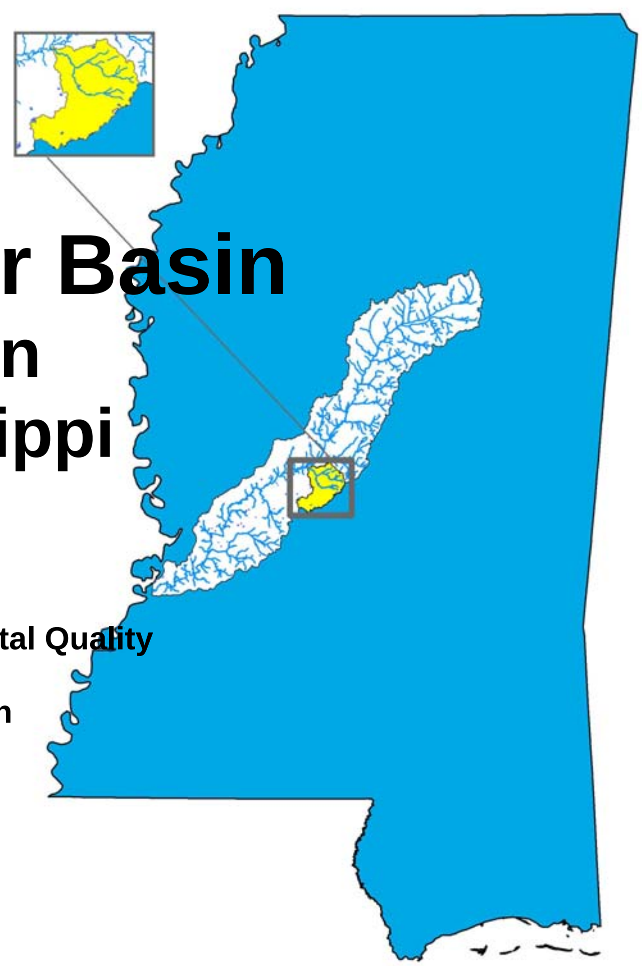
FINAL REPORT
October 2009

Total Maximum Daily Load for

Nutrients and Organic Enrichment / Low DO for Bear Creek and Tilda Bogue



Big Black River Basin

Hinds and Madison Counties, Mississippi

Prepared By

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FOREWORD

The report contains one or more Total Maximum Daily Loads (TMDLs) for water body segments found on Mississippi's current Section 303(d) List of Impaired Water Bodies. The implementation of the TMDLs contained herein will be prioritized within Mississippi's rotating basin approach.

As additional information becomes available, the TMDLs may be updated. Such additional information may include water quality and quantity data, changes in pollutant loadings, modifications to the water quality standards or criteria, 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	µ	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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TMDL INFORMATION

Table 1. Listing Information

Name	ID	County	HUC	Evaluated Cause
Bear Creek	MS431BE	Hinds, Madison	08060202	Nutrients and Organic Enrichment / Low DO
Near Virlilia from headwaters at Walnut to the mouth at the Big Black River				
Tilda Bogue	MS431TE	Madison	08060202	Nutrients and Organic Enrichment / Low DO
Near Virlilia from headwaters to the mouth at Bear Creek				

Table 2. Water Quality Standards

Parameter	Beneficial use	Water Quality Criteria
Nutrients	Aquatic Life Support	Waters shall be free from materials attributable to municipal, industrial, agricultural, or other dischargers 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 uses.
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. Natural conditions are defined as background water quality conditions due only to non-anthropogenic sources. The criteria herein apply specifically with regard to substances attributed to sources (discharges, nonpoint sources, or instream activities) as opposed to natural phenomena. Waters may naturally have characteristics outside the limits established by these criteria. Therefore, naturally occurring conditions that fail to meet criteria should not be interpreted as violations of these criteria.

Table 3. Total Maximum Daily Load for Bear Creek (includes Tilda Bogue)

	WLA lbs/day	WLAsw lbs/day	LA lbs/day	MOS	TMDL lbs/day
Total Nitrogen	**279.10**	**72.58**	**974.88**	**Implicit**	**1326.20**
Total Phosphorous	**94.78**	**6.55**	**88.23**	**Implicit**	**189.56**
TBODu	**1646.68**	**11.08**	**148.87**	**1263.60**	**3070.43**

Table 4. Total Maximum Daily Load for Tilda Bogue

	WLA lbs/day	WLAsw lbs/day	LA lbs/day	MOS	TMDL lbs/day
TBODu	**0**	**NA***	**0.21**	**1.02**	**1.23**

***TBODu from LA considered insignificant for calculating WLAsw**

Table 5. Allocated Point Source Loads for Bear Creek Watershed

Permit	Facility	Flow MGD	TN Load lbs/day	TP Load lbs/day	TBODu lbs/day
MS0042455	**Canton POTW, 001***	**2.6**	**249.37**	**84.57**	**1471.26**
MS0042455	**Canton POTW, 003***	**0.31**	**29.73**	**10.08**	**175.42**
	Total		**279.10**	**94.65**	**1646.68**

***HCR Facility with a concentration based permit limit**

EXECUTIVE SUMMARY

This TMDL is for Bear Creek and Tilda Bogue which were placed on the Mississippi 2008 Section 303(d) List of Impaired Water Bodies due to monitored causes. This TMDL will provide an estimate of the total nitrogen (TN), total phosphorus (TP) and total ultimate biological oxygen demand (TBODu) allowable in these streams. Other causes of impairment will be addressed in separate TMDL reports.

Mississippi does not have water quality standards for allowable nutrient concentrations. MDEQ currently has a Nutrient Task Force (NTF) working on the development of criteria for nutrients. An annual concentration of 1.12 mg/l is an applicable target for TN and 0.16 mg/l for TP for water bodies located in Ecoregion 74. MDEQ is presenting these preliminary target values for TMDL development which are subject to revision after the development of numeric nutrient criteria.

The Bear Creek and Tilda Bogue watershed is located in HUC 08060202. The listed segment of Bear Creek is from the headwaters at Walnut Creek to the mouth of the Big Black River. The listed segment of Tilda Bogue is from the headwaters to the mouth at Bear Creek. The location of the combined watersheds for the listed segments is shown in Figure 1.

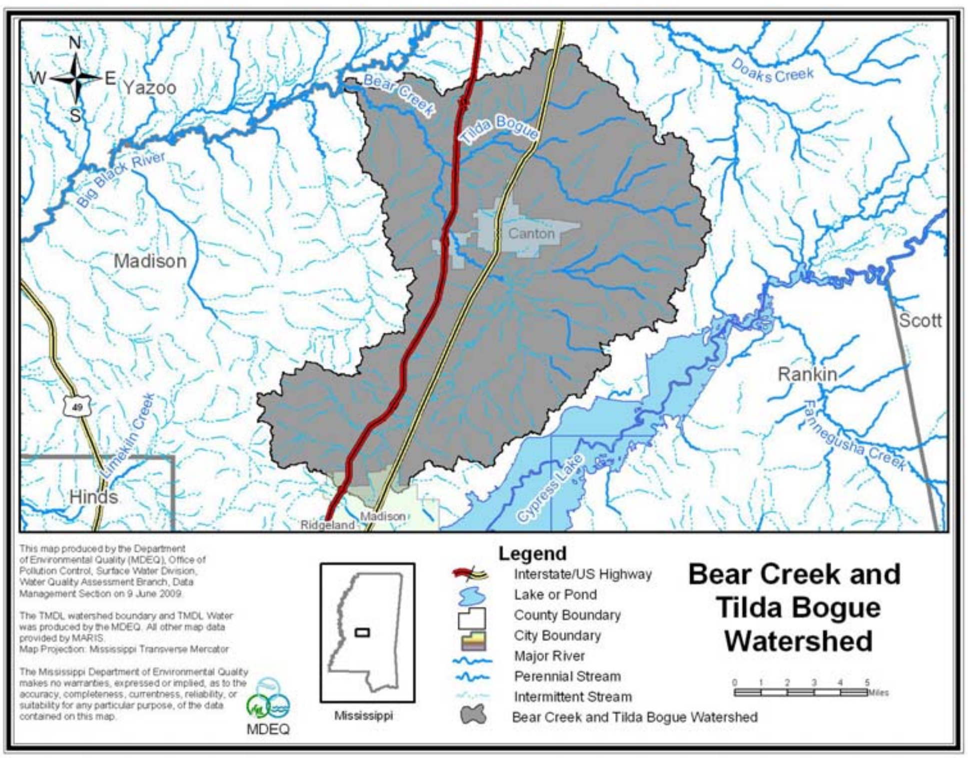


Figure 1. Bear Creek and Tilda Bogue Watershed

The Bear Creek watershed (inclusive of Tilda Bogue) mass balance calculations showed that the estimated existing TP concentration indicates a reduction of TP is needed from the point source. MDEQ believes the estimated existing concentration reductions of nutrients can be accomplished with implementation of best management practices (BMPs) and TP reductions from the point sources. Additionally, according to the STREAM model, the current TBODu load in Bear Creek does not exceed the assimilative capacity for the water body for organic material at the critical conditions (HCR conditions for this report). Therefore, reductions are not needed for TBODu in Bear Creek. TBODu violations were also not shown in Tilda Bogue utilizing the STREAM model. However, MDEQ does not believe that there is available assimilative capacity in these water bodies.

