Proposed

Total Maximum Daily Loads

for

Charlotte Harbor and Peace River WBIDs

(WBIDs 1774, 1948, 1962, 1995, 1997, 2054, 2056A, 2056B, and 2071)

Nutrients, BOD and Dissolved Oxygen

September 30, 2009

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SUMMARY SHEET

Total Maximum Daily Load (TMDL)

1. **303(d) Listed Water body Information**
   State: Florida
   Major Basin:
   Charlotte Harbor and Peace River

1998 303(d) Listed Water bodies for TMDLs addressed in this report:

WBID	Segment Name	County	Class and Water body Type	Constituent(s)
1774	Little Charlie Creek	Hardee / Polk	III Freshwater	Nutrients
1948	Bear Branch	Desoto / Hardee	III Freshwater	Nutrients
1962	Prairie Creek	Charlotte / Desoto	I	DO and Nutrients
1995	Myrtle Slough	Desoto	I	BOD and DO
1997	Hawthorne Creek	Desoto	III Freshwater	Nutrients
2054	Myrtle Slough	Charlotte	III Marine	BOD and DO
2056A	Peace River Lower Estuary	Charlotte	III Marine	DO and Nutrients
2056B	Peace River Mid Estuary	Charlotte	III Marine	Do and Nutrients
2071	North Prong Alligator Creek	Charlotte	I	DO

2. **TMDL Approach**
   Calibration of a watershed and water quality model to current conditions, load reduction scenarios to meet water quality standards.

3. TMDL Allocations for Charlotte Harbor and Peace River TMDL WBIDs

	TMDL Condition						Percent Reduction		
	WLA			LA					
WBID	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)	BOD (kg/yr)	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)	BOD (kg/yr)	Total Nitrogen	Total Phosphrus	BOD
1774	0	0	0	19,929	4,840	67,759	61.0%	61.0%	61.0%
1948	0	0	0	2,705	396	11,650	43.0%	43.0%	43.0%
1962	0	0	0	231,709	55,486	788,959	23.72%	23.69%	23.46%
1995	0	0	0	74,233	17,721	252,642	24.28%	24.38%	24.02%
1997	0	0	0	185,622	44,333	631,971	29.57%	29.61%	29.25%
2054	0	0	0	590,001	141,521	2,010,376	23.67%	23.50%	23.24%
2071	0	0	0	7,022	1,678	23,644	48.07%	47.88%	47.84%
2056 A	0	0	0	3,867,316	924,675	13,201,482	27.81%	27.79%	27.60%
2056 B	0	0	0	3,672,778	878,350	12,542,161	27.23%	27.23%	27.02%

Notes for TMDL Allocations table:

1. Total N = total nitrogen; Total P = total phosphorus; BOD=Biochemical Oxygen Demand.
2. N/A=Not applicable.
3. Kg/yr=Kilograms per Year
4. This TMDL addresses 303(d) listings for nutrients and dissolved oxygen. The TMDL is provided in units of and kilograms/year.
5. The WLA component includes individual allocations for NPDES facilities (e.g., WWTPs) and MS4s as contained in Table 4 of this report. Due to the infeasibility of separating the contributions from diffuse MS4 and non-MS4 sources, MS4s are incorporated into the Load Allocation, and are allocated the same percent reductions.
6. Percent reduction in current non-point source loading to achieve the Load Allocation for the TMDL WBIDs. The percent reductions are applied to non-point sources and MS4s.

4. Endangered Species (yes or blank): Yes

5. USEPA Lead on TMDL (USEPA or blank): USEPA

6. TMDL Considers Point Source, Non-point Source, or both: Both

7. TMDL Considers Point Source, Non-point Source, or both: Both

1. Introduction

Section 303(d) of the Clean Water Act requires each state to list those waters within its boundaries for which technology based effluent limitations are not stringent enough to protect any water quality standard applicable to such waters. Listed waters are prioritized with respect to designated use classifications and the severity of pollution. In accordance with this prioritization, states are required to develop Total Maximum Daily Loads (TMDLs) for those water bodies that are not meeting water quality standards. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and in-stream water quality conditions. This helps states establish water quality-based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources (USEPA, 1991).

The State of Florida Department of Environmental Protection (FDEP) developed a statewide, watershed-based approach to water resource management. Under the watershed management approach, water resources are managed on the basis of natural boundaries, such as river basins, rather than political boundaries. The watershed management approach is the framework FDEP uses for implementing TMDLs. The state's 52 basins are divided into five groups. Water quality is assessed in each group on a rotating five-year cycle. All WBIDs except WBID 2071 (North Prong Alligator Creek) are group 3 basins. North Prong Alligator Creek is a Group 2 Basin. FDEP established five water management districts (WMD) responsible for managing ground and surface water supplies in the counties encompassing the districts. All WBIDs reside in the Southwest Florida Water Management District (SWFWMD).

For the purpose of planning and management, the WMDs divided the district into planning units defined as either an individual primary tributary basin or a group of adjacent primary tributary basins with similar characteristics. These planning units contain smaller, hydrological based units called drainage basins, which are further divided by FDEP into "water segments." A water segment usually contains only one unique water body type (stream, lake, canal, etc.) and is about five square miles. Unique numbers or water body identification (WBIDs) numbers are assigned to each water segment.

2. Problem Definition

Florida's final 1998 Section 303(d) list identified several WBIDs near Charlotte Harbor and Peace River as not supporting water quality standards (WQS). The TMDL addressed in this document is being established pursuant to USEPA commitments in the 1998 Consent Decree in the Florida TMDL lawsuit (Florida Wildlife Federation, et al. v. Carol Browner, et al., Civil Action No. 4: 98CV356-WS, 1998). After assessing all readily available water quality data, USEPA is responsible for developing TMDLs in WBIDs 1774, 1948, 1962, 1995, 1997, 2054, 2056A, 2056B, and 2071. The parameters addressed in this TMDL are total nitrogen, total phosphorus, and biochemical oxygen demand.

The Charlotte Harbor and Peace River WBIDs are designated as Class I Marine, Class III Freshwater, and Class III Marine WBIDs having a designated use for recreation, and propagation and maintenance of a healthy, well-balanced population of fish and wildlife. In addition, WBIDs 1962, 1995, and 2071 have been designated for their water to have a potable use. The level of impairment is denoted as threatened, partially or not supporting designated uses. A water body that is classified as threatened currently meets WQS but trends indicate the designated use may not be met in the next listing cycle. A water body classified as partially supporting designated uses is defined as somewhat impacted by pollution and water quality criteria are exceeded on some frequency. For this category, water quality is considered moderately impacted. A water body that is categorized as not supporting is highly impacted by pollution and water quality criteria are exceeded on a regular or frequent basis. In such water bodies, water quality is considered severely impacted.

To determine the status of surface water quality in the state, three categories of data – chemistry data, biological data, and fish consumption advisories – were evaluated to determine potential impairments. The level of impairment is defined in the Identification of Impaired Surface Waters Rule (IWR), Section 62-303 of the Florida Administrative Code (F.A.C.). The IWR defines the threshold for determining if waters should be included on the state's planning list and verified list. Potential impairments are determined by assessing whether a water body meets the criteria for inclusion on the planning list. Once a water body is on the planning list, additional data and information will be collected and examined to determine if the water should be included on the verified list.

3. Watershed Description

The Peace River watershed begins in northern Polk County. From the junction of Saddle Creek and the Peace Creek Drainage Canal, it runs 106 miles south to the Charlotte Harbor estuary, where it blends with the outflows of the Caloosahatchee and the Myakka rivers. Its waters are a dark brew of leaf detritus, organic acids and tannin, distilled from the peaty soils of the wetlands and forests through which it flows, which cause it to be labeled as a blackwater stream. The watershed is low and flat, scattered with shallow lakes and wetlands, and partially flooded by summer rains. The climate is humid and subtropical throughout. The temperature averages about 73 degrees. Annual rainfall averages between 50 and 56 inches, with more than half occurring between June and September. Most of the rainwater reenters the atmosphere through evaporation and plant transpiration. The rest recharges the aquifer or seeps into the Peace River and its tributary streams.

Charlotte Harbor Estuary is a natural estuary spanning the west coast of Florida from Venice to Bonita Springs on the Gulf of Mexico and is one of the most productive wetlands in Florida. The estuary has a large watershed, including the Peace River, Caloosahatchee River (via Pine Island Sound) and Myakka River basins and covering 12,653 square kilometers, the second largest open water estuary in the state. It is classified as a bar-built estuary, formed when sandbars build up along the coastline. The sand bars block the waters behind them from the sea. Such estuaries tend to be shallow with minimal tidal action. The WBIDs addressed in this.

Several WBIDs are within an MS4 permitted area and are addressed later in these TMDLs. The land distribution for each TMDL WBID can be seen in Table 1.

Table 1. Land Use Breakdown for the Charlotte Harbor and Peace River Watershed

WBID	1774		1948		1962		1995		1997		2054		2056A		2056B		2071	
Landuse	km^2	% of Total	km^2	% of Total	km^2	% of Total	km^2	% of Total	km^2	% of Total	km^2	% of Total	km^2	% of Total	km^2	% of Total	km^2	% of Total
Agriculture	47.3	67.4	7.3	77.2	163.3	62.6	29.4	46.7	55.3	77.7	8.1	10.5	0.0	0.0	0.0	0.0	1.1	54.5
Barren / Transitional	0.0	0.0	0.0	0.0	0.4	0.2	0.0	0.0	0.0	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Forest	2.9	4.1	0.5	5.4	16.1	6.2	3.7	5.9	1.9	2.6	27.0	34.9	0.0	0.0	0.0	0.0	0.5	22.2
Rangeland	6.0	8.6	0.1	1.2	39.1	15.0	12.8	20.4	2.4	3.4	25.0	32.3	0.0	0.0	0.0	0.0	0.1	5.5
Transportation/Communication	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.1	0.1	0.9	1.2	0.0	0.0	0.0	0.0	0.1	2.5
Urban	2.2	3.2	0.2	1.8	9.1	3.5	0.6	0.9	3.9	5.5	0.8	1.0	0.1	0.3	0.1	0.6	0.1	6.6
Water	0.2	0.3	0.0	0.3	1.8	0.7	0.3	0.4	0.6	0.8	0.5	0.7	17.4	99.6	12.5	90.9	0.0	0.0
Wetlands	11.5	16.4	1.3	13.7	31.0	11.9	16.2	25.7	7.1	9.9	14.9	19.3	0.0	0.1	1.2	8.5	0.2	8.8
Total	70.2	100.0	9.5	100.0	260.8	100.0	63.0	100.0	71.2	100.0	77.4	100.0	17.5	100.0	13.7	100.0	2.1	100.0

Notes:

1. Land use data are based on 2006 SWFWMD land cover features categorized according to the Florida Land Use and Cover Classification System (FLUCCS). The features were photo interpreted from 2006 one-foot color infrared digital aerial photographs at the 1:12,000 scale. Areas in the table represent the watershed draining to the impaired segment.
2. km^2= square kilometers.

4. Water Quality Standards

Most of the Charlotte Harbor and Peace River TMDL WBIDS are Class III Freshwater and Marine with a designated use of recreation, propagation and maintenance of a healthy, well-balanced population of fish and wildlife. In addition to this, WBIDs 1962, 1995, and 2071 are Class I waters with the added designated use of potability. Designated use classifications are described in the Florida Administrative Code (F.A.C.), Section 62-302.400(1), and water quality criteria for protection of all classes of water are established in F.A.C. 62-302.530. Individual criteria should be considered in conjunction with other provisions in water quality standards, including Section 62-302.500 F.A.C. [Surface Waters: Minimum Criteria, General Criteria] that apply to all waters unless alternative criteria is specified in F.A.C. Section 62-302.530. Several WBIDs were listed due to elevated concentrations of chlorophyll *a*.

4.1 Narrative Nutrients (All Classes)

The State of Florida has a narrative water quality criterion for nutrients that applies to Class I, III Freshwater, and III Marine states that:

> "In no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna." [Section 62.302.530 (48)(b) F.A.C.]

