM 75.8 – 74.8) | 1.1 | 2 | 154.2 | 0.1 | 35.2 | 189.4 |
| Red Creek (RM 74.8 - 71.6) | 3.5 | 2 | 490.5 | 0.1 | 112.1 | 602.6 |
| Red Creek (RM 71.6 – 68.1) | 3.9 | 2 | 546.5 | 0.1 | 124.9 | 671.4 |
| | **19.3** | | **2,704.7** | | **618.0** | **3,322.7** |

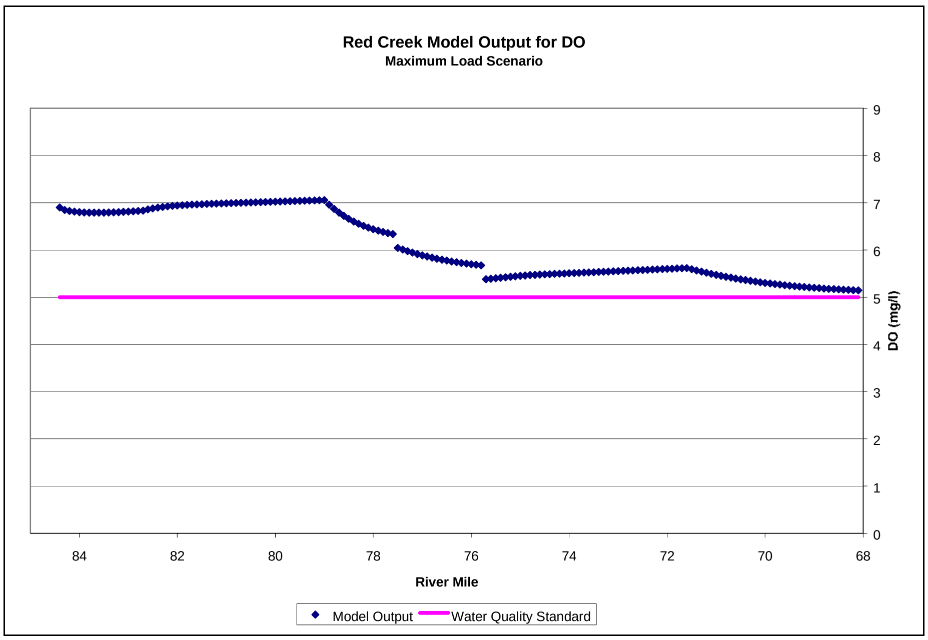



**Figure 10. Model Output for Red Creek at Maximum Load Scenario**

## 3.5 Evaluation of Ammonia Toxicity

Ammonia must not only be considered due to its effect on dissolved oxygen in the receiving water, but also due to its toxicity potential. Ammonia nitrogen concentrations can be evaluated using the criteria given in 1999 Update of Ambient Water Quality Criteria for Ammonia (EPA-822-R-99-014). The maximum allowable instream ammonia nitrogen ($NH_3$-N) concentration at a pH of 7.0 and stream temperature of 26°C is 2.82 mg/l. Based on the model results for the maximum load scenario, Figure 11, this standard was not exceeded in Red Creek.