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 Section 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 2008 §303(d) listed segments shown in Figure 2.

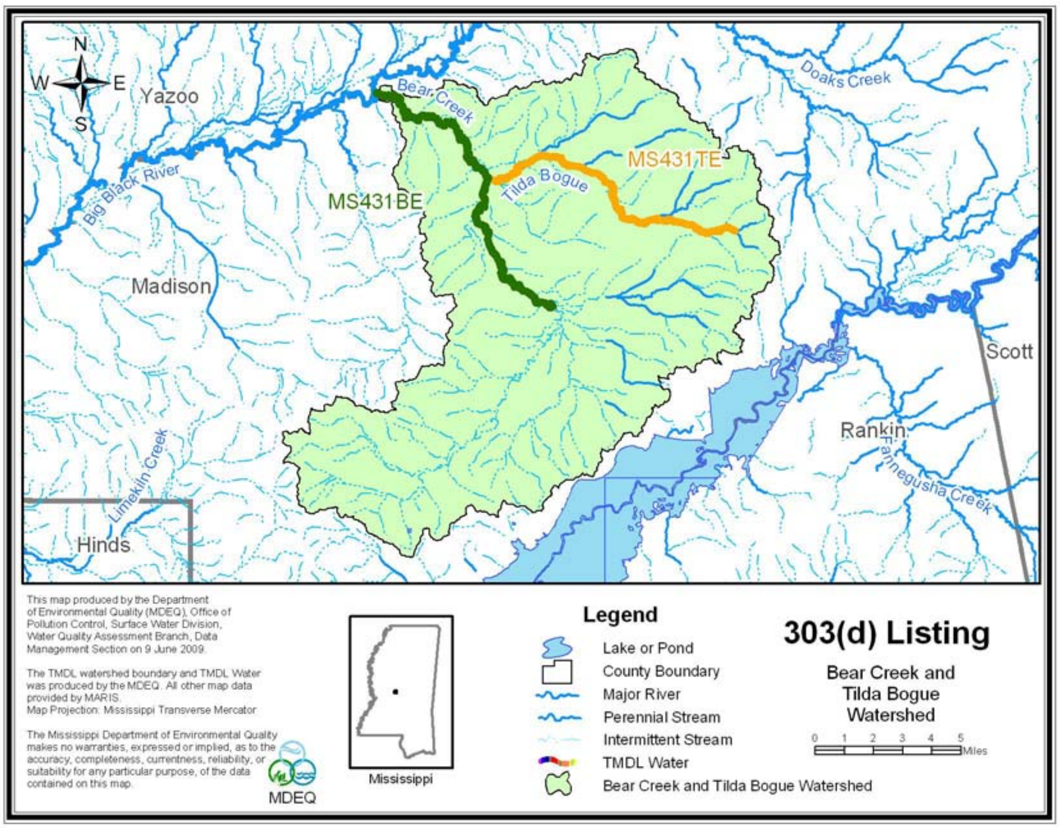


Figure 2. §303(d) Listed Segments of Bear Creek and Tilda Bogue

1.2 Listing History

In 2002, Bear Creek and Tilda Bogue were determined to be biologically impaired due to organic enrichment and nutrients. Stressor identification reports were completed by MDEQ in 2006. (MDEQ, 2006)

1.3 Applicable Water Body Segment Use

The water use classifications are established by the State of Mississippi in the document *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters* (MDEQ, 2007). The designated beneficial use for Bear Creek and Tilda Bogue is Fish and Wildlife.

1.4 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, 2007).

Mississippi's current standards contain a narrative criteria that can be applied to nutrients which states "*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, 2007)." 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 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 current nutrient criteria development plan.

1.5 Nutrient Target Development

Nutrient data were collected quarterly at 99 discrete sampling stations state wide where biological data already existed. These stations were identified and used to represent a range of stream reaches according to biological health status, geographic location (selected to account for ecoregion, bioregion, basin and geologic variability) and streams that potentially receive non-point source pollution from urban, agricultural, and silviculture lands as well as point source pollution from NPDES permitted facilities.

Nutrient concentration data were not normally distributed; therefore, data were log transformed for statistical analyses. Data were evaluated for distinct patterns of various data groupings (stratification) according to natural variability. Only stations that were characterized as "least disturbed" through a defined process in the M-BISQ process (M-BISQ 2003) or stations that resulted in a biological impairment rating of "fully attaining" were used to evaluate natural variability of the data set. Each of these two groups was evaluated separately ("least disturbed sites" and "fully attaining sites). Some stations were used in both sets, in other words, they were considered "least disturbed" and "fully attaining". The number of stations considered "least disturbed" was 30 of 99, and the number of stations considered "fully attaining" was 53 of 99.

Several analysis techniques were used to evaluate nutrient data. Graphical analyses were used as the primary evaluation tool. Specific analyses used included; scatter plots, box plots, Pearson's correlation, and general descriptive statistics.

In general, natural nutrient variability was not apparent based on box plot analyses according to the 4 stratification scenarios. Bioregions were selected as the stratification scheme to use for TMDLs in the Pascagoula Basin. However, this was not appropriate for some water bodies in smaller bioregions. Therefore, MDEQ now uses ecoregions as a stratification scheme for the water bodies in the remainder of the state.

In order to use the data set to determine possible nutrient thresholds, nutrient concentrations were evaluated as to their correlation with biological metrics. That thorough evaluation was completed prior to the Pascagoula River Basin TMDLs. The methodology and approach were verified. The same methodology was applied to the subsequent basins and ecoregions.

For the preliminary target concentration for each ecoregion, the 90th percentile was derived from the mean nutrient value at each site found to be fully supporting of aquatic life support according to the M-BISQ scores.

WATER BODY ASSESSMENT

2.1 Water Quality Data

The impaired segments for Bear Creek and Tilda Bogue were monitored and found to be biologically impaired due to organic enrichment and nutrients. Data exist for Bear Creek and Tilda Bogue at IBI Sites 702 and 309, respectively. Based upon the completed stressor identification reports, the strength of evidence analysis showed low DO to be a primary probable cause of impairment. Some biological metrics also indicated altered food sources (nutrient enrichment). Physical/chemical data for Bear Creek indicate water quality standard exceedances, lower DO % saturation, higher nutrients and higher TOC at IBI site 702. Physical/chemical data for Tilda Bogue also indicate low DO with water quality standard violations and elevated nutrients at IBI site 309. Channelization with moderate to heavy entrenchment and ponding was observed throughout the watershed.

2.2 Assessment of Point Sources

There is 1 NPDES point source in the Bear Creek watershed included in the TMDL. There are no point sources in the Tilda Bogue Watershed. Table 6 indicates the existing estimates of loads for these outfalls at the maximum daily load scenario.

Table 6. Loads from Point Sources

Permit	Facility	Flow MGD	TN Load lbs/day	TP Load lbs/day	CBODu lbs/day	NBODu lbs/day	TBODu lbs/day
MS0042455	Canton POTW, 001*	2.6	249.37	112.76	975.78	495.48	1471.26
MS0042455	Canton POTW, 003*	0.31	29.73	13.44	116.34	59.08	175.42
	Total		**279.10**	**126.20**	**1092.12**	**554.56**	**1646.68**

*HCR facility

Canton’s POTW has two outfalls and is a hydrograph controlled release systems, or HCR. These outfalls do not discharge when the flow in the receiving stream is less than 20.6 cfs. The flows given in Table 6 are based on design flow and loadings are based on NPDES permit limits.

Bear Creek and Tilda Bogue are located within a Phase II MS4 county. Therefore, MDEQ has established a method to estimate the stormwater waste load allocation (WLAsw). The WLAsw = LA * % Urban Area in the MS4 in watershed *70%. The intent of the stormwater NPDES permit is not to treat the water after collection, but to reduce the exposure of stormwater runoff to pollutants by implementing various controls. Stormwater NPDES permits require the establishment of controls or BMPs to reduce the pollutants entering the environment. (GA, 2009) The TMDL loads were then calculated, using Equation 1 and the results are shown in Table 6.

