# SECOND CALIBRATED MODEL AND

# WASTELOAD ALLOCATION FOR THE TOWN OF KINDER STP

## WLA Report

**William C. Berger, Jr.**

**Engineering Section 2**
**Environmental Technology Division**
**Office of Environmental Assessment**
**Louisiana Department of Environmental Quality**

**September 1, 2000**

# ABSTRACT

This report presents the development of a calibrated model and a wasteload allocation (WLA) for the Town of Kinder Sewage Treatment Pond (STP). The permit number for the facility is LA0020605. The facility is located in Allen parish near Kinder, Louisiana. It is included in the LDEQ water quality management subsegment 030103 of the Calcasieu River Basin. A previous modeling effort had produced a calibrated model and a summer TMDL. This model was presented in the report "Water Quality Advanced Treatment Facilities Review For The Town of Kinder, Louisiana, Summary of Findings", dated May 25, 1990. Additional calibration graphs were presented in an addendum dated August 10, 1990. Due to the omission of some incoming stream and nonpoint flows, it was demonstrated that this model was not fully calibrated. This model was also developed based upon an instream dissolved oxygen criterion of 5.0 mg/L. The instream dissolved oxygen criteria for Kinder Ditch has since been changed to 3.0 mg/L. Therefore, a new, calibrated model was developed. (Rogers, 1990)

LIMNOSS modeling software was used to develop the calibration and projection models.

The calibrated model was used to project the in-stream water quality under defined loading conditions. The defined loading conditions included a facility upgrade at the Kinder STP. The upgrade would include an increased design capacity and improved treatment system. Previous reports discussed the upgrades and the facility permit dated September 17, 1994 showed the design capacity to be 0.46 MGD with daily average effluent limits of 5 mg/L $CBOD_5$, 2 mg/L $NH_3$-N, and 5 mg/L DO. However, subsequent reviews of the application and discussions with the permit writer revealed that the projected design flow would be 0.605 MGD. (LA DEQ)

A WLA was developed for the Kinder STP. The resulting summer WLA was 126.85 lbs./day for the summer months including a MOS of 25.37 lbs./day. The winter WLA was 416.52 lbs./day including a MOS of 83.30 lbs./day. Incidentally, SOD loads and nonpoint loads believed to be associated with nearby agricultural practices were also estimated.

The combined results of the modeling effort should only be used as a tool or aid in making water quality based decisions. The resulting limits for the Town of Kinder STP were 5/2/6 mg/L $CBOD_5$ / mg/L $NH_3$-N / mg/L DO for the summer critical conditions. The limits for the winter critical conditions were 10/10/6 mg/L $CBOD_5$ / mg/L mg/L $NH_3$-N / mg/L DO. Both of these treatment levels produced model runs that met the dissolved oxygen criteria of 3.0 mg/L.

TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES

# 1. INTRODUCTION

This report provides the methodology involved in the development of the calibrated model and wasteload allocation (WLA) for the Town of Kinder Sewage Treatment Pond (STP). The permit number for the facility is LA 0020605. A previous calibrated model was presented in the "Water Quality Advanced Treatment Facilities Review For The Town of Kinder, Louisiana, Summary of Findings", report number ATR 90.08, dated May 25, 1990. Review of this model revealed that additional point source and nonpoint source flows had been omitted from the model. The model was also based upon an instream dissolved oxygen criterion of 5.0 mg/L, whereas the new dissolved oxygen criteria for Kinder Ditch is 3.0 mg/L. (Rogers, 1990)

# 2. STUDY AREA DESCRIPTION

## 2.1 General Information

### 2.1.1 Geography

The unnamed ditch and Kinder Ditch are located in southwestern Louisiana. They are a part of the Calcasieu River Basin in subsegment 030103. The headwaters of the unnamed ditch are located east of Kinder, LA, while the headwaters of Kinder Ditch are located in the immediate vicinity of the Town of Kinder. The Kinder STP is located on the unnamed ditch. From the STP, the unnamed ditch flows approximately 2.1 miles to its confluence with Kinder Ditch. Kinder Ditch then flows approximately 6.7 miles to the Calcasieu River.

The Calcasieu River Basin has a drainage area of approximately 3,910 square miles. The basin extends from the hills west of Alexandria, LA, to the Gulf of Mexico, approximately 30 miles from the Texas-Louisiana state border. Pine forested hills exist in the northern end of the basin. The landscape in the southern end of the basin consists of brackish and saltwater marshes. (LDEQ, 1996)

The unnamed ditch and Kinder Ditch are located eastern-central portion of the basin. Survey pictures showed that the northern end of the survey reach was forested and had a significant amount of canopy provided by trees. The southern end of the study reach was surrounded by a prairie-like landscape. The study reach exists inside the northern edge of a land area that is used for agriculture. That agricultural use is primarily rice production.

The study reach is in a natural region of Louisiana known as the Terraces, which consists of blufflands, flatwoods, and prairies. Kinder Ditch and its unnamed tributary reside in the prairies. Low relief features, prairie grasslands and soils, pimple mounds, dendritic streams, ice-age channels, and marais existed throughout the area before human alterations and modifications became evident. Marais is a French term meaning a small, shallow undrained pond in the prairie. The principal soil types are Coastal Prairie soils, which consist of a dark to gray topsoil on top of an impervious claypan. This soil structure provides for shallow flooding, which is excellent for rice and crawfish farming. Rivers and the Gulf of Mexico deposited the soils. The elevation of the oceans rose and fell during glacial advances and retreats, thereby allowing the waters of the rivers and the Gulf of Mexico to deposit the soils. (Kniffen and Hilliard, 1988)

### 2.1.2 Climatology

Louisiana has a humid, subtropical climate. South Louisiana, in particular, tends to have a marine climate. The climate is influenced by the large continental landmass to the north and the Gulf of Mexico to the south. The Gulf of Mexico helps to provide warmer summers and milder winters with less temperature variation than is experienced in North Louisiana. South Louisiana has an average annual temperature of 68.5 degrees Fahrenheit (20.3 degrees Celsius). The prevailing winds are from the south and southeast and they bring in warm, moist air from the Gulf of Mexico. This results in an abundance of rainfall. The annual average rainfall for the area surrounding Kinder, LA, is approximately 58 inches. (LA DEQ, 1996), (Kniffen and Hilliard, 1988)

### 2.1.3 Hydrology

The headwater streamflow was 0.05 cfs for the calibration survey. The model depths ranged from 0.708 feet for the headwater to 1.80 feet between RM 8.80 and RM 8.56. Model widths ranged from 8.0 feet between RM 8.02 and RM 8.54, to 25.0 feet immediately downstream of the STP outfall.

### 2.1.4 Land Use Patterns

The unnamed ditch, which leads to Kinder Ditch, is surrounded by agricultural land use with a buffer zone of forested lands. The headwaters of Kinder Ditch are located near the urban areas of the Town of Kinder.

Below the confluence with the unnamed ditch, at river mile 6.7, the primary land use around Kinder Ditch is agricultural. Rice and soybean production is the primary form of agricultural land use.

## 2.2 Water Quality Standards

General narrative standards and numerical criteria have been defined for the waters of the State of Louisiana. General narrative standards include the preservation of aesthetics and prevention of floating, suspended, and settleable solids. The standards also include the prevention of objectionable color, taste and odor, toxic substances, oil and grease, foaming or frothing materials, nutrients, turbidity, flow, radioactive materials, and the preservation of biological and aquatic community integrity (LA DEQ, 2000).

Table 2.1 shows the numerical criteria that applies to Kinder Ditch.

The designated uses for Kinder Ditch and the unnamed ditch include secondary contact recreation and the propagation of fish and wildlife. (LA DEQ, 2000)

**Table 2.1 Numerical Criteria for Kinder ditch, Subsegment 030103, Headwaters (unnamed tributary) to Confluence with Calcasieu River (LA DEQ, 2000)**

| PARAMETER | CRITERIA |
|---|---|
| Chlorides | 65 mg/L |
| Sulfates | 35 mg/L |
| Dissolved Oxygen | 3.0 mg/L |
| pH | 6.0-8.5 |
| Bacteria | Primary Contact Recreation |
| Temperature | 32 degrees C |
| Total Dissolved Solids | 225 mg/L |

2.3 Wastewater Discharges

At the time of the reconnaissance and calibration surveys, the main point-source discharger for the along the study reach was the Town of Kinder STP.