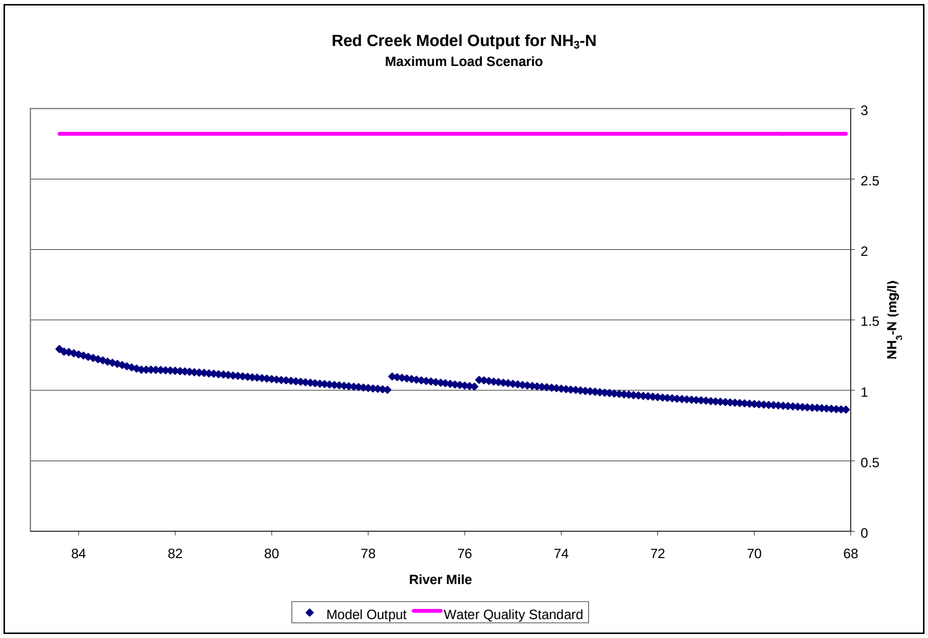



**Figure 11. Model Output for $NH_3$-N in Red Creek at Maximum Load Scenario**

## 3.6 Total Phosphorus Estimates

The primary data available for Red Creek were collected as part of the M-BISQ project. As a result, the §303(d) listing for Red Creek was changed to biological impairment and a Stressor Identification Report was prepared by MDEQ in 2004. The stressor identification process determined that the biological impairment in Red Creek was most likely due to organic enrichment/low dissolved oxygen and nutrients.

Due to the limited amount of total phosphorus data available for Red Creek, the estimated existing total phosphorus concentration is based on the median total phosphorus concentrations measured in wadeable streams in the East Bioregion with impaired biology and elevated nutrient levels. For wadeable streams in the East Bioregion, the estimated existing total phosphorus concentration from sites with impaired biology and elevated nutrient levels is 0.22 mg/l.

The use of the mass balance approach was used only to get an initial estimate of the relative contribution of point and non-point loads. To convert the estimated existing total phosphorus concentration to a total phosphorus load, the average annual flow for Red Creek was estimated based on USGS monitoring data. The annual average flow for Red Creek at Vestry (02479300) is 861 cfs, with a drainage area of 441 square miles. This flow monitoring station is located on Red Creek downstream of the impaired segment. To estimate the amount of flow in Red Creek within the segment, a drainage area ratio was calculated (861 cfs/441 square miles = 1.95 cfs/square mile). The ratio was then multiplied by the drainage area of the modeled segment, 78.8 square miles (1.95 cfs/square mile * 78.8 square miles = 154 cfs). Thus, the annual average flow in Red Creek is estimated as 154 cfs (100 MGD).

The estimated existing TP load was then calculated, using Equation 5 as shown below, to be 182.6 lbs/day. The existing total phosphorous load consists of both point and non-point components. Since many treatment facilities in Mississippi do not have permit limits for phosphorous, nor are they currently required to report effluent phosphorous concentrations, MDEQ used an estimated effluent concentration based on literature values for different treatment types. Table 10 shows the median effluent phosphorus concentrations for four conventional treatment processes. The appropriate concentration for each of the facilities was then used in Equation 5 to estimate the total phosphorus load from point sources. The Hunt Southland Refining Company does not have a maximum permitted flow. Instead, this facility is required to report their flow on a monthly basis. The permitted discharge for this facility given in Table 11 is based on the average flow measured during a 19 month period (January 2003 through July 2004).

**TP Load (lb/day) = Flow(MGD) *8.34 (conversion factor)* TP Concentration (mg/L) (Eq. 5)**

**Table 10. Median Phosphorous Concentrations in Wastewater Effluents**

| | Treatment Type | | | |
|---|---|---|---|---|
| | **Primary** | **Trickling Filter** | **Activated Sludge** | **Stabilization Pond** |
| No. of plants sampled | 55 | 244 | 244 | 149 |
| Total P (mg/L) | 6.6 ± 0.66 | 6.9 ± 0.28 | 5.8 ± 0.29 | 5.2 ± 0.45 |

Source: After Ketchum, 1982 in EPA 823-B-97-002 (USEPA, 1997)

**Table 11. NPDES Permitted Facilities Treatment Types with Phosphorus Estimates**

| Facility Name | NPDES | Treatment Type | Permitted Discharge (MGD) | TP concentration estimate (mg/l) | TP Load estimate (lbs/day) |
|---|---|---|---|---|---|
| Hunt Southland Refining Company, Lumberton Refinery | MS0001678 | Dissolved Air Flotation, Activated Sludge, and Aerated Lagoon | *0.097** | 5.8 | 4.7 |
| Lumberton POTW | MS0020206 | Aerated Lagoon | 0.5 | 5.2 | 21.7 |
| Total | | | 0.597 | | 26.4 |

* Assumed value based on average flow reported in DMR Data

The average TP point source load is estimated to be 26.4 pounds per day. The annual average total load based on the estimated total phosphorus concentration of 0.22 mg/L and an annual average flow of 100 MGD is 182.6 pounds per day. The point source load is 14.4% of the total load. Therefore, 85.6% of the estimated existing total load is from non-point sources.