The state also has an additional narrative water quality criterion for nutrients that applies to all classes of water and states that:

> "The discharge of nutrients shall continue to be limited as needed to prevent violations of other standards contained in this chapter. Man-induced nutrient enrichment (total nitrogen or total phosphorus) shall be considered degradation in relation to the provisions of Sections 62-302.300, 62-302.700, and 62-4.242, F.A.C." [see Section 62.302.530 (48)(a) F.A.C.]

4.2 Dissolved Oxygen

The State of Florida has a dissolved oxygen standard for each class that can be seen in Table 2.

Table 2. Florida Water Quality Standards for Dissolved Oxygen

Class I Waters	Class III Freshwaters	Class III Marine Waters
Shall not be less than 5.0. Normal daily and seasonal fluctuations above this level shall be maintained.	Shall not be less than 5.0. Normal daily and seasonal fluctuations above these levels shall be maintained.	Shall not average less than 5.0 in a 24-hour period and shall never be less than 4.0. Normal daily and seasonal fluctuations above these levels shall be maintained

5. Water Quality Assessment

A water quality assessment was conducted to review pertinent water quality data and information for the Charlotte Harbor and Peace River TMDL WBIDs. The primary constituents that were evaluated were: dissolved oxygen, chlorophyll *a*, nitrogen, phosphorus, and biochemical oxygen demand. Readily available water quality data were assessed using the Florida Department of Environmental Protection (FDEP) IWR database, version 35. The IWR database contains data from readily available sources within the State of Florida, including data from the Water Management Districts.

5.1 Water Quality Data

The water quality parameters and WBIDs are required to be included in the present TMDL because they were included on Florida's 1998 303(d) listing (see summary sheet). In addition, an independent assessment was made using the most recent data for WBIDs 1774, 1948, 1962, 1995, 1997, 2054, 2056A, 2056B, and 2071 in order to determine present water quality conditions and confirm impairment. Data were compared to the State of Florida Water Quality Standards to determine potential for impairment for dissolved oxygen and nutrients. Nutrients were assessed based on a weight-of-evidence approach that takes into account nutrient concentrations, chlorophyll *a* levels, and dissolved oxygen concentrations. The State of Florida typically uses chlorophyll *a* as the primary indicator of nutrient enrichment, because its concentrations are a good measure of the biomass of phytoplankton, i.e. microscopic algae that drift in the water column.

6. Source and Load Assessment

An important part of the TMDL analysis is the identification of source categories, source subcategories, or individual sources of pollutants in the watershed and the amount of loading contributed by each of these sources. Sources are broadly classified as either point or non-point sources. Nutrients enter surface waters from both point and non-point sources. A point source is defined as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Point source discharges of industrial wastewater and treated sanitary wastewater must be authorized by National Pollutant Discharge Elimination System (NPDES) permits. NPDES permitted facilities, including certain urban stormwater discharges such as municipal separate storm sewer systems (MS4 areas), certain industrial facilities, and construction sites over one acre, are stormwater driven sources considered “point sources” in this report.

Non-point sources of pollution are diffuse sources that cannot be identified as entering a water body through a discrete conveyance at a single location. For nutrients, these sources include runoff of agricultural fields, golf courses, lawns, septic tanks, and residential developments outside of MS4 areas. Non-point sources generally, but not always, involve accumulation of nutrients on land surfaces and wash-off as a result of storm events.

6.1 Point Sources

6.1.1 Permitted Point Sources

A TMDL wasteload allocation (WLA) is given to NPDES permitted facilities discharging to surface waters within an impaired watershed. Facilities that dispose of wastewater by means other than a surface water discharge, such as spray irrigation or underground injection wells, typically treat wastewater to less stringent secondary standards. These facilities would be considered in the load allocation for non-point sources. There are currently no facilities permitted to discharge directly to any of the TMDL WBIDs.

6.1.2 Municipal Separate Storm Sewer System Permits

Municipal Separate Storm Sewer Systems (MS4s) are point sources also regulated by the NPDES program. According to 40 CFR 122.26(b)(8), a municipal separate storm sewer system is,

> “A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):
>
> (i) Owned or operated by a State, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law)...including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal

organization, or a designated and approved management agency under section 208 of the Clean Water Act that discharges into waters of the United States.

(ii) Designed or used for collecting or conveying stormwater;

(iii) Which is not a combined sewer; and

(iv) Which is not part of a Publicly Owned Treatment Works."

Municipal separate storm sewer system may discharge nutrients and other pollutants to water bodies in response to storm events. In 1990, USEPA developed rules establishing Phase I of the National Pollutant Discharge Elimination System (NPDES) stormwater program, designed to prevent harmful pollutants from being washed by stormwater runoff MS4s (or from being dumped directly into the MS4) and then discharged from the MS4 into local water bodies. Phase I of the program required operators of "medium" and "large" MS4s (those generally serving populations of 100,000 or greater) to implement a stormwater management program as a means to control polluted discharges from MS4s. Approved stormwater management programs for medium and large MS4s are required to address a variety of water quality related issues including roadway runoff management, municipal owned operations, hazardous waste treatment, etc.

Phase II of the rule extends coverage of the NPDES stormwater program to certain "small" MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES stormwater program. Only a select subset of small MS4s, referred to as "regulated small MS4s", requires an NPDES stormwater permit. Regulated small MS4s are defined as all small MS4s located in "urbanized areas" as defined by the Bureau of the Census, and those small MS4s located outside of "urbanized areas" that are designated by NPDES permitting authorities.

All MS4 permits in TMDL WBIDs are identified in Table 3.

Table 3. MS4 permits potentially affected by the Charlotte Harbor and Peace River WBID TMDLs

WBID	Phase	Permit Name	Permit Number	County
1962	II-C	Charlotte County MS4	FLR04E043	Charlotte
1774	I-C	Polk County MS4	FLS000015	Bay
2054	II-C	Charlotte County MS4	FLR04E043	Charlotte
2056A	II-C	Charlotte County MS4	FLR04E043	Charlotte
2056B	II-C	Charlotte County MS4	FLR04E043	Charlotte
2071	II-C	Charlotte County MS4	FLR04E043	Charlotte

6.2 Non-point Sources

Non-point source pollution generally involves a buildup of pollutants on the land surface that wash-off during rain events and as such, represent contributions from diffuse sources, rather than from a defined outlet. Potential non-point sources are commonly identified, and their loads estimated, based on land cover data. Most methods calculate non-point source loadings as the product of the water quality concentration and runoff water volume associated with certain land use practices. The mean concentration of pollutants in the runoff from a storm event is known as the Event Mean Concentration, or EMC.

Non-point sources account for a large amount of pollutants in the TMDL WBIDs. The land use distribution of the Charlotte Harbor and Peace River WBIDs provides insight into potential non-point sources of nutrients and biochemical oxygen demand. As can be seen in Figure 1, the majority of the land use most WBIDs is agriculture and rangeland. WBIDs 2056A and 2056B are located in Charlotte Harbor's estuary and are primarily all water.

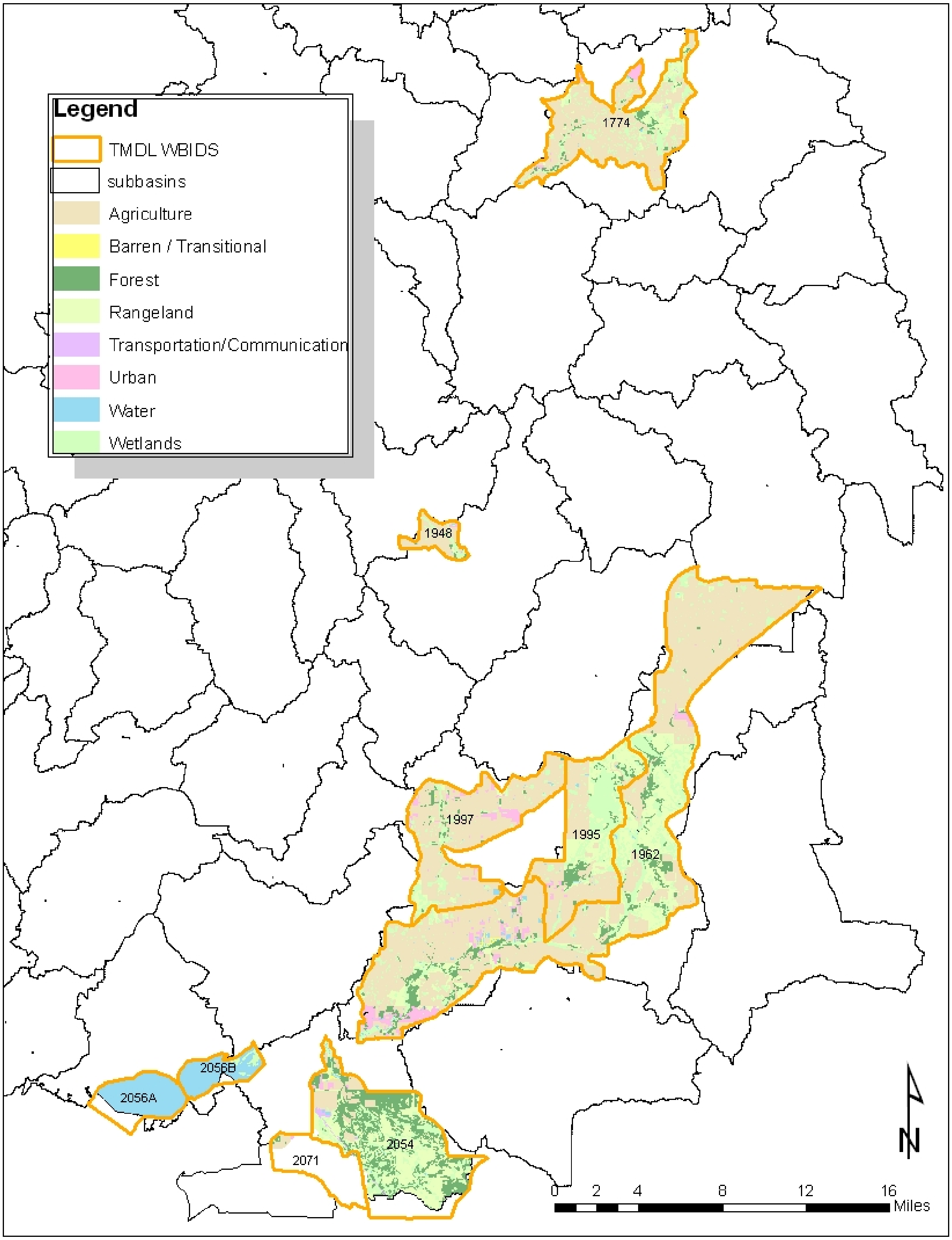

Figure 1 Land Uses within the Charlotte Harbor and Peace River TMDL WBIDs

6.2.1 Urban Areas

Urban areas include land uses such as residential, industrial, extractive, and commercial. Land uses in this category typically have somewhat high total nitrogen event mean concentrations and average total phosphorus event mean concentrations. Urban and other built-up land uses occur throughout the watershed in small numbers.

Nutrient and biochemical oxygen demand loading from MS4 and non-MS4 urban areas are attributable to multiple sources including stormwater runoff, leaks, and overflows from sanitary sewer systems, illicit discharges of sanitary waste, runoff from improper disposal of waste materials, leaking septic systems, and domestic animals.

In 1982, Florida became the first state in the country to implement statewide regulations to address the issue of non-point source pollution by requiring new development and redevelopment to treat stormwater before it is discharged. The Stormwater Rule, as outlined in Chapter 403 Florida Statutes (F.S.), was established as a technology-based program that relies upon the implementation of BMPs that are designed to achieve a specific level of treatment (i.e., performance standards) as set forth in Chapter 62-40, F.A.C.

Florida's stormwater program is unique in having a performance standard for older stormwater systems that were built before the implementation of the Stormwater Rule in 1982. This rule states: "the pollutant loading from older stormwater management systems shall be reduced as needed to restore or maintain the beneficial uses of water" (Section 62-4-.432 (5)(c), F.A.C.).

Nonstructural and structural BMPs are an integral part of the state's stormwater programs. Nonstructural BMPs, often referred to as "source controls," are those that can be used to prevent the generation of non-point source pollutants or to limit their transport off-site. Typical nonstructural BMPs include public education, land use management, preservation of wetlands and floodplains, and minimization of impervious surfaces. Technology-based structural BMPs are used to mitigate the increased stormwater peak discharge rate, volume, and pollutant loadings that accompany urbanization.