The Town of Kinder STP is located immediately north of Neilson Road (Allen Parish Road 11) along the unnamed ditch (Shearer Publishing, 1997). Data from reconaissance surveys did indicate various point source outfalls which were either not discharging or had a discharge that was negligible (discharge approximately 0.01-0.02 cfs).

2.4 Water Quality Conditions

During the survey of the unnamed Ditch and Kinder Ditch conducted on October 16 - 19, 1989, the water quality for a portion of the study reach was at or near septic conditions, according to the survey data. The minimum dissolved oxygen level was 2.20 mg/L at RM 8.82 and 2.3 mg/L at RM 8.02.

From field notes and pictures, the water being discharged from the single-cell oxidation pond at RM 8.80 was observed to be “pea soup green.” This color was caused by a high concentration of algae. The stream water was also noted to be green or greenish-brown from Site 1 (RM 8.82) to a location below Site 4 (RM 8.02). It is believed that backwash of the algae-laden discharge was causing the stream to have a green color at site 1, which was upstream of the STP discharge.

## 3. DOCUMENTATION OF WATER QUALITY MODEL

3.1 Model Description

Input data for the calibration and projection models have been provided in Table 5.1. Appendices D presents the input and output files for the calibrated model. The input and output files for the projection summer and winter models are in Appendices G1 and Appendices G2, respectively.

#### 3.1.1 Program Description

LIMNOSS was used to develop the calibration and projection models for Kinder STP. LIMNOSS is a one-dimensional, steady-state dissolved oxygen model, developed by LimnoTech, Inc. A detailed description of this program is available elsewhere (LimnoTech, 1984).

#### 3.1.2 Vector Diagram

The unnamed ditch and Kinder Ditch were modeled from RM 8.90 to RM 5.50. In the field, the headwater measurement was taken at RM 8.82, the established location of Site 1. In the model, the headwater values were input at RM 8.90 in order to keep the headwater values and the STP values from being put into the same input cell. The outfall for the Town of Kinder STP was located at RM 8.80. Site 2 was located at RM 8.56. Site 3 was established at an irrigation ditch flume at RM 8.27. Sites 4 and 5 were located at RM 8.02 and RM 6.74, respectively. The confluence of the unnamed ditch and Kinder Ditch was at RM 6.70. Site 6 was located in Kinder Ditch, immediately upstream of the confluence with the unnamed ditch. Site 7 was located at RM 5.67. A vector diagram of the study reach is provided in Figure 3.1, shown on the following page.

#### 3.1.3 Boundary Conditions

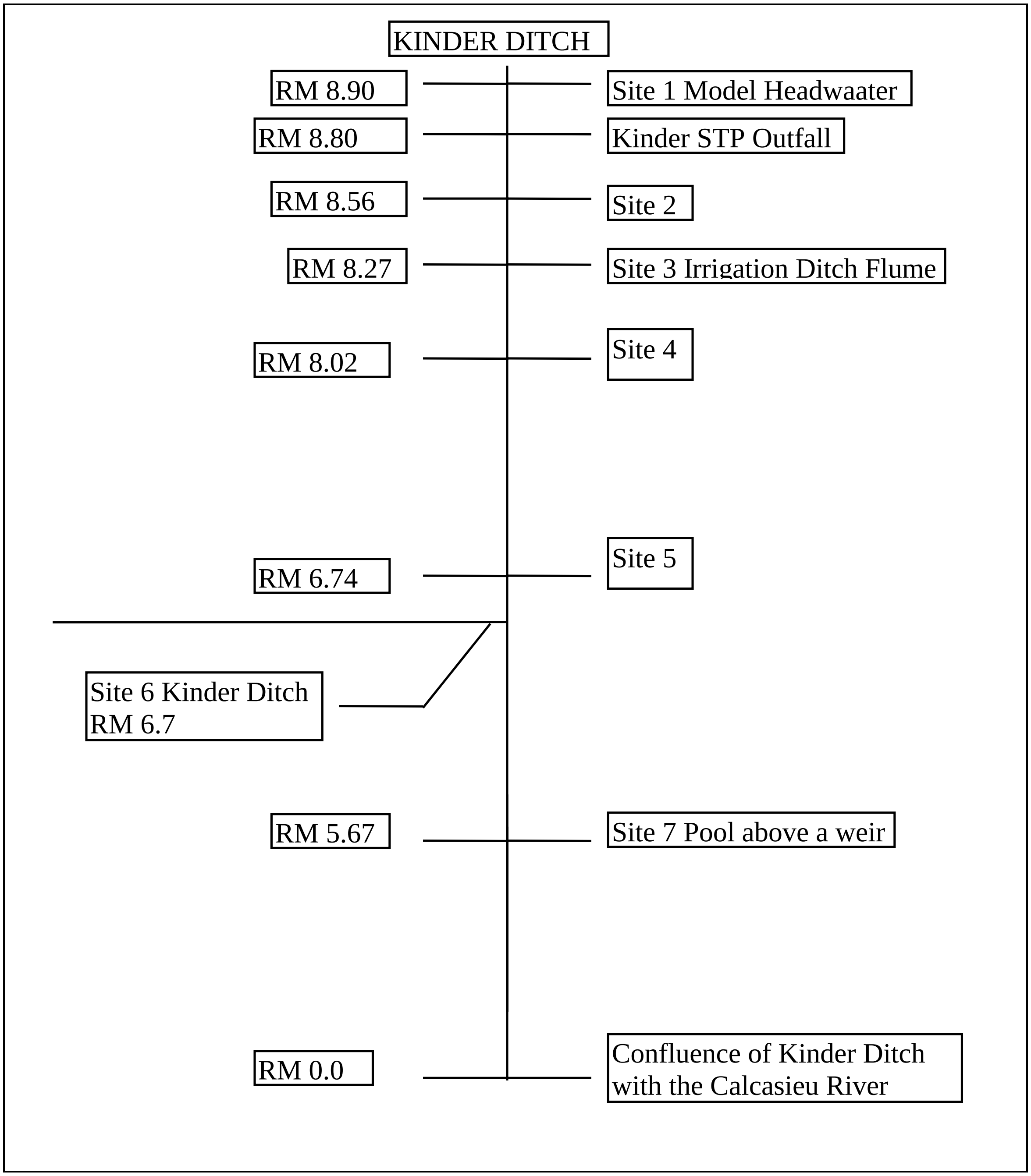
Headwater flow characteristics were the only known upstream boundary conditions. Downstream conditions were determined by a series of weirs. One weir existed immediately downstream of site 7, while several more weirs existed further downstream. It was believed that the purpose of these weirs was to ensure that the farmers would have water for irrigation. No modeling assumptions were made based upon the existence of these weirs.

## 4. SURVEY DISCUSSION

### 4.1 Reconaissance Survey

A reconnaissance survey of the study reach had been conducted on September 9, 1989. During this survey, several stream flow measurements were made. These measurements included the only measurement that was made at Site 1 during either the reconnaissance survey or the intensive survey, which was conducted on October 18 - 19, 1989. This measurement was conducted while the stream was at a different flow than the one which was used as a headwater boundary condition when developing the calibrated model. Therefore the values obtained at this point were used only as a reference.