The annual total phosphorus concentration range for this TMDL is 0.07 to 0.11 mg/L based on total phosphorus concentrations measured for non-impaired wadeable streams in the East Bioregion. The existing concentration was assumed to be 0.22 mg/L based on total phosphorus concentrations measured for wadeable streams in the East Bioregion with impaired biology and elevated nutrient levels. This indicates that an estimated percent reduction of 50 to 68% of estimated instream total phosphorus concentration is needed in Red Creek to meet the concentration range for non-impaired wadeable streams in the East Bioregion.

# ALLOCATION

The allocation for this TMDL involves a wasteload allocation for point sources and a load allocation for non-point sources necessary for attainment of water quality standards in Red Creek. The TMDL also includes a margin of safety to ensure that water quality standards will be maintained under all conditions. The load and wasteload allocations and margin of safety are given in terms of TBODu for this Phase 1 TMDL.

The nutrient portion of this TMDL is addressed through initial estimates of the existing and target total phosphorus concentrations. In agreement with EPA Region 4 MDEQ is continuing work on a six year plan to establish criteria for nutrients in wadeable streams, non-wadeable rivers, lakes, and estuaries. The target for this TMDL is only preliminary and will be subject to revision as the work of the NTF continues. When water quality standards and additional information become available, a Phase 2 TMDL may be developed for Red Creek that includes a modified nutrient target and reduction scenario.

## 4.1 Wasteload Allocation

Federal regulations require that effluent limits developed to protect water quality criteria are consistent with the assumptions and requirements of any available wasteload allocation prepared by the state and approved by EPA. The NPDES Permitted facilities that discharge $BOD_5$ and ammonia nitrogen in Red Creek are included in the wasteload allocation, Table 12. No reduction of the permitted TBODu load is needed in order for the model to show compliance with the TMDL endpoint.

**Table 12. Wasteload Allocation**

| Facility | CBODu (lbs/day) | NBODu (lbs/day) | TBODu (lbs/day) |
|---|---|---|---|
| Hunt Southland Refining Company, Lumberton Refinery | 98.3 | 59.9 | 158.2 |
| Lumberton POTW | 187.7 | 38.1 | 225.8 |
| | **286.0** | **98.0** | **384.0** |

**Table 13. Wasteload Allocation TP***

| Facility | Existing Estimated TP Point Source Concentration (mg/l) | Permitted Discharge (MGD)) | Existing Estimated TP Point Source Load (lbs/day) | Allocated Average TP Point Source Load (lbs/day) | Percent Reduction |
|---|---|---|---|---|---|
| Hunt Southland Refining Company, Lumberton Refinery | 5.2 | *0.097*** | 4.7 | 4.7 | 0 |
| Lumberton POTW | 5.2 | 0.5 | 21.7 | 21.7 | 0 |
| | | 0.597 | 26.4 | 26.4 | 0 |

*Due to the lack of nutrient water quality criteria these Phase 1 TMDL allocations are estimates based on literature assumptions and projected targets. The State of Mississippi is in the process of developing numeric nutrient criteria in accordance with an EPA approved work plan for nutrient criteria development. This TMDL recommends quarterly monitoring of nutrients for NPDES facilities. MDEQ's calculations of the annual average load indicate that the majority of the estimated nutrient load is from non-point sources. Therefore, the State will focus on striving to attain the goal set by the LA portion of the TMDL.
** Assumed value based on average flow reported in DMR Data

The estimated load of total phosphorus from point sources shown in Table 13 is 14.4% of the estimated existing average annual load of total phosphorus in Red Creek, as described in Section 3.6. Because this estimate is based on literature values this TMDL recommends quarterly nutrient monitoring for the Hunt Southland Refining Company and the Lumberton POTW.

Although this wasteload allocation is based on the permit limits of facilities present in the Red Creek watershed, it is not intended to prevent the issuance of permits for future facilities. This is because the model results show that Red Creek has additional assimilative capacity for organic material. Future permits will be considered on a case-by-case basis.