Waste Load Allocation stormwater (WLAsw) = LA * % Urban Area in MS4 within watershed * 70%
(Equation 1)

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, groundwater infiltration, and atmospheric deposition. The two primary nutrients of concern are nitrogen and phosphorus. Total nitrogen is a combination of many forms of nitrogen found in the environment. Inorganic nitrogen can be transported in particulate and dissolved phases in surface runoff. Dissolved inorganic nitrogen can be transported in groundwater and may enter a water body from groundwater infiltration. Finally, atmospheric gaseous nitrogen may enter a water body from atmospheric deposition.

Unlike nitrogen, phosphorus is primarily transported in surface runoff when it has been sorbed by eroding sediment. Phosphorus may also be associated with fine-grained particulate matter in the atmosphere and can enter streams as a result of dry fallout and rainfall (USEPA, 1999). However, phosphorus is typically not readily available from the atmosphere or the natural water supply (Davis and Cornwell, 1988). As a result, phosphorus is typically the limiting nutrient in most non-point source dominated rivers and streams, with the exception of watersheds which are dominated by agriculture and have high concentrations of phosphorus contained in the surface runoff due to fertilizers and animal excrement or watersheds with naturally occurring soils which are rich in phosphorus (Thomann and Mueller, 1987).

Watersheds with a large number of failing septic tanks may also deliver significant loadings of phosphorus to a water body. All domestic wastewater contains phosphorus which comes from humans and the use of phosphate containing detergents. Table 9 presents the estimated loads from various land use types in the Bear Creek Watershed based on information from USDA ARS Sedimentation Laboratory (Shields, et. al., 2008). Table 10 presents the estimated loads from various land use types in the Tilda Bogue Watershed based on information from USDA ARS Sedimentation Laboratory (Shields, et. al., 2008).

The Bear Creek Watershed (which includes the Tilda Bogue Watershed) contains mainly forest but also has different landuse types, including urban, water, scrub/barren, pasture, cropland, and wetlands. The landuse information is based on the National Land Cover Dataset (NLCD). The landuse distribution for the Bear Creek watershed is shown in Table 7, and the landuse distribution for the Tilda Bogue watershed is shown in Table 8. The combined watershed landuses are depicted in Figure 3. By multiplying the landuse category size by the estimated nutrient load, the watershed specific estimate can be calculated.

Table 7. Landuse Distribution for Bear Creek Watershed

In Acres	Urban	Forest	Cropland	Pasture	Scrub/Barren	Water	Wetlands
Bear Creek (Acres)	1472.92	10228.38	7757.80	21944.37	34734.74	18498.14	9137.09
Percentage	1.4%	9.9%	7.5%	21.1%	33.5%	17.8%	8.8%

Table 8. Landuse Distribution for Tilda Bogue Watershed

In Acres	Urban	Forest	Cropland	Pasture	Scrub/Barren	Water	Wetlands
Tilda Bogue (Acres)	837.09	4818.18	3641.05	10090.28	14820.17	9473.35	4450.34
Percentage	1.74%	10.01%	7.56%	20.96%	30.79%	19.68%	9.25%

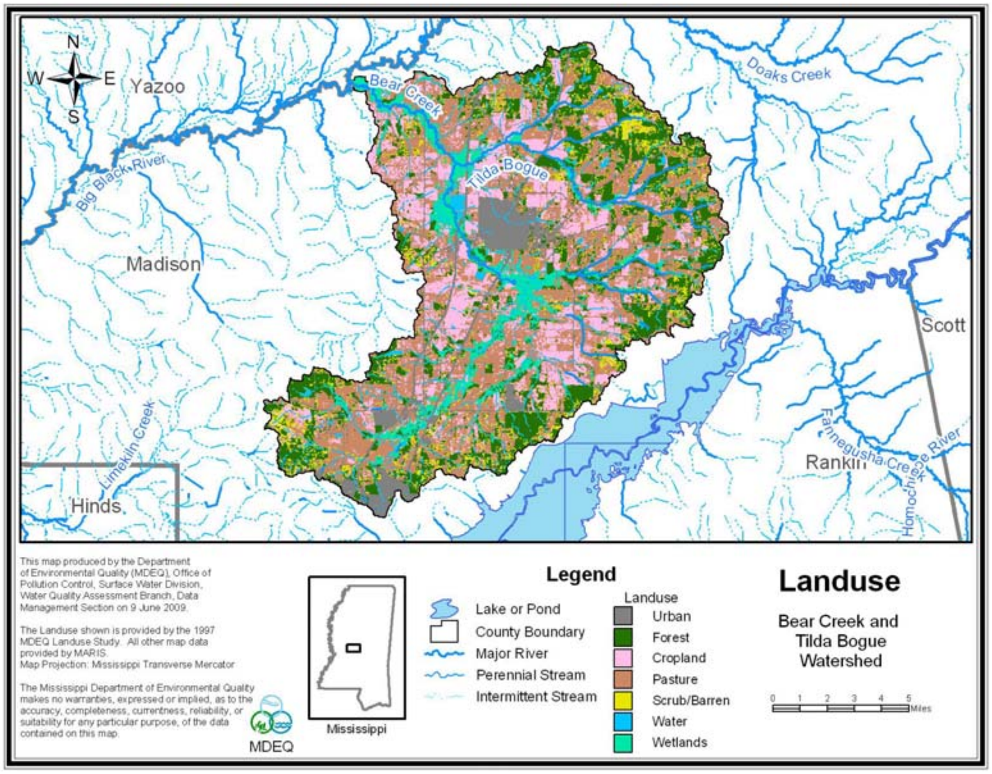


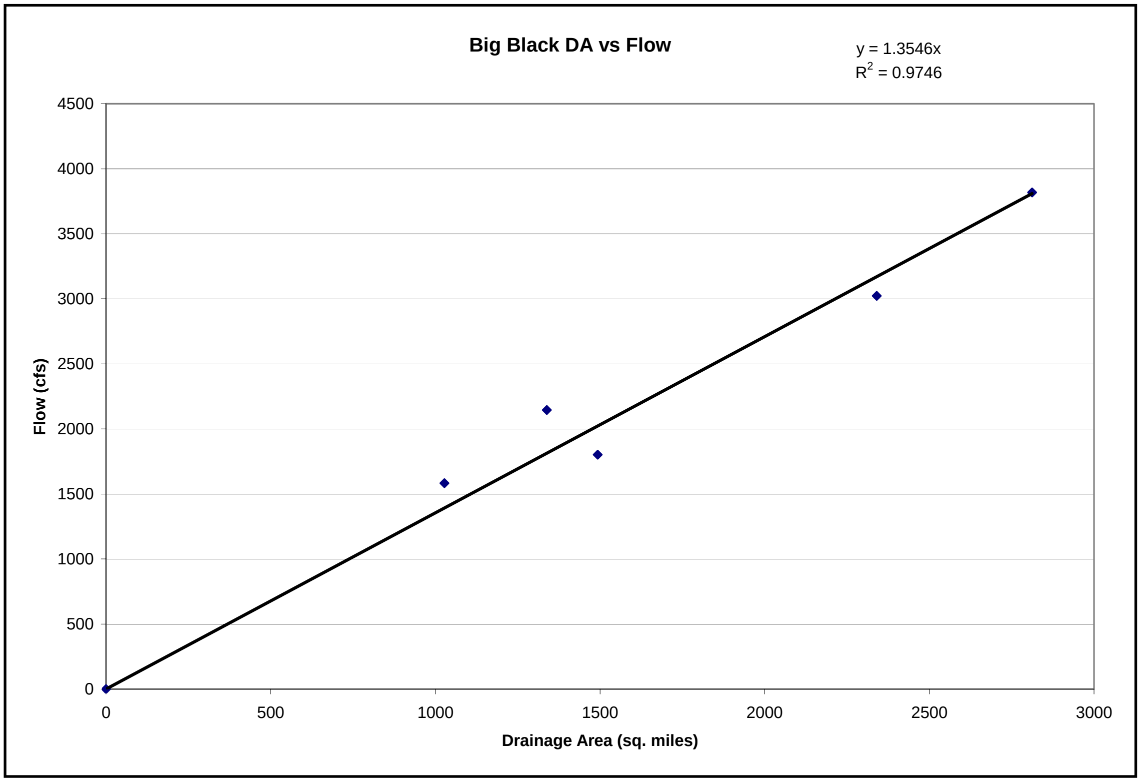
Figure 3. Landuse in the Bear Creek and Tilda Bogue Watershed

2.4 Estimated Existing Load for Total Nitrogen

The estimated existing total nitrogen concentration is based on the average concentrations measured in runoff from various landuses. The target concentration for TN for Ecoregion 74 is 1.12 mg/l. The estimated existing concentration is 1.05 mg/. Therefore, no nitrogen reduction is needed.