**FIGURE 3.1 UNNAMED DITCH TO KINDER DITCH VECTOR DIAGRAM**




4.2 Intensive Survey

The intensive survey included stream flow measurements at site 4 (RM 8.02), site 5 (RM 6.74), site 6 (RM 6.70), and site7 (RM 5.67). Site 6 was actually located in Kinder Ditch, upstream of its confluence with the unnamed ditch. A flow measurement was also made for the STP effluent. The STP outfall was located at RM 8.80. (Hebel, 1990)

A headwater flow for the unnamed ditch of 0.36 cfs was measured in the field during the reconaissance survey. A headwater flow of 0.05 cfs was used in the calibration model. The basis of the headwater flow will be explained in the Calibration Model Discussion section of this report. Headwater samples from the intensive survey yielded $CBOD_U$ and $NBOD_U$ concentrations of 12.634 mg/L and 9.718 mg/L, respectively from the laboratory analysis. The concentrations produced loads of 3.40 lbs./day and 2.62 lbs./day for $CBOD_U$ and $NBOD_U$ , respectively. (Hebel, 1990)

Water quality and BOD samples were also taken at these sites as well as site 1 (headwater site, RM 8.82), which was located immediately upstream of the STP outfall.
In order to avoid the combining of headwater and STP input values within the same element of the model, site 1 was adjusted so that it was located at RM 8.90 of the model. (Hebel, 1990)

Other field data measured during the survey included dissolved oxygen, pH, water temperature, conductance, stream depth, sample depth, air temperature, date, and time. Laboratory data collected during the intensive survey included nitrates and nitrites ($NO_x$-N), ammonia nitrogen (NH3-N), total Kjeldahl nitrogen (TKN), phosphorous (P), total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), sulfates ($SO_4$), chlorides (Cl), chemical oxygen demand COD, and total organic carbon (TOC). (Hebel, 1990)

Pictures of the ditches and the oxidation pond were taken during the intensive survey. These pictures proved to be helpful in the model calibration because they displayed the algae in the pond and portions of the stream. The pond effluent was described as “pea soup green” in field notes provided by the survey team on the back of one of the pictures. The pictures also provided a view of the stream geometry, tree canopy, riparian zone, and local geography. (Hebel, 1990)

## 5. CALIBRATION MODEL DISCUSSION

The input data for the calibration and projection files are presented in Table 5.1.
The files and graphs for the calibrated model have been provided in Appendix D.

### 5.1 Hydrology and Stream Geometry

Calibration model values for flows and load concentrations for the Town of Kinder STP and the Kinder Ditch headwaters were obtained during a stream survey that was conducted on October 18 and 19, 1989. The flows for the Town of Kinder STP and Kinder Ditch were 0.44 and 0.66 cfs, respectively. The load concentrations for headwaters (site 1) of the unnamed ditch were also obtained during this survey. The only stream flow at site 1 was obtained during a reconnaissance survey dated September 9, 1989, and was used strictly as a reference. The headwater flow was therefore estimated by performing a mass balance using the flows and chlorine concentrations for the STP and Site 4 and the chlorine concentration for site 1. This resulted in a headwater flow of

### Table 5.1 Summary of Input Parameters, Unnamed Ditch to Kinder Ditch Model

| PARAMETER | CALIBRATION | PROJECTION | PROJECTION |
|---|---|---|---|
| Time Period | 10/16-19/89 | Summer Critical | Winter Critical |
| River Miles, mi | 8.9-5.5 | 8.9-5.5 | 8.9-5.5 |
| **Flow:** | | | |
| Headwater, cfs | .05 | 0.1 | 1.0 |
| Kinder STP, cfs | 0.44 | 1.17 | 1.17 |
| Kinder Ditch, cfs | 0.66 | 0.5 | 1.0 |
| Nonpoint Flow, cfs/mi/day | Varies 0.0-0.55 | Varies 0.0-0.55 | Varies 0.0-0.55 |
| * Outflow, cfs (from output files) | 1.885 | 2.50 | 3.90 |
| **Loading:** | | | |
| **$CBOD_U$:** | | | |
| Headwater, mg/L | 12.634 | 12.634 | 12.634 |
| Kinder STP, mg/L | 80.007 | 11.5 | 23.0 |
| Kinder Ditch, mg/L | 6.376 | 6.376 | 6.376 |
| Nonpoint $CBOD_U$, lb/mi/day | Varies 0-10.0 | Varies 0.0-10.0 | Varies 0.0-10.0 |
| **$NBOD_U$:** | | | |
| Headwater, mg/L | 9.718 | 9.718 | 9.718 |
| Kinder STP, mg/L | 39.775 | 8.6 | 43.0 |
| Kinder Ditch, mg/L | 6.579 | 6.579 | 6.579 |
| Nonpoint $NBOD_U$, lb/mi/day | Varies 0.0-100.0 | Varies 0.0-100.0 | Varies 0.0-100.0 |
| **Dissolved Oxygen:** | | | |
| Headwater, mg/L | 2.20 | 7.045 | 8.360 |
| Kinder STP, mg/L | 9.34 | 6.0 | 6.0 |
| Kinder Ditch, mg/L | 6.60 | 7.045 | 8.360 |
| Nonpoint DO, lb/mi/day | 0.0 | 0.0 | 0.0 |
| **Kinetic Rates:** | | | |
| CBOD Decay Rate, day-1 | 0.375 | 0.375 | 0.375 |
| NBOD Decay Rate, day-1 | 0.30 | 0.30 | 0.30 |
| SOD, g $O_2/m^2$/day | Varies 3.0-7.0 | 1.7 | 1.7 |
| Photosynthesis, g $O_2/m^2$/day | Varies 2.0-0.0 | Varies 2.0-0.0 | Varies 2.0-0.0 |
| Respiration, g $O_2/m^2$/day | 0.0 | 0.0 | 0.0 |
| CBOD Settling Rate, day-1 | Varies 0.05-0.6 | 0.05 | 0.05 |
| NBOD Settling Rate, day-1 | 0.05 | 0.05 | 0.05 |
| Reaeration Rate, day-1 | Louisiana Equation, 1995 | Louisiana Equation, 1995 | Louisiana Equation, 1995 |
| **Miscallaneous Parameters:** | | | |
| Velocity, ft/sec (from output files) | Varies 0.001-0.170 | Varies 0.0-0.148 | Varies 0.01-0.194 |
| Depth, ft | Varies 0.708-1.80 | Varies 0.98–2.78 | Varies 1.390-4.280 |
| Width, ft | Varies 8.0-25.0 | Varies 8.97-28.03 | Varies 9.600-29.890 |
| Nonpoint Clorides lb/day/mi | Varies 0.0-200.0 | Varies 0.0-200.0 | Varies 0.0-200.0 |
| Nonpoint Sulfates lb/day/mi | Varies 0.0-20.0 | Varies 0.0-20.0 | Varies 0.0-20.0 |
| Temperature, deg C | Varies 14.30-18.10 | 28.0 | 18.91 |
| D.O. Sat., mg/L | Varies 9.448-10.239 | 7.828 | 9.293 |
| Dispersion | 10.0 | 10.0 | 10.0 |

0.05 cfs.  Based upon the measured streamflows, it was observed that some additional flow was coming into the stream.  These flows were incorporated into the calibration model as nonpoint flows from RM 6.7 to RM 5.67.  They were also incorporated into the projection models.

Hydrologic calibration was achieved by adjusting the stream geometry values that had been developed in a previously calibrated model of the study reach.  The stream geometry values for the earlier model were derived from the data obtained from the reconnaissance survey (for Site 1) and the intensive survey (for the remaining sites). Subsequent runs of this model and comparisons of the graphs for the simulated values of time-of-travel, chlorides, and sulfates with the corresponding graphs for the measured values proved that the model was not properly calibrated for flow.  The model omitted some nonpoint source flow from RM 6.7 to RM 5.67 and the flow of Kinder Ditch at RM 6.7.  This resulted in a simulated time-of-travel between RM 6.7 and RM 5.67 that was longer than the measured time-of-travel between the two points.

During the model calibration, it became apparent that a deep, pooled area must have existed in the vicinity of the discharge outfall.  This assumption was based on the inability of the model to be calibrated for the time-of-travel and the water quality parameters, while using realistic decay and settling rates.  The pooled area acted as a settling basin, which increased the time-of-travel.  It also allowed some of the $CBOD_U$ and $NBOD_U$ to settle out of the water column, which decreased the settling and decay rates required for the model to calibrate.  As a result, this settling basin also affected the dissolved oxygen calibration.