6.2.2 Agriculture

Agricultural lands include improved and unimproved pasture, row and field crops, citrus, and specialty farms. The highest total nitrogen and total phosphorus event mean concentrations are associated with agricultural land uses. There are a large presence agriculture in all of the TMDL WBIDs except 2056A and 2056B.

6.2.3 Rangeland

Upland non-forested includes herbaceous, scrub, disturbed scrub, and coastal scrub areas. Event mean concentrations for rangeland are about average for total nitrogen and low for total phosphorus.

6.2.4 Upland Forests

Upland forests include flatwoods, oak, various types of hardwoods, conifers and tree plantations. Event mean concentrations for upland forests are low for both total nitrogen and total phosphorus.

6.2.5 Water and Wetlands

These occur throughout the watershed in the areas directly surrounding the stream, and have very low event mean concentrations down to zero. There is very little open water in any of the TMDL WBIDs other than 2056A and 2056B.

6.2.6 Transportation, Communications, and Utilities

Transportation uses include airports, roads, and railroads. Event mean concentrations for these types of uses are in the mid-range for total nitrogen and total phosphorus.

6.2.7 Barren/Transitional

Barren and transitional land is land that is transitioning from one type of land use to another. This could mean the land is in the process of being developed, or that it doesn't fit any of the other categories. Event mean concentrations for these types of uses are in the mid-range for total nitrogen and total phosphorus.

6.2.8 Groundwater and Atmospheric Sources

This source was considered to provide only a background level contribution and was not considered.

7. Analytical Approach

The Waste Load Allocations (WLAs) for each facility were developed considering their current permit limits, the quality and frequency of the actual discharge, and the assimilation capacity of the receiving watershed. Since TMDLs are the sum of the Load Allocation (LA) for non-point sources, the Waste Load Allocation for point sources, and the Margin of Safety (MOS), the LA was calculated as the difference:

$$\sum LA = \sum TMDL - \sum WLA - MOS$$

The modeling approach that was applied to simulate nutrient and biochemical oxygen demand fate and transport further in Sections 7.1, 7.2, 7.3, and 7.4. The causative pollutants targeted for these TMDLs are total nitrogen (TN), total phosphorus (TP), and biochemical oxygen demand (BOD).

7.1 Loading Simulation Program C++ (LSPC)

The Loading Simulation Program C++ (LSPC) was used to represent the hydrological and water quality conditions in the Charlotte Harbor and Peace River watershed. LSPC is a comprehensive data management and modeling system that is capable of representing loading, both flow and water quality, from non-point and point sources and simulating in-stream processes. It is capable of simulating flow, sediment, metals, nutrients, pesticides, and other conventional pollutants, as well as temperature and pH for pervious and impervious lands and water bodies. LSPC was configured to simulate the watershed as a series of hydrologically connected sub-watersheds.

7.2 Environmental Fluid Dynamics Code (EFDC)

The EFDC was selected to perform the hydrodynamic simulations because it was able to fulfill all of the requirements presented in the goals of the study. EFDC has been applied on many water bodies within USEPA Region 4 for TMDL and permitting modeling projects including complex systems such as Mobile Bay, AL, Neuse River and Estuary, NC, Brunswick Harbor, GA, Fenholloway River and Estuary, FL, Loxahatchee River and Estuary, FL, Indian River Lagoon, FL, Lake Worth Lagoon FL, Florida Bay, Lake Okeechobee, FL, Cape Fear River, NC, and St. Johns River, FL. EFDC has proven to capture the complex hydrodynamics in similar systems.

The EFDC model is a part of the USEPA TMDL Modeling Toolbox due to its application in many TMDL-type projects. As such, the code has been peer reviewed and tested and has been freely distributed and supported by Tetra Tech. EFDC was developed by Dr. John Hamrick and is currently supported by Tetra Tech for USEPA Office of Research and Development (ORD), USEPA Region 4, and USEPA Headquarters. The EFDC model is nonproprietary and publicly available through USEPA Region 4 and USEPA ORD from the Watershed and Water Quality Modeling Technical Support Center (http://www.epa.gov/athens/wwqtsc/index.html). The models, tools, and databases in the TMDL Modeling Toolbox are continually updated and upgraded through TMDL development in Region 4.

7.3 Water Quality Analysis Simulation Program (WASP)

The Water Quality Analysis Simulation Program — (WASP7) is a dynamic compartment-modeling program for aquatic systems, including both the water column and the underlying benthos. The time-varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the basic program. The conventional pollutant model within the WASP framework is capable of predicting time varying concentrations for chlorophyll *a*, dissolved oxygen, nutrients (nitrogen, phosphorus) as function of loadings, flows, and environmental conditions.

WASP was calibrated to the current conditions in Charlotte Harbor and Peace River using loadings from the LSPC model and point sources. Furthermore, WASP was used in determining the load reductions that would be needed to achieve the water quality standards (DO) and nutrient targets for the Charlotte Harbor and Peace River TMDL WBIDs.

7.4 SOD Spreadsheet Model

In addition to WASP7, another model was used to establish a defensible link between instream loads versus SOD for Bear Branch and Little Charlie Creek. An SOD model developed by Quantitative Environmental Analysis (QEA) and modified by Dr. James Martin at Mississippi State University (MSU), was implemented to determine the relative change in SOD by altering the watershed load of CBODu and nutrients. Nutrient and CBODu parameters were input to the model, and SOD was calibrated to the exiting WASP7 model. All results for the SOD spreadsheet model are presented in Appendix G.

7.5 Scenarios

Several modeling scenarios were developed and evaluated in these TMDL determinations. The results of these scenarios are presented in the following sections.

7.5.1 Current Condition

The first scenario was to model the current conditions of the watersheds and the bay. This included the development of a watershed, hydrodynamic, and water quality model. The watershed model was parameterized using the current land uses and measured meteorological conditions to predict the current loadings of nitrogen, phosphorus, and BOD. These predicted loadings and flow time series are passed on to the water quality model where the predicted algal, nitrogen, phosphorus, BOD, and dissolved oxygen concentrations are predicted over time. The models (watershed and water quality) are calibrated to a period of time to take into account varying environmental, meteorological, or hydrological conditions on water quality. The calibration results can be seen in the Charlotte Harbor and Peace River Modeling Report and the Charlotte Harbor and Peace River Watershed Modeling Report.

7.5.2 Natural Condition

The natural condition scenario was developed to estimate what water quality conditions would exist if there were no impact from anthropogenic sources. All NPDES facilities were removed from all models. Any land use that is associated with man induced (urban, agriculture, transportation, barren lands, and rangeland) activities gets converted to its native undisturbed land use for the purpose of this analysis and the associated event mean concentration for nitrogen, phosphorus, and BOD are used. These natural condition loadings from the watershed model are passed onto the water quality model where natural water quality conditions are predicted. The natural condition modeling results are presented in the Charlotte Harbor and Peace River Modeling Report and the Charlotte Harbor and Peace River Watershed Modeling Report.

7.5.3 Natural Condition with NPDES Discharges

The natural condition scenario with NPDES facilities was the same scenario described in the natural condition run above, with the exception being the NPDES discharges were input in the models at their permitted values. Current model inputs for point sources can be seen in Table 4.

Table 4. Point Sources Inputs to the LSPC, EFDC, and WASP Model

Name	Permit	Flow (MGD)	BOD (mg/l)	TN (mg/l)	TP (mg/l)
MOSAIC FERTILIZER LLC	FL0000230	9.51	2.00	1.23	2.37
FARMLAND INDUSTRIES, INC.	FL0000752	2.06	2.00	1.58	4.13
CARGILL FERTILIZER INC. S. FT. MEADE MINE	FL0001198	7.50	2.00	1.81	0.54
U S AGRI-CHEMICALS CORPORATION - FT MEADE CHEMICAL PLANT	FL0001902	6.43	2.00	2.82	5.41
FLORIDA DISTILLERS COMPANY	FL0003051	0.51	1.17	0.59	0.04
LARSEN MEMORIAL POWER PLANT	FL0026298	40.06	2.00	1.00	1.00
ARCADIA CITY OF - WILLIAM TYSON WWTF	FL0027511	0.25	2.00	1.00	1.00
NU-GULF INDUSTRIES INC. WINGATE CREEK MINE	FL0032522	1.78	2.00	0.93	1.30
CF INDUSTRIES, INC - BARTOW CHEMICAL PLANT	FL0035271	0.92	2.00	1.53	0.84
CHARLOTTE HARBOR WATER ASSOC REVERSE OSMOSIS WATER TRT PLT	FL0035378	0.21	2.00	1.00	0.12
WINTER HAVEN, CITY OF - WWTP#3	FL0036048	5.92	3.04	3.42	1.00
CARGILL FERTILIZER	FL0037958	1.94	2.00	1.15	1.64
GLENDALE WATER RECLAMATION FACILITY	FL0039772	9.11	2.34	1.24	2.70
CF INDUSTRIES, INC - BARTOW CHEMICAL PLANT	FL0040177	0.92	2.00	1.53	0.84
HARDEE POWER STATION	FL0041751	5.09	2.00	1.00	1.00
CYPRESS GARDENS INC	FL0042463	0.20	2.55	0.67	0.30
HARDEE POWER STATION	FL0044229	5.09	2.00	1.00	1.00
US AGRI-CHEMICALS CORPORATION - BARTOW CHEMICAL PLANT	FL0174106	5.06	2.00	13.81	10.25
VENICE MINERALS	FL0179256	1.03	2.00	1.00	1.00

7.5.4 TMDL

The TMDL scenario determines how much the current loadings would need to be reduced to achieve the applicable water quality standards for dissolved oxygen and nutrient (nitrogen and phosphorus) interpretation of the narrative to protect against imbalance of flora and fauna. Because the natural condition model results showed little to no deviation from the current conditions in the WBIDs, it was determined that a series of plots needed to be examined in order to see whether the WBIDs have a naturally low dissolved oxygen level, as well as determine whether any of the point sources in the bay were impacting the dissolved oxygen levels.

7.5.5.1 Existing Conditions compared with Natural Conditions

It was determined that the existing conditions needed to be compared to the natural conditions in order to see whether development has had an impact on the dissolved oxygen levels in the bay and TMDL WBIDs. Figures 2 through 8 show the existing conditions for dissolved oxygen in the TMDL WBIDs compared to the natural conditions in the WBIDs. The blue line represents the existing condition, while the red line represents the natural condition. It can be seen that there is little difference between the two scenarios, and the low dissolved oxygen can be attributed to natural causes.