The average annual flow in the watershed was calculated by utilizing the flow vs. watershed area graph shown in Figure 4. All available gages were compared to the watershed size. A very strong correlation between flow and watershed size was developed for the Big Black River Basin. The equation for the line that best fits the data was then used to estimate the annual average flow for the Bear Creek and Tilda Bogue Watershed. The TMDL target TN loads were then calculated, using Equation 2.

Figure 4. Drainage Area and Flow in the Big Black River Basin



Nutrient Load (lb/day) = Flow (cfs) * 5.394 (conversion factor)* Nutrient Concentration (mg/L)
(Equation 2)

Table 9. Estimated Existing Total Nitrogen Load for Bear Creek

Stream	Area (sq miles)	Average Annual Flow (cfs)	TN (mg/l)	TN (lbs/day)
Bear Creek	162.2	219.64	1.05	1243.30

The existing TN load consists of both point and non-point components. Since many treatment facilities in Mississippi do not have permit limits for nitrogen, nor are they currently required to report effluent nitrogen concentrations, MDEQ used an estimated effluent concentration based on literature values for different treatment types. Table 10 shows the median effluent nitrogen concentrations for four conventional treatment processes. The appropriate concentration for each of the facilities was then used in Equation 2 to estimate the TN load from point sources, Table 11.

Table 10. Median Nitrogen Concentrations in Wastewater Effluents

	Treatment Type			
	Primary	Trickling Filter	Activated Sludge	Stabilization Pond
No. of plants sampled	55	244	244	149
Total N (mg/l)	22.4 ± 1.30	16.4 ± 0.54	13.6 ± 0.62	11.5 ± 0.84

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

Table 11. NPDES Permitted Facilities Treatment Types with Nitrogen Estimates

Facility Name	Treatment Type	Permitted Discharge (MGD)	TN concentration estimate (mg/l)	TN Load estimate (lbs/day)
Canton POTW, 001	Hydrograph Controlled Release	2.6	11.5	249.37
Canton POTW, 003	Hydrograph Controlled Release	0.31	11.5	29.73

The annual average TN point source load is estimated to be 278.74 lbs/day. The annual average target load based on the target TN concentration of 1.12 mg/l and an annual average flow of 219.64 cfs is 1326.20 lbs/day. The point source load is 21.0% of the total load. Therefore, 78.9% of the TN target load is from non-point sources. Because the TN target load is higher than the estimated existing TN load and because the majority of the load is from non-point sources, no TN reductions are needed from these facilities. However, TN limits will be capped at estimated existing loads for facilities.

2.5 Estimated Existing Load for Total Phosphorus

The estimated existing total phosphorous concentration is based on the average concentrations measured in runoff from various landuses. The target concentration for TP for Ecoregion 74 is 0.16 mg/l. The estimated existing concentration is 0.63 mg/l. To convert the estimated existing total phosphorous concentration to a total phosphorous load, the average annual flow was estimated based on flow data as shown above, Table 12. The existing TP load was then calculated using Equation 2.

Table 12. Estimated Existing Total Phosphorus Load for Fourteen Mile Creek

Stream	Area (sq miles)	Average Annual Flow (cfs)	TP (mg/l)	TP (lbs/day)
Bear Creek	162.2	219.64	0.63	745.98

The existing TP 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 13 shows the median effluent phosphorous concentrations for four conventional treatment processes. The appropriate concentration for each of the facilities was then used in Equation 2 to estimate the TP load from point sources, Table 14.

Table 13. 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 14. NPDES Permitted Facilities Treatment Types with Phosphorous Estimates

Facility Name	Treatment Type	Permitted Discharge (MGD)	TP concentration estimate (mg/l)	TP Load estimate (lbs/day)
Canton POTW, 001	Hydrograph Controlled Release	2.6	5.2	112.76
Canton POTW, 003	Hydrograph Controlled Release	0.31	5.2	13.44

The annual average TP point source load is estimated to be 126.20 lbs/day. The annual average target load based on the target total phosphorous concentration of 0.16 mg/l and an annual average flow of 162.2 cfs is 189.56 lbs/day. The point source load is 67.0% of the total target load. Therefore, 33% of the estimated target load is from non-point sources. Because the point source TP load represents a significant portion of the target TP load, reductions for phosphorus limits are needed.

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.

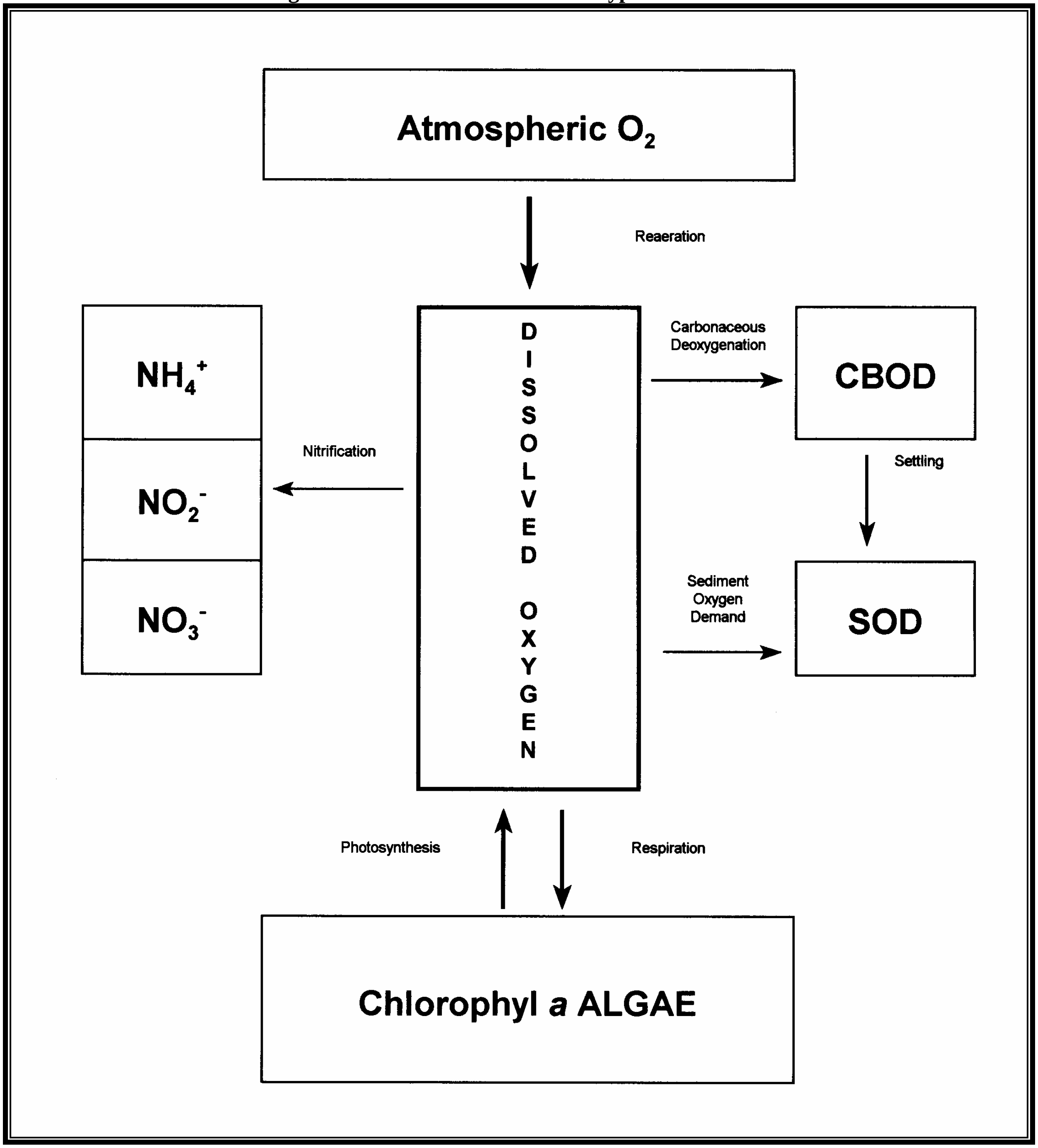
STREAM is a steady-state, daily average computer model that utilizes a modified Streeter-Phelps DO sag equation. Instream processes simulated by the model include CBODu decay, nitrification, reaeration, sediment oxygen demand, and respiration and photosynthesis of algae. Figure 6 shows how these processes 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 3.

$$\mathbf{K}_a = \mathbf{C^*S^*U} \qquad \textbf{(Eq. 3)}$$

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 streams with flows less than 10 cfs and 0.0597 for stream flows equal to or greater than 10 cfs. Reach velocities were calculated using an equation based on slope. The slope of each reach was estimated with the NHD Plus GIS coverage and input into the model in units of feet/mile.