The first step taken to correct these problems was to install nonpoint flow and the Kinder Ditch stream flow into the model.  The nonpoint flow was installed from RM 6.7 to RM 5.67.  The headwaters of Kinder Ditch were modeled as a tributary source, which entered the unnamed ditch at RM 6.7.

Step two involved simulating the affects of the settling basin.  The modeled widths and depths were adjusted, making the stream cross-sections wider and deeper in the vicinity of the discharge outfall.  The cross-sections were tapered back to smaller values immediately downstream of Site 2. The stream geometry from Site 2 to Site 5 was adjusted to values that were believed to be more realistic based upon the pictures taken during one of the surveys.  However, the cross-sectional area was kept constant in order to ensure that the simulated time-of–travel between these points would still match the measured time-of–travel.  These cross-sections were made wider and shallower.

These steps resulted in an acceptable hydrologic calibration of the model.  The second step also proved to be critical in the achievement of the water quality calibration.

## 5.2 Water Quality

### 5.2.1 Wasteloads

It should be noted that the $NBOD_U$ values obtained using the laboratory results and GSBOD were believed to be erroneous. This assumption was based upon the $NBOD_U$ values and graphs produced by the GSBOD spreadsheet. The GSBOD spreadsheet uses the unfiltered, suppressed and unfiltered, unsuppressed BOD values taken at various days over a 60-day period. The spreadsheet then creates graphs for the total BOD, CBOD, and NBOD values versus number of days over the 60-day period. The spreadsheet also calculates ultimate CBOD and NBOD values, decay rates, and lag times. The graphs produced decay rates and lag times that did not appear to be consistent and realistic. Therefore, TKN values were substituted for $NBOD_U$ values using a conversion factor of 4.3.

The primary point sources of loads at the time of the survey were the unnamed ditch headwater flow, the Town of Kinder STP discharge, and the Kinder Ditch headwater flow.

The calibration model had a $CBOD_U$ load of 189.90 lbs./day and a $NBOD_U$ 94.41 lbs./day for the Town of Kinder STP.

### 5.2.2 Nonpoint Loads

Nonpoint loads were used within the model that was not necessarily intended to be associated with a nonpoint flow. A nonpoint load of 100 lbs./mi/day was developed during the calibration process for $NBOD_U$ from RM 6.9 to RM 6.5. A nonpoint load of 10 lbs./mi/day was also developed for $CBOD_U$ from RM 7.0, through the end of the modeled reach. These nonpoint loads were intended to model the resuspension of oxygen depleting material that was apparently caused by the confluence of Kinder Ditch and the unnamed ditch. There may have also been some suspended particles introduced to the stream flow through runoff. The use of these nonpoint loads enabled the model to be calibrated for $CBOD_U$ and $NBOD_U$ without causing significant effects to the dissolved oxygen values. The nonpoint loads were also utilized in the summer and winter projection models.

### 5.2.3 Photosynthesis

Several other assumptions were made while calibrating the water quality parameters of the model. One assumption was that the Kinder STP effluent was introducing algae into the stream and the algae were dying in the stream. Scouring and resuspension was another process that was assumed to be occurring within the stream. It was also assumed that some nonpoint loading may have been present in the form of runoff or bank-related flow near the confluence of the unnamed ditch and Kinder Ditch. This assumption of bank-related flow is based on the fact that this portion of the stream had a dredged streambed. Therefore the streambed was moderately entrenched. Some of the nonpoint flows may include fertilizers (nitrogen) since the major landuse in the area is agricultural.

Pictures indicated that algae were prevalent in the oxidation pond. While in the pond, the algae receive a sufficient amount of sunlight. The algae were then introduced into the stream at the discharge outfall. Due to photosynthesis and the location of the outfall above the water surface, the effluent entered the stream with elevated dissolved oxygen levels. The pictures showed that the algae were present in the stream from the pooled area of the stream immediately upstream of the STP outfall to somewhere between the irrigation pipe, which crossed the unnamed ditch (approx. RM 8.25) and the second bridge (approx. RM 8.0) downstream of the STP outfall. At this point the water color was brown again.

Photosynthesis values ranging from 2.0 to 0.0 g O2/m2/day were developed for the calibration model. It was assumed that algal photosynthesis had occurred during the survey. This assumption was based upon calibration observation and field notes. The photosynthesis values were also utilized in the projection models.

Values for algal respiration were not utilized in the calibration and projection models.

### 5.2.4 Sediment Oxygen Demand

Relatively high sediment oxygen demand (SOD) values were used in the development of the calibrated model. During the development process of the model and the subsequent analysis of the data, it became apparent that much of the SOD near the outfall had been washed out prior to the survey. This SOD then settled out several miles downstream of the survey. This scouring and resettling process may have been caused by a storm event or the kinetic energy that the flow from the oxidation pond outfall has when it reaches the stream. The discharge pipe was located three to five feet above the water surface at the time of the survey. Therefore, it was assumed that the effluent had enough energy to create turbulence and scouring at that location. The resulting SOD values required in order to calibrate the model ranged from 3.0 g $O_2/m^2$/day near RM 8.90 to 7.0 g $O_2/m^2$/day near RM 6.50.

### 5.2.5 Kinetic Rates and Their Sources

Another model assumption was that the algae would die off due to the fact that the algae were going from a pond with a large surface area to a small ditch that was covered by a considerable amount of tree canopy. As the algae would die off, it would settle on the streambed and become SOD. This was simulated with elevated SOD levels in the model.

At the same time, the outfall appeared to be three to five feet above the water surface of the stream. This caused turbulence and scouring of the streambed. This scouring action of the outfall caused the bed material to be resuspended and deposited downstream, where it shows up as nonpoint loading and SOD. Dead algal material is typically high in

$NBOD_U$. This action was modeled with elevated SOD levels, high nonpoint $NBOD_U$ loading and minimal nonpoint $CBOD_U$ loading.

Decay rates were developed for the calibration model. The decay rate used for ultimate carbonaceous biochemical oxygen demand ($CBOD_U$ ) was 0.375 $day^{-1}$ while the decay rate for ultimate nitrogenous biochemical oxygen demand ($NBOD_U$ ) was 0.30 $day^{-1}$. These rates were also used in the projection models.

The development of the calibration model also produced $CBOD_U$ and $NBOD_U$ settling rates. The values for $CBOD_U$ varied from 0.05/day to 0.6/day for the calibration model. The calibration value for $NBOD_U$ was 0.05 1/day. This $NBOD_U$ settling rate was also used for the projection models.

The reaeration equation utilized in the calibration model was the 1995 version of the Louisiana Equation. (Waldon and Smythe, 1995)

Dispersion values were also used within the model. A dispersion value of 10.0 was used for all models. This value was based upon previous values of advective dispersion used in stream models developed for LA DEQ.

All kinetic reaction rate values used in the input files are shown in Table 5.1.

The calibration model input file has been provided in Appendix D.

The graph for dissolved oxygen is presented on the following page. It shows two sags in the dissolved oxygen levels. The first sag is caused by the Town of Kinder STP. The second sag is near the confluence of Kinder ditch and the resuspension loads. This second sag is typical of a smaller, nutrient-laden stream flowing into a larger, slow moving stream. All calibration graphs are presented in Appendix D along with the input and output files.