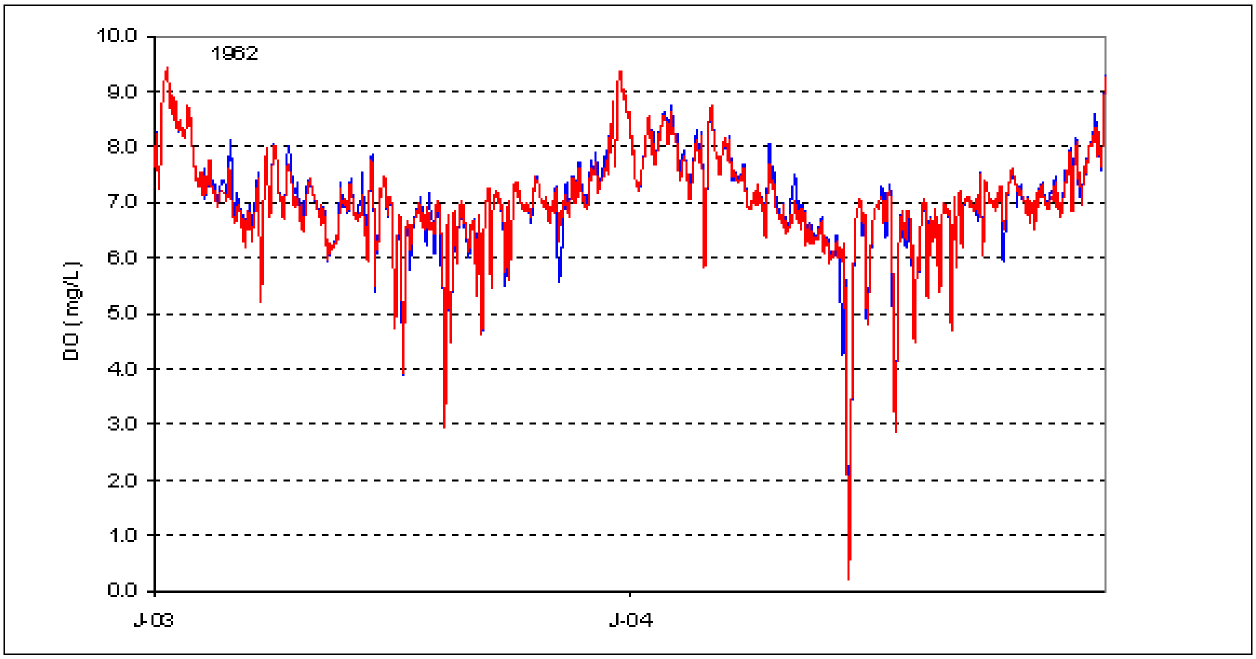

Figure 2 Existing vs Natural Conditions Dissolved Oxygen in WBID 1962

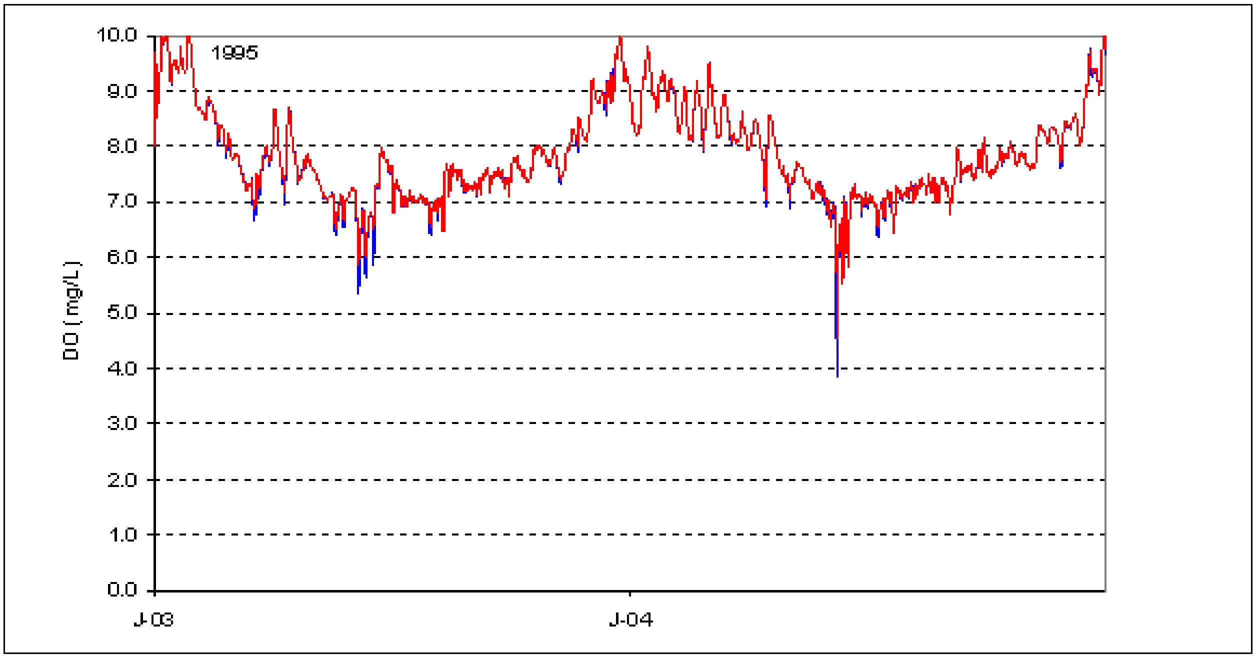

Figure 3 Existing vs Natural Conditions Dissolved Oxygen in WBID 1995

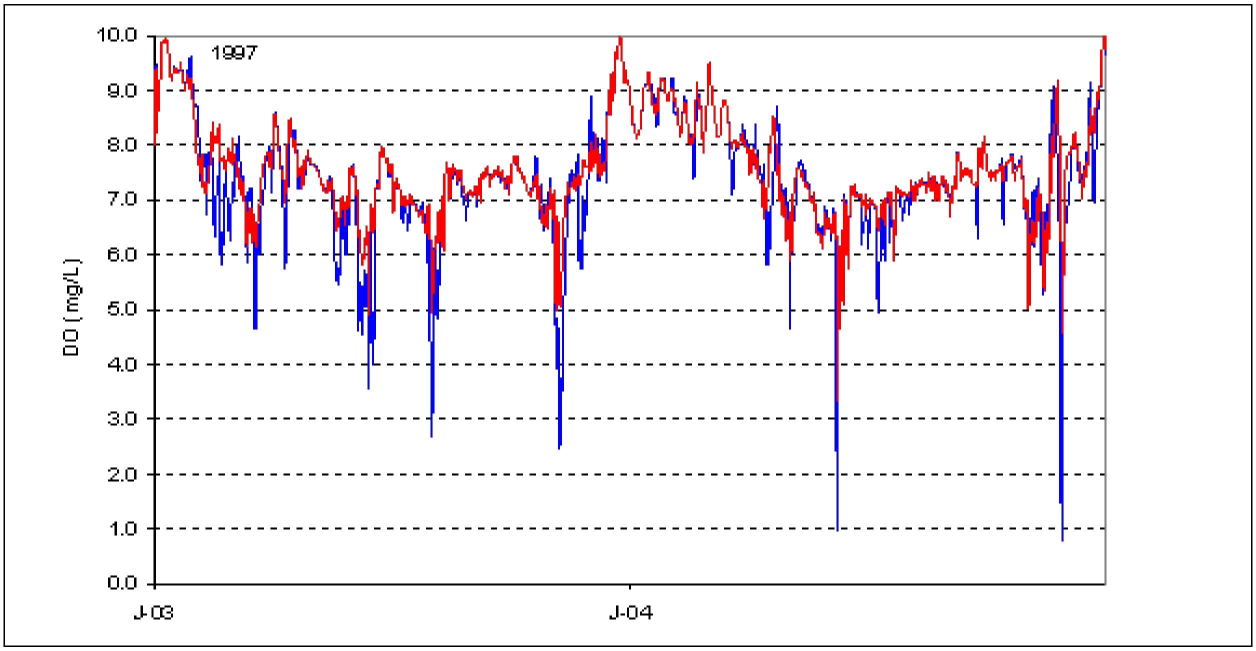

Figure 4 Existing vs Natural Conditions Dissolved Oxygen in WBID 1997

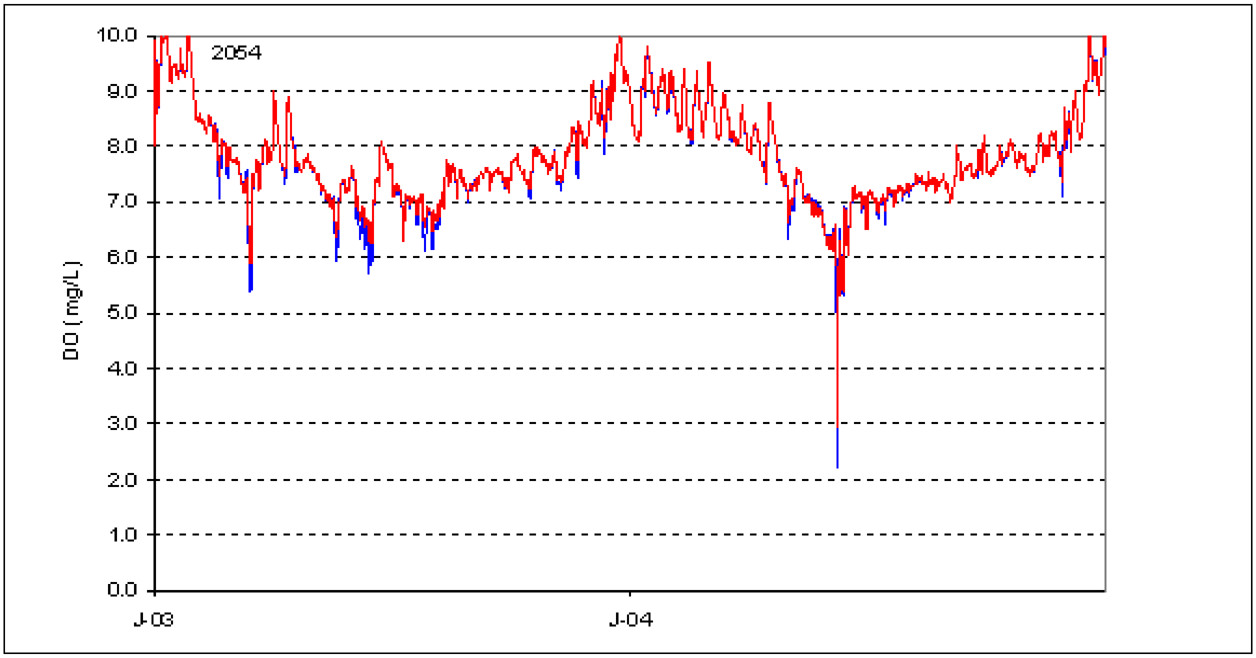

Figure 5 Existing vs Natural Conditions Dissolved Oxygen in WBID 2054

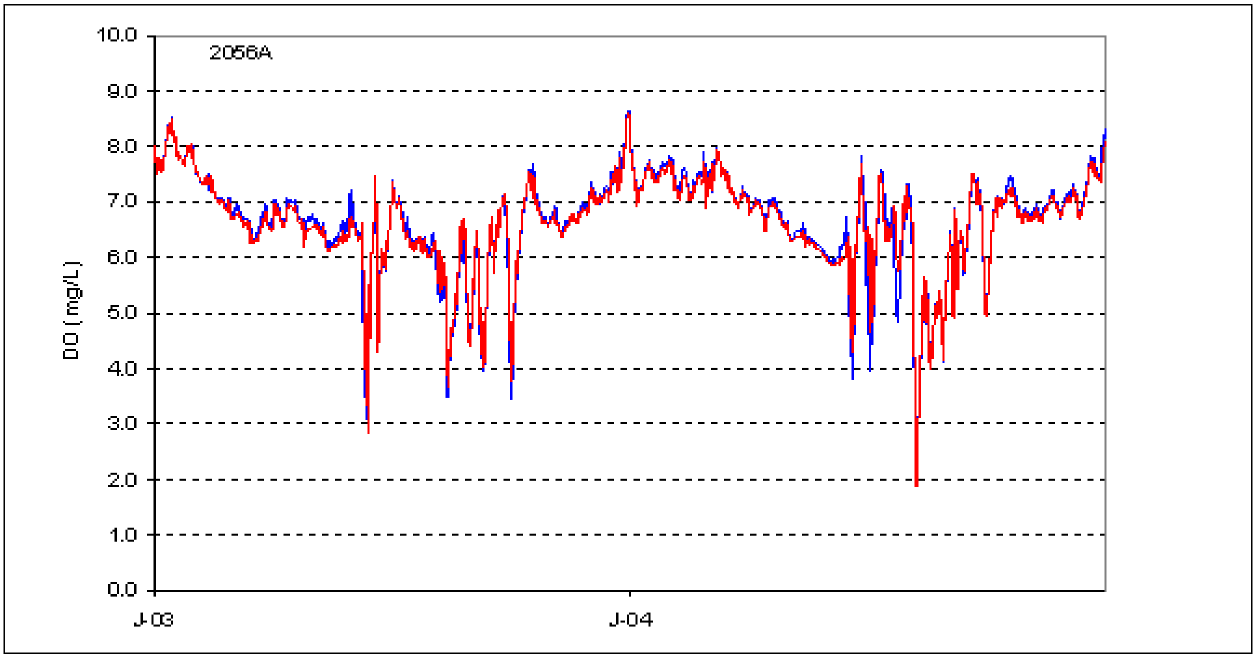

Figure 6 Existing vs Natural Conditions Dissolved Oxygen in WBID 2056A

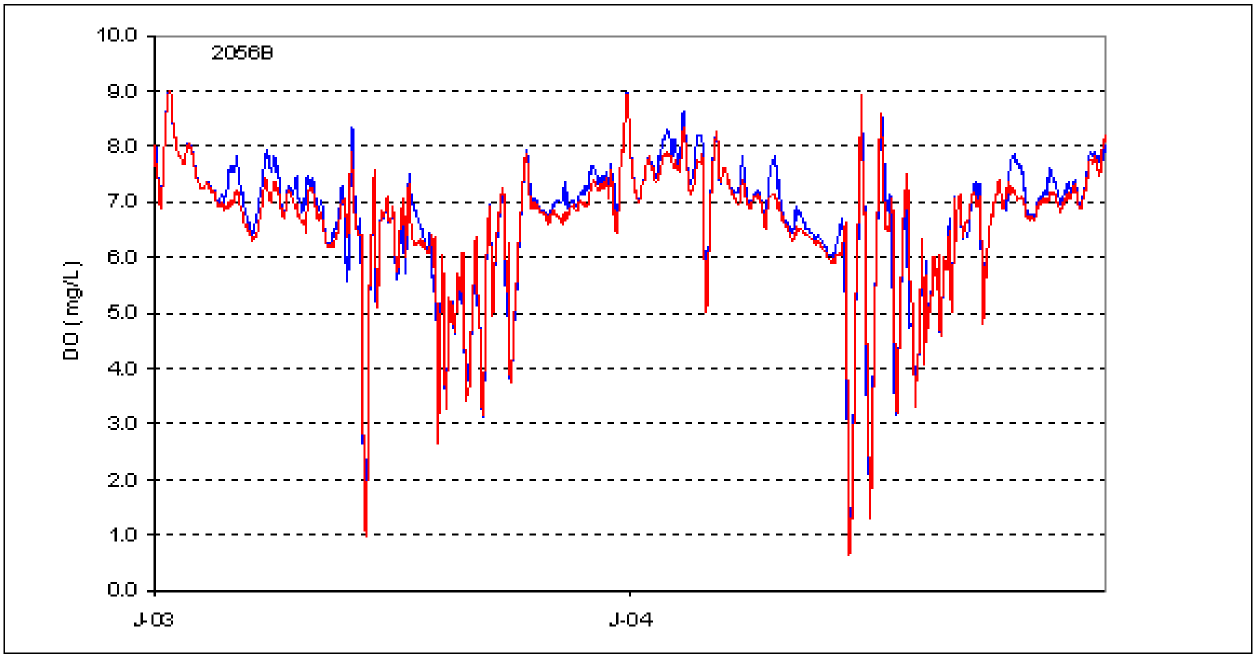

Figure 7 **Existing vs Natural Conditions Dissolved Oxygen in WBID 2056B**

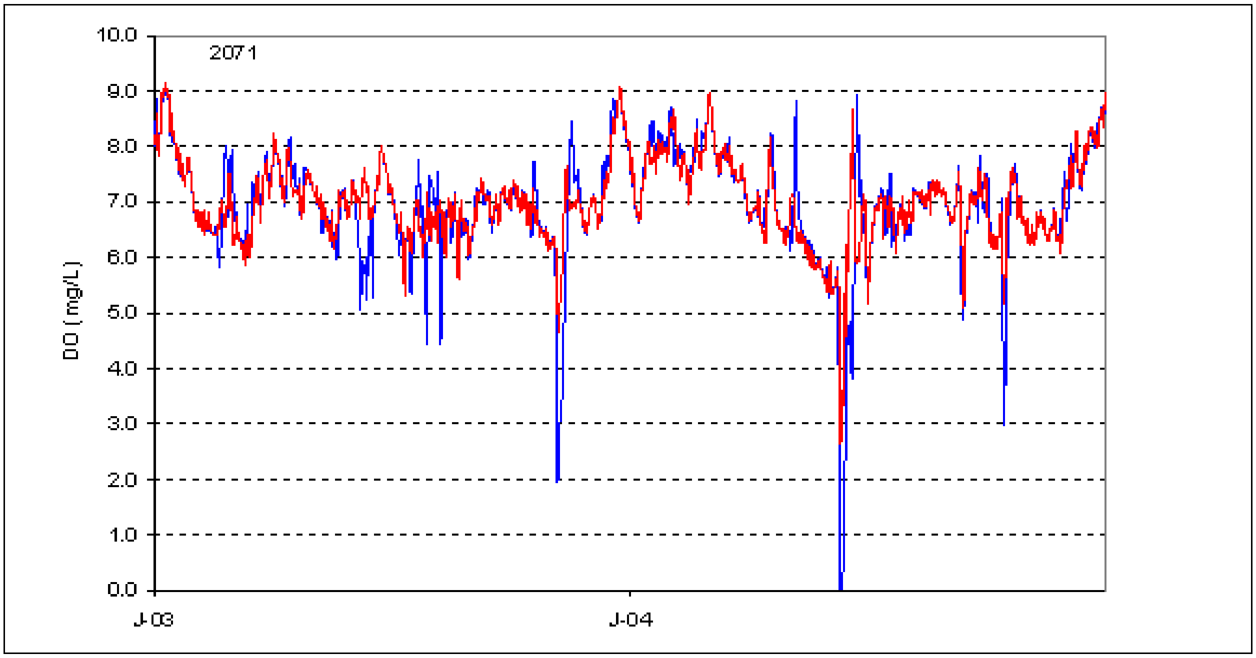

Figure 8 **Existing vs Natural Conditions Dissolved Oxygen in WBID 2071**

