"And it is He who has let free the two seas (kinds of water), one palatable and sweet, the other salty and bitter, and He has set a barrier and a complete partition between them."

Al-Quran, 25:53

DISSERTATION

COMPARISON OF FIELD MEASUREMENTS TO PREDICTED REAERATION COEFFICIENTS, k_2, IN THE APPLICATION OF WATER QUALITY MODEL, QUAL2E, TO A TROPICAL RIVER

Submitted by

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In partial fulfillment of the requirements
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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY MAKETAB MOHAMED ENTITLED COMPARISON OF FIELD MEASUREMENTS TO PREDICTED REAERATION COEFFICIENTS, k_2, IN THE APPLICATION OF WATER QUALITY MODEL. QUAL2E, TO A TROPICAL RIVER BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

Comparison of Field Measurements to Predicted Reaeration Coefficients, k_2, in the Application of Water Quality Model, QUAL2E, to a Tropical River

Some of the tools used for watershed management in the last two decades are the computer models for wasteload allocations. QUAL2E, one of the most popular water quality models used for such purposes, was developed by the United States Environmental Protection Agency (USEPA). Therefore it is not surprising that the model mostly has been used and refined in a temperate environment.

The question raised is whether the model is applicable in a different climate such as tropical rivers. The null hypothesis (H_o) is that the measured reaeration coefficient (k_2) for a tropical river will give better results than the predictive equations in QUAL2E since these equations were developed in a temperate environment using temperate climate river variables.

QUAL2E uses either the predictive equations within the model or measured reaeration coefficient input. The present study was done on Sg. Selangor River in Malaysia. The results indicate that QUAL2E worked best with measured reaeration coefficient (k_2), which gave the lowest standard error (SE = 1.31) for the simulation of water quality using the 7Q10 discharge data, considered as the worst case scenario in water quality modeling. At the same time several predictive equations within QUAL2E (Langbein-Durum (1.29), O'Connor-Dobbins (1.34), Churchill et al. (1.35) and Owens et al. (1.42)) gave better results (lower

SE) during calibration and validation using actual low-flow discharge data. At high-flow conditions, the Thackston-Krenkel (SE = 1.45) and the Tsivoglou-Wallace (1.22) predictive equations tended to have the lower standard errors. But these results are suspect since the channel geometry parameters used in the modeling were measured during a low-flow period.

The decision of whether to measure specific reaeration coefficients for each river to be modeled or to use the predictive equations depends on the specific needs of the modeler. If accurate results are needed, the modeler would probably need to measure the reaeration coefficients. Otherwise, the four predictive equations within QUAL2E (Langbein-Durum, O'Connor-Dobbins, Churchill et al and Owens et al. equations) would be adequate.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 General Remarks

The level of dissolved oxygen in a river or stream can be a primary indicator of the overall water quality of the water body and the condition of the aquatic habitat within. Dissolved oxygen is reduced as a result of the biodegradation of carbonaceous and nitrogenous effluents discharged into the river or deposited onto the benthos.

Atmospheric reaeration is the most important natural means by which a stream affected by effluent discharges may recover its dissolved oxygen. This atmospheric reaeration is the process of oxygen exchange between the atmosphere and a water body. Usually the net transfer of oxygen is from the atmosphere into the water since the dissolved oxygen levels in most natural waters are below saturation concentrations. However, when the water body's photosynthetic activity produces supersaturated dissolved oxygen, the net transfer is from the water to the atmosphere (Bowie et al., 1985). This condition occurs when there is high algal growth and/or proliferation of submergent plants in the water body.

Reaeration coefficient (k_2) is the measure of the reaeration rate from the atmosphere to the water body and the unit used is per day (day^{-1}). It is the singular most dominant parameter affecting the reliability of the simulation of the dissolved oxygen concentrations in streams (Melching and Yoon, 1996). Accurate knowledge of the reaeration coefficient is important as it would allow an accurate estimation of the wasteload allocation for a given stream or river. An accurate wasteload allocation would allow for a reliable prediction of the permissible limits of wastewater discharge. This would further create a satisfactory basis for planning and regulating effluent discharges into a given river (Wilson and MacLeod, 1974).

A wasteload allocation, by definition, is the computation of the maximum amount of effluent that can be discharged into a stream or river while still meeting the water quality standards during low-flow conditions (usually using 7Q10, the seven consecutive day low-flow with a probability of occurring once in ten years) (Shanahan et al., 1998). The above process is necessary if acceptable water quality is to be maintained in the river system.

There are several components to the overall wasteload allocation including the determination of desirable water quality standards and the relationship between wasteload and water quality (Thomann and Mueller, 1987).

In the United States, the determination of allowable effluent discharges from wastewater treatment plants often uses a computer model such QUAL2E which is the most widely used one-dimensional stream water quality model (Chapra, 1997). The QUAL2E simulations require the most accurate and reliable data possible. This is because the wasteload allocation will affect multimillion-dollar decisions related to the possible upgrade of wastewater treatment plants within the watershed (Melching and Flores, 1999). In that sense, the reaeration coefficient used in the computer model must be determined with care whether by direct field measurement or by using a particular predictive equation or a combination of such equations. However, the development of QUAL2E has been in a temperate climate with limited usage in subtropical or tropical climates (Tsihrintzis et al., 1995). The same argument can be applied to the research and development of the predictive equations used in QUAL2E as these equations were developed in the United States and England.

In Malaysia, present and future growth of population and industry occur within sensitive watersheds such as the Sungai Selangor, which makes compliance with water quality standards increasingly difficult and necessitates controlling discharges of both domestic and industrial wastewater into the river. Therefore, the wasteload allocation process as used in the United States is needed for the management of river water quality in the Malaysian situation. The usage of QUAL2E and similar water quality models would then be necessary.

QUAL2E is a tested and verified water quality model used not only in the United States (Van Orden and Uchrin, 1993), but also in many foreign countries such as Slovenia (Drohc and Koncan, 1996), Spain (Cubillo et al., 1992) and in Korea (Tischler et al., 1984). Some researchers only used a certain feature in the model (Van Orden and Uchrin, 1993). Here, the authors studied the dissolved oxygen dynamics of the Whippany River in New Jersey. Meanwhile, in

Spain, researchers used the QUAL2E model to control the river water quality for the community of Madrid (Cubillo et al., 1992).

The indirect result of this study is the use of the QUAL2E water quality model by the Department of Environment (DOE) in the management of Sungai Selangor River, and later other rivers in Malaysia, by applying the wasteload allocation process. There are recent major developments within the Sungai Selangor watershed, including a large industrial area near Rawang. Meanwhile, there is a water intake downstream near Batang Berjuntai for a major domestic water treatment plant (Bukit Badong Treatment Plant), which was commissioned in 1998 with a capacity of 200 million liters per day (MLD). The capacity of the water treatment plant was doubled at the end of 1999. Therefore, these kinds of development need tools to alleviate water quality problems especially during low-flow periods.

The crucial question at this juncture is whether QUAL2E with its predictive equations for reaeration coefficients would work well in a tropical environment or it would work well only with the use of direct field measurement of reaeration coefficients.

1.2 Hypotheses

The null hypothesis (H_o) for the study is that the predictive equations in QUAL2E work well only in a temperate environment since they were developed using temperate climate river variables. The measured reaeration coefficient (k_2)

for a particular tropical river will give better results than these predictive equations.

1.3 Objectives

The specific objectives of this study are:

(1) to calibrate the QUAL2E model for the Sg. Selangor River watershed using historical water quality and discharge data;

(2) to compare the predictive equations for the reaeration coefficient, k_2, in QUAL2E to the measured reaeration coefficients at two locations on Sg. Selangor River;

(3) to carry out model evaluation of the QUAL2E model for the Sg. Selangor River watershed, including validation and sensitivity analysis;

(4) to determine whether the QUAL2E is a water quality model applicable in a tropical climate when used with the predictive equations for the reaeration coefficients or if the model only works with the reaeration coefficients measured directly in the field for Sg. Selangor River.

The calibration and model evaluation of the QUAL2E model for Sungai Selangor would be a successful step towards using water quality modeling for watershed and water quality management purposes. The study would indicate the general applicability of QUAL2E in a tropical climate. The long term result from the modeling and successful application of a Sungai Selangor QUAL2E model would be the modeling of other important watersheds in the country using the individual water quality and discharge data from each watershed, which can help in the planning and management of such watersheds by the relevant federal and state agencies. The pollution of Sungai Langat, which borders the Sungai Selangor watershed, and the closure of one of the major water treatment plants for the Klang Valley twice in 1997, indicated the need for a water quality model for watershed management in Malaysia.

1.4 Research Approach

The study needed a lot of data such as water quality, streamflow records, meteorological data (i.e. solar radiation, temperature, evapotranspiration) and water diversions, from the various agencies responsible for river management in Malaysia (Table 1.1). The Department of Environment (DOE) is the agency responsible for water quality management, while the Department of Irrigation and Drainage (DID) is responsible for river hydrology, especially flow measurements. There are incompatible water quality stations relative to gauging stations, because where there is a water quality station, there is no stream gauging at the same location and vice versa. Therefore, necessary adjustments or extrapolations were needed. Data analysis was one of the major works carried out. Other data not measured regularly by government agencies such as the sediment oxygen demand (SOD) had to be measured with a SOD chamber, which had to be constructed.

The principal task in the study was the comparisons of the measured reaeration coefficient, k_2, at two chosen locations of Sungai Selangor to the predictive equations used in QUAL2E. The purpose of this was to learn if any of the predictive equations was applicable to the river system and to analyze discrepancies between the measured and predicted k_2.

The calibration of the model as well as the validation was carried out after the data analysis. Model sensitivity relative to k_2 and SOD was carried out using a hypothetical river.

Table 1.1. Data and Facilities and the Source Agencies

Support Agencies	**Data and Facilities Provided**
Department of Environment (DOE)	water quality, pollution sources and waste loads, computer facilities, instruments, and manpower
Department of Irrigation and Drainage (DID)	streamflow, rainfall, relative humidity, water quality
Department of Chemistry (DOC)	water quality analyses
Meteorological Services Department	solar radiation, rainfall, ambient temperatures
Selangor Waterworks Department and Punca Niaga Sdn. Bhd.	domestic water abstraction quantity

1.5 Literature Review

1.5.1 General

In this study, there were several different scientific literature topics of interrelated subjects that needed to be reviewed. Although the major topic is on reaeration coefficient (k_2), other important topics include water quality modeling especially on QUAL2E usage, sediment oxygen demand (SOD) and photosynthesis/respiration in surface waters.

The amount of published literature for water quality modeling and reaeration coefficient, k_2, is vast. But most of the earlier works tend to be the predecessors of the most recent literature on the subject. This temporal progress helps in understanding the advancement of the knowledge for both water quality modeling and reaeration coefficient.

1.5.2 Water Quality Modeling

General

Water quality modeling is the development of abstractions of phenomena of river systems. The main objective of river water quality modeling is to describe and to predict the observed effects of a change in the river system. The usual application of a water quality model is for forecasting changes in water quality parameters resulting from changes in the quality, discharge or location of the point or non-point input sources (Crabtree et al., 1986).

River water quality models are generally used to predict the dissolved oxygen concentrations along the river system reaches resulting from the interaction of the physical, chemical and biological processes of oxygen demand. The model can be utilized to predict the effects of the available or proposed water quality control methods on water quality. The water quality models can therefore be used to assist in watershed management decision making in achieving the designated water quality objectives.

Generally there are two types of water quality models; stochastic and deterministic models. Deterministic models attempt to simulate the natural processes of self purification in a river system with each process modeled mathematically using derived parameters and rate constants. A deterministic model will predict a unique result from a specified set of input conditions without any consideration of the true relationship between the inputs and the predicted results. Meanwhile, stochastic or probabilistic models attempt to randomize error by containing one or more random variability of each parameter for each output (Crabtree et al., 1986).

Both deterministic and stochastic models can be empirical or theoretical or both. An empirical model relates a water quality parameter to a specified output on the basis of past observed empirical relationships while a theoretical model tries to represent mathematically the physical, chemical and biological processes affecting each water quality parameter. In the past, the most commonly used water quality models were the theoretical deterministic type although the use of these models has been limited by the lack of understanding of some of the complex relationships involved. Another constraint on the theoretical, deterministic models has been imposed by numerical methods. Models are generally limited to one dimensional, steady state conditions.

Streeter and Phelps (1925) developed the first water quality model. Later research in surface water quality modeling indicated the dissolved oxygen sag model postulated was incapable of describing all the complexities of actual river systems (Orlob, 1992).

QUAL2E Water Quality Model

The QUAL2E model was developed by the United States Environmental Protection Agency (USEPA) for wasteload allocations, discharge-permit allocations, and other pollution evaluations. QUAL2E is applicable to well-mixed dendritic streams where the major transport mechanisms of advection and dispersion are only significant along the longitudinal axis of flow for a stream. Streamflow and input of waste loads are considered to be constant i.e. in steady state during the simulation period. The model can also be used to study the assimilative capacities of receiving streams and to identify non-point waste loads (Brown and Barnwell, Jr., 1987).

A river is represented in the QUAL2E model as a linked group of streams and tributary reaches that consist of headwaters (the beginning of a stream reach) and sequential strings of completely mixed reactors, which are referred to as computational elements (Figure 1.1). Within each reach, all the computational elements have the same average depth, stream slope, channel cross-section, and biological/chemical rate constants. The QUAL2E model calculates a flow and mass balance for each computational element (Figure 1.2). The model can also simulate streamflow and as many as 15 water quality constituents, which are dissolved oxygen, biochemical oxygen demand (BOD), temperature, algae as chlorophyll a, organic nitrogen, ammonia, nitrite, nitrate, organic phosphorus, dissolved phosphorus, coliforms, an arbitrary non-conservative constituent, and three conservative constituents.

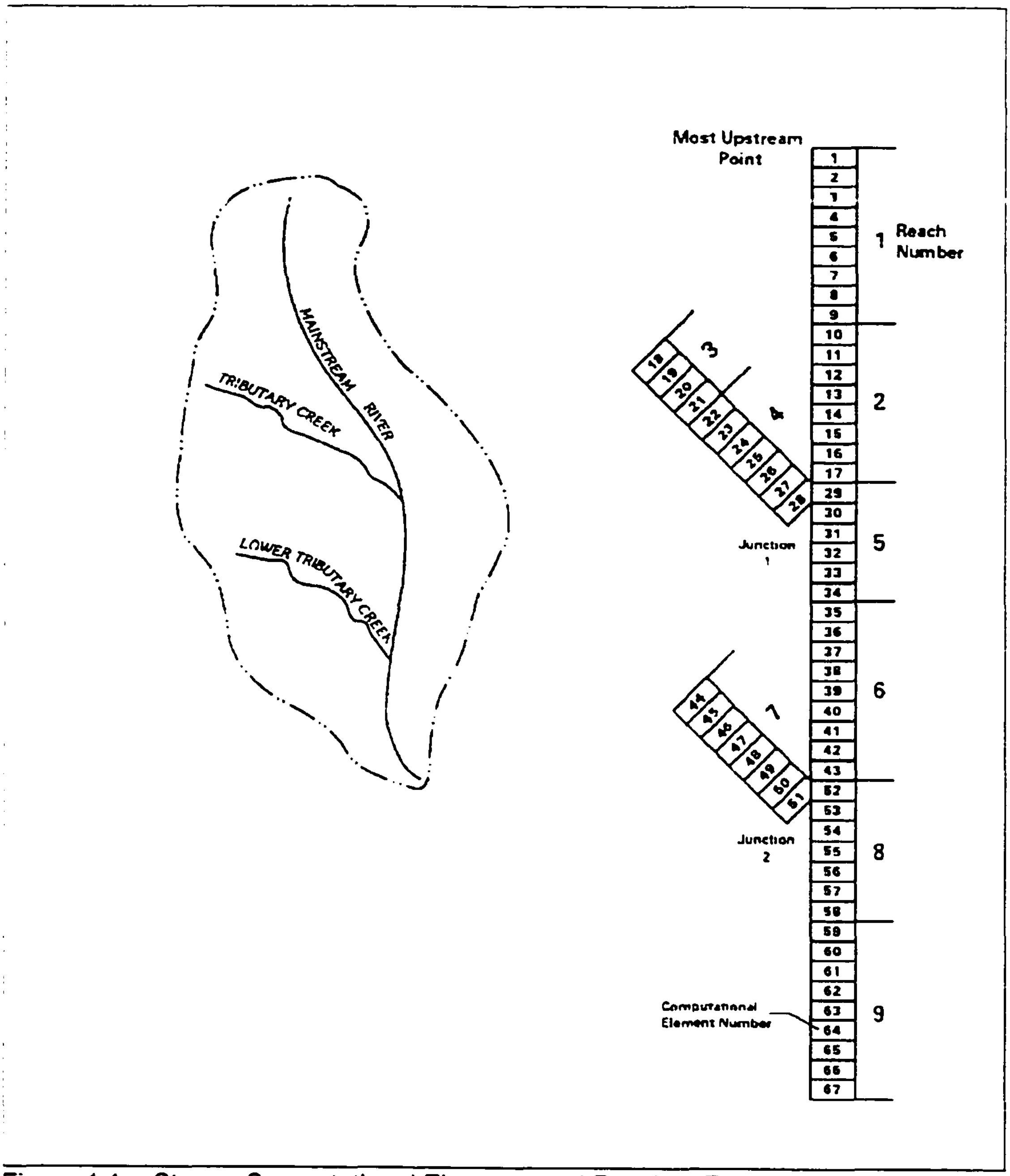

Figure 1.1. Stream Computational Elements and Reaches Presentation (after Brown and Barnwell, Jr., 1987)

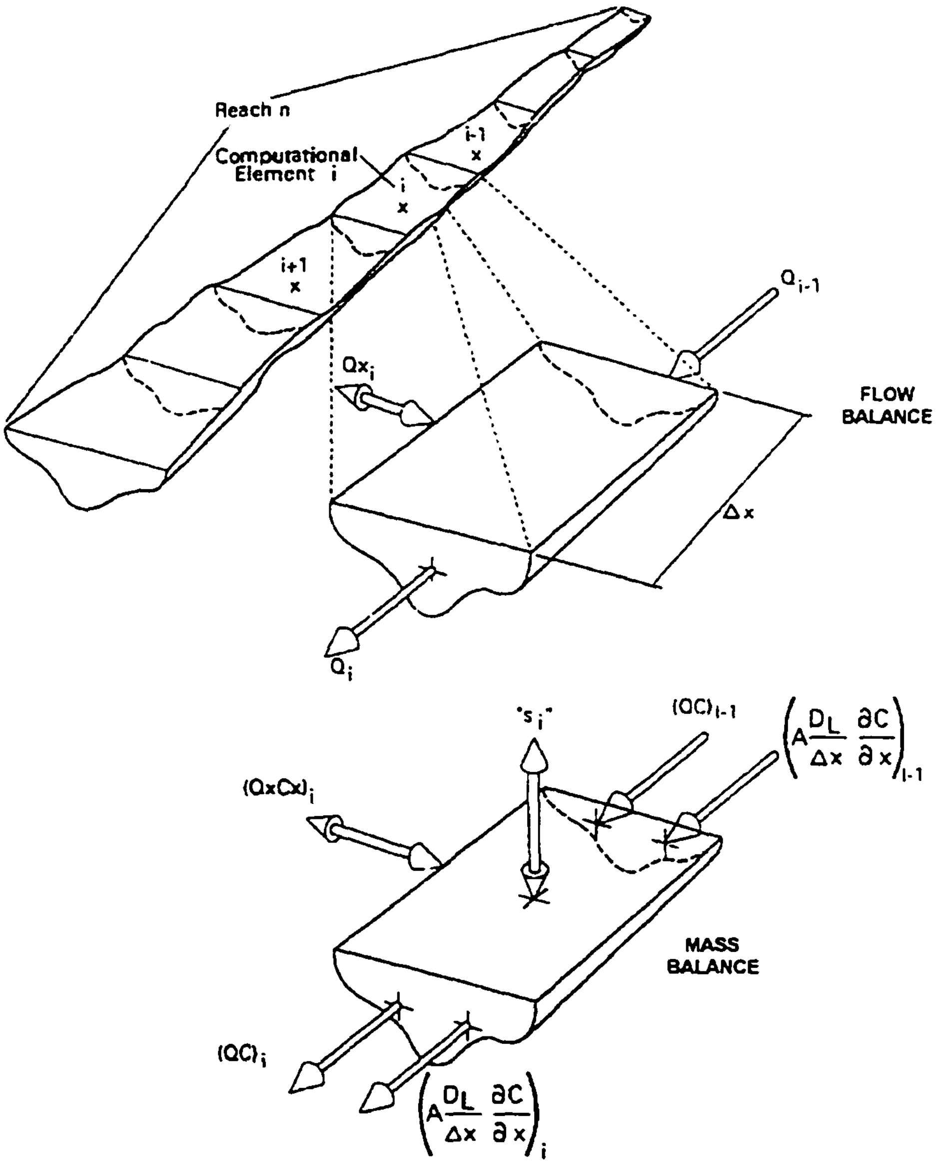

Figure 1.2. Flow and Mass Balances within a Computational Element (after Brown and Barnwell, Jr., 1987)

The forcing function used for estimating transport is the stream discharge, which is assumed to be constant. Stream velocity, cross-sectional area, and depth are computed from streamflow. The QUAL2E model performs dissolved oxygen balance by including major source and sink terms in the mass balance equation. The nitrogen cycle is composed of four compartments: organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. The phosphorus cycle consists of dissolved phosphorus and organic phosphorus. Ultimate carbonaceous biochemical oxygen demand (CBOD) is modeled as a first order degradation process, but if the modeler uses BOD_5 as the input, QUAL2E converts the 5-day BOD to ultimate BOD for internal calculations. The major source of dissolved oxygen is algal photosynthesis and atmospheric reaeration.

There are QUAL2E limitations that must be considered. These limitations become obvious during attempts to simulate conditions other than the steady state, constant effluent discharge for which it was developed.

QUAL2E is also best suited for point sources discharges. The model is unsuitable for rivers that experience temporal variations or major discharges that fluctuate significantly over a diurnal period or even shorter time period (Shanahan et al., 1998).

The limitations of QUAL2E are more significant when examining non-point source (NPS) pollution contribution to the river water quality degradation. NPS loads are often driven by rainfall events and therefore both the wasteload and streamflow vary significantly over time. Therefore both variations deviate significantly from QUAL2E assumptions of steady streamflow and steady effluent discharge (Shanahan et al., 1998).

The above limitations compromise QUAL2E ability to model rivers with dams which usually have pulse releases of water, urban stormwater discharges, and the effect of industrial effluent discharged on a pulse basis.

1.5.3 Stream reaeration coefficient (k_2)

General

The oxygen balance in a stream system depends on the capacity of the stream to reaerate itself. This capacity is a function of the advection and diffusion processes occurring within the system and the internal sources and sinks of oxygen. The major sources of oxygen, in addition to atmospheric reaeration, are the oxygen produced by photosynthesis and the oxygen contained in the incoming flow. The sinks of dissolved oxygen include biochemical oxidation of carbonaceous and nitrogenous organic matter, benthic oxygen demand and the oxygen utilized by algal respiration (Bowie et al., 1985). One of the important factors involved in the oxygen balance of streams is the rate of exchange of oxygen between the atmosphere and water. This natural reaeration capacity controls and limits the stream's ability to receive and assimilate oxygen-depleting wastes without becoming seriously degraded. The rate of reaeration, under constant conditions of temperature and turbulence, is directly proportional to the oxygen deficit in the water.

The reaeration coefficient, k_2 (log base e) is a measure of this rate of change in the concentration which the transfer of oxygen through the surface produces in the column of water beneath it for a given saturation deficit. Researchers in the past have used radioactive tracers, non-radioactive tracers and predictive mathematical equations in calculating the stream reaeration coefficient (k_2). All the methods mentioned above have limitations. Predictive equations can be very inaccurate on one stream while being more accurate on another. Tracer methods are accurate and reliable, but implementation difficulties and financial cost are much greater.

In recent literature all values of k_2 are written as log base e, and are referenced to 20 °C, unless otherwise noted. In earlier days of reaeration coefficient research, k_2 values were often written as log base 10. The relationship between log base e and log base 10 reaeration coefficients can be written as:

$$k_{2_{\text{base e}}} = \ln(10) k_{2_{\text{base 10}}} = 2.303\, k_{2_{\text{base 10}}}$$

Dissolved Oxygen Saturation Concentration

Dissolved oxygen solubility in water increases with decreasing temperature, decreasing total dissolved solids concentration and increasing atmospheric pressure (Bowie et al., 1985). In QUAL2E the equation used for calculating the saturation or equilibrium concentration of dissolved oxygen is the one recommended by the American Public Health Association (APHA, 1998).

$$\ln O_{sc} = -139.34411 + \left[\frac{1.575701 \times 10^5}{T_a}\right] - \left[\frac{6.642308 \times 10^7}{T_a^2}\right] + \left[\frac{1.243800 \times 10^{10}}{T_a^3}\right] - \left[\frac{8.621949 \times 10^{11}}{T_a^4}\right] \quad \text{(Eqn. 1.1)}$$

where,

O_{sc} = saturation concentration of dissolved oxygen in fresh water at 1atm (mg/L)

T_a = absolute temperature (°K) = (°C + 273.15). °C is between 0.0 to 40.0 °C

Salinity or chlorides in the water reduce the saturation value of dissolved oxygen. The equation includes corrections for chlorinity, where it is defined as salinity in parts per thousand (ppt) divided by 1.80655 (APHA, 1998).

$$\ln O_{ss} = \ln O_{sc} - Chl\left(3.1929 \times 10^{-2} - \frac{1.9428 \times 10^1}{T_a} + \frac{3.8673 \times 10^3}{T_a^2}\right) \quad \text{(Equation 1.2)}$$

where,

O_{ss} = saturation concentration of dissolved oxygen in saline water at 1 atm (mg/L)

Chl = chlorinity

Neither salinity nor chlorinity is explicitly modeled within QUAL2E, therefore the water quality model does not correct for these parameters.

The recommended method for calculating the saturation dissolved oxygen concentration at non-standard pressure is shown below (APHA, 1998):

$$O_{sp} = O_{sc}P\left[\frac{\left(1-\frac{P_{wv}}{P}\right)(1-\theta P)}{(1-P_{wv})(1-\theta)}\right] \qquad \text{(Equation 1.3)}$$

where,

O_{sp} = equilibrium oxygen concentration at non-standard pressure, mg/L

O_{sc} = equilibrium oxygen concentration at 1.0 atm, mg/L

P = pressure, atm (within 0.0 to 2.0 atm)

P_{wv} = partial pressure of water vapor, atm

P_{wv} can be calculated using:

$$\ln P_{wv} = 11.8571 - \frac{3840.70}{T_a} - \frac{216{,}961}{T_a^2} \qquad \text{(Equation 1.4)}$$

Meanwhile, parameter θ can be computed using:

$$\theta = 0.000975 - 1.426 \times 10^{-5}T + 6.436 \times 10^{-8}T^2 \qquad \text{(Equation 1.5)}$$

The terms of temperature in the above formula are in °C, not °K as in the formula in calculating P_{wv}.

There is a handy formulation that can be used to estimate saturation dissolved oxygen based on elevation which is written as (Zison, 1978):

$$O_{sp} = O_{sc}\,[1 - 0.1148 \times \text{elevation in km}] \qquad \text{(Equation 1.6)}$$

where the elevation is in reference to the elevation above sea level.

Stream Reaeration Theories

There are various conceptual models of reaeration postulated including film, renewal, penetration and two-film theory models. The two-film theory assumes that the gas moving between gaseous and liquid phases encounters maximum resistance in two laminar boundary layers where mass transfer is via molecular diffusion. The mass transfer through the individual films would be a function of a mass transfer velocity and the gradient between the gas concentrations at the interface and in the bulk fluid. The gas transfer through the liquid film can be written as:

$$J_l = K_l(c_a - c_l) \qquad \text{(Equation 1.7)}$$

where,

J_l	=	mass flux from the bulk liquid to the interface (mole/(m^2/day))
K_l	=	mass transfer velocity in the liquid laminar layer (m/day)
c_a and c_l	=	gas concentrations at the air-water interface and in the bulk liquid, respectively (mole/m^3)

The two-film theory which is for a stagnant condition, represents a good estimation of reaeration for standing waters such ponds and lakes (Chapra, 1997).

The surface renewal model conceptualizes parcels of water that are brought to the surface for a certain period of time. The gas transfer or exchange occurs during those particular parcels period at the water surface. These parcels of water later move away from the water surface, to be replaced with other parcels, and are mixed with the main bulk of the water (Chapra, 1997). Higbie

(1935) assumed that all parcels of water have the same contact time at the water surface while Danckwerts (1951) on the other hand assumed that these water parcels reach and leave the water surface randomly. The exposure to the water surface is described by a statistical distribution. In the case of oxygen, the surface renewal theory was used to derive:

$$J = \sqrt{D_l r_l}(c_s - c_l) \qquad \text{(Equation 1.8)}$$

where,

J = the flux of oxygen across the air-water interface (mole/(m^2/day))

D_l = water diffusion coefficient (m^2/day)

c_s = DO concentration at the air-water interface (mole/m^3)

c_l = DO concentration in the bulk water (mole/m^3)

r_l = liquid renewal rate (time^{-1})

The surface renewal theory can also be applied to the gaseous side of the interface by assuming that parcels of gas are brought into contact with the air-water interface in a random fashion.

The transfer velocity for the liquid phase can be written as:

$$K_l = \sqrt{r_l D_l} \qquad \text{(Equation 1.9)}$$

O'Connor and Dobbins (1956) hypothesized that the surface renewal rate can be estimated by the ratio of the average stream velocity (U) to the depth (H),

$$r_l = \frac{U}{H} \qquad \text{(Equation 1.10)}$$

Therefore the formula can be rewritten as:

$$K_l = \sqrt{\frac{D_l U}{H}} \quad \text{or} \quad K_l = \sqrt{D_l}\,\frac{U^{0.5}}{H^{0.5}} \qquad \text{(Equation 1.11)}$$

The formula above became the standard form for many reaeration coefficient (k_2) formulas.

Critical Literature Review of Reaeration Coefficient (k_2)

Many empirical as well as theoretical approaches relating the reaeration rate constant with measurable hydraulic properties of streams have been reported. A recent literature review indicated that at least 15 different predictive equations based on such physical parameters as mean depth, mean velocity, slope, surface renewal rate, surface tension, and dispersion coefficients may be employed to calculate indirectly the reaeration rate constant.

Selecting one of the many empirical equations to compute reaeration rate constant in Table 1.2 can be a difficult task. The problem was shown in a study of the Passaic River, New Jersey, using the mean velocity and mean depth information at various flow conditions (Whipple et al., 1969).

Table 1.2. Comparison of Equation Constants for Various Predictive Models (log-base e)

$$\text{General Predictive Equation: } k_2 = a\frac{V^b}{H^c}$$

where,

k_2 = reaeration coefficient, (1/day)
V = average velocity of the cross-section, m/s
H = average depth of the cross-section, m

Researchers	k_2 Predictive Equation Constants		
	a	b	c
O'Connor and Dobbins (1956)	3.93	0.50	1.50
Churchill et al. (1962)	5.026	0.969	1.673
Owens et al. (shallow)(1964)	6.91	0.73	1.75
Owens et al. (deep)(1964)	5.35	0.67	1.85
Langbein and Durum (1967)	5.14	1.00	1.33
Isaacs and Gaudy (1968)	4.76	1.00	1.50
Padden and Gloyna (1971)	4.70	0.73	1.054
Bansal (1973)	1.81	0.6	1.4

The results indicated major discrepancies between the predictive equations. Considerable discrepancy occurs at low-flow period - the condition that is usually most critical in terms of dissolved oxygen resources and, therefore, in the prediction of k_2 values. The question is why do these empirical models predict differently? The problem may be partially explained by consideration of the following factors:

(a) Each equation has been developed under a specific range of values for the physical parameters of stream velocity (V), stream depth (H), stream discharge (Q), and k_2. The application of the specific predictive equation outside of this range has been shown to produce excessive error in estimating k_2 values (Zogorski and Faust, 1973a);

(b) Some models have been either derived or adjusted so that they predict reaeration values for "clean" water. A correction factor must be applied to these models when used in other aquatic environments. Other predictive equations are based on data obtained in the presence of varying amounts of organic matter and will, therefore, predict k_2 values for a certain degree of pollution (Zogorski and Faust, 1973a);

(c) Several techniques can be employed for measurement of the mean velocity and mean depth of a stream. If each method of measuring V and H resulted in the same value, then each would be equally applicable in computing k_2 values. In actual practice, however, each will predict a different value of V and H and, therefore, different values of the reaeration coefficient (Zogorski and Faust, 1973a);

(d) Different values for the dissolved oxygen saturation levels have been used in calculating the reaeration coefficient. Likewise different temperature coefficients (θ) have been applied to adjust the measured k_2 values to other temperatures;

(e) Although the empirical models consider the depth of aeration (through the mean depth), they fail to evaluate the shape of the surface area and channel geometry. Since the rate of transfer of oxygen across the air-water interface is partially determined by the surface area, an accurate assessment of this configuration is important. Usually the surface area is assumed to be laminar. However, in shallow streams with irregular streambeds and in all water bodies receiving an input of energy from wind velocity, an irregular surface area exists which, in effect, increases the rate of mass transfer due to the increase in the surface area through which diffusion can occur (Zogorski and Faust, 1973a);

(f) Most investigators have failed to recognize the influence of wind velocity on the reaeration rate constant. Some researchers have presented a relationship between wind velocity and the reaeration coefficient determined on large rivers and estuaries (Juliano, 1969). It was noted that a brisk wind could increase the reaeration coefficient as much as twenty times the expected value in a shallow stream

(Gloyna et al., 1970). Therefore, it appears likely that wind can influence the k_2 value through changes in the degree of turbulence, rate of surface renewal, and surface area. Needless to say none of the empirical equations presently accounts for this phenomenon (Zogorski and Faust, 1973a).

It is evident from the above discussion that many factors are responsible for the variation in the k_2 values that are calculated from several empirical models. It is also evident that the arbitrary selection of one equation, without any prior justification, can lead to an erroneous estimation of the reaeration capacity. Some form of verification, a direct method or by another indirect method is necessary before empirical equations can be expected to accurately evaluate the reaeration coefficient.

A critical review of all major prediction equations for reaeration coefficient indicated that those which incorporated only simple flow parameters of such as mean stream depth and mean velocity do not accurately predict k_2 on the entire range of data investigated (Wilson and MacLeod, 1974). There are differences between results from river and stream experiments relative to those from laboratory experiments. They suggested that there is at least one missing parameter, most likely a hydraulic parameter, whose absence on the predictive equations leads to the apparent inadequacy to predict reliable results.

Field experiments tend to agree more closely with equations, which include terms for rates of energy dissipation or surface renewal. Predictive equations by Dobbins (1963) and Parkhurst and Pomeroy (1972) gave the best fit to all data investigated. Several other equations such as by Thackton and Krenkel (1969), by Krenkel and Orlob (1962), and Calwallader and McDonnell (1969) did not exhibit excessive scatter, but at the same time did not give " the best fit" lines for all data.

Some equations gave unreliable reaeration rate predictions and in many cases are many times larger or smaller than those observed. Simple equations, which incorporated only simple hydraulic parameters such as mean depth and velocity, have a tendency to predict higher values of reaeration coefficients than observed data.

A predictive equation containing only basic hydraulic parameters (stream velocity and mean depth) cannot satisfactorily predict reaeration coefficient for both river and laboratory flumes (Wilson and MacLeod, 1974). Equations derived from field studies of rivers tend to overpredict reaeration coefficients observed in channels. On the other hand, equations derived from channel studies generally underpredict the k_2 values in rivers and streams.

River water contaminated with minute amounts of naturally occurring surface-active materials can significantly affect mass transfer of gas such as oxygen to river water, and possibly becomes the major source of variance in observed reaeration rates.

The above arguments indicate the need for the measurement of k_2 for the purpose of QUAL2E modeling of Sungai Selangor, as the direct usage of predictive equations for estimating k_2 would be very presumptive especially in an environment totally different from where these predictive equations were made.

Mathematical Equations for Predicting the Reaeration Coefficient, k_2, in QUAL2E

The research by Churchill et al. (1962) indicated that, of all the physical parameters affecting the reaeration rate constant, mean velocity and mean depth are preferred because they are measured as accurately as other physical parameters in calculating k_2 values. Since Churchill's work, numerous investigators have evolved similar formulas relating k_2 as a function of mean depth and mean velocity. A comparison of the equation constants for eight of the predictive models is shown in Table 1.2. Note that considerably more influence is given to the mean depth as compared to the mean velocity. This is unfortunate because the mean depth is sometimes difficult to evaluate, while the mean velocity can be accurately determined from the use of fluorescent dyes and radioactive tracers. Therefore, any error in measuring H will be reflected and magnified in estimating k_2 since the exponent of the mean depth, c, is generally greater than one.

There are six reaeration predictive equations incorporated into QUAL2E, and the measured k_2 at Sg. Selangor River was compared to the first four prediction equations described below (Churchill et al., 1962; O'Connor and Dobbins, 1956; Langbein and Durum, 1967; Owens et al., 1964). The reason for using the first four equations is because these equations use similar stream measurements i.e. mean velocity, hydraulic radius and/or mean depth in the calculations as indicated above. The last two predictive equations (Thackston and Krenkel, 1966; Tsivoglou and Wallace, 1972) use different parameters such as escape coefficient, Froude number and shear velocity, which can be estimated or measured, but these parameters are different from the ones used in the first four equations. The comparison would use the first O'Connor and Dobbins (1956) equation because of the low stream velocities and isotropic conditions. Although some of the prediction equations below used English units, this study exclusively used SI units and this was automatically specified in the Windows version of QUAL2E. The prediction equations used are, namely:

(1) Churchill, Elmer and Buckingham (1962)

The predictive equation is similar to the disturbed equilibrium method except that the study did not use chemicals to depress the dissolved oxygen from the stream water. Churchill et al. (1962) derived the predictive equation based on the observed reaeration rate below dams from which oxygen deficient water was released. The equation is written as:

$$k_2 \text{ at } 20^\circ \text{ C} = 5.026\, V^{0.969}\, R^{-1.673} \qquad \text{(Equation 1.12)}$$

where,

k_2 = reaeration coefficient, day^{-1}
V = mean velocity of the cross-section, m/s
R = hydraulic radius or the mean depth of the cross-section, m

The recommended usage for the equation is for the depth to be between 2 to 11 feet (0.61 to 3.35 m) and the stream velocity between 1.8 to 5 feet per second (fps) (0.55 to 1.5 m/s).

(2) Langbien and Durum (1967)

The predictive equation is based the synthesis of data from O'Connor and Dobbins (1956), Churchill et al. (1962), Krenkel and Orlob (1963) and Streeter et al. (1936). The predicted equation developed is written as:

$$k_2 \text{ at } 20^{\circ}C = 5.14V/H^{1.33} \qquad \text{(Equation1.13)}$$

where,

V = mean velocity, m/s
H = mean depth, m

(3) O'Connor and Dobbins (1956)

O'Connor and Dobbins proposed their predictive equation for k_2 based on the turbulence of a river. The equation for streams with low velocities and isotropic conditions is:

$$k_2 \text{ at } 20^{\circ}C = 292.4[D_m V]^{0.5}/H^{1.50} \qquad \text{(Equation 1.14)}$$

while the equation for streams with high velocities and non-isotropic conditions is:

$$k_2 \text{ at } 20^{\circ}C = [1105.2 D_m{}^{0.5} S_o{}^{0.25}]/H^{1.25} \qquad \text{(Equation 1.15)}$$

where,

S_o = slope of the stream, m/m
H = mean stream depth, m

V = mean velocity, m/s

k_2 = reaeration coefficient, day^{-1}

D_m = molecular diffusion coefficient, m^2/day.

D_m is calculated as:

$$D_m = 1.806 \times 10^{-4} \, m^2/day \, (1.037)^{T-20}$$

where,

T = temperature (°C)

In practice, the O'Connor and Dobbins equation has formed a reasonable basis for estimating the reaeration coefficients although it appears to underestimate the k_2 value for small streams (Brown and Barnwell, 1987).

Non-isotropic conditions are assumed to exist when Chezy's C is less than or equal to 4.3 to 6.1 (SI units) when $V = C\sqrt{(HS)}$, where S is the slope of the river channel. If C is impossible to compute, non-isotropic turbulence is assumed to occur at stream depth less than 1.5 meters. Isotropic conditions is assumed at depth greater or equal to 1.5 meters (Nemerow, 1974).

Equation 1.14 is recommended for streams which are moderately deep to deep channels between 1 to 30 ft. in depth (0.31 to 9.1 m), with the stream velocity between 0.5 to 1.6 fps (0.15 to 0.49 m/s).

(4) Owens, Edwards and Gibbs (1964)

Owens and co-researchers used data from six streams in England using the disturbed equilibrium method, and combined those data with those of Churchill et al. (1962). The reaeration coefficient predictive equation is for shallow, fast moving streams:

$$k_2 \text{ at } 20^{\circ}C = 5.35\, V^{0.67}/H^{1.85} \qquad \text{(Equation 1.16)}$$

where,

V = mean velocity, m/s
H = mean depth, m

The appropriate streams are with velocities of 0.1 to 5.0 fps (0.03 to 1.52 m/s) and those exhibiting depths of 0.4 to 11.0 ft. (0.12 to 3.35 m).

Owens et al. (1964) also postulated another predictive equation recommended for streams with velocity between 0.1 to 1.8 fps (0.03 to 0.55 m/s), that is written as:

$$k_2 \text{ at } 20^{\circ}C = 6.91 V^{0.73}/H^{1.75} \qquad \text{(Equation 1.17)}$$

(5) Thackston and Krenkel (1966)

The equation was proposed by the two researchers mentioned above based on their studies of several rivers in the Tennessee Valley Authority (TVA) system. They assumed that the reaeration coefficient is directly proportional to the vertical mass coefficient and inversely proportional to H^2. The equation is written as:

$$k_2 \text{ at } 20^{\circ}C = 24.9(1 + F^{0.5})[V^*/H] \qquad \text{(Equation 1.18)}$$

where,

F = Froude number (dimensionless)

V^* = shear velocity, m/s

H = mean stream depth, m

Froude number is computing as:

$$F = \frac{V^*}{\sqrt{gH}} \qquad \text{(Equation 1.19)}$$

and V^* , the shear velocity, is derived from:

$$V^* = \sqrt{HS_e g} \qquad \text{(Equation 1.20)}$$

where,

S_e = slope of the energy gradient

g = acceleration of gravity, m/s^2

(6) Tsivoglou and Wallace (1972)

The predictive equation is derived from a five-river (the Flint, South, Patuxent, Jackson and Chattahoochee Rivers) study using radioactive tracers. In this equation, it is assumed that the reaeration coefficient for a reach is proportional to the change in elevation of the water surface in the reach and inversely proportional to the flow time through the reach:

$$k_2 \text{ at } 20^{\circ}C = c\,[\Delta h/t_f] \qquad \text{(Equation 1.21)}$$

where,

c = escape coefficient, m^{-1}

t_f = flow time within reach, days

Δh = change in water surface elevation in reach, m.

The change in water surface elevation, assuming uniform stream flow is:

$$\Delta h = S_e \Delta x \quad \text{(Equation 1.22)}$$

where,

S_e = slope of the energy gradient, m/m

Δx = reach length, m

Therefore flow time within a reach can be written as:

$$t_f = \frac{\Delta x}{\overline{V}} \quad \text{(Equation 1.23)}$$

where,

$\overline{V}$ = mean velocity in the reach, m/s

Substituting the above equation into Equation 1.21, we have:

$$k_2 \text{ at } 20\ ^\circ\text{C} = (3600 \times 24) c S_e \overline{V} \quad \text{(Equation 1.24)}$$

The constant 3600 and 24 convert the mean velocity in the reach to meters per day.

The escape coefficient is assumed to remain unchanged until the degree or type of pollution is changed or the hydraulic mixing regime is altered significantly (Gromiec, 1989). The escape coefficient is also considered as a variable and determined empirically. Tsivoglou and Neal (1976) recommend the following c values:

c = 0.054 $ft.^{-1}$ (0.0165 m^{-1})(at 20°C) for 15 $ft.^3/s$ (1.25 m^3/s) $\leq Q \leq$ 3000 $ft.^3/s$ (85.0 m^3/s)

c = 0.110 $ft.^{-1}$ (0.0335 m^{-1})(at 20°C) for 1 $ft.^3/s$ (0.03 m^3/s) $\leq Q \leq$ 15 $ft.^3/sec$ (0.42 m^3/s)

Methods of Reaeration Coefficient (k_2) Measurement

There are numerous methods for the measurement of stream reaeration coefficient (k_2) discussed in the literature. Four major field measurements discussed below are the most commonly used. The first two procedures are direct methods, where the experimenters measure the mass of oxygen passing through the air-water interface. The disturbed equilibrium method is the most applicable of the direct methods as the Churchill's approach described below requires stringent stream characteristics: (a) a dissolved oxygen deficit exists i.e. bottom discharge from a reservoir, (b) the rate reaeration is large enough so that a measurable difference in dissolved oxygen deficit can be seen between two sampling stations, and (c) the water is free from organic pollution.

The advantages of the tracer methods are that no assumptions are made as to stream channel uniformity or mixing characteristics and the tracer methods can be applied in polluted as well as clean rivers as the methods would not be affected by nitrification, photosynthesis, biochemical oxygen demand, etc. The disadvantages would be the cost and the requirements of elaborate equipment to monitor the tracers and the method appears to be limited to small streams due to injection difficulties.

(1) Disturbed equilibrium method using sodium sulfite and cobalt catalyst (Owens et al.,1964; Gameson and Truesdale, 1959)

The dissolved oxygen equilibrium of the stream water is "disturbed" by deaeration using sodium sulfite and cobalt chloride catalyst:

$$O_2 + 2Na_2SO_3 \longrightarrow 2Na_2SO_4 \qquad \text{(Equation 1.25)}$$

The change in oxygen deficit with time at any point should be proportional to the deficit at that point and time. If samples are taken at spatial point intervals, and the logarithm of the deficit is plotted against time, a straight line usually results. Measurement at another station downstream will result in another straight line, which should be parallel to the first (Owens et al., 1964).

The reaeration coefficient, k_2, (log base e) can be calculated as:

$$k_2 = \frac{\ln D_2 - \ln D_1}{\Delta t} \qquad \text{(Equation 1.26)}$$

where,

D_1 = deficit at Point 1, mg/L
D_2 = deficit at Point 2, mg/L
Δt = flow time between Point 1 and Point 2, days.

D_1 refers to the upstream deficit while D_2 is the downstream deficit.

(2) Reservoir discharge of deoxygenated water (Churchill et al., 1962)

Instead of using chemicals to deoxygenate stream water, the authors studied stream reaches located downstream from deep storage impoundment to calculate reaeration coefficients. This is because water released from such reservoirs through low-level outlets tends to be low in dissolved oxygen, especially during the summer months.

The streamflows or reservoir discharges in such studies must be held steady during the study period. During a 24-hour period of controlled river flow, a set of multiple dissolved oxygen measurements was collected at frequent intervals from each end of the reach studied.

The reaeration coefficients, k_2, were calculated using the same method as in the disturbed equilibrium. Using 12,000 sample results, the authors calculated mathematical prediction equations using multiple regression analysis, with the most commonly used one being:

$$k_2 \text{ at } 20^{\circ} \text{C} = 5.026\, V^{0.969}\, R^{-1.673} \qquad \text{(Equation 1.27)}$$

where,

V = mean velocity of the cross-section, m/s

R = hydraulic radius or the mean depth of the cross-section, m

(3) Tracer method (Tsivoglou et al., 1967; 1968; 1974) (Tsivoglou and Neal, 1976).

The original gas radioactive tracer method for measuring reaeration coefficient in streams and rivers was developed by Tsivoglou et al. (1965). The methodology used called for the injection of radioactive krypton gas (krypton-85) and tritium, in the form of tritiated water molecules as a dispersion indicator, instantaneously into the stream. Water samples are then collected at two or more locations downstream of the injection site. The samples are analyzed to determine the concentrations of both tracers. These resulting concentrations are used to calculate the desorption coefficients of radioactive krypton gas in the stream. The concentrations of tritium, a conservative tracer, are used to calculate the travel time of the tracers as well as to calculate for the compensation for the reduction of the krypton gas concentrations due to dispersion and dilution. The calculated desorption coefficient of krypton gas can be directly related to the stream's reaeration coefficient. Later, the method involves the simultaneous release of three tracers - a fluorescent dye, Rhodamine-WT; tritium, in the form of tritiated water molecules as a dispersion indicator and krypton-85, a gaseous tracer. The dye provides information on time of flow and longitudinal dispersion and indicates when to sample for the other two tracers.

(4) Modified tracer method (Rathbun et al., 1975; Rathbun and Grant, 1978; Shultz et al., 1976; Grant and Skavroneck, 1980)

The hydrocarbon gas tracer method is similar in principle to the radioactive krypton gas and tritium method described above. The researchers mentioned above, who developed the method, worked for the United States Geological Survey (USGS). The technique employed the use of a hydrocarbon gas tracer whose desorption or loss to the atmosphere characteristics can be related to the adsorption characteristics of oxygen. The hydrocarbon tracer gas (propane or ethylene) and a fluorescent dye (Rhodamine-WT) are injected simultaneously upstream of the study reach. As the gas and dye travel downstream, the river or stream is sampled at two or more sampling sites. The gas and dye concentrations in the samples are then measured in the laboratory and used to compute the desorption coefficient of the gas (Rathbun et al., 1975, 1977) (Rathbun, 1977) (Stedfast and Draper, 1986). A direct linear relationship between the desorption coefficient of the hydrocarbon gas and the adsorption coefficient of oxygen is then used to compute the reaeration coefficient for the stream reach studied (Rathbun et al., 1978).

1.5.4 Sediment Oxygen Demand (SOD)

General

The process of calibration and validation of QUAL2E for the study needs two major independent variable data other than the measurements of reaeration coefficients and river hydrogeometry of Sg. Selangor River. If available, the data can be in the form of past research data carried out on other rivers in Malaysia, but if there are no data available, field measurements have to be carried out. These variables are sediment oxygen demand (SOD) and photosynthesis/respiration, which are discussed in this section and Section 1.9 respectively.

Sediment oxygen demand is defined as the rate of dissolved oxygen removal from the water column by the decomposition of organic materials in the bottom sediments, including chemical oxidation and respiration of benthic organisms. The death of rooted aquatic plants and leaves and other organic detritus as well as the discharge of settleable waste components cause the formation of sludge at the river bottom. The surface layer of the bottom sludge in direct contact with water undergoes aerobic decomposition and creates a demand for oxygen in the overlying river water. The deeper layer of the sludge undergoes anaerobic decomposition, producing of gases such as CO_2, CH_4 and H_2S, which proceed to the upper sludge layer and the water surface. Severe aesthetic problems and DO depletion can occur in that particular river. SOD could be the major source of low dissolved oxygen in water bodies (Murphy and Hicks, 1986).

The SOD rate is an important parameter in water quality modeling especially for modeling dissolved oxygen in surface waters. The predictions from these models are used by government agencies such as USEPA for determining specifications for wastewater discharge permits from municipal and industrial effluent dischargers.

Accurate SOD rates are important, as they will allow for more precise permits specifications and therefore the degree or level of wastewater treatment needed. On the other hand, if inaccurate SOD rate coefficients are used, the models' predictions may lead to erroneous calculations and conclusions of the permit specifications and the level or degree of wastewater treatment needed to be constructed. For example, if the SOD rates used for the model were higher than actual SOD rates, it would lead to unnecessary wastewater treatment, while if the SOD rates used were lower than actual rates, the water quality impacts to the receiving water would be greater (Hatcher, 1986).

The SOD in the water column is determined by the continuous but variable supply of the settling of the organic materials. The organic matter sources include natural leaf and litter fall, death of aquatic organisms, atmospheric deposition, wastewater effluent discharges, and stormwater runoffs. The organic matter from each source differs in both chemical composition and physical characteristics.

The fate of the organic materials from their settled condition in the water column is determined by one of these processes – transportation downstream, decomposition in the water column or settling to the sediments. The processes for different sources would therefore be different due to the different chemical composition and physical characteristics. Larger organic matter would settle out quickly, while smaller particles would be suspended longer in the water column and therefore be transported downstream (Murphy and Hicks, 1986).

The organic matter, which settles from the water column, accumulates on the bottom of the water bodies in irregular patches or islands. The distribution of these oxygen-demanding deposits along the stream bottom is due to the irregular settling pattern of the organic materials. Larger, denser particles settle faster than smaller, lighter particles, and organic matter settles faster in slow, meandering stream areas than in turbulent areas (Hatcher, 1986).

The distance that a suspended matter travels downstream before it is deposited depends upon the velocity of the stream and its depth and upon the particle's settling velocity. The equation could be written as:

$$x = H * \frac{V}{s} \qquad \text{(Equation 1.28)}$$

where,

x = distance traveled by the suspended particle downstream

H = stream depth

V = stream velocity

s = settling velocity of the particle

Rivers tend to deposit their load of suspended solids in zones of suddenly decreasing velocity such as in the backwaters of reservoirs and in areas of increasing salinity. Increasing salinity flocculates the clay-based particles, which increases the settling velocity of the particles as they increase in size.

Even in a uniform stream, particles of different sizes and densities settle differentially, with the larger, denser materials settling out and the smaller, lighter materials being carried downstream, where they might undergo partial decomposition before they are deposited. This particular settling pattern leads to a non-uniform organic particle deposit which causes higher SOD rates near the source and gradually decreasing SOD rates further downstream. The longitudinal SOD gradient due to the particles' different settling velocities and SOD variability due to lateral and longitudinal non-uniformity in the stream velocity and the variability of the depth makes it difficult to predict the sediment deposits' locations, depths and their properties.

At the same time, the organic matter deposits can be scoured, resuspended and moved further downstream at higher water velocities (Hatcher, 1986).