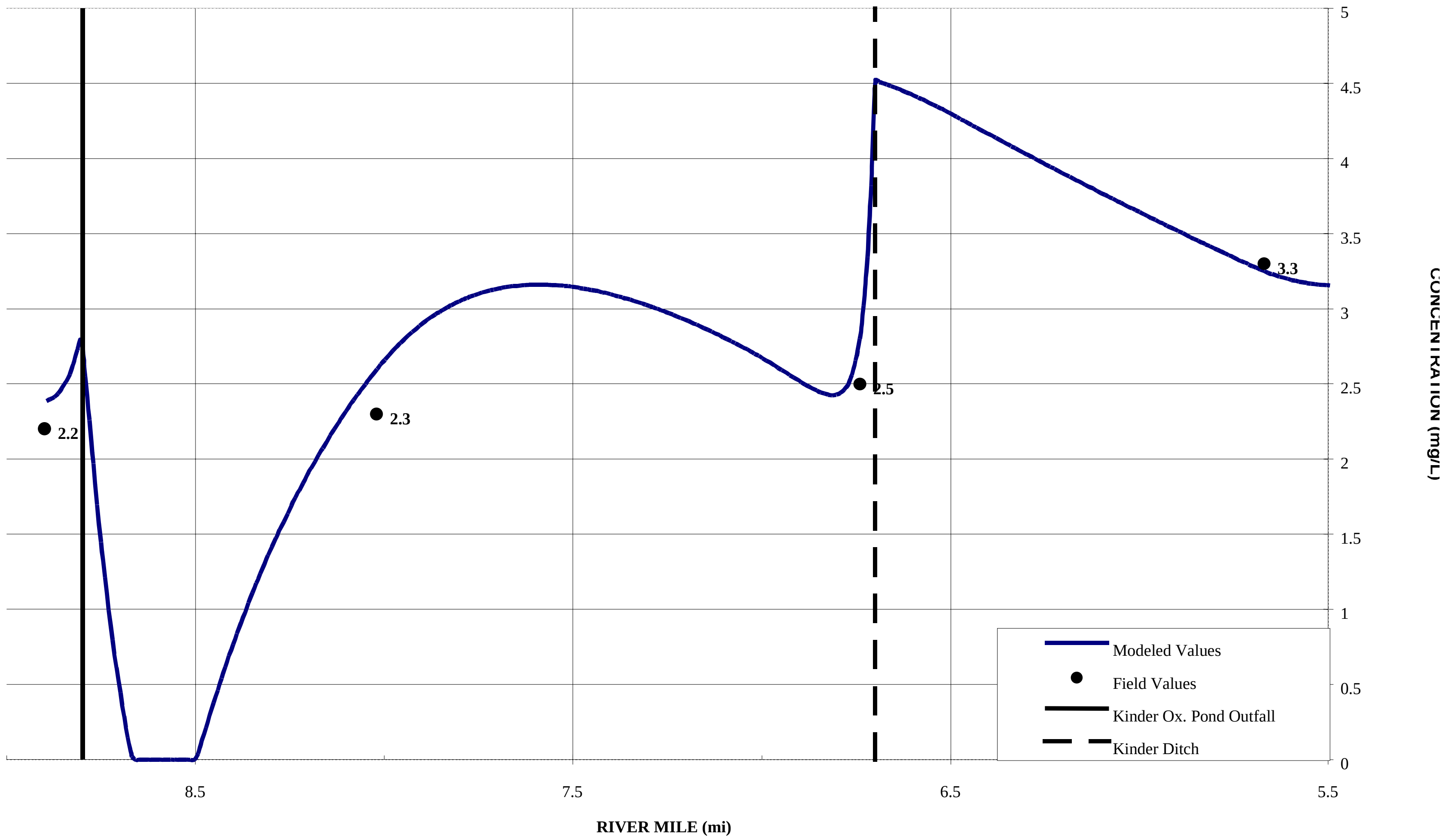
## 6. PROJECTION MODELS DISCUSSION

Parameters that define the summer and winter critical conditions are the headwater flows and the stream temperatures. The values used for these parameters were presented in Table 5.1, and the input files were provided in Appendices G1 and G2.

### 6.1 Hydrology and Stream Geometry

Headwater flows for the projection models were based upon the critical flows for the summer and winter months. The summer critical flow for the unnamed ditch and Kinder Ditch was estimated to be 0.0 cfs and 0.5 cfs, respectively. Since Limnoss cannot handle a flow of 0.0 cfs, a flow of 0.1 cfs was used for the summer critical flow of the unnamed ditch. The corresponding winter critical flows were estimated to be 0.1 cfs and 0.6 cfs, respectively. Based upon the recommendations in the Louisiana Total Maximum Daily Load Technical Procedures, 1999 (LTP, 1999), the flow used for the headwaters of both

**FIGURE 5.1 UNNAMED DITCH TO KINDER DITCH DISSOLVED OXYGEN CALIBRATION**



the unnamed ditch and Kinder Ditch in the projection model was 1.0 cfs. The design flow listed in the facility permit was used as the projection flow for the facility after applying a factor of 1.25 to account for growth and safety. For the purpose of estimating the critical flows, the summer and winter seasons were established as May to October and November to April, respectively. The seasons were based upon recommendation in the LTP, 1999.

Adjustments in stream geometry were made for the different flows associated with the projection models. Spreadsheets, which used the Luna Leopold equations, were used to develop the stream geometry based upon the critical stream flows and the design flows for the STP. These spreadsheets have been provided in Appendix F.

The LIMNOSS model generated the velocity ranges shown in Table 5.1.

## 6.2 Wasteloads

The $CBOD_U$ and $NBOD_U$ loads used in the summer projection model for the town of Kinder STP were 72.58 lbs./day and 54.27 lbs./day, respectively. The total summer wasteload allocation (WLA) was 126.85 lbs./day. The margin of safety (MOS) was 25.37 lbs./day.

The $CBOD_U$ and $NBOD_U$ loads for the Kinder STP in the winter projection model were 145.15 lbs./day and 271.37 lbs./day, respectively. The total winter WLA was 416.52 lbs./day. The MOS was 83.30 lbs./day.

Load calculations are presented in Appendix H.

## 6.3 Temperature

The seasonal stream temperatures and the dissolved oxygen saturation levels were modified for the projection models. The seasonal stream temperatures used were the 90$^{th}$ percentile of the seasonal temperature obtained from the Ambient Water Quality Network Database. These percentiles were based upon the LTP, 1999, which was the most recent edition at the time that the model was completed. The corresponding dissolved oxygen saturation levels were interpolated from the Standard Methods for the Examination of Water and Wastewater 18$^{th}$ Edition, 1992. The headwater values for dissolved oxygen were set to 90 percent of the dissolved oxygen saturation levels at the seasonal critical temperature. The spreadsheets used to calculate the 90$^{th}$ percentile temperatures and the dissolved oxygen saturation levels are in Appendix G.

## 6.4 Nonpoint Loads

Nonpoint loads used in the calibration model were also used in the projection models. These values are presented in Table 5.1.

## 6.5 Photosynthesis

Values for photosynthesis used in the calibration model were also used in the projection models. These values are presented in Table 5.1.

## 6.6 Sediment Oxygen Demand

Modifications in the SOD values were included in the third set of adjustments. These modifications were made in an attempt to project the SOD loading and allocate the SOD loading among three types of sources: treatment level, natural background, and other nonpoint agricultural runoff. We assumed that the SOD values would improve from those that were used to calibrate the stream model.

For the projection models, SOD values were allocated for natural background, treatment level, and nonpoint agricultural runoff. The resulting total SOD values used in the summer and winter projection models was 1.7 g $O_2/m^2$/day. This value was obtained from the summation of the values allocated for the natural background, the treatment level, and the nonpoint agricultural runoff.

In order to create graphs from which to determine the amount of SOD to be allocated to the nonpoint agricultural runoff, five model runs were created for each treatment level. The model runs included input SOD values of 0.0, 1.0, 2.0, 3.0, 4.0, and 5.0 g $O_2/m^2$/day. A total SOD value of 0.0 g $O_2/m^2$/day represented values of 0.0 g $O_2/m^2$/day for each of the three individual SOD allocations. A total SOD value of 1.0 g $O_2/m^2$/day represented a value 1.0 g $O_2/m^2$/day for the natural background allocation. For the remaining SOD levels, 1.0 g $O_2/m^2$/day was allocated to the natural background load, 0.5 g $O_2/m^2$/day was allocated to the treatment level load, while any remaining SOD which could be applied while maintaining the D.O. criteria was allocated to agricultural runoff. The critical value for SOD occurred during the simulation of the summer months.

The natural background levels of SOD were based on the reference stream work of E. De Ette Smythe. Of all reference streams that had been studied at the time of this report, Pearl Creek was considered to be the most similar to Kinder Ditch and the surrounding area. Therefore the average SOD values obtained from the Pearl Creek study were used to represent the natural background SOD values for Kinder Ditch. This value was 1.0 g $O_2/m^2$/day.