7.5.5.2 Natural Conditions compared with Natural Conditions with NPDES Facilities

Since there was naturally low dissolved oxygen in the WBIDs, the verification that NPDES discharges were not lowering the natural dissolved oxygen was required. Figures 9 through 15 show the natural condition for dissolved oxygen in the TMDL WBIDs, compared to the natural conditions with NPDES discharges. The blue lines indicate natural conditions with point sources, while red lines indicate natural conditions. It can be seen that the NPDES discharges have no impact on dissolved oxygen levels in the WBIDs.

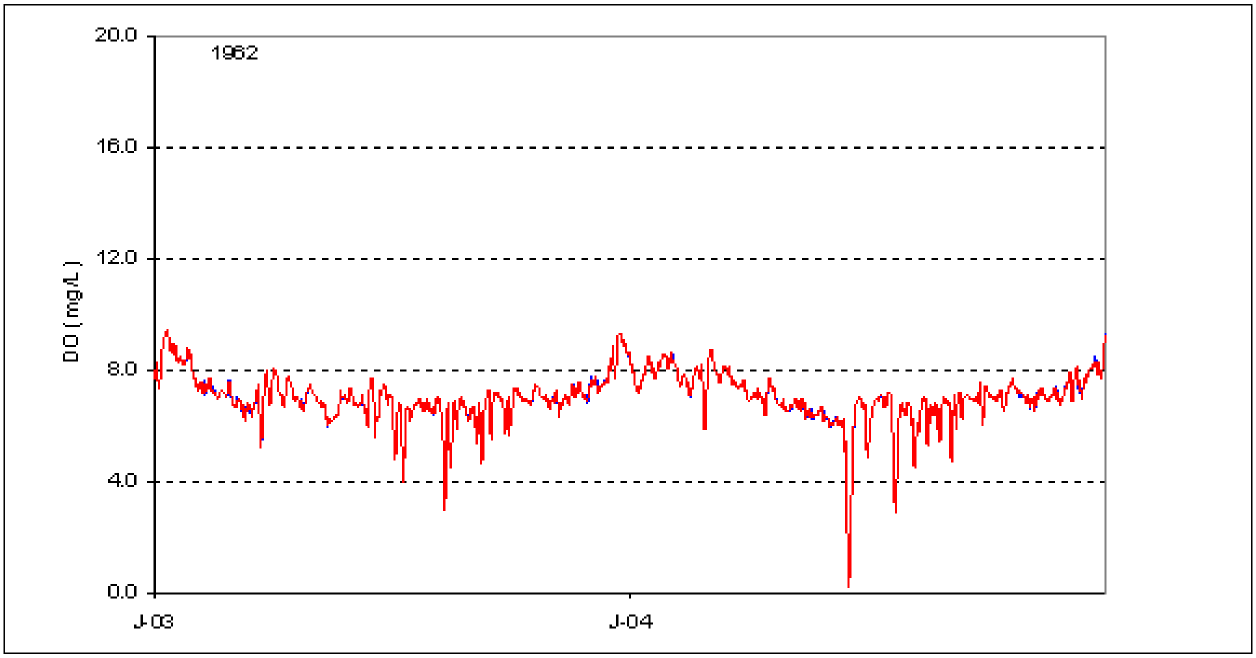

Figure 9 Natural vs Natural Conditions with NPDES Discharges Dissolved Oxygen in WBID 1962

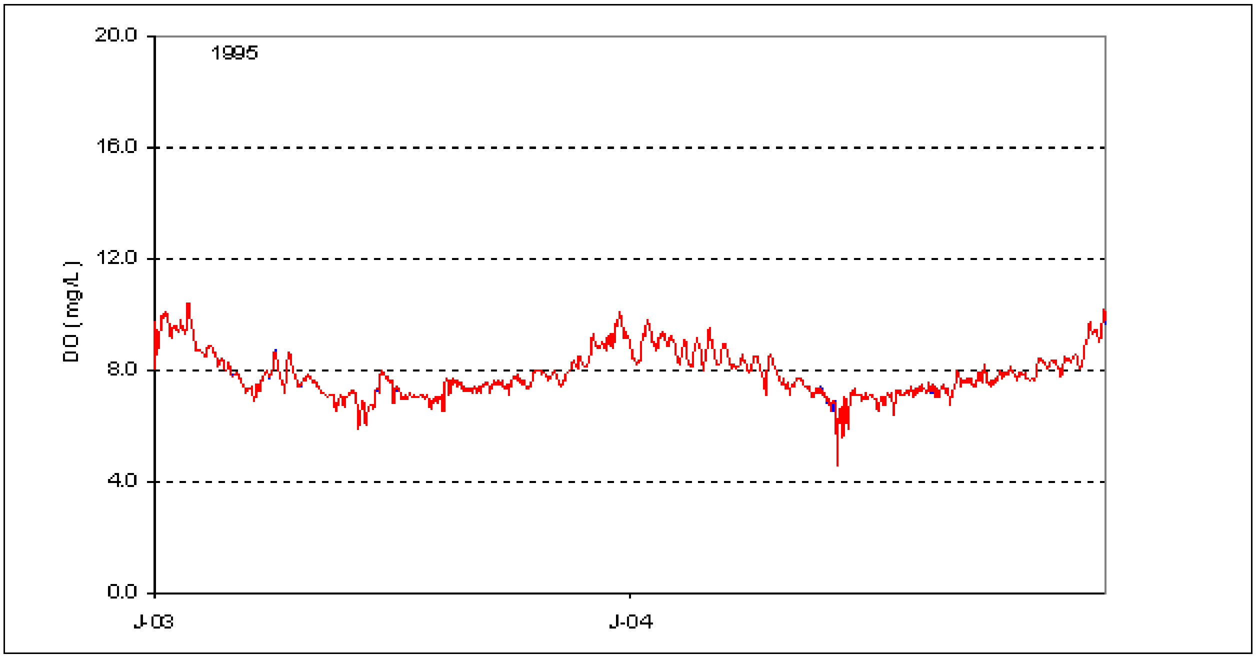

Figure 10 **Natural vs Natural Conditions with NPDES Discharges Dissolved Oxygen in WBID 1995**