## 4.2 Load Allocation

The BOD non-point source loads in Red Creek and its tributaries are included in the load allocation, Table 13. This TMDL does not require a reduction of the BOD load allocation, but does recommend reduction of the nonpoint source contribution of total phosphorus. Note that the non-point source loads are reflected in the model output from the baseline scenario and are equal to the loads given in Table 8. The baseline non-point source BOD loads represent an approximation of the loads currently going into Red Creek at low-flow conditions based on data and regulatory assumptions

**Table 13. Load Allocation**

| Reach | CBODu (lbs/day) | NBODu (lbs/day) | TBODu (lbs/day) |
|---|---|---|---|
| Unnamed Tributary (RM 0.8 – 0.0) | 9.7 | 2.2 | 11.9 |
| Dry Branch (RM 0.3 – 0.0) | 3.2 | 0.7 | 4.0 |
| Red Creek (RM 84.4 – 82.7) | 20.5 | 4.7 | 25.2 |
| Red Creek (RM 82.7 -79.0) | 44.2 | 10.1 | 54.3 |
| Red Creek (RM 79.0 – 77.6) | 17.2 | 3.9 | 21.2 |
| Red Creek (RM 77.6 – 75.8) | 21.6 | 4.9 | 26.5 |
| Red Creek (RM 75.8 – 74.8) | 11.9 | 2.7 | 14.6 |
| Red Creek (RM 74.8 - 71.6) | 37.7 | 8.6 | 46.4 |
| Red Creek (RM 71.6 – 68.1) | 42.0 | 9.6 | 51.6 |
| | **208.1** | **47.5** | **255.6** |

Based on initial estimates in Section 3.6, approximately 85.6% of the total phosphorus load in this watershed comes from non-point sources. Therefore, best management practices (BMPs) should be encouraged in the watershed to reduce potential total phosphorus loads from non-point sources. The Red Creek watershed should be considered a priority for riparian buffer zone restoration and any nutrient reduction BMPs. For land disturbing activities related to silviculture, construction, and agriculture, it is recommended that practices, as outlined in "Mississippi's BMPs: Best Management Practices for Forestry in Mississippi" (MFC, 2000), "Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater" (MDEQ, et. al, 1994), and "Field Office Technical Guide" (NRCS, 2000), be followed, respectively. Table 14 shows the load allocation for Total Phosphorus based on the estimates given in Section 3.6.

**Table 14. Load Allocation for Estimated Total Phosphorus**

| Existing Estimated TP Nonpoint Source Load (lbs/day) | Allocated Average TP Nonpoint Source Load (lbs/day) | Percent Reduction |
|---|---|---|
| 156.2 | 31.7 to 64.9 | 58% to 80% |

## 4.3 Incorporation of a Margin of Safety

The margin of safety is a required component of a TMDL and accounts for the uncertainty about the relationship between pollutant loads and the quality of the receiving water body. The two types of MOS development are to implicitly incorporate the MOS using conservative model assumptions or to explicitly specify a portion of the total TMDL as the MOS. The MOS selected for this TMDL includes both an implicit and explicit component.

Conservative assumptions which place a higher oxygen demand on the water body than may actually be present are considered part of the implicit margin of safety. The assumption that all of the ammonia nitrogen present in the water body is oxidized to nitrate nitrogen, for example, is a conservative assumption. In addition, the TMDL is based on the critical condition of the water body represented by the low-flow, high-temperature condition. Modeling the water body at this flow provides protection during the worst-case scenario.

The explicit MOS for this report is the difference between the non-point loads calculated in the maximum load scenario and the baseline non-point loads. The baseline non-point source loads represent an approximation of the loads currently going into Red Creek at low-flow conditions based on flow data and regulatory assumptions. The maximum non-point source loads are the maximum TBODu loads that allow maintenance of water quality standards under 7Q10 flow conditions. MDEQ has set the MOS as the difference in these loads to account for the uncertainty in the desktop model that was used to develop this Phase 1 TMDL. There were very little data available to set up the model, and many assumptions based on regulations and literature values were used. The rate of sediment oxygen demand, for example, was set to zero due to lack of monitoring data. Sediment oxygen demand, however, can be a significant factor in the DO balance of a large water body such as Red Creek. The STREAM model is a steady state, daily average model that assumes complete mixing throughout the water column. There is some uncertainty in applying this type of model to large rivers such as Red Creek. Due to the uncertainty in the model, MDEQ set a large, explicit MOS instead of increasing either the WLA or LA to express the maximum assimilative capacity determined for the water body.

For this TMDL the explicit MOS will be set as the difference between these two load scenarios, 3,067 lbs/day TBODu. The calculation of the MOS is shown in Table 15.

**Table 15. Calculation of the Explicit Margin of Safety**

| | Maximum Non-point Load | Baseline Non-point Load | Margin of Safety (Maximum – Baseline) |
|---|---|---|---|
| CBODu (lbs/day) | 2,704.7 | 208.1 | 2,496.6 |
| NBODu (lbs/day) | 618.0 | 47.5 | 570.5 |
| **TBODu (lbs/day)** | **3,322.7** | **255.6** | **3,067.1** |

The total phosphorus allocations incorporate an implicit margin of safety in the estimation of the allocations using annual average flow estimates and literature values for loading based on facility type. The estimation of the preliminary target also includes implicitly conservative assumptions in the use of only the non-impaired streams for target development.