SOD values were allocated for the treatment levels as well. These values were obtained from the Louisiana Total Maximum Daily Load Procedures, 1999 for the individual treatment levels. The resulting values for the summer and winter treatment levels were 0.5 g $O_2/m^2$/day.

Nonpoint agricultural SOD values were allocated, since agricultural practices occur in the area, primarily in the form of rice production. These practices also have discharges, which introduce extended duration BOD and suspended solids into neighboring waterbodies. The BOD and suspended solids may then settle out of the water column and become SOD. The resulting SOD value allocated to nonpoint agricultural runoff was 0.2 g $O_2/m^2$/day.

As a result of these model runs, total allowable SOD values were obtained for the summer and winter critical conditions. The summer conditions were determined to be more critical than the winter conditions. Therefore, the SOD value obtained for the summer scenario at a treatment level of 5/2/6 mg/L CBOD5/mg/L NH3-N/mg/L D.O. was used. The resulting value for the total allowable SOD was 1.7.

### 6.7 Projection Model Kinetic Rates

The $CBOD_U$ and $NBOD_U$ decay rates used in the projection models were 0.375 1/day and 0.30 1/day, respectively.

The $CBOD_U$ settling rates used in the projection model were different than the rates used in the calibration model. The change was based on the assumption that the water quality would improve. Therefore, the value used in the projection models was 0.05 1/day. The value used for the $NBOD_U$ settling rate was also 0.05 1/day.

The reaeration equation utilized in the calibration model was the 1995 version of the Louisiana Equation. (Waldon and Smythe, 1995)

Dispersion values were also used within the model. A dispersion value of 10.0 was used for all models. This value was based upon previous values of advective dispersion used in stream models developed for LA DEQ.

Dissolved oxygen graphs for the summer and winter projection models are presented on the following pages. The summer projection graphs for dissolved oxygen, CBODU, and NBODU are presented in Appendix G1 along with the input and output files. The winter projection graphs for dissolved oxygen, CBODU, and NBODU are presented in Appendix G2 along with the input and output files.

## 7. SENSITIVITY ANALYSIS

Any model is dependent upon the certainty of the input parameters that make up the model. Therefore, a sensitivity analysis was performed on the calibrated model in order to determine the sensitivity of the model to changes in the parameters. This was done by varying the each parameters individually by $\pm$ 30 %, except temperature and the dissolved oxygen saturation levels. Temperature was varied by $\pm$ 2 degrees Celsius. The dissolved oxygen saturation levels were varied simultaneously with the temperatures based upon values presented in the Standard Methods for the Examination of Water and Wastewater, 18th Edition. Results of the sensitivity analysis can be seen in Appendix E.

The minimum dissolved oxygen level produced by the calibrated model was 0.0 mg/L. The critical dissolved oxygen level was located immediately downstream of the Kinder