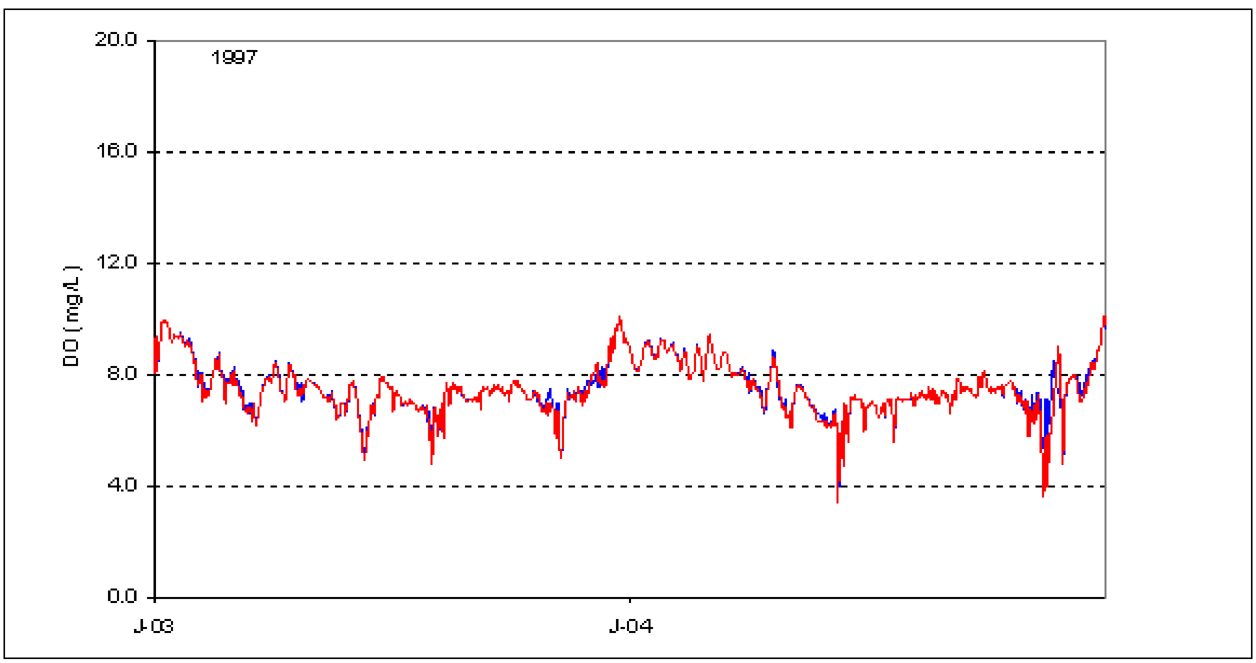

Figure 11 **Natural vs Natural Conditions with NPDES Discharges Dissolved Oxygen in WBID 1997**

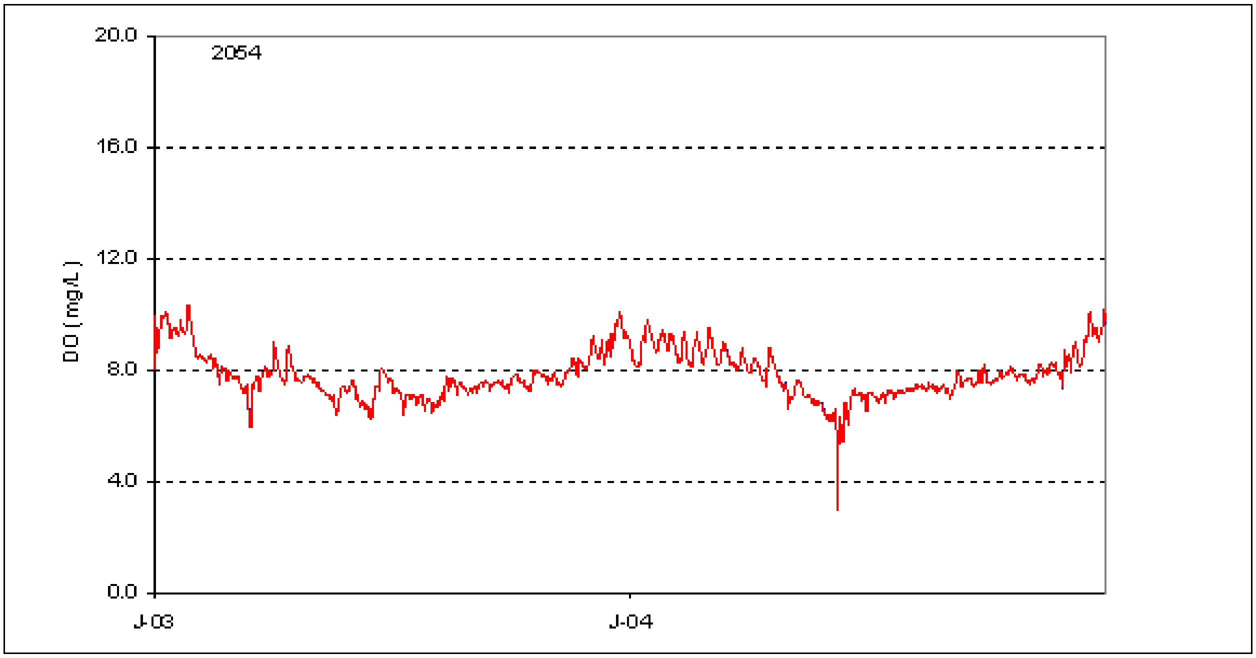

Figure 12 Natural vs Natural Conditions with NPDES Discharges Dissolved Oxygen in WBID 2054

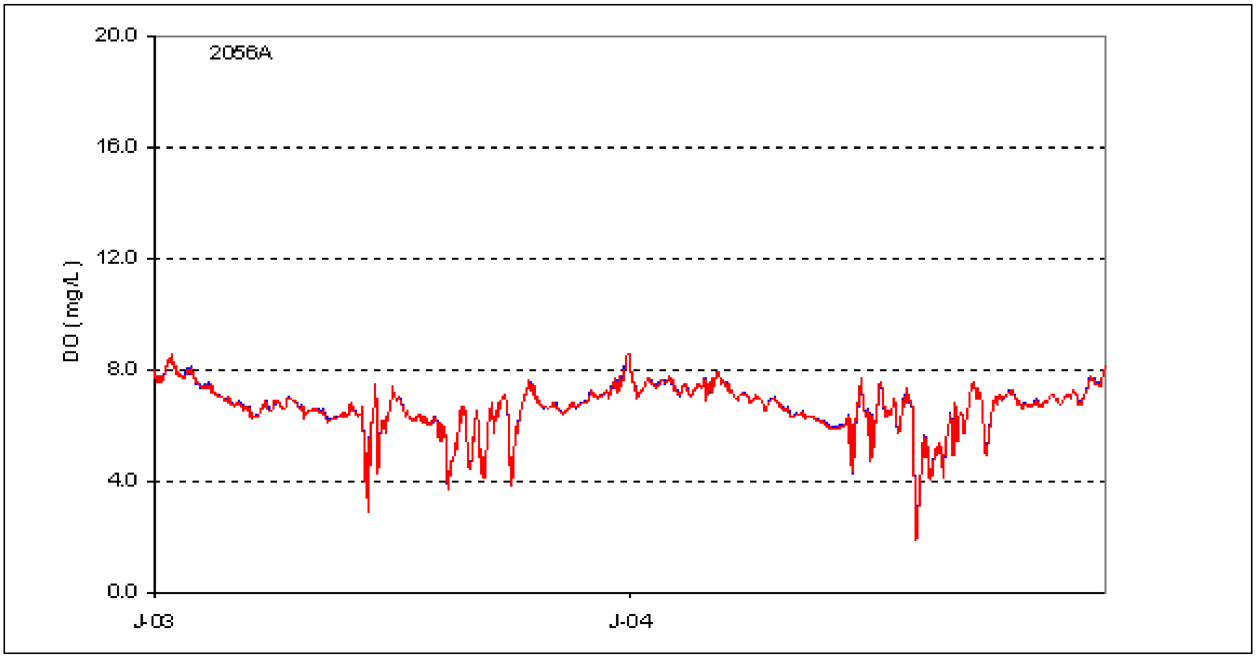

Figure 13 Natural vs Natural Conditions with NPDES Discharges Dissolved Oxygen in WBID 2056A

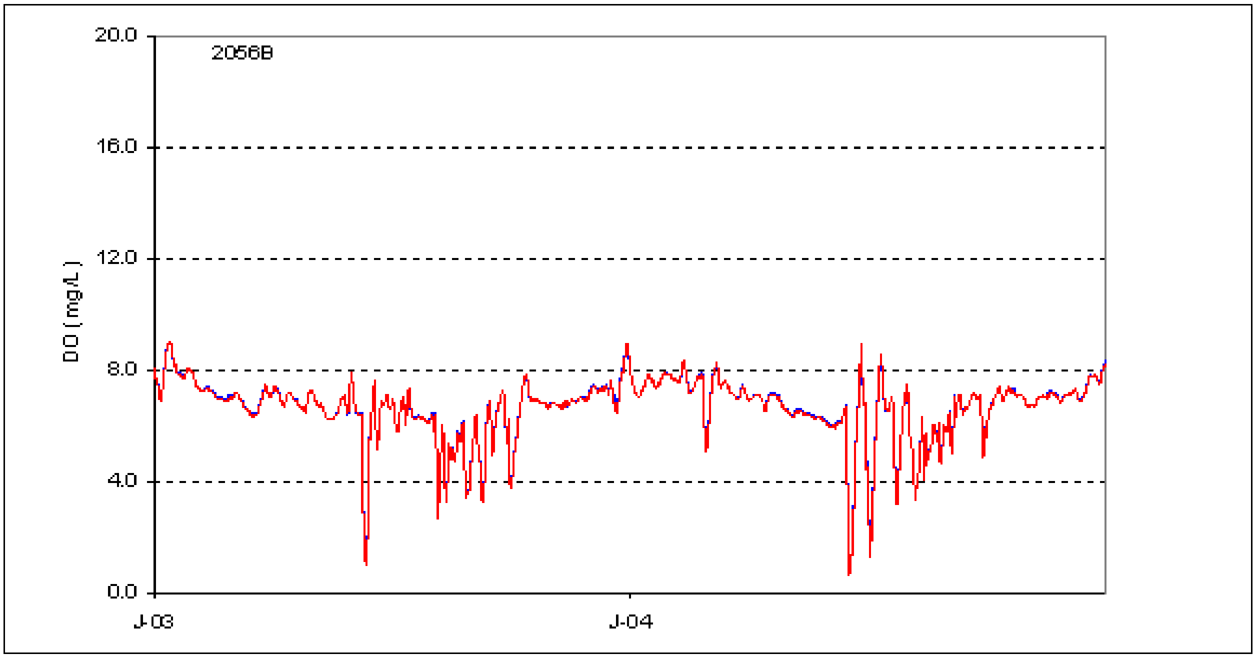

Figure 14 **Natural vs Natural Conditions with NPDES Discharges Dissolved Oxygen in WBID 2056B**

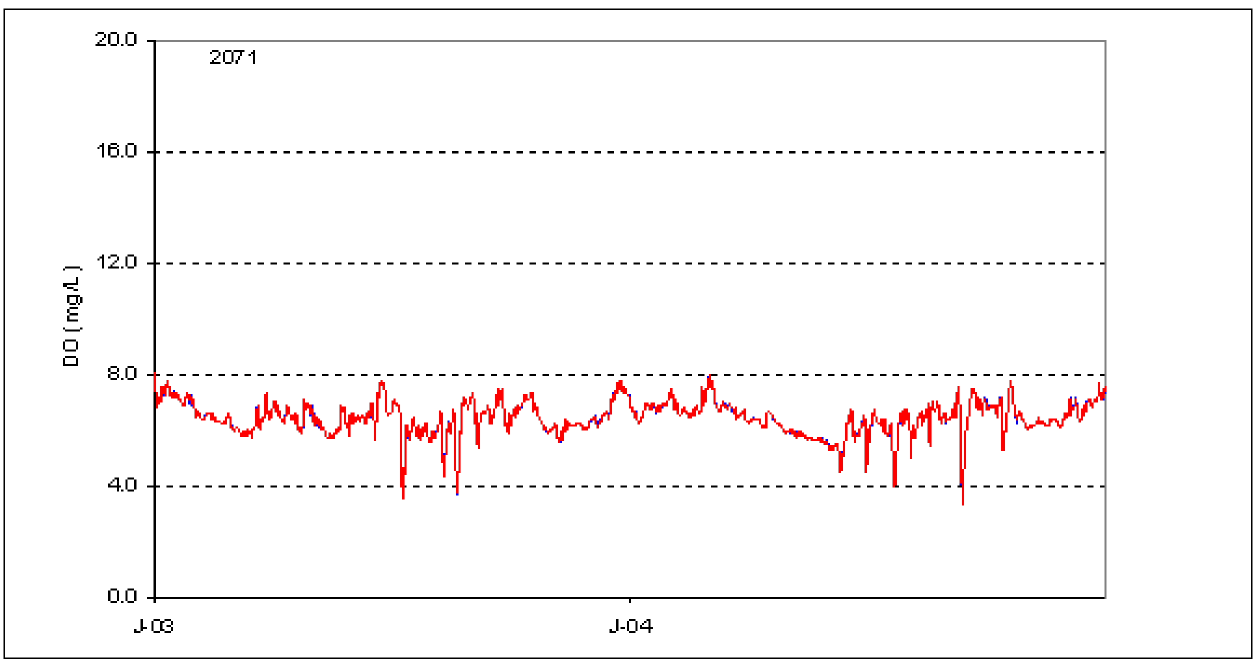

Figure 15 **Natural vs Natural Conditions with NPDES Discharges Dissolved Oxygen in WBID 2071**

8. TMDL Determination

A total maximum daily load (TMDL) for a given pollutant and water body is comprised of the sum of individual wasteload allocations (WLAs) for point sources, and load allocations (LAs) for both non-point sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the equation:

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

The TMDL is the total amount of pollutants that can be assimilated by the receiving water body and still achieve water quality standards and the water bodies designated use. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be set and thereby provide the basis to establish water quality-based controls. These TMDLs are expressed as annual mass loads, since the approach used to determine the TMDL targets relied on annual loadings. The TMDLs targets were determined to be the conditions needed to restore and maintain a balanced aquatic system. Furthermore, it is important to consider nutrient loading over time, since nutrients can accumulate in water bodies.