## 4.4 Seasonality

Seasonal variation may be addressed in the TMDL by using seasonal water quality standards or developing model scenarios to reflect seasonal variations in flow, temperature, and other parameters. Mississippi's water quality standards for dissolved oxygen, however, do not vary according to the seasons. This model was set up to simulate dissolved oxygen during the critical condition period, the low-flow, high-temperature period that typically occurs during the late summer season. Since the critical condition represents the worst-case scenario, the TMDL developed for critical conditions is protective of the water body at all times. Thus, this TMDL will ensure attainment of water quality standards for each season

## 4.5 Calculation of the TMDL

The TMDLs were calculated based on Equation 6.

$$\mathbf{TMDL = WLA + LA + MOS} \qquad \textbf{(Equation 6)}$$

In this equation, WLA is the wasteload allocation, LA is the load allocation, and MOS is the margin of safety. All units are in lbs/day of TBODu. The Phase 1 TMDL for TBODu was calculated based on the current loading of pollutant in Red Creek. The TMDL calculations are shown in Tables 16 and 17. As shown in Table 16, TBODu is the sum of CBODu and NBODu. The wasteload allocations incorporate the CBODu and $NH_3$-N contributions from identified NPDES Permitted facilities. The load allocations include the background and non-point sources of CBODu and $NH_3$-N from surface runoff and groundwater infiltration. The implicit margin of safety for this TMDL is derived from the conservative assumptions used in setting up the model. An explicit margin of safety has also been included in the TMDL to account for the difference between non-point source loads calculated in the maximum load scenario and baseline non-point source loads.

**Table 16. Phase 1 TMDL for TBODu in Red Creek Segment MS102RE**

| | WLA (lbs/day) | LA (lbs/day) | MOS (lbs/day) | TMDL (lbs/day) |
|---|---|---|---|---|
| CBODu | 158.2 | 208.1 | 2,496.6 | 2,862.9 |
| NBODu | 225.8 | 47.5 | 570.5 | 843.8 |
| **TBODu** | **384.0** | **255.6** | **3,067.1** | **3,706.7** |

**Table 17. Phase 1, TMDL for TP* in the Red Creek Watershed**

| | WLA (lbs/day) | LA (lbs/day) | MOS (lbs/day) | TMDL (lbs/day) |
|---|---|---|---|---|
| **TP** | **26.4*** | **31.7 to 64.9*** | **Implicit** | **58.1 to 91.3*** |

* Due to the lack of nutrient water quality criteria these Phase 1 TMDL allocations are estimates based on literature assumptions and projected targets. The State of Mississippi is in the process of developing numeric nutrient criteria in accordance with an EPA approved work plan for nutrient criteria development. This TMDL recommends quarterly monitoring of nutrients for NPDES facilities. MDEQ's calculations of the annual average load indicate that the majority of the estimated nutrient load is from non-point sources. Therefore, the State will focus on striving to attain the goal set by the LA portion of the TMDL.

The TMDL presented in this report represents the current load of a pollutant allowed in the water body. Although it has been developed for critical conditions in the water body, the allowable load is not tied to any particular combination of point and non-point loads. The LA given in the TMDL applies to all non-point sources and does not assign loads to specific sources. Also, the WLA does not dictate a specific distribution of the loads among individual point sources.

BMPs, as outlined in "Mississippi's BMPs: Best Management Practices for Forestry in Mississippi" (MFC, 2000), "Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater" (MDEQ, et. al, 1994), and "Field Office Technical Guide" (NRCS, 2000), are an effective means of reducing the sediment load from a majority of potential upland sources. While these BMPs address the issue of sediment control, it is believed that these BMP's would also help alleviate any non-point source runoff that would contribute to organic enrichment and nutrient loading in Bogue Homo. The adoption of numeric nutrient criteria will be reflected in the Phase 2 TMDL that will be completed using data based allocations in lieu of the literature based allocations included in this TMDL. MDEQ's calculations of the annual average load indicate that the majority of the estimated nutrient load is from non-point sources. Therefore, the State will focus on striving to attain the goal set by the LA portion of the TMDL.

## 4.6 Reasonable Assurance

This component of the TMDL development does not apply to this TMDL Report. There are no point sources (WLA) requesting a reduction based on promised LA components and reductions. Currently, the opportunity for this option is available for future discussion.

MDEQ has adopted the Basin Approach to Water Quality Management, a plan that divides Mississippi's major drainage basins into five groups. Each TMDL is evaluated through the Basin Team for prioritization and targeting of implementation activities.

# CONCLUSION

This Phase 1 TMDL is based on a desktop model using MDEQ's regulatory assumptions and literature values in place of actual field data. The model results indicate that Red Creek is meeting the water quality standard for dissolved oxygen at the present loading of TBODu. Thus, this TMDL does not limit the expansion of existing permits or issuance of new permits in the watershed as long as new facilities do not cause impairment in Red Creek. Nutrients were addressed through an estimate of a preliminary total phosphorus concentration range. This TMDL has been developed as a Phase 1 TMDL so that TBOD and/or nutrients may be further evaluated when more data are available or when numeric water quality standards are finalized for nutrients.

In lieu of state water quality standards for nitrogen and phosphorus, MDEQ developed this estimated TMDL for total phosphorus based on various assumptions. The TMDL recommends a 50 to 68% reduction of the nutrient concentration in Red Creek to meet the preliminary range of 0.07 to 0.11 mg/l. Because 85.6% of the existing total phosphorus load is estimated to be due to non-point sources, the State will focus on striving to attain the goal set by the LA portion of the TMDL. This TMDL recommends quarterly nutrient monitoring for the Hunt Southland Refining Company and the Lumberton POTW. Additionally, it is recommended that the Red Creek watershed be considered as a priority watershed for riparian buffer zone restoration and any nutrient reduction BMPs. The implementation of these BMP activities should reduce the nutrient load entering Red Creek. This will provide improved water quality for the support of aquatic life in the water body and will result in the attainment of the applicable water quality standards.

## 5.1 Future Monitoring

Additional monitoring needed for model refinement may be prioritized by the local stakeholders, MDEQ, and EPA. MDEQ has adopted the Basin Approach to Water Quality Management, a plan that divides Mississippi's major drainage basins into five groups. During each year-long cycle, MDEQ's resources for water quality monitoring will be focused on one of the basin groups. During the next monitoring Phase in the Pascagoula River Basin, Red Creek Watershed will receive additional monitoring to identify any change in water quality.

## 5.2 Public Participation

This TMDL will be published for a 30-day public notice. During this time, the public will be notified by publication in the statewide newspaper. The public will be given an opportunity to review the TMDL and submit comments. MDEQ also distributes all TMDLs at the beginning of the public notice to those members of the public who have requested to be included on a TMDL mailing list. TMDL mailing list members may request to receive the TMDL reports through either, email or the postal service. Anyone wishing to become a member of the TMDL mailing list should contact Greg Jackson at (601) 961-5098 or Greg_Jackson@deq.state.ms.us.

All comments should be directed to Greg Jackson at Greg_Jackson@deq.state.ms.us or Greg Jackson, MDEQ, PO Box 10385, Jackson, MS 39289. All comments received during the public notice period and at any public hearings become a part of the record of this TMDL and will be considered in the submission of this TMDL to EPA Region 4 for final approval.

At the end of the 30-day period, MDEQ will determine the level of interest in the TMDL and make a decision on the necessity of holding a public hearing. If a public hearing is deemed appropriate, the public will be given a 30-day notice of the hearing to be held at a location near the watershed. That public hearing would be an official hearing of the Mississippi Commission on Environmental Quality, and would be transcribed.

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# DEFINITIONS

**5-Day Biochemical Oxygen Demand**: Also called $BOD_5$, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over a period of 5 days.

**Activated Sludge:** A secondary wastewater treatment process that removes organic matter by mixing air and recycled sludge bacteria with sewage to promote decomposition

**Aerated Lagoon**: A relatively deep body of water contained in an earthen basin of controlled shape which is equipped with a mechanical source of oxygen and is designed for the purpose of treating wastewater.

**Ammonia**: Inorganic form of nitrogen ($NH_3$); product of hydrolysis of organic nitrogen and denitrification. Ammonia is preferentially used by phytoplankton over nitrate for uptake of inorganic nitrogen.

**Ammonia Nitrogen**: The measured ammonia concentration reported in terms of equivalent ammonia concentration; also called total ammonia as nitrogen ($NH_3$-N)

**Ammonia Toxicity**: Under specific conditions of temperature and pH, the unionized component of ammonia can be toxic to aquatic life. The unionized component of ammonia increases with pH and temperature.

**Ambient Stations**: A network of fixed monitoring stations established for systematic water quality sampling at regular intervals, and for uniform parametric coverage over a long-term period.

**Assimilative Capacity**: The capacity of a body of water or soil-plant system to receive wastewater effluents or sludge without violating the provisions of the State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters and Water Quality regulations.

**Background**: The condition of waters in the absence of man-induced alterations based on the best scientific information available to MDEQ. The establishment of natural background for an altered water body may be based upon a similar, unaltered or least impaired, water body or on historical pre-alteration data.

**Biological Impairment**: Condition in which at least one biological assemblage (e.g., fish, macroinvertebrates, or algae) indicates less than full support with moderate to severe modification of biological community noted.

**Carbonaceous Biochemical Oxygen Demand**: Also called CBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous compounds under aerobic conditions over an extended time period.

**Calibrated Model**: A model in which reaction rates and inputs are significantly based on actual measurements using data from surveys on the receiving water body.

**Conventional Lagoon**: An un-aerated, relatively shallow body of water contained in an earthen basin of controlled shape and designed for the purpose of treating water.

**Critical Condition**: Hydrologic and atmospheric conditions in which the pollutants causing impairment of a water body have their greatest potential for adverse effects.

**Daily Discharge**: The "discharge of a pollutant" measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling. For pollutants with limitations expressed in units of mass, the "daily discharge" is calculated as the total mass of the pollutant discharged over the day. For pollutants with limitations expressed in other units of measurement, the "daily average" is calculated as the average.

**Designated Use**: Use specified in water quality standards for each water body or segment regardless of actual attainment.

**Discharge Monitoring Report**: Report of effluent characteristics submitted by a NPDES Permitted facility.

**Dissolved Oxygen**: The amount of oxygen dissolved in water. It also refers to a measure of the amount of oxygen that is available for biochemical activity in a water body. The maximum concentration of dissolved oxygen in a water body depends on temperature, atmospheric pressure, and dissolved solids.

**Dissolved Oxygen Deficit**: The saturation dissolved oxygen concentration minus the actual dissolved oxygen concentration.

**DO Sag**: Longitudinal variation of dissolved oxygen representing the oxygen depletion and recovery following a waste load discharge into a receiving water.

**Effluent Standards and Limitations**: All State or Federal effluent standards and limitations on quantities, rates, and concentrations of chemical, physical, biological, and other constituents to which a waste or wastewater discharge may be subject under the Federal Act or the State law. This includes, but is not limited to, effluent limitations, standards of performance, toxic effluent standards and prohibitions, pretreatment standards, and schedules of compliance.

**Effluent**: Treated wastewater flowing out of the treatment facilities.

**First Order Kinetics**: Describes a reaction in which the rate of transformation of a pollutant is proportional to the amount of that pollutant in the environmental system.

**Groundwater**: Subsurface water in the zone of saturation. Groundwater infiltration describes the rate and amount of movement of water from a saturated formation.

**Impaired Water body**: Any water body that does not attain water quality standards due to an individual pollutant, multiple pollutants, pollution, or an unknown cause of impairment.

**Land Surface Runoff**: Water that flows into the receiving stream after application by rainfall or irrigation. It is a transport method for non-point source pollution from the land surface to the receiving stream.

**Load Allocation (LA)**: The portion of receiving water's loading capacity attributed to or assigned to non-point sources (NPS) or background sources of a pollutant

**Loading**: The total amount of pollutants entering a stream from one or multiple sources.

**Mass Balance**: An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving a defined area, the flux in must equal the flux out.

**Non-point Source**: Pollution that is in runoff from the land. Rainfall, snowmelt, and other water that does not evaporate become surface runoff and either drains into surface waters or soaks into the soil and finds its way into groundwater. This surface water may contain pollutants that come from land use activities such as agriculture; construction; silviculture; surface mining; disposal of wastewater; hydrologic modifications; and urban development.

**Nitrification**: The oxidation of ammonium salts to nitrites via *Nitrosomonas* bacteria and the further oxidation of nitrite to nitrate via *Nitrobacter* bacteria.

**Nitrogenous Biochemical Oxygen Demand**: Also called NBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading nitrogenous compounds under aerobic conditions over an extended time period.

**NPDES Permit**: An individual or general permit issued by the Mississippi Environmental Quality Permit Board pursuant to regulations adopted by the Mississippi Commission on Environmental Quality under Mississippi Code Annotated (as amended) §§ 49-17-17 and 49-17-29 for discharges into State waters.

**Photosynthesis**: The biochemical synthesis of carbohydrate based organic compounds from water and carbon dioxide using light energy in the presence of chlorophyll.

**Point Source**: Pollution loads discharged at a specific location from pipes, outfalls, and conveyance channels from either wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving stream.

**Pollution**: Contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the State, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance, or leak into any waters of the State, unless in compliance with a valid permit issued by the Permit Board.