**FIGURE 6.1 DISSOLVED OXYGEN PROJECTIONS: STREAM TEMPERATURE = 28.0°CELSIUS**

**KINDER STP EFFLUENT D.O. = 5.0 mg/L**

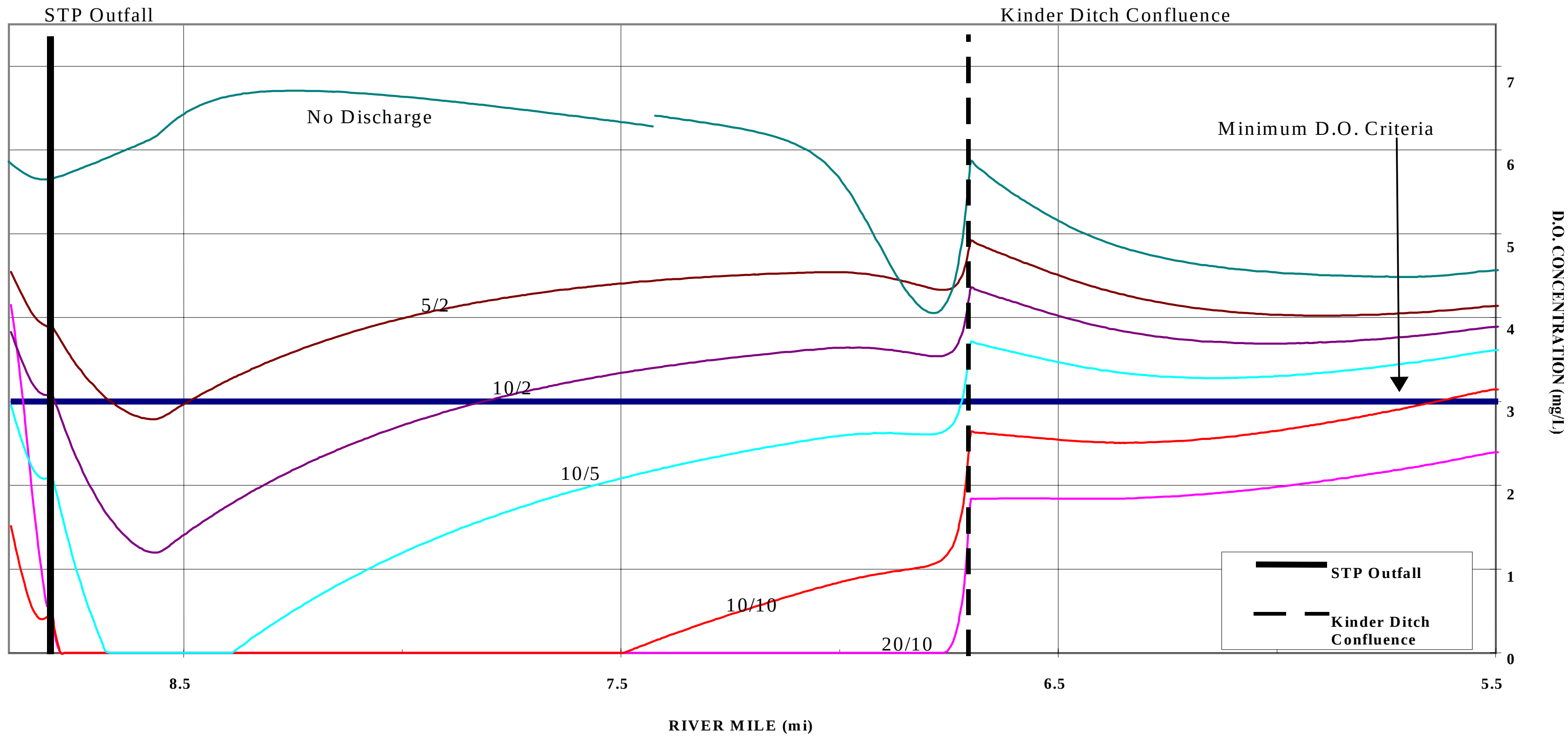


**FIGURE 6.2  DISSOLVED OXYGEN PROJECTIONS:  STREAM TEMPERATURE = 28.0 °**

**KINDER STP EFFLUENT D.O. = 6.0 mg/L**

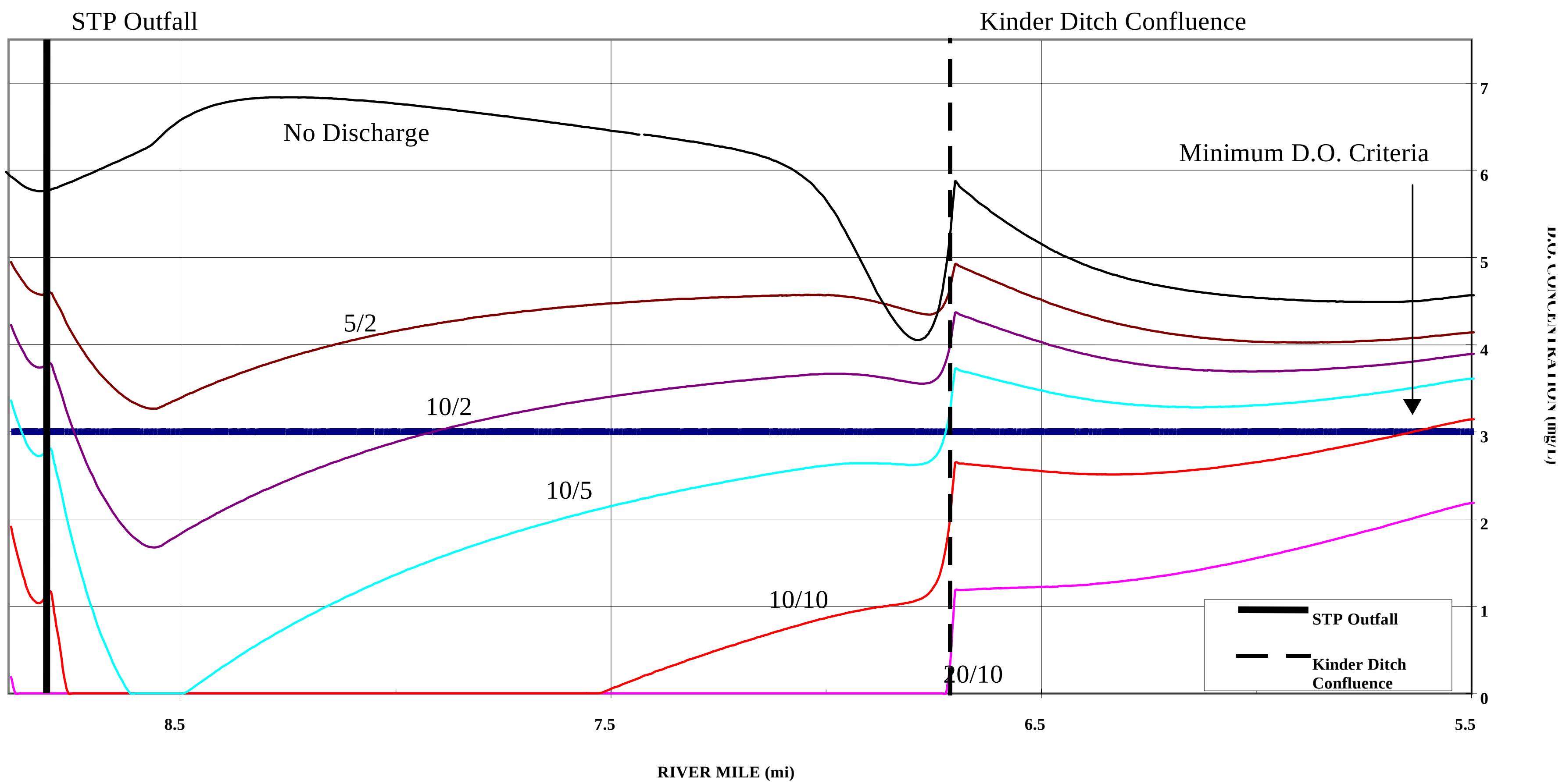


**FIGURE 6.3  DISSOLVED OXYGEN PROJECTIONS:  STREAM TEMPERATURE = 18.91° CELSIUS**

**KINDER STP EFFLUENT D.O. = 5.0 mg/L**

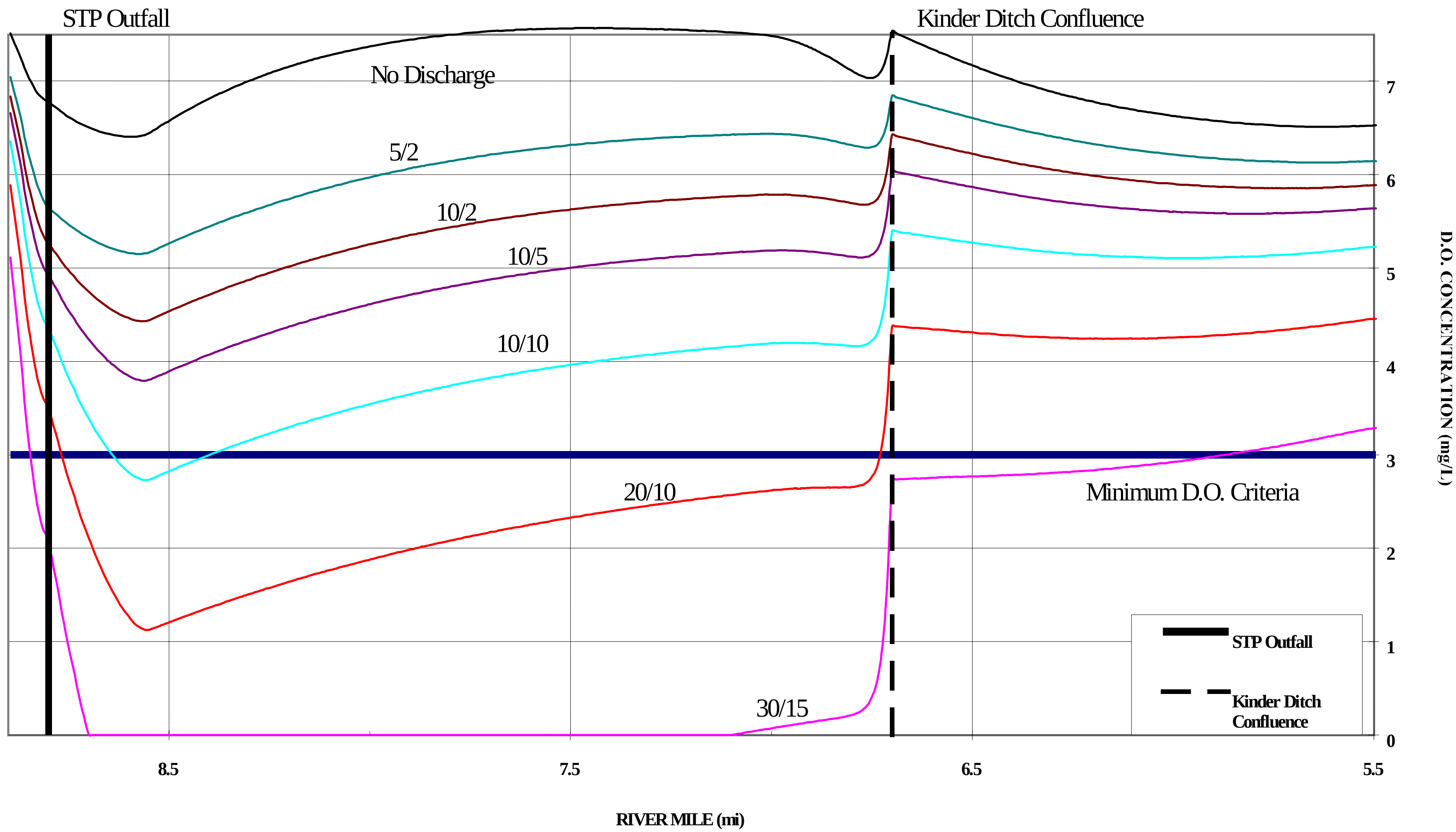
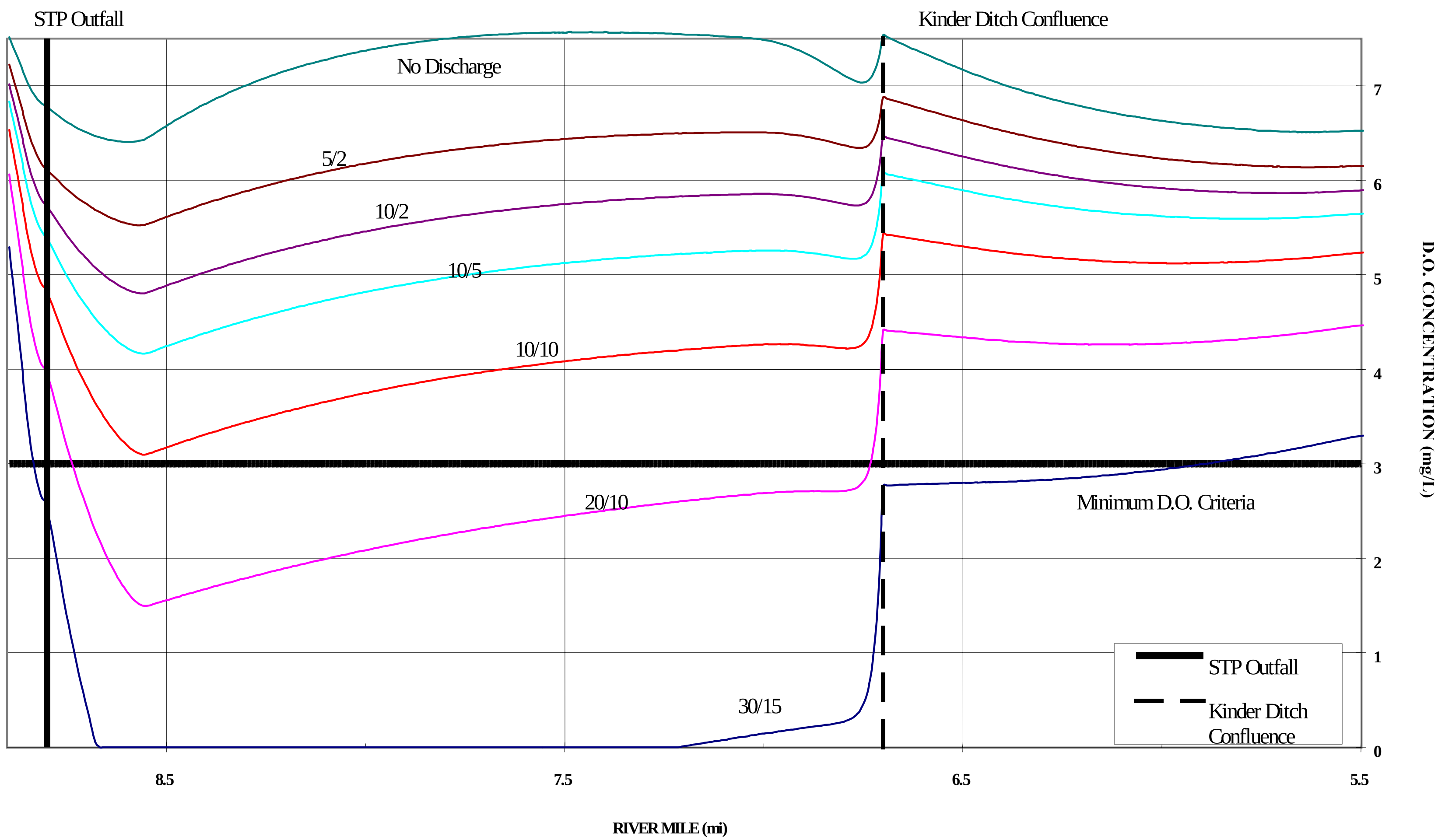