The TMDLs were determined for the loadings coming from the upstream watersheds that drain directly into each WBID. The allocations are given in Table 5.

Due to the naturally low dissolved oxygen, the loading will need to achieve the loading under natural conditions. This will result in no load allocations being permitted throughout the watershed. The MS4 service areas will be required to have no contribution of BOD or nutrients above background levels.

8.1 Critical Conditions and Seasonal Variation

USEPA regulations at 40 CFR 130.7(c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The critical condition is the combination of environmental factors creating the "worst case" scenario of water quality conditions in the water body. By achieving the water quality standards at critical conditions, it is expected that water quality standards should be achieved during all other times. Seasonal variation must also be considered to ensure that water quality standards will be met during all seasons of the year, and that the TMDLs account for any seasonal change in flow or pollutant discharges, and any applicable water quality criteria or designated uses (such as swimming) that are expressed on a seasonal basis.

The critical condition for non-point source loadings is typically an extended dry period followed by a rainfall runoff event. During the dry weather period, nutrients build up on the land surface, and are washed off by rainfall. The critical condition for continuous point source loading typically occurs during periods of low stream flow when dilution is minimized. Although loading of non-point source pollutants contributing to a nutrient impairment may occur during a runoff event, the expression of that nutrient impairment is more likely to occur during warmer months, and at times when the water body is poorly flushed.

Since nutrients can accumulate in water bodies, it is important to consider their loading over longer time periods. For Charlotte Harbor and Peace River, the LSPC simulation was performed over a 10-year period to account for both wet and dry years, while the EFDC and WASP simulations were performed over a two year period with one year being a wet year and another being a normal year.

8.2 Margin of Safety

The margin of safety (MOS) accounts for uncertainty in the relationship between a pollutant load and the resultant condition of the water body. There are two methods for incorporating a MOS into TMDLs (USEPA, 1991):

- Implicitly incorporate the MOS using conservative model assumptions to develop allocations
- Explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations

The Charlotte Harbor and Peace River TMDLs were developed using an implicit margin of safety by using conservative approaches throughout the modeling process.

8.3 Waste Load Allocations

The MS4s and NPDES facilities discharging in waters that drain into the TMDL WBIDs are assigned a WLA. The WLA, if applicable, is expressed separately for continuous discharge facilities (e.g., WWTPs) and MS4 areas, as the former discharges during all weather conditions whereas the later discharges in response to storm events.

8.3.1 NPDES Dischargers

As set above, EPA believes Charlotte Harbor and its tributaries are naturally below the applicable water quality standard for dissolved oxygen without anthropogenic sources. While this TMDL does not propose loads to abate that natural condition, there is no assimilative capacity available in the watershed for a nutrient or BOD waste load allocation above natural background conditions. A revised DO criterion (SSAC) for Charlotte Harbor and its tributaries should be considered by FDEP to determine whether there is some amount of these constituents, above natural background, that can be added to the watershed while still protecting its designated uses. The TMDL wasteload allocations are presented in Table 5.

Table 5. Summary of Waste load Allocations for each WBID

Name	Permit	Waste Load Allocation		
		BOD (kg/yr)	TN (kg/yr)	TP (kg/yr)
MOSAIC FERTILIZER LLC	FL0000230	0.00	0.00	0.00
FARMLAND INDUSTRIES, INC.	FL0000752	0.00	0.00	0.00
CARGILL FERTILIZER INC. S. FT. MEADE MINE	FL0001198	0.00	0.00	0.00
U S AGRI-CHEMICALS CORPORATION - FT MEADE CHEMICAL PLANT	FL0001902	0.00	0.00	0.00
FLORIDA DISTILLERS COMPANY	FL0003051	0.00	0.00	0.00
LARSEN MEMORIAL POWER PLANT	FL0026298	0.00	0.00	0.00
ARCADIA CITY OF - WILLIAM TYSON WWTF	FL0027511	0.00	0.00	0.00
NU-GULF INDUSTRIES INC. WINGATE CREEK MINE	FL0032522	0.00	0.00	0.00
CF INDUSTRIES, INC - BARTOW CHEMICAL PLANT	FL0035271	0.00	0.00	0.00
CHARLOTTE HARBOR WATER ASSOC REVERSE OSMOSIS WATER TRT PLT	FL0035378	0.00	0.00	0.00
WINTER HAVEN, CITY OF - WWTP#3	FL0036048	0.00	0.00	0.00
CARGILL FERTILIZER	FL0037958	0.00	0.00	0.00
GLENDALE WATER RECLAMATION FACILITY	FL0039772	0.00	0.00	0.00
CF INDUSTRIES, INC - BARTOW CHEMICAL PLANT	FL0040177	0.00	0.00	0.00
HARDEE POWER STATION	FL0041751	0.00	0.00	0.00
CYPRESS GARDENS INC	FL0042463	0.00	0.00	0.00
HARDEE POWER STATION	FL0044229	0.00	0.00	0.00
US AGRI-CHEMICALS CORPORATION - BARTOW CHEMICAL PLANT	FL0174106	0.00	0.00	0.00
VENICE MINERALS	FL0179256	0.00	0.00	0.00

8.3.2 Municipal Separate Storm System Permits

The WLA for MS4s are expressed in terms of percent reductions equivalent to the reductions required for non-point sources. Given the available data, it is not possible to estimate loadings coming exclusively from the MS4 areas. Although the aggregate wasteload allocations for stormwater discharges are expressed in numeric form, i.e. percent reduction, based on the information available today, it is infeasible to calculate numeric WLAs for individual stormwater outfalls. This is because discharges from these sources can be highly intermittent, are usually characterized by very high flows occurring over relatively short time intervals, and carry a variety of pollutants whose nature and extent varies according to geography and local land use. Water quality impacts depend on a wide range of factors, including the magnitude and duration of rainfall events, the time period between events, soil conditions, fraction of land that is impervious to rainfall, other land use activities, and the ratio of stormwater discharge to receiving water flow.

This TMDL assumes for the reasons stated above that it is infeasible to calculate numeric water quality-based effluent limitations for stormwater discharges. Therefore, in the absence of information presented to the permitting authority showing otherwise, this TMDL assumes that water quality-based effluent limitations for stormwater sources of nutrients derived from this TMDL can be expressed in narrative form (e.g., as best management practices), provided that:

> (1) The permitting authority explains in the permit fact sheet the reasons it expects the chosen BMPs to achieve the aggregate wasteload allocation for these stormwater discharges.

(2) The state will perform ambient water quality monitoring for nutrients for the purpose of determining whether the BMPs in fact are achieving such aggregate wasteload allocation.

The percent reduction calculated for non-point sources is assigned to the MS4 as loads from both sources typically occur in response to storm events. Permitted MS4s will be responsible for reducing only the loads associated with stormwater outfalls which it owns, manages, or otherwise has responsible control. MS4s are not responsible for reducing other non-point source loads within its jurisdiction. The MS4 service areas will be required to have no contribution of BOD or nutrients above background levels.

8.4 Load Allocations

Load Allocations were determined by the difference between the TMDL and Waste Load Allocations for the Charlotte Harbor and Peace River WBIDs (Table 6):

$$\sum \text{LAs} = \text{TMDL} - \sum \text{WLAs}$$

Table 6. Summary of TMDL Loading Allocations for each WBID

	TMDL Condition						Percent Reduction		
	WLA			LA					
WBID	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)	BOD (kg/yr)	Total Nitrogen (kg/yr)	Total Phosphorus (kg/yr)	BOD (kg/yr)	Total Nitrogen	Total Phosphorus	BOD
1774	0	0	0	19,929	4,840	67,759	61.0%	61.0%	61.0%
1948	0	0	0	2,705	396	11,650	43.0%	43.0%	43.0%
1962	0	0	0	231,709	55,486	788,959	23.72%	23.69%	23.46%
1995	0	0	0	74,233	17,721	252,642	24.28%	24.38%	24.02%
1997	0	0	0	185,622	44,333	631,971	29.57%	29.61%	29.25%
2054	0	0	0	590,001	141,521	2,010,376	23.67%	23.50%	23.24%
2071	0	0	0	7,022	1,678	23,644	48.07%	47.88%	47.84%
2056 A	0	0	0	3,867,316	924,675	13,201,482	27.81%	27.79%	27.60%
2056 B	0	0	0	3,672,778	878,350	12,542,161	27.23%	27.23%	27.02%

Note: 1. To convert the units of the Load Allocations to kg/day, divide by 365 days.

References

Florida Administrative Code. Chapter 62-302, Surface Water Quality Standards.

Florida Administrative Code. Chapter 62-303, Identification of Impaired Surface Waters.

United States Census Bureau (US Census Bureau). 2006. Bureau of Economic Analysis, Bureau of Labor Statistics, National Agricultural Statistics Service, National Center for Health Statistics, U.S. Census Bureau. (www.fedstats.gov, www.census.gov)

United States Environmental Protection Agency (USEPA). 1991. *Guidance for Water Quality–based Decisions: The TMDL Process.* U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA-440/4-91-001, April 1991.

9. Appendix A: SOD Spreadsheet Model

In addition to WASP7, another model was used to establish a defensible link between instream loads versus SOD for Bear Branch (WBID 1948) and Little Charlie Creek (WBID 1774). An SOD model developed by Quantitative Environmental Analysis (QEA) and modified by Dr. James Martin at Mississippi State University (MSU) was implemented to determine the relative change in SOD by altering the watershed load of CBODu and nutrients. Nutrient and CBODu parameters were input to the model, and SOD was calibrated to the exiting Bear Branch needed to achieve an SOD of 1.1 g/m^2/d in order to meet the dissolved oxygen standard. Little Charlie Creek needed to achieve an SOD of 1.44 g/m^2/d in order to meet the dissolved oxygen standard.

Tables 7 and 8 and Figures 16 and 17 show results from the SOD spreadsheet model for CBODu and nutrient reductions of 10, 25, 50, 75 and 90 percent. Also shown is the SOD corrected to 20 deg-C.