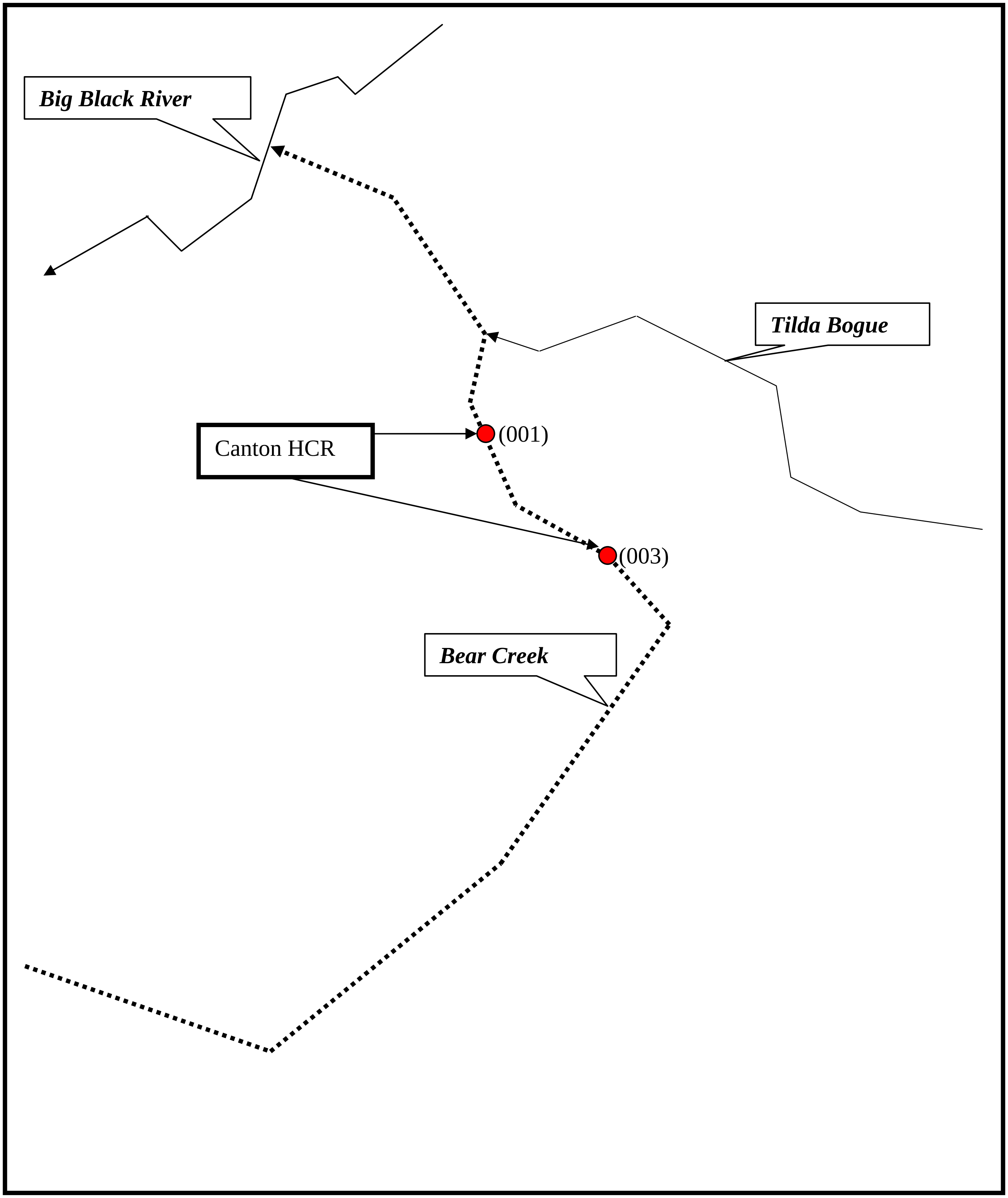
Figure 5. Instream Processes in a Typical DO Model



3.2 Model Setup

The model for this TMDL includes the §303(d) listed segments of Bear Creek and Tilda Bogue, both beginning at the headwaters and flowing to their respective mouths. A diagram showing the model setup is shown in Figure 6.

Figure 6. Bear Creek and Tilda Bogue Model Setup (Note: Not to Scale)



The water body was divided into reaches for modeling purposes. Reach divisions were 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 were divided into computational elements of 0.1 mile. The simulated hydrological and water quality characteristics were 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. MDEQ Regulations state that when the flow in a water body is less than 50 cfs, the temperature used in the model is 26°C. The headwater instream DO was assumed to be 85% of saturation at the stream temperature. The instream CBODu decay rate at K_d at 20°C was input as 0.3 day^{-1} (base e) as specified in MDEQ regulations. The model adjusts the K_d rate based on temperature, according to Equation 4.

$$\mathbf{K_{d(T)} = K_{d(20°C)}(1.047)^{T-20}} \qquad \textbf{(Eq. 4)}$$

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 are not available.

3.3 Source Representation

Both point and non-point sources were represented in the model. The loads from the NPDES permitted point sources were added as direct inputs into the appropriate reach as flows 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 the modeled water body.

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 $CBOD_5$ while TMDLs are typically developed using CBODu, a ratio between the two terms is needed, Equation 5.

$$\mathbf{CBODu = CBOD_5 * Ratio} \qquad \textbf{(Eq. 5)}$$

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 wastewater treatment type.

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 permitted loads of TBODu from the existing point source to be used in the STREAM model are given in Table 15. The model was run at HCR conditions at the minimum stream flows for the point sources to discharge.

Table 15. Point Sources, Maximum Permitted Model Inputs

Permit	Facility	Flow MGD	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
MS0042455	Canton POTW, 001*	2.6	975.78	495.48	1471.26
MS0042455	Canton POTW, 003*	0.31	116.34	59.08	175.42
	Total		**1092.12**	**554.56**	**1646.68**

*HCR facility

Direct measurements of background concentrations of CBODu were not available for Bear Creek or Tilda Bogue. 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 concentration used in modeling for BOD_5 is 1.33 mg/l and for NH_3-N is 0.1 mg/l. These concentrations were also used as estimates for the CBODu and NH_3-N levels of water entering the water bodies through non-point source flow and tributaries. Non-point source flows were included in the model to account for water entering due to groundwater infiltration, overland flow, and small, unmeasured tributaries. The non-point source loads were assumed to be distributed evenly on a river mile basis throughout the modeled reaches.

3.4 Model Calibration

The model used to develop the Bear Creek and Tilda Bogue TMDL was not calibrated due to the limited amount of instream monitoring data collected during critical conditions. Future monitoring is essential to improve the accuracy of the model and the results.

3.5 Model Results

Once the model setup was complete, the model was used to predict water quality conditions in Bear Creek and Tilda Bogue. The model was first run at 7Q10 conditions to determine if violations were present without any of the facilities discharging. The model was then run at HCR conditions to determine if violations were present when the facilities were allowed to discharge at the appropriate stream flows. (It is noted that Bear Creek was run at 7Q10 and HCR conditions although, all of the point sources are HCR facilities. Tilda Bogue was run at 7Q10 conditions only because no point sources are within its watershed.) The loads from the NPDES permitted point sources were based on their current location and loads shown in Table 7.

3.5.1 Regulatory Load Scenario

As shown in Figures 7 and 8, the model does not predict DO violations at 7Q10 conditions for Bear Creek or Tilda Bogue because there is no effluent at 7Q10. The model also does not show violations at the HCR conditions, Figure 9. Thus, permit limit reductions are not needed to meet the current TMDL.