**Publicly Owned Treatment Works (POTW)**: A waste treatment facility owned and/or operated by a public body or a privately owned treatment works which accepts discharges which would otherwise be subject to Federal Pretreatment Requirements.

**Reaeration:** The net flux of oxygen occurring from the atmosphere to a body of water across the water surface.

**Regression Coefficient**: An expression of the functional relationship between two correlated variables that is often empirically determined from data, and is used to predict values of one variable when given values of the other variable.

**Respiration**: The biochemical process by means of which cellular fuels are oxidized with the aid of oxygen to permit the release of energy required to sustain life. During respiration, oxygen is consumed and carbon dioxide is released.

**Sediment Oxygen Demand**: The solids discharged to a receiving water are partly organics, which upon settling to the bottom decompose aerobically, removing oxygen from the surrounding water column.

**Storm Runoff**: Rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate than rainfall intensity, but instead flows into adjacent land or water bodies or is routed into a drain or sewer system.

**Streeter-Phelps DO Sag Equation**: An equation which uses a mass balance approach to determine the DO concentration in a water body downstream of a point source discharge. The equation assumes that the stream flow is constant and that CBODu exertion is the only source of DO deficit while reaeration is the only sink of DO deficit.

**Total Ultimate Biochemical Oxygen Demand**: Also called TBODu, the amount of oxygen consumed by microorganisms while stabilizing or degrading carbonaceous or nitrogenous compounds under aerobic conditions over an extended time period.

**Total Kjeldahl Nitrogen**: Also called TKN, organic nitrogen plus ammonia nitrogen.

**Total Maximum Daily Load or TMDL**: The calculated maximum permissible pollutant loading to a water body at which water quality standards can be maintained.

**Waste**: Sewage, industrial wastes, oil field wastes, and all other liquid, gaseous, solid, radioactive, or other substances which may pollute or tend to pollute any waters of the State.

**Wasteload Allocation (WLA)**: The portion of a receiving water's loading capacity attributed to or assigned to point sources of a pollutant.

**Water Quality Standards**: The criteria and requirements set forth in *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. Water quality standards are standards composed of designated present and future most beneficial uses (classification of waters), the numerical and narrative criteria applied to the specific water uses or classification, and the Mississippi antidegradation policy.

**Water Quality Criteria**: Elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports the present and future most beneficial uses.

**Waters of the State**: All waters within the jurisdiction of this State, including all streams, lakes, ponds, wetlands, impounding reservoirs, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, and all other bodies or accumulations of water, surface and underground, natural or artificial, situated wholly or partly within or bordering upon the State, and such coastal waters as are within the jurisdiction of the State, except lakes, ponds, or other surface waters which are wholly landlocked and privately owned, and which are not regulated under the Federal Clean Water Act (33 U.S.C.1251 et seq.).

**Watershed**: The area of land draining into a stream at a given location.

# ABBREVIATIONS

7Q10 .......... Seven-Day Average Low Stream Flow with a Ten-Year Occurrence Period

BMP .......... Best Management Practice

$CBOD_5$ .......... 5-Day Carbonaceous Biochemical Oxygen Demand

CBODu .......... Carbonaceous Ultimate Biochemical Oxygen Demand

CWA .......... Clean Water Act

DMR .......... Discharge Monitoring Report

DO .......... Dissolved Oxygen

EPA .......... Environmental Protection Agency

GIS .......... Geographic Information System

HCR .......... Hydrograph Controlled Release

HUC .......... Hydrologic Unit Code

LA .......... Load Allocation

MARIS .......... Mississippi Automated Resource Information System

MDEQ .......... Mississippi Department of Environmental Quality

MGD .......... Million Gallons per Day

MOS .......... Margin of Safety

NBODu .......... Nitrogenous Ultimate Biochemical Oxygen Demand

$NH_3$ .......... Total Ammonia

$NH_3$-N .......... Total Ammonia as Nitrogen

$NO_2$+ $NO_3$ .......... Nitrite Plus Nitrate

NPDES .......... National Pollution Discharge Elimination System

NTF .......... Nutrient Task Force

POTW ........................................................................................Public Owned Treatment Works

RBA ........................................................................................ Rapid Biological Assessment

TBODu........................................................................Total Ultimate Biochemical Oxygen Demand

TKN ........................................................................................................ Total Kjeldahl Nitrogen

TN .......................................................................................................................... Total Nitrogen

TOC.......................................................................................................... Total Organic Carbon

TP ................................................................................................................ Total Phosphorous

USGS ........................................................................................ United States Geological Survey

WLA ........................................................................................................ Waste Load Allocation