Table 7. SOD Spreadsheet Model Results for Bear Branch

		Existing Conditions		10% Reduction		25% Reduction		50% Reduction		75% Reduction		90% Reduction	
	Temp	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC
1	18.86	1.60	1.75	1.53	1.66	1.39	1.52	1.08	1.18	0.64	0.69	0.33	0.37
30	18.40	1.85	2.09	1.74	1.97	1.57	1.77	1.19	1.34	0.68	0.77	0.36	0.41
60	18.73	1.67	1.84	1.59	1.75	1.44	1.59	1.12	1.23	0.65	0.72	0.34	0.38
90	19.82	1.30	1.31	1.24	1.26	1.15	1.17	0.95	0.96	0.60	0.61	0.31	0.32
120	21.39	2.06	1.85	1.93	1.73	1.71	1.54	1.27	1.14	0.72	0.65	0.39	0.35
150	23.01	1.71	1.36	1.62	1.29	1.47	1.17	1.14	0.90	0.67	0.53	0.35	0.28
180	24.24	1.15	0.83	1.10	0.80	1.03	0.74	0.86	0.62	0.57	0.41	0.30	0.22
210	24.75	1.26	0.87	1.21	0.84	1.13	0.79	0.94	0.65	0.59	0.41	0.31	0.22
240	24.39	2.06	1.47	1.93	1.38	1.71	1.22	1.26	0.90	0.71	0.51	0.40	0.28
270	23.27	1.86	1.45	1.76	1.37	1.58	1.23	1.19	0.93	0.69	0.53	0.36	0.28
300	21.70	1.69	1.48	1.61	1.41	1.46	1.28	1.12	0.99	0.65	0.57	0.35	0.30
330	20.09	1.77	1.76	1.67	1.66	1.51	1.50	1.15	1.15	0.67	0.66	0.35	0.35
360	18.86	1.60	1.75	1.53	1.66	1.39	1.52	1.08	1.18	0.64	0.69	0.33	0.37
390	18.40	1.85	2.09	1.74	1.97	1.57	1.77	1.19	1.34	0.68	0.77	0.36	0.41
420	18.73	1.67	1.84	1.59	1.75	1.44	1.59	1.12	1.23	0.65	0.72	0.34	0.38
450	19.82	1.30	1.31	1.24	1.26	1.15	1.17	0.95	0.96	0.60	0.61	0.31	0.32
480	21.39	2.06	1.85	1.93	1.73	1.71	1.54	1.27	1.14	0.72	0.65	0.39	0.35
510	23.01	1.71	1.36	1.62	1.29	1.47	1.17	1.14	0.90	0.67	0.53	0.35	0.28
540	24.24	1.15	0.83	1.10	0.80	1.03	0.74	0.86	0.62	0.57	0.41	0.30	0.22
570	24.75	1.26	0.87	1.21	0.84	1.13	0.79	0.94	0.65	0.59	0.41	0.31	0.22
600	24.39	2.06	1.47	1.93	1.38	1.71	1.22	1.26	0.90	0.71	0.51	0.40	0.28
630	23.27	1.86	1.45	1.76	1.37	1.58	1.23	1.19	0.93	0.69	0.53	0.36	0.28
660	21.70	1.69	1.48	1.61	1.41	1.46	1.28	1.12	0.99	0.65	0.57	0.35	0.30
700	20.09	1.69	1.68	1.61	1.59	1.46	1.45	1.12	1.12	0.65	0.65	0.35	0.34
	Average =	**1.66**	**1.50**	**1.58**	**1.42**	**1.43**	**1.29**	**1.10**	**1.00**	**0.65**	**0.59**	**0.35**	**0.31**

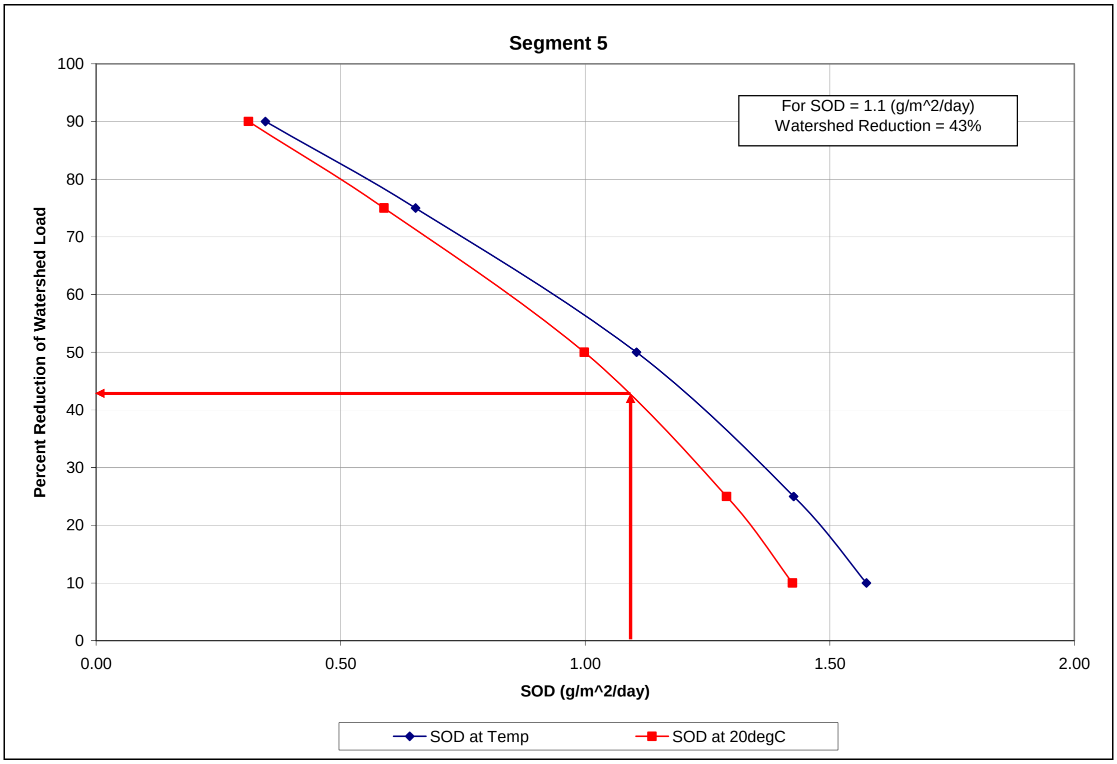

Figure 16 SOD Spreadsheet Model Results for Bear Branch

Table 8. SOD Spreadsheet Model Results for Little Charlie Creek

		Existing Conditions		10% Reduction		25% Reduction		50% Reduction		75% Reduction		90% Reduction	
	Temp	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC	SOD at Temp	SOD at 20degC
1	18.86	2.23	2.43	2.15	2.35	2.03	2.21	1.74	1.90	1.23	1.34	0.62	0.68
30	18.40	2.79	3.16	2.67	3.02	2.47	2.80	2.04	2.31	1.36	1.54	0.66	0.75
60	18.73	2.36	2.61	2.28	2.52	2.14	2.36	1.82	2.01	1.27	1.40	0.64	0.70
90	19.82	1.70	1.72	1.65	1.67	1.57	1.59	1.38	1.40	1.05	1.06	0.58	0.59
120	21.39	3.21	2.88	3.07	2.75	2.82	2.53	2.29	2.06	1.46	1.32	0.70	0.63
150	23.01	2.49	1.98	2.40	1.90	2.23	1.77	1.88	1.49	1.29	1.02	0.66	0.52
180	24.24	1.49	1.08	1.45	1.05	1.38	1.00	1.22	0.88	0.94	0.68	0.56	0.40
210	24.75	1.58	1.09	1.54	1.07	1.48	1.03	1.33	0.92	1.03	0.72	0.58	0.40
240	24.39	3.17	2.26	3.04	2.17	2.81	2.00	2.30	1.64	1.46	1.04	0.69	0.50
270	23.27	2.76	2.15	2.65	2.06	2.47	1.92	2.05	1.60	1.37	1.06	0.67	0.52
300	21.70	2.39	2.10	2.31	2.03	2.17	1.90	1.84	1.62	1.28	1.12	0.64	0.56
330	20.09	2.59	2.57	2.49	2.47	2.32	2.30	1.94	1.93	1.32	1.31	0.65	0.64
360	18.86	2.23	2.43	2.15	2.35	2.03	2.21	1.74	1.90	1.23	1.34	0.62	0.68
390	18.40	2.79	3.16	2.67	3.02	2.47	2.80	2.04	2.31	1.36	1.54	0.66	0.75
420	18.73	2.36	2.61	2.28	2.52	2.14	2.36	1.82	2.01	1.27	1.40	0.64	0.70
450	19.82	1.70	1.72	1.65	1.67	1.57	1.59	1.38	1.40	1.05	1.06	0.58	0.59
480	21.39	3.21	2.88	3.07	2.75	2.82	2.53	2.29	2.06	1.46	1.32	0.70	0.63
510	23.01	2.49	1.98	2.40	1.90	2.23	1.77	1.88	1.49	1.29	1.02	0.66	0.52
540	24.24	1.49	1.08	1.45	1.05	1.38	1.00	1.22	0.88	0.94	0.68	0.56	0.40
570	24.75	1.58	1.09	1.54	1.07	1.48	1.03	1.33	0.92	1.03	0.72	0.58	0.40
600	24.39	3.17	2.26	3.04	2.17	2.81	2.00	2.30	1.64	1.46	1.04	0.69	0.50
630	23.27	2.76	2.15	2.65	2.06	2.47	1.92	2.05	1.60	1.37	1.06	0.67	0.52
660	21.70	2.39	2.10	2.31	2.03	2.17	1.90	1.84	1.62	1.28	1.12	0.64	0.56
700	20.09	2.39	2.37	2.31	2.29	2.17	2.15	1.84	1.83	1.28	1.27	0.64	0.63
	Average =	**2.39**	**2.16**	**2.30**	**2.08**	**2.15**	**1.95**	**1.82**	**1.64**	**1.25**	**1.13**	**0.64**	**0.57**

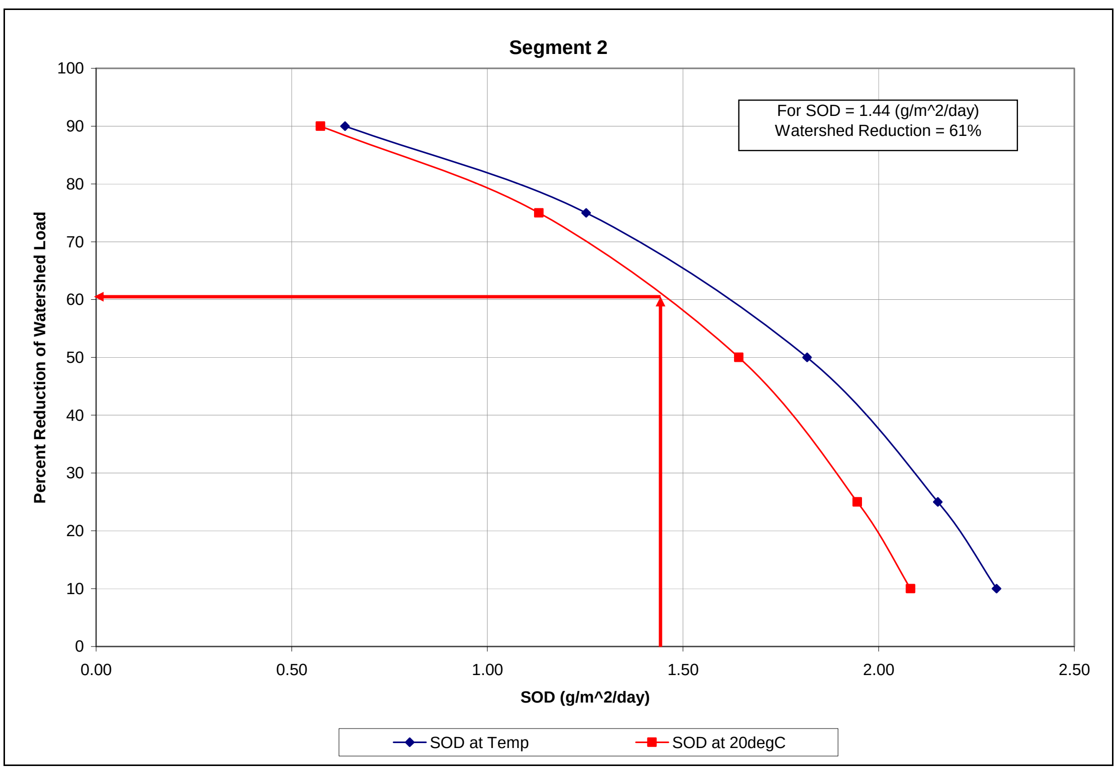

Figure 17 SOD Spreadsheet Model Results for Little Charlie Creek