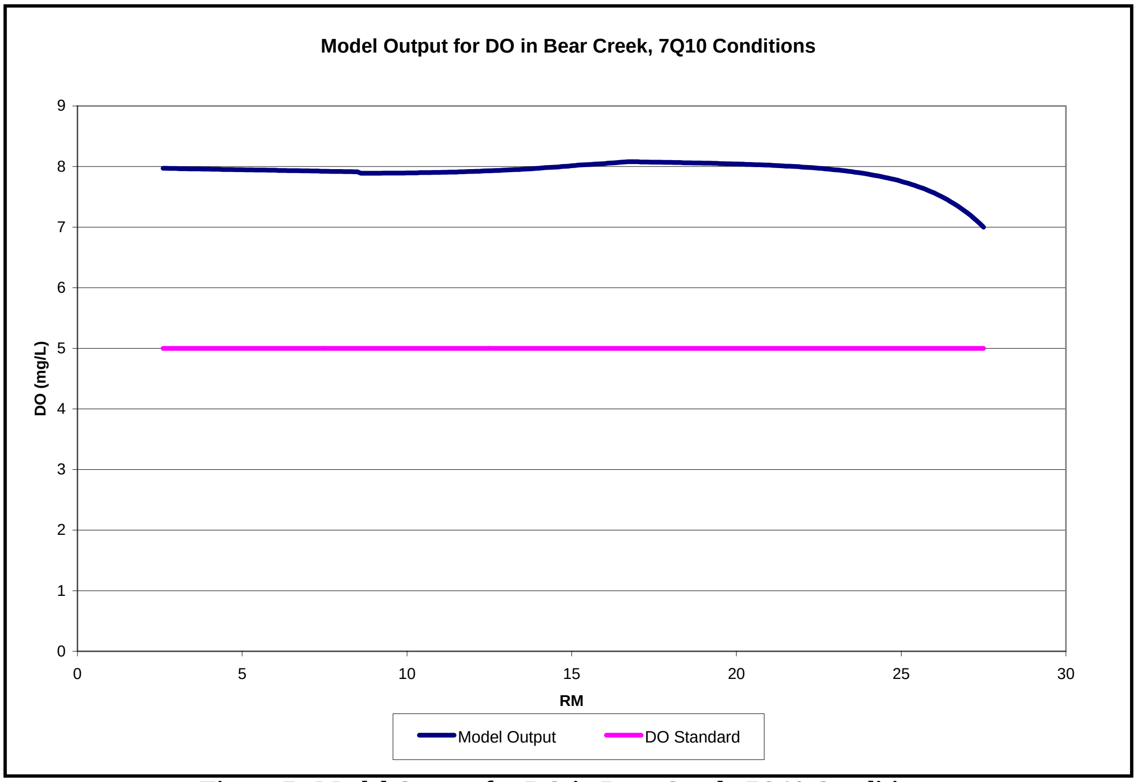


Figure 7. Model Output for DO in Bear Creek, 7Q10 Conditions

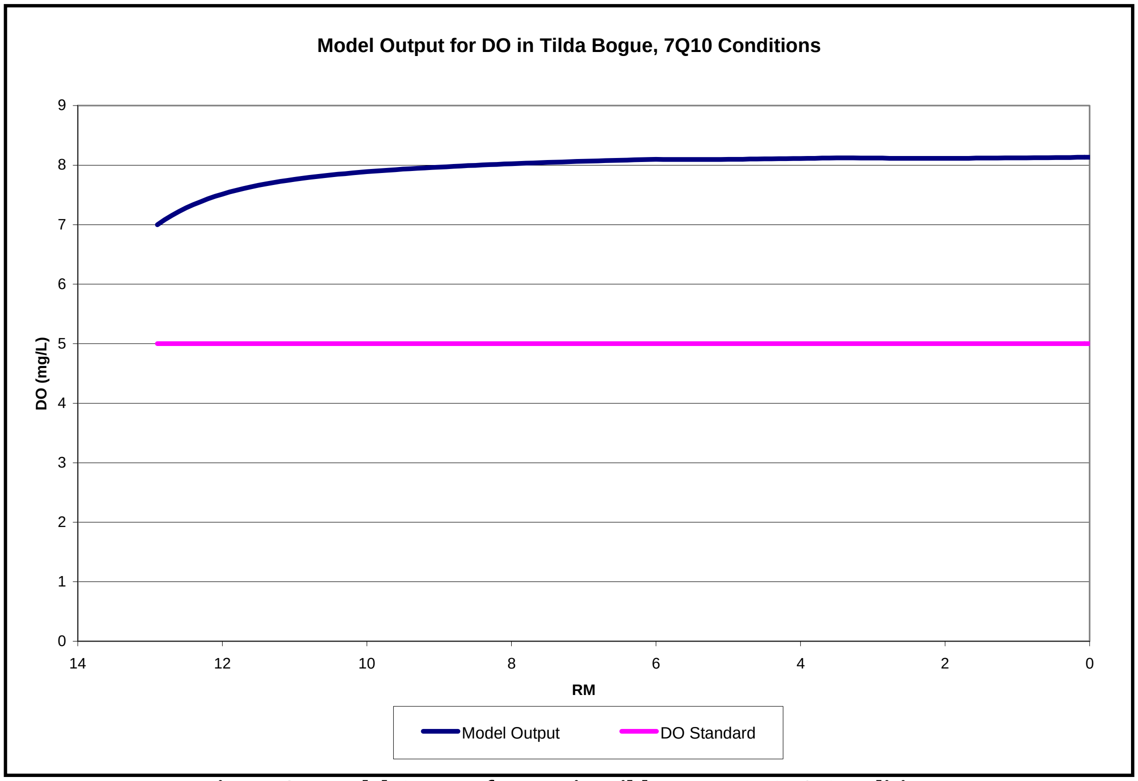


Figure 8. Model Output for DO in Tilda Bogue, 7Q10 Conditions

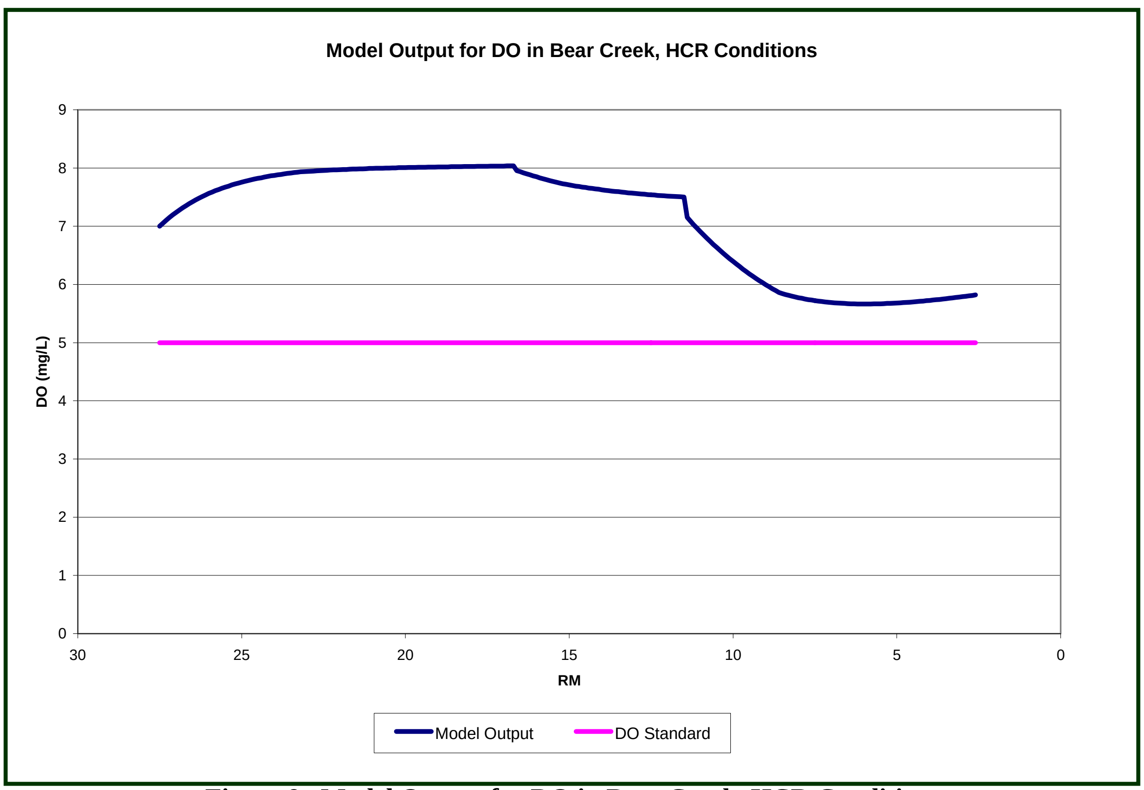


Figure 9. Model Output for DO in Bear Creek, HCR Conditions

3.5.2 Maximum Load Scenario

The graph of the HCR model output for Bear Creek shows that the predicted DO does not fall below the DO standard. It is noted that the HCR conditions will be used, however, because this is the only time that will allow the point source to discharge. Therefore, this scenario will be used to calculate the TMDL for Bear Creek. Reductions are not necessary to meet the DO standard. Although, the graph does not indicate DO violations, the stressor identification report identifies low DO/organic enrichment as a cause of impairment for this water body. MDEQ does not believe that there is assimilative capacity in the stream. However, in order to calculate the maximum allowable load of TBODu, the non-point source loads were increased using a trial-and-error process until the modeled DO was at 5.0 mg/l. The non-point source loads were increased by a factor of 8.9 in this process. It is believed that this increase is representative of the non-point source load and will be allocated to the Margin of Safety (MOS) discussed in Section 4.3. The increased loads were used to develop the allowable maximum daily load for Bear Creek. The maximum load scenario model output for Bear Creek is shown in Figure 10.