**FIGURE 6.4 DISSOLVED OXYGEN PROJECTIONS: STREAM TEMPERATURE = 18.91° CELSIUS**

**KINDER STP EFFLUENT D.O. = 6.0 mg/L**



STP. However, the impacts caused by the adjustments of each parameter can be determined by observing the length of the stream reach that has a minimum dissolved oxygen level of 0.0 mg/L.

Positive sensitivity refers to those parameters that cause a directly proportional change in the minimum dissolved oxygen level when the parameter value is changed. The parameters with the greatest positive sensitivity were photosynthesis, the $CBOD_U$ settling rates, dispersion, and point source flow.

Negative sensitivity refers to those parameters that cause an increase in the dissolved oxygen level when the parameter is decreased or a decrease in the dissolved oxygen level when the parameter is increased. The parameters with the greatest negative sensitivity were depth, width, $CBOD_U$ and $NBOD_U$ decay rates, SOD, and temperature with the corresponding saturated D.O. levels.

All of the parameters that have the greatest effects on the minimum dissolved oxygen level of the calibrated model are associated with depth and/or temperature.

## 8. RESULTS

Summer and winter projection models were run based upon the flows, stream geometry, kinetic coefficients, temperatures, dissolved oxygen saturation levels, and reaeration equation presented in Table 5.1. The models were run for all scenarios of treatment required in the Louisiana Total Maximum Daily Load Procedures. Graphs of the dissolved oxygen results are provided in Appendices G1 and G2. The minimal limits required to protect the dissolved oxygen standard of 3.0 mg/L are 5/2/6 mg/L $CBOD_5$/mg/L $NH^3$-N/mg/L DO for the summer months and 10/10/6 mg/L $CBOD_5$/mg/L $NH^3$-N/mg/L DO for the winter months. The summer months were June to November. The winter months were December to May.

A margin of safety (MOS) factor of 1.25 was applied to the Kinder STP flow to account for future growth and safety. The resulting summer WLA was 126.85 lbs./day for the summer months including a MOS of 25.37 lbs./day. The winter WLA was 416.52 lbs./day including a MOS of 83.30 lbs./day
.

## 9. LIST OF REFERENCES

Greenberg, Arnold E., Lenore S. Clesceri, and Andrew D. Eaton. 1992. Standard Methods For the Examination of Water and Wastewater. 18th edition. American Public Health Association, American Water Works Association, and Water Environment Federation.

Hebel, Max. November, 1990. *Survey Report for the Kinder Ditch Intensive Survey*, Report No. 90.25, Center for Louisiana Inland Water Studies (CLIWS), Department of Civil Engineering, University of Southwestern Louisiana, for the Louisiana Department of Environmental Quality, Office of Water Resources, Water Pollution Control Division, Engineering Section.

Kniffen, Fred Bowerman, and Sam Bowers Hilliard. 1988. Louisiana, Its Land and People. Revised edition. Baton Rouge, Louisiana: Louisiana State University Press.

LimnoTech, Inc. 1984. Limnoss User's Manual: A One Dimensional Steady-State Water Quality Model Based on the USEPA AUTOQUAL Framework. Ann Arbor, MI: LimnoTech, Inc. 71p.

Louisiana Department of Environmental Quality. 1996. State of Louisiana Water Quality Management Plan , Volume 5, Part B, Water Quality Inventory. Baton Rouge, Louisiana: LDEQ Office of Water Resources, Water Quality Management Division.

Louisiana Department of Environmental Quality. 2000. Environmental Regulatory Code: Part IX. Water Quality Regulation. Baton Rouge, Louisiana: LDEQ, Office of Water Resources, Water Quality Management Division.

Louisiana Department of Environmental Quality. Ambient Water Quality Network Database.

Louisiana Department of Environmental Quality. Permit Fileroom.

Rogers, Madeline. 25 May, 1990. *Water Quality Advanced Treatment Review for the Town of Kinder, Louisiana, Summary of Findings*, ATR 90.08, Center for Louisiana Inland Water Studies (CLIWS), Department of Civil Engineering, University of Southwestern Louisiana, for the Louisiana Department of Environmental Quality, Office of Water Resources, Water Pollution Control Division, Engineering Section.

Rogers, Madeline. 10 August, 1990. *Addendum: Advanced Treatment Review Report for the Town of Kinder contract No. 24024-90-01, Task 1, Subtask 1; Grant C6-220000-27-0 (FY88205(j)(1)) Work Element 2, Task 1, Subtask 1,* Center for Louisiana Inland Water Studies (CLIWS), Department of Civil Engineering, University of Southwestern Louisiana, for the Louisiana Department of Environmental Quality, Office of Water Resources, Water Pollution Control Division, Engineering Section.

Waldon, Michael G., Ph.D.  March 1994. *Louisiana Total Maximum Daily Load Technical Procedures, 1994*, CLIWS-WQR 91.10. 1994 (revised) Center of Louisiana Inland Water Studies (CLIWS), Department of Civil Engineering, University of Southwestern Louisiana, for the LA Department of Environmental Quality, Office of Water Resources, Water Pollution Control Division, Engineering Section.

Waldon Michael G., Ph.D, and E.D. Smythe. 1995. *Reaeration Rates for Shallow, Low Flow Streams*. for the Engineering Section, Office of Water Resources, Louisiana Department of Environmental Quality.

# 10. APPENDICES