The unsteady stream hydraulics and variable organic particle loading rates of most natural streams cause spatial and temporal variability in the distribution of the sediment deposits and the sediment oxygen demand. Therefore, it is most difficult to accurately characterize a stream's SOD distribution by using SOD measurements taken at only a few locations at only limited time periods.

The organic matter in the bottom sediments of the water column undergoes various physical, chemical and biological processes. The decomposition transforms the organic matter and releases energy and nutrients. Biological respiration and chemical oxidation, two most important decomposition processes, consume oxygen and therefore cause sediment oxygen demand, SOD. The biological component of SOD is caused by the combined respiration of benthic organisms. The chemical component of SOD is caused by the abiotic chemical oxidation of chemical species such as hydrogen sulfide (H_2S), ammonia (NH_3), and methane (CH_4), which are released as by-products of biological decomposition.

Researchers have tried to develop equations for predicting SOD rate, but the search has been frustrating because of the intricacies of many factors affecting SOD.

The potential SOD cannot be exerted until oxygen comes in contact with oxygen demanding constituents in the bottom sediments. The process occurs if oxygen in the water column is transported downward into the sediment layer or the oxygen demanding constituents form the bottom sediment travel upward into the oxygenated water column.

This vertical transport is caused by the physical mixing between overlying water and sediment interstitial waters, and by molecular diffusion. Molecular diffusion increases with increased temperature and concentration differentials, while physical mixing increases with increased concentration differentials and with increased velocity and turbulence of the underlying water. The vertical transport or mixing water also depends on the sediment deposits' physical structure, with higher mixing rates for sediments with a looser structure and higher porosity. Gravel or pebble deposits, therefore, would have higher vertical mixing rates than consolidated silt deposits (Murphy and Hicks, 1986).

Oxygen demanding constituents in the sediment pore water can be transported to the water column when they are pushed out by groundwater pressure or squeezed out due to gradual sediment consolidation. This is important as during low-flow periods the stream discharge consists mainly of groundwater, which may transport oxygen-demanding constituents from the sediment pore water into the water column. This condition may cause SOD rates to be higher during low-flow periods.

Methods of SOD Measurement

There is no standard methodology of SOD measurements, but two basic procedures are used by researchers; *in situ* measurements and laboratory analysis. The *in situ* method appears to be the better approach to measuring SOD as it minimizes manipulation of sediment sample and other ambient conditions (Belanger, 1981). However, some studies have indicated that the results are more reproducible in laboratory analysis (Bowman and Delfino, 1980).

1.5.5 Photosynthesis and Respiration

General

The presence of phytoplanktons or macrophytes in the water column can have a major impact on the dissolved oxygen (DO) resources and the variability of the DO during the day. Therefore, the measurements of the photosynthetic and respiration rates would be needed in the modeling process.

Stream plant activity is important as photosynthesis produces oxygen while respiration depletes oxygen from the water. Photosynthesis is light dependent and therefore can have both diurnal and seasonal impact.

Seasonally photosynthesis dominates during the growing season, while during the non-growing season respiration and decomposition of plant materials dominate. During the growing season, swings in the dissolved oxygen can be induced by the variability of the diurnal light levels. Stream dissolved oxygen tends to supersaturates in the afternoon and nearly depleted just before sunrise (Chapra, 1997). The growing season and non-growing season variability tends to be more pronounced in the temperate zones as compared to the more tropical climates. This is due to the changing length of daylight hours and light intensity.

Methods of Photosynthesis and Respiration Measurements

There are four major methods used to estimate the average production and respiration of dissolved oxygen for use in the DO balance equation. The four estimation methods are:

(a) Light-bottle/dark-bottle method is considered the direct measurement approach, which calculates the net production of DO by exposing the phytoplanktons to natural light conditions (the "light" chamber or bottle). The increase in dissolved oxygen is measured, which is the estimate of the photosynthetic gross DO production minus the DO utilized in respiration in the "dark" chamber. Corrections have to be made for the respiration by bacteria;

(b) The measurement of chlorophyll a in the water column is a direct measurement of the concentration of phytoplankton. In the modeling process other parameters needed to estimate the photosynthetic rate include solar radiation and depth. The method is an indirect biomass estimate. According to this author's past experience with the Department of Environment (DOE) and the Department of Chemistry (DOC), chlorophyll a is not analyzed for all water quality monitoring of stations in Malaysia;

(c) The measurement of DO over a period of at least a day can be used to obtain an estimate of the range of DO throughout the day. A method has been developed as an analytical formulation that relates this diurnal DO range (c_{max} - c_{min}) to p_a, the average daily photosynthetic production (Di Toro, 1975). c_{max} and c_{min} are the maximum dissolved oxygen concentration and the minimum dissolved oxygen concentration measured in the river, respectively;

(d) A modification of method (c) is the Delta method (Chapra and Di Toro, 1991), which also needs the diurnal dissolved oxygen data. Other data needed include water temperature and elevation (to calculate the saturation dissolved oxygen), and photoperiod (the fraction of daylight hours over 24 hours).

Measurement methods (a) and (b) are discussed in more details below.

Light-bottle/Dark-bottle Method

The light bottle/dark bottle method consists of placing a sample each of river water placed in a clear (light) BOD bottle and a black (dark) BOD bottle. The light bottle allows for both photosynthesis and respiration while the dark bottle, which does not allow light penetration, exhibits only respiration. After reading the initial dissolved oxygen levels of each bottle using a DO meter and a BOD bottle probe, the bottles are capped tightly and placed at about 0.3 meter below the water surface. After a designated time, t, passed, the final dissolved oxygen measurement is carried out (Chapra, 1997).

The net photosynthesis can be determined by:

$$P_{net} = \frac{do_{lf} - do_{li}}{t} \qquad \text{(Equation 1.29)}$$

where,

P_{net} = net photosynthesis
do_{li} = initial dissolved oxygen in the "light" bottle (mg/L)
do_{lf} = final dissolved oxygen in the "light" bottle (mg/L)
t = time between do_{li} and do_{lf}

The net photosynthesis P_{net} is defined as:

$$P_{net} = P_b - R_{cm} \qquad \text{(Equation 1.30)}$$

where,

P_b = "bottle" photosynthesis rate

R_{cm} = "community" respiration rate

The community respiration rate can be written as:

$$R_{cm} = \frac{do_{di} - do_{df}}{t} \qquad \text{(Equation 1.31)}$$

where,

do_{di} = initial dissolved oxygen in the "dark" bottle (mg/L)

do_{df} = final dissolved oxygen in the "dark" bottle (mg/L)

Therefore, P_b can be calculated using Equation 1.30 and Equation 1.31.

The community respiration, R_{cm}, can be corrected to calculate the "bottle" respiration, R_b, by using the filtered BOD result of the river water during the study period (BOD_f). The equation is written as:

$$R_b = R_{cm} - \frac{BOD_f}{t} \qquad \text{(Equation 1.32)}$$

The correction can be measured directly or computed from the bottle decomposition rate k_1 as:

$$k_1 BOD_{fi} = \frac{BOD_f}{t} \qquad \text{(Equation 1.33)}$$

where,

BOD_{fi} = the initial filtered BOD in the bottle

The Delta Method

Odum (1956) originally used diurnal oxygen measurement in a mass balance equation to estimate photosynthetic production in streams. The method was later extended and refined by later investigators (O'Connor and Di Toro, 1970; Hornberger and Kelly, 1972; Erdmann, 1979a, 1979b). Chapra and Di Toro (1991) presented the Delta method, which is to implement Odum's original idea in an easier form.

The mass balance for dissolved oxygen deficit in a stream is written as:

$$\frac{\partial D}{\partial t} = -V\frac{\partial D}{\partial x} - k_2 D + R - P(t) \qquad \text{(Equation 1.34)}$$

where,

D	=	oxygen deficit (mg/L)
t	=	time (day)
V	=	stream velocity (m/day)
x	=	distance (m)
k_2	=	reaeration coefficient (1/day)
R	=	respiration ((mg/L)/day)
P(t)	=	primary production ((mg/L)/day)

If the plants are considered uniformly distributed for a long stretch of the stream (greater than $3V/k_2$), then the oxygen deficit is not considered vary spatially ($\partial D/\partial x = 0$). The above equation is therefore simplified as:

$$\frac{\partial D}{\partial t} + k_2 D = R - P(t) \qquad \text{(Equation 1.35)}$$

The diurnal dissolved oxygen cycle of the stream is used to estimate the oxygen deficit and therefore one of the main factors has to be measured during the study.

CHAPTER 2

STUDY AREA

2.1 Introduction

There are several reasons for Sungai Selangor River to be chosen for the study. First, it is located close to water quality laboratories at Universiti Teknologi Malaysia (where the author works) and other universities such as Universiti Malaya, Universiti Kebangsaan Malaysia and Universiti Putra Malaysia as well as the headquarters of the Malaysian Department of Chemistry (DOC) and the Department of Environment (DOE). Secondly, there are a lot of data for the Sungai Selangor River compared to other Malaysian rivers of its size and importance. It was one of the ten rivers studied in the proposed river water quality standards for Malaysia (DOE, 1994). Finally, a lot of growth is occurring within the watershed, both for residential and industrial growth, which could eventually lead to the future deterioration of the water quality. In 1999, an environmental impact assessment (EIA) was completed of the proposed dam on Sungai Selangor River,

2.2 Sungai Selangor and Vicinity

The study area is situated in the state of Selangor, north of Kuala Lumpur on latitude $03^0 40'$ N to $03^0 15'$ N, and longitude $101^0 14'$ to $101^0 47'$ (Figure 2.1) (DOE, 1994).

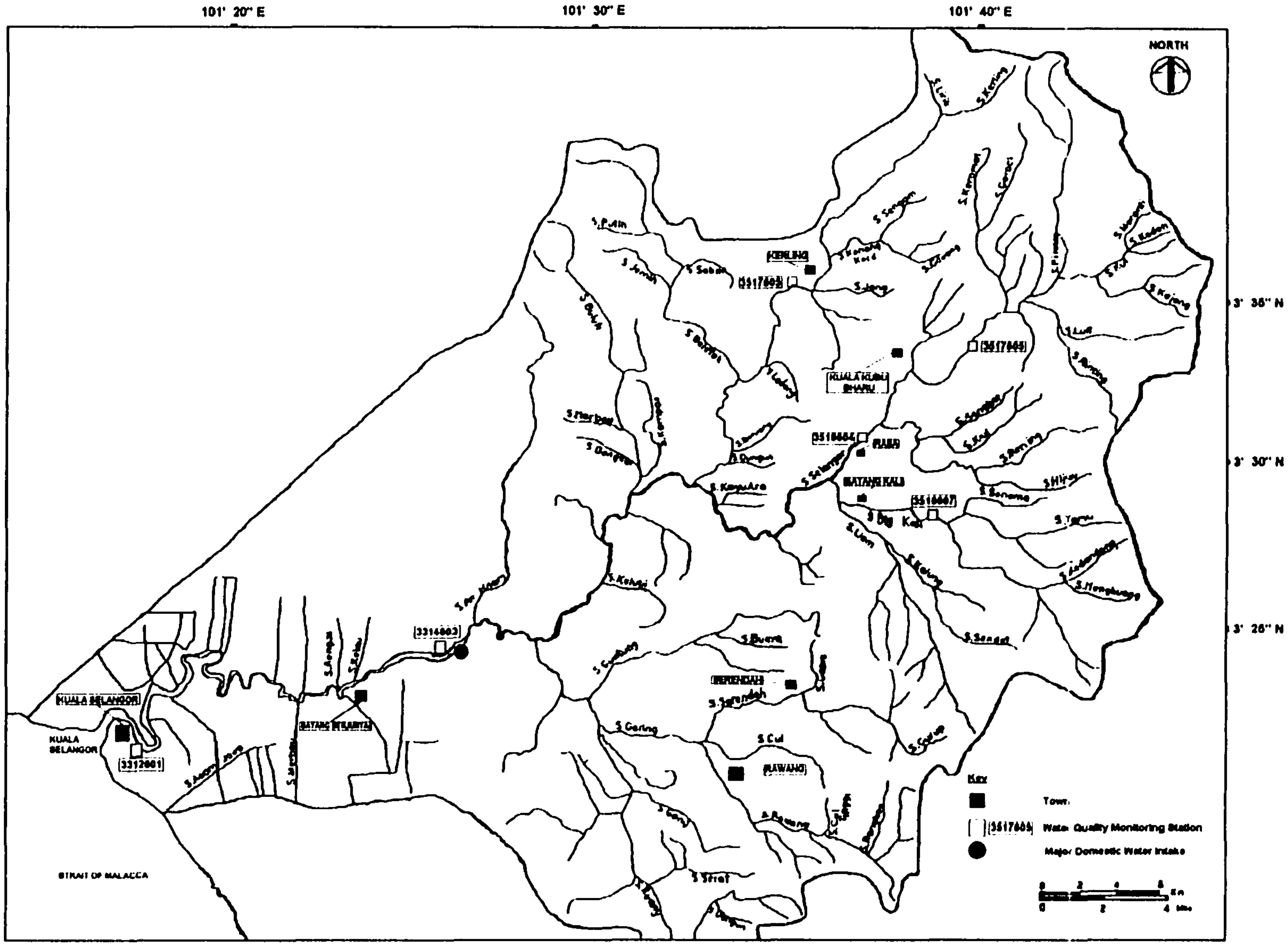

Figure 2.1. Sg. Selangor River, Malaysia: Watershed, Major Domestic Water Intakes and Water Quality Monitoring Stations

Sungai Selangor River (Sungai, abbreviated to Sg., is a Malay word for river) flows from east to west, starting from the Titiwangsa Range, which forms the backbone of Peninsular Malaysia or West Malaysia. The highest point of the Sg. Selangor River watershed is Gunung Hulu Kali (1772 m.) (Gunung, abbreviated to G., is a Malay word for mountain) which borders Sg. Bentong, a tributary of Sg. Pahang, the longest river in Peninsular Malaysia. Other notable mountains within the watershed include Bukit Tunggul (1663 m) and G. Rajah (1683 m) (DOE, 1994).

Sg. Selangor River flows from the tropical rainforests near Fraser's Hill, a popular mountain resort, through aboriginal settlements, fruit orchards, rubber plantations, oil palm plantations, small towns, abandoned tin mines, housing estates, industrial estates, golf courses, traditional Malay villages, freshwater swamps and brackish water swamps before emptying into the Straits of Malacca. The study is limited to Rantau Panjang where brackish water reaches during high tide. There are several small towns within the watershed with Kuala Kubu Bharu as one of the important ones. This quaint town built by the British is host to the Royal Malaysian Police Training Center as well as the training grounds for the Malaysian Firefighters Department. Rawang is another town, which owes its growth to its location just north of Kuala Lumpur. The presence of the old trunk road, the new North-South Highway as well as the Malayan Railway railroad, has attracted investors to build housing estates and industrial estates.

The Sungai Selangor watershed has a humid tropical climate as it is situated close to the equator. High temperature and humidity with relatively small seasonal variations characterize it. The watershed is subjected to two monsoon periods: the northeast monsoon from October to January and the southwest monsoon from May to September. The rainfall tends to peak during the monsoons with a larger peak during October to December. The inter-monsoon periods in February and July/August have the least rainfall. The average annual rainfall ranges from 2000 mm to 3500 mm (79 to 138 inches) (DOE, 1994). Mean isohyets of the watershed are shown in Figure 2.2.

2.3 Past Data

2.3.1 Stream Discharge

The British started collecting data for stream discharge for Sg. Selangor River at several locations, but later abandoned most of the stations except for the ones at Rasa and Rantau Panjang (Table 2.1) (DOE, 1994). The Malaysian Department of Irrigation and Drainage (DID) continue the discharge measurement after Malaysia (then Malaya) gained its independence on August 31, 1957. For the purpose of the study, only data collected from 1960 to the present were used.

Table 2.1. Sg. Selangor River, Malaysia: Gauging stations' history and locations.

Gauging Station	Years
Batang Berjuntai	1930-1940
Rantau Panjang	1921-present
Rasa	1960-present

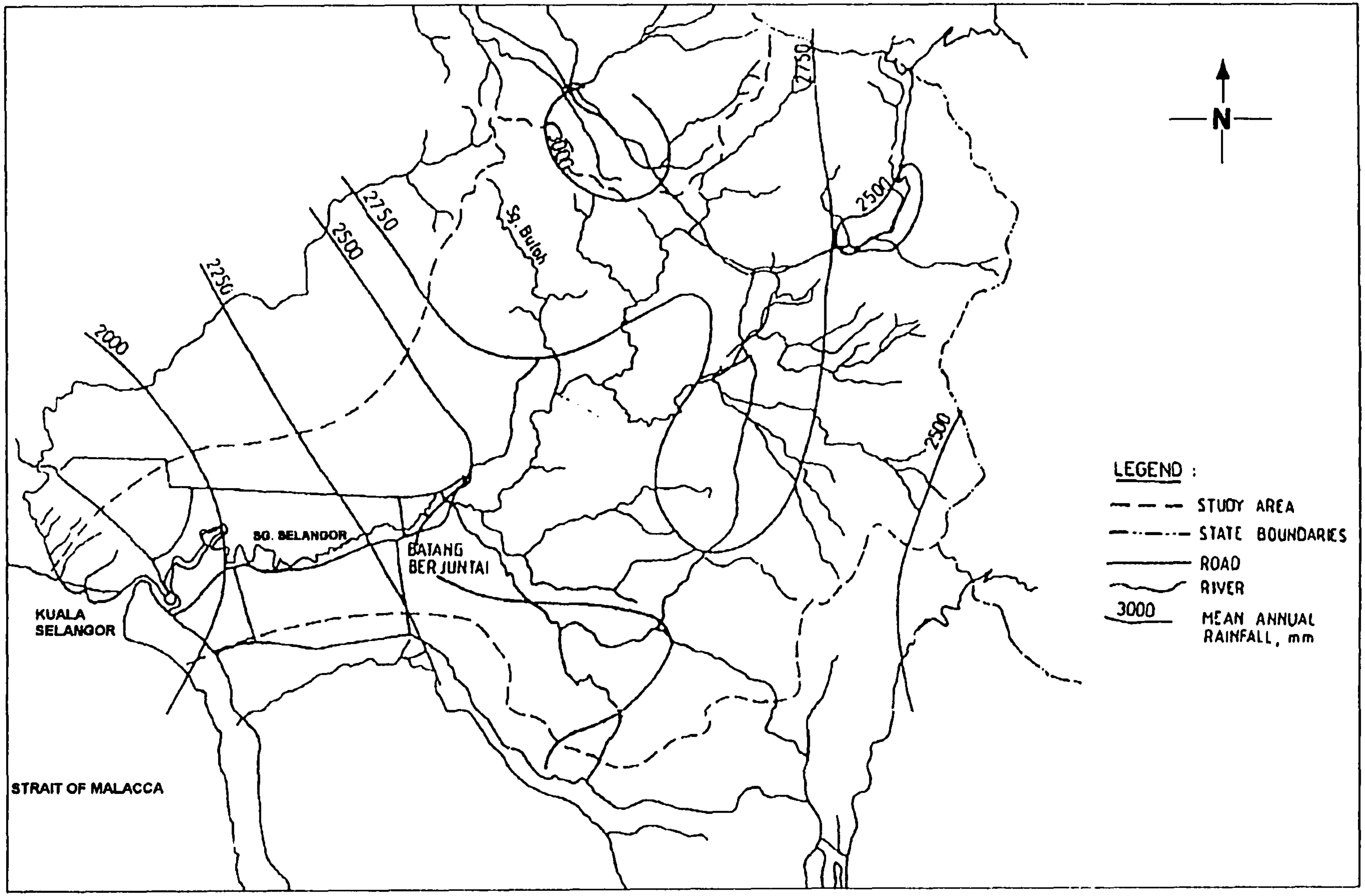

Figure 2.2. Sg. Selangor River, Malaysia: Mean Isohyets

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2.3.2 Meteorological Data

The main authority for meteorological data collection is the Meteorological Services Department although DID have also carried out some rainfall gauging activities. There are several meteorological stations within the Sg. Selangor River watershed, which include Kuala Kubu Bharu (Station # 3516322), Rawang, and Fraser's Hill.

2.3.3 Water Quality Data

Water quality data is not as extensive as stream discharge, although both the DID and the Health Ministry carried out water quality monitoring at several locations before the formation of the Department of Environment in 1978. The water quality monitoring stations tend to fulfill the specific needs of the department carrying out the monitoring i.e. DID sampled for suspended solids (SS) while the Health Ministry for total and/or fecal coliforms at domestic water supply intake points. The Department of Environment has six water quality stations in the Sg. Selangor River watershed. The stations are situated, consecutively from the source to the estuary, Pertak (Station # 3517605), Batangkali (Station # 3516607), Rasa (Station # 3516604), Kerling (Station # 3516606), Rantau Panjang (Station # 3314603), and the estuary (Station #3312601) (Figure 2.1) (DOE, 1994). These monitoring stations are usually sampled manually (grab sampling) every two months for *in situ* data such as dissolved oxygen, turbidity, pH, electrical conductivity, salinity and temperature as well as laboratory analyses of parameters such as BOD_5, COD, ammoniacal nitrogen, nitrate, and heavy metals. The Department of Chemistry (DOC) usually carries out the laboratory analysis.

Coincidentally, both the Rantau Panjang and Rasa water quality stations are situated at or near the discharge measuring stations maintained by the DID. Unfortunately, these government departments lack coordination whereby water quality data collected was not usually accompanied by the discharge although the staff gauge was within sight of the water quality collecting team. The major challenge of water quality analysis for the QUAL2E modeling of Sg. Selangor River was to match water quality results and stream discharge at Rasa and Rantau Panjang on the same sampling date.

Additional water quality data was collected during the study especially for phosphate, nitrate and nitrite as these parameters were not analyzed for the DOE water quality samples through the years.

2.3.4 Pollution Sources Inventory

Pollution sources inventory is the most lacking for all the past data for Sg. Selangor River. Although the Department of Environment has a specific unit or section for this very purpose, the data is sparse. The population within the watershed is estimated or projected using data from the past census.

The sewage collection and treatment, although some areas are centralized, still rely on septic/Imhoff tanks, oxidation pond systems. For the purpose of this study, the sewage treatment is conservatively estimated at 60 percent although the lack of facility maintenance such as desludging, which occurred frequently, could mean overestimating the treatment (DOE, 1994).

The Department of Environment also maintains the inventory of pollutant sources. The sources are categorized as sewage, rubber-processing factories, palm oil mills, pig farms and other industries not covered by the other categories. The pollutant loads estimated to actually reach a water course is calculated by using the Runoff Factor, where:

$$\text{Runoff Factor} = \frac{\text{Mean Mass of Pollutant Entering Water Course}}{\text{Mean Mass of Pollutant Discharged at Source}} \quad \text{(Equation 2.1)}$$

QUAL2E uses point sources data such as flow and concentrations of water quality parameters of the effluent to estimate the loading, but in most cases in Malaysia, such data is scarce, therefore loading estimations using the Runoff Factor is the best method applicable (DOE, 1994).

The runoff factors for Sungai Selangor can be estimated for the different, common polluting sources within the watershed (Table 2.2) (DOE, 1994):

Table 2.2. Sg. Selangor River, Malaysia: Runoff factors for major industries.

POLLUTION SOURCE	1990 BOD	1990 COD/TN	2000 BOD	2000 COD/TN
Urban population	0.6	1.0	0.6	1.0
Rural population	0.1	0.3	1.0	0.3
Industry	0.6	1.0	0.6	1.0
Rubber mills	0.6	1.0	0.5	0.9
Palm oil mills	0.4	0.8	0.2	0.5
Pig farms	0.1	0.3	0.1	0.3

Table 2.3. Gross Loading Rates from Common Sources of Pollution, Malaysia.

Source	Year	Loading Rates BOD	Loading Rates COD	Loading Rates TN	Comments
Urban population	All	40	100	8	Less than rural as there are some treatment
Rural population	All	50	125	10	
Industrial	1980	200	600	20	Improvement assumed for 1990 and subsequent years
	1990	100	300	10	
Rubber mills		See Table 3.4			
Palm Oil mills		See Table 3.5			
Pig Farms	All	(in kg/head/day) 0.13	0.32	0.016	

Table 2.4. Gross Loading Rates for Rubber and Palm Oil Mills, Malaysia.

Factory Type	Year	Effluent Quantity Per Tonne of Rubber or Palm Oil (m^3/metric tonne)	Effluent Quality (mg/L)			Loading (g/metric tonne of rubber)		
			BOD	COD	TN	BOD	COD	TN
Standard Malaysian Rubber (SMR) (effluent treated)	1980	20	100	350	40	2000	7000	1000
	1990		50	200	40	1000	4000	800
	2000		50	150	40	1000	3000	800
Latex (effluent treated)	1980	10	150	600	500	1500	6000	2000
	1990		75	300	100	750	3000	1000
	2000		50	200	75	500	2000	750
Standard Palm Oil Mill (effluent treated)	1980	2.5	400	2000	200	1000	5000	500
	1990		100	800	100	250	2000	250
	2000		50	400	50	125	1000	800

The total gross average daily loads at the source could be calculated and tabulated from available data (Tables 2.3 and 2.4) (DOE, 1994).

Land use and development within the watershed mainly affect water quality of Sungai Selangor. High turbidity, low pH, and high total solids affect some sections of the river especially during low-flow periods. The major problems include urban population with inefficient sewage treatments (septic tanks, Imhoff tanks, unlined pour and flush toilets and "hanging" latrines) and pig farms and industries with ineffective treatment systems. In the United States, the pollution loads from point sources such as sewage treatment plants can be calculated relatively easily compared to the Malaysian situation whereby small towns still do not have a centralized sewerage treatment, although the recent privatization of the sewerage system to Indah Water Konsortium (IWK) will move the nation towards centralized treatment soon. Calculating the net loading rates will still rely on estimates using Table 2.5 (DOE, 1994).

Table 2.5. Estimated Net Pollutant Loading Rates, Malaysia.

POLLUTION SOURCE		1990			2000		
		BOD	COD	TN	BOD	COD	TN
Urban population (g/capita/day)		24	100	8	24	100	8
Rural population (g/capita/day)		5	38	3	5	38	3
Industrial effluent (tonne/m^3)		60	300	10	-	-	-
Rubber mills (g/tonne of rubber)	SMR	600	4000	800	500	2700	720
	Latex	450	3000	1000	250	1800	675
Palm oil mills (g/tonne of oil)		100	1600	200	25	500	63
Pig farms (g/head/day)		13	96	48	13	96	68

2.3.5 Domestic Water Intakes

The state body that is responsible for domestic water supply is Jabatan Bekalan Air Selangor (Selangor Water Supply Department), but most of the department duties were recently relegated by privatization to Puncak Niaga Sdn. Bhd. There are currently five major locations of domestic water intakes (Table 2.7).

Table 2.6. Sg. Selangor River, Malaysia: Location and Capacity of Domestic Water Treatment Plants

Location	Capacity (MLD)
Batangkali	20.5
Kuala Kubu Bahru	5.9
Rantau Panjang	31.8
Sg. Selangor Plant (completed in 1998)	200 (doubled at the end of 1999)

The domestic water intake points are important, as one of the major problems faced by the Department of Environment is the increasing water pollution threatening the water sources for the country.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses the field measurement of the central parameter in question, reaeration coefficient (k_2). The field measurements of SOD and photosynthesis/respiration are also discussed, as there were no known measurements in Sg. Selangor River or other rivers in the country prior to this study.

The field data collected and other data collected from the various agencies such as water quality and river discharge were used to calibrate and validate the QUAL2E for Sg. Selangor River.

3.2 Field Measurement Method of Stream Reaeration Coefficient (k_2)

The field procedure adopted for the study is the disturbed equilibrium method discussed in Section 1.7.6. The method was developed by Gameson, Truesdale and Downing (Gameson et al., 1955). Modifications were later made by Gameson and Truesdale, (Gameson and Truesdale, 1959), and Edwards, Owens and Gibbs (Edwards et al., 1961; Owens et al., 1964). The disturbed equilibrium method is relatively cheap and accurate for the purpose of the study.

The locations chosen for the study represented two predominant characteristics of Sg. Selangor River. Alor Lempah, on Sg. Selangor River proper, represented the middle and lower reaches that tend to be wide, with slow to medium velocity and relatively deep. Meanwhile Sg. Serendah, a tributary, represented the narrower, shallow and fast upper parts of the river (Figure 3.1).

As discussed in Chapter 1 (page 34), the stream water is deaerated using sodium sulfite and cobalt chloride catalyst:

$$O_2 + 2Na_2SO_3 \longrightarrow 2Na_2SO_4 \qquad \text{(Equation 1.25)}$$

And the reaeration coefficient, k_2, (log base e) can be calculated as:

$$k_2 = \frac{\ln D_2 - \ln D_1}{\Delta t} \qquad \text{(Equation 1.26)}$$

where,

D_1 = deficit at Point 1 (upstream deficit), mg/L

D_2 = deficit at Point 2 (downstream deficit), mg/L

Δt = flow time between Point 1 and Point 2, days

Zogorski and Faust modified the application method, and the addition of the chemicals into the stream was carried out in a more systematic way in comparison to earlier methods of application (Zogorski and Faust, 1973a, 1973b; Owens et. al, 1964). The method is the easiest to apply in the Malaysian study situation considering the logistics and financial constraints. Therefore, the above procedure was adopted, with some modifications, in this particular study. The detailed methodology of the measurements is as follows:

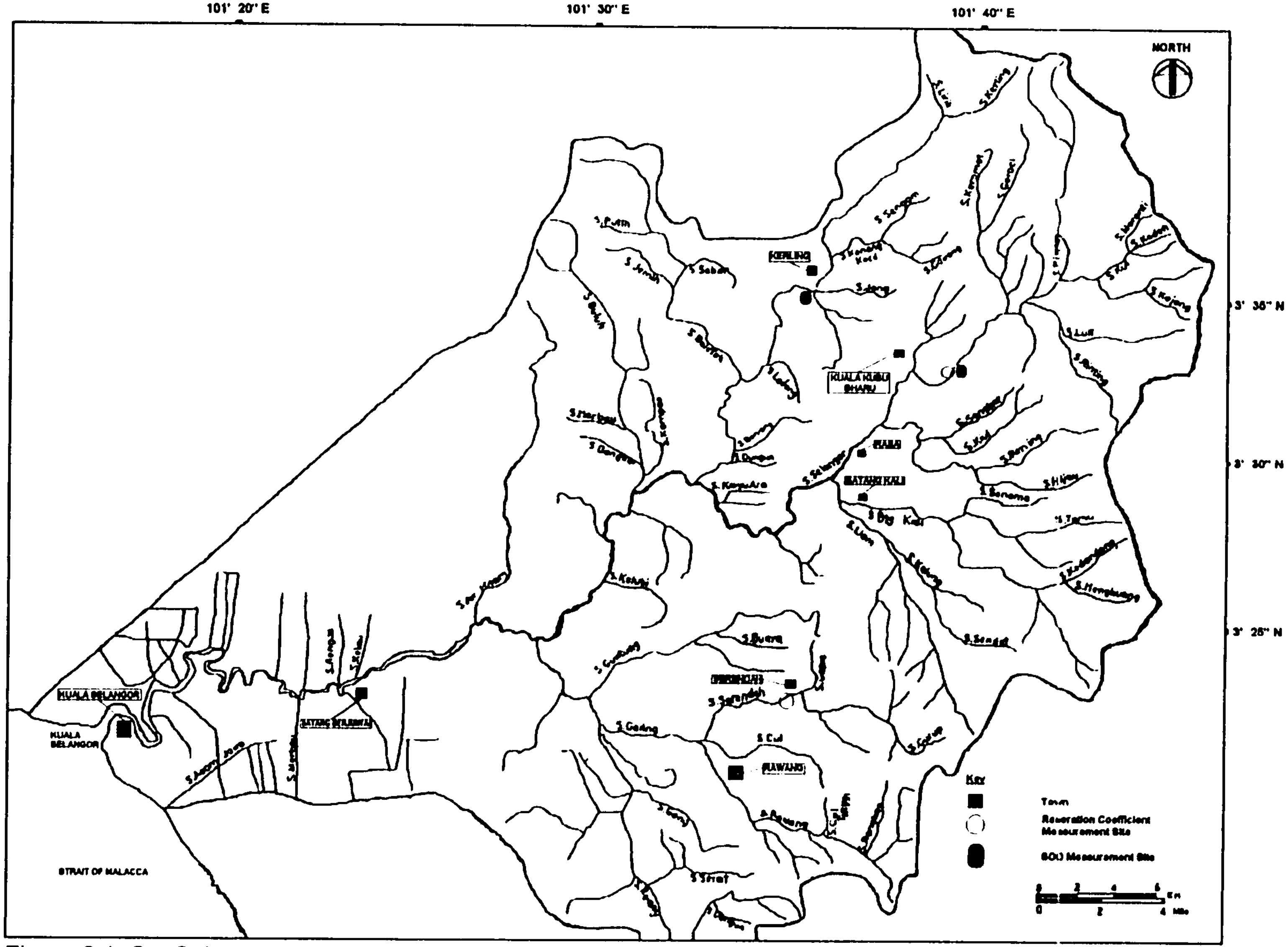

Figure 3.1. Sg. Selangor River, Malaysia: Reaeration Coefficient and SOD Measurement Sites

(a) For each k_2 measurement, a straight stretch of a river is chosen with minimal surface turbulence. Two points, D_1 and D_2, of known distances from the sulfite dosing points are chosen. Examples of distances used were 100 meters and 60 meters respectively (Gameson et al., 1955). If possible, structures such as bridges would be the natural choice, as it would easily accommodate the placement of a technician with a dissolved oxygen meter. In the study, the distances used for Alor Lempah (Sg. Selangor River) were 38.7 meters and 82.2 meters. At Sg. Serendah, the distances used were 42 meters and 114.3 meters ;

(b) Flow measurements were carried out first using the current meter method, to estimate the retention periods between the dosing point to point D_1 and between D_1 and D_2. The discharge results were also used to calculate the quantity of the chemical dosage needed for that particular study section. The current meter used was a propeller type "Braystoke" BFM001 Current Meter (Valeport Marine Scientific Ltd., Dartmouth, South Devon, UK) with a wading rod;

(c) The sulfite solution was prepared with 100 g of sodium sulfite (Na_2SO_3) per liter of deionized water. The preparation was done at the experimental site just before the dosing. The dosing of the sulfite solution was carried out using a set-up similarly used by Zogorski and Faust (Figure 3.2) (Zogorski and Faust, 1973b);

(d) A solution of cobalt chloride was added to catalyze the oxidation of the sulfite solution by the dissolved oxygen in the water. A study by

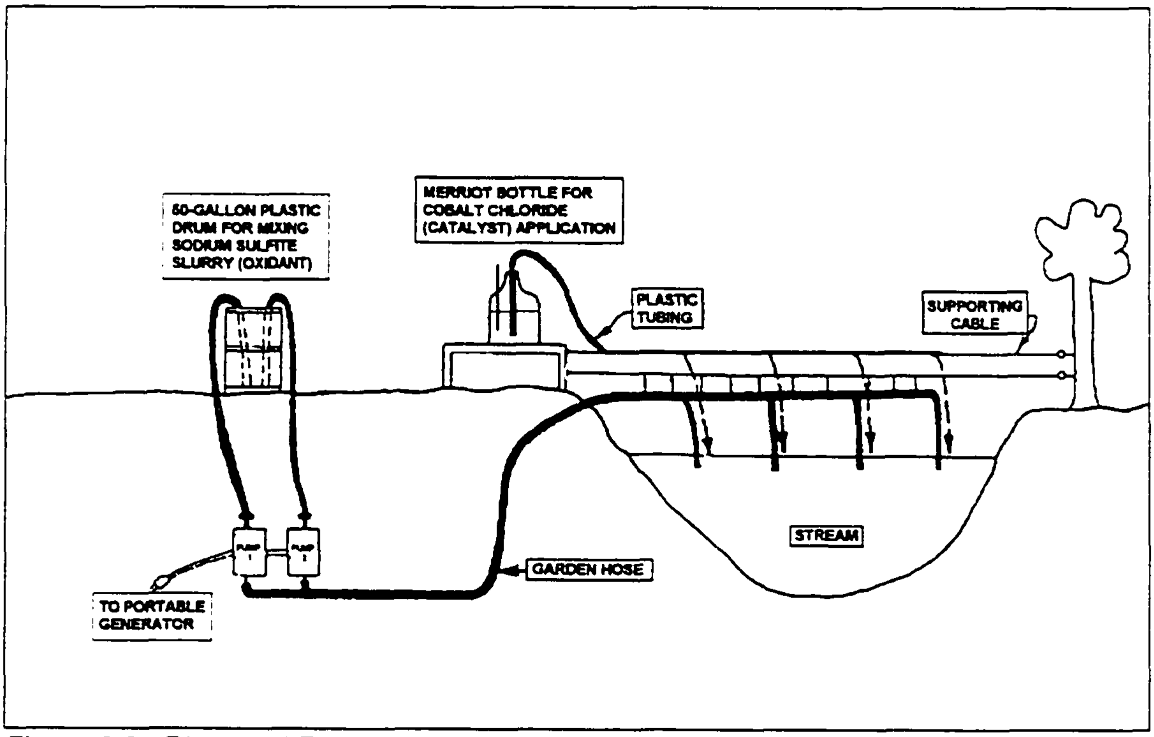

Figure 3.2. Disturbed Equilibrium Chemical Application Set-up (after Zogorski and Faust, 1973b)

Edwards, Owens, and Gibbs indicated that in a clean river a concentration of 0.1 ppm of cobalt solution is appropriate (Edwards et al., 1961). Meanwhile, 1 ppm is necessary for a polluted stream. A range of concentration between 0.3 ppm and 1 ppm is recommended (Zogorski and Faust, 1973b). The dosing of the cobalt catalyst and sulfite solution must be carried out simultaneously using separate dosing devices because premixing of the solutions is not practical as the precipitation of cobalt hydroxide causes the accurate control of sulfite dosing rate to be difficult. The method of dosing cobalt chloride is by using a Merriott bottle or small pump (Figure 3.2). The amount of sodium sulfite and cobalt chloride can be calculated after measuring the discharge of the river (Zogorski and Faust, 1973b);

(e) The level of dissolved oxygen immediately below the dosing point was measured and the dosing adjusted to prevent the dissolved oxygen from dropping below 3 mg/L, which is considered as the safe level for fish survival. The dissolved oxygen concentration at D_1 and D_2 are noted as well as the travel time between the two points. Time has to be synchronized at all points. Three two-way radios were used for purposes of communication between technicians placed at the sampling points and the dosing points. Several runs were carried out for each study area. Night sampling was considered, but not carried out because of the absence of aquatic plants growing in the river at both k_2 measuring locations;

(f) Important river parameters such as mean depth, slope, and mean velocity were measured. The measurements were used for the predicted k_2 equations. Mean travel time between D_1 and D_2 was measured by dosing a salt solution at D_1 and measuring the electrical conductivity every 15 seconds. The centroid of the graph of the conductivity levels over time is considered the average time traveled.

An approximate sample size for the measurements of reaeration coefficient (k_2) was calculated using a two-sided test of H_o: $\mu = \mu_o$, which used a formula as indicated below (Ott, 1993):

$$n = \frac{\sigma^2 / \Delta^2}{(z_{\alpha/2} + z_\beta)^2} \quad \text{(Equation 3.1)}$$

where,

n = sample size
μ = population mean
μ_o = sample mean
σ^2 = population variance
Δ = difference expected between μ and μ_o
z_α = probability of Type I error
z_β = probability of Type II error

As σ^2 is unknown, an estimated value from literature of 0.168 was used (Wilson and MacLeod, 1974). The probability of Type I error is taken to be 0.025 which has the z-value of 1.96 and the probability of Type II error is taken to be 0.01 which has the z-value of 2.326. The difference expected between μ and μ_o

is 0.2. The resulting sample size is 12.96 or conservatively taken at 13 as the sample size.

The amount of chemicals acquired for the study was enough for more than 13 measurements at each site, but due to unforeseen circumstances, where the amount used per experimental run was three times more than calculated (Zogorski and Faust, 1973b). Only 12 measurements were carried out at Alor Lempah and nine experimental runs were done at Sg. Serendah. Both chemicals, sodium sulfite and cobalt chloride, have to be purchased in the United States due to the amount required and local chemical companies in Malaysia carried only small, impractical amounts of these chemicals.

3.3 Field Measurement Method for Sediment Oxygen Demand (SOD)

The method used for measuring SOD for Sungai Selangor and Sg. Kerling is a modified version of the one used by Murphy and Hicks (Murphy and Hicks, 1989). The method was developed and employed by USEPA, Region IV for the "in situ" measurement of SOD. An "in situ" SOD measurement involves isolating a known volume of water and area of sediment under an opaque chamber placed on the bottom of a water body (Figure 3.3). The dimensions of the SOD chamber used by the author are shown in Table 3.1.

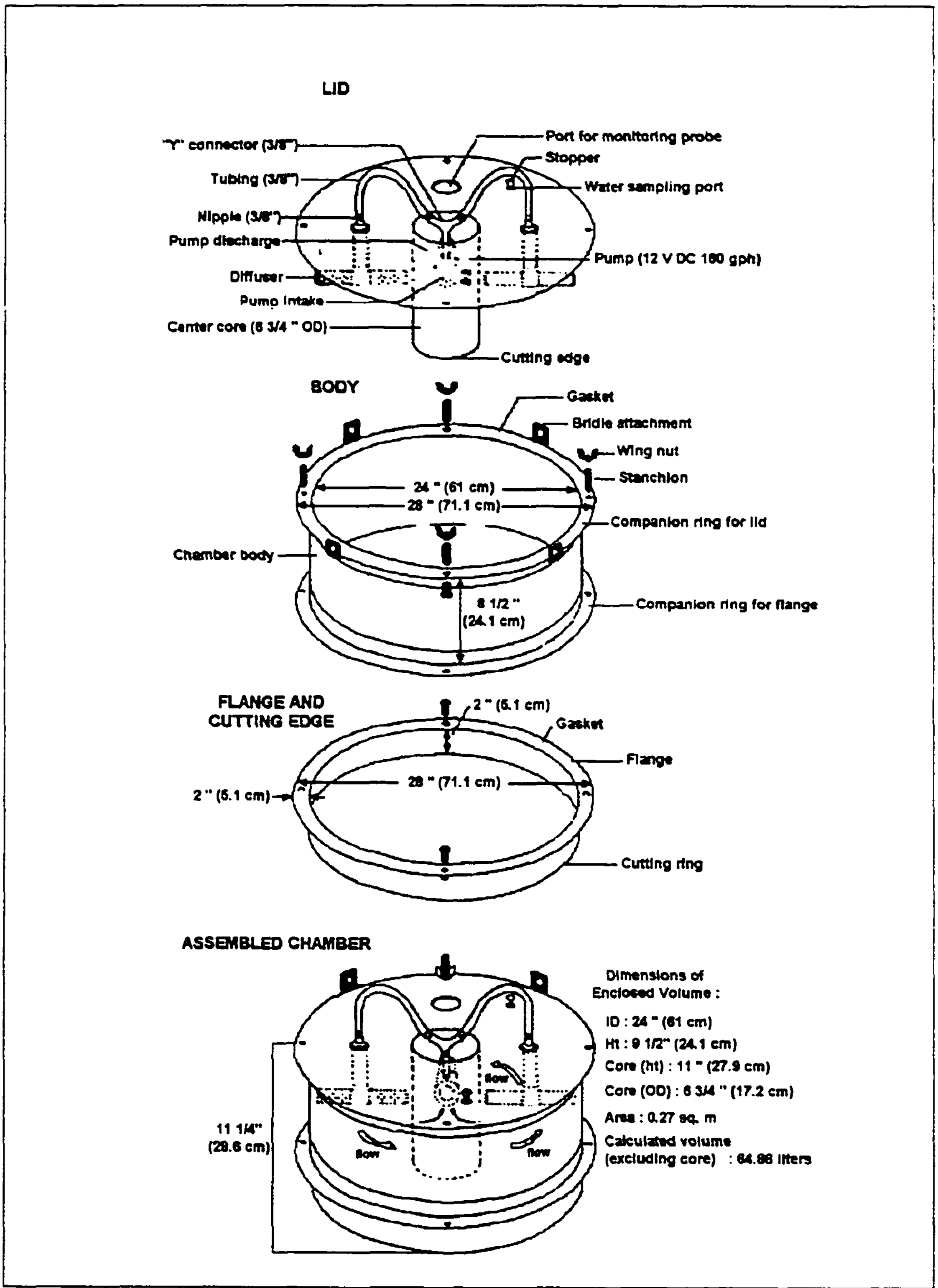

Figure 3.3. Sediment Oxygen Demand Chamber (after Murphy and Hicks, 1986)

Table 3.1. Sediment Oxygen Demand Chamber Dimensions

Measurement	Unit	Dimension
Diameter	cm	50.48
Height (from flange to top of chamber)	cm	30.64
Cross-sectional area	cm^2	2000.57
Volume	liter	61.33

The dissolved oxygen concentration in the chamber is monitored until sufficient time has passed to establish a measurable rate of change in dissolved oxygen concentration. The SOD rate is calculated using the equation:

$$SOD = 1.44 \frac{V}{A}(b_1 - b_2) \quad \text{(Equation 3.2)}$$

where,

SOD = the sediment oxygen demand (g/m^2/day)

b_1 = the rate of change of dissolved oxygen concentration inside the SOD chamber (mg/L/min)

b_2 = the rate of change of dissolved oxygen inside a blank chamber (mg/L/min)(water column respiration rate in the chamber)

V = the volume of the chamber (liters)

A = area of the chamber covering the bottom sediment (m^2)

1.44 = the constant for converting mg/L/min to g/m^2/day.

The blank chamber is a replicate of the SOD chamber, but with the bottom sealed. Therefore, the blank chamber does not measure the SOD demand, but the respiration rate of the contained water. The blank chamber is to be employed simultaneously with the actual SOD chamber (Murphy and Hicks, 1986). In the study, considering the financial constraints, only one chamber was built and the blank chamber used was the SOD chamber with a removable bottom. The "blank" chamber was employed after the SOD measurements were carried out at that particular location.

The values for b_1 and b_2 may be determined from a linear regression analysis, where b_1 and b_2 are the slopes of the curves obtained by plotting the SOD chamber and the blank chamber dissolved oxygen levels versus time, respectively.

The key factors in SOD measurement using the SOD chamber are the chamber volume, chamber surface area, rate of change of dissolved oxygen, and the time elapsed. These factors are important considerations in designing a SOD chamber.

A SOD chamber has to be practical, whereby the chamber should be easily handled and deployed, the trapped air can be purged easily, and the chamber is stable and sealed at high current flows, suitable for use on various river bottom substrates. The SOD chamber also should measure a broad range of SOD rates.

Some technical considerations that must be addressed are volume to surface area ratio, circulation pattern, and over-bottom current velocity within the sealed chamber.

The ratio of volume to surface area is an important initial consideration in chamber design. This factor would dictate several important operational considerations of the SOD chamber such as (1) the total amount of dissolved oxygen available in the chamber, (2) the range of SOD rates capable of being measured, (3) the rate of change of the dissolved oxygen detection capability, (4) the time required to conduct each SOD measurement, and (5) the resuspension effect at the start of the measurement, as the chamber is placed on the substrate (Murphy and Hicks, 1986).

Knowledge about the expected SOD rate ranges to be measured and precision and accuracy of the dissolved oxygen measuring tool are important for the calculation of the volume to surface area ratio. The chamber volume must be large enough to ensure that sufficient dissolved oxygen is available in the chamber to allow for a measurement to be carried out. Too small of a volume, a high SOD from the substrate and the resuspension during the placement of the chamber would deplete the dissolved oxygen before a sufficient number of observations.

The method of dissolved oxygen measurement within the chamber is to preferably use an electronic probe coupled to a dissolved oxygen meter as it allows the chamber dissolved oxygen to be continuously read without the need to extract water samples, which by itself would create water bubbles within the chamber. A well-maintained and calibrated dissolved oxygen probe and dissolved oxygen meter can be used to monitor dissolved oxygen concentrations as low as 0.05 mg/L every 15 minutes' interval with precision and accuracy. In the study, Yellow Springs Instruments YSI Model 57 Dissolved Oxygen meter was used with the oxygen probe of model YSI 5739 with a 100 feet cable (Yellow Springs Instruments, Yellow Springs, Ohio).

Several important operational considerations can be examined due to volume to surface area ratio of a SOD chamber. Minimizing the volume to surface area ratio, for a given SOD rate, increases the rate of change of the dissolved oxygen in the chamber. Therefore, the accuracy within of the dissolved oxygen readings is enhanced because of the larger changes occurring within the shorter time period. Increasing the volume to surface area ratio expectedly has the opposite effect and would cause dissolved oxygen rate of change to be too small to be detected within an acceptable time limit. One disadvantage of decreasing the volume to surface area ratio of the SOD chamber is that it would decrease the total dissolved oxygen in the chamber. Excessive resuspension during the placement of the chamber would cause a rapid decrease in the dissolved oxygen content of the chamber. This condition, plus a high SOD rate of the substrate could deplete the total dissolved oxygen within the chamber before a good SOD rate can be measured.

Mixing of the water within the enclosed chamber is also critical as the mixing allows for uniform dissolved oxygen concentrations throughout the chamber. Self-stirring dissolved oxygen probes are not adequate for the purpose as the attached stirrer circulates too little volume to effectively mix the whole chamber. Diffusers or immersible pumps such as the ones used for aquarium circulation purposes could fulfil the need but must be placed and oriented to achieve complete mixing within the chamber, providing reasonably uniform over-bottom velocities and at the same time the velocity is not fast enough to cause excessive disturbance and resuspension of the bottom sediments which can cause erroneous readings. The submersible pump used to circulate water in the SOD chamber for the study was Model 25D from Rule® 500 (Rule Industries Inc., Gloucester, Ma.) obtained from Grainger Incorporated. The capacity of the pump is 500 gallons per hour (gph).

Ideally, over-bottom velocity in the SOD chamber should emulate the ambient velocity of the stream being tested, but such a condition is difficult to achieve. Therefore, a fixed mixing rate with a constant over-bottom velocity low enough to avoid excessive resuspension is recommended.

The SOD chamber must be designed with a flange and a cutting edge. A vertical cutting edge and a horizontal flange stabilize and seal the chamber to the sediment surface. In soft and muddy sediment the flange limits the chamber intrusion into the sediment thus ensuring a known chamber volume.

Another important consideration that has to be examined is the prevention and detection of chamber leakage, as an effective chamber to substrate seal is essential to prevent ambient water from leaking into the chamber and altering the chamber dissolved oxygen concentration. The integrity of the chamber seal can be tested by injecting a concentrated salt solution such potassium chloride (KCl) or sodium chloride (NaCl) at the beginning of the experiment and monitoring the electrical conductivity within the chamber to detect declining values after stabilization of readings, which indicates a leak of ambient waters into the chamber. The method is applicable only in freshwater as the conductivity of brackish and salt water is too high for the method to be used. A Salinity-Conductivity-Temperature (SCT) meter Model 33 (Yellow Springs Instruments, Yellow Springs, Ohio) was used for leakage detection from the SOD chamber in the study.

The locations for the SOD samplings were at Alor Lempah and Kerling at the Department of Environment's water quality station (Station # 3516606)(Sg. Kerling) (Figure 3.1).

3.4 Field Measurement Methods for Photosynthesis and Respiration

The measurement of photosynthesis/respiration is to confirm that these activities in Sg. Selangor River are minimal. If the results either one or both of the measurement methods indicated high rate of photosynthesis, then it would be necessary to measure chlorophyll a, an algal biomass parameter, which also calculates algal photosynthesis/respiration in QUAL2E. This is because both the light-bottle/dark-bottle and the Delta methods cannot be modeled directly into QUAL2E.

As mentioned before, chlorophyll a is not one of the parameters analyzed for the Department of Environment water quality monitoring program.

3.4.1 Light-Bottle/Dark-Bottle Method

The method calculates the net production of DO by exposing the phytoplanktons to natural light conditions (the "light" chamber or bottle) and measuring the increase in DO which is the estimate of the photosynthetic gross DO production minus the DO utilized in respiration in the "dark" chamber.

The experiment was carried out at Alor Lempah using two sets of transparent glass BOD bottles and black BOD bottles (HACH Company). The bottles were filled with the river water; the initial dissolved oxygen of each was read using a DO meter (Yellow Springs Instruments YSI Model 57) and a BOD bottle probe (YSI 5730 Self-Stirring BOD bottle probe). The bottles were closed tightly and placed in the middle of the stream below the water surface tied to stakes. The experiment started at 9:40 a.m. and concluded at 6:50 p.m.. The final dissolved oxygen was read at the end of the experiment for each bottle.

3.4.2 The Delta Method

The diurnal dissolved oxygen measurement was carried out at Alor Lempah for the application of the Delta method (Chapra and Di Toro, 1991). The experiment used a DO meter (Yellow Springs Instruments YSI Model 57) with a DO probe with a long cable (YSI 5739). Other necessary data acquired include water temperature and elevation (to calculate the saturation dissolved oxygen), and photoperiod (the fraction of daylight hours over 24 hours).

In QUAL2E for Windows the chlorophyll a method is directly used. but as the water quality data within the Sungai Selangor watershed have no data for the parameter the method cannot be used. The Department of Environment long-term water quality results and communications with the Department of Chemistry indicated that the measurement of chlorophyll *a* was not carried out in all

Malaysian water quality stations. Therefore, only the light-bottle/dark-bottle method and the Delta method were used in the study.

3.5 Model Calibration and Validation Methods

3.5.1 General

The calibration and validation process is critical to determine confidence in model simulations and the overall reliability of the calibrated model. Calibration is the process of adjusting or "tuning" the parameter values to obtain an optimal agreement between the simulated observed data. During model calibration, numerical values for each of the parameters, state variable initial condition, boundary conditions etc. must be supplied for the model.

Model validation is the process of assessing the degree of reliability of the calibrated model using one or more independent data sets data i.e. not the same data used for calibration. It is a process of testing whether the model meets the objectives stated. The calibrated model parameters are held constant (i.e. hydraulic conditions, climatic conditions etc.) and the independent initial and boundary conditions (stream water quality, headwater stream discharge) are entered into the model to simulate new conditions (Martin and McCutcheon, 1999).

Calibration and validation data sets are independent measurements of the simulated dependent variables (i.e. stream discharge, depth, stream velocity, and water quality parameter concentrations) that can be used to compare and assess model performance.

If model parameters needed for calibration cannot be measured directly in the field or laboratory, estimates can be made from literature (Bowie et al.. 1985). Most of the estimates will be sufficient for the calibration, but several critical parameters must normally be iteratively modified until model simulation results match or nearly match measured calibration data. Due care has to be taken in the above process as iteratively derived critical parameters can produce improbable values physically.

The calibration and validation data used must be statistically independent. Independence requires the time series data to be free of correlation with the data collected the previous hour. day or month. Ideally. samples collected in one year are analyzed and used to calibrate a model before validation data are collected. In the present study. stream discharge and water quality data were already collected before the study, and therefore, the test of independence was not carried out.

Normally, the best method is to use extreme condition calibration and validation data sets to provide a rigorous test to the model. Therefore. in a conventional water quality modeling process. the calibration and validation data set used is for the low-flow period for the river. which has the highest possible impact on the water quality of the river. In the Sg. Selangor River study, three extreme conditions of discharge and water quality data sets were used for calibration and validation. The first was the use of actual measured low-flow discharge and water quality data sets from Rasa and Rantau Panjang. The second combination used the same water quality as in the first one except the discharge data used were from the 7Q10 low-flow analysis. The last method was to calibrate and validate using high-flow data sets. The calibration and validation combinations are shown in Table 3.2.

Table 3.2. Sg. Selangor River, Malaysia: Calibration and Validation Data Record

Discharge Data	Calibration Data Date	Validation 1 Data Date	Validation 2 Data Date
Actual Low-Flow	March 4, 1986	Jan. 13, 1987	May 17, 1989
7Q10 Low-Flow	March 4, 1986	Jan. 13, 1987	May 17, 1989
Actual High-Flow	Sept. 27, 1989	Nov.14, 1989	Nov. 12, 1993

The purpose of the several calibrations and validations exercise is to compare the results as most water quality modeling only emphasize low-flow data calibration and validations.

The calibration and validation process develops an operational model that can be used to set wasteload allocation permits or watershed management purposes. This is not by far a final process. The state of South Carolina for example, has adopted a watershed management approach whereby every five years, new data are collected and used to calibrate and validate its wasteload allocation water quality model (Martin and McCutcheon, 1999).

The output results were analyzed for the sum of squares of errors (SSE), mean of squares of errors (MSE), standard error (SE) or root-mean-square (RMS) between water quality results simulated by using each particular reaeration coefficient (k_2) calculation, and the measured water quality results for both the calibration and validation. The simulated temperature, BOD, and other parameters remained the same even though different predictive equations were used, therefore the comparative error analysis is more for the dissolved oxygen results. The equations for the statistical analysis are:

1) Sum of Squares of the Residuals

   If we take O_i for a given value (for instance, measured dissolved oxygen) and S_i denotes the predicted value or the simulated value of dissolved oxygen, then the difference between the given value O_i and the predicted value, S_i is called the error of prediction or the residual. The sum of squares of the residuals or the sum of squares of error is written as:

$$SSE = \sum_{i=1}^{N} (O_i - S_i)^2 \qquad \text{(Equation 3.3)}$$

2) Mean Sum of Squares of the Residuals

   The term is also called the mean squares of error (MSE) and can be expressed as:

$$MSE = \frac{\sum_{i=1}^{N} (O_i - S_i)^2}{N} \qquad \text{(Equation 3.4)}$$

   where n is the number of samples, which in the Sg. Selangor River study is the number of reaches (24 reaches).

3) Root Mean Square (RMS) or squared error (SE)

This is a commonly used statistical measure, which is defined as the square root of MSE and written as:

$$SE = \sqrt{\frac{\sum_{i=1}^{N}(O_i - S_i)}{N}} \qquad \text{(Equation 3.5)}$$

4) Coefficient of Variation (CV)

Populations with large means tend to indicate a higher variation than populations with smaller means. For comparison, the coefficient of variation (CV) can be used to calculate the variability about the different-sized sample means (Stednick, 1991).

In the case of the study, the coefficient of variation is defined as the quotient of the root mean square (RMS) or standard error (SE) and the mean of the measured value multiplied by 100:

$$SE = \frac{SE}{O_a} \times 100 \qquad \text{(Equation 3.6)}$$

where,

O_a = the mean of the measured observations.

Mean sum of squares of the residuals during calibration is also called the estimation error in modeling, which is a measure of how well the simulated output matches the ***same data*** it was developed from. Meanwhile, in the validation process the mean sum of squares of the residuals between the simulated and the observed historical data is called the standard error of prediction.

Another statistical analysis used for comparing pairs of measured and simulated results was regression analysis. The method is useful in evaluating the calibration and validation of a water quality model such as QUAL2E (Martin and McCutcheon, 1999).

A regression equation can be written as:

$$O_i = \alpha_i + \beta_i S_i + \varepsilon \qquad \text{(Equation 3.7)}$$

where,

O_i = observed value
S_i = simulated value
α_i = y intercept (dimensionless)
β_i = slope (dimensionless)
ε = error in simulation S_i

If the slope is not significantly different from one and the intercept more or less equal to zero, then the statistics indicate accuracy. The correlation coefficient R^2 or the coefficient of determination R should be close to one when a high degree of correlation between the simulated and observed data occurs. Both R and R^2 approach zero when the data pairs are not correlated. Therefore the desired regression analysis results should be with $\alpha_1 \approx 0$, $\beta_1 \approx 1$, and R^2 approaches 1 QUAL2E (Martin and McCutcheon, 1999).

The process of calibration and validation of QUAL2E will need other important data such as water quality and discharge data of Sg. Selangor River. This will be discussed in the following sections.

3.5.2 Water Quality Data Analysis

The water quality monitoring results obtained from the Department of Environment (DOE) were analyzed and matched with the available discharge data from the Rasa and Rantau Panjang stations. The analysis not only emphasized the low-flow periods but also high-flow periods as both were used for comparative purposes as mentioned above.

Several water quality parameters were not analyzed in the DOE water quality monitoring program for Sg. Selangor River. These parameters include nitrite, nitrate and phosphorus. Therefore, during the study period the author analyzed these parameters at several strategic locations. These water quality analyses can not replace the missing long-term water quality results, but at least give some idea of the levels of the parameters in the Sg. Selangor River system.

The water sampling used the "grab" sampling method, where an eight-liter bucket at the end of a length of rope was used to sample at mid-stream. Therefore, the sampling was surface only (non depth-integrated). The method used was similar to the one adopted by the Department of Environment for the Malaysian surface water quality monitoring program.

Several parameters were measured "in situ" such as dissolved oxygen and temperature (DO meter YSI Model 57 with YSI 5739 DO probe, Yellow

Springs Instruments, Yellow Springs, Ohio), electrical conductivity (SCT meter Model 33). and total dissolved solids (TDS) (Hach Total Dissolved Solids meter). Hach DR 2000 Direct Spectrophotometer was used to analyzed nitrite, nitrate and phosphate. The methods used were:

Table 3.3. Hach DR 2000 Chemical Analysis Methods

Parameter	Name of Method	Range (mg/L)	Comments
Nitrite	Diazotization Method	0 - 0.350 mg/L NO_2-N	USEPA approved for reporting wastewater analysis (Federal Register 44/85)
Nitrate	Nitrate MR (medium range) (Cadmium Reduction - Method 8371)	0 - 0.45 mg/L NO_3-N	
Phosphate	Reactive Phosphorus (Ascorbic Acid Method)	0 - 2.50 mg/L PO_4^{3-}	USEPA approved for reporting. Procedure equivalent to USEPA Method 365.2 and Standard Methods 4500-P-E for wastewater

3.5.3 <u>Low-Flow Analysis (7Q10)</u>

Low-flow quantiles are used in water quality management applications such as waste-load allocations and discharge permits. Low-flow analysis allows for water supply planning to calculate allowable water transfer and water withdrawals from a stream without causing detrimental effects to the ecosystem. Therefore, as water quality of a river is affected during low-flow periods. water quality models such as QUAL2E use the low-flow analysis for creating a worst condition scenario.

The commonly used low-flow index is the 7Q10, which is defined as the minimum 7-day flow that would be expected to occur every 10 years. This low-flow index is generally accepted as the standard design flow for water quality modeling (Chapra, 1997).

The method of calculating the 7Q10 incorporates several steps, the first step being procurement of a long-term flow record for the river or stream to be studied. The 7Q10 value can be used to calculate for the whole year, by season or by month. The second step is to tabulate n flow in an ascending order and ranking (i) is assigned. The cumulative probability of occurrence is calculated by:

$$p = \frac{i}{N+1} \qquad \text{(Equation 3.8)}$$

where,

p = probability of occurrence
i = rank in the low-flow data series
N = number of low-flow record

Discharge (Q) is plotted against cumulative probability of occurrence and the value of 7Q10 can therefore be determined.

An alternative method used for calculating 7Q10 low-flow is the procedure postulated by the Department of Irrigation and Drainage (DID), Malaysia (DID, 1985).

The probability distribution used the Type III Extreme Value (EV-III) distribution described by Gumbel (1954) and Jenkinson (1969).

After the acquisition of the low-flow records, the data are ranked in the ascending order. If the record is 20 years or less the Weibull plotting position is used. The formula used is the reciprocal of the cumulative probability of occurrence above as T = 1/p and therefore is written as:

$$T = \frac{N+1}{i} \qquad \text{(Equation 3.9)}$$

where,

T = the return period (years)

The Gringorten plotting position is used for records longer than 20 (DID, 1985), which is written as:

$$T = \frac{N+0.12}{i-0.44} \qquad \text{(Equation 3.10)}$$

Cunnane recommends these general extreme value distribution (GEV) formulae (Cunnane, 1978). The log values of the rankings are plotted against the EV III values, which are calculated by using the formula:

$$y = -\ln(1-\ln(1-\frac{1}{T})) \qquad \text{(Equation 3.11)}$$

As the Sg. Selangor River records are longer than 20 years (1966 to 1998), the Gringorten plotting position was use to compute the 7Q10 for both Rasa and Rantau Panjang.

3.5.4 Reaeration Coefficient (k_2) and Predictive Equations Sensitivity in QUAL2E

Sensitivity analyses are numerous tests of the response of the model to its processes, initial conditions, boundary conditions, extremes of driving variables, parameters etc. As QUAL2E is a proven, validated model, only some sensitivity analyses were carried out especially parameter sensitivity. Parameter sensitivity is a useful test to improve model performance and it also reveals which parameters must be determined with high precision and which parameters can be used with lower precision.

The sensitivity analysis that was carried out consisted of two parts; the first part was to gauge the sensitivity of k_2 when used in QUAL2E. In this case, a hypothetical river system with six reaches and 51 computational elements (Figure 3.4) was used for the purpose (Chapra, 1997). The sensitivity of SOD was also carried using the same river.

The second part was to see the sensitivity of the different predictive equations relative to the variables used for the formulations. The four common equations compared with field k_2 measurements were O'Connor-Dobbins (O'Connor and Dobbins, 1956), Churchill et al. (Churchill et al., 1962), Owens et al. (Owens et al., 1964), and Langbein-Durum (Langbein and Durum, 1967). The equations were tested for their sensitivity to the change in mean depth (H) and stream velocity (U).

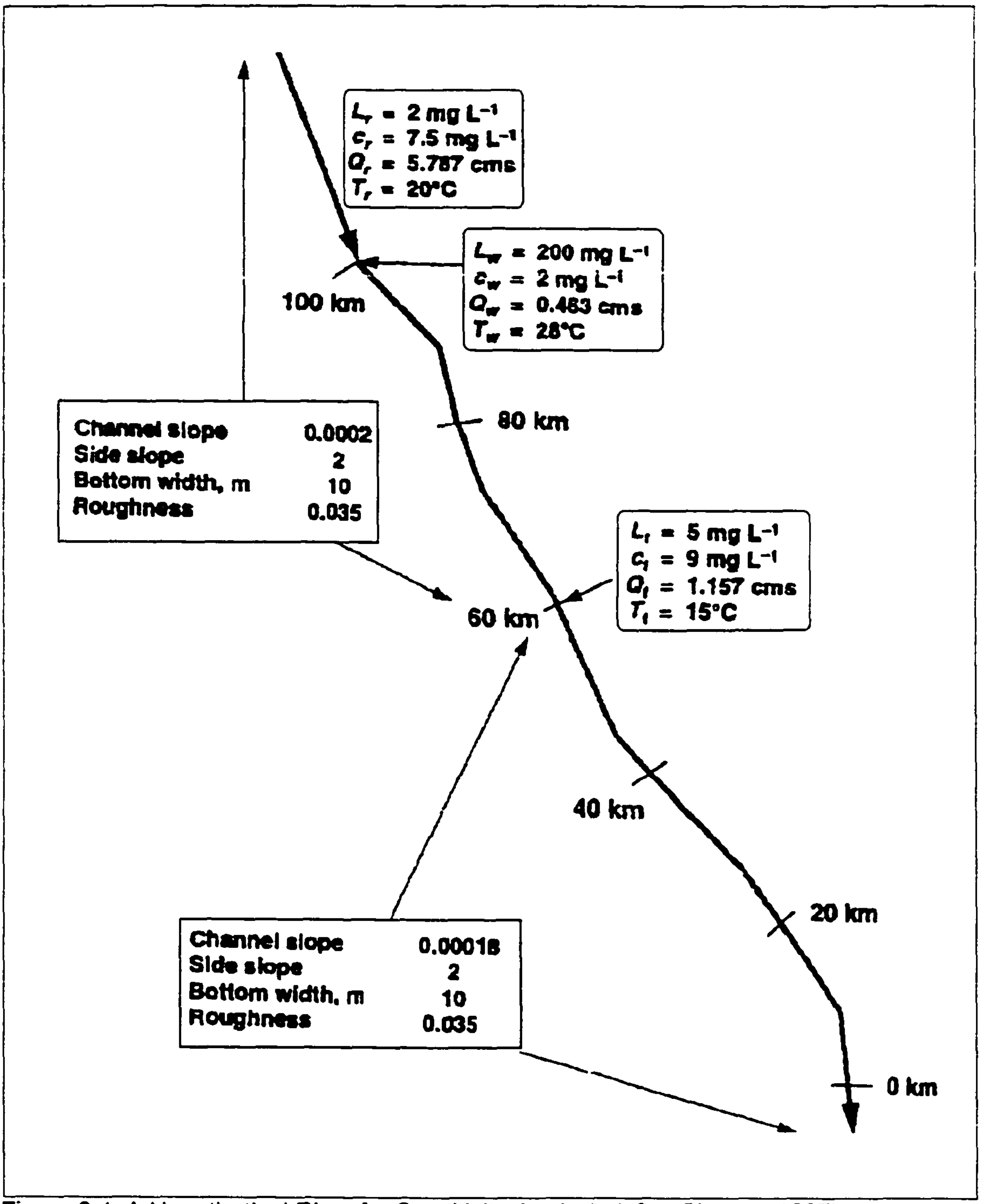

Figure 3.4. A Hypothetical River for Sensitivity Analysis (after Chapra, 1987)

Reaeration Coefficient (k_2) Sensitivity Analysis in QUAL2E due to Discharge

A hypothetical river (Chapra, 1997) was utilized to test the sensitivity of reaeration coefficient, k_2 within QUAL2E (Figure 3.4). The river, which was 102 km in length, received sewage treatment plant effluent at Kilometer 100 and tributary inflow at Kilometer 60. The river had a headwater inflow of 5.787 m^3/s (BOD_5 = 2 mg/L; DO = 7.5 mg/L; T = 20 °C), wastewater discharge at Kilometer 100 was 0.463 m^3/s (BOD_5 = 200 mg/L; DO = 2 mg/L; T = 28 °C), and the tributary inflow was 1.157 m^3/s (BOD_5 = 5 mg/L; DO = 9 mg/L; T = 15 °C).

As the QUAL2E model does not allow direct input of both velocity and depth, some changes and outside calculations had to be made. The stream channel was assumed to be rectangular instead of trapezoidal, which allowed for the input of the coefficients and exponents of velocity ($V = aQ^b$) and depth ($H = cQ^d$).

Several calculations and assumptions are as follows:

(1) The width of the river was set at 5 meters (estimated width of Sg. Selangor River at Rasa), Manning's n at 0.035, and stream surface slope at 0.001;

(2) The headwater Q was set at 5.787 m^3/s, which was later adjusted i.e. reduced at 25 percent (4.34 m^3/s), 50 percent (2.89 m^3/s), 75 percent (1.45 m^3/s) and 90 percent (0.58 m^3/s). As the channel width was fixed, the depth and stream velocity would change according to the amount of discharge;

(3) The depth, H, could be calculated using the formula:

$$H = \left[\frac{Qn(B + 2H)^{2/3}}{S^{1/2}B^{5/3}} \right]^{3/5} \qquad \text{(Equation 3.12)}$$

where,

H = depth (m)

Q = discharge (m^3/s)

n = Manning's n

B = width (m)

S = stream surface slope (dimensionless)

This circular formula could be iterated using a spreadsheet such as Excel. When H is derived for each reach, velocity can also be calculated for the reach.

(4) The natural log values of total Q, velocity and depth from the spreadsheet were used for calculating the coefficients and exponent for Q as related to velocity and depth. This could be done using the regression analysis of the natural log values. Basically, the relationships are:

$$V = aQ^b \qquad \text{(Equation 3.13)}$$

$$H = cQ^d \qquad \text{(Equation 3.14)}$$

Therefore, to get the value of a, b, c and d, the following (as an example) equation was used:

$$\ln V_i = \ln a + b \ln Q_i \qquad \text{(Equation 3.15)}$$

where,

i = number of reaches

And using regression analysis for the data sets indicated above:

$\ln a$ = intercept (i.e. $a = e^{(intercept)}$)
b = slope

The resulting coefficients and exponents were used as inputs for the Hydraulic Data section of QUAL2E (Table 4.1):

(5) The headwater discharge had to be changed according to the values indicated in (2) above. The wastewater discharge at Kilometer 100 and tributary discharge at Kilometer 60 were kept constant. For each change in the headwater discharge, all of the predictive equations studied were used, one at a time.

The results from the above sensitivity analysis compared the simulated dissolved oxygen for the predictive equations as the discharge was reduced.

Reaeration Coefficient (k_2) Sensitivity Analysis in QUAL2E (Single Measured Coefficient)

In another sensitivity analysis, the reaeration coefficient effect on the dissolved oxygen was tested by fixing a central value of k_2 at 2/day and two other values were used for comparative purposes. These k_2 values were ±10 percent, ±25 percent and ±50 percent of 2/day.

These values were incorporated into the hypothetical river above using the single measured reaeration coefficient option in the QUAL2E instead of the predictive equations. The discharge was fixed at 5.787 m^3/s.

Sediment Oxygen Demand (SOD) Sensitivity Analysis in QUAL2E

SOD data from Fox River, Illinois (Butts and Evans, 1978) was used for the testing of the sensitivity of the variable in QUAL2E. The average value was used and compared to plus or minus one standard deviation and two standard deviations.

Predictive Equations Sensitivity in QUAL2E

The equations mentioned above are four of the six predictive equations used in the QUAL2E model. The other two equations are Thackston and Krenkel and Tsivoglou-Wallace, which use variables such as stream surface slope in addition to stream velocity and mean depth.

The formulae for the equations used shown below are the same ones as in Section 2.3.5:

1. O'Connor-Dobbins (1956)

$$k_2 = 3.93\frac{U^{0.5}}{H^{1.5}} \qquad \text{(Equation 3.16)}$$

where,

k_2 = reaeration coefficient (day^{-1})
U = stream velocity (m/s)
H = mean depth (m)

The equation for streams with low velocities and isotropic conditions. The constant, 3.93, was derived from D_m as indicated in Equation 1.14 (page 29). The molecular diffusion coefficient (D_m) was 1.806 x 10^{-4} m^2/day when the water temperature is at 20 °C.

2. Churchill et al. (1962)

$$k_2 = 5.026\frac{U^{0.969}}{H^{1.673}} \qquad \text{(Equation 3.17)}$$

3. Owens et al. (1964)

$$k_2 = 5.35\frac{U^{0.67}}{H^{1.85}} \qquad \text{(Equation 3.18)}$$

4. Langbien-Durum (1967)

$$k_2 = 5.14\frac{U}{H^{1.33}} \qquad \text{(Equation 3.19)}$$

A spreadsheet was used to compare changes for each variable while the other was held constant. During the sensitivity analysis of stream velocity, the depth (H) was fixed at 0.5 m and the minimum velocity started at 0.05 m/s which was increased by 10 percent increments until about 3 m/s. Meanwhile, stream velocity was fixed at 0.1 m/s for a sensitivity analysis of mean depth (H). Depth started at 0.2 m, and was increased in intervals of 10 percent until about 3 m.

3.5.5 QUAL2E Calibration and Validation Methods for Comparison of Predicted to Measured Reaeration Coefficients (k_2)

Together with the calculated k_2, SOD and other parameters, QUAL2E was calibrated for Sungai Selangor using the measured parameters above and observed historical data from 1986 to 1990. Major water quality variables used for calibration and later simulated in the model are:

1. Dissolved oxygen
2. Temperature
3. Biochemical oxygen demand (BOD)
4. Ammonia as N
5. Nitrite as N
6. Nitrate as N
7. Organic phosphorus as P
8. Dissolved phosphorus as P
9. Total dissolved solids
10. Total suspended solids
11. Fecal coliforms

The reach division and presentation of Sg. Selangor River in QUAL2E are shown in Table 3.4 and Figure 3.5, respectively, which includes all the major tributaries in the Sg. Selangor River watershed. The process was greatly assisted by the presence of maps acquired from the Malaysian Survey Department (1:50,000 scale) (Director of National Mapping, Malaysia, 1993).

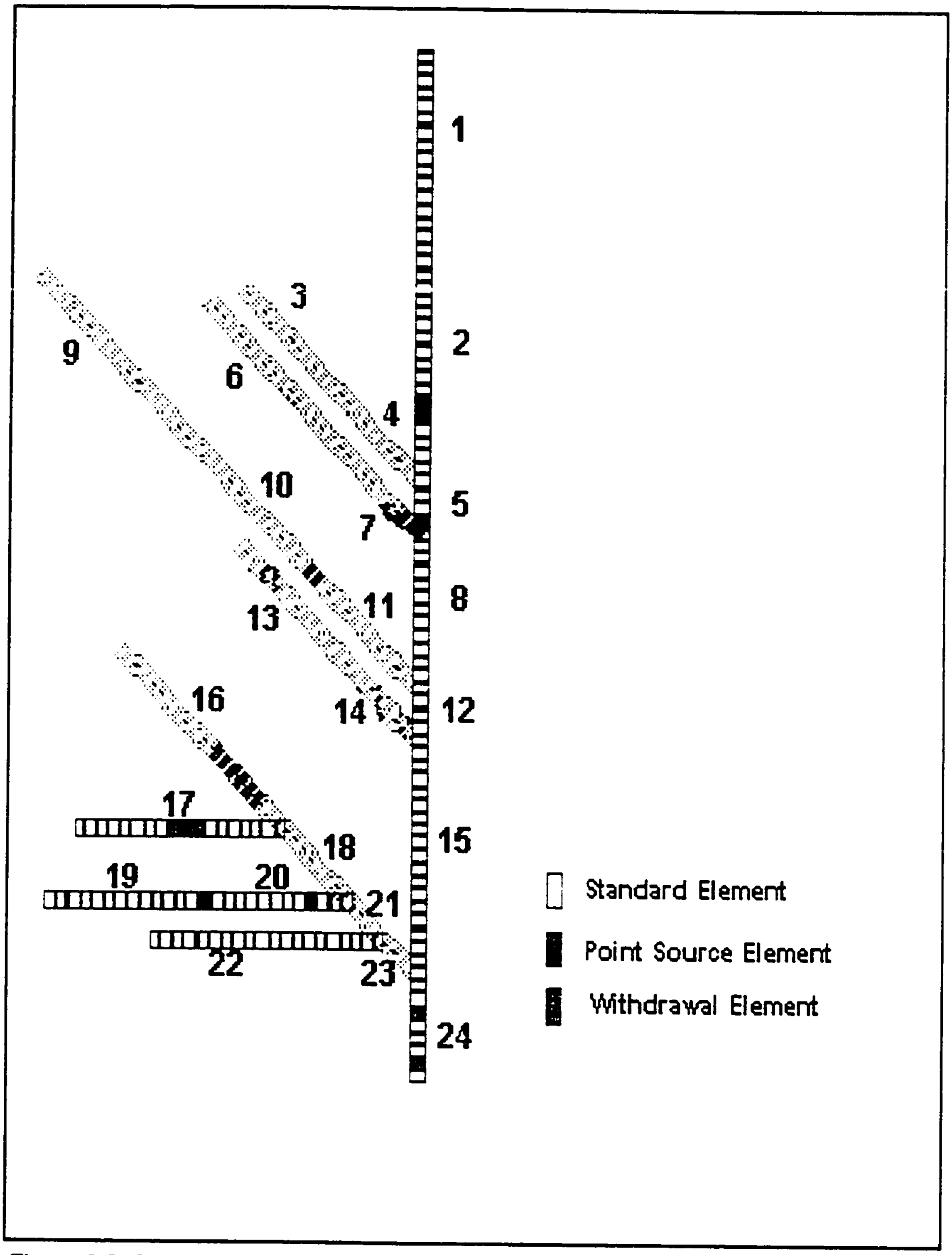

Figure 3.5. Sg. Selangor River, Malaysia: Reach Presentation

Table 3.4. Sg. Selangor River, Malaysia: Reach Division.

Reach Number	Reach Name	River Name	Starts (River km)	Ends (River km)
1	Ulu Selangor 1	Sg. Selangor	295	275
2	Ulu Selangor 2	Sg. Selangor	275	261
3	Sg. Rening 1	Sg. Rening	22	4
4	Sg. Rening 2	Sg. Rening	4	0
5	Sg. Rening confluence to Sg Batangkali confluence	Sg Selangor	261	257
6	Sg. Batangkali 1	Sg. Batangkali	26	6
7	Sg. Batangkali 2	Sg. Batangkali	6	0
8	Sg. Batangkali confluence to Sg. Kerling confluence	Sg. Selangor	257	245
9	Sg. Kerling 1	Sg. Kerling	46	26
10	Sg. Kerling 2	Sg. Kerling	26	6
11	Sg. Kerling 3	Sg. Kerling	6	0
12	Sg. Kerling confluence to Sg. Buluh confluence	Sg. Selangor	245	241
13	Sg. Buluh 1	Sg. Buluh	22	4
14	Sg. Buluh 2	Sg. Buluh	4	0
15	Sg. Buluh confluence to Sg. Rawang confluence	Sg. Selangor	241	223
16	Ulu Rawang	Sg. Rawang	36	16
17	Sg. Serendah	Sg. Serendah	18	0
18	Sg. Serendah confluence to Sg. Kundang confluence	Sg. Rawang	16	8
19	Sg. Kundang 1	Sg. Kundang	26	6
20	Sg. Kundang 2	Sg. Kundang	6	0
21	Sg. Kundang to Sg. Guntung confluence	Sg. Rawang	8	4
22	Sg. Guntung	Sg. Guntung	20	0
23	Sg. Guntung confluence to Sg. Rawang confluence	Sg. Rawang	4	0
24	Rantau Panjang	Sg. Selangor	223	215

The maps also helped in calculating the percentage of each sub-watershed relative to the main Sg. Selangor River watershed (Table 3.5). The data allowed for the estimation of the streamflow of the sub-watersheds, as only two major gauging stations with long-term data are present for Sg. Selangor River (at Rasa and Rantau Panjang). The modeling of Sg. Selangor River covered all the upstream tributaries until the main bridge at Rantau Panjang, which is the saline-fresh water boundary for the river.

Table 3.5. Sg. Selangor River and its Main Tributaries, Malaysia.

River name	Watershed Area (km^2)	Percent of Sg. Selangor watershed (%)
Sg. Selangor (until Rantau Panjang)	1577.50	100
Ulu Sg. Selangor (until Sg. Rening)	246.20	15.61
Sg. Rening	68.33	4.33
Sg. Batangkali	211.98	13.44
Sg. Kerling	253.45	16.07
Sg. Buloh	84.85	5.38
Sg. Rawang	413.73	26.23

The Sg. Rawang River watershed is the largest sub-watershed for Sg. Selangor River and also the most developed, with large industrial areas and housing development especially surrounding the Rawang township. Therefore it is prudent to concentrate on the Sg. Rawang River tributaries, which was not done on other Sg. Selangor River sub-watersheds (Table 3.6).

Table 3.6. Sg. Rawang River and its Main Tributaries, Malaysia.

Tributary name	Watershed Area (km^2)	Percent of Sg. Rawang watershed (%)
Sg. Rawang	413.73	100
Ulu Sg. Rawang (until Sg. Serendah)	86.76	20.97
Sg. Serendah	71.05	17.17
Sg. Kundang	144.58	34.95
Sg. Guntung	67.30	16.27

During the modeling, Sg. Selangor River was divided into 24 reaches with each element in the model representing a one-kilometer stretch (Table 3.4 and Figure 3.5). Originally subdivided into 17 reaches, it was increased to 24, as it was hard to "squeeze" various data into a single reach especially in an urban, industrialized area. It was decided to not further subdivide the watershed (i.e. half a kilometer per element) as it would unrealistic because of the lack of detailed data such as stream width and depth to differentiate between one element to the next.

The steady-state option was used with the simulation started on July 1 (Day 182) which is within the dry, low-flow season for this region of the country. The stream channel was considered as rectangular, not trapezoidal as this was the best explanation for Sg. Selangor River and its tributaries. The decision was reached after an extensive survey of the Sg. Selangor River watershed during the study and on the advice of the Drainage and Irrigation Department, the river authority in Malaysia (Low Koon Sing, 1998).

Discharge contributions from sub-watersheds were estimated using Excel spreadsheet and later fine-tuned by trial and error using QUAL2E such that the resulting discharge at Rasa and Rantau Panjang during model simulation was similar to the actual data of discharge at the stations. Tables 3.5 and 3.6 show the examples of the discharge estimation used for the modeling.

Table 3.7. Discharge Estimation Example for Sg. Selangor River, Malaysia (May 19, 1989).

Actual Discharge (Rantau Panjang) =		49.37 m^3/s
Actual Discharge (Rasa) =		9.84 m^3/s
Watershed Name	**Ratio to Sg. Selangor watershed**	**Estimated Discharge (m^3/s)**
Ulu Sg. Selangor	0.1561	7.7067
Sg. Kerling	0.1607	7.9338
Sg. Rening	0.0433	2.1377
Sg. Batangkali	0.1344	6.6353
Sg. Buluh	0.0538	2.6561
Sg. Rawang	0.2623	12.9498
Total Discharge (estimated) =		40.0193
Estimated Discharge (Rasa) (Ulu Sg. Selangor + Sg. Rening) =		9.8444
Ratio of estimated/actual discharge at Rasa =		1.0004

Table 3.8. Discharge Estimation Example for Sg. Rawang River, Malaysia (May 19,1989).

Watershed Name	Ratio to Sg. Rawang watershed	Estimated Discharge (m^3/s)
Ulu Sg. Rawang	0.2097	2.7156
Sg. Serendah	0.1717	2.2235
Sg. Kundang	0.3495	4.5259
Sg. Guntung	0.1627	2.1069
Estimated Total Discharge =		11.5719

The calibration and validation process was carried out with two different simulations. The first one was where only temperature, dissolved oxygen and biochemical oxygen demand (BOD) were simulated, and the second simulation involved the three parameters mentioned above and the remaining parameters as listed on page 95.

Rates and Constants

BOD decay (k_d) and BOD settling (k_s) are estimated using the formulae indicated below (Chapra, 1997):

$$k_d = 0.3\left(\frac{H}{8}\right)^{-0.434} \qquad 0 \leq H \leq 8 \text{ ft } (2.44 \text{ m}) \qquad \text{(Eq. 3.20a)}$$

$$k_d = 0.3 \qquad H > 8 \text{ ft } (2.44 \text{ m}) \qquad \text{(Eq.3.20b)}$$

$$k_s = \frac{v_s}{H} \qquad \text{where } v_s \text{ is the settling velocity} \qquad \text{(Eq. 3.21)}$$

In the case of Sg. Selangor River, the settling velocity was calculated to be 0.3 m/day.

Other rates and constants used were the default values within the QUAL2E, which were based on rates and constant recommended by the USEPA (Zison, 1978; Bowie et al., 1985). The calibration data set and the temperature coefficients used in QUAL2E for the Sg. Selangor River study are shown in Tables 3.9 and 3.10 respectively.

Table 3.9. Sg. Selangor River, Malaysia: Calibration Data Set.

Parameter	Unit	Value
Temperature	°C	25
BOD decay (k_1)	day^{-1}	0.3
Reaeration coefficient (k_2)	day^{-1}	24.52 (Sg. Selangor) 57.88 (Sg. Serendah)
Discharge	m^3/s	7.66
Nitrogen inhibition coefficient	-	0.6
Hydraulic coefficient a	-	0.431
Hydraulic coefficient b	-	0.132
Hydraulic coefficient c	-	0.831
Hydraulic coefficient d	-	0.93

The initial conditions of the river used for the calibration of Sg. Selangor River were the discharge and water quality data for March 4, 1986. Meanwhile, two validations were carried out with the discharge and water quality data from January 13, 1987 and May 17, 1989. Unfortunately, not all major tributaries or reaches have monitoring stations for water quality, notably, Sg. Rawang River which is not only the largest sub-watershed, but also is the most developed. The supplementary water quality analysis carried out by the author during the field study helped (Table 4.12), but some estimation of water quality parameters using professional judgement therefore had to be carried out at certain reaches.

Table 3.10. Temperature coefficients for QUAL2E calibration of Sg. Selangor River, Malaysia.

Parameter	Temperature coefficient (θ)
BOD	
BOD decay (k_1)	1.047
BOD settling	1.024
DO	
SOD uptake	1.060
Reaeration coefficient (k_2)	1.024
Nitrogen	
Organic N decay	1.047
Organic N settling	1.024
Ammonia decay	1.083
Ammonia source	1.074
Nitrite decay	1.047
Phosphorus	
Organic P decay	1.047
Organic P settling	1.024
Dissolved P source	1.074
Non-conservative parameter	
Decay	1.000
Settling	1.024
Source	1.000
Coliform decay	1.047

During simulation, all predictive equations for the reaeration coefficient (k_2) available as options in the QUAL2E were used (Langbein-Durum, Churchill et al., Owens et. al, Thackston-Krenkel, Tsivoglou-Wallace and O'Connor-Dobbins) for the comparison with the use of the single coefficient k_2 as measured above at Alor Lempah (Sg. Selangor River) and Sg. Serendah.

Most pollution sources are from human settlements such as towns and also the industrial areas within or near the urban areas. Therefore, the point source locations are considered to be close to the position of towns and industrial sites, and the reaches or elements next to these sites are to be the ones receiving the pollution loads.

The sewage loading for the towns used the projected population in Year 2000 and other related data such as the Runoff Factor (Equation 2.1) discussed in Section 2.3.4 and the use of Tables 2.2 to 2.5. Another reference was also used for this purpose (Metcalf and Eddy, Inc., 1991). The resulting estimated effluent discharge (Table 3.11) and its quality were used in the water quality modeling (DOE, 1994).

Table 3.11. Actual and Projected Town Populations in Sg. Selangor River (Malaysia) Watershed and Related Sewage Loading.

Town	1980	1990	2000 (projected)	Year 2000 Estimated sewage (m^3/s)*
Kuala Kubu Baru/Ampang Pecah	3,817	6,806	7,007	0.0154
Batangkali	6,501	4,174	3,868	0.0085
Kerling	2,950	2,280	1,732	0.0038
Rasa	1,670	1,614	1,534	0.0034
Serendah	7,420	6,498	5,597	0.0123
Rawang	21,690	28,980	38,077	0.0837

*based on 0.19 $m^3 capita^{-1} day^{-1}$ (DOE, 1994)

The longitudinal dispersion constant used for the simulation is the QUAL2E default value of 60 for all reaches. Meanwhile, the model's Manning's n default value is 0.035 but a personal communication with an engineer at the Malaysian Drainage and Irrigation Department recommended the value of 0.02 for Sg. Selangor River and its tributaries (Low Koon Sing, 1998).

River Hydraulic Data

The natural log values of total discharge, velocity and depth measured at several locations during various flow conditions were used for calculating the hydraulic conditions of Sg. Selangor River. The data was entered into the spreadsheet and the coefficients and exponents were used to calculate Q as related to velocity (V) and depth (H) (Equations 3.13 and 3.14). The calculation method was discussed in Section 3.5.4.1 and the results shown in Table 4.1.

The time traveled between the upstream and the downstream station was measured before the reaeration coefficient experiment using sodium chloride (NaCl) dosing and the electrical conductivity was measured at the downstream station until it returned to the normal stream conductivity level. The time needed to reach the centroid of the electrical conductivity curve is assumed as the average time traveled from the upstream to the downstream station (Figures 3.6 and 3.7). Experimenters have used both the fluorescent dye such as Rhodamine WT and potassium chloride (KCl) for this purpose (Zogorski and Faust, 1973b). The choice of using sodium chloride was because it was available in most small grocery stores.

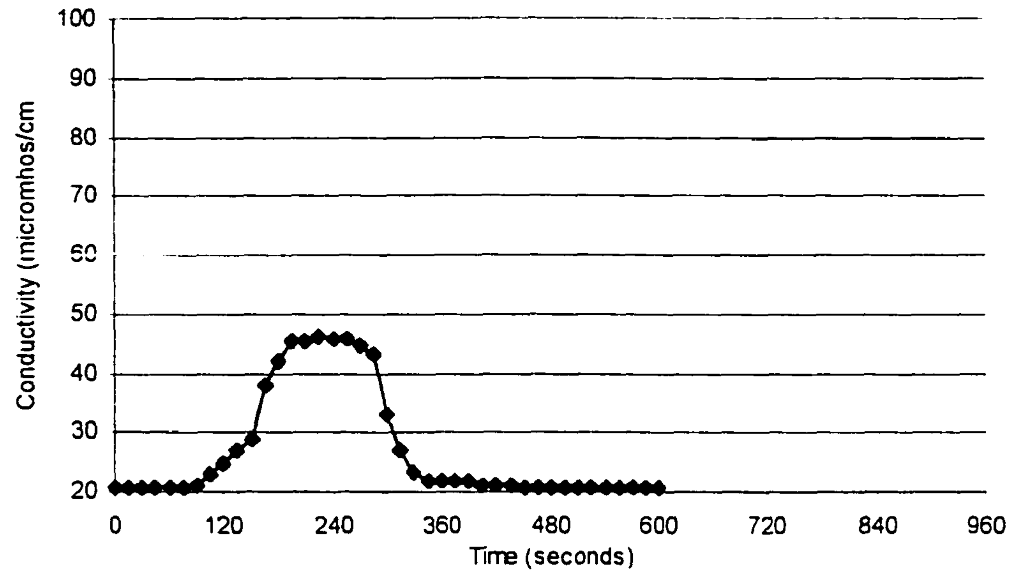

Figure 3.6. Conductivity Profile Example Using NaCl for Mean Travel Time Calculation at Alor Lempah (Sg. Selangor River, Malaysia).

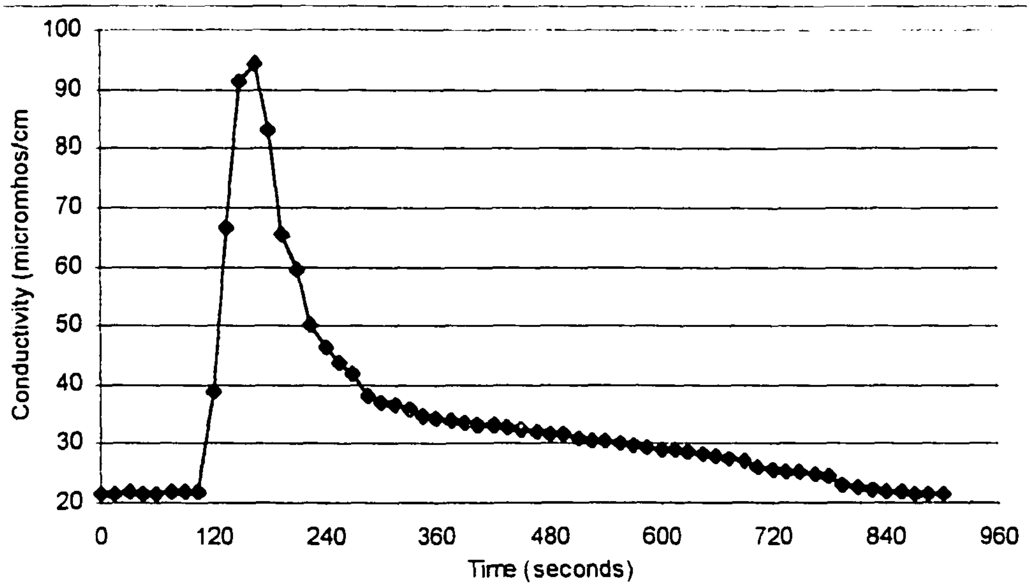

Figure 3.7. Conductivity Profile Example Using NaCl for Mean Travel Time Calculation at Sg. Serendah River, Malaysia.

CHAPTER 4

STUDY RESULTS

4.1 Introduction

Due to the sizable amount of data resulting from field measurements, sensitivity analysis, and modeling, the author has compiled them in the Appendices instead of the main text, citing only examples of the results in the main text itself.

4.2 Sg. Selangor River Hydrogeometry

Sg. Selangor River hydrogeometry measurements were measured at Alor Lempah and at one of its tributary, Sg. Serendah, where the measurements of field reaeration coefficients were carried out. The results are presented below in Table 4.1, where the coefficients and exponents were derived from discharge relationships to velocity ($V = aQ^b$) and depth ($H = cQ^d$). The Manning's n recommended by the Drainage and Irrigation Department (DID) was 0.02 (Low Koon Sing, 1998) and the stream slopes at Alor Lempah and Sg. Serendah were calculated from topographic maps to be 0.0001.

The hydrogeometry measurements were carried out only four times at each location due to the time constraint. These measurements were carried out only during a low-flow period. Some measurements during high-flow period would be ideal to give a better discharge to velocity and discharge to depth relationships.

Table 4.1. Sg. Selangor River, Malaysia: Hydrogeometry at Alor Lempah and Sg. Serendah River.

River Name	Date of Discharge Measurement	Total Q (m^3/s)	Average Depth (m)	Average Velocity (m/s)	Velocity coefficient (a)	Velocity exponent (b)	Depth coefficient (c)	Depth exponent (d)
Sg. Selangor (at Alor Lempah)	July 20, 1998	4.627	0.342	0.519	0.431	0.132	0.083	0.930
	August 11, 1998	5.092	0.364	0.542	-	-	-	-
	August 12, 1998	12.690	0.842	0.600	-	-	-	-
	August 13, 1998	7.990	0.630	0.569	-	-	-	-
Sg. Serendah (at Serendah Town)	August 17, 1998	1.696	0.738	0.330	0.275	0.396	0.657	0.279
	August 18, 1998	0.752	0.632	0.260	-	-	-	-
	August 21, 1998	0.561	0.543	0.210	-	-	-	-
	August 23, 1998	1.922	0.802	0.360	-	-	-	-

4.3 Results of Field Measurement of Reaeration Coefficient (k_2)

Similar to the measurement of sediment oxygen demand, the measurement of the actual reaeration coefficient using the disturbed equilibrium method was carried out only at two places, Alor Lempah (Sg. Selangor River proper) and Sg. Serendah. The term "disturbed equilibrium" is used as the dissolved oxygen equilibrium of the stream water is basically disrupted by the addition of sodium sulfite and cobalt chloride catalyst, which lowered the dissolved oxygen concentration.

The choice of measuring the reaeration coefficient at Sg. Serendah instead of Sg. Kerling was because Sg. Kerling did not have all of the accessibility needed for the siting of the dissolved oxygen measuring stations such as bridges, roads or footpaths. At the same time sediment oxygen demand measurement was not done at Sg. Serendah because of the relatively high stream velocity, which would easily upset the placement of the SOD chamber, and the stream bottom was full of concrete and cinder rubble as the site is near a main road and the Malaysian Railway trunk line. While the measured reaeration coefficient at Alor Lempah represents the wider Sg. Selangor River proper, the Sg. Serendah measurements represent the narrower, faster tributaries. The average results for each location were used in all the reaches depending on the river characteristics at the particular stretch. The dissolved oxygen profiles for the upstream and downstream of a sample run at each location are shown in Appendix D (Figures D-1 to D-42). Examples of these dissolved oxygen profiles during the disturbed equilibrium study are shown in Figures 4.1 to 4.4. The example used for Alor Lempah is from Run 5 from a total of 12 runs, and the example chosen for Sg. Serendah is from Run 6 from a total of 9 runs. The upstream (Point 1) results are from the dissolved oxygen measurements just after the chemical application while the downstream results are from the second point (Point 2).

The reaeration coefficient measured in the study is the recovery of dissolved oxygen between Point 1 and Point 2.

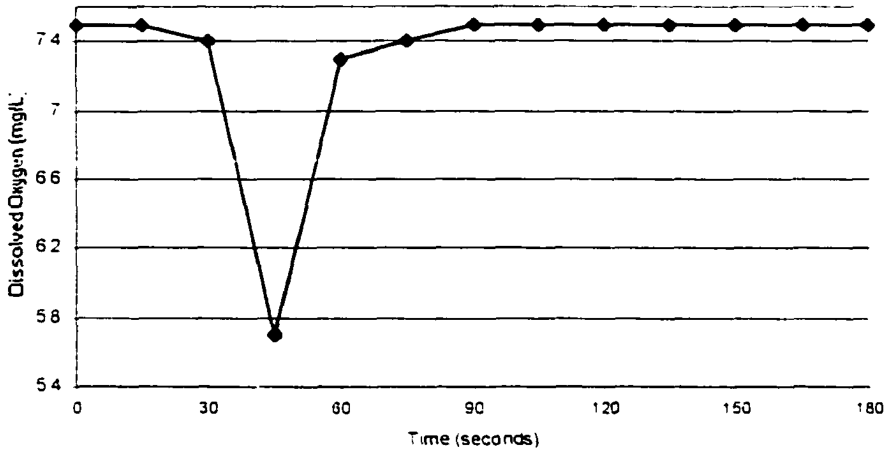

Figure 4.1. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 5) (upstream), Sg. Selangor River, Malaysia.

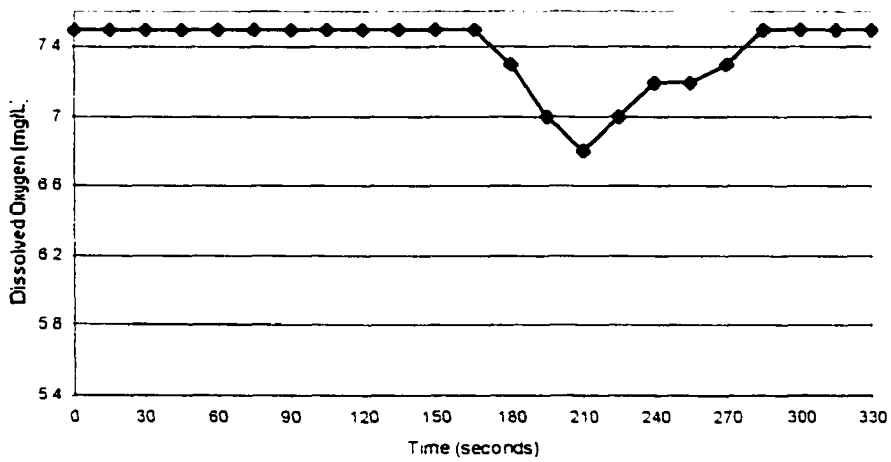

Figure 4.2. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 5) (downstream), Sg. Selangor River, Malaysia.

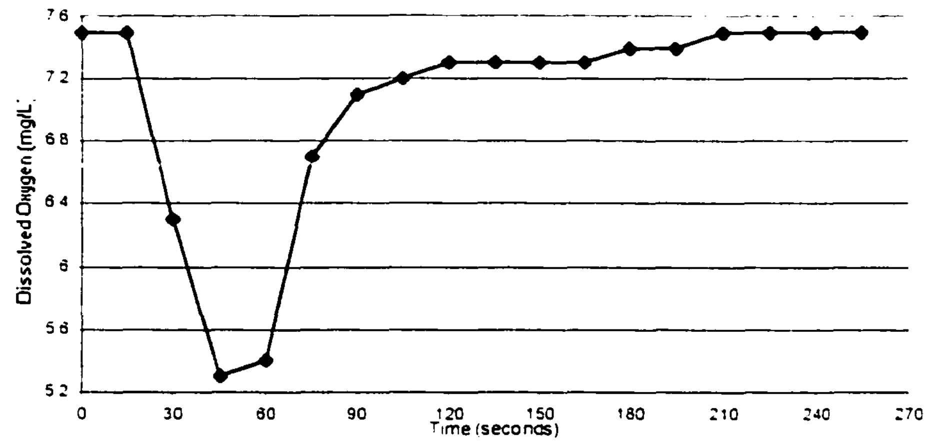

Figure 4.3. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 6) (upstream), Serendah, Malaysia.

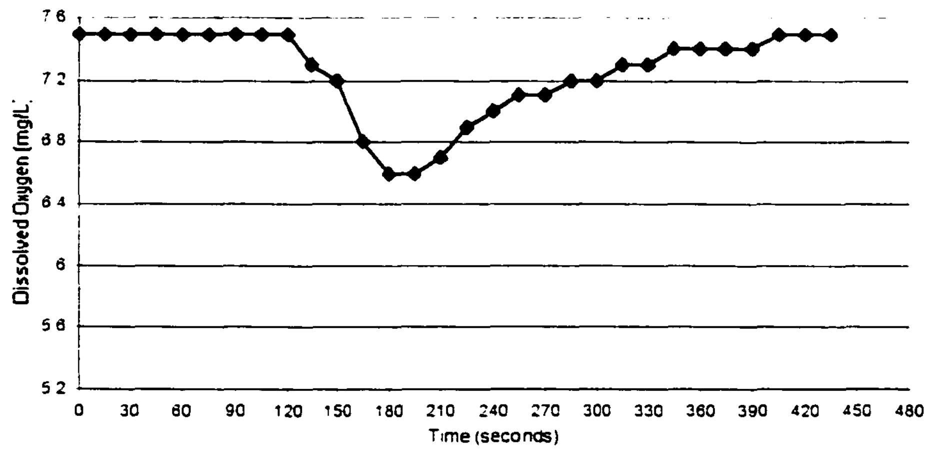

Figure 4.4. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 6) (downstream), Serendah, Malaysia.

When atmospheric reaeration is the only process affecting the dissolved oxygen concentration in the stream water, the computation of reaeration coefficient uses Equation 1.26. Meanwhile, if organic pollution is present, and other sources and sinks of dissolved oxygen become significant, the equation for calculating the k_2 (in log base e) is:

$$k_2 = \frac{1}{\Delta t} \ln \frac{C_1 - C'_1}{C_2 - C'_2} \qquad \text{(Equation 4.1)}$$

where,

C_1 and C_2 are the normal dissolved oxygen levels at the upstream and downstream stations before the chemicals were added (mg/L)

C'_1 and C'_2 are the dissolved oxygen levels after the chemicals were added (mg/L)

Δt is the time of travel between the upstream station to the downstream station (days)

Both the reaeration coefficient study sites at Alor Lempah and Sg. Serendah were absent of organic pollution; therefore Equation 1.26 was used to calculate k_2:

$$k_2 = \frac{\ln D_2 - \ln D_1}{\Delta t}$$

The averaged values of D_1 and D_2 rather than instantaneous values were used because the use of a single lowest point tends to give a large range of unrealistic results of reaeration coefficient (Zogorski and Faust, 1973a).

The Sg. Selangor River reaeration coefficient averaged at 24.52/day for 12 chemical runs (Table 4.2) while for Sg. Serendah the average k_2 was 57.88/day for nine runs (Table 4.3).

Table 4.2. Measured Reaeration Coefficient Results at Alor Lempah (Sg. Selangor River, Malaysia).

Run Number	Reaeration Coefficient Measured (day^{-1})
1	30.80
2	24.00
3	22.88
4	19.70
5	25.70
6	25.44
7	29.87
8	17.94
9	21.96
10	25.99
11	30.76
12	19.37
Mean	24.52

Table 4.3. Measured Reaeration Coefficient Results at Sg. Serendah River, Malaysia.

Run Number	Reaeration Coefficient Measured (day^{-1})
1	71.67
2	57.40
3	66.77
4	67.96
5	42.72
6	51.83
7	38.82
8	65.89
9	60.55
Mean	57.88

The results for the field measurements of reaeration coefficient (k_2) at Alor Lempah and Sg. Serendah indicated the variability of the readings. The standard deviation of the averaged reaeration coefficient for Sg. Selangor River at Alor Lempah is calculated to be at 4.41/day. Meanwhile the Sg. Serendah standard deviation for the averaged reaeration coefficient was calculated to be at 11.57/day.

4.4 Results of Field Measurement of Sediment Oxygen Demand (SOD)

Sediment oxygen demand (SOD) rates were measured only at Alor Lempah (Sg. Selangor River proper) and at Sg. Kerling. This is due to time and financial resource constraints, especially at the lower reaches of Sg. Selangor River where boats and scuba equipment would have been needed for the placement of the chamber due to the depth of the river. The SOD results measured at Alor Lempah and Sg. Kerling were averaged and used for all the tributaries depending on the physical characteristics such as sediment type. An example of the measurement results are shown in Figures 4.5 to 4.7, while the averaged results are indicated in Table 4.4. These figures indicated that the reduction of the dissolved oxygen within the chamber was linear (Alor Lempah, $R^2 = 0.97$) (Sg. Kerling, $R^2 = 0.87$).

The dissolved oxygen in the water enclosed within the chamber was read about ten minutes after its placement on the riverbed. This was to allow for the settling of the disturbed sediment. The purpose of the blank chamber readings, where the bottom of the SOD chamber was sealed and the chamber was filled

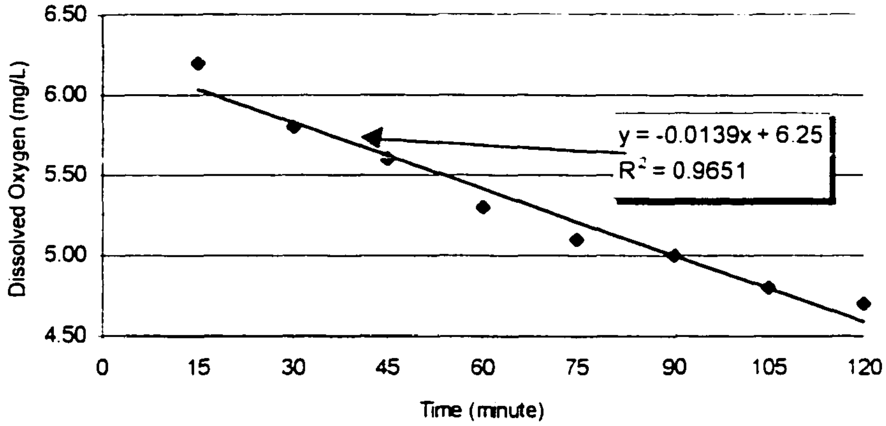

Figure 4.5. A Sediment Oxygen Demand Measurement at Alor Lempah (Sg. Selangor River proper), Malaysia.

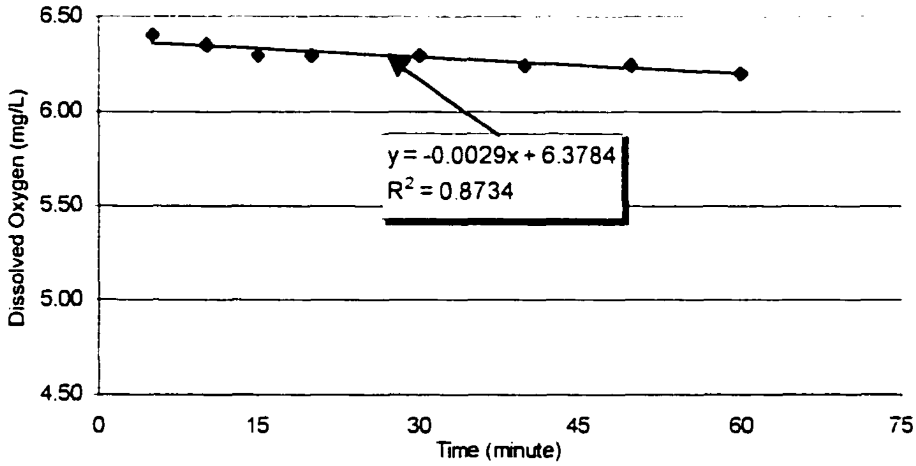

Figure 4.6. A Sediment Oxygen Demand Measurement at Sg. Kerling River, Malaysia.

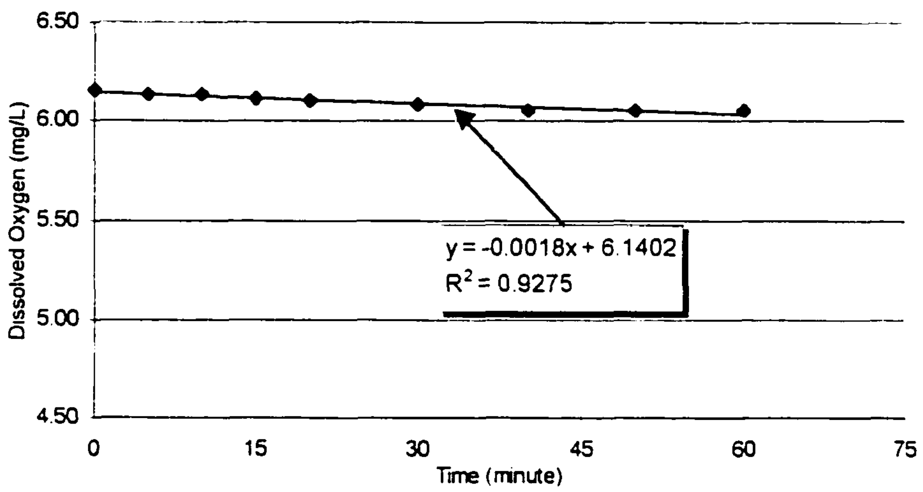

Figure 4.7. A Sediment Oxygen Demand Measurement at Sg. Kerling River (empty chamber), Malaysia.

with the river water on location, was to measure the respiration rate of the water column. The SOD rate was calculated using Equation 3.2 (page 71), where the values of b_1 and b_2 can be obtained by linear regression.

Table 4.4. Sediment Oxygen Demand (SOD) Results for Sg. Selangor River, Malaysia.

Site	Average SOD Result (g/m²/day)
Alor Lempah (Sg. Selangor proper)	4.230
Sg. Kerling	0.384

The benthic substrates in both SOD measurement locations were sandy, but as Table 4.4 above indicates the SOD rate at Alor Lempah was 11 times greater than at Sg. Kerling. There are no viable explanations for this large discrepancy.

SOD rates of tributaries with high growth such as Sg. Rawang River, by an educated guess would be higher than Alor Lempah, which did not have any major polluting source. This was due to the effluent discharges from industrial areas and partially treated domestic wastes from housing estates.

4.5 Results of Field Measurement of Photosynthesis and Respiration

4.5.1 Light-Bottle/Dark-Bottle Method Results

The result of the experiment carried out at Alor Lempah is shown in Table 4.5 below:

Table 4.5. Light-Bottle/Dark-Bottle Method Results at Alor Lempah (Sg. Selangor River, Malaysia) (August 11, 1998)

Time (hours)	Temperature (°C)	Dissolved Oxygen Levels (mg/L)			
		Light Bottle 1	Dark Bottle 1	Light Bottle 2	Dark Bottle 2
09:40 (initial)	22	7.4	7.4	7.5	7.5
18:50 (final)	24	8.2	8.0	8.5	8.5

The results in the table above for both duplicates of light-bottle and dark-bottle at Alor Lempah are quite similar. The expected results of such an experiment are the light bottles reading higher levels of dissolved oxygen due to the net production of oxygen by photosynthetic activity, and the dark bottles giving lower final dissolved oxygen as there was only respiration in these bottles. Therefore, although the P_{net} could be calculated as in Equation 1.29 (page 47), R_{cm} cannot be calculated using Equation 1.31 as do_{df} is greater than do_{di}. Therefore, photosynthesis could not be calculated using the light-bottle/dark-bottle method.

4.5.2 The Delta Method Results

The diurnal dissolved oxygen levels result for Alor Lempah to be used for the Delta Method as postulated by Chapra and Di Toro (1991) is shown in Figure 4.8. The figure shows that the diurnal dissolved oxygen concentrations in the river follows the shape of the saturation dissolved oxygen concentrations

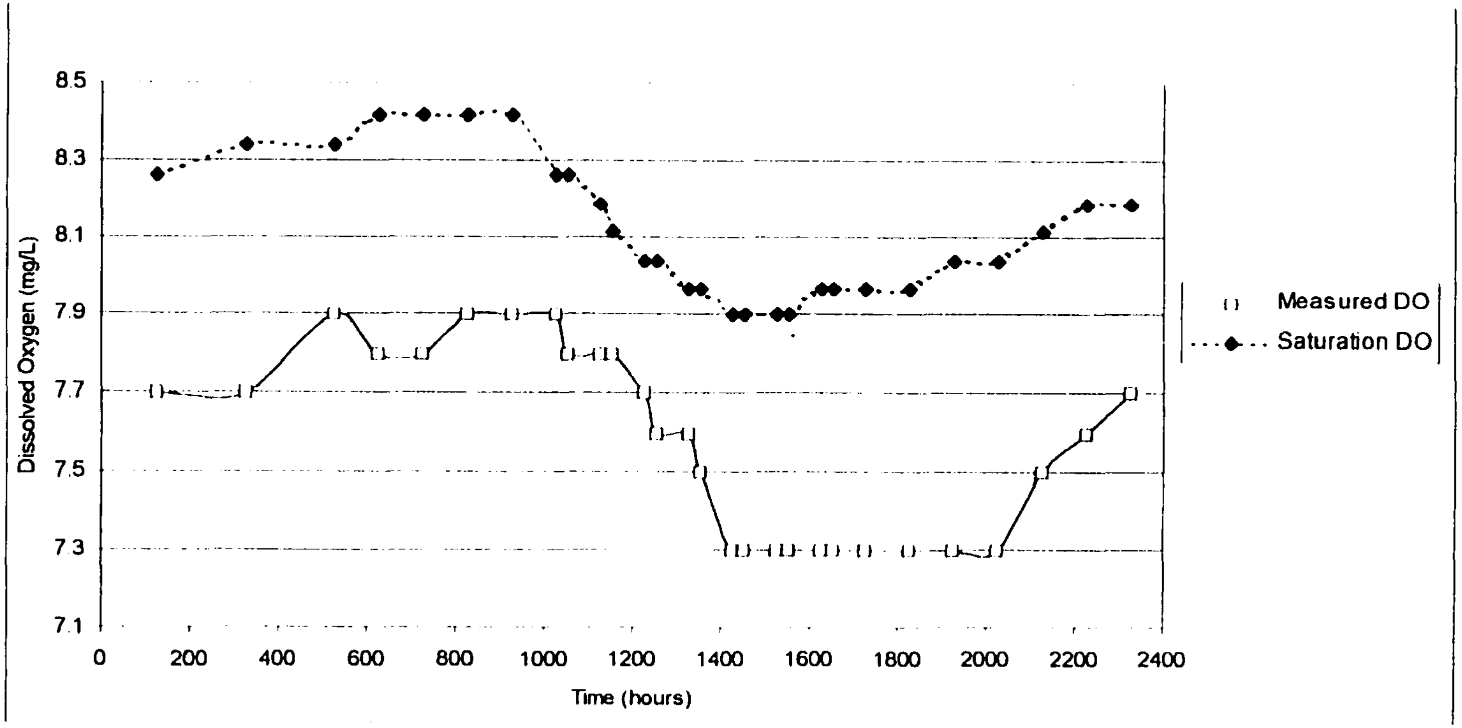

Figure 4.8. Diurnal Dissolved Oxygen Concentrations at Alor Lempah, Sg. Selangor River, Malaysia (July 19 and 20, 1998).

calculated using Equation 1.1 in Section 1.7.2 (temperature = 24.5 to 27.5 °C; pressure = 1atm). The diurnal dissolved oxygen result was not the expected one as seen in a typical river with photosynthesis (Chapra, 1997). The expected results of the diurnal dissolved oxygen concentrations for a stream with significant photosynthesis would indicate an opposite cycle where the dissolved oxygen concentrations would be lower during the night time due to respiration only situation and the dissolved oxygen concentrations would be higher during the day time due to the net production of dissolved oxygen produced by photosynthesis.

4.6 Model Calibration and Validation Results

4.6.1 Water Quality Data Analysis Results

Water quality and discharge data are shown in Tables 4.6 to 4.11. The water quality data collected by the Department of Environment (DOE) were matched with the discharge data measured by the Department of Irrigation and Drainage (DID). Some of the water quality data used were not sampled on the exact date of the discharge measurement, but on a date close to it.

The site survey of Sg. Selangor River watershed not only allowed for a first hand knowledge of the river, but also allowed for a supplementary water quality sampling for parameters not analyzed by the Department of Environment water quality monitoring program. The supplementary water quality data analyzed by the author using HACH DR 2000 (Hach, Loveland, Colorado) are shown in Table 4.12.

Table 4.6. Water Quality and Discharge Data for Sg. Selangor River, Malaysia (Low-Flow, March 4, 1986)

Station Name	Discharge (m^3/s)	Station Number	River Name	Sampling Date	Temp. (°C)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)(lab)	NAN (mg/L)	Total-N (mg/L)	Reactive-P (mg/L)	Hardness	Turbidity (NTU)	Suspended Solids (mg/L)	Dissolved Solids (mg/L)	Total Solids (mg/L)	pH	Electrical Conductivity (μmhos/cm)	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)
Pertak		3517605	Sg Selangor	4-Mar-86	22	8.5	1.0	11.0	0.23	0.62		0.15		4.3	14	28	42	7.20	20	3.5E+03	9.8E+04
Kerling		3516606	Sg Kerling	4-Mar-86	23	8.0	0.5	8.9	0.21	0.31		0.07		3.5	16	33	49	6.9	20		5.5E+03
Rasa	6.1	3516604	Sg Selangor	4-Mar-86	23	7.6	0.9	8.9	0.20	0.30		0.10		1.0	27	44	71	7.00	20	1.4E+04	3.3E+04
Batangkali		3416607	Sg Batangkali	4-Mar-86	23	7.8	0.9	14.0	0.14	0.26		0.04		20	58	34	92	6.50	220	4.5E+04	6.2E+04
Rantau Panjang	29.69	3314603	Sg Selangor	3-Mar-86	26.0	6.3	1.0	12.0	0.29	0.36		0.20		62	87	44	131	6.00	50	5.6E+04	2.8E+05

Table 4.7. Water Quality and Discharge Data for Sg. Selangor River, Malaysia (Low-Flow, Jan. 13, 1987)

Station Name	Discharge (m^3/s)	Station Number	River Name	Sampling Date	Temp. (°C)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)(lab)	NAN (mg/L)	Total-N (mg/L)	Reactive-P (mg/L)	Hardness	Turbidity (NTU)	Suspended Solids (mg/L)	Dissolved Solids (mg/L)	Total Solids (mg/L)	pH	Electrical Conductivity (μmhos/cm)	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)
Pertak		3517605	Sg Selangor	13-Jan-87	23	8.3	1.1	2.9	0.08	0.07		0.90		4.6	4	36	40	7.10	20	2.5E+03	2.5E+03
Kerling		3516606	Sg Kerling	13-Jan-87	23	8.1	0.9	1.1	0.04	0.12		0.12		5.8	5	42	47	6.8	20	5.5E+03	1.6E+04
Rasa	6.81	3516604	Sg Selangor	13-Jan-87	23	7.9	1.5	3.3	0.02	0.14		0.90		8.0	12	46	58	7.90	20	1.4E+04	3.3E+04
Batangkali		3416607	Sg Batangkali	13-Jan-87	23	7.4	1.1	19.7	0.04	0.17		0.14		10	20	40	60	6.70	20	9.0E+03	9.0E+04
Rantau Panjang	17.23	3314603	Sg Selangor	12-Jan-87	26.0	5.8	0.7	15.8	0.23	0.24		0.31		240	69	48	117	7.40	40	5.6E+04	2.8E+05

Table 4.8. Water Quality and Discharge Data for Sg. Selangor River, Malaysia (Low-Flow, May 17, 1989)

Station Name	Discharge (m^3/s)	Station Number	River Name	Sampling Date	Temp. (°C)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)(lab)	NAN (mg/L)	Total-N (mg/L)	Reactive-P (mg/L)	Hardness	Turbidity (NTU)	Suspended Solids (mg/L)	Dissolved Solids (mg/L)	Total Solids (mg/L)	pH	Electrical Conductivity (μmhos/cm)	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)
Pertak		3517605	Sg Selangor	17-May-89	23	4.1	1.1	17.2	0.06	0.36		0.70	1.0	9.0	131	82	213	7.20	27	5.7E+04	7.3E+05
Kerling		3516606	Sg Kerling	17-May-89	24	4.0	0.7	12.9	0.13	0.59		0.14	10.0	320.0	569	80	649	6.9	20	5.5E+03	9.0E+03
Rasa	9.84	3516604	Sg Selangor	14-May-89	24	7.0	1.3	16.0	0.27	0.46		0.60	1.0	26.0	435	78	513	7.10	30	1.1E+04	5.5E+04
Batangkali		3416607	Sg Batangkali	17-May-89	24	7.2	0.5	18.0	0.13	0.43		0.16	7.0	312	492	70	562	6.70	30	2.5.E+04	3.5.E+04
Rantau Panjang	49.37	3314603	Sg Selangor	22-May-89	27.0	5.7	1.9	7.1	0.07	0.47		0.40		53	63	66	129	7.20	40	5.6E+04	2.8E+05

Table 4.9. Water Quality and Discharge Data for Sg. Selangor River, Malaysia (High-Flow, Sept. 27, 1989)

Station Name	Discharge (m^3/s)	Station Number	River Name	Sampling Date	Temp. (°C)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)(lab)	NAN (mg/L)	Total-N (mg/L)	Reactive-P (mg/L)	Hardness	Turbidity (NTU)	Suspended Solids (mg/L)	Dissolved Solids (mg/L)	Total Solids (mg/L)	pH	Electrical Conductivity (μmhos/cm)	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)
Pertak		3517605	Sg Selangor	27-Sep-89	23	8.2	0.4	20.5	0.03	0.20		0.10		76.0	71	66	137	7.30	20	1.7E+04	3.5E+04
Kerling		3517606	Sg Kerling	27-Sep-89	28	8.0	0.9	16.5	0.11	0.22		0.03		110.0	114	52	166	7.4	20	1.4E+04	9.5E+04
Rasa	29.59	3516604	Sg Selangor	27-Sep-89	28	7.5	0.3	12.5	0.09	0.34		0.10		14.0	134	73	207	7.70	30	9.0E+03	2.5E+04
Batangkali		3416607	Sg Batangkali	27-Sep-89	28	7.7	0.7	16.1	0.30	0.00		0.04		150	167	48	215	6.60	30	2.5 E+04	5.5 E+04
Rantau Panjang	142.68	3314603	Sg Selangor	28-Sep-89	26.9	3.2	0.9	22.9	0.06	0.46		0.60	13.0	332	309	92	401	6.52	68	5.6E+04	2.8E+05

Table 4.10. Water Quality and Discharge Data for Sg. Selangor River, Malaysia (High-Flow, Nov. 14, 1989)

Station Name	Discharge (m^3/s)	Station Number	River Name	Sampling Date	Temp. (°C)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)(lab)	NAN (mg/L)	Total-N (mg/L)	Reactive-P (mg/L)	Hardness	Turbidity (NTU)	Suspended Solids (mg/L)	Dissolved Solids (mg/L)	Total Solids (mg/L)	pH	Electrical Conductivity (μmhos/cm)	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)
Pertak		3517605	Sg Selangor	14-Nov-89	22	8.9	1.9	4.4	0.02	0.22		0.14		48.0	50	47	97	6.90	20	5.5E+03	9.0E+03
Kerling		3516606	Sg Kerling	14-Nov-89	23	8.4	1.4	15.7	0.08	0.38		0.16		120.0	150	40	190	6.9	15	1.7E+03	1.4E+04
Rasa	38.04	3516604	Sg Selangor	14-Nov-89	23	8.5	2.0	14.1	0.09	0.34		0.26		13.0	142	54	196	6.90	20	1.4E+04	3.3E+04
Batangkali		3416607	Sg Batangkali	14-Nov-89	24	7.7	1.5	7.6	0.01	0.63		0.13		75	27	64	91	6.10	20	1.1 E+03	5.5 E+03
Rantau Panjang	180.12	3314603	Sg Selangor	13-Nov-89	28.0	6.2	1.2	22.1	0.04	0.00		0.30		280	349	77	426	6.80	280	5.6E+04	2.8E+05

Table 4.11. Water Quality and Discharge Data for Sg. Selangor River, Malaysia (High-Flow, Nov. 12, 1993)

Station Name	Discharge (m^3/s)	Station Number	River Name	Sampling Date	Temp. (°C)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH_3-N (mg/L)(lab)	NAN (mg/L)	Total-N (mg/L)	Reactive-P (mg/L)	Hardness	Turbidity (NTU)	Suspended Solids (mg/L)	Dissolved Solids (mg/L)	Total Solids (mg/L)	pH	Electrical Conductivity (μmhos/cm)	Fecal Coliform (MPN/100 mL)	Total Coliform (MPN/100 mL)
Pertak		3416607	Sg Selangor	12-Nov-93	23	5.8	2.1	24.8	0.02	1.310		0.10		180	230	49	279	6.62	120	2.4 E+03	2.4 E+03
Kerling		3516606	Sg Kerling	12-Nov-93	25	5.2	1.6	14.3	0.13	18.47		0.10		22.0	21	30	51	6.8	30	9.3E+03	2.4E+04
Rasa	26.54	3516604	Sg Selangor	15-Nov-93	24	6.9	1.7	17.5	0.08	0.11		0.10		72.0	77	69	146	6.51	30	1.4E+04	3.3E+04
Batangkali		3416607	Sg Batangkali	12-Nov-93	23	5.8	2.1	24.8	0.02	1.310		0.10		180	230	49	279	6.62	120	2.4 E+03	2.4 E+03
Rantau Panjang	253.75	3314603	Sg Selangor	12-Nov-93	26.0	4.7	2.2	54.9	0.24	3.59		0.10		344	479	75	554	6.50	50	1.5E+05	1.1E+06

Table 4.12. Supplementary Water Quality Results Analyzed for Sg. Selangor **River, Malaysia** using HACH DR 2000 Direct Spectrophotometer (July/August, 1998)

LOCATION NAME	LOCATION DESCRIPTION	RIVER NAME	DATE	TIME (hrs.)	TEMP (°C)	DO (mg/L)	NITRITE (mg/L)	NITRATE (mg/L)	P (mg/L)	TDS (mg/L)	CONDUCTIVITY (microS/cm)	COMMENTS
Alor Lempah	road to Bina Semangat	Selangor	19-Jul-98	1055	26 0	7 8	0 017	0 3	0 02			
Ulu Sg. Rawang	Near ASEAN Scouts Campground	Rawang	2-Aug-98	1400	28 0	8 2	0 029	0 5	0 09			
Kuala Garing	Sg. Rawang before Sg Serendah	Rawang	2-Aug-98	1600	29 0	4 5	0 038	0 7	0 27	80 0	180 0	
Kundang	bridge to Kundang New Village	Kundang	6-Aug-98	1240	29 5	4 7	0 028	0 9	0 10	39 7	79 1	
Kundang	bridge to Kuala Selangor	Kundang	6-Aug-98	1320	30 5	0 8	?	?	0 08	44 4	88 4	highly turbid sample, questionable results for nitrate and nitrite (100 m below garbage dump)
Rantau Panjang	above New Water Treatment Plant	Selangor	6-Aug-98	1530	30 0	4 8	0 037	0 6	0 14	32 7	65 6	
Kuala Sembah/Rawang	dirt road to a goat farm	Rawang	6-Aug-98	1815	31 0	4 1	0 023	1 3	0 15	62 0	125 5	
Alor Lempah	road to Bina Semangat	Selangor	13-Aug-98	1710	-	-	0 003	0 5	0 71	12 0	24 0	
Kerling Town	bridge on old North-South trunk road near Hindu temple	Kerling	16-Aug-98	1400	26 0	7 0	0 004	0 6	0 29	14 0	28 0	before rain
Kerling Town	bridge on old North-South trunk road near Hindu temple	Kerling	16-Aug-98	1515	25 0	6 6	0 004	0 7	0 16	13 6	27 2	after rain
Alor Lempah	road to Bina Semangat	Selangor	16-Aug-98	1745	25 0	9 0	0 000	0 7	0 07	11 3	22 6	after heavy rain
Batangkali	bridge on old North-South trunk road	Batangkali	16-Aug-98	1822	25 0	7 8	0 000	1 1	0 07	17 6	35 6	after heavy rain
Serendah Town	road to Bina Semangat	Serendah	16-Aug-98	1850	26 5	8 4	0 029	0 9	0 61	15 6	31 7	after heavy rain
Kuala Garing	Sg Rawang before Sg Serendah	Rawang	16-Aug-98	1920	26 5	6 7	0 021	1 5	0 29	44 8	89 5	
Serendah Town	bridge on old North-South trunk road	Serendah	17-Aug-98	1615	26 0	7 5	0 000	0 9	1 63	18 4	36 7	

The missing parameters are critical for the water quality modeling using QUAL2E, especially for a more realistic water quality of the river. These parameters include nitrite, which would consume dissolved oxygen, albeit in small amounts during its conversion to nitrate. Other parameters analyzed were nitrate and phosphate.

4.6.2 Low-Flow Analysis (7Q10) Results

The discharge data for Sg. Selangor River at both Rasa and Rantau Panjang indicated the large variability of the flow. The low-flow seasons tend to occur during the dry months of February/March and July/August (Figure 4.9). This period coincided with the dry inter-monsoon seasons (DOE, 1994).

The low-flow analysis for Sg. Selangor River at Rasa and Rantau Panjang are shown in Figures 4.10 and 4.11. The figures gave the calculated low-flows at Rasa and at Rantau Panjang to be 3.93 m^3/s and 11.75 m^3/s respectively. The results from these figures also indicated that the flow contribution from the Ulu Selangor watershed at Rasa is relatively high (33 percent) considering the ratio of the watershed to the total Sg. Selangor River watershed is only at about 16 percent (Tables 3.5 and 3.7).

The use of 7Q10 low-flow discharge data in the second combination of the calibration and validation process is considered the most important in water quality modeling. During this low-flow period the dilution factor of the river is minimal and therefore it is considered as the worst case scenario where the river is most vulnerable to the effects of pollution.

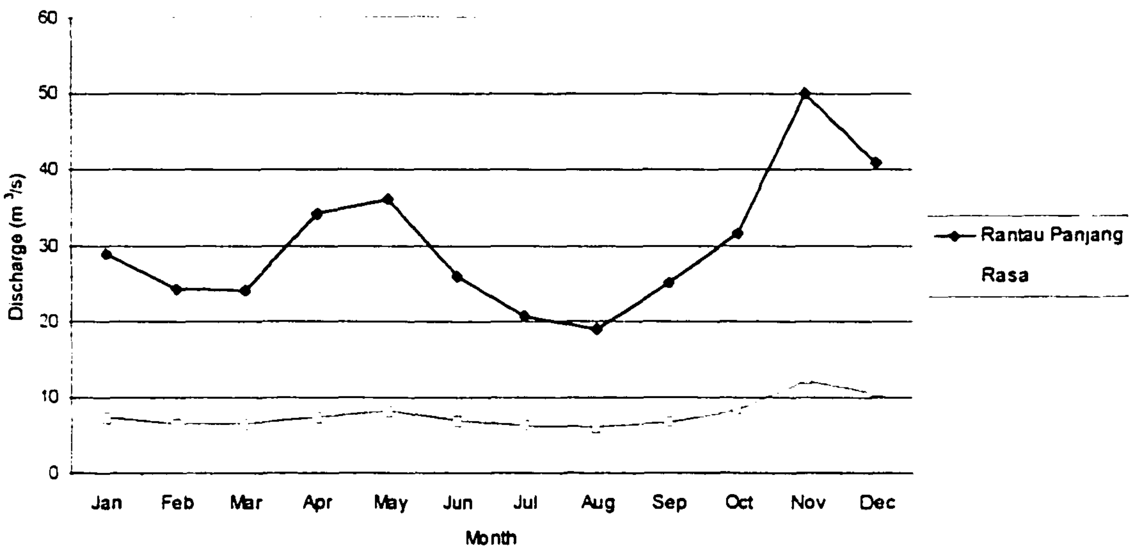

Figure 4.9. Sg. Selangor River, Malaysia: Mean Minimum Monthly Discharge (Rasa and Rantau Panjang) (1960 to 1998).

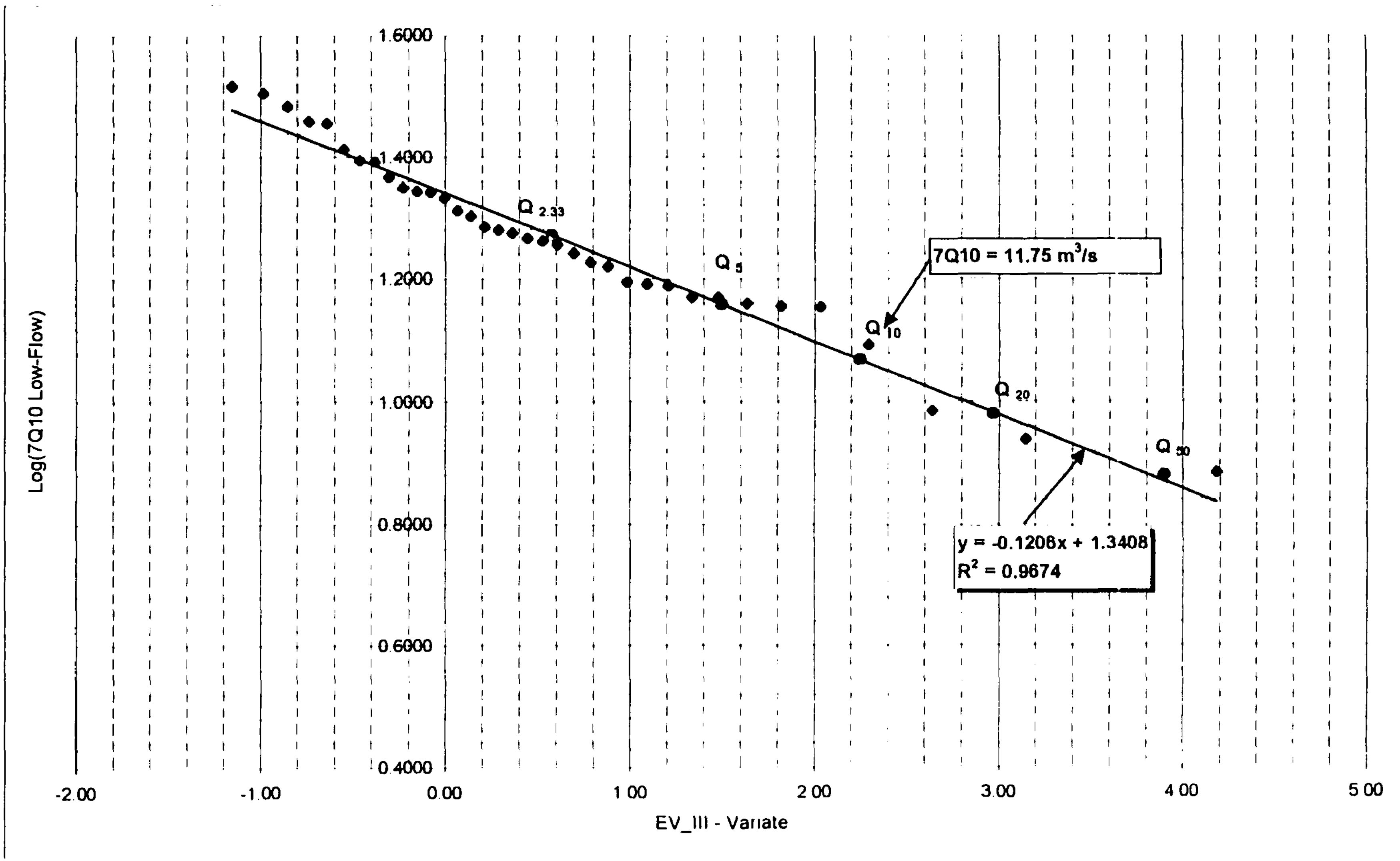

Figure 4.10. 7Q10 Low-Flow Frequency Analysis for Sg Selangor River at Rantau Panjang, Selangor, Malaysia.

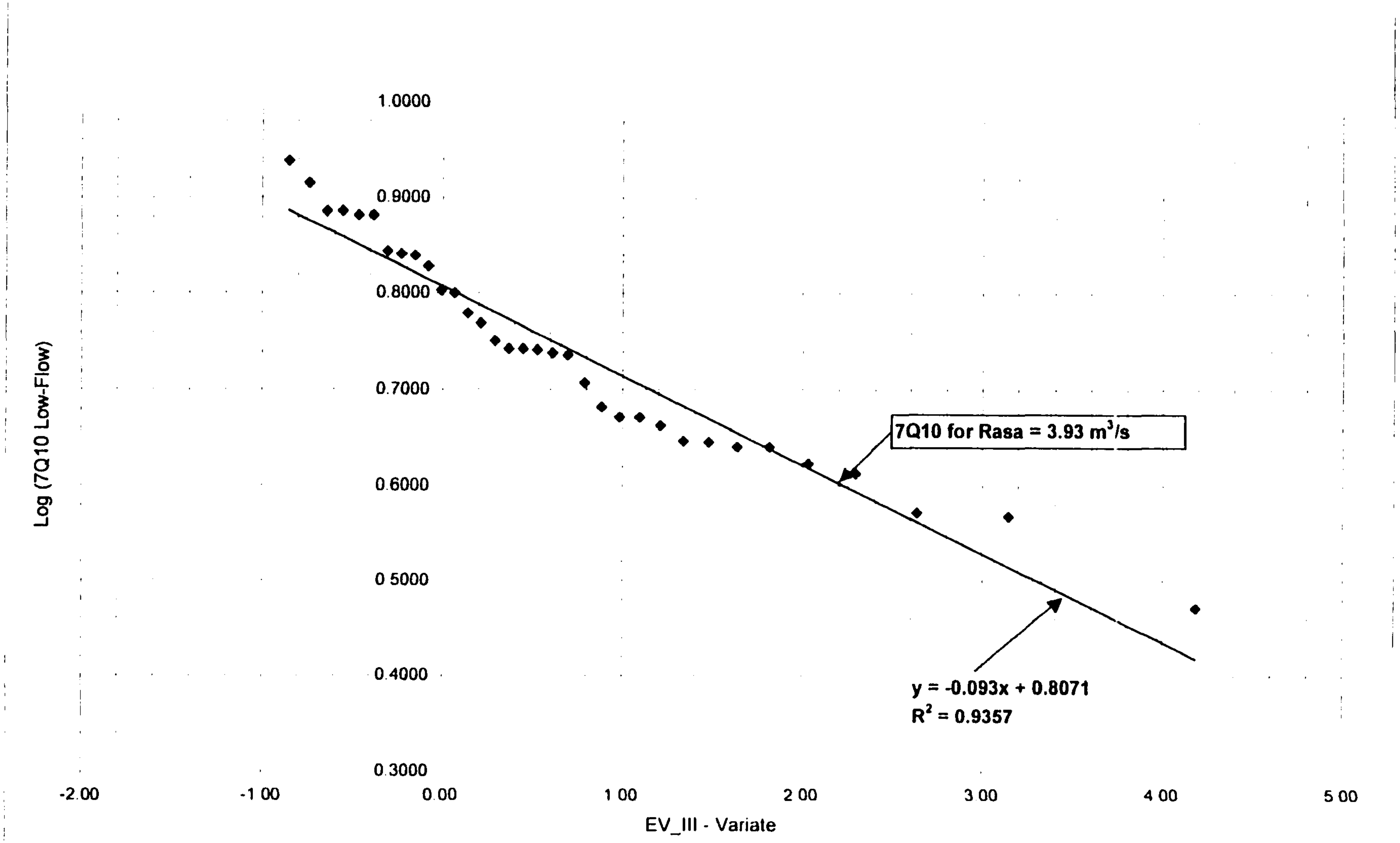

Figure 4.11. 7Q10 Low-Flow Frequency Analysis of Sg Selangor River at Rasa, Selangor, Malaysia.

4.6.3 Results of QUAL2E Calibration and Validation Methods for Comparison of Predicted to Measured Reaeration Coefficients (k_2)

All-Reaches Results Analysis

The results of the error analysis of the calibrations and validations for all-reaches of Sg. Selangor River are shown in Appendix F (Tables F-1 to F-36). A summary of the results is necessary considering the voluminous data in the Appendices. Therefore, the all-reaches error analysis results from Appendix F are summarized in Tables 4.13 to 4.15.

The first calibration used the actual discharge data from both the Rasa and Rantau Panjang stations. The water quality data were from March 4, 1986 low-flow data. Two validations were carried out using January 13, 1987 and May 17, 1989 data.

The second calibration/validation used the same water quality data as the above calibration/validation except the discharge data for Rasa and Rantau Panjang. The discharge data employed the 7Q10 analysis results (Figures 4.10 and 4.11). Therefore, the 7Q10 discharge used for Rasa was 3.93 m^3/s and at Rantau Panjang it was 11.75 m^3/s.

Meanwhile, the third calibration used the water quality data and discharge data from September 27, 1989 high-flow data. The validations used November 14, 1989 and November 12, 1993 data. This high-flow calibration/validation is not considered as important as the 7Q10 calibration/validation, which is considered as the worst case scenario due to the minimal dilution factor of the

Table 4.13. Sg. Selangor River, Malaysia: All-Reaches Error Analysis Results of Calibration and Validations for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Low-Flow Data

Error Analysis Parameter	Churchill et al. Predictive Equation	Langbein-Durum Predictive Equation	O'Connor-Dobbins Predictive Equation	Owens et al. Predictive Equation	Single coefficient (measured k_2)	Thackston-Krenkel Predictive Equation	Tsivoglou-Wallace Predictive Equation
Calibration 1 (March 4, 1986 Data)							
SSE	43.5778	**40.2053**	43.1184	48.6858	56.1931	73.2944	399.9877
MSE	1.8157	1.6752	1.7966	2.0286	2.3414	3.0539	16.6662
SE	1.3475	1.2943	1.3404	1.4243	1.5302	1.7476	4.0824
CV	19.6475	18.8720	19.5437	20.7671	22.3109	25.4807	59.5250
Validation 1.1 (Jan. 13, 1987 Data)							
SSE	46.5650	**42.6763**	44.8724	50.4928	48.4090	86.7553	439.2187
MSE	1.9402	1.7782	1.8697	2.1039	2.0170	3.6148	18.3008
SE	1.3929	1.3335	1.3674	1.4505	1.4202	1.9013	4.2779
CV	20.3098	19.4433	19.9373	21.1490	20.7080	27.7220	62.3758
Validation 1.2 (May 17, 1989 Data)							
SSE	156.1902	150.9941	156.2236	168.8527	216.9692	**122.9086**	128.1283
MSE	6.5079	6.2914	6.5093	7.0355	9.0404	5.1212	5.3387
SE	2.5511	2.5083	2.5513	2.6525	3.0067	2.2630	2.3106
CV	45.9996	45.2280	46.0046	47.8279	54.2159	40.8055	41.6630

Table 4.14. Sg. Selangor River, Malaysia. All-Reaches Error Analysis Results of Calibration and Validations for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Low-Flow Water Quality Data and 7Q10 Discharge

Error Analysis Parameter	Churchill et al. Predictive Equation	Langbein-Durum Predictive Equation	O'Connor-Dobbins Predictive Equation	Owens et al. Predictive Equation	Single coefficient (measured k_2)	Thackston-Krenkel Predictive Equation	Tsivoglou-Wallace Predictive Equation
Calibration 2 (March 4, 1986 Data)							
SSE	48.9792	49.4281	44.5575	49.5956	**40.9419**	140.7199	643.2354
MSE	2.0408	2.0595	1.8566	2.0665	1.7059	5.8633	26.8015
SE	1.4286	1.4351	1.3626	1.4375	1.3061	2.4214	5.1770
CV	20.8296	20.9249	19.8672	20.9603	19.0441	35.3064	75.4850
Validation 2.1 (Jan. 13, 1987 Data)							
SSE	50.2099	50.8546	45.9220	50.8696	**42.6335**	142.3891	649.9555
MSE	2.0921	2.1189	1.9134	2.1196	1.7764	5.9329	27.0815
SE	1.4464	1.4557	1.3833	1.4559	1.3328	2.4358	5.2040
CV	21.0897	21.2247	20.1691	21.2278	19.4335	35.5152	75.8783
Validation 2.2 (May 17, 1989 Data)							
SSE	127.3485	113.1294	121.5012	139.4114	**112.4034**	155.8555	493.5423
MSE	5.3062	4.7137	5.0625	5.8088	4.6835	6.4940	20.5643
SE	2.3035	2.1711	2.2500	2.4101	2.1641	2.5483	4.5348
CV	41.5360	39.1485	40.5712	43.4587	39.0227	45.9503	81.7692

Table 4.15. Sg. Selangor River, All-Reaches Malaysia: Error Analysis Results of Calibration and Validations for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using High-Flow Data

Error Analysis Parameter	Churchill et al. Predictive Equation	Langbein-Durum Predictive Equation	O'Connor-Dobbins Predictive Equation	Owens et al. Predictive Equation	Single coefficient (measured k_2)	Thackston-Krenkel Predictive Equation	Tsivoglou-Wallace Predictive Equation
Calibration 3 (Sept. 27, 1989 Data)							
SSE	65.3209	67.7186	65.6139	69.4181	131.5025	50.2916	**35.4938**
MSE	2.7217	2.8216	2.7339	2.8924	5.4793	2.0955	1.4789
SE	1.6498	1.6798	1.6535	1.7007	2.3408	1.4476	1.2161
CV	24.3507	24.7936	24.4052	25.1028	34.5503	21.3665	17.9499
Validation 3.1 (Nov. 14, 1989 Data)							
SSE	60.4627	61.4226	60.2347	62.2899	101.5606	54.2170	**51.6028**
MSE	2.5193	2.5593	2.5098	2.5954	4.2317	2.2590	2.1501
SE	1.5872	1.5998	1.5842	1.6110	2.0571	1.5030	1.4663
CV	21.4490	21.6186	21.4085	21.7707	27.7988	20.3110	19.8152
Validation 3.2 (Nov. 12, 1993 Data)							
SSE	130.7434	138.3608	130.1892	132.1280	246.2479	115.7543	**91.3243**
MSE	5.4476	5.7650	5.4245	5.5053	10.2603	4.8231	3.8052
SE	2.3340	2.4010	2.3291	2.3463	3.2032	2.1962	1.9507
CV	40.6801	41.8483	40.5937	40.8949	55.8288	38.2772	33.9989

river. The high-flow calibration/validation was carried out for comparative purposes.

The results of the study are summarized in Tables 4.13 to 4.15. The Langbein-Durum predictive equation gave the best result (lowest SE or RMS) during the first calibration for dissolved oxygen. This was followed by O'Connor-Dobbins, Churchill et al., Owens et al., measured reaeration coefficients, Thackston-Krenkel, and Tsivoglou-Wallace. During the first validation (January 13, 1987 data), the sequence in ascending order (from lowest SE to highest) was Langbein-Durum, O'Connor-Dobbins, Churchill et al., measured single coefficients, Owens et al., Thackston-Krenkel, and Tsivoglou-Wallace. Meanwhile, in the second validation (May 17, 1989 data), the sequence was Thackston-Krenkel, Tsivoglou-Wallace, Langbein-Durum, Churchill et al., O'Connor-Dobbins, Owens et al. and measured single coefficients.

The measured reaeration coefficients gave the best results (lowest SE) for the second calibration. This calibration/validation sequence used the same water quality data as the first calibration/validation (i.e. March 4, 1986 water quality data for calibration and January 13, 1987 and May 17, 1989 water quality data for validations). But the discharge data used were the 7Q10 discharge data for Rasa and Rantau Panjang. The ascending order sequence of the SE for the calibration was the measured reaeration coefficients, O'Connor-Dobbins, Churchill et al., Langbein-Durum, Owens et al., Thackston-Krenkel and Tsivoglou-Wallace. The first validation using January 13, 1987 water quality data gave the same sequence. Meanwhile the second validation using May 17, 1989 water quality data gave relatively higher SE results where the lowest SE was more than twice the lowest SE in the calibration. The ascending SE sequence was the measured single coefficients, Langbein-Durum, O'Connor-Dobbins, Churchill et al., Owens et al., Thackston-Krenkel and Tsivoglou-Wallace (Table 4.14) (Appendix F; Tables F-16 to F-18). In Table 4.14 it can be observed that the differences of the measured reaeration coefficients standard error (SE) to the standard errors of the Langbein-Durum, O'Connor-Dobbins, Churchill et al., Owens et al. predictive equations are relatively smaller than the differences to Thackston-Krenkel and Tsivoglou-Wallace equations standard errors.

The final calibration/validations used the water quality data and discharge data from September 27, 1989 high-flow data for calibration, and the validations used November 14, 1989 and November 12, 1993 data. The results indicated that the Thackston-Krenkel and the Tsivoglou-Wallace predictive equations gave the lower SE (Table 4.15). But these high-flow calibration/validations results are questionable as most of the river parameters were measured during a low-flow period, not during a high-flow period.

Main-stem Reaches Results Analysis

A graphical analysis was used for the comparison of the predicted or simulated dissolved oxygen concentrations to the measured values spatially by river reach. In QUAL2E the reaches are sequentially arranged from the headwaters to the estuary without separating the main-stem reaches from the tributaries. Therefore it would be erroneous to analyze the Sg. Selangor River results from Reach 1 to Reach 24 consecutively as some of the reaches are spatially apart. The main-stem reaches of Sg. Selangor River could be identified in Figure 3.5 as Reaches 1, 2, 5, 8, 12, 15 and 24. The results of the comparison of the simulated or predicted dissolved oxygen to the measured values by the main-stem river reaches are shown in Appendix H (Figures H-1 to H-36).

The regression analysis as discussed on page 84 would also be used to compare the measured versus simulated dissolved oxygen concentrations for the main-stem reaches. The results of the analysis are shown in Appendix G (Figures G-1 to G-63). Examples of Appendix G and Appendix H are shown as Figures 4.12 to 4.18 (Appendix G) and Figures 4.19 to 4.30 (Appendix H).

The main-stem reaches error analysis gave mixed results relative to the all-reaches error analysis discussed above (Tables 4.16 to 4.18). In the actual low-flow calibration/validations results, Owens et al. equation and the measured reaeration coefficients have the lower standard error (SE) compared to the Langbein-Durum equation, which has the lowest SE in the all-reaches error analysis (Table 4.16).

Owens et al. and Churchill et al. predictive equations SE are smaller than the measured reaeration coefficients SE for the 7Q10 calibration/validations (Table 4.17). Meanwhile, in the high-flow calibration/validations the Thackton-Krenkel and the Tsivoglou-Wallace equations SE are consistent with the all-reaches error analysis where their standard errors are smaller than other predictive equations (Table 4.18).

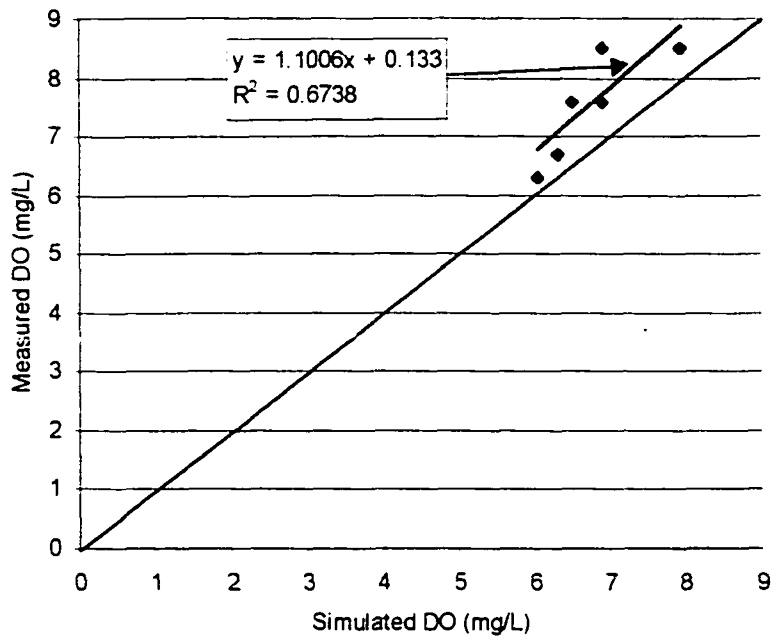

Figure 4.12. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

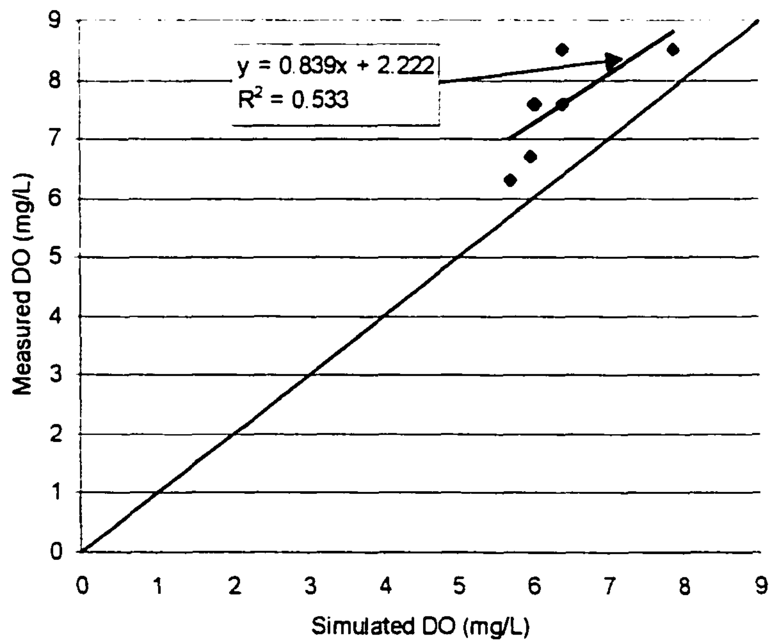

Figure 4.13. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

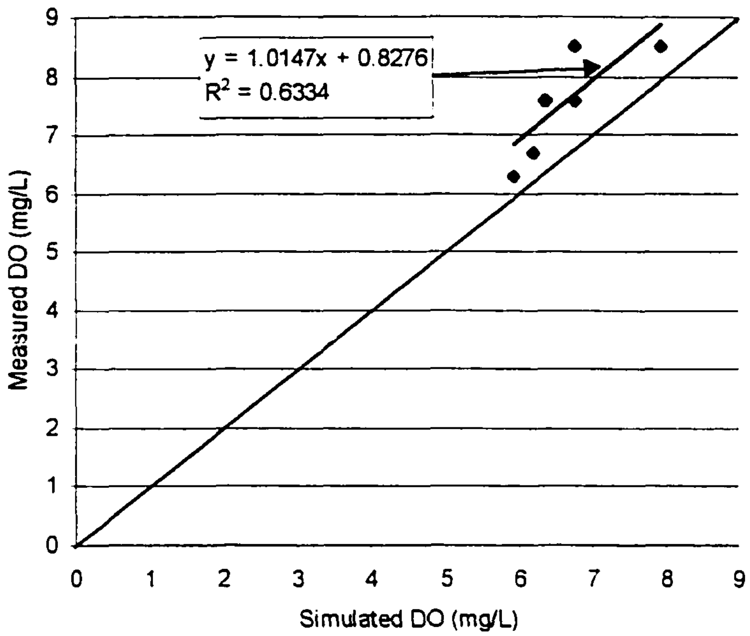

Figure 4.14. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

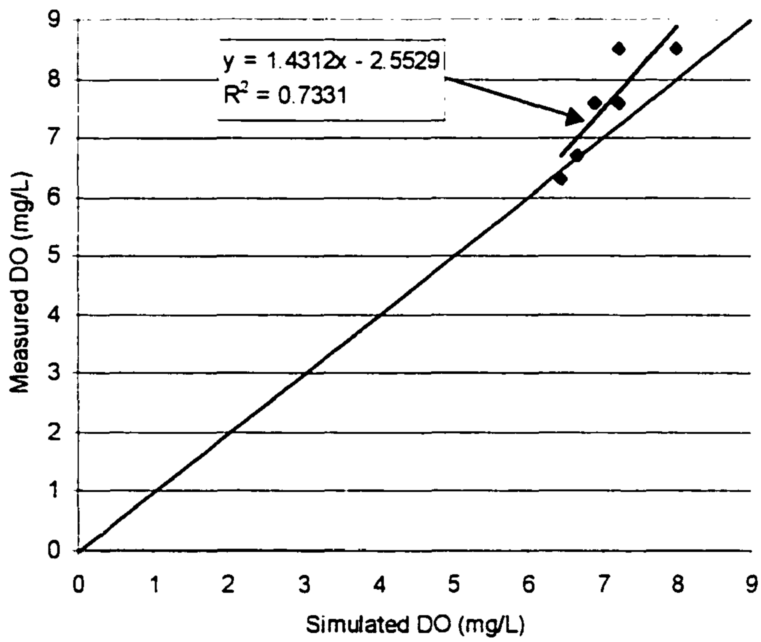

Figure 4.15. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

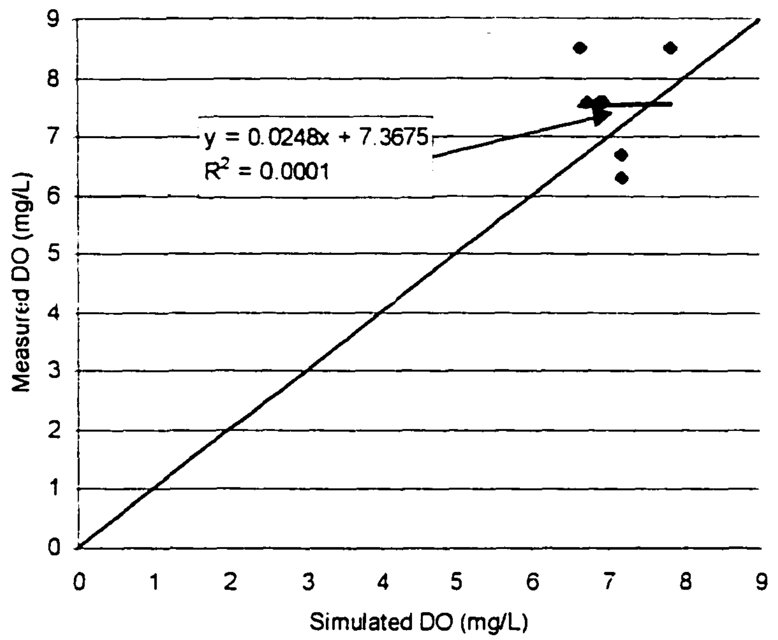

Figure 4.16. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

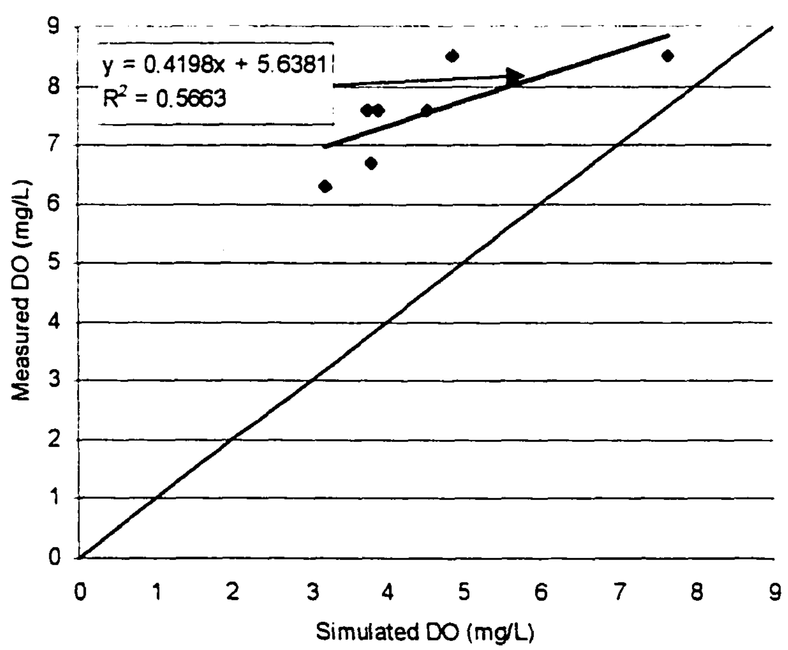

Figure 4.17. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

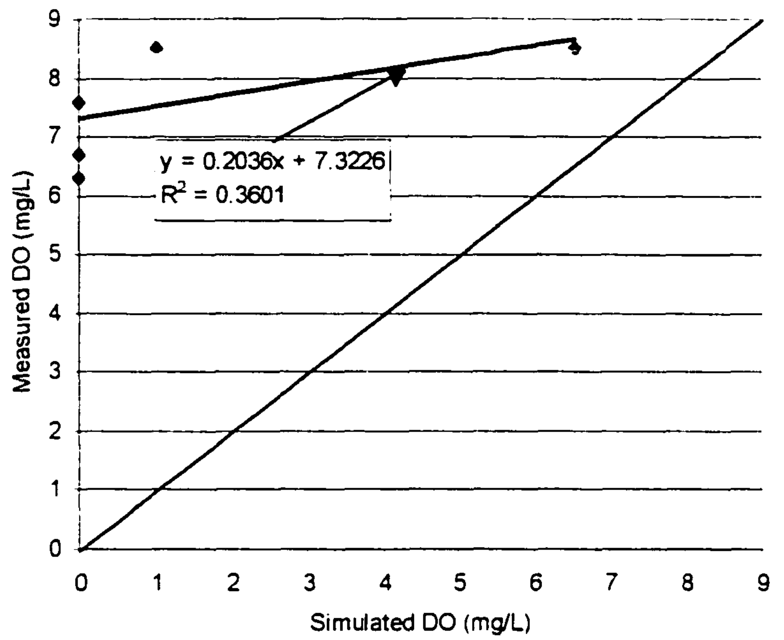

Figure 4.18. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

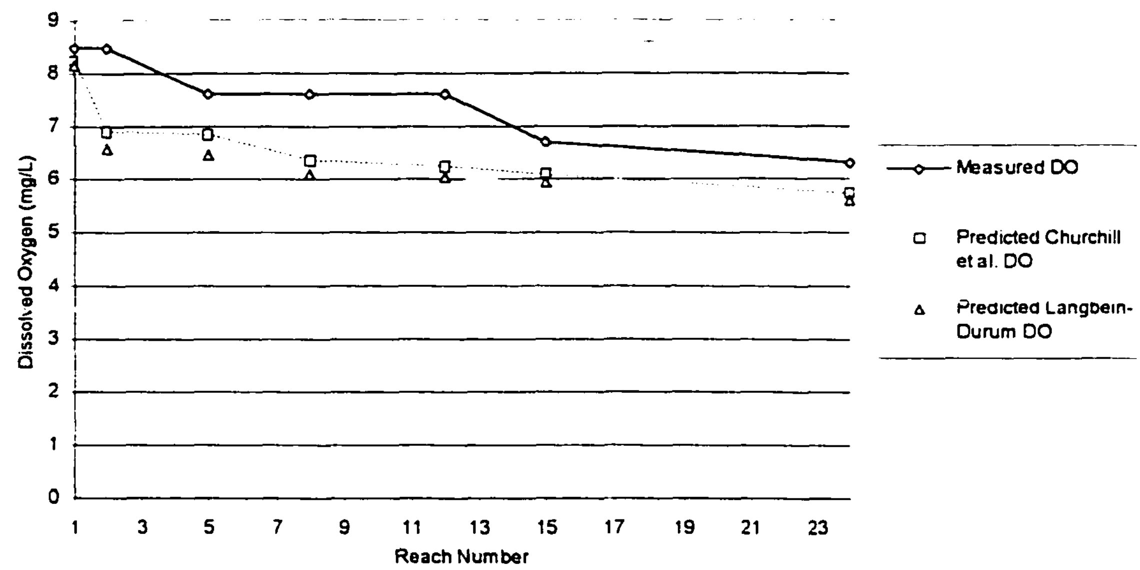

Figure 4.19. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

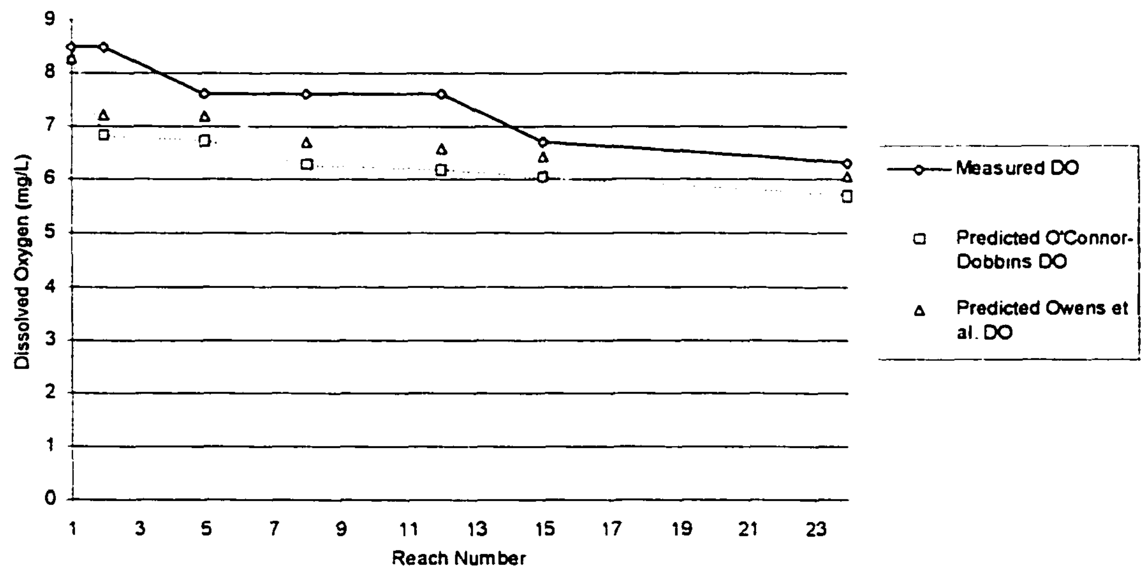

Figure 4.20. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

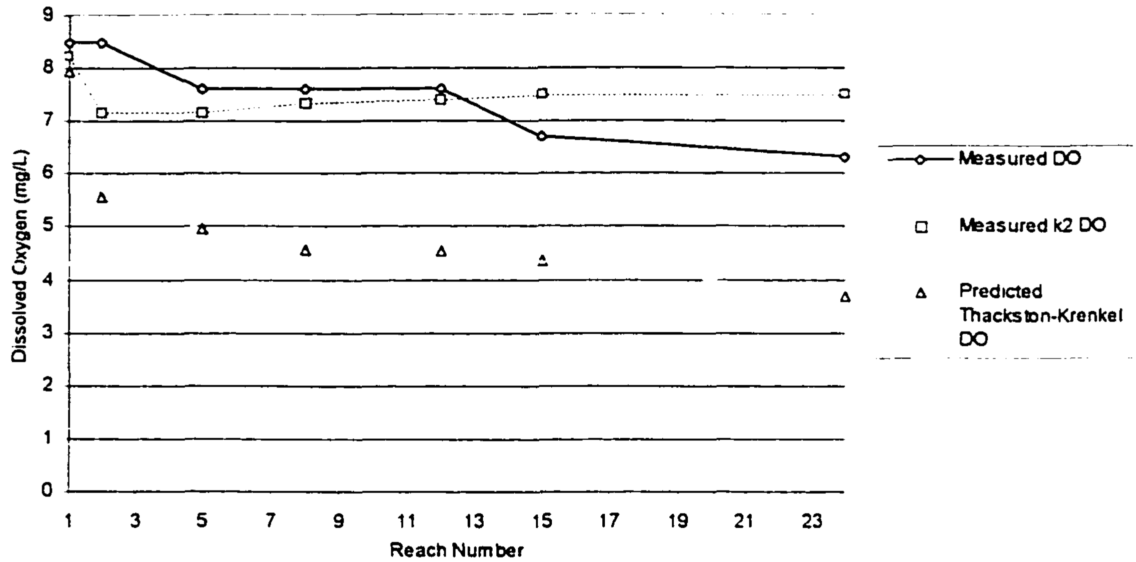

Figure 4.21. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

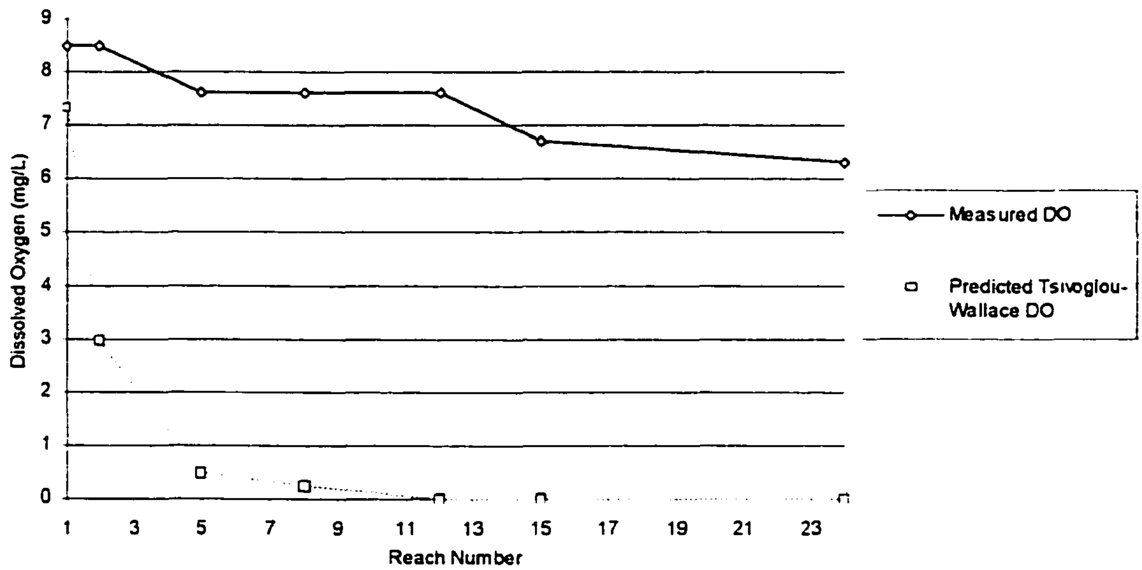

Figure 4.22. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

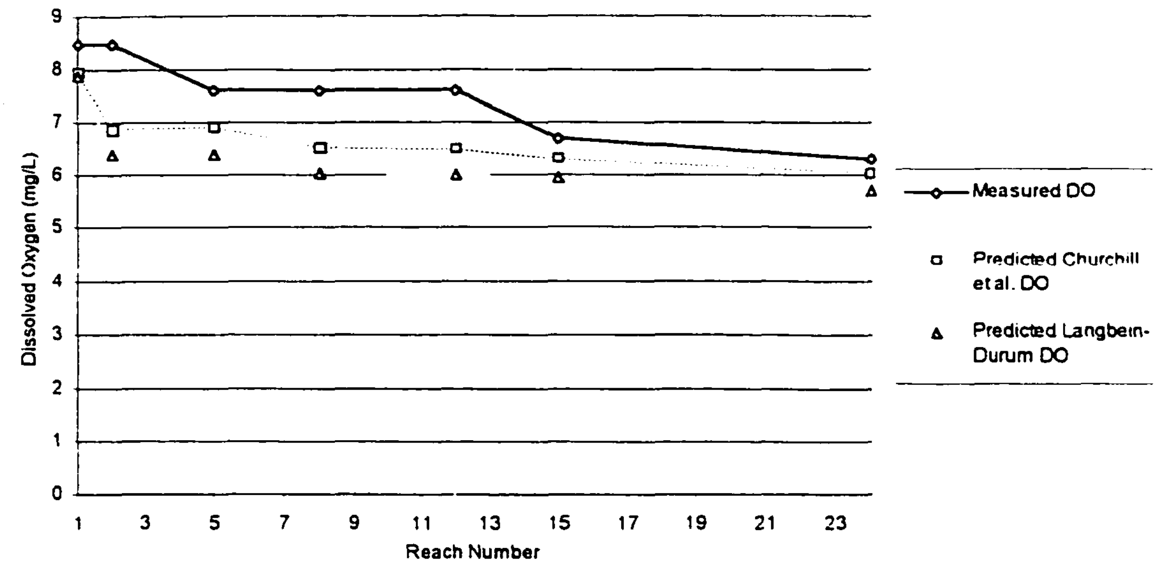

Figure 4.23. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

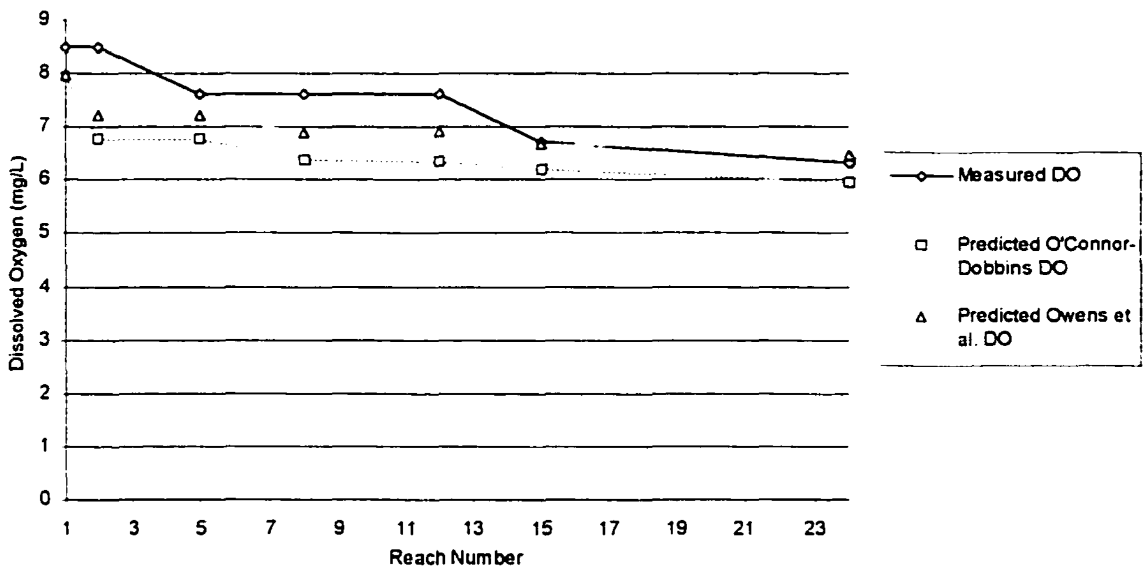

Figure 4.24. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

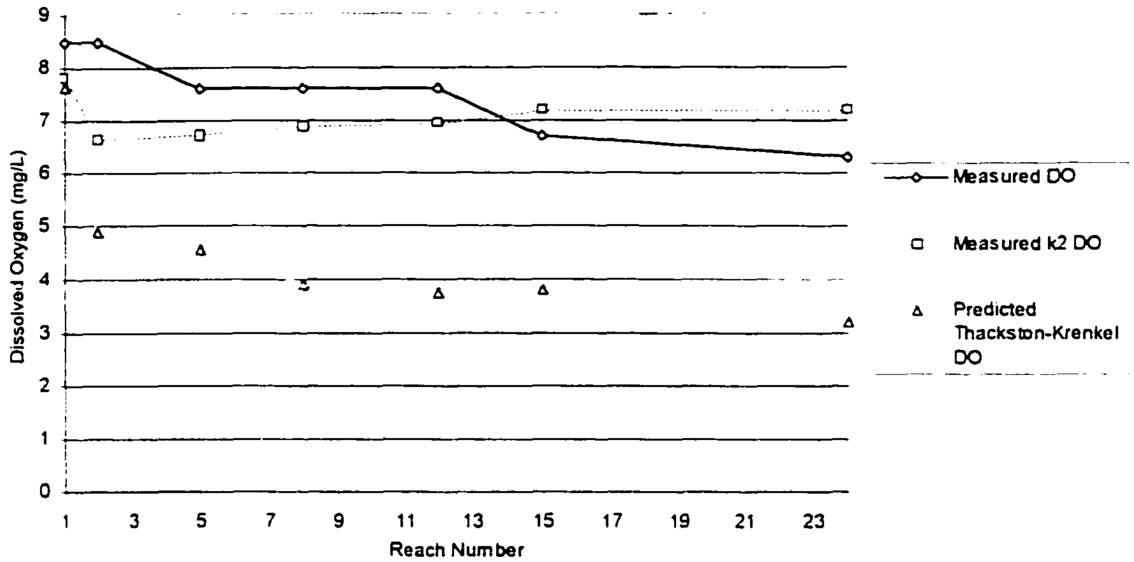

Figure 4.25. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

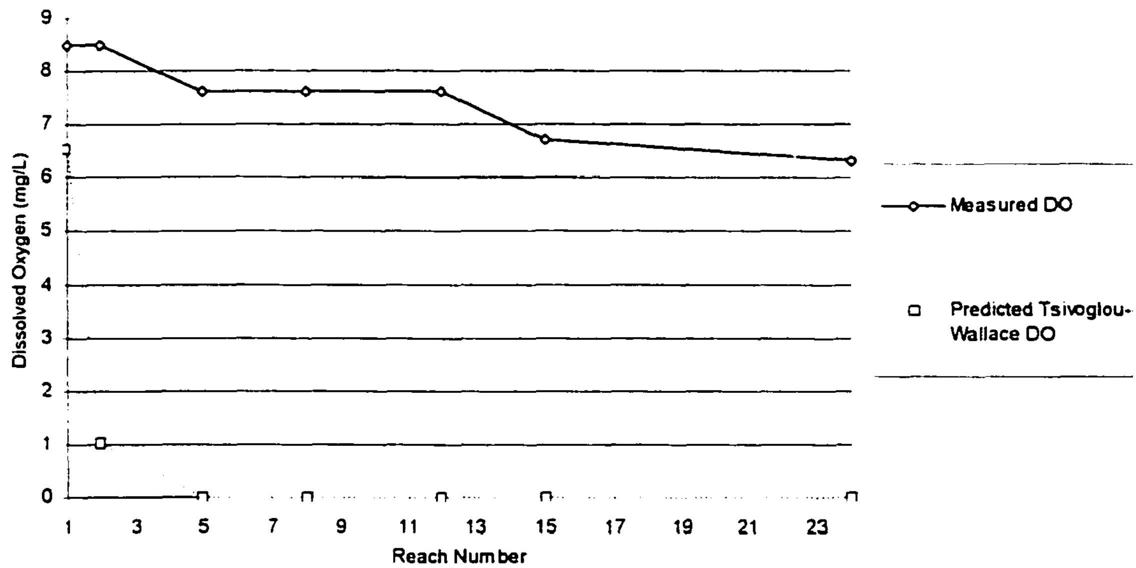

Figure 4.26. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

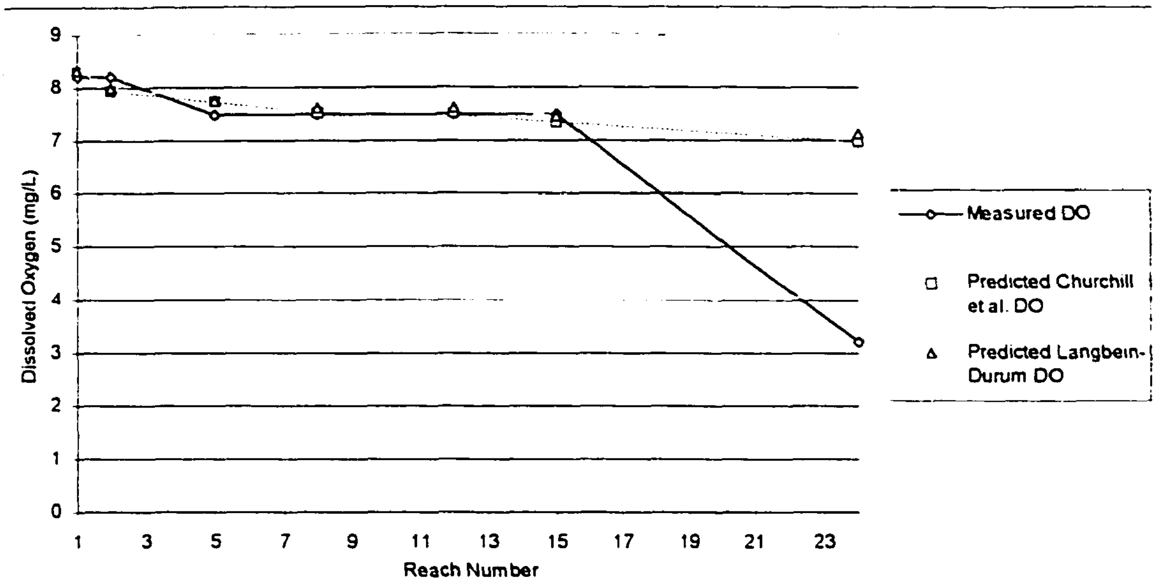

Figure 4.27. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27,1989 Data)

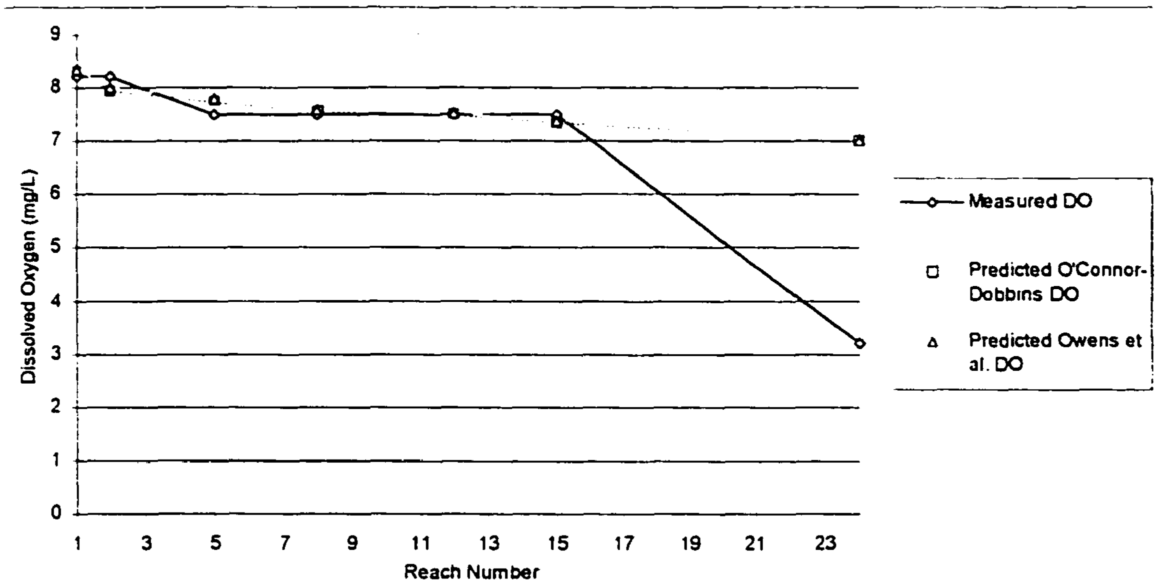

Figure 4.28. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27, 1989 Data)

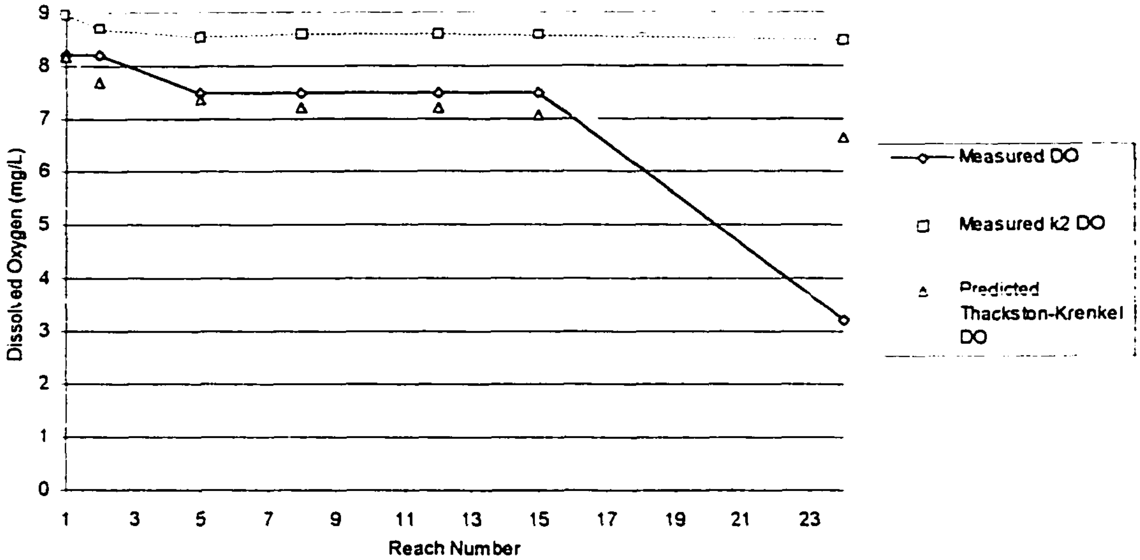

Figure 4.29. Comparison of Predicted DO (Measured k_2 and Thackton-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27, 1989 Data)

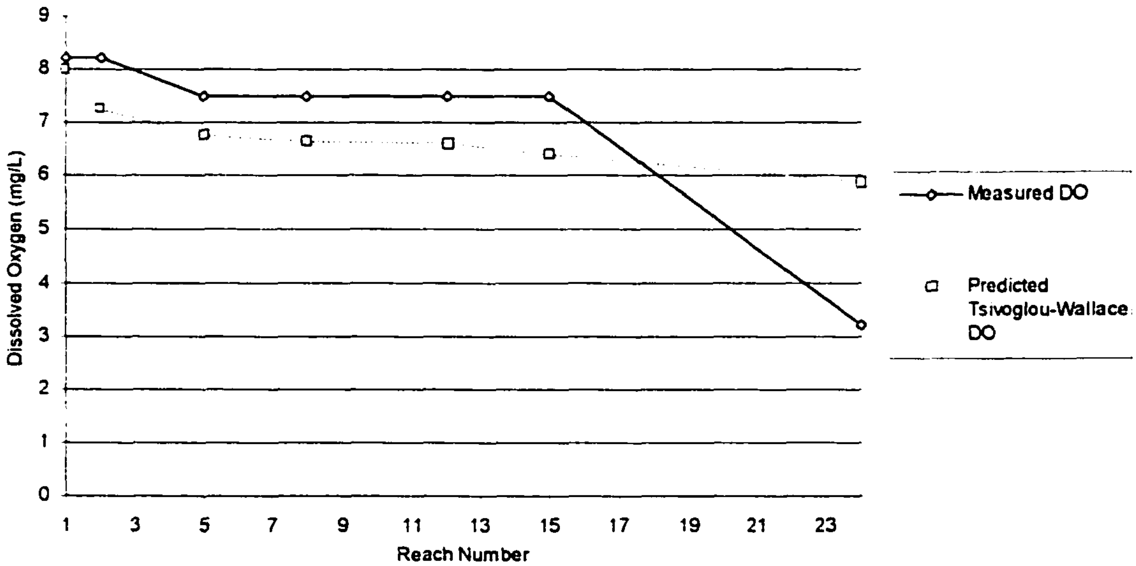

Figure 4.30. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27, 1989 Data)

Table 4.16. Sg. Selangor River, Malaysia: Main-Stem Reaches Error Analysis Results of Calibration and Validations for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Low-Flow Data

Error Analysis Parameter	Churchill et al. Predictive Equation	Langbein-Durum Predictive Equation	O'Connor-Dobbins Predictive Equation	Owens et al. Predictive Equation	Single coefficient (measured k_2)	Thackston-Krenkel Predictive Equation	Tsivoglou-Wallace Predictive Equation
Calibration 1 (March 4, 1986 Data)							
SSE	7.1463	10.7685	8.2423	3.8374	4.2474	46.9918	279.6853
MSE	1.0209	1.5384	1.1775	0.5482	0.6068	6.7131	39.9550
SE	1.0104	1.2403	1.0851	0.7404	0.7790	2.5910	6.3210
CV	13.3954	16.4435	14.3860	9.8160	10.3270	34.3500	83.8011
Validation 1.1 (Jan. 13, 1987 Data)							
SSE	8.2999	12.1709	9.4844	4.9253	5.4518	49.7969	269.8905
MSE	1.1857	1.7387	1.3549	0.7036	0.7788	7.1138	38.5558
SE	1.0889	1.3186	1.1640	0.8388	0.8825	2.6672	6.2093
CV	14.4361	17.4814	15.4319	11.1207	11.7000	35.3603	82.3207
Validation 1.2 (May 17, 1989 Data)							
SSE	29.4726	28.4330	29.1037	31.3524	42.0271	27.7611	60.1115
MSE	4.2104	4.0619	4.1577	4.4789	6.0039	3.9659	8.5874
SE	2.0519	2.0154	2.0390	2.1163	2.4503	1.9914	2.9304
CV	34.5275	33.9130	34.3107	35.6116	41.2307	33.5100	49.3099

Table 4.17. Sg. Selangor River, Malaysia: Main-Stem Reaches Error Analysis Results of Calibration and Validations for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Low-Flow Water Quality Data and 7Q10 Discharge

Error Analysis Parameter	Churchill et al. Predictive Equation	Langbein-Durum Predictive Equation	O'Connor-Dobbins Predictive Equation	Owens et al. Predictive Equation	Single coefficient (measured k_2)	Thackston-Krenkel Predictive Equation	Tsivoglou-Wallace Predictive Equation
Calibration 2 (March 4, 1986 Data)							
SSE	5.9534	12.0862	7.4862	3.0394	6.6453	69.4563	317.4222
MSE	0.8505	1.7266	1.0695	0.4342	0.9493	9.9223	45.3460
SE	0.9222	1.3140	1.0341	0.6589	0.9743	3.1500	6.7339
CV	12.2264	17.4205	13.7102	8.7359	12.9173	41.7610	89.2758
Validation 2.1 (Jan. 13, 1987 Data)							
SSE	7.1660	13.6120	8.7819	4.1606	8.4649	71.5301	321.6312
MSE	1.0237	1.9446	1.2546	0.5944	1.2093	10.2186	45.9473
SE	1.0118	1.3945	1.1201	0.7710	1.0997	3.1967	6.7784
CV	13.4138	18.4874	14.8494	10.2210	14.5789	42.3799	89.8657
Validation 2.2 (May 17, 1989 Data)							
SSE	23.3931	22.3476	22.8820	25.5553	22.9153	54.0073	239.6996
MSE	3.3419	3.1925	3.2689	3.6508	3.2736	7.7153	34.2428
SE	1.8281	1.7868	1.8080	1.9107	1.8093	2.7776	5.8517
CV	30.7609	30.0657	30.4231	32.1511	30.4451	46.7393	98.4667

Table 4.18. Sg. Selangor River, Malaysia: Main-Stem Reaches Error Analysis Results of Calibration and Validations for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using High-Flow Data

Error Analysis Parameter	Churchill et al. Predictive Equation	Langbein-Durum Predictive Equation	O'Connor-Dobbins Predictive Equation	Owens et al. Predictive Equation	Single coefficient (measured k_2)	Thackston-Krenkel Predictive Equation	Tsivoglou-Wallace Predictive Equation
Calibration 3 (Sept. 27, 1989 Data)							
SSE	14.3669	15.4808	14.5875	14.7521	33.4827	12.4960	11.4164
MSE	2.0524	2.2115	2.0839	2.1074	4.7832	1.7851	1.6309
SE	1.4326	1.4871	1.4436	1.4517	2.1871	1.3361	1.2771
CV	20.2185	20.9876	20.3732	20.4877	30.8658	18.8561	18.0232
Validation 3.1 (Nov. 14, 1989 Data)							
SSE	5.5953	4.8374	5.4200	5.4138	5.9114	7.5041	13.6515
MSE	0.7993	0.6911	0.7743	0.7734	0.8445	1.0720	1.9502
SE	0.8940	0.8313	0.8799	0.8794	0.9190	1.0354	1.3965
CV	10.7902	10.0329	10.6199	10.6138	11.0909	12.4960	16.8543
Validation 3.2 (Nov. 12, 1993 Data)							
SSE	22.0449	24.1636	22.2381	22.6400	52.9259	18.0221	11.8454
MSE	3.1493	3.4519	3.1769	3.2343	7.5608	2.5746	1.6922
SE	1.7746	1.8579	1.7824	1.7984	2.7497	1.6046	1.3008
CV	29.0241	30.3869	29.1510	29.4133	44.9717	26.2427	21.2755

The regression analysis and the spatial comparison of the main-stem reaches' predicted and measured dissolved oxygen levels complemented each other in interpretation. For example, Figure H-1 (Appendix H) indicated a consistent under-prediction of dissolved oxygen concentrations by both the Churchill et al. and Langbein-Durum predictive equations. The regression analysis results in Appendix G (Figures G-1 and G-2) indicated both the slopes and R^2 close to 1, and the regression lines are nearly parallel to the diagonal line of perfect-fit. The above results can be interpreted as a good prediction or simulation with a constant systematic error. The position of the regression lines above the line of perfect-fit indicated that the simulated dissolved oxygen levels were a little under-predicted. Similar interpretation also applies for Figure H-2 and Figures G-3 and G-4. If the regression lines are below the line of perfect-fit, the dissolved oxygen levels were over-predicted.

Meanwhile the consistent grouping of points close to the diagonal line of perfect-fit for the measured reaeration coefficients results with R^2 close to 0 indicated an accurate, but imprecise prediction (Martin and McCutcheon, 1999).

Both the Tsivoglou-Wallace and Thackston-Krenkel predictive equations results in low-flow and 7Q10 calibration/validations indicated inaccurate predictions in both Appendices J and K. In Figures G-6 and G-7 for example, the slopes are small and the y-intercepts are larger than 1.

CHAPTER 5

DISCUSSION

5.1 Introduction

In an ideal scientific study, the researcher will have an error-free methodology that gives perfect results. But the above condition, if it ever happens, is rare. The focus of this chapter is to further discuss and explain the study results.

5.2 Results of Field Measurement of Reaeration Coefficient (k_2)

One of the major questions with regard to the chemical application procedure of the disturbed equilibrium method was the amount of chemicals that had to be added to the stream water. The recommended method was to first measure the discharge of the study stream and then calculate the amount of sodium sulfite and cobalt chloride (Zogorski and Faust, 1973b).

Another question related to the chemical application procedure was the separate-tubing and simultaneous application method. The oxidant (sodium sulfite) was applied through a garden hose using two Teel™ immersible chemical pumps as mentioned in Chapter 3. The catalyst (cobalt chloride) was applied using a smaller diameter hose which was gravity-fed using a Merriott bottle set-up. Both hoses had holes drilled every 20 cm using a hot metal wire. These hoses were strung across the study stream using the lower beam of a bridge or in the absence of bridges, using wooden stakes driven into the streambed.

Several modifications had to be made as both the amount of the chemicals used and the chemical application procedure postulated by Zogorski and Faust (1973b) did not work in the field. The actual amount of sodium sulfite used turned out to be three times higher than recommended and the readings of the dissolved oxygen in the river at the first station (Point 1) barely indicated the expected sag after the application of the chemicals using the double tubing method. The modifications were:

(a) The catalyst (cobalt chloride) was mixed with the oxidant (sodium sulfite) immediately before the application. This was due to the fact that the set up recommended by Zogorski and Faust (1973b) failed to produce results. In the set up postulated by the two researchers using separate containers and pump/Merriott bottle, the chemicals failed to mix and oxidize the dissolved oxygen in the water. In the modification, the chemicals were mixed in separate containers, and the catalyst solution was poured into the catalyst container just before the application.

The chemical application was carried out using two epoxy-capsulated Teel™ submersible centrifugal pumps (Grainger Incorporated;

submerged operation only, 1/30 horsepower, 230V, 50/60 Hz). A portable, petrol-powered generator supplied electrical power. Each pump generated head of 1564 liters/hour (344 gph) at 1.22 m (4 ft.);

(b) The amount of chemicals recommended also failed to produce results (Zogorski and Faust, 1973b). The amount of sodium sulfite recommended for Sg. Selangor River with the discharge at 7.66 m^3/s was 574 g per 10-minute run targeted for a 4-mg/L deficit of dissolved oxygen. The recommendation for cobalt chloride was 72 g for a 10-minute run with the desired 1 mg/L of cobalt in the stream. The amount of sodium sulfite actually used for Sg. Selangor River was 1.5 kg, which was nearly three times the recommended amount. The amount of cobalt chloride catalyst was adjusted accordingly. No explanation can be postulated for this discrepancy as the river was clean and without major pollutant sources upstream.

A single garden hose was used in the chemical applications for Sg. Selangor River at Alor Lempah using the Teel pumps. Meanwhile at Sg. Serendah River, the chemical mixture was sprayed from a short hose connected to both pumps. This was possible because the width of the latter stream never exceeded four meters at the study reach.

One of the problems in the disturbed equilibrium method is the question of where to start measuring for the dissolved oxygen after the addition of the chemicals. The first point of dissolved oxygen measurement is at Point 1, which is the first deficit (D_1) in Equation 1.26. The question is due to fact that it is not easy to identify where the oxidant stops depleting the stream water of its oxygen and where the atmospheric reaeration starts. In the Sg. Selangor River study, to ensure that complete oxidation of sulfite to sulfate occurs, a sufficient amount of cobalt chloride must be added to maintain a concentration of between 0.3 to 1 mg/L. As a method of testing, a dilute mixture of starch and iodine was poured into the stream at several points before the first measurement (Point 1).

Despite the variability of the reaeration coefficients measured at Sg. Selangor River (Alor Lempah) and Sg. Serendah River, results indicate that the disturbed equilibrium method is an acceptable one although not the best. The state of the art method now is using the modified tracer method (Rathbun et al., 1975; Rathbun and Grant, 1978; Shultz et al., 1976; Grant and Skavroneck, 1980), but for the purpose of this study the cost would have been too prohibitive.

5.3 Results of Field Measurement of Sediment Oxygen Demand (SOD)

As the measurements were carried out in the cleaner upper reaches, the averaged SOD results for the lower reaches tend to be on the conservative side considering that there are more polluting sources in these reaches.

Chamber leakage was a chronic problem in both the Sg. Selangor River and Sg. Kerling River SOD measurements. The problem was due to the fact that the bottom sediment was sandy and would be easily washed away by eddies created by stream current and the SOD chamber during the course of the measurement. The eddies scoured the sediment on the upstream part of the chamber and deposited it on the downstream part. Continuous monitoring of the situation and alleviating the problem by piling the sand on the upstream portion of the chamber reduced the possibility of chamber leakage.

In QUAL2E modeling, sediment oxygen demand (SOD) relatively is not a very sensitive parameter. The SOD changes affected the simulated dissolved oxygen results linearly as indicated in the sensitivity analysis. The SOD rate changes will cause corresponding, inversely proportional simulated dissolved oxygen results (Appendix E; Figures E-13 and E-14).

Therefore, if SOD was used without actual measurements, but estimated within the acceptable range of values (i.e. within one standard deviation), the resulting error would be relatively small. On the other hand, the above assumption is unacceptable if the estimated SOD value was very far from the actual value. If the water quality modeling is for the purpose of wasteload allocation such under or overestimation of SOD would lead to erroneous management decisions.

5.4 Results of Field Measurement of Photosynthesis and Respiration

The measurement of photosynthesis and respiration using both the light-bottle/dark-bottle method and the Delta method failed to measure these two important parameters. Therefore it was assumed that there was minimal photosynthetic activity in Sg. Selangor River at Alor Lempah. It was assumed that the whole watershed remained unchanged during the extensive survey of the watershed in the beginning of the study; it was found then that there were no submergent plants in the river.

It is possible that a long-term study using both methods might give different results, but limited time did not allow for such an option. Furthermore, any river water quality modeling cannot ignore the photosynthesis/respiration factor out of hand as this also will give erroneous results.

5.4.1 Light-Bottle/Dark-Bottle Method Results

The expected results are basically the light bottles reading higher levels of dissolved oxygen due to the net production of oxygen by photosynthetic activity, and the dark bottles giving lower final dissolved oxygen as there was only respiration in these bottles. Therefore, although the P_{net} could be calculated using Equation 1.29 (page 44), R_{cm} cannot be calculated using Equation 1.31 as do_{df} is greater than do_{di}.

5.4.2 The Delta Method Results

The expected graph of the diurnal dissolved oxygen levels for a water body with significant photosynthetic activity would indicate an opposite cycle i.e. the dissolved oxygen levels would be lower during the night time (from 2000 hours to 0800 hours) due to respiration only situation, while the dissolved oxygen levels would be higher during the day time (0800 hours to 2000 hours) due to the net production of dissolved oxygen produced by photosynthetic activity. The dissolved oxygen levels were higher during the night at Alor Lempah due to the relatively cooler water temperature, which increased the saturation level (Figure 4.8).

The expected position of the diurnal dissolved oxygen concentration cycles also should be with the first cycle (night time) ***below*** the saturation dissolved oxygen while the second half of the cycle (day time) should be ***above*** the saturation dissolved oxygen (Chapra, 1997). Contrary to expectations, Figure 4.8 shows that the diurnal dissolved oxygen concentrations at Alor Lempah are ***below*** the saturation dissolved oxygen.

The light-bottle/dark-bottle method and the Delta method results above (Tables 4.5 and Figure 4.8, respectively) indicate that both methods cannot be used to calculate the photosynthetic rate and respiration in Sg. Selangor River. Therefore, due to the above results and the absence of submerged macrophytes at all reaches of Sg. Selangor River during the extensive survey, the photosynthesis/respiration factor was not used for the calibration and validation of Sg. Selangor River. It was assumed unnecessary to sample and analyze stream water for chlorophyll a, the algal biomass indicator. This parameter also directly calculates algal photosynthesis/respiration activities in QUAL2E.

5.5 Model Calibration and Validation Results

5.5.1 Water Quality Data Analysis Results

The site survey of the Sg. Selangor River watershed not only allowed for a first hand knowledge of the river, but also allowed for supplementary water quality sampling for parameters not analyzed by the Department of Environment water quality monitoring program. The missing parameters are critical for the water quality modeling using QUAL2E, especially for a more realistic water quality modeling of the river. These parameters include nitrite, which would consume dissolved oxygen, albeit in small amounts during its conversion to nitrate.

The water quality data analyzed for the study had several shortcomings with respect to the need to find water quality data with reliable discharge data. Several water quality parameter results were missing, and had to be filled with the averaged data from other water sampling dates. This problem is especially true for total coliforms (TC) and fecal coliforms (FC).

5.5.2 Low-Flow Analysis (7Q10) Results

The discharge data for Sg. Selangor River at both Rasa and Rantau Panjang indicate the large variability of the flow. The low-flow season tends to occur during the dry inter-monsoon season months of July to August although there is also a low-flow period during the other intermonsoon season in the months of February and March (Figure 4.9) (DOE, 1994).

5.5.3 Reaeration Coefficient and Predictive Equations Sensitivity Analysis

Results of Reaeration Coefficient (k_2) Sensitivity Analysis in QUAL2E due to Discharge

The results of the sensitivity analysis of the reaeration coefficient in QUAL2E due to discharge are shown in Appendix E (Figures E-1 to E-5). The same analysis, but presented in a different perspective i.e. the difference of simulated dissolved oxygen by predictive equations as the discharge was reduced (25 percent, 50 percent, 75 percent and 90 percent) are also shown in Appendix E (Figures E-6 to E-9). Examples from Appendix E are also shown in Figures 5.1 to 5.4.

The reduction of stream discharge by 25 percent does not seem to have caused different dissolved oxygen results between the equations (Appendix E; Figures E-6 and E-7). But the Owens et al. equation indicated relatively higher values after a 50 percent reduction in discharge (Appendix E; Figures E-7 to E-9). Be reminded that, the sudden drops at Kilometer 100 and Kilometer 60 in the figures are caused by the discharge of wastewater and inflow of a tributary with a relatively higher BOD concentration, respectively.

There is a marked difference in results at 75 percent reduction of the river headwater discharge (Appendix E; Figure E-8). The lowest dissolved oxygen values are from the Langbein-Durum equation between Kilometer 100 and Kilometer 60, while the highest values are from the Owens et al equation. The

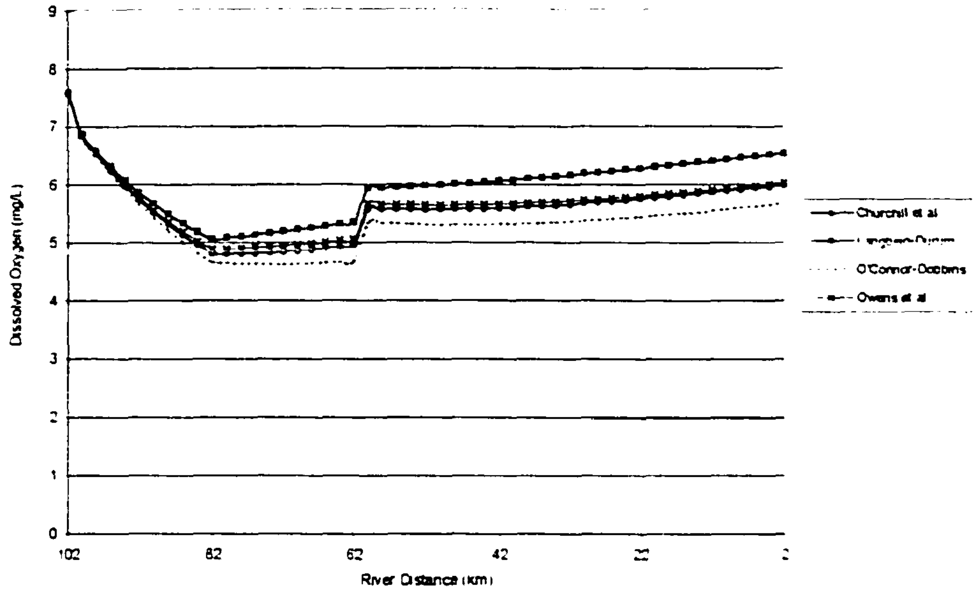

Figure 5.1. Sensitivity Analysis: Simulated DO in QUAL2E by Predictive Equations (Headwater Q = 5.787 m^3/s)

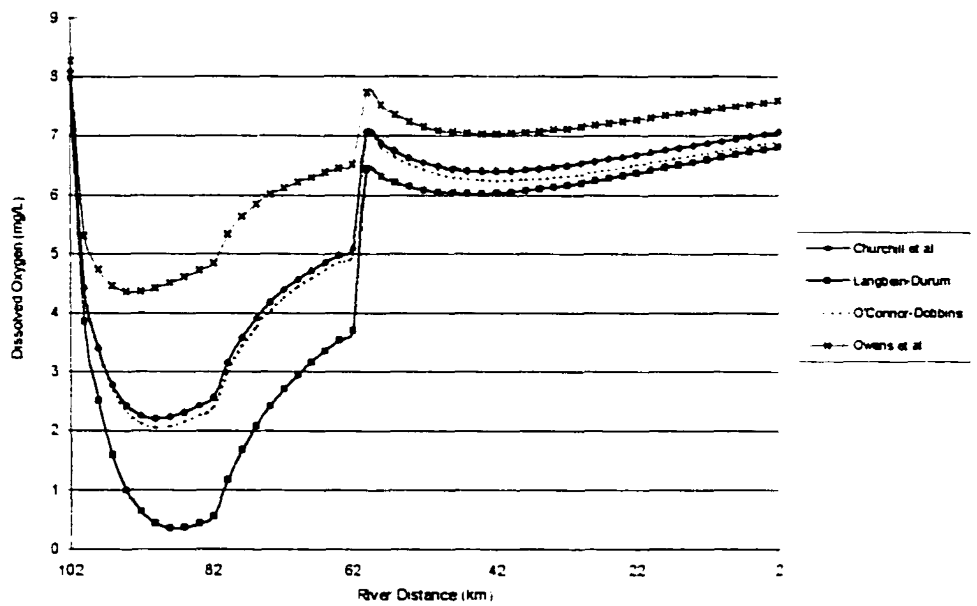

Figure 5.2. Sensitivity Analysis: Simulated DO in QUAL2E by Predictive Equations (Headwater Q = 0.58 m^3/s) (90 percent reduction)

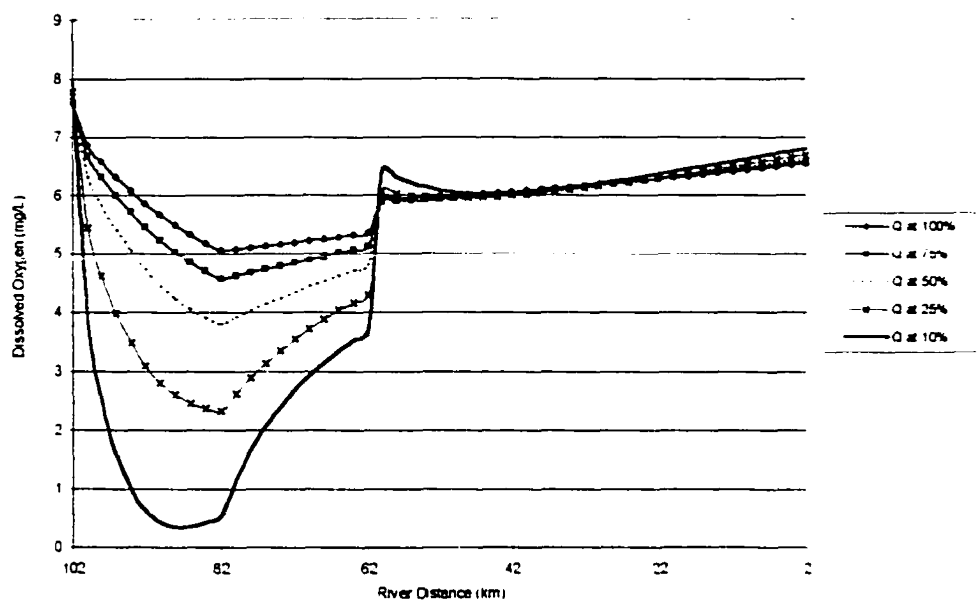

Figure 5.3. Sensitivity Analysis: Simulated DO Sensitivity to Discharge in QUAL2E (Langbein-Durum Predictive Equation)

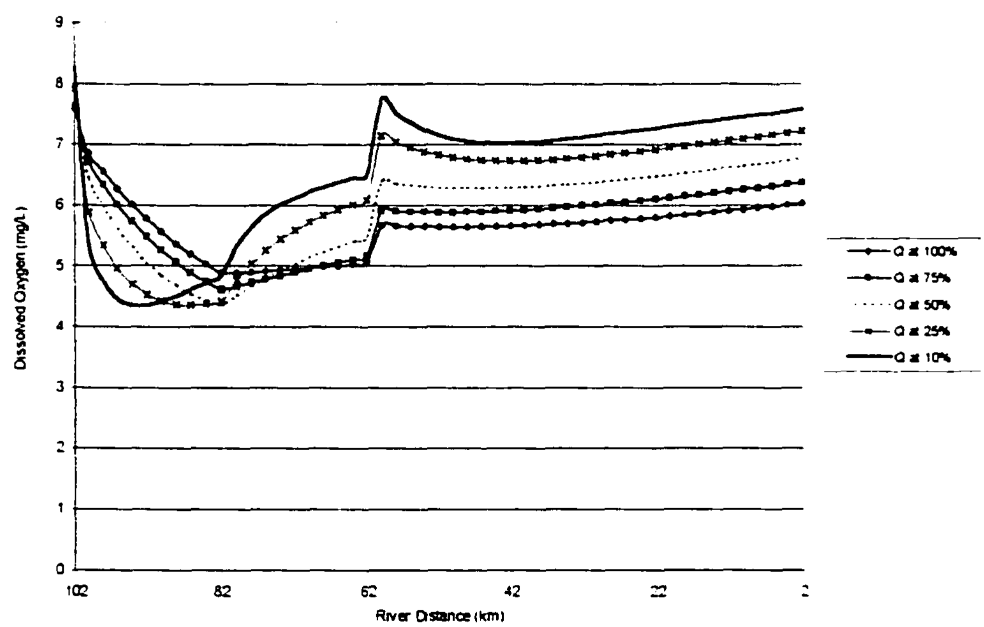

Figure 5.4. Sensitivity Analysis: Simulated DO Sensitivity to Discharge in QUAL2E (Owens et al. Predictive Equation)

difference between the highest and lowest values is about 2 mg/L at some points. The difference between the two equations seems more prominent at 90 percent headwater discharge reduction, with 4 mg/L difference of dissolved oxygen at some points (Appendix E; Figure E-9). At the same time, the O'Connor-Dobbins and Churchill equations seem to give relatively similar dissolved oxygen results.

When each equation is graphed on its own with the changes, from no reduction (Q = 5.787 m^3/s) to 90 percent reduction (Q = 0.58 m^3/s) in the headwater discharge, the Langbein-Durum equation indicates that it is most sensitive to the low-flow period (Appendix E; Figures E-10 to E-13).

Results of Reaeration Coefficient (k_2) Sensitivity Analysis in QUAL2E (Single Measured Coefficient)

Meanwhile, the results of the changes of the simulated dissolved oxygen in QUAL2E due to the changes in single coefficient reaeration coefficient (i.e. measured k_2) are shown in Figures E-10 to E-12 (Appendix E).

The results for the simulated dissolved oxygen are non-linear i.e. although the increase and decrease of the reaeration coefficient from the central value of 2 day^{-1} were of the same amount; the difference between the results was higher for the lower reaeration coefficient. This can be seen more prominently in the 50 percent change of reaeration coefficient. For example, at the 50th km reach the central k_2 (2 day^{-1}) dissolved oxygen was 6.18 mg/L while the upper k_2 (3 day^{-1}) simulated dissolved oxygen was 7.28 mg/L (a difference of

+1.1 mg/L). With the lower k_2 (1 day^{-1}), the simulated dissolved oxygen was 3.48 mg/L (a difference of -2.7 mg/L) (Appendix E; Figures E-10 to E-12).

Results of Sediment Oxygen Demand (SOD) Sensitivity Analysis in QUAL2E

The results of the simulated dissolved oxygen in QUAL2E due to sediment oxygen demand (SOD) are shown in Figures E-13 and E-14 in Appendix E. It can be summarized that SOD increases and decreases will affect the corresponding simulated dissolved oxygen proportionally in the inverse manner i.e. any increase in SOD will cause a decrease in dissolved oxygen.

SOD values changed linearly from the initial or central value as they were increased or decreased (Appendix E; Figures E-13 and E-14). Therefore, they are not as sensitive relative to k_2 in QUAL2E modeling. Nevertheless, measurements are needed for the river to be modeled because the variability of SOD ***between*** rivers can be large.

Results of Predictive Equations Sensitivity Analysis

The sensitivity analysis of the predictive equations due to depth (H) and stream velocity (V) was analyzed by fixing one of the variables and adjusting the other. The results are shown in Appendix E (Figures E-15 and E-16) as well as in Figures 5.5 and 5.6. The sensitivity of the reaeration coefficient (k_2) due to stream velocity in the predictive equation seems small during low velocity but even then the difference can be 1 day^{-1} to 2 day^{-1} difference between the equations. The difference can be very large as velocity increases. For example,

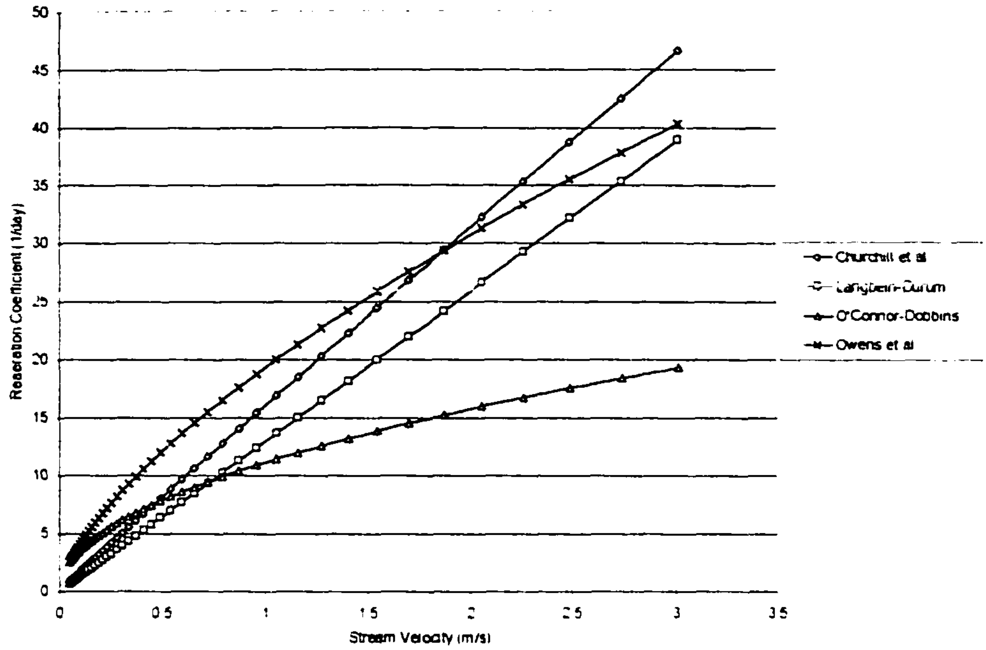

Figure 5.5. Sensitivity Analysis: Reaeration Coefficient (k_2) Sensitivity to Stream Velocity

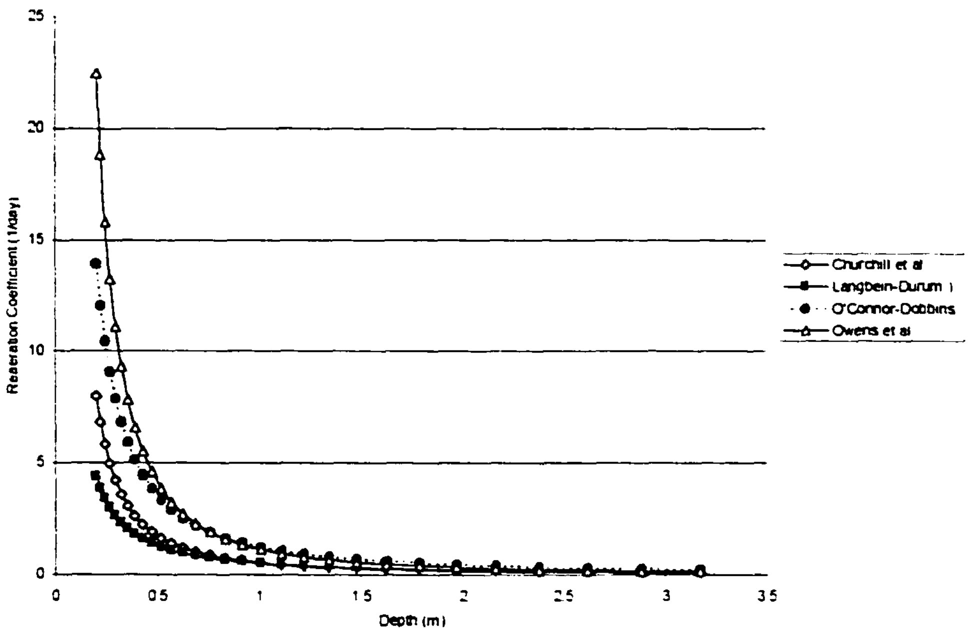

Figure 5.6. Sensitivity Analysis: Reaeration Coefficient (k_2) Sensitivity to Stream Depth

at 1.70 m/s, the O'Connor–Dobbins equation approximately calculated k_2 at 14.5 day^{-1}, while the Churchill et al. equation calculated it at 26.8 day^{-1} and the Owens et al. equation estimated it at 27.5 day^{-1} (Appendix E; Figure E-15).

As for depth, there are large differences between the equations when mean depth of the stream is low (Appendix E; Figure E-16). The k_2 differences become more prominent if the depth is less than 0.5 meter. The difference is more than four-fold between the Owens et al. k_2 and the Langbein-Durum k_2. The reaeration coefficient therefore is not sensitive to depth when the latter is on the high end. Since QUAL2E is used to model rivers and streams during low-flow periods and therefore shallow rivers, the use of the right predictive equation is necessary or there would be large errors in the results.

The results indicate that mean depth is the more sensitive parameter of the two as the relationship to reaeration coefficient (k_2) is a second order relationship. The Owens et al. equation results in the highest value of k_2 followed by O'Connor-Dobbins', Churchill et al.'s, and Langbein-Durum's. As depth was increased to about 1.1 m, the Churchill et al. equation resulted in k_2 similar to that from the Langbein-Durum equation and the O'Connor-Dobbins equation resulted in k_2 nearly equal to that from the Owens et al. equation.

5.5.4 Results of QUAL2E Calibration and Validation Methods for Comparison of Predicted to Measured Reaeration Coefficients (k_2)

Discussion of the Study Results (All-Reaches)

The measured reaeration coefficients did not give the best results for dissolved oxygen (DO) during the calibration and validations using the actual low-flow as comparatively indicated in Tables 4.13 to 4.15 and Appendix F (Tables F-4 to F-9).

The predictive equation that gave the best result (lowest SE or RMS) during the first calibration (actual low-flow data), was the Langbein-Durum predictive equation. This was followed by O'Connor-Dobbins, Churchill et al., Owens et al., measured reaeration coefficients, Thackston-Krenkel, and Tsivoglou-Wallace. During the first validation (January 13, 1987 data), the sequence in ascending order (from lowest SE to highest) was Langbein-Durum, O'Connor-Dobbins, Churchill et al., measured single coefficients, Owens et al., Thackston-Krenkel, and Tsivoglou-Wallace. Meanwhile, from the second validation (May 17, 1989 data) the sequence was Thackston-Krenkel, Tsivoglou-Wallace, Langbein-Durum, Churchill et al., O'Connor-Dobbins, Owens et al. and measured single coefficients.

On the other hand, the second calibration using March 4, 1986 water quality data and validations using January 13, 1987 and May 17, 1989 water quality data, with 7Q10 discharge data for Rasa and Rantau Panjang, gave different results from those above. Here, the measured reaeration coefficients gave the best results (lowest SE). The ascending order sequence of the SE for the calibration was the measured reaeration coefficients, O'Connor-Dobbins, Churchill et al., Langbein-Durum, Owens et al., Thackston-Krenkel and Tsivoglou-Wallace. The first validation using January 13, 1987 water quality data gave the same sequence. Meanwhile, the second validation using May 17, 1989 water quality data gave relatively higher SE results where the lowest SE was more than twice the lowest SE as in the calibration. The ascending SE sequence was the measured single coefficients, Langbein-Durum, O'Connor-Dobbins, Churchill et al., Owens et al., Thackston-Krenkel and Tsivoglou-Wallace (Table 4.14) (Appendix F; Tables F-16 to F-18).

The third calibration, which used the water quality data and discharge data from September 27, 1989 high-flow data and with the validations using November 14, 1989 and November 12, 1993 high-flow data gave surprising results as the lowest SE belonged to the Tsivoglou-Wallace predictive equation followed by the Thackston-Krenkel equation. But these results are suspect considering that many parameters used in the modeling such as the hydrogeometric parameters were measured during a low-flow period, rather than a high-flow period.

The remaining four predictive equations (O'Connor-Dobbins, Langbein-Durum, Churchill et al. and Owens et al.) gave SE values that were very similar to each other. The highest SE results belonged to the measured reaeration coefficients.

The results of the error analysis indicated that the temperature, BOD and dissolved oxygen only simulation gave similar SE results as the all-parameter simulation. It can be summarized that the dissolved oxygen assimilated by the nitrogen and phosphorus species of the water quality parameters was relatively minute.

The error analysis results for other parameters were the same for all predictive equations and measured single coefficients. During calibration, fecal coliforms (FC) gave the highest error due to their inherent large units, followed by total suspended solids (TSS), and total dissolved solids (TDS). Both parameters also have large units (Appendix F; Tables F-10 to F-12, Tables F-22 to F-24 and Tables F-34 to F-36).

The coefficient of variation (CV) was highest for organic phosphorus and organic nitrogen during both calibration and validation. Both parameters indicated large differences between the measured and predicted values. The averaged measured values of both parameters were three to seven times smaller than the averaged predicted values. The sinks of these parameters might not be all accounted for during the modeling. It is also viable to assume that the rate of decay and settling for both the organic phosphorus and organic nitrogen used were too small relative to the actual rates. The rates used were the ones proposed in water quality modeling literature (Bowie et al., 1985).

Discussion of the Study Results (Main-stem Reaches)

The regression analysis and the graphical comparison of the measured to the predicted dissolved oxygen levels gave important insight into the study that cannot be seen in the all-reaches analysis (Appendices K and J) (Figures 4.12 to 4.30).

Four predictive equations within QUAL2E (O'Connor-Dobbins, Langbein-Durum, Churchill et al. and Owens et al.) exhibit consistent, good predictions, with constant systematic errors in both of the above analyses. The measured reaeration coefficients indicated constant, accurate but imprecise predictions, where the points tended to group at one location at or near the diagonal line of perfect-fit.

Both the Thackston-Krenkel and Tsivoglou-Wallace equations predicted inaccurate dissolved oxygen values for Sg. Selangor River for the low-flow and 7Q10 data sets. These results indicate that both predictive equations are not suitable for Sg. Selangor River water quality modeling.

The analyses results also show up the quirkiness of water quality modeling, where good predictions at most reaches can statistically be influenced by a single large over prediction or under prediction at another reach. In the Sg. Selangor River case, the problem was due to underestimation of the wasteload from the Sg. Rawang River watershed, which has high residential and industrial growth. The under estimation led to the over prediction of dissolved oxygen in the reaches within Sg. Rawang River and also downstream of its confluence with Sg. Selangor River proper (main-stem).

It was difficult to estimate wasteload in a high-growth area such as Rawang especially from non-point sources considering that even point source data such as daily flow and loads were not all known. This is particularly true for treated sewage outfalls, which are covered by law but are lacking due to weak enforcement (Government of Malaysia, 1979). For the long-term benefit of water quality in Malaysia, it would be desirable for the Department of Environment (DOE) to implement a program comparable to the National Pollution Discharge Elimination System (NPDES) carried out by the USEPA in the United States, which would allow for the full documentation of all pollution sources.

Comparison to Past Studies

Most literature indicates that the O'Connor-Dobbins equation performs better in deeper, slower velocity streams than the Owens et al. and Churchill predictive equations which are better for faster, shallower streams (Covar, 1976; Zison, 1978 and Chapra, 1997). Sg. Selangor River and its tributaries tend to have both the characteristics, with the main stem maintaining the deeper, slower velocity characteristics at the lower and middle reaches and the tributaries and upper reaches of the main stem having the shallower, faster velocity characteristics. The three predictive equations mentioned above performed equally well in Sg. Selangor River, but relatively, the best predictive equation is the Langbein-Durum equation. The Tsivoglou-Wallace predictive equation did not perform well for Sg. Selangor River during the low-flow and 7Q10 discharge data calibration and validations. The predictive equation tends to simulate very low dissolved oxygen values at the lower reaches with the Tsivoglou-Wallace equation predicting zero values at several places.

Most comparative studies of predictive equations of the reaeration coefficient analyzed the difference of the results predicted by these equations to observed data (Grant and Skavroneck, 1980; Rathbun, 1977). Several other studies used standard error of the estimate as measures of the predictive values (Bennett and Rathbun, 1972; Wilson and MacLeod, 1974). There was no known study carried out by incorporating the predictive equations into a specific water quality model.

The Bennett and Rathbun study (1972) evaluated 13 equations. The equations that best fit the entire range of data were O'Connor-Dobbins (1956), Dobbins (1965) and Thackston and Krenkel (1969). Meanwhile in the Wilson and MacLeod study (1974), it was concluded that the Dobbins equation (1964) and the Parkhurst-Pomeroy equation (1972) best fit the observed data.

Rathbun (1977) reviewed 19 equations by comparing the predicted data to radioactive tracer measurements on five rivers (Chattahoochee, Jackson, Flint, South, and Patuxent). The best equations in descending order are Tsivoglou-Wallace (1972), Parkhurst-Pomeroy (1972), Padden-Gloyna (1971) and Owens et al. (1964).

In the Grant and Skavroneck study (1980), the predicted reaeration coefficients were compared to measured reaeration coefficients obtained using radioactive tracers. In this particular study the Tsivoglou-Neal equation (1976) gave the smallest error at 18 percent.

The mix of results above indicates that there is no one formula or even a chosen few that are best for all rivers. Therefore, it cannot be concluded that a single predictive equation is best for a particular river. But this kind of conclusion does not assist decision makers, and has therefore brought about the classification of rivers such as deeper, slower velocity streams versus faster, shallower streams, and the suggestion that predictive equations be used (Covar, 1976; Zison, 1978 and Chapra, 1997).

CHAPTER 6

CONCLUSIONS

The main purpose of this study was to determine if the QUAL2E water quality model is applicable in a tropical climate to predict dissolved oxygen concentrations using the reaeration coefficient (k_2). QUAL2E uses either the six predictive equations within the model or the measured reaeration coefficients input. The model works best with the reaeration coefficients measured directly in the field for Sg. Selangor River in Malaysia.

The conclusions of this study are:

1. The reaeration coefficient (k_2) measured at Sg. Selangor River gave the lowest standard error (SE = 1.31) for the simulation of water quality using the 7Q10 discharge data, which is considered as the worst case scenario in water quality modeling;
2. During calibration and validation using actual low-flow discharge data, the measured reaeration coefficients did not give the lowest standard error (1.53), but several predictive equations within QUAL2E gave better results, including Langbein-Durum (1.29), O'Connor-Dobbins (1.34), the Churchill et al. (1.35) and the Owens et al. (1.42) equations;

3. During high-flow conditions, the Thackston-Krenkel and the Tsivoglou-Wallace predictive equations tended to have the lower standard errors (1.45 and 1.22, respectively). But these results are suspect since the channel geometry parameters used in the modeling were measured during a low-flow period, not high-flows;
4. Changes in SOD values would inversely affect the corresponding simulated dissolved oxygen i.e. any increase in SOD would cause a decrease in dissolved oxygen. SOD values are not as sensitive relative to k_2 in QUAL2E modeling;
5. The reaeration coefficient (k_2) is very sensitive to depth especially if the depth is less than 0.5 meter. The reaeration coefficient is not as sensitive when the river is deeper.

The final answer of whether to measure specific reaeration coefficients for each river to be modeled or to use the predictive equations depends on the specific needs of the modeler. If accurate results are needed, the modeler would probably need to measure the reaeration coefficients. If less accurate results are sufficient such as for the purpose of wasteload allocations, the four predictive equations within QUAL2E (Langbein-Durum, O'Connor-Dobbins, Churchill et al and Owens et al. equations) can be used. Only further modeling of other rivers within Malaysia will point to which predictive equation(s) are the best to use.

The lack of success of the measured reaeration coefficients to give the best results (i.e. smallest SE) for both the actual and 7Q10 conditions may be due to the measurement of reaeration coefficients at only two locations of Sg. Selangor River. The results could be improved if all tributaries and additional locations on the main stem of Sg. Selangor River were measured. Realistically, the cost of such a venture would be prohibitive. In the case of Sg. Selangor River, the use of one or a mixture of the predictive equations within QUAL2E (Langbein-Durum, O'Connor-Dobbins, Churchill et al. and Owens et al. equations) seems adequate.

CHAPTER 7

RECOMMENDATIONS

Water quality models have come a long way since the Streeter and Phelps dissolved oxygen sag model. Still, the focus of even the most advanced model such as QUAL2E remains on the all important water quality parameter, dissolved oxygen, which depends on the atmospheric reaeration and reaeration coefficient (k_2).

Model users have utilized models in their respective fields without considering the suitability of those models to the specific locale, and the central theme of this study is to question the validity of such action. The question was raised in surface water quality modeling due to the history of the research in reaeration coefficient (k_2), which was done mostly in temperate zones, especially in the United States and United Kingdom.

Several important recommendations based on the research performed in this study on reaeration coefficient (k_2) include:

(a) Reaeration coefficient field measurements in tropical rivers using better methods such as the modified tracer method should be implemented (Rathbun et al., 1975; Rathbun and Grant, 1978; Shultz et al., 1976; Grant and Skavroneck, 1980). The results from such studies would enable the formulations of predictive equations for use in tropical conditions;

(b) Comparative research on reaeration coefficient in other climates such as desert, sub-arctic or other tropical regions of the world should be implemented;

(c) Comparative studies on the application of other reaeration coefficient predictive equations not presently used in QUAL2E would be useful. Incorporating these predictive equations into QUAL2E by changing the computer codes of the model can do this;

(d) Studies on specific parameters such as SOD rates, rates of decay and settling of BOD, organic nitrogen and organic phosphorus should be carried out. Over reliance on literature based on studies in other climates and environment could lead to erroneous results.

(e) It would be desirable for the Department of Environment, Malaysia (DOE) to implement a long-term program comparable to the National Pollution Discharge Elimination System (NPDES) carried out by the USEPA in the United States, which would allow for the full documentation of **ALL** pollution sources.

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APPENDIX A

QUAL2E Reach Presentation Method

River reach designation is neither straightforward nor explained in detail in both the QUAL2E Manual and QUAL2E Windows Manual. The method postulated below will help the first time user of the water quality model.

1) Draw ALL the elements and reaches of the river to be presented in the model. One square represents a single element within a reach. The length of each element depends on the amount of data available on the watershed; if more data is available, the length of each element can be shorter. Element length examples – 0.5 km, 1 km or 2 km;

2) Count and designate the element numbers starting from the headwater of the mainstem river. Upon reaching an element before a junction with a modeled tributary (a tributary not modeled is assumed as a point source discharge), continue the count and element number designation from the headwater of the tributary until reaching the mainstem again;

3) Continue the count and element number designation until the selected last reach of the river is arrived at;

4) The total number of elements in the whole river to be modeled is the total designated elements count plus an extra element as the numbering convention is subtracting the end of the reach from the beginning of the reach;

5) The numbering in QUAL2E Windows (second window – Stream Reach System) is in descending order i.e. the headwater of the mainstem river starts with the total number of elements as in (4) until the reach meets a

junction with a modeled tributary or a maximum of 20 elements, whichever comes first;

6) Each modeled tributary reach presentation is numbered separately from the mainstem river. Counting the total number of elements in a tributary starts from the headwater of that particular tributary and proceeds in descending order until the junction of the tributary and mainstem river is reached. The 20-element limit also applies, which means a tributary with more than 20 elements has to be broken down into two or more reaches. The confluence with the mainstem must be designated as 0;

7) The process continues until the final element. NOTE: The final element will not end as 1.

8) To check your reach presentation, click on GRAPHICS on QUAL2E Windows and then click on REACHES. The resulting graphic shows all tributaries on the left of the mainstem river although in nature it could be otherwise.

APPENDIX B

QUAL2E Output Example

* * * QUAL-2E STREAM QUALITY ROUTING MODEL * * *
Version 3.21 Feb 1995

$$$ (PROBLEM TITLES) $$$

CARD TYPE		QUAL-2E PROGRAM TITLES
TITLE01		Sungai Selangor Calibration (Temp., Do and Bod) ... Flow
TITLE02		
TITLE03	NO	CONSERVATIVE MINERAL I
TITLE04	NO	CONSERVATIVE MINERAL II
TITLE05	NO	CONSERVATIVE MINERAL III
TITLE06	YES	TEMPERATURE
TITLE07	YES	5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08	NO	ALGAE AS CHL-A IN UG/L
TITLE09	NO	PHOSPHORUS CYCLE AS P IN MG/L
TITLE10		(ORGANIC-P; DISSOLVED-P)
TITLE11	NO	NITROGEN CYCLE AS N IN MG/L
TITLE12		(ORGANIC-N, AMMONIA-N, NITRITE-N,' NITRATE-N)
TITLE13	YES	DISSOLVED OXYGEN IN MG/L
TITLE14	NO	FECAL COLIFORM IN NO./100 ML
TITLE15	NO	ARBITRARY NON-CONSERVATIVE
ENDTITLE		

$$$ DATA TYPE 1 (CONTROL DATA) $$$

CARD TYPE		CARD TYPE	
LIST DATA INPUT	0.00000		0.00000
NO WRITE OPTIONAL SUMMARY	0.00000		0.00000
NO FLOW AUGMENTATION	0.00000		0.00000
STEADY STATE	0.00000		0.00000
NO TRAP CHANNELS	0.00000		0.00000
NO PRINT LCD/SOLAR DATA	0.00000		0.00000
NO PLOT DO AND BOD DATA	0.00000		0.00000
FIXED DNSTM CONC (YES=1)=	0.00000	5D-ULT BOD CONV K COEF	0.23000
INPUT METRIC	1.00000	OUTPUT METRIC	1.00000
NUMBER OF REACHES	24.00000	NUMBER OF JUNCTIONS	8.00000
NUM OF HEADWATERS	9.00000	NUMBER OF POINT LOADS	21.00000
TIME STEP (HOURS)	1.00000	LNTH. COMP. ELEMENT (DX)=	1.00000
MAXIMUM ROUTE TIME (HRS)=	10.00000	TIME INC. FOR RPT2 (HRS)=	1.00000
LATITUDE OF BASIN (DEG)	3.50000	LONGITUDE OF BASIN (DEG)	101.50000
STANDARD MERIDIAN (DEG) =	75.00000	DAY OF YEAR START TIME	160.00000
EVAP. COEF.,(AE)	0.00061	EVAP. COEF.,(BE)	0.00061
ELEV. OF BASIN (ELEV)	15.00000	DUST ATTENUATION COEF.	0.13000
ENDATA1	0.00000		0.00000

$$$ (TEMPERATURE CORRECTION CONSTANTS FOR RATE COEFFICIENTS) $$$

CARD TYPE	RATE CODE	THETA VALUE	
THETA(1)	BOD DECA	1.047	USER
THETA(2)	BOD SETT	1.024	USER
THETA(3)	OXY TRAN	1.024	USER

THETA(4)	SOD RATE	1.060	DFLT
THETA(5)	ORGN DEC	1.047	DFLT
THETA(6)	ORGN SET	1.024	DFLT
THETA(7)	NH3 DECA	1.083	DFLT
THETA(8)	NH3 SRCE	1.074	DFLT
THETA(9)	NO2 DECA	1.047	DFLT
THETA(10)	PORG DEC	1.047	DFLT
THETA(11)	PORG SET	1.024	DFLT
THETA(12)	DISP SRC	1.074	DFLT
THETA(13)	ALG GROW	1.047	DFLT
THETA(14)	ALG RESP	1.047	DFLT
THETA(15)	ALG SETT	1.024	DFLT
THETA(16)	COLI DEC	1.047	DFLT
THETA(17)	ANC DECA	1.000	DFLT
THETA(18)	ANC SETT	1.024	DFLT
THETA(19)	ANC SRCE	1.000	DFLT
ENDATA1B			

CARD TYPE	REACH ORDER AND IDENT				R. MI/KM		R. MI/KM
STREAM REACH	1.0	RCH	Ulu Selangor 1	FROM	295.0	TO	275.0
STREAM REACH	2.0	RCH	Ulu Selangor 2	FROM	275.0	TO	261.0
STREAM REACH	3.0	RCH	Sg. Kening 1	FROM	25.0	TO	4.0
STREAM REACH	4.0	RCH	Sg. Kening 2	FROM	4.0	TO	0.0
STREAM REACH	5.0	RCH	Kening Btgkali	FROM	261.0	TO	257.0
STREAM REACH	6.0	RCH	Sg. Btgkali 1	FROM	26.0	TO	6.0
STREAM REACH	7.0	RCH	Sg. Btgkali 2	FROM	6.0	TO	0.0
STREAM REACH	8.0	RCH	Btgkali Kerling	FROM	257.0	TO	245.0
STREAM REACH	9.0	RCH	Sg. Kerling 1	FROM	46.0	TO	26.0
STREAM REACH	10.0	RCH	Sg. Kerling 2	FROM	26.0	TO	6.0
STREAM REACH	11.0	RCH	Sg. Kerling 3	FROM	6.0	TO	0.0
STREAM REACH	12.0	RCH	Kerling Buloh	FROM	245.0	TO	241.0
STREAM REACH	13.0	RCH	Sg. Buloh 1	FROM	22.0	TO	4.0
STREAM REACH	14.0	RCH	Sg. Buloh 2	FROM	4.0	TO	0.0
STREAM REACH	15.0	RCH	Buloh Rawang	FROM	241.0	TO	223.0
STREAM REACH	16.0	RCH	Ulu Rawang	FROM	36.0	TO	16.0
STREAM REACH	17.0	RCH	Sg. Serendah	FROM	16.0	TO	0.0
STREAM REACH	18.0	RCH	Serendah K'dang	FROM	16.0	TO	8.0
STREAM REACH	19.0	RCH	Kundang 1	FROM	26.0	TO	6.0
STREAM REACH	20.0	RCH	Kundang 2	FROM	6.0	TO	0.0
STREAM REACH	21.0	RCH	K'dang Gunt'g	FROM	8.0	TO	4.0
STREAM REACH	22.0	RCH	Sg. Guntung	FROM	10.0	TO	0.0
STREAM REACH	23.0	RCH	Gunt'g Sembah	FROM	4.0	TO	0.0
STREAM REACH	24.0	RCH	Kantan Panjang	FROM	223.0	TO	215.0
ENDATA2	0.0				0.0		0.0

HYDRAULIC DATA FOR DETERMINING VELOCITY AND DEPTH

CARD TYPE	REACH	COEF DSPN	COEFQV	EXPOQV	COEFQH	EXPOQH	CMANN
HYDRAULICS	1	60.00	0.431	0.132	0.063	0.930	0.020
HYDRAULICS	2	60.00	0.431	0.132	0.063	0.930	0.020
HYDRAULICS	3	60.00	0.275	0.496	0.657	0.279	0.020
HYDRAULICS	4	60.00	0.431	0.132	0.063	0.930	0.020
HYDRAULICS	5	60.00	0.431	0.132	0.063	0.930	0.020

HYDRAULICS	6	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	7	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	8	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	9	60.00	0.275	0.396	0.657	0.279	0.020
HYDRAULICS	10	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	11	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	12	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	13	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	14	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	15	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	16	60.00	0.275	0.396	0.657	0.279	0.020
HYDRAULICS	17	60.00	0.275	0.396	0.657	0.279	0.020
HYDRAULICS	18	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	19	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	20	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	21	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	22	60.00	0.275	0.396	0.657	0.279	0.020
HYDRAULICS	23	60.00	0.431	0.132	0.083	0.910	0.020
HYDRAULICS	24	60.00	0.431	0.132	0.083	0.910	0.020
ENDATA5	0	0.00	0.000	0.000	0.000	0.000	0.000

(REACTION COEFFICIENTS FOR DEOXYGENATION AND REAERATION)

CARD TYPE	REACH	K1	K3	SOD RATE	K2OPT	K2	COEQK2 OR TSIV COEF FOR OPT 8	OR	EXPQK2 OR SLOPE FOR OPT 8
REACT COEF	1	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	2	0.70	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	3	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	4	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	5	0.55	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	6	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	7	0.55	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	8	0.70	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	9	0.70	0.00	0.384	8	57.00	0.000		0.00000
REACT COEF	10	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	11	0.55	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	12	0.46	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	13	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	14	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	15	0.46	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	16	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	17	0.70	0.00	4.230	8	57.00	0.000		0.00000
REACT COEF	18	0.55	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	19	0.70	0.00	0.384	8	24.52	0.000		0.00000
REACT COEF	20	0.55	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	21	0.46	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	22	0.55	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	23	0.41	0.00	4.230	8	24.52	0.000		0.00000
REACT COEF	24	0.41	0.00	4.230	8	24.52	0.000		0.00000
ENDATA6	0	0.00	0.00	0.000	0	0.00	0.000		0.00000

(INITIAL CONDITIONS)

CARD TYPE	REACH	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INITIAL COND-1	1	22.00	6.50	1.00	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	2	22.00	6.50	1.00	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	3	22.00	6.50	1.00	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	4	23.00	7.60	0.90	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	5	23.00	7.60	0.90	44.00	0.00	0.00	27.00	0.00
INITIAL COND-1	6	23.00	7.80	0.90	34.00	0.00	0.00	58.00	0.00
INITIAL COND-1	7	23.00	7.80	0.90	34.00	0.00	0.00	58.00	0.00
INITIAL COND-1	8	23.00	7.60	0.90	44.00	0.00	0.00	27.00	0.00
INITIAL COND-1	9	26.00	7.00	0.90	34.00	0.00	0.00	16.00	0.00
INITIAL COND-1	10	26.00	7.00	0.90	34.00	0.00	0.00	16.00	0.00
INITIAL COND-1	11	26.00	7.60	0.90	34.00	0.00	0.00	16.00	0.00
INITIAL COND-1	12	26.00	7.60	0.90	44.00	0.00	0.00	27.00	0.00
INITIAL COND-1	13	23.00	8.00	0.90	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	14	23.00	7.60	0.90	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	15	26.00	6.70	2.00	44.00	0.00	0.00	27.00	0.00
INITIAL COND-1	16	25.00	8.20	0.40	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	17	26.00	7.50	0.40	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	18	29.00	4.50	2.00	44.00	0.00	0.00	27.00	0.00
INITIAL COND-1	19	29.50	4.70	0.90	28.00	0.00	0.00	14.00	0.00
INITIAL COND-1	20	30.50	4.70	2.00	34.00	0.00	0.00	58.00	0.00
INITIAL COND-1	21	29.00	4.50	2.00	34.00	0.00	0.00	58.00	0.00
INITIAL COND-1	22	29.00	4.70	0.90	24.00	0.00	0.00	58.00	0.00
INITIAL COND-1	23	31.00	4.10	1.00	44.00	0.00	0.00	87.00	0.00
INITIAL COND-1	24	30.00	4.30	1.00	44.00	0.00	0.00	87.00	0.00
ENDATA7	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(INCREMENTAL INFLOW CONDITIONS)

CARD TYPE	REACH	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3	ANC	COLI
INCR INFLOW-1	1	1.100	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	2	0.700	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	3	0.360	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	4	0.080	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	5	0.120	25.00	4.00	5.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	6	0.450	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	7	0.120	25.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	8	0.340	25.00	4.00	5.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	9	0.450	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	10	0.350	25.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	11	0.120	25.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	12	0.080	25.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	13	0.360	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	14	0.080	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	15	0.320	25.00	4.00	5.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	16	0.450	25.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	17	0.320	25.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	18	0.160	26.00	4.00	10.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	19	0.320	25.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW-1	20	0.120	28.00	4.00	5.00	0.00	0.00	0.00	0.00	0.00

INCR INFLOW 1	21	0.100	26.00	4.00	10.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW 1	22	0.200	26.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW 1	23	0.080	28.00	4.00	5.00	0.00	0.00	0.00	0.00	0.00
INCR INFLOW 1	24	0.160	26.00	4.00	3.00	0.00	0.00	0.00	0.00	0.00
ENDATA8	0	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

(HEADWATER SOURCES)

CARD TYPE	HDWTR ORDER	NAME	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
HEADWTR 1	1	Ulu Selangor 1	1.33	19.00	8.20	0.50	0.00	0.00	0.00
HEADWTR 1	2	Sg Rening 1	0.31	19.00	8.00	0.50	0.00	0.00	0.00
HEADWTR 1	3	Sg Btgkali 1	0.74	19.00	8.00	0.50	0.00	0.00	0.00
HEADWTR 1	4	Sg Perling 1	0.76	19.00	8.20	0.50	0.00	0.00	0.00
HEADWTR 1	5	Sg Buluh 1	0.43	20.00	8.00	0.50	0.00	0.00	0.00
HEADWTR 1	6	Ulu Rawang	0.45	20.00	8.00	0.50	0.00	0.00	0.00
HEADWTR 1	7	Sg Serendah	0.39	20.00	8.20	0.50	0.00	0.00	0.00
HEADWTR 1	8	Fundang 1	0.40	22.00	7.80	0.50	0.00	0.00	0.00
HEADWTR 1	9	Sg Guntung	0.25	22.00	7.80	0.50	0.00	0.00	0.00
ENDATA10	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00

(POINT SOURCE / POINT SOURCE CHARACTERISTICS)

CARD TYPE	POINT LOAD ORDER	NAME	EFF	FLOW	TEMP	D.O.	BOD	CM-1	CM-2	CM-3
POINTLD 1	1	E Kuala Baru	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	2	E Kuala Baru	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	3	Rasa	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	4	BatangKali1	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	5	BatangKali2	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	6	BatangKali3	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	7	Perling1	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	8	Perling2	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	9	Rawang1	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	10	Rawang2	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	11	Rawang3	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	12	Rawang4	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	13	Rawang5	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	14	Rawang6	0.60	0.01	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	15	Serendah1	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	16	Serendah2	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	17	Serendah3	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	18	Pekan Fundan	0.60	0.05	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	19	Fundang2	0.60	0.00	28.00	2.00	120.00	0.00	0.00	0.00
POINTLD 1	20	Rantau Panjang	0.00	0.25	28.00	6.00	1.00	0.00	0.00	0.00
POINTLD 1	21	SS Phase 2	0.00	4.58	28.00	6.00	1.00	0.00	0.00	0.00
ENDATA11	0		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC KILO	END LOC KILO	FLOW CMS	POINT SRCE CMS	INCR FLOW CMS	VEL MPS	TRVL TIME DAY	DEPTH M	WIDTH M	VOLUME K-CU M	BOTTOM AREA K-SQ M	X-SECT AREA SQ M	DISPRSN COEF SQ M/S
1	1	1	295.00	294.00	1.38	0.00	0.05	0.450	0.026	0.112	[illegible]	3.08	[illegible]	3.08	0.27
2	1	2	294.00	293.00	1.44	0.00	0.05	0.452	0.026	0.117	[illegible]	3.18	[illegible]	3.18	0.28
3	1	3	293.00	292.00	1.49	0.00	0.05	0.454	0.025	0.121	[illegible]	3.29	27.46	3.29	0.29
4	1	4	292.00	291.00	1.55	0.00	0.05	0.457	0.025	0.125	27.17	3.39	27.43	3.39	0.30
5	1	5	291.00	290.00	1.60	0.00	0.05	0.459	0.025	0.129	[illegible]	3.50	27.38	3.50	0.31
6	1	6	290.00	289.00	1.66	0.00	0.05	0.461	0.025	0.133	[illegible]	3.60	27.33	3.60	0.32
7	1	7	289.00	288.00	1.71	0.00	0.05	0.463	0.025	0.137	[illegible]	3.71	27.28	3.71	0.33
8	1	8	288.00	287.00	1.77	0.00	0.05	0.465	0.025	0.141	[illegible]	3.81	27.24	3.81	0.34
9	1	9	287.00	286.00	1.82	0.00	0.05	0.467	0.025	0.145	26.898	3.91	27.20	3.91	0.35
10	1	10	286.00	285.00	1.88	0.00	0.05	0.468	0.025	0.149	26.849	4.01	27.15	4.01	0.36
11	1	11	285.00	284.00	1.93	0.00	0.05	0.470	0.025	0.154	26.801	4.12	27.11	4.11	0.37
12	1	12	284.00	283.00	1.99	0.00	0.05	0.472	0.025	0.158	26.754	4.22	27.08	4.22	0.38
13	1	13	283.00	282.00	2.04	0.00	0.05	0.474	0.024	0.162	26.709	4.32	27.04	4.32	0.39
14	1	14	282.00	281.00	2.10	0.00	0.05	0.475	0.024	0.166	26.665	4.42	27.00	4.42	0.40
15	1	15	281.00	280.00	2.15	0.00	0.05	0.477	0.024	0.170	26.622	4.52	26.97	4.52	0.41
16	1	16	280.00	279.00	2.21	0.00	0.05	0.479	0.024	0.174	26.581	4.62	26.93	4.62	0.42
17	1	17	279.00	278.00	2.26	0.00	0.05	0.480	0.024	0.178	26.540	4.72	26.90	4.72	0.43
18	1	18	278.00	277.00	2.32	0.00	0.05	0.482	0.024	0.182	26.501	4.82	26.87	4.82	0.44
19	1	19	277.00	276.00	2.37	0.00	0.05	0.483	0.024	0.186	26.462	4.92	26.84	4.92	0.45
20	1	20	276.00	275.00	2.43	0.00	0.05	0.485	0.024	0.190	26.425	5.02	26.81	5.01	0.46
21	2	1	275.00	274.00	2.48	0.00	0.05	0.486	0.024	0.193	26.392	5.11	26.78	5.10	0.46
22	2	2	274.00	273.00	2.53	0.00	0.05	0.487	0.024	0.197	26.359	5.19	26.76	5.19	0.47
23	2	3	273.00	272.00	2.58	0.00	0.05	0.488	0.024	0.201	26.327	5.26	26.73	5.28	0.48
24	2	4	272.00	271.00	2.63	0.00	0.05	0.490	0.024	0.204	26.296	5.37	26.71	5.37	0.49
25	2	5	271.00	270.00	2.68	0.00	0.05	0.491	0.024	0.208	26.265	5.46	26.69	5.46	0.50
26	2	6	270.00	269.00	2.73	0.00	0.05	0.492	0.024	0.211	26.235	5.55	26.66	5.55	0.51
27	2	7	269.00	268.00	2.78	0.00	0.05	0.493	0.024	0.215	26.205	5.64	26.64	5.64	0.52
28	2	8	268.00	267.00	2.84	0.01	0.05	0.495	0.023	0.219	26.172	5.74	26.62	5.74	0.53
29	2	9	267.00	266.00	2.90	0.01	0.05	0.496	0.023	0.223	26.139	5.84	26.59	5.84	0.53
30	2	10	266.00	265.00	2.95	0.00	0.05	0.497	0.023	0.227	26.112	5.93	26.57	5.93	0.54
31	2	11	265.00	264.00	3.00	0.00	0.05	0.498	0.023	0.231	26.084	6.01	26.55	6.01	0.55
32	2	12	264.00	263.00	3.05	0.00	0.05	0.499	0.023	0.234	26.058	6.10	26.54	6.10	0.56
33	2	13	263.00	262.00	3.10	0.00	0.05	0.500	0.023	0.238	26.031	6.19	26.51	6.19	0.57
34	2	14	262.00	261.00	3.15	0.00	0.05	0.501	0.023	0.241	26.005	6.27	26.49	6.27	0.58
35	3	1	22.00	21.00	0.33	0.00	0.02	0.177	0.065	0.482	[illegible]	[illegible]	4.03	[illegible]	0.36
36	3	2	21.00	20.00	0.35	0.00	0.02	0.181	0.064	0.490	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
37	3	3	20.00	19.00	0.37	0.00	0.02	0.185	0.062	0.497	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
38	3	4	19.00	18.00	0.39	0.00	0.02	0.189	0.061	0.505	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
39	3	5	18.00	17.00	0.41	0.00	0.02	0.193	0.060	0.512	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
40	3	6	17.00	16.00	0.43	0.00	0.02	0.197	0.059	0.519	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
41	3	7	16.00	15.00	0.45	0.00	0.02	0.200	0.058	0.525	[illegible]	[illegible]	[illegible]	[illegible]	0.44
42	3	8	15.00	14.00	0.47	0.00	0.02	0.204	0.057	0.532	[illegible]	[illegible]	5.40	[illegible]	0.45
43	3	9	14.00	13.00	0.49	0.00	0.02	0.207	0.056	0.538	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

44	3	10	13.00	12.00	0.51	0.00	0.02	0.211	0.055	0.544	4.451	2.42	5.54	2.42	0.48
45	3	11	12.00	11.00	0.53	0.00	0.02	0.214	0.054	0.550	4.506	2.48	5.61	2.48	0.49
46	3	12	11.00	10.00	0.55	0.00	0.02	0.217	0.053	0.554	4.561	2.53	5.67	2.53	0.50
47	3	13	10.00	9.00	0.57	0.00	0.02	0.220	0.053	0.561	4.613	2.59	5.74	2.59	0.51
48	3	14	9.00	8.00	0.59	0.00	0.02	0.223	0.052	[illegible]	4.666	2.64	5.80	2.64	0.52
49	3	15	8.00	7.00	0.61	0.00	0.02	0.226	0.051	0.572	4.717	2.70	5.86	2.70	0.53
50	3	16	7.00	6.00	0.63	0.00	0.02	0.229	0.051	0.577	4.767	2.75	5.92	2.75	0.54
51	3	17	6.00	5.00	0.65	0.00	0.02	0.232	0.050	0.582	4.815	2.80	5.98	2.80	0.56
52	3	18	5.00	4.00	0.67	0.00	0.02	0.235	0.049	0.586	4.863	2.86	6.04	2.86	0.57
53	4	1	4.00	3.00	0.69	0.00	0.02	0.410	0.028	0.659	28.570	1.68	28.69	1.68	0.15
54	4	2	3.00	2.00	0.71	0.00	0.02	0.412	0.028	0.660	28.520	1.72	28.65	1.72	0.15
55	4	3	2.00	1.00	0.73	0.00	0.02	0.413	0.028	0.662	28.470	1.77	28.60	1.77	0.15
56	4	4	1.00	0.00	0.75	0.00	0.02	0.415	0.028	0.664	28.423	1.81	28.56	1.81	0.16
57	5	1	261.00	260.00	3.91	0.00	0.03	0.516	0.022	0.296	25.651	7.61	26.25	7.60	0.70
58	5	2	260.00	259.00	3.96	0.00	0.03	0.517	0.022	0.299	25.639	7.66	26.24	7.65	0.71
59	5	3	259.00	258.00	3.99	0.00	0.03	0.517	0.022	0.301	25.625	7.71	26.23	7.71	0.72
60	5	4	258.00	257.00	4.02	0.00	0.03	0.518	0.022	0.303	25.613	7.76	26.23	7.76	0.72
61	6	1	26.00	25.00	0.76	0.00	0.02	0.416	0.028	0.665	28.394	1.83	28.51	1.83	0.16
62	6	2	25.00	24.00	0.79	0.00	0.02	0.417	0.028	0.667	28.343	1.88	28.48	1.88	0.16
63	6	3	24.00	23.00	0.81	0.00	0.02	0.419	0.028	0.668	28.293	1.93	28.44	1.93	0.17
64	6	4	23.00	22.00	0.83	0.00	0.02	0.421	0.028	0.670	28.245	1.97	28.39	1.97	0.17
65	6	5	22.00	21.00	0.85	0.00	0.02	0.422	0.027	0.672	28.198	2.02	28.35	2.02	0.18
66	6	6	21.00	20.00	0.88	0.00	0.02	0.423	0.027	0.673	28.152	2.07	28.31	2.07	0.18
67	6	7	20.00	19.00	0.90	0.00	0.02	0.425	0.027	0.675	28.108	2.11	28.26	2.11	0.18
68	6	8	19.00	18.00	0.92	0.00	0.02	0.426	0.027	0.677	28.065	2.16	28.23	2.16	0.19
69	6	9	18.00	17.00	0.94	0.00	0.02	0.428	0.027	0.679	28.023	2.20	28.19	2.20	0.19
70	6	10	17.00	16.00	0.97	0.00	0.02	0.429	0.027	0.680	27.982	2.25	28.15	2.25	0.20
71	6	11	16.00	15.00	0.99	0.00	0.02	0.430	0.027	0.682	27.942	2.30	28.11	2.29	0.20
72	6	12	15.00	14.00	1.01	0.00	0.02	0.432	0.027	0.684	27.903	2.34	28.08	2.34	0.21
73	6	13	14.00	13.00	1.03	0.00	0.02	0.433	0.027	0.686	27.865	2.39	28.04	2.39	0.21
74	6	14	13.00	12.00	1.05	0.00	0.02	0.434	0.027	0.687	27.828	2.43	28.01	2.43	0.21
75	6	15	12.00	11.00	1.08	0.00	0.02	0.435	0.027	0.689	27.791	2.48	27.98	2.48	0.22
76	6	16	11.00	10.00	1.10	0.00	0.02	0.436	0.027	0.691	27.756	2.52	27.94	2.52	0.22
77	6	17	10.00	9.00	1.12	0.00	0.02	0.438	0.026	0.693	27.721	2.57	27.91	2.56	0.23
78	6	18	9.00	8.00	1.14	0.00	0.02	0.439	0.026	0.694	27.687	2.61	27.88	2.61	0.23
79	6	19	8.00	7.00	1.17	0.00	0.02	0.440	0.026	0.696	27.654	2.65	27.85	2.65	0.23
80	6	20	7.00	6.00	1.19	0.00	0.02	0.441	0.026	0.698	27.621	2.70	27.82	2.70	0.24
81	7	1	6.00	5.00	1.21	0.00	0.02	0.442	0.026	0.699	27.592	2.74	27.80	2.74	0.24
82	7	2	5.00	4.00	1.23	0.00	0.02	0.443	0.026	0.701	27.564	2.78	27.77	2.78	0.25
83	7	3	4.00	3.00	1.25	0.00	0.02	0.444	0.026	0.702	27.537	2.82	27.75	2.82	0.25
84	7	4	3.00	2.00	1.27	0.00	0.02	0.445	0.026	0.704	27.506	2.86	27.72	2.86	0.25
85	7	5	2.00	1.00	1.30	0.00	0.02	0.446	0.026	0.705	27.476	2.91	27.69	2.91	0.26
86	7	6	1.00	0.00	1.32	0.00	0.02	0.447	0.026	0.707	27.446	2.95	27.67	2.95	0.26
87	8	1	257.00	256.00	5.37	0.00	0.03	0.538	0.022	0.396	25.159	9.98	25.96	9.97	0.94
88	8	2	256.00	255.00	5.39	0.00	0.03	0.538	0.022	0.398	25.150	10.02	25.95	10.02	0.94
89	8	3	255.00	254.00	5.42	0.00	0.03	0.539	0.021	0.400	25.142	10.07	25.95	10.06	0.94
90	8	4	254.00	253.00	5.45	0.00	0.03	0.539	0.021	0.402	25.134	10.11	25.94	10.11	0.95
91	8	5	253.00	252.00	5.48	0.00	0.03	0.539	0.021	0.403	25.129	10.16	25.93	10.16	0.95
92	8	6	252.00	251.00	5.51	0.00	0.03	0.540	0.021	0.404	25.118	10.20	25.93	10.20	0.96

93	8	7	251.00	250.00	5.54	0.00	0.03	0.540	0.021	0.406	25.110	16.25	25.94	16.25	0.96
94	8	8	250.00	249.00	5.56	0.00	0.03	0.541	0.021	0.410	25.102	16.29	25.93	16.29	0.97
95	8	9	249.00	248.00	5.59	0.00	0.03	0.541	0.021	0.412	25.094	16.34	25.92	16.34	0.97
96	8	10	248.00	247.00	5.62	0.00	0.03	0.541	0.021	0.414	25.086	16.38	25.92	16.38	0.98
97	8	11	247.00	246.00	5.65	0.00	0.03	0.542	0.021	0.416	25.078	16.43	25.92	16.43	0.98
98	8	12	246.00	245.00	5.68	0.00	0.03	0.542	0.021	0.418	25.071	16.46	25.91	16.47	0.98
99	9	1	46.00	45.00	0.78	0.00	0.02	0.250	0.046	0.613	5.114	3.14	6.34	3.14	0.62
100	9	2	45.00	44.00	0.81	0.00	0.02	0.252	0.046	0.618	5.162	3.19	6.40	3.19	0.64
101	9	3	44.00	43.00	0.83	0.00	0.02	0.255	0.045	0.623	5.208	3.24	6.45	3.24	0.65
102	9	4	43.00	42.00	0.85	0.00	0.02	0.258	0.045	0.627	5.253	3.30	6.51	3.30	0.66
103	9	5	42.00	41.00	0.87	0.00	0.02	0.261	0.044	0.632	5.298	3.35	6.56	3.35	0.67
104	9	6	41.00	40.00	0.90	0.00	0.02	0.263	0.044	0.637	5.342	3.40	6.62	3.40	0.68
105	9	7	40.00	39.00	0.92	0.00	0.02	0.266	0.044	0.641	5.385	3.45	6.67	3.45	0.69
106	9	8	39.00	38.00	0.94	0.00	0.02	0.268	0.043	0.645	5.428	3.50	6.72	3.50	0.70
107	9	9	38.00	37.00	0.96	0.00	0.02	0.271	0.043	0.650	5.470	3.55	6.77	3.55	0.71
108	9	10	37.00	36.00	0.98	0.00	0.02	0.273	0.042	0.654	5.511	3.60	6.82	3.60	0.72
109	9	11	36.00	35.00	1.01	0.00	0.02	0.276	0.042	0.658	5.552	3.65	6.87	3.65	0.73
110	9	12	35.00	34.00	1.03	0.00	0.02	0.278	0.042	0.662	5.592	3.70	6.92	3.70	0.74
111	9	13	34.00	33.00	1.05	0.00	0.02	0.281	0.041	0.666	5.631	3.75	6.96	3.75	0.75
112	9	14	33.00	32.00	1.07	0.00	0.02	0.283	0.041	0.670	5.670	3.80	7.01	3.80	0.76
113	9	15	32.00	31.00	1.10	0.00	0.02	0.285	0.041	0.674	5.708	3.85	7.06	3.85	0.77
114	9	16	31.00	30.00	1.12	0.00	0.02	0.288	0.040	0.678	5.746	3.89	7.10	3.89	0.78
115	9	17	30.00	29.00	1.14	0.00	0.02	0.290	0.040	0.681	5.783	3.94	7.15	3.94	0.79
116	9	18	29.00	28.00	1.16	0.00	0.02	0.292	0.040	0.685	5.820	3.99	7.19	3.99	0.80
117	9	19	28.00	27.00	1.19	0.00	0.02	0.294	0.039	0.689	5.856	4.03	7.24	4.03	0.81
118	9	20	27.00	26.00	1.21	0.00	0.02	0.297	0.039	0.693	5.892	4.08	7.28	4.08	0.82
119	10	1	26.00	25.00	1.23	0.00	0.02	0.443	0.026	0.101	27.568	2.77	27.78	2.77	0.25
120	10	2	25.00	24.00	1.24	0.00	0.02	0.444	0.026	0.102	27.544	2.81	27.75	2.81	0.25
121	10	3	24.00	23.00	1.26	0.00	0.02	0.444	0.026	0.103	27.520	2.84	27.73	2.84	0.25
122	10	4	23.00	22.00	1.28	0.00	0.02	0.445	0.026	0.105	27.496	2.88	27.71	2.87	0.26
123	10	5	22.00	21.00	1.30	0.00	0.02	0.446	0.026	0.106	27.473	2.91	27.69	2.91	0.26
124	10	6	21.00	20.00	1.31	0.00	0.02	0.447	0.026	0.107	27.450	2.94	27.67	2.94	0.26
125	10	7	20.00	19.00	1.33	0.00	0.02	0.448	0.026	0.109	27.428	2.98	27.65	2.98	0.26
126	10	8	19.00	18.00	1.35	0.00	0.02	0.448	0.026	0.110	27.406	3.01	27.63	3.01	0.27
127	10	9	18.00	17.00	1.37	0.00	0.02	0.449	0.026	0.111	27.384	3.05	27.61	3.04	0.27
128	10	10	17.00	16.00	1.38	0.00	0.02	0.450	0.026	0.112	27.362	3.08	27.59	3.08	0.27
129	10	11	16.00	15.00	1.40	0.00	0.02	0.451	0.026	0.114	27.341	3.11	27.57	3.11	0.28
130	10	12	15.00	14.00	1.42	0.00	0.02	0.451	0.026	0.115	27.320	3.15	27.56	3.15	0.28
131	10	13	14.00	13.00	1.44	0.00	0.02	0.452	0.026	0.117	27.297	3.18	27.54	3.18	0.28
132	10	14	13.00	12.00	1.46	0.00	0.02	0.453	0.026	0.118	27.274	3.22	27.52	3.22	0.29
133	10	15	12.00	11.00	1.48	0.00	0.02	0.454	0.026	0.119	[illegible]	3.25	27.50	3.25	0.29
134	10	16	11.00	10.00	1.49	0.00	0.02	0.454	0.025	0.121	27.234	3.29	27.48	3.29	0.29
135	10	17	10.00	9.00	1.51	0.00	0.02	0.455	0.025	0.122	27.215	3.32	27.46	3.32	0.30
136	10	18	9.00	8.00	1.53	0.00	0.02	0.456	0.025	0.124	[illegible]	3.35	27.45	3.35	0.30
137	10	19	8.00	7.00	1.55	0.00	0.02	0.457	0.025	0.125	[illegible]	3.39	27.43	3.39	0.30
138	10	20	7.00	6.00	1.56	0.00	0.02	0.457	0.025	0.126	[illegible]	3.42	27.42	3.42	0.31
139	11	1	6.00	5.00	1.58	0.00	0.02	0.458	0.025	0.127	27.136	3.46	27.40	3.46	0.31
140	11	2	5.00	4.00	1.60	0.00	0.02	0.459	0.025	0.129	27.114	3.50	27.38	3.50	0.31
141	11	3	4.00	3.00	1.62	0.00	0.02	0.459	0.025	0.130	27.094	3.53	27.36	3.53	0.32
142	11	4	3.00	2.00	1.64	0.00	0.02	0.460	0.025	0.132	27.073	3.57	27.34	3.57	0.32
143	11	5	2.00	1.00	1.66	0.00	0.02	0.461	0.025	0.133	[illegible]	3.61	27.33	3.61	0.32

144	11	6	1.00	0.00	1.68	0.00	0.02	0.462	0.025	0.135	27.0[illegible]	[illegible].65	2[illegible].[illegible]1	[illegible].[illegible]5	0.[illegible]
145	12	1	245.00	244.00	7.38	0.00	0.02	0.561	0.021	0.533	24.[illegible]	13.16	25.74	13.15	1.25
146	12	2	244.00	243.00	7.40	0.00	0.02	0.561	0.021	0.535	24.[illegible]	13.19	25.74	13.18	1.25
147	12	3	243.00	242.00	7.42	0.00	0.02	0.562	0.021	0.536	24.658	13.22	25.74	13.22	1.26
148	12	4	242.00	241.00	7.44	0.00	0.02	0.562	0.021	0.53[illegible]	24.654	13.25	25.[illegible]	13.25	1.26
149	13	1	22.00	21.00	0.45	0.00	0.02	0.388	0.030	0.040	29.[illegible]	1.16	29.4[illegible]	1.16	0.10
150	13	2	21.00	20.00	0.47	0.00	0.02	0.390	0.030	0.041	29.258	1.21	29.35	1.20	0.10
151	13	3	20.00	19.00	0.49	0.00	0.02	0.392	0.030	0.043	29.183	1.25	29.28	1.25	0.11
152	13	4	19.00	18.00	0.51	0.00	0.02	0.394	0.029	0.044	29.111	1.29	29.21	1.29	0.11
153	13	5	18.00	17.00	0.53	0.00	0.02	0.396	0.029	0.046	29.041	1.34	29.14	1.33	0.11
154	13	6	17.00	16.00	0.55	0.00	0.02	0.398	0.029	0.048	28.97[illegible]	1.38	29.08	1.38	0.12
155	13	7	16.00	15.00	0.57	0.00	0.02	0.400	0.029	0.049	28.911	1.42	29.02	1.42	0.12
156	13	8	15.00	14.00	0.59	0.00	0.02	0.402	0.029	0.051	28.849	1.47	28.96	1.47	0.13
157	13	9	14.00	13.00	0.61	0.00	0.02	0.404	0.029	0.052	28.789	1.51	28.90	1.51	0.13
158	13	10	13.00	12.00	0.63	0.00	0.02	0.405	0.029	0.054	28.732	1.55	28.85	1.55	0.13
159	13	11	12.00	11.00	0.65	0.00	0.02	0.407	0.028	0.056	28.676	1.60	28.79	1.60	0.14
160	13	12	11.00	10.00	0.67	0.00	0.02	0.409	0.028	0.057	28.622	1.64	28.74	1.64	0.14
161	13	13	10.00	9.00	0.69	0.00	0.02	0.410	0.028	0.059	28.570	1.68	28.69	1.68	0.15
162	13	14	9.00	8.00	0.71	0.00	0.02	0.412	0.028	0.060	28.520	1.72	28.65	1.72	0.15
163	13	15	8.00	7.00	0.73	0.00	0.02	0.413	0.028	0.062	28.470	1.77	28.60	1.77	0.15
164	13	16	7.00	6.00	0.75	0.00	0.02	0.415	0.028	0.064	28.423	1.81	28.56	1.81	0.16
165	13	17	6.00	5.00	0.77	0.00	0.02	0.416	0.028	0.065	28.376	1.85	28.51	1.85	0.16
166	13	18	5.00	4.00	0.79	0.00	0.02	0.418	0.028	0.067	28.331	1.89	28.47	1.89	0.16
167	14	1	4.00	3.00	0.81	0.00	0.02	0.419	0.028	0.068	28.288	1.93	28.43	1.93	0.17
168	14	2	3.00	2.00	0.83	0.00	0.02	0.421	0.028	0.070	28.245	1.97	28.39	1.97	0.17
169	14	3	2.00	1.00	0.85	0.00	0.02	0.422	0.027	0.071	28.203	2.02	28.35	2.01	0.18
170	14	4	1.00	0.00	0.87	0.00	0.02	0.423	0.027	0.073	28.162	2.06	28.31	2.06	0.18
171	15	1	241.00	240.00	8.33	0.00	0.02	0.570	0.020	0.597	24.482	14.61	25.68	14.61	1.39
172	15	2	240.00	239.00	8.35	0.00	0.02	0.570	0.020	0.598	24.479	14.64	25.68	14.63	1.40
173	15	3	239.00	238.00	8.36	0.00	0.02	0.570	0.020	0.599	24.475	14.67	25.68	14.66	1.40
174	15	4	238.00	237.00	8.38	0.00	0.02	0.571	0.020	0.600	24.472	14.69	25.68	14.69	1.40
175	15	5	237.00	236.00	8.40	0.00	0.02	0.571	0.020	0.601	24.469	14.72	25.68	14.72	1.40
176	15	6	236.00	235.00	8.42	0.00	0.02	0.571	0.020	0.603	24.466	14.75	25.68	14.74	1.41
177	15	7	235.00	234.00	8.44	0.00	0.02	0.571	0.020	0.604	24.463	14.77	25.68	14.77	1.41
178	15	8	234.00	233.00	8.45	0.00	0.02	0.571	0.020	0.605	24.459	14.80	25.68	14.80	1.41
179	15	9	233.00	232.00	8.47	0.00	0.02	0.571	0.020	0.606	24.456	14.83	25.67	14.82	1.42
180	15	10	232.00	231.00	8.49	0.00	0.02	0.572	0.020	0.607	24.453	14.85	25.67	14.85	1.42
181	15	11	231.00	230.00	8.51	0.00	0.02	0.572	0.020	0.609	24.450	14.88	25.67	14.88	1.42
182	15	12	230.00	229.00	8.52	0.00	0.02	0.572	0.020	0.610	24.447	14.91	25.67	14.91	1.42
183	15	13	229.00	228.00	8.54	0.00	0.02	0.572	0.020	0.611	24.444	14.94	25.67	14.93	1.43
184	15	14	228.00	227.00	8.56	0.00	0.02	0.572	0.020	0.612	24.440	14.96	25.67	14.96	1.43
185	15	15	227.00	226.00	8.58	0.00	0.02	0.572	0.020	0.613	24.437	14.99	25.67	14.99	1.43
186	15	16	226.00	225.00	8.60	0.00	0.02	0.573	0.020	0.614	24.434	15.02	25.67	15.01	1.43
187	15	17	225.00	224.00	8.61	0.00	0.02	0.573	0.020	0.616	24.431	15.04	25.67	15.04	1.44
188	15	18	224.00	223.00	8.63	0.00	0.02	0.573	0.020	0.617	24.428	15.07	25.67	15.07	1.44
189	16	1	36.00	35.00	0.47	0.00	0.02	0.203	0.057	0.533	4.[illegible]	2.31	[illegible].41	[illegible].31	0.45
190	16	2	35.00	34.00	0.50	0.00	0.02	0.208	0.056	0.540	4.408	2.38	[illegible].4[illegible]	[illegible].38	0.47
191	16	3	34.00	33.00	0.52	0.00	0.02	0.212	0.055	0.546	4.[illegible]	2.44	[illegible].[illegible]	[illegible].44	0.48
192	16	4	33.00	32.00	0.54	0.00	0.02	0.215	0.054	0.55[illegible]	4.334	2.[illegible]	[illegible].[illegible]4	2.[illegible]	0.4[illegible]

193	16	5	32.00	31.00	0.56	0.00	0.02	0.219	0.053	0.559	4.594	2.57	5.71	2.57	0.51
194	16	6	31.00	30.00	0.59	0.00	0.02	0.222	0.052	0.565	4.653	2.63	5.79	2.63	0.52
195	16	7	30.00	29.00	0.61	0.00	0.02	0.226	0.051	0.571	4.711	2.69	5.85	2.69	0.53
196	16	8	29.00	28.00	0.63	0.00	0.02	0.229	0.051	0.577	4.767	2.75	5.92	2.75	0.54
197	16	9	28.00	27.00	0.65	0.00	0.02	0.232	0.050	0.583	4.823	2.81	5.99	2.81	0.56
198	16	10	27.00	26.00	0.68	0.00	0.02	0.235	0.049	0.588	4.875	2.87	6.05	2.87	0.57
199	16	11	26.00	25.00	0.70	0.00	0.02	0.238	0.049	0.594	4.927	2.93	6.12	2.93	0.58
200	16	12	25.00	24.00	0.73	0.01	0.02	0.243	0.048	0.602	5.009	3.02	6.22	3.02	0.60
201	16	13	24.00	23.00	0.77	0.01	0.02	0.248	0.047	0.610	5.089	3.11	6.31	3.11	0.62
202	16	14	23.00	22.00	0.81	0.01	0.02	0.253	0.046	0.618	5.166	3.20	6.40	3.19	0.64
203	16	15	22.00	21.00	0.84	0.01	0.02	0.257	0.045	0.626	5.240	3.28	6.49	3.28	0.65
204	16	16	21.00	20.00	0.88	0.01	0.02	0.261	0.044	0.634	5.313	3.37	6.58	3.37	0.67
205	16	17	20.00	19.00	0.92	0.01	0.02	0.266	0.044	0.641	5.384	3.45	6.67	3.45	0.69
206	16	18	19.00	18.00	0.94	0.00	0.02	0.268	0.043	0.645	5.426	3.50	6.72	3.50	0.70
207	16	19	18.00	17.00	0.96	0.00	0.02	0.271	0.043	0.649	5.468	3.55	6.77	3.55	0.71
208	16	20	17.00	16.00	0.98	0.00	0.02	0.273	0.042	0.654	5.509	3.60	6.82	3.60	0.72
209	17	1	18.00	17.00	0.41	0.00	0.02	0.193	0.060	0.511	4.139	2.12	5.16	2.12	0.41
210	17	2	17.00	16.00	0.43	0.00	0.02	0.196	0.059	0.517	4.197	2.17	5.23	2.17	0.43
211	17	3	16.00	15.00	0.44	0.00	0.02	0.199	0.058	0.523	4.253	2.23	5.30	2.22	0.44
212	17	4	15.00	14.00	0.46	0.00	0.02	0.202	0.057	0.529	4.307	2.28	5.37	2.28	0.45
213	17	5	14.00	13.00	0.48	0.00	0.02	0.205	0.056	0.535	4.361	2.33	5.43	2.33	0.46
214	17	6	13.00	12.00	0.50	0.00	0.02	0.208	0.054	0.540	4.412	2.38	5.49	2.38	0.47
215	17	7	12.00	11.00	0.51	0.00	0.02	0.211	0.055	0.545	4.463	2.43	5.56	2.43	0.48
216	17	8	11.00	10.00	0.53	0.00	0.02	0.214	0.054	0.551	4.513	2.48	5.62	2.48	0.49
217	17	9	10.00	9.00	0.55	0.00	0.02	0.218	0.053	0.557	4.572	2.55	5.69	2.55	0.50
218	17	10	9.00	8.00	0.58	0.00	0.02	0.221	0.052	0.563	4.630	2.61	5.76	2.61	0.51
219	17	11	8.00	7.00	0.60	0.00	0.02	0.224	0.052	0.569	4.686	2.67	5.83	2.67	0.53
220	17	12	7.00	6.00	0.62	0.00	0.02	0.227	0.051	0.573	4.731	2.71	5.88	2.71	0.54
221	17	13	6.00	5.00	0.63	0.00	0.02	0.230	0.050	0.578	4.775	2.76	5.93	2.76	0.55
222	17	14	5.00	4.00	0.65	0.00	0.02	0.232	0.050	0.582	4.818	2.81	5.98	2.81	0.56
223	17	15	4.00	3.00	0.67	0.00	0.02	0.235	0.049	0.587	4.860	2.85	6.04	2.85	0.57
224	17	16	3.00	2.00	0.69	0.00	0.02	0.237	0.049	0.591	4.902	2.90	6.09	2.90	0.57
225	17	17	2.00	1.00	0.70	0.00	0.02	0.239	0.048	0.595	4.943	2.94	6.14	2.94	0.58
226	17	18	1.00	0.00	0.72	0.00	0.02	0.242	0.048	0.600	4.983	2.99	6.18	2.99	0.59
227	18	1	16.00	15.00	1.73	0.00	0.02	0.463	0.025	0.138	26.991	3.73	27.27	3.73	0.33
228	18	2	15.00	14.00	1.75	0.00	0.02	0.464	0.025	0.140	26.972	3.77	27.26	3.76	0.34
229	18	3	14.00	13.00	1.77	0.00	0.02	[illegible]	0.025	0.141	26.953	3.80	27.24	3.80	0.34
230	18	4	13.00	12.00	1.79	0.00	0.02	0.465	0.025	0.143	26.934	3.84	27.23	3.84	0.35
231	18	5	12.00	11.00	1.81	0.00	0.02	0.466	0.025	0.144	26.915	3.88	27.21	3.88	0.35
232	18	6	11.00	10.00	1.83	0.00	0.02	0.467	0.025	0.146	26.897	3.91	27.19	3.91	0.35
233	18	7	10.00	9.00	1.85	0.00	0.02	0.467	0.025	0.147	26.879	3.95	27.18	3.95	0.36
234	18	8	9.00	8.00	1.87	0.00	0.02	0.468	0.025	0.148	26.861	3.99	27.16	3.99	0.36
235	19	1	26.00	25.00	0.42	0.00	0.02	0.384	0.030	0.037	29.461	1.08	29.56	1.08	0.09
236	19	2	25.00	24.00	0.43	0.00	0.02	0.386	0.030	0.038	29.412	1.12	29.49	1.12	0.10
237	19	3	24.00	23.00	0.45	0.00	0.02	0.388	0.030	0.039	29.345	1.16	29.43	1.16	0.10
238	19	4	23.00	22.00	0.46	0.00	0.02	0.389	0.030	0.041	29.282	1.19	29.37	1.19	0.10
239	19	5	22.00	21.00	0.48	0.00	0.02	0.391	0.030	0.042	29.220	1.23	29.31	1.23	0.10
240	19	6	21.00	20.00	0.50	0.00	0.02	0.393	0.029	0.043	29.161	1.26	29.25	1.26	0.11
241	19	7	20.00	19.00	0.51	0.00	0.02	0.395	0.029	0.045	29.104	1.30	29.20	1.30	0.11
242	19	8	19.00	18.00	0.53	0.00	0.02	0.396	0.029	0.046	29.048	1.33	29.15	1.33	0.11
243	19	9	18.00	17.00	0.54	0.00	0.02	0.398	0.029	0.047	28.994	1.37	29.10	1.37	0.12

244	19	10	17.00	16.00	0.56	0.00	0.02	0.399	0.029	0.048	28.942	1.40	29.05	1.40	0.12
245	19	11	16.00	15.00	0.58	0.00	0.02	0.401	0.029	0.050	28.895	1.44	29.00	1.44	0.12
246	19	12	15.00	14.00	0.59	0.00	0.02	0.402	0.029	0.051	28.843	1.47	28.95	1.47	0.13
247	19	13	14.00	13.00	0.61	0.00	0.02	0.404	0.029	0.052	28.795	1.51	28.91	1.51	0.13
248	19	14	13.00	12.00	0.63	0.00	0.02	0.405	0.029	0.054	28.742	1.55	28.86	1.55	0.13
249	19	15	12.00	11.00	0.64	0.00	0.02	0.407	0.028	0.055	28.698	1.58	28.81	1.58	0.14
250	19	16	11.00	10.00	0.66	0.00	0.02	0.408	0.028	0.056	28.654	1.61	28.77	1.61	0.14
251	19	17	10.00	9.00	0.67	0.00	0.02	0.409	0.028	0.058	28.611	1.65	28.73	1.65	0.14
252	19	18	9.00	8.00	0.69	0.00	0.02	0.410	0.028	0.059	28.570	1.68	28.69	1.68	0.15
253	19	19	8.00	7.00	0.71	0.00	0.02	0.412	0.028	0.060	28.529	1.72	28.66	1.72	0.15
254	19	20	7.00	6.00	0.72	0.00	0.02	0.413	0.028	0.061	28.489	1.75	28.62	1.75	0.15
255	20	1	6.00	5.00	0.74	0.00	0.02	0.414	0.028	0.063	28.441	1.79	28.57	1.79	0.16
256	20	2	5.00	4.00	0.76	0.00	0.02	0.416	0.028	0.065	28.394	1.83	28.53	1.83	0.16
257	20	3	4.00	3.00	0.78	0.00	0.02	0.417	0.028	0.066	28.344	1.88	28.48	1.88	0.16
258	20	4	3.00	2.00	0.80	0.00	0.02	0.419	0.028	0.068	28.300	1.92	28.44	1.92	0.17
259	20	5	2.00	1.00	0.82	0.00	0.02	0.420	0.028	0.069	28.257	1.96	28.40	1.96	0.17
260	20	6	1.00	0.00	0.84	0.00	0.02	0.421	0.027	0.071	28.215	2.00	28.36	2.00	0.17
261	21	1	8.00	7.00	2.74	0.00	0.03	0.492	0.024	0.212	26.241	5.56	26.66	5.56	0.51
262	21	2	7.00	6.00	2.76	0.00	0.03	0.493	0.023	0.214	26.217	5.60	26.65	5.60	0.51
263	21	3	6.00	5.00	2.79	0.00	0.03	0.493	0.023	0.215	26.202	5.65	26.64	5.65	0.52
264	21	4	5.00	4.00	2.81	0.00	0.03	0.494	0.023	0.217	26.188	5.69	26.63	5.69	0.52
265	22	1	20.00	19.00	0.26	0.00	0.01	0.161	0.072	0.451	3.576	1.61	4.48	1.61	0.31
266	22	2	19.00	18.00	0.27	0.00	0.01	0.164	0.071	0.455	3.620	1.65	4.53	1.65	0.32
267	22	3	18.00	17.00	0.28	0.00	0.01	0.166	0.070	0.460	3.663	1.69	4.58	1.69	0.33
268	22	4	17.00	16.00	0.29	0.00	0.01	0.168	0.069	0.465	3.705	1.72	4.64	1.72	0.33
269	22	5	16.00	15.00	0.30	0.00	0.01	0.171	0.068	0.469	3.746	1.76	4.69	1.76	0.34
270	22	6	15.00	14.00	0.31	0.00	0.01	0.173	0.067	0.473	3.786	1.79	4.73	1.79	0.35
271	22	7	14.00	13.00	0.32	0.00	0.01	0.175	0.066	0.478	3.825	1.83	4.78	1.83	0.36
272	22	8	13.00	12.00	0.33	0.00	0.01	0.177	0.065	0.482	3.864	1.86	4.83	1.86	0.36
273	22	9	12.00	11.00	0.34	0.00	0.01	0.179	0.065	0.486	3.902	1.90	4.87	1.90	0.37
274	22	10	11.00	10.00	0.35	0.00	0.01	0.181	0.064	0.490	3.938	1.93	4.92	1.93	0.38
275	22	11	10.00	9.00	0.36	0.00	0.01	0.183	0.063	0.494	3.975	1.96	4.96	1.96	0.38
276	22	12	9.00	8.00	0.37	0.00	0.01	0.185	0.062	0.497	4.010	2.00	5.01	[illegible]	0.39
277	22	13	8.00	7.00	0.38	0.00	0.01	0.187	0.062	0.501	4.045	2.03	5.05	2.03	0.40
278	22	14	7.00	6.00	0.39	0.00	0.01	0.189	0.061	0.505	4.079	2.06	5.09	2.06	0.40
279	22	15	6.00	5.00	0.40	0.00	0.01	0.191	0.061	0.508	4.113	2.09	5.13	2.09	0.41
280	22	16	5.00	4.00	0.41	0.00	0.01	0.193	0.060	0.512	4.146	2.12	5.17	2.12	0.42
281	22	17	4.00	3.00	0.42	0.00	0.01	0.195	0.059	0.515	4.179	2.15	5.21	2.15	0.42
282	22	18	3.00	2.00	0.43	0.00	0.01	0.197	0.059	0.519	4.211	2.18	5.25	2.18	0.43
283	22	19	2.00	1.00	0.44	0.00	0.01	0.199	0.058	0.522	4.242	[illegible]	5.29	[illegible]	0.43
284	22	20	1.00	0.00	0.45	0.00	0.01	0.200	0.058	0.525	4.273	[illegible]	5.33	[illegible]	0.44
285	23	1	4.00	3.00	3.28	0.00	0.02	0.504	0.023	0.251	[illegible]	6.51	26.45	6.51	0.60
286	23	2	3.00	2.00	3.30	0.00	0.02	0.505	0.023	0.252	[illegible]	6.54	26.44	6.54	0.60
287	23	3	2.00	1.00	3.32	0.00	0.02	0.505	0.023	0.253	[illegible]	6.58	26.43	6.58	0.61
288	23	4	1.00	0.00	3.34	0.00	0.02	0.505	0.023	[illegible]	[illegible]	6.61	26.42	6.61	0.61
289	24	1	223.00	222.00	11.99	0.00	0.02	0.598	0.019	[illegible]	[illegible]	20.05	[illegible]	[illegible]	1.34
290	24	2	222.00	221.00	12.01	0.00	0.02	0.598	0.019	0.839	[illegible]	20.08	[illegible]	[illegible]	1.34
291	24	3	221.00	220.00	11.77	0.26	0.02	0.597	0.019	0.823	23.962	19.73	25.61	[illegible]	1.31
292	24	4	220.00	219.00	11.79	0.00	0.02	0.597	0.019	0.824	[illegible]	[illegible]	25.61	[illegible]	1.31

293	24	5	219.00	218.00	11.61	0.00	0.62	0.597	0.619	0.826	[illegible]	19.79	25.61	19.78	1.91
294	24	6	218.00	217.00	11.83	0.00	0.62	0.597	0.619	0.827	[illegible]	19.62	25.61	19.61	1.92
295	24	7	217.00	216.00	7.27	4.58	0.62	0.560	0.623	0.526	[illegible]	13.99	25.7[illegible]	13.98	1.23
296	24	8	216.00	215.00	7.29	0.00	0.62	0.560	0.621	0.527	[illegible]	13.62	25.7[illegible]	13.62	1.21

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	F. OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/M2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/M2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/M2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/M2D
1	1	8.98	8	0.00	0.73	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	2	8.70	8	0.00	0.79	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	3	8.49	8	0.00	0.84	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	4	8.34	8	0.00	0.88	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	5	8.21	8	0.00	0.91	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	6	8.12	8	0.00	0.94	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	7	8.04	8	0.00	0.96	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	8	7.99	8	0.00	0.98	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	9	7.94	8	0.00	1.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	10	7.90	8	0.00	1.01	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	11	7.87	8	0.00	1.02	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	12	7.85	8	0.00	1.03	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	13	7.82	8	0.00	1.03	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	14	7.81	8	0.00	1.04	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	15	7.79	8	0.00	1.04	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	16	7.78	8	0.00	1.05	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	17	7.77	8	0.00	1.05	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	18	7.76	8	0.00	1.06	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	19	7.76	8	0.00	1.06	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
1	20	7.75	8	0.00	1.06	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	1	7.74	8	0.00	1.06	0.00	7.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	2	7.74	8	0.00	1.06	0.00	7.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	3	7.74	8	0.00	1.07	0.00	7.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	4	7.73	8	0.00	1.07	0.00	7.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	5	7.73	8	0.00	1.07	0.00	7.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	6	7.73	8	0.00	1.07	0.00	7.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	7	7.72	8	0.00	1.07	0.00	7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	8	7.72	8	0.00	1.07	0.00	7.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	9	7.72	8	0.00	1.07	0.00	7.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	10	7.72	8	0.00	1.07	0.00	7.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	11	7.72	8	0.00	1.07	0.00	7.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	12	7.71	8	0.00	1.07	0.00	7.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	13	7.71	8	0.00	1.07	0.00	7.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
2	14	7.71	8	0.00	1.07	0.00	7.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
3	1	9.08	8	0.00	0.72	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
3	2	8.87	8	0.00	0.76	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
3	3	8.70	8	0.00	0.79	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00

3	4	8.56	8	0.00	0.82	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	5	8.45	8	0.00	0.85	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	6	8.36	8	0.00	0.87	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	7	8.28	8	0.00	0.89	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	8	8.22	8	0.00	0.91	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	9	8.16	8	0.00	0.93	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	10	8.12	8	0.00	0.94	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	11	8.08	8	0.00	0.95	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	12	8.05	8	0.00	0.96	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	13	8.02	8	0.00	0.97	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	14	7.99	8	0.00	0.98	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	15	7.97	8	0.00	0.99	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	16	7.95	8	0.00	0.99	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	17	7.93	8	0.00	1.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
3	18	7.92	8	0.00	1.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
4	1	7.90	8	0.00	1.03	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
4	2	7.81	8	0.00	1.04	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
4	3	7.76	8	0.00	1.06	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
4	4	7.72	8	0.00	1.07	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
5	1	7.71	8	0.00	0.84	0.00	7.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
5	2	7.71	8	0.00	0.85	0.00	7.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
5	3	7.71	8	0.00	0.85	0.00	7.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
5	4	7.70	8	0.00	0.85	0.00	7.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	1	8.78	8	0.00	0.78	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	2	8.41	8	0.00	0.86	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	3	8.17	8	0.00	0.92	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	4	8.01	8	0.00	0.97	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	5	7.90	8	0.00	1.01	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	6	7.83	8	0.00	1.03	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	7	7.78	8	0.00	1.05	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	8	7.74	8	0.00	1.06	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	9	7.72	8	0.00	1.07	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	10	7.70	8	0.00	1.08	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
6	11	7.69	8	0.00	1.08	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	12	7.68	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	13	7.67	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	14	7.67	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	15	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	16	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	17	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	18	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	19	7.66	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
6	20	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
7	1	7.65	8	0.00	0.86	0.00	7.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
7	2	7.65	8	0.00	0.86	0.00	7.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
7	3	7.65	8	0.00	0.86	0.00	7.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
7	4	7.65	8	0.00	0.86	0.00	7.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
7	5	7.65	8	0.00	0.86	0.00	7.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
7	6	7.65	8	0.00	0.86	0.00	7.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00

8	1	7.69	8	0.00	1.08	0.00	7.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	2	7.69	8	0.00	1.08	0.00	7.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	3	7.69	8	0.00	1.08	0.00	7.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	4	7.69	8	0.00	1.08	0.00	7.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	5	7.68	8	0.00	1.08	0.00	7.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	6	7.68	8	0.00	1.09	0.00	7.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	7	7.68	8	0.00	1.09	0.00	7.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
8	8	7.68	8	0.00	1.09	0.00	7.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
8	9	7.68	8	0.00	1.09	0.00	7.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
8	10	7.68	8	0.00	1.09	0.00	7.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
8	11	7.68	8	0.00	1.09	0.00	7.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
8	12	7.68	8	0.00	1.09	0.00	7.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	1	9.20	8	0.00	0.69	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	2	9.06	8	0.00	0.72	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	3	8.94	8	0.00	0.74	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	4	8.83	8	0.00	0.76	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	5	8.74	8	0.00	0.78	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	6	8.65	8	0.00	0.80	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	7	8.58	8	0.00	0.82	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	8	8.51	8	0.00	0.84	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	9	8.45	8	0.00	0.85	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	10	8.40	8	0.00	0.86	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	11	8.35	8	0.00	0.88	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	12	8.30	8	0.00	0.89	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	13	8.26	8	0.00	0.90	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	14	8.23	8	0.00	0.91	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	15	8.19	8	0.00	0.92	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
9	16	8.16	8	0.00	0.93	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
9	17	8.13	8	0.00	0.94	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
9	18	8.11	8	0.00	0.94	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
9	19	8.09	8	0.00	0.95	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
9	20	8.06	8	0.00	0.96	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	1	8.03	8	0.00	0.97	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	2	7.95	8	0.00	0.99	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	3	7.88	8	0.00	1.01	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	4	7.83	8	0.00	1.03	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	5	7.79	8	0.00	1.05	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	6	7.76	8	0.00	1.06	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	7	7.74	8	0.00	1.06	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	8	7.72	8	0.00	1.07	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	9	7.70	8	0.00	1.08	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	10	7.69	8	0.00	1.08	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	11	7.68	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	12	7.67	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	13	7.67	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	14	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	15	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	16	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	17	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	18	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	19	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
10	20	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

11	1	7.65	8	0.00	0.86	0.00	7.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
11	2	7.65	8	0.00	0.86	0.00	7.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
11	3	7.65	8	0.00	0.86	0.00	7.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
11	4	7.65	8	0.00	0.86	0.00	7.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
11	5	7.65	8	0.00	0.86	0.00	7.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
11	6	7.65	8	0.00	0.86	0.00	7.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
12	1	7.67	8	0.00	0.72	0.00	7.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
12	2	7.67	8	0.00	0.72	0.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
12	3	7.67	8	0.00	0.72	0.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
12	4	7.67	8	0.00	0.72	0.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	1	8.44	8	0.00	0.85	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	2	8.08	8	0.00	0.95	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	3	7.89	8	0.00	1.01	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	4	7.79	8	0.00	1.05	0.00	0.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	5	7.73	8	0.00	1.07	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	6	7.69	8	0.00	1.08	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	7	7.67	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	8	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	9	7.66	8	0.00	1.09	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	10	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	11	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	12	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	13	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	14	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	15	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	16	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	17	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
13	18	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
14	1	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
14	2	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
14	3	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
14	4	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
15	1	7.67	8	0.00	0.72	0.00	7.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	2	7.67	8	0.00	0.72	0.00	7.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	3	7.67	8	0.00	0.72	0.00	7.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	4	7.66	8	0.00	0.72	0.00	7.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	5	7.66	8	0.00	0.72	0.00	7.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	6	7.66	8	0.00	0.72	0.00	7.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	7	7.66	8	0.00	0.72	0.00	7.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	8	7.66	8	0.00	0.72	0.00	7.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	9	7.66	8	0.00	0.72	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	10	7.66	8	0.00	0.72	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	11	7.66	8	0.00	0.72	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	12	7.66	8	0.00	0.72	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	13	7.66	8	0.00	0.72	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	14	7.66	8	0.00	0.72	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	15	7.66	8	0.00	0.72	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	16	7.66	8	0.00	0.72	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	17	7.66	8	0.00	0.72	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	18	7.66	8	0.00	0.72	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00

16	1	8.97	8	0.00	0.74	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	2	8.82	8	0.00	0.77	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	3	8.68	8	0.00	0.80	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	4	8.57	8	0.00	0.82	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	5	8.48	8	0.00	0.84	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	6	8.40	8	0.00	0.86	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	7	8.33	8	0.00	0.88	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	8	8.27	8	0.00	0.90	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	9	8.22	8	0.00	0.91	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	10	8.18	8	0.00	0.92	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	11	8.14	8	0.00	0.93	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	12	8.10	8	0.00	0.95	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	13	8.07	8	0.00	0.96	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	14	8.04	8	0.00	0.96	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	15	8.02	8	0.00	0.97	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	16	7.99	8	0.00	0.98	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	17	7.98	8	0.00	0.98	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	18	7.96	8	0.00	0.99	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
16	19	7.95	8	0.00	0.99	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
16	20	7.93	8	0.00	1.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
17	1	8.96	8	0.00	0.74	0.00	4.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
17	2	8.80	8	0.00	0.77	0.00	4.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
17	3	8.66	8	0.00	0.80	0.00	5.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
17	4	8.54	8	0.00	0.83	0.00	5.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
17	5	8.45	8	0.00	0.85	0.00	5.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00
17	6	8.36	8	0.00	0.87	0.00	5.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
17	7	8.29	8	0.00	0.89	0.00	5.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
17	8	8.23	8	0.00	0.91	0.00	5.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
17	9	8.18	8	0.00	0.92	0.00	6.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	10	8.13	8	0.00	0.94	0.00	6.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	11	8.09	8	0.00	0.95	0.00	6.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	12	8.06	8	0.00	0.96	0.00	6.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	13	8.03	8	0.00	0.97	0.00	6.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	14	8.00	8	0.00	0.98	0.00	6.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	15	7.98	8	0.00	0.98	0.00	6.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	16	7.96	8	0.00	0.99	0.00	6.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	17	7.94	8	0.00	1.00	0.00	6.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
17	18	7.92	8	0.00	1.00	0.00	6.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	1	7.91	8	0.00	0.79	0.00	6.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	2	7.86	8	0.00	0.80	0.00	6.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	3	7.83	8	0.00	0.81	0.00	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	4	7.79	8	0.00	0.82	0.00	7.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	5	7.77	8	0.00	0.83	0.00	7.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	6	7.75	8	0.00	0.83	0.00	7.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	7	7.73	8	0.00	0.84	0.00	7.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
18	8	7.71	8	0.00	0.84	0.00	7.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00
19	1	8.24	8	0.00	0.91	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	2	7.96	8	0.00	0.99	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	3	7.81	8	0.00	1.04	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	4	7.73	8	0.00	1.07	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	5	7.69	8	0.00	1.08	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

19	6	7.67	8	0.00	1.09	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	7	7.66	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	8	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	9	7.65	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	10	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	11	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	12	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	13	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	14	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	15	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	16	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	17	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	18	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	19	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	20	7.64	8	0.00	1.10	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	1	7.64	8	0.00	0.87	0.00	7.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	2	7.63	8	0.00	0.87	0.00	7.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	3	7.63	8	0.00	0.87	0.00	7.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	4	7.63	8	0.00	0.87	0.00	7.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	5	7.63	8	0.00	0.87	0.00	7.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
20	6	7.63	8	0.00	0.87	0.00	7.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
21	1	7.68	8	0.00	0.71	0.00	7.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	2	7.68	8	0.00	0.71	0.00	7.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	3	7.67	8	0.00	0.72	0.00	7.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	4	7.67	8	0.00	0.72	0.00	7.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	1	8.62	8	0.00	0.64	0.00	5.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	2	8.47	8	0.00	0.66	0.00	5.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	3	8.35	8	0.00	0.69	0.00	5.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	4	8.24	8	0.00	0.71	0.00	5.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	5	8.16	8	0.00	0.73	0.00	6.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	6	8.09	8	0.00	0.74	0.00	6.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	7	8.04	8	0.00	0.76	0.00	6.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	8	7.99	8	0.00	0.77	0.00	6.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	9	7.95	8	0.00	0.78	0.00	6.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	10	7.91	8	0.00	0.79	0.00	6.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	11	7.89	8	0.00	0.80	0.00	6.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	12	7.86	8	0.00	0.80	0.00	6.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	13	7.84	8	0.00	0.81	0.00	6.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	14	7.82	8	0.00	0.81	0.00	6.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	15	7.81	8	0.00	0.82	0.00	6.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	16	7.80	8	0.00	0.82	0.00	7.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	17	7.78	8	0.00	0.82	0.00	7.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	18	7.77	8	0.00	0.83	0.00	7.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	19	7.76	8	0.00	0.83	0.00	7.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
22	20	7.76	8	0.00	0.83	0.00	7.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
23	1	7.68	8	0.00	0.64	0.00	7.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	2	7.68	8	0.00	0.63	0.00	7.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	3	7.67	8	0.00	0.64	0.00	7.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	4	7.67	8	0.00	0.64	0.00	7.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

24	1	7.66	8	0.00	0.64	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	2	7.66	8	0.00	0.64	0.00	7.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	3	7.66	8	0.00	0.64	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	4	7.66	8	0.00	0.64	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	5	7.66	8	0.00	0.64	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	6	7.66	8	0.00	0.64	0.00	7.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	7	7.66	8	0.00	0.64	0.00	7.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	8	7.65	8	0.00	0.64	0.00	7.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG C	CM 1	CM 2	CM 3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM N MG/L	ORGP MG/L	DIS P MG/L	SUM P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	21.66	28.00	0.00	0.00	8.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	2	22.68	28.00	0.00	0.00	7.81	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	3	23.96	28.00	0.00	0.00	7.63	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	4	24.97	28.00	0.00	0.00	7.45	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	5	25.77	28.00	0.00	0.00	7.27	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	6	26.41	28.00	0.00	0.00	7.11	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	7	26.93	28.00	0.00	0.00	6.95	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	8	27.34	28.00	0.00	0.00	6.79	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	9	27.67	28.00	0.00	0.00	6.65	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	10	27.94	28.00	0.00	0.00	6.51	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	11	28.16	28.00	0.00	0.00	6.37	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	12	28.34	28.00	0.00	0.00	6.24	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	13	28.49	28.00	0.00	0.00	6.12	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	14	28.61	28.00	0.00	0.00	6.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
1	15	28.72	28.00	0.00	0.00	5.89	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
1	16	28.80	28.00	0.00	0.00	5.78	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
1	17	28.88	28.00	0.00	0.00	5.68	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
1	18	28.94	28.00	0.00	0.00	5.58	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
1	19	28.99	28.00	0.00	0.00	5.49	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
1	20	29.04	28.00	0.00	0.00	5.40	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	1	29.08	28.00	0.00	0.00	4.49	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	2	29.11	28.00	0.00	0.00	3.62	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	3	29.15	28.00	0.00	0.00	2.78	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	4	29.18	28.00	0.00	0.00	1.97	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	5	29.20	28.00	0.00	0.00	1.20	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	6	29.22	28.00	0.00	0.00	0.45	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	7	29.24	28.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	8	29.25	28.00	0.00	0.00	0.00	0.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	9	29.27	28.00	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	10	29.28	28.00	0.00	0.00	0.00	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	11	29.29	28.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	12	29.30	28.00	0.00	0.00	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	13	29.31	28.00	0.00	0.00	0.00	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00
2	14	29.32	28.00	0.00	0.00	0.00	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.06	0.00

3	1	20.49	28.00	0.00	0.00	7.76	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	2	21.70	28.00	0.00	0.00	7.57	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	3	22.71	28.00	0.00	0.00	7.38	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	4	23.55	28.00	0.00	0.00	7.20	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	5	24.25	28.00	0.00	0.00	7.03	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	6	24.83	28.00	0.00	0.00	6.88	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	7	25.33	28.00	0.00	0.00	6.73	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	8	25.75	28.00	0.00	0.00	6.59	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	9	26.11	28.00	0.00	0.00	6.46	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	10	26.42	28.00	0.00	0.00	6.33	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	11	26.69	28.00	0.00	0.00	6.21	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	12	26.92	28.00	0.00	0.00	6.10	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	13	27.12	28.00	0.00	0.00	5.99	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	14	27.30	28.00	0.00	0.00	5.89	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	15	27.45	28.00	0.00	0.00	5.80	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	16	27.59	28.00	0.00	0.00	5.71	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	17	27.70	28.00	0.00	0.00	5.62	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
3	18	27.81	28.00	0.00	0.00	5.53	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
4	1	27.97	28.00	0.00	0.00	5.23	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
4	2	28.58	28.00	0.00	0.00	4.93	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
4	3	28.99	28.00	0.00	0.00	4.65	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
4	4	29.25	28.00	0.00	0.00	4.38	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
5	1	29.32	44.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
5	2	29.35	44.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
5	3	29.37	44.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
5	4	29.39	44.00	0.00	0.00	0.00	1.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
6	1	22.22	34.00	0.00	0.00	7.74	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	2	24.46	34.00	0.00	0.00	7.46	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	3	26.05	34.00	0.00	0.00	7.18	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	4	27.15	34.00	0.00	0.00	6.89	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	5	27.91	34.00	0.00	0.00	6.62	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	6	28.44	34.00	0.00	0.00	6.34	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	7	28.82	34.00	0.00	0.00	6.08	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	8	29.08	34.00	0.00	0.00	5.83	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	9	29.27	34.00	0.00	0.00	5.58	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	10	29.41	34.00	0.00	0.00	5.35	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	11	29.51	34.00	0.00	0.00	5.12	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	12	29.58	34.00	0.00	0.00	4.90	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	13	29.63	34.00	0.00	0.00	4.69	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	14	29.66	34.00	0.00	0.00	4.49	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	15	29.69	34.00	0.00	0.00	4.30	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	16	29.71	34.00	0.00	0.00	4.12	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	17	29.72	34.00	0.00	0.00	3.94	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	18	29.73	34.00	0.00	0.00	3.77	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	19	29.74	34.00	0.00	0.00	3.61	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
6	20	29.75	34.00	0.00	0.00	3.45	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
7	1	29.76	34.00	0.00	0.00	1.45	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
7	2	29.77	34.00	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00

7	3	29.77	34.00	0.00	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
7	4	29.78	34.00	0.00	0.00	0.00	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
7	5	29.78	34.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
7	6	29.78	34.00	0.00	0.00	0.00	1.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
8	1	29.49	44.00	0.00	0.00	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	2	29.50	44.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	3	29.51	44.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	4	29.52	44.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	5	29.53	44.00	0.00	0.00	0.00	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	6	29.54	44.00	0.00	0.00	0.00	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	7	29.54	44.00	0.00	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	8	29.55	44.00	0.00	0.00	0.00	1.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	9	29.55	44.00	0.00	0.00	0.00	1.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	10	29.56	44.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	11	29.56	44.00	0.00	0.00	0.00	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
8	12	29.57	44.00	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
9	1	19.84	33.00	0.00	0.00	8.08	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	2	20.59	33.00	0.00	0.00	7.96	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	3	21.28	33.00	0.00	0.00	7.84	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	4	21.90	33.00	0.00	0.00	7.73	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	5	22.46	33.00	0.00	0.00	7.63	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	6	22.96	33.00	0.00	0.00	7.52	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	7	23.43	33.00	0.00	0.00	7.42	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	8	23.85	33.00	0.00	0.00	7.32	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	9	24.23	33.00	0.00	0.00	7.22	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	10	24.58	33.00	0.00	0.00	7.13	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	11	24.90	33.00	0.00	0.00	7.04	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	12	25.19	33.00	0.00	0.00	6.95	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	13	25.45	33.00	0.00	0.00	6.87	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	14	25.70	33.00	0.00	0.00	6.79	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	15	25.92	33.00	0.00	0.00	6.71	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	16	26.12	33.00	0.00	0.00	6.63	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	17	26.31	33.00	0.00	0.00	6.55	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	18	26.49	33.00	0.00	0.00	6.48	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	19	26.65	33.00	0.00	0.00	6.41	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
9	20	26.80	33.00	0.00	0.00	6.34	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.03	0.00
10	1	27.02	33.00	0.00	0.00	6.13	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	2	27.61	33.00	0.00	0.00	5.93	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	3	28.07	33.00	0.00	0.00	5.73	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	4	28.43	33.00	0.00	0.00	5.53	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	5	28.72	33.00	0.00	0.00	5.33	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	6	28.95	33.00	0.00	0.00	5.13	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	7	29.13	33.00	0.00	0.00	4.94	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	8	29.27	33.00	0.00	0.00	4.74	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	9	29.39	33.00	0.00	0.00	4.56	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	10	29.48	33.00	0.00	0.00	4.37	0.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	11	29.55	33.00	0.00	0.00	4.19	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	12	29.60	33.00	0.00	0.00	4.01	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	13	29.65	33.00	0.00	0.00	3.82	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	14	29.68	33.00	0.00	0.00	3.64	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00
10	15	29.71	33.00	0.00	0.00	3.46	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.00

10	16	29.74	33.00	0.00	0.00	3.28	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.66	0.00
10	17	29.75	33.00	0.00	0.00	3.11	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.66	0.00
10	18	29.77	33.00	0.00	0.00	2.94	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
10	19	29.78	33.00	0.00	0.00	2.77	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
10	20	29.79	33.00	0.00	0.00	2.61	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
11	1	29.79	33.00	0.00	0.00	1.09	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
11	2	29.79	33.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
11	3	29.79	33.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
11	4	29.79	33.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
11	5	29.79	33.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
11	6	29.79	33.00	0.00	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.63	0.00
12	1	29.62	44.00	0.00	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.03	0.00
12	2	29.63	44.00	0.00	0.00	0.00	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.03	0.00
12	3	29.64	44.00	0.00	0.00	0.00	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.03	0.00
12	4	29.64	44.00	0.00	0.00	0.00	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.03	0.00
13	1	24.29	28.00	0.00	0.00	7.52	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
13	2	26.69	28.00	0.00	0.00	7.02	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
13	3	28.02	28.00	0.00	0.00	6.54	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
13	4	28.77	28.00	0.00	0.00	6.07	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
13	5	29.20	28.00	0.00	0.00	5.62	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	6	29.45	28.00	0.00	0.00	5.20	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	7	29.60	28.00	0.00	0.00	4.81	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	8	29.68	28.00	0.00	0.00	4.44	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	9	29.73	28.00	0.00	0.00	4.10	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	10	29.76	28.00	0.00	0.00	3.78	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	11	29.78	28.00	0.00	0.00	3.47	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	12	29.79	28.00	0.00	0.00	3.19	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	13	29.80	28.00	0.00	0.00	2.92	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	14	29.80	28.00	0.00	0.00	2.66	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.04	0.00
13	15	29.80	28.00	0.00	0.00	2.42	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
13	16	29.80	28.00	0.00	0.00	2.20	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
13	17	29.80	28.00	0.00	0.00	1.98	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
13	18	29.80	28.00	0.00	0.00	1.78	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
14	1	29.80	28.00	0.00	0.00	1.58	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
14	2	29.80	28.00	0.00	0.00	1.40	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
14	3	29.80	28.00	0.00	0.00	1.22	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
14	4	29.80	28.00	0.00	0.00	1.05	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.01	0.00
15	1	29.66	44.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	2	29.67	44.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	3	29.67	44.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	4	29.68	44.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	5	29.68	44.00	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.06	0.00
15	6	29.69	44.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	7	29.69	44.00	0.00	0.00	0.00	0.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	8	29.69	44.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	9	29.70	44.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	10	29.70	44.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.04	0.00
15	11	29.70	44.00	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00
15	12	29.71	44.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	[illegible]	0.00

15	13	29.71	44.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.60	0.00
15	14	29.71	44.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.60	0.00
15	15	29.72	44.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.60	0.00
15	16	29.72	44.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.60	0.00
15	17	29.72	44.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.60	0.00
15	18	29.72	44.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.60	0.00
16	1	21.08	28.00	0.00	0.00	7.72	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	2	21.99	28.00	0.00	0.00	7.15	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	3	22.78	28.00	0.00	0.00	7.20	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	4	23.46	28.00	0.00	0.00	6.96	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	5	24.04	28.00	0.00	0.00	6.73	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	6	24.55	28.00	0.00	0.00	6.51	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	7	24.99	28.00	0.00	0.00	6.30	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	8	25.38	28.00	0.00	0.00	6.09	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	9	25.72	28.00	0.00	0.00	5.90	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	10	26.02	28.00	0.00	0.00	5.71	1.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	11	26.28	28.00	0.00	0.00	5.53	1.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	12	26.54	28.00	0.00	0.00	5.15	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	13	26.77	28.00	0.00	0.00	4.65	5.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	14	26.96	28.00	0.00	0.00	4.08	7.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	15	27.13	28.00	0.00	0.00	3.45	8.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	16	27.28	28.00	0.00	0.00	2.76	9.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	17	27.41	28.00	0.00	0.00	2.04	11.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	18	27.52	28.00	0.00	0.00	1.39	10.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	19	27.62	28.00	0.00	0.00	0.79	9.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
16	20	27.71	28.00	0.00	0.00	0.24	9.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00
17	1	21.14	28.00	0.00	0.00	7.32	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	2	22.11	28.00	0.00	0.00	6.45	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	3	22.94	28.00	0.00	0.00	5.61	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	4	23.65	28.00	0.00	0.00	4.79	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	5	24.27	28.00	0.00	0.00	3.99	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	6	24.80	28.00	0.00	0.00	3.22	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	7	25.26	28.00	0.00	0.00	2.46	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	8	25.66	28.00	0.00	0.00	1.73	0.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	9	26.02	28.00	0.00	0.00	0.96	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	10	26.34	28.00	0.00	0.00	0.17	2.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	11	26.61	28.00	0.00	0.00	0.00	3.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	12	26.84	28.00	0.00	0.00	0.00	3.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	13	27.05	28.00	0.00	0.00	0.00	3.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	14	27.23	28.00	0.00	0.00	0.00	2.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	15	27.39	28.00	0.00	0.00	0.00	2.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	16	27.53	28.00	0.00	0.00	0.00	2.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	17	27.66	28.00	0.00	0.00	0.00	2.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
17	18	27.78	28.00	0.00	0.00	0.00	2.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.03	0.00
18	1	27.87	44.00	0.00	0.00	0.00	6.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
18	2	28.20	44.00	0.00	0.00	0.00	6.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
18	3	28.48	44.00	0.00	0.00	0.00	6.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
18	4	28.71	44.00	0.00	0.00	0.00	6.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
18	5	28.91	44.00	0.00	0.00	0.00	6.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
18	6	29.08	44.00	0.00	0.00	0.00	5.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00
18	7	29.21	44.00	0.00	0.00	0.00	5.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.00	0.00

18	8	29.31	44.00	0.00	0.00	0.00	[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	27.[illegible]0	0.00
19	1	25.60	28.00	0.00	0.00	7.27	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	2	27.54	28.00	0.00	0.00	6.73	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	3	28.58	28.00	0.00	0.00	6.20	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	4	29.15	28.00	0.00	0.00	5.69	0.5[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	5	29.47	28.00	0.00	0.00	5.21	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	6	29.64	28.00	0.00	0.00	4.75	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	7	29.74	28.00	0.00	0.00	4.32	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	8	29.79	28.00	0.00	0.00	3.91	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	9	29.82	28.00	0.00	0.00	3.53	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	10	29.84	28.00	0.00	0.00	3.16	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	11	29.85	28.00	0.00	0.00	2.82	0.5[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	12	29.85	28.00	0.00	0.00	2.50	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	13	29.86	28.00	0.00	0.00	2.19	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	14	29.85	28.00	0.00	0.00	1.88	0.9[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	15	29.86	28.00	0.00	0.00	1.59	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	16	29.86	28.00	0.00	0.00	1.31	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	17	29.86	28.00	0.00	0.00	1.05	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	18	29.86	28.00	0.00	0.00	0.80	0.8[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	19	29.86	28.00	0.00	0.00	0.56	0.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
19	20	29.86	28.00	0.00	0.00	0.33	0.7[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.[illegible]0	0.00
20	1	29.90	34.00	0.00	0.00	0.00	0.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
20	2	29.92	34.00	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
20	3	29.9[illegible]	34.00	0.00	0.00	0.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
20	4	29.94	34.00	0.00	0.00	0.00	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
20	5	29.95	34.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
20	6	29.96	34.00	0.00	0.00	0.00	1.[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
21	1	29.5[illegible]	34.00	0.00	0.00	0.00	4.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
21	2	29.58	34.00	0.00	0.00	0.00	4.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
21	3	29.60	34.00	0.00	0.00	0.00	4.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
21	4	29.62	34.00	0.00	0.00	0.00	4.3[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	1	23.15	24.00	0.00	0.00	6.68	0.5[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	2	24.11	24.00	0.00	0.00	5.58	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	3	24.91	24.00	0.00	0.00	4.49	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	4	25.57	24.00	0.00	0.00	3.41	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	5	26.13	24.00	0.00	0.00	2.39	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	6	26.60	24.00	0.00	0.00	1.37	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	7	26.99	24.00	0.00	0.00	0.38	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	8	27.33	24.00	0.00	0.00	0.00	0.4[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	9	27.61	24.00	0.00	0.00	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	10	27.85	24.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	11	28.05	24.00	0.00	0.00	0.00	0.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	12	28.22	24.00	0.00	0.00	0.00	0.4[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	13	28.37	24.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	14	28.50	24.00	0.00	0.00	0.00	0.4[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	15	28.61	24.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	16	28.71	24.00	0.00	0.00	0.00	0.4[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	17	28.79	24.00	0.00	0.00	0.00	0.4[illegible]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	18	28.86	24.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00
22	19	28.9[illegible]	24.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.0[illegible]	0.00

22	20	28.99	24.00	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.00	0.00
23	1	29.55	44.00	0.00	0.00	0.00	3.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.00	0.00
23	2	29.59	44.00	0.00	0.00	0.00	3.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.00	0.00
23	3	29.63	44.00	0.00	0.00	0.00	3.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.00	0.00
23	4	29.66	44.00	0.00	0.00	0.00	3.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.00	0.00
24	1	29.71	44.00	0.00	0.00	0.00	1.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00
24	2	29.72	44.00	0.00	0.00	0.00	1.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00
24	3	29.72	44.00	0.00	0.00	0.00	1.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00
24	4	29.73	44.00	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00
24	5	29.73	44.00	0.00	0.00	0.00	1.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00
24	6	29.74	44.00	0.00	0.00	0.00	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00
24	7	29.75	44.00	0.00	0.00	0.00	1.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00
24	8	29.75	44.00	0.00	0.00	0.00	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.03	0.00

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY)

ELE ORD	RCH NUM	ELE NUM	TEMP DEG C	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	F FNCTN INPUT	OXYGN REATR	C BOD	SOD	NET P-R	NH3 N	NO2 N
1	1	1	21.06	8.98	8.00	0.97	0.00	0.00	415.30	0.00	0.38	3.63	0.00	0.00	0.00
2	1	2	22.68	8.70	7.81	0.89	0.00	0.00	8.92	0.00	0.41	3.85	0.00	0.00	0.00
3	1	3	23.96	8.45	7.63	0.82	0.00	0.00	8.67	0.00	0.44	4.00	0.00	0.00	0.00
4	1	4	24.97	8.34	7.45	0.89	0.00	0.00	8.46	0.00	0.47	4.11	0.00	0.00	0.00
5	1	5	25.77	8.21	7.27	0.94	0.00	0.00	8.15	0.00	0.49	4.17	0.00	0.00	0.00
6	1	6	26.41	8.12	7.11	1.01	0.00	0.00	7.91	0.00	0.51	4.19	0.00	0.00	0.00
7	1	7	26.93	8.04	6.95	1.10	0.00	0.00	7.69	0.00	0.52	4.19	0.00	0.00	0.00
8	1	8	27.34	7.99	6.79	1.19	0.00	0.00	7.46	0.00	0.53	4.17	0.00	0.00	0.00
9	1	9	27.67	7.94	6.65	1.29	0.00	0.00	7.29	0.00	0.54	4.13	0.00	0.00	0.00
10	1	10	27.94	7.90	6.51	1.39	0.00	0.00	7.10	0.00	0.55	4.08	0.00	0.00	0.00
11	1	11	28.16	7.87	6.37	1.50	0.00	0.00	6.93	0.00	0.55	4.03	0.00	0.00	0.00
12	1	12	28.34	7.85	6.24	1.60	0.00	0.00	6.76	0.00	0.55	3.96	0.00	0.00	0.00
13	1	13	28.49	7.82	6.12	1.70	0.00	0.00	6.60	0.00	0.56	3.90	0.00	0.00	0.00
14	1	14	28.61	7.81	6.00	1.80	0.00	0.00	6.45	0.00	0.56	3.83	0.00	0.00	0.00
15	1	15	28.72	7.79	5.89	1.90	0.00	0.00	6.31	0.00	0.56	3.76	0.00	0.00	0.00
16	1	16	28.80	7.78	5.78	2.00	0.00	0.00	6.17	0.00	0.56	3.69	0.00	0.00	0.00
17	1	17	28.88	7.77	5.68	2.09	0.00	0.00	6.04	0.00	0.56	3.63	0.00	0.00	0.00
18	1	18	28.94	7.76	5.58	2.18	0.00	0.00	5.92	0.00	0.56	3.56	0.00	0.00	0.00
19	1	19	28.99	7.76	5.49	2.27	0.00	0.00	5.80	0.00	0.56	3.49	0.00	0.00	0.00
20	1	20	29.03	7.75	5.40	2.36	0.00	0.00	5.68	0.00	0.56	3.43	0.00	0.00	0.00
21	2	1	29.08	7.74	4.49	3.25	0.00	0.00	5.08	0.00	0.57	17.34	0.00	0.00	0.00
22	2	2	29.11	7.74	3.62	4.12	0.00	0.00	4.89	0.00	0.55	16.53	0.00	0.00	0.00
23	2	3	29.15	7.73	2.78	4.95	0.00	0.00	4.94	0.00	0.57	15.94	0.00	0.00	0.00
24	2	4	29.18	7.73	1.97	5.76	0.00	0.00	4.82	0.00	0.55	15.37	0.00	0.00	0.00
25	2	5	29.20	7.73	1.20	6.53	0.00	0.00	4.75	0.00	0.54	14.80	0.00	0.00	0.00
26	2	6	29.22	7.73	0.45	7.28	0.00	0.00	4.67	0.00	0.54	14.25	0.00	0.00	0.00
27	2	7	29.24	7.72	0.00	7.72	0.00	0.00	4.60	0.00	0.54	13.72	0.00	0.00	0.00
28	2	8	29.25	7.72	0.00	7.72	0.00	0.00	4.75	0.00	0.53	13.19	0.00	0.00	0.00

29	2	9	29.27	7.72	0.00	7.72	0.00	0.00	4.[illegible]	0.00	1.23	32.[illegible]	0.00	0.00	0.00
30	2	10	29.28	7.72	0.00	7.72	0.00	0.00	4.37	0.00	1.20	32.[illegible]	0.00	0.00	0.00
31	2	11	29.29	7.72	0.00	7.72	0.00	0.00	4.31	0.00	1.17	31.[illegible]	0.00	0.00	0.00
32	2	12	29.30	7.71	0.00	7.71	0.00	0.00	4.2[illegible]	0.00	1.14	31.[illegible]	0.00	0.00	0.00
33	2	13	29.31	7.71	0.00	7.71	0.00	0.00	4.19	0.00	1.11	30.[illegible]	0.00	0.00	0.00
34	2	14	29.32	7.71	0.00	7.71	0.00	0.00	4.13	0.00	1.08	30.[illegible]	0.00	0.00	0.00
35	3	1	20.49	9.08	7.78	1.30	0.00	0.00	[illegible]	0.00	0.36	0.[illegible]	0.00	0.00	0.00
36	3	2	21.70	8.87	7.57	1.29	0.00	0.00	5.37	0.00	0.39	0.[illegible]	0.00	0.00	0.00
37	3	3	22.71	8.70	7.38	1.32	0.00	0.00	5.20	0.00	0.41	0.90	0.00	0.00	0.00
38	3	4	23.55	8.56	7.20	1.36	0.00	0.00	5.03	0.00	0.42	0.94	0.00	0.00	0.00
39	3	5	24.25	8.45	7.03	1.42	0.00	0.00	4.88	0.00	0.43	0.96	0.00	0.00	0.00
40	3	6	24.83	8.36	6.88	1.48	0.00	0.00	4.75	0.00	0.44	0.98	0.00	0.00	0.00
41	3	7	25.33	8.28	6.73	1.55	0.00	0.00	4.62	0.00	0.45	1.00	0.00	0.00	0.00
42	3	8	25.75	8.22	6.59	1.63	0.00	0.00	4.50	0.00	0.46	1.01	0.00	0.00	0.00
43	3	9	26.11	8.16	6.46	1.71	0.00	0.00	4.39	0.00	0.46	1.02	0.00	0.00	0.00
44	3	10	26.42	8.12	6.33	1.79	0.00	0.00	4.28	0.00	0.46	1.03	0.00	0.00	0.00
45	3	11	26.69	8.08	6.21	1.87	0.00	0.00	4.18	0.00	0.46	1.03	0.00	0.00	0.00
46	3	12	26.92	8.05	6.10	1.94	0.00	0.00	4.09	0.00	0.46	1.03	0.00	0.00	0.00
47	3	13	27.12	8.02	5.99	2.02	0.00	0.00	4.00	0.00	0.46	1.04	0.00	0.00	0.00
48	3	14	27.30	7.99	5.83	2.16	0.00	0.00	3.92	0.00	0.46	1.01	0.00	0.00	0.00
49	3	15	27.45	7.97	5.80	2.17	0.00	0.00	3.84	0.00	0.46	1.03	0.00	0.00	0.00
50	3	16	27.59	7.95	5.71	2.25	0.00	0.00	3.77	0.00	0.45	1.04	0.00	0.00	0.00
51	3	17	27.70	7.93	5.62	2.32	0.00	0.00	3.70	0.00	0.45	1.03	0.00	0.00	0.00
52	3	18	27.81	7.92	5.53	2.39	0.00	0.00	3.63	0.00	0.45	1.[illegible]	0.00	0.00	0.00
53	4	1	27.97	7.90	5.23	2.67	0.00	0.00	6.17	0.00	0.45	10.[illegible]	0.00	0.00	0.00
54	4	2	28.58	7.81	4.93	2.88	0.00	0.00	6.01	0.00	0.46	10.48	0.00	0.00	0.00
55	4	3	28.99	7.76	4.65	3.11	0.00	0.00	5.87	0.00	0.47	10.46	0.00	0.00	0.00
56	4	4	29.25	7.72	4.38	3.35	0.00	0.00	5.73	0.00	0.48	10.5[illegible]	0.00	0.00	0.00
57	5	1	29.32	7.71	0.00	7.71	0.00	0.00	1.36	0.00	0.78	24.[illegible]	0.00	0.00	0.00
58	5	2	29.35	7.71	0.00	7.71	0.00	0.00	1.3[illegible]	0.00	0.79	24.34	0.00	0.00	0.00
59	5	3	29.37	7.71	0.00	7.71	0.00	0.00	1.42	0.00	0.89	24.[illegible]	0.00	0.00	0.00
60	5	4	29.39	7.70	0.00	7.70	0.00	0.00	1.34	0.00	0.90	24.14	0.00	0.00	0.00
61	6	1	22.22	8.78	7.74	1.04	0.00	0.00	[illegible]	0.00	0.39	6.[illegible]	0.00	0.00	0.00
62	6	2	24.48	8.41	7.46	0.95	0.00	0.00	6.20	0.00	0.44	7.[illegible]	0.00	0.00	0.00
63	6	3	26.05	8.17	7.18	1.00	0.00	0.00	6.05	0.00	0.47	8.[illegible]	0.00	0.00	0.00
64	6	4	27.15	8.01	6.89	1.12	0.00	0.00	5.91	0.00	0.49	8.34	0.00	0.00	0.00
65	6	5	27.91	7.90	6.62	1.29	0.00	0.00	5.77	0.00	0.51	8.[illegible]	0.00	0.00	0.00
66	6	6	28.44	7.83	6.34	1.49	0.00	0.00	5.64	0.00	0.52	8.[illegible]	0.00	0.00	0.00
67	6	7	28.82	7.78	6.08	1.70	0.00	0.00	5.52	0.00	0.53	8.[illegible]	0.00	0.00	0.00
68	6	8	29.08	7.74	5.83	1.91	0.00	0.00	5.40	0.00	0.53	8.40	0.00	0.00	0.00
69	6	9	29.27	7.72	5.58	2.14	0.00	0.00	5.29	0.00	0.53	8.[illegible]	0.00	0.00	0.00
70	6	10	29.41	7.70	5.35	2.35	0.00	0.00	5.18	0.00	0.53	8.[illegible]	0.00	0.00	0.00
71	6	11	29.51	7.69	5.12	2.57	0.00	0.00	5.08	0.00	0.53	8.14	0.00	0.00	0.00
72	6	12	29.58	7.68	4.90	2.78	0.00	0.00	4.98	0.00	0.53	8.00	0.00	0.00	0.00
73	6	13	29.63	7.67	4.69	2.98	0.00	0.00	4.8[illegible]	0.00	0.53	7.[illegible]	0.00	0.00	0.00
74	6	14	29.66	7.67	4.49	3.17	0.00	0.00	4.80	0.00	0.53	7.[illegible]	0.00	0.00	0.00
75	6	15	29.69	7.66	4.30	3.36	0.00	0.00	4.71	0.00	0.53	7.[illegible]	0.00	0.00	0.00
76	6	16	29.71	7.66	4.12	3.54	0.00	0.00	4.63	0.00	0.52	7.45	0.00	0.00	0.00
77	6	17	29.72	7.66	3.94	3.72	0.00	0.00	4.55	0.00	0.52	7.32	0.00	0.00	0.00
78	6	18	29.73	7.66	3.77	3.89	0.00	0.00	4.47	0.00	0.52	7.[illegible]	0.00	0.00	0.00

79	6	19	29.74	7.66	3.61	4.05	0.00	0.00	3.39	0.00	0.51	7.06	0.00	0.00	0.00
80	6	20	29.75	7.65	3.44	4.21	0.00	0.00	4.32	0.00	0.51	6.94	0.00	0.00	0.00
81	7	1	29.76	7.65	1.45	6.20	0.00	0.00	2.52	0.00	0.43	75.36	0.00	0.00	0.00
82	7	2	29.77	7.65	0.00	7.65	0.00	0.00	2.49	0.00	0.45	74.25	0.00	0.00	0.00
83	7	3	29.77	7.65	0.00	7.65	0.00	0.00	2.45	0.00	0.48	73.14	0.00	0.00	0.00
84	7	4	29.78	7.65	0.00	7.65	0.00	0.00	2.58	0.00	0.73	71.33	0.00	0.00	0.00
85	7	5	29.78	7.65	0.00	7.65	0.00	0.00	2.55	0.00	0.98	70.76	0.00	0.00	0.00
86	7	6	29.78	7.65	0.00	7.65	0.00	0.00	2.51	0.00	1.21	69.62	0.00	0.00	0.00
87	8	1	29.49	7.69	0.00	7.69	0.00	0.00	0.98	0.00	1.24	18.56	0.00	0.00	0.00
88	8	2	29.50	7.69	0.00	7.69	0.00	0.00	0.98	0.00	1.24	18.48	0.00	0.00	0.00
89	8	3	29.51	7.69	0.00	7.69	0.00	0.00	0.97	0.00	1.23	18.40	0.00	0.00	0.00
90	8	4	29.52	7.69	0.00	7.69	0.00	0.00	0.97	0.00	1.22	18.32	0.00	0.00	0.00
91	8	5	29.53	7.68	0.00	7.68	0.00	0.00	0.96	0.00	1.22	18.24	0.00	0.00	0.00
92	8	6	29.54	7.68	0.00	7.68	0.00	0.00	0.96	0.00	1.21	18.16	0.00	0.00	0.00
93	8	7	29.54	7.68	0.00	7.68	0.00	0.00	0.96	0.00	1.21	18.08	0.00	0.00	0.00
94	8	8	29.55	7.68	0.00	7.68	0.00	0.00	0.95	0.00	1.20	18.00	0.00	0.00	0.00
95	8	9	29.55	7.68	0.00	7.68	0.00	0.00	0.95	0.00	1.19	17.93	0.00	0.00	0.00
96	8	10	29.56	7.68	0.00	7.68	0.00	0.00	0.94	0.00	1.19	17.85	0.00	0.00	0.00
97	8	11	29.56	7.68	0.00	7.68	0.00	0.00	0.94	0.00	1.18	17.77	0.00	0.00	0.00
98	8	12	29.57	7.68	0.00	7.68	0.00	0.00	0.93	0.00	1.18	17.69	0.00	0.00	0.00
99	9	1	19.84	9.20	8.08	1.12	0.00	0.00	175.40	0.00	0.35	0.62	0.00	0.00	0.00
100	9	2	20.59	9.06	7.96	1.10	0.00	0.00	3.66	0.00	0.36	0.64	0.00	0.00	0.00
101	9	3	21.28	8.94	7.84	1.09	0.00	0.00	3.60	0.00	0.37	0.66	0.00	0.00	0.00
102	9	4	21.90	8.83	7.73	1.10	0.00	0.00	3.54	0.00	0.37	0.68	0.00	0.00	0.00
103	9	5	22.46	8.74	7.63	1.11	0.00	0.00	3.48	0.00	0.38	0.70	0.00	0.00	0.00
104	9	6	22.96	8.65	7.52	1.13	0.00	0.00	3.43	0.00	0.39	0.72	0.00	0.00	0.00
105	9	7	23.43	8.58	7.42	1.16	0.00	0.00	3.38	0.00	0.39	0.73	0.00	0.00	0.00
106	9	8	23.85	8.51	7.32	1.19	0.00	0.00	3.33	0.00	0.40	0.74	0.00	0.00	0.00
107	9	9	24.23	8.45	7.22	1.23	0.00	0.00	3.28	0.00	0.40	0.76	0.00	0.00	0.00
108	9	10	24.58	8.40	7.13	1.26	0.00	0.00	3.24	0.00	0.40	0.77	0.00	0.00	0.00
109	9	11	24.90	8.35	7.04	1.31	0.00	0.00	3.19	0.00	0.40	0.78	0.00	0.00	0.00
110	9	12	25.19	8.30	6.95	1.35	0.00	0.00	3.15	0.00	0.40	0.78	0.00	0.00	0.00
111	9	13	25.45	8.26	6.87	1.39	0.00	0.00	3.11	0.00	0.40	0.79	0.00	0.00	0.00
112	9	14	25.70	8.23	6.79	1.44	0.00	0.00	3.07	0.00	0.40	0.80	0.00	0.00	0.00
113	9	15	25.92	8.19	6.71	1.49	0.00	0.00	3.03	0.00	0.40	0.80	0.00	0.00	0.00
114	9	16	26.12	8.16	6.63	1.53	0.00	0.00	2.99	0.00	0.40	0.81	0.00	0.00	0.00
115	9	17	26.31	8.13	6.55	1.58	0.00	0.00	2.96	0.00	0.40	0.81	0.00	0.00	0.00
116	9	18	26.49	8.11	6.48	1.63	0.00	0.00	2.92	0.00	0.40	0.82	0.00	0.00	0.00
117	9	19	26.65	8.09	6.41	1.68	0.00	0.00	2.89	0.00	0.40	0.82	0.00	0.00	0.00
118	9	20	26.80	8.06	6.34	1.73	0.00	0.00	2.86	0.00	0.40	0.82	0.00	0.00	0.00
119	10	1	27.02	8.03	6.13	1.90	0.00	0.00	2.18	0.00	0.42	5.75	0.00	0.00	0.00
120	10	2	27.61	7.95	5.93	2.02	0.00	0.00	2.15	0.00	0.44	5.87	0.00	0.00	0.00
121	10	3	28.07	7.88	5.73	2.16	0.00	0.00	2.13	0.00	0.49	5.94	0.00	0.00	0.00
122	10	4	28.43	7.83	5.53	2.31	0.00	0.00	2.10	0.00	0.52	6.01	0.00	0.00	0.00
123	10	5	28.72	7.79	5.33	2.47	0.00	0.00	2.08	0.00	0.55	6.03	0.00	0.00	0.00
124	10	6	28.95	7.76	5.13	2.63	0.00	0.00	2.05	0.00	0.57	6.04	0.00	0.00	0.00
125	10	7	29.13	7.74	4.94	2.80	0.00	0.00	2.03	0.00	0.60	6.03	0.00	0.00	0.00
126	10	8	29.27	7.72	4.74	2.97	0.00	0.00	2.01	0.00	0.62	6.00	0.00	0.00	0.00
127	10	9	29.39	7.70	4.56	3.15	0.00	0.00	1.99	0.00	0.64	5.97	0.00	0.00	0.00
128	10	10	29.48	7.69	4.37	3.32	0.00	0.00	1.96	0.00	0.67	5.93	0.00	0.00	0.00

129	10	11	29.55	7.68	4.19	3.49	0.00	0.00	1.94	0.00	0.67	5.89	0.00	0.00	0.00
130	10	12	29.60	7.67	4.01	3.67	0.00	0.00	1.95	0.00	0.69	5.64	0.00	0.00	0.00
131	10	13	29.65	7.67	3.82	3.84	0.00	0.00	2.00	0.00	0.88	5.78	0.00	0.00	0.00
132	10	14	29.68	7.66	3.64	4.03	0.00	0.00	1.98	0.00	1.06	5.72	0.00	0.00	0.00
133	10	15	29.71	7.66	3.46	4.20	0.00	0.00	1.86	0.00	1.06	5.67	0.00	0.00	0.00
134	10	16	29.73	7.66	3.28	4.38	0.00	0.00	1.84	0.00	1.06	5.61	0.00	0.00	0.00
135	10	17	29.75	7.65	3.11	4.55	0.00	0.00	1.82	0.00	1.05	5.56	0.00	0.00	0.00
136	10	18	29.77	7.65	2.94	4.72	0.00	0.00	1.80	0.00	1.05	5.50	0.00	0.00	0.00
137	10	19	29.78	7.65	2.77	4.88	0.00	0.00	1.79	0.00	1.05	5.45	0.00	0.00	0.00
138	10	20	29.79	7.65	2.61	5.04	0.00	0.00	1.77	0.00	1.04	5.40	0.00	0.00	0.00
139	11	1	29.79	7.65	1.09	6.56	0.00	0.00	2.00	0.00	0.82	58.74	0.00	0.00	0.00
140	11	2	29.79	7.65	0.00	7.65	0.00	0.00	1.98	0.00	0.83	58.06	0.00	0.00	0.00
141	11	3	29.79	7.65	0.00	7.65	0.00	0.00	1.96	0.00	0.83	57.40	0.00	0.00	0.00
142	11	4	29.79	7.65	0.00	7.65	0.00	0.00	1.93	0.00	0.84	56.75	0.00	0.00	0.00
143	11	5	29.79	7.65	0.00	7.65	0.00	0.00	1.91	0.00	0.84	56.12	0.00	0.00	0.00
144	11	6	29.79	7.65	0.00	7.65	0.00	0.00	1.89	0.00	0.84	55.50	0.00	0.00	0.00
145	12	1	29.62	7.67	0.00	7.67	0.00	0.00	0.53	0.00	0.75	13.90	0.00	0.00	0.00
146	12	2	29.63	7.67	0.00	7.67	0.00	0.00	0.52	0.00	0.75	13.87	0.00	0.00	0.00
147	12	3	29.64	7.67	0.00	7.67	0.00	0.00	0.52	0.00	0.74	13.84	0.00	0.00	0.00
148	12	4	29.64	7.67	0.00	7.67	0.00	0.00	0.52	0.00	0.73	13.81	0.00	0.00	0.00
149	13	1	24.29	8.44	7.52	0.92	0.00	0.00	265.07	0.00	0.43	12.47	0.00	0.00	0.00
150	13	2	26.69	8.08	7.02	1.06	0.00	0.00	8.60	0.00	0.49	13.78	0.00	0.00	0.00
151	13	3	28.02	7.89	6.53	1.35	0.00	0.00	8.30	0.00	0.53	14.32	0.00	0.00	0.00
152	13	4	28.77	7.79	6.07	1.72	0.00	0.00	8.01	0.00	0.55	14.42	0.00	0.00	0.00
153	13	5	29.20	7.73	5.62	2.11	0.00	0.00	7.75	0.00	0.56	14.26	0.00	0.00	0.00
154	13	6	29.45	7.69	5.20	2.49	0.00	0.00	7.51	0.00	0.57	13.98	0.00	0.00	0.00
155	13	7	29.60	7.67	4.81	2.86	0.00	0.00	7.28	0.00	0.57	13.64	0.00	0.00	0.00
156	13	8	29.68	7.66	4.44	3.22	0.00	0.00	7.06	0.00	0.58	13.28	0.00	0.00	0.00
157	13	9	29.73	7.66	4.10	3.56	0.00	0.00	6.86	0.00	0.58	12.91	0.00	0.00	0.00
158	13	10	29.76	7.65	3.78	3.88	0.00	0.00	6.67	0.00	0.58	12.55	0.00	0.00	0.00
159	13	11	29.78	7.65	3.47	4.18	0.00	0.00	6.49	0.00	0.57	12.20	0.00	0.00	0.00
160	13	12	29.79	7.65	3.19	4.46	0.00	0.00	6.32	0.00	0.57	11.87	0.00	0.00	0.00
161	13	13	29.80	7.65	2.92	4.73	0.00	0.00	6.17	0.00	0.57	11.55	0.00	0.00	0.00
162	13	14	29.80	7.65	2.66	4.98	0.00	0.00	6.01	0.00	0.57	11.25	0.00	0.00	0.00
163	13	15	29.80	7.65	2.42	5.22	0.00	0.00	5.87	0.00	0.57	10.97	0.00	0.00	0.00
164	13	16	29.80	7.65	2.20	5.45	0.00	0.00	5.73	0.00	0.56	10.70	0.00	0.00	0.00
165	13	17	29.80	7.65	1.98	5.67	0.00	0.00	5.61	0.00	0.56	10.44	0.00	0.00	0.00
166	13	18	29.80	7.65	1.78	5.87	0.00	0.00	5.48	0.00	0.56	10.19	0.00	0.00	0.00
167	14	1	29.80	7.65	1.58	6.06	0.00	0.00	5.30	0.00	0.55	9.90	0.00	0.00	0.00
168	14	2	29.80	7.65	1.40	6.25	0.00	0.00	5.25	0.00	0.55	9.73	0.00	0.00	0.00
169	14	3	29.80	7.65	1.22	6.43	0.00	0.00	5.14	0.00	0.55	9.52	0.00	0.00	0.00
170	14	4	29.80	7.65	1.05	6.59	0.00	0.00	5.04	0.00	0.54	9.32	0.00	0.00	0.00
171	15	1	29.66	7.67	0.00	7.67	0.00	0.00	0.42	0.00	0.69	12.45	0.00	0.00	0.00
172	15	2	29.67	7.67	0.00	7.67	0.00	0.00	0.42	0.00	0.69	12.43	0.00	0.00	0.00
173	15	3	29.67	7.67	0.00	7.67	0.00	0.00	0.42	0.00	0.69	12.41	0.00	0.00	0.00
174	15	4	29.68	7.66	0.00	7.66	0.00	0.00	0.42	0.00	0.68	12.39	0.00	0.00	0.00
175	15	5	29.68	7.66	0.00	7.66	0.00	0.00	0.42	0.00	0.68	12.37	0.00	0.00	0.00
176	15	6	29.69	7.66	0.00	7.66	0.00	0.00	0.42	0.00	0.67	12.35	0.00	0.00	0.00
177	15	7	29.69	7.66	0.00	7.66	0.00	0.00	0.42	0.00	0.67	12.33	0.00	0.00	0.00

178	15	8	29.69	7.66	0.00	7.66	0.00	0.00	0.42	0.00	0.67	12.31	0.00	0.00	0.00
179	15	9	29.70	7.66	0.00	7.66	0.00	0.00	0.41	0.00	[illegible]	12.28	0.00	0.00	0.00
180	15	10	29.70	7.66	0.00	7.66	0.00	0.00	0.41	0.00	[illegible]	12.26	0.00	0.00	0.00
181	15	11	29.70	7.66	0.00	7.66	0.00	0.00	0.41	0.00	[illegible]	12.24	0.00	0.00	0.00
182	15	12	29.71	7.66	0.00	7.66	0.00	0.00	0.41	0.00	0.65	12.22	0.00	0.00	0.00
183	15	13	29.71	7.66	0.00	7.66	0.00	0.00	0.41	0.00	[illegible]	12.20	0.00	0.00	0.00
184	15	14	29.71	7.66	0.00	7.66	0.00	0.00	0.41	0.00	0.65	12.18	0.00	0.00	0.00
185	15	15	29.72	7.66	0.00	7.66	0.00	0.00	0.41	0.00	0.64	12.16	0.00	0.00	0.00
186	15	16	29.72	7.66	0.00	7.66	0.00	0.00	0.41	0.00	0.64	12.13	0.00	0.00	0.00
187	15	17	29.72	7.66	0.00	7.66	0.00	0.00	0.41	0.00	0.64	12.11	0.00	0.00	0.00
188	15	18	29.72	7.66	0.00	7.66	0.00	0.00	0.41	0.00	0.64	12.09	0.00	0.00	0.00
189	16	1	21.08	8.97	7.72	1.25	0.00	0.00	137.86	0.00	0.44	0.77	0.00	0.00	0.00
190	16	2	21.99	8.62	7.45	1.16	0.00	0.00	3.27	0.00	0.52	0.80	0.00	0.00	0.00
191	16	3	22.78	8.68	7.20	1.48	0.00	0.00	3.18	0.00	0.59	0.83	0.00	0.00	0.00
192	16	4	23.46	8.57	6.96	1.62	0.00	0.00	3.10	0.00	0.66	0.85	0.00	0.00	0.00
193	16	5	24.04	8.48	6.73	1.75	0.00	0.00	3.03	0.00	0.72	0.87	0.00	0.00	0.00
194	16	6	24.55	8.40	6.51	1.89	0.00	0.00	2.96	0.00	0.77	0.89	0.00	0.00	0.00
195	16	7	24.99	8.33	6.30	2.04	0.00	0.00	2.89	0.00	0.82	0.90	0.00	0.00	0.00
196	16	8	25.38	8.27	6.09	2.18	0.00	0.00	2.83	0.00	0.86	0.91	0.00	0.00	0.00
197	16	9	25.72	8.22	5.90	2.32	0.00	0.00	2.77	0.00	0.90	0.92	0.00	0.00	0.00
198	16	10	26.02	8.18	5.71	2.46	0.00	0.00	2.71	0.00	0.93	0.93	0.00	0.00	0.00
199	16	11	26.28	8.14	5.53	2.61	0.00	0.00	2.66	0.00	0.97	0.93	0.00	0.00	0.00
200	16	12	26.54	8.10	5.15	2.95	0.00	0.00	3.38	0.00	3.18	0.93	0.00	0.00	0.00
201	16	13	26.77	8.07	4.65	3.41	0.00	0.00	3.28	0.00	5.14	0.93	0.00	0.00	0.00
202	16	14	26.96	8.04	4.08	3.96	0.00	0.00	3.19	0.00	6.88	0.93	0.00	0.00	0.00
203	16	15	27.13	8.02	3.45	4.57	0.00	0.00	3.11	0.00	8.41	0.93	0.00	0.00	0.00
204	16	16	27.28	7.99	2.76	5.23	0.00	0.00	3.03	0.00	9.76	0.93	0.00	0.00	0.00
205	16	17	27.41	7.98	2.04	5.94	0.00	0.00	2.95	0.00	10.96	0.92	0.00	0.00	0.00
206	16	18	27.52	7.96	1.39	6.57	0.00	0.00	2.22	0.00	10.38	0.92	0.00	0.00	0.00
207	16	19	27.62	7.95	0.79	7.16	0.00	0.00	2.19	0.00	9.84	0.92	0.00	0.00	0.00
208	16	20	27.71	7.93	0.24	7.69	0.00	0.00	2.16	0.00	9.33	0.92	0.00	0.00	0.00
209	17	1	21.14	8.96	7.32	1.65	0.00	0.00	133.50	0.00	0.43	8.85	0.00	0.00	0.00
210	17	2	22.11	8.80	6.45	2.34	0.00	0.00	2.83	0.00	0.51	9.25	0.00	0.00	0.00
211	17	3	22.94	8.66	5.61	3.05	0.00	0.00	2.76	0.00	0.57	9.60	0.00	0.00	0.00
212	17	4	23.65	8.54	4.79	3.75	0.00	0.00	2.70	0.00	0.63	9.90	0.00	0.00	0.00
213	17	5	24.27	8.45	3.99	4.45	0.00	0.00	2.64	0.00	0.69	10.15	0.00	0.00	0.00
214	17	6	24.80	8.36	3.22	5.15	0.00	0.00	2.58	0.00	0.74	10.36	0.00	0.00	0.00
215	17	7	25.26	8.29	2.46	5.83	0.00	0.00	2.52	0.00	0.79	10.54	0.00	0.00	0.00
216	17	8	25.66	8.23	1.73	6.50	0.00	0.00	2.47	0.00	0.83	10.69	0.00	0.00	0.00
217	17	9	26.02	8.18	0.96	7.22	0.00	0.00	2.69	0.00	1.69	10.79	0.00	0.00	0.00
218	17	10	26.34	8.13	0.17	7.96	0.00	0.00	2.63	0.00	2.47	10.88	0.00	0.00	0.00
219	17	11	26.61	8.09	0.00	8.09	0.00	0.00	2.57	0.00	3.17	10.94	0.00	0.00	0.00
220	17	12	26.84	8.06	0.00	8.06	0.00	0.00	2.26	0.00	3.05	11.00	0.00	0.00	0.00
221	17	13	27.05	8.03	0.00	8.03	0.00	0.00	2.23	0.00	2.93	11.04	0.00	0.00	0.00
222	17	14	27.23	8.00	0.00	8.00	0.00	0.00	2.19	0.00	2.82	11.07	0.00	0.00	0.00
223	17	15	27.39	7.98	0.00	7.98	0.00	0.00	2.15	0.00	2.71	11.09	0.00	0.00	0.00
224	17	16	27.53	7.96	0.00	7.96	0.00	0.00	2.12	0.00	2.61	11.10	0.00	0.00	0.00
225	17	17	27.66	7.94	0.00	7.94	0.00	0.00	2.09	0.00	2.53	11.11	0.00	0.00	0.00
226	17	18	27.78	7.92	0.00	7.92	0.00	0.00	2.06	0.00	2.43	11.10	0.00	0.00	0.00
227	18	1	27.87	7.91	0.00	7.91	0.00	0.00	1.85	0.00	5.01	46.38	0.00	0.00	0.00
228	18	2	28.20	7.86	0.00	7.86	0.00	0.00	1.84	0.00	5.02	46.91	0.00	0.00	0.00

229	18	3	28.46	7.83	0.00	7.83	0.00	0.00	1.82	0.00	5.02	49.18	0.00	0.00	0.00
230	18	4	28.71	7.79	0.00	7.79	0.00	0.00	1.80	0.00	5.01	49.33	0.00	0.00	0.00
231	18	5	28.91	7.77	0.00	7.77	0.00	0.00	1.78	0.00	4.99	49.39	0.00	0.00	0.00
232	18	6	29.08	7.75	0.00	7.75	0.00	0.00	1.77	0.00	4.96	49.35	0.00	0.00	0.00
233	18	7	29.21	7.73	0.00	7.73	0.00	0.00	1.75	0.00	4.92	49.25	0.00	0.00	0.00
234	18	8	29.33	7.71	0.00	7.71	0.00	0.00	1.73	0.00	4.89	49.10	0.00	0.00	0.00
235	19	1	25.60	8.24	7.27	0.97	0.00	0.00	256.35	0.00	0.46	14.48	0.00	0.00	0.00
236	19	2	27.54	7.96	6.74	1.22	0.00	0.00	7.41	0.00	0.50	15.65	0.00	0.00	0.00
237	19	3	28.58	7.81	6.20	1.61	0.00	0.00	7.18	0.00	0.53	16.08	0.00	0.00	0.00
238	19	4	29.15	7.73	5.69	2.04	0.00	0.00	6.96	0.00	0.55	16.09	0.00	0.00	0.00
239	19	5	29.47	7.69	5.21	2.49	0.00	0.00	6.76	0.00	0.55	15.89	0.00	0.00	0.00
240	19	6	29.64	7.67	4.75	2.92	0.00	0.00	6.57	0.00	0.56	15.56	0.00	0.00	0.00
241	19	7	29.74	7.66	4.32	3.34	0.00	0.00	6.39	0.00	0.56	15.20	0.00	0.00	0.00
242	19	8	29.79	7.65	3.91	3.74	0.00	0.00	6.22	0.00	0.56	14.81	0.00	0.00	0.00
243	19	9	29.82	7.65	3.53	4.12	0.00	0.00	6.06	0.00	0.56	14.43	0.00	0.00	0.00
244	19	10	29.84	7.64	3.16	4.48	0.00	0.00	5.91	0.00	0.56	14.06	0.00	0.00	0.00
245	19	11	29.85	7.64	2.82	4.82	0.00	0.00	5.77	0.00	0.55	13.71	0.00	0.00	0.00
246	19	12	29.85	7.64	2.50	5.14	0.00	0.00	5.63	0.00	0.55	13.37	0.00	0.00	0.00
247	19	13	29.86	7.64	2.19	5.45	0.00	0.00	5.50	0.00	0.55	13.04	0.00	0.00	0.00
248	19	14	29.86	7.64	1.88	5.76	0.00	0.00	5.61	0.00	1.02	12.69	0.00	0.00	0.00
249	19	15	29.86	7.64	1.59	6.05	0.00	0.00	5.25	0.00	1.00	12.39	0.00	0.00	0.00
250	19	16	29.86	7.64	1.31	6.33	0.00	0.00	5.14	0.00	0.97	12.12	0.00	0.00	0.00
251	19	17	29.86	7.64	1.05	6.59	0.00	0.00	5.03	0.00	0.94	11.85	0.00	0.00	0.00
252	19	18	29.86	7.64	0.80	6.84	0.00	0.00	4.93	0.00	0.92	11.59	0.00	0.00	0.00
253	19	19	29.86	7.64	0.56	7.08	0.00	0.00	4.83	0.00	0.89	11.35	0.00	0.00	0.00
254	19	20	29.86	7.64	0.33	7.31	0.00	0.00	4.74	0.00	0.87	11.11	0.00	0.00	0.00
255	20	1	29.90	7.64	0.00	7.64	0.00	0.00	3.86	0.00	0.77	119.62	0.00	0.00	0.00
256	20	2	29.92	7.63	0.00	7.63	0.00	0.00	3.77	0.00	0.84	116.86	0.00	0.00	0.00
257	20	3	29.93	7.63	0.00	7.63	0.00	0.00	3.68	0.00	1.21	113.86	0.00	0.00	0.00
258	20	4	29.94	7.63	0.00	7.63	0.00	0.00	3.60	0.00	1.26	111.30	0.00	0.00	0.00
259	20	5	29.95	7.63	0.00	7.63	0.00	0.00	3.52	0.00	1.30	108.84	0.00	0.00	0.00
260	20	6	29.96	7.63	0.00	7.63	0.00	0.00	3.45	0.00	1.35	106.47	0.00	0.00	0.00
261	21	1	29.55	7.68	0.00	7.68	0.00	0.00	1.55	0.00	3.19	34.85	0.00	0.00	0.00
262	21	2	29.58	7.68	0.00	7.68	0.00	0.00	1.53	0.00	3.17	34.61	0.00	0.00	0.00
263	21	3	29.60	7.67	0.00	7.67	0.00	0.00	1.53	0.00	3.16	34.36	0.00	0.00	0.00
264	21	4	29.62	7.67	0.00	7.67	0.00	0.00	1.52	0.00	3.14	34.12	0.00	0.00	0.00
265	22	1	23.15	8.62	6.68	1.94	0.00	0.00	107.7	0.00	0.32	11.28	0.00	0.00	0.00
266	22	2	24.11	8.47	5.58	2.89	0.00	0.00	3.14	0.00	0.33	11.80	0.00	0.00	0.00
267	22	3	24.91	8.35	4.49	3.86	0.00	0.00	3.07	0.00	0.34	12.24	0.00	0.00	0.00
268	22	4	25.57	8.24	3.42	4.82	0.00	0.00	3.01	0.00	0.34	12.60	0.00	0.00	0.00
269	22	5	26.13	8.16	2.39	5.78	0.00	0.00	2.95	0.00	0.35	12.89	0.00	0.00	0.00
270	22	6	26.60	8.09	1.37	6.72	0.00	0.00	2.89	0.00	0.35	13.13	0.00	0.00	0.00
271	22	7	26.99	8.04	0.38	7.65	0.00	0.00	2.84	0.00	0.35	13.32	0.00	0.00	0.00
272	22	8	27.33	7.99	0.00	7.99	0.00	0.00	2.78	0.00	0.35	13.46	0.00	0.00	0.00
273	22	9	27.61	7.95	0.00	7.95	0.00	0.00	2.73	0.00	0.35	13.57	0.00	0.00	0.00
274	22	10	27.85	7.91	0.00	7.91	0.00	0.00	2.69	0.00	0.35	13.65	0.00	0.00	0.00
275	22	11	28.05	7.89	0.00	7.89	0.00	0.00	2.64	0.00	0.35	13.70	0.00	0.00	0.00
276	22	12	28.22	7.86	0.00	7.86	0.00	0.00	2.60	0.00	0.35	13.74	0.00	0.00	0.00
277	22	13	28.37	7.84	0.00	7.84	0.00	0.00	2.56	0.00	0.34	13.75	0.00	0.00	0.00
278	22	14	28.50	7.82	0.00	7.82	0.00	0.00	2.52	0.00	0.34	13.76	0.00	0.00	0.00

279	22	15	28.61	7.83	0.00	7.83	0.00	0.00	2.48	0.00	0.34	13.75	0.00	0.00	0.00
280	22	16	28.71	7.80	0.00	7.80	0.00	0.00	2.41	0.00	0.33	13.73	0.00	0.00	0.00
281	22	17	28.79	7.78	0.00	7.78	0.00	0.00	2.43	0.00	0.33	13.71	0.00	0.00	0.00
282	22	18	28.86	7.77	0.00	7.77	0.00	0.00	2.37	0.00	0.33	13.67	0.00	0.00	0.00
283	22	19	28.93	7.76	0.00	7.76	0.00	0.00	2.34	0.00	0.33	13.64	0.00	0.00	0.00
284	22	20	28.99	7.76	0.00	7.76	0.00	0.00	2.31	0.00	0.33	13.60	0.00	0.00	0.00
285	23	1	29.55	7.68	0.00	7.68	0.00	0.00	1.06	0.00	2.42	29.44	0.00	0.00	0.00
286	23	2	29.59	7.68	0.00	7.68	0.00	0.00	1.04	0.00	2.39	29.33	0.00	0.00	0.00
287	23	3	29.63	7.67	0.00	7.67	0.00	0.00	1.07	0.00	2.37	29.23	0.00	0.00	0.00
288	23	4	29.66	7.67	0.00	7.67	0.00	0.00	1.05	0.00	2.34	29.12	0.00	0.00	0.00
289	24	1	29.71	7.66	0.00	7.66	0.00	0.00	0.34	0.00	1.06	8.90	0.00	0.00	0.00
290	24	2	29.72	7.66	0.00	7.66	0.00	0.00	0.34	0.00	1.05	8.89	0.00	0.00	0.00
291	24	3	29.72	7.66	0.00	7.66	0.00	0.00	0.35	0.00	1.03	9.06	0.00	0.00	0.00
292	24	4	29.73	7.66	0.00	7.66	0.00	0.00	0.35	0.00	1.02	9.05	0.00	0.00	0.00
293	24	5	29.73	7.66	0.00	7.66	0.00	0.00	0.35	0.00	1.01	9.04	0.00	0.00	0.00
294	24	6	29.74	7.66	0.00	7.66	0.00	0.00	0.35	0.00	1.00	9.03	0.00	0.00	0.00
295	24	7	29.75	7.66	0.00	7.66	0.00	0.00	0.53	0.00	0.99	14.20	0.00	0.00	0.00
296	24	8	29.75	7.65	0.00	7.65	0.00	0.00	0.54	0.00	0.98	14.17	0.00	0.00	0.00

QUAL2E Output Method of Analysis

The output for QUAL2E is in WordPad and for the purpose of statistical and graphical analyses the data have to be transferred to a spreadsheet such as Microsoft Excel or Quattro Pro. The short cut method of transferring the data is as follows:

1) Run QUAL2E Windows by clicking at the RUN button and later clicking at the MS-DOS Model Execution at the bottom of the screen;
2) Click YES for the message screen to display the output;
3) Highlight and COPY the needed results (the results need to be subdivided as the number of columns for the three sections, namely, Hydraulics, Water Quality, and DO Components, are not the same in size);
4) PASTE and name the new WordPad file in Text Document (this is usually stored in the Userman Folder in QUAL2E);
5) Open Microsoft Excel or Quattro Pro and open the WordPad file name within the spreadsheet;
6) Subdivide the parameters in the necessary number of columns (Caution: the default columns are not accurate, visually check to see whether you have the right number of columns);
7) Click FINISH.

Excel 97 tends to copy the data to its own file, therefore if you need to have a specific file or sheet for the data, you have to highlight and copy the data from the default file. The resulting spreadsheet file can then be used for further analysis.

APPENDIX D

Dissolved Oxygen Temporal Profile Results for the Reaeration Coefficient Measurements at Alor Lempah (Sg. Selangor River) and Sg. Serendah River

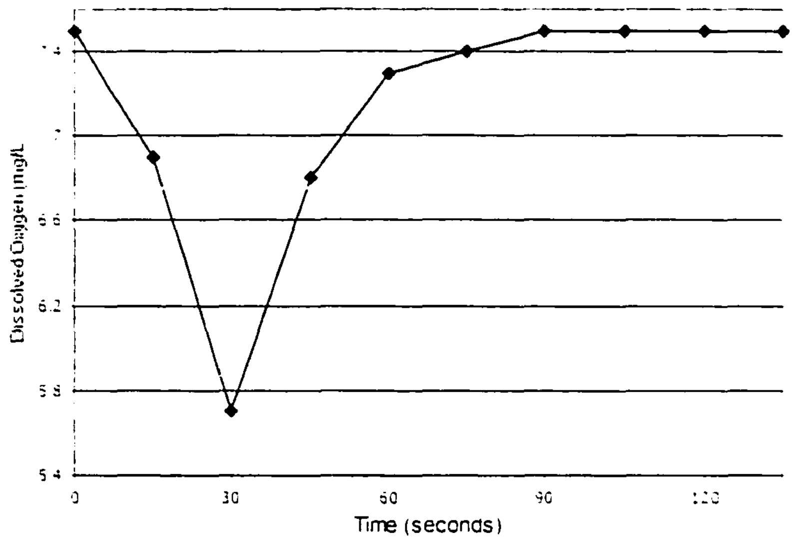

Figure D-1. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 1) (upstream), Sg. Selangor River, Malaysia.

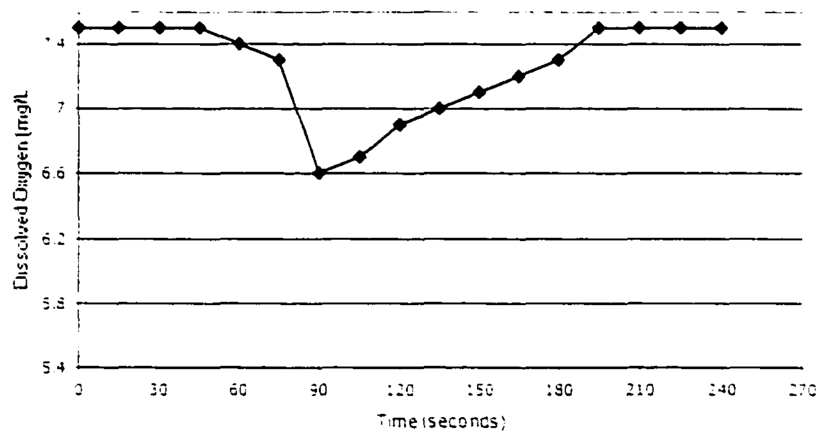

Figure D-2. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 1)(downstream), Sg. Selangor River, Malaysia.

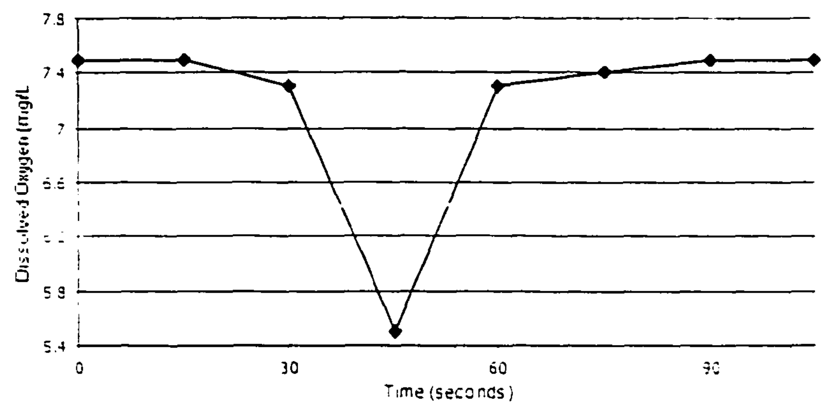

Figure D-3. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 2) (upstream), Sg. Selangor River, Malaysia.

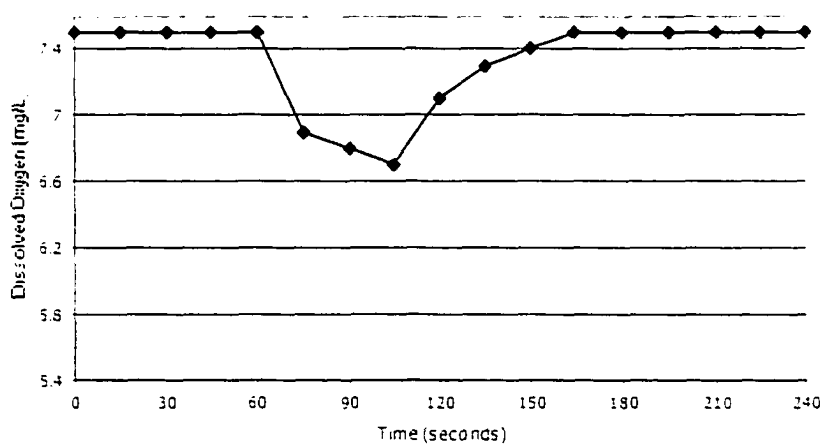

Figure D-4. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 2) (downstream), Sg. Selangor River, Malaysia.

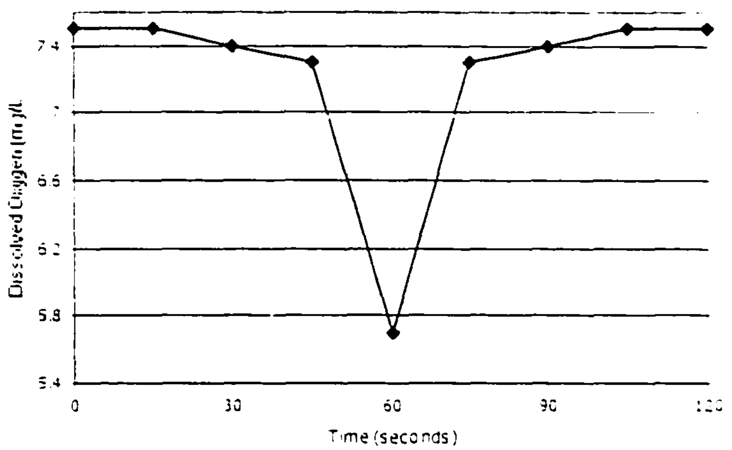

Figure D-5. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 3) (upstream), Sg. Selangor River, Malaysia.

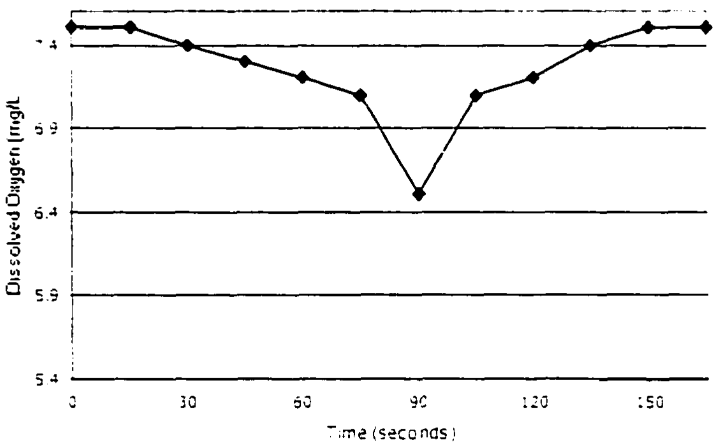

Figure D-6. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 3) (downstream), Sg. Selangor River, Malaysia.

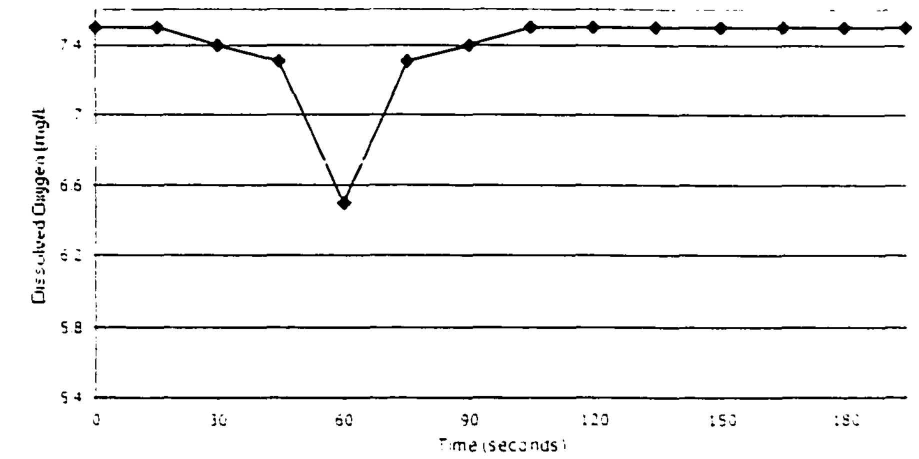

Figure D-7. DO Profile of a Disturbed Equilibrium at Alor Lempah (Run 4) (upstream), Sg. Selangor River, Malaysia.