The graph of the Tilda Bogue 7Q10 model output shows that the predicted DO does not fall below the DO standard in Tilda Bogue during 7Q10 conditions. Although, the graph does not indicate DO violations, the stressor identification report identifies low DO/organic enrichment as a cause of impairment for this water body. MDEQ does not believe that there is assimilative capacity in the stream. However, in order to calculate the maximum allowable load of TBODu, the non-point source loads were increased using a trial-and-error process until the modeled DO was at 5.0 mg/l. The non-point source loads were increased by a factor of 6.0 in this process. It is believed that this increase is representative of the non-point source load and will be allocated to the Margin of Safety (MOS) discussed in Section 4.3. The increased loads were used to develop the allowable maximum daily load for Tilda Bogue. The maximum load scenario model output for Tilda Bogue is shown in Figure 11.

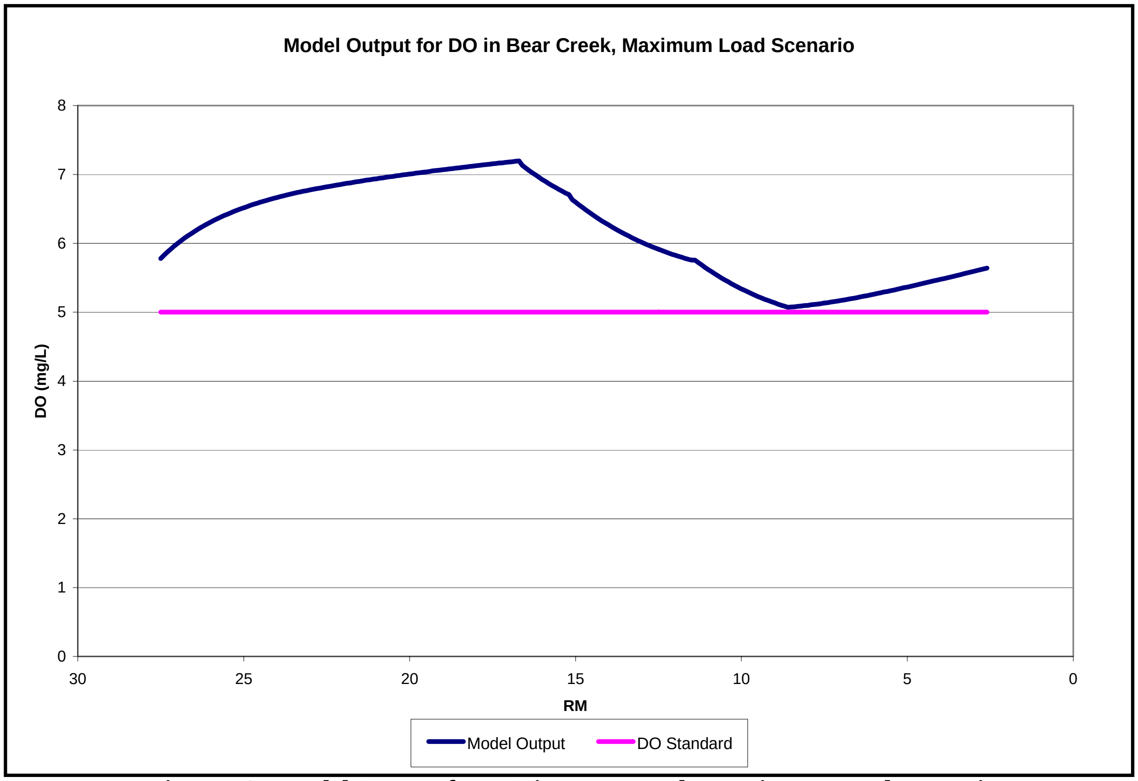


Figure 10. Model Output for DO in Bear Creek, Maximum Load Scenario

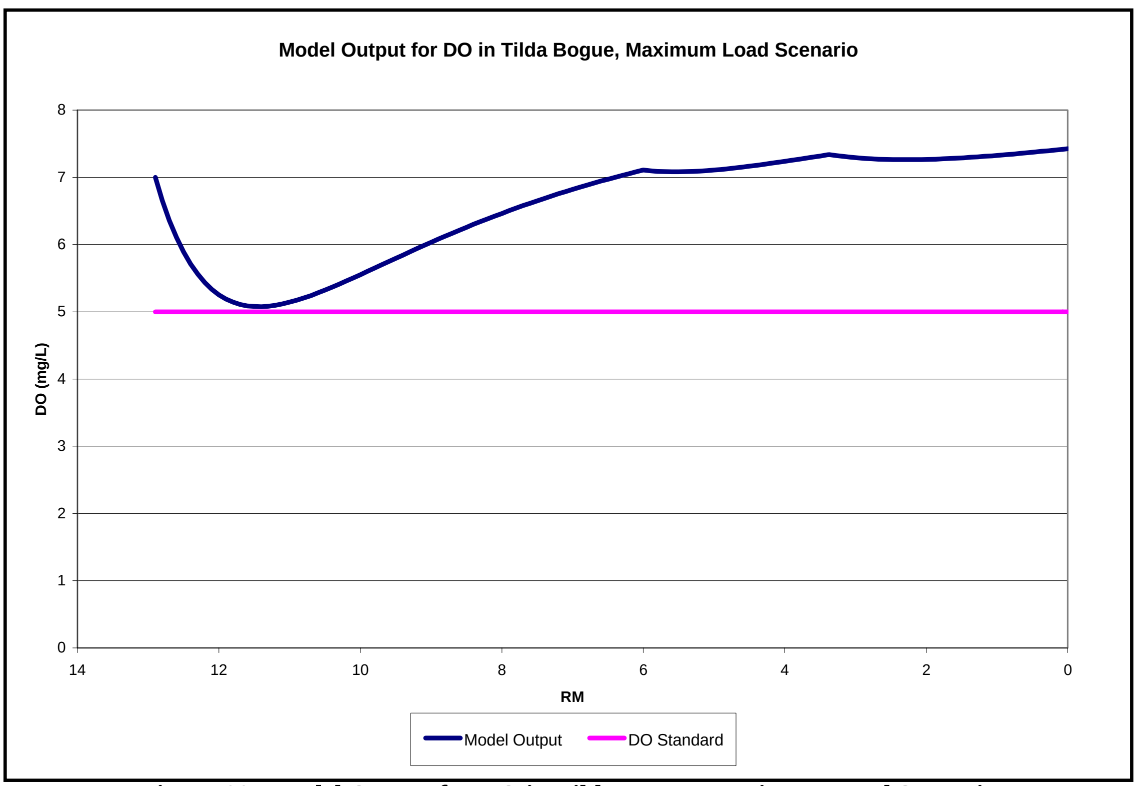


Figure 11. Model Output for DO in Tilda Bogue, Maximum Load Scenario

ALLOCATION

4.1 Wasteload Allocation

The TMDL indicates that reductions are not needed from the point source. Table 16 gives the wasteload allocation for TBODu. Table 17 gives the wasteload allocation for TN and TP.

Future permits will be considered in accordance with Mississippi's *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*(1994).

Table 16. TMDL Loads for TBODu

Permit	Facility	Flow MGD	$CBOD_5$ mg/L	CBODu lbs/day	NH_3-N mg/L	NBODu lbs/day	TBODu lbs/day	% Reduction
MS0042455	Canton POTW, 001*	2.6	30	975.78	5	495.48	1471.26	0
MS0042455	Canton POTW, 003*	0.31	30	116.34	5	59.08	175.42	0
	Total			**1092.12**		**554.56**	**1646.68**	

Table 17. TMDL Loads for TN and TP

Permit	Facility	Flow MGD	TN (mg/l)	TN Load lbs/day	% TN Reduction	TP (mg/l)	TP Load lbs/day	% TP Reduction
MS0042455	Canton POTW, 001*	2.6	11.5	249.37	0	3.9	84.57	25
MS0042455	Canton POTW, 003*	0.31	11.5	29.73	0	3.9	10.08	25
	Total			**279.10**			**94.65**	

4.1.1 Wasteload Allocation Stormwater

There is a phase II MS4 in this TMDL watershed. MDEQ has established a method to estimate the stormwater waste load allocation (WLAsw). The WLAsw = LA * % Urban Area in MS4 in watershed *70%. The intent of the stormwater NPDES permit is not to treat the water after collection, but to reduce the exposure of stormwater runoff to pollutants by implementing various controls. Stormwater NPDES permits require the establishment of controls or BMPs to reduce the pollutants entering the environment. (GA, 2009)

4.2 Load Allocation

Best management practices (BMPs) should be encouraged in the watersheds to reduce potential TBODu, TN, and TP loads from non-point sources. The LA for TN and TP was calculated by subtracting the WLA from the TMDL. The LA for TBODu is shown in Table 18 and 19 for Bear Creek and Tilda Bogue, respectively.

For land disturbing activities related to silvaculture, 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 18. Load Allocation for Bear Creek at HCR conditions

	Flow (cfs)	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Non-point source	**26.5**	**1158.23**	**265.32**	**1423.55**

Table 19. Load Allocation for Tilda Bogue Creek at 7Q10 conditions

	Flow (cfs)	CBODu (lbs/day)	NBODu (lbs/day)	TBODu (lbs/day)
Non-point source	**0.01**	**1.0**	**0.23**	**1.23**

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 model is implicit and explicit.

For Bear Creek, the MOS is primarily explicit and is the difference between the non-point loads calculated in the maximum load scenario and the background non-point loads from the HCR regulatory model. The background non-point source loads represent an approximation of the loads currently going into Bear creek at the critical conditions. The maximum non-point source loads are the maximum TBODu loads with a factor increase of 8.9 that allow maintenance of water quality standards. 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 TMDL. The explicit MOS is shown in Table 20.

For Bear Creek and Tilda Bogue, the MOS is primarily explicit and is the difference between the non-point loads calculated in the maximum load scenario and the background non-point loads from the 7Q10 regulatory model. The background non-point source loads represent an approximation of the loads currently going into Tilda Bogue at the critical conditions. The maximum non-point source loads are the maximum TBODu loads with a factor increase of 6.0 that allow maintenance of water quality standards. 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 TMDL. The explicit MOS is shown in Table 21.

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Table 20. Calculation of Explicit MOS for Bear Creek

	Maximum Non-Point Load	Background Non-Point Load	Margin of Safety
CBODu (lbs/day)	1158.23	130.14	1028.09
NBODu (lbs/day)	265.32	29.81	235.51
TBODu (lbs/day)	**1423.55**	**159.95**	**1263.60**

Table 21. Calculation of Explicit MOS for Tilda Bogue

	Maximum Non-Point Load	Background Non-Point Load	Margin of Safety
CBODu (lbs/day)	1.0	0.17	0.83
NBODu (lbs/day)	0.23	0.04	0.19
TBODu (lbs/day)	**1.23**	**0.21**	**1.02**

4.4 Calculation of the TMDL

Equation 2 was used to calculate the TMDL for TP and TN (see Table 18). The target concentration was used with the average flow for the watershed to determine the nutrient TMDLs. The STREAM model was used to calculate the TBODu TMDL. The allocations for TN, TP, and TBODu are given in Table 22 and 23. These allocations are established to attain the applicable water quality standards. The LA was further reduced by calculating the WLAsw. The sum of the WLA, WLAsw, LA, and MOS equal the TMDL.

Table 22. TMDL Loads for Bear Creek (TN and TP are inclusive of Tilda Bogue)

	WLA lbs/day	WLAsw lbs/day	LA lbs/day	MOS	TMDL lbs/day
Total Nitrogen	**279.10**	**72.58**	**974.88**	**Implicit**	**1326.20**
Total Phosphorous	**94.78**	**6.55**	**88.23**	**Implicit**	**189.56**
TBODu	**1646.88**	**11.08**	**148.87**	**1263.60**	**3070.43**

Table 23. TMDL Loads for Tilda Bogue

	WLA lbs/day	WLAsw lbs/day	LA lbs/day	MOS	TMDL lbs/day
TBODu	**0**	**NA**	**0.21**	**1.02**	**1.23**

A 25% reduction in TP loading is recommended for the point source in Bear Creek. Best management practices are encouraged in this watershed to reduce the non-point nutrient loads.

4.5 Seasonality and Critical Condition

This TMDL accounts for seasonal variability by requiring allocations that ensure year-round protection of water quality standards, including during critical conditions.

CONCLUSION

The model results indicate that Bear Creek is not meeting water quality standards for dissolved oxygen at the present loading of TBODu. The current model used for these calculations does not have adequate data to support all of the assumptions used, however, it is clear that the stream is impaired based upon the stressor identification report. A reduction from Canton POTW will be necessary to help meet water quality standards.

Although, the model results indicate that Tilda Bogue is meeting the water quality standard for DO at the present loading of TBODu, the stressor identification report indicates that low DO/organic enrichment and nutrients are the probable primary stressors. MDEQ does not believe that there is TBODu assimilative capacity in the creek. Because of the uncertainty involving the model, MDEQ has given a large MOS as a placeholder for the non-point source TBODu contribution to the water body.

Nutrients were addressed through an estimate of a preliminary TN concentration target and a preliminary TP concentration target. Based on the estimated existing and target TN concentrations, this TMDL does not recommend a reduction of TN loads entering this water body to meet the preliminary TN target of 1.12 mg/l. Based on the estimated existing and target TP concentrations, this TMDL recommends a 25% reduction of the point source TP loads entering the Bear Creek watershed to meet the preliminary TP target of 0.16 mg/l. Best management practices are encouraged in this watershed to reduce the non-point nutrient loads

5.1 Next Steps

MDEQ's Basin Management Approach and Nonpoint Source Program emphasize restoration of impaired waters with developed TMDLs. During the watershed prioritization process to be conducted by the South Indpendent Streams Basin Team, this TMDL will be considered as a basis for implementing possible restoration projects. The basin team is made up of state and federal resource agencies and stakeholder organizations and provides the opportunity for these entities to work with local stakeholders to achieve quantifiable improvements in water quality. Together, basin team members work to understand water quality conditions, determine causes and sources of problems, prioritize watersheds for potential water quality restoration and protection activities, and identify collaboration and leveraging opportunities. The Basin Management Approach and the Nonpoint Source Program work together to facilitate and support these activities.

The Nonpoint Source Program provides financial incentives to eligible parties to implement appropriate restoration and protection projects through the Clean Water Act's Section 319 Nonpoint Source (NPS) Grant Program. This program makes available around $1.6M each grant year for restoration and protections efforts by providing a 60% cost share for eligible projects.

Mississippi Soil and Water Conservation Commission (MSWCC) is the lead agency responsible for abatement of agricultural NPS pollution through training, promotion, and installation of BMPs on agricultural lands. USDA Natural Resource Conservation Service (NRCS) provides technical assistance to MSWCC through its conservation districts located in each county. NRCS assists animal producers in developing nutrient management plans and grazing management plans. MDEQ, MSWCC, NRCS, and other governmental and nongovernmental organizations work closely together to reduce agricultural runoff through the Section 319 NPS Program.

Mississippi Forestry Commission (MFC), in cooperation with the Mississippi Forestry Association (MFA) and Mississippi State University (MSU), have taken a leadership role in the development and promotion of the forestry industry Best Management Practices (BMPs) in Mississippi. MDEQ is designated as the lead agency for implementing an urban polluted runoff control program through its Stormwater Program. Through this program, MDEQ regulates most construction activities. Mississippi Department of Transportation (MDOT) is responsible for implementation of erosion and sediment control practices on highway construction.

Due to this TMDL, projects within this watershed will receive a higher score and ranking for funding through the basin team process and Nonpoint Source Program described above.

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 TMDLs 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. Anyone wishing to become a member of the TMDL mailing list should contact Kay Whittington at Kay_Whittington@deq.state.ms.us.

All comments should be directed to Kay_Whittington@deq.state.ms.us or Kay Whittington, MDEQ, PO Box 2261, Jackson, MS 39225. 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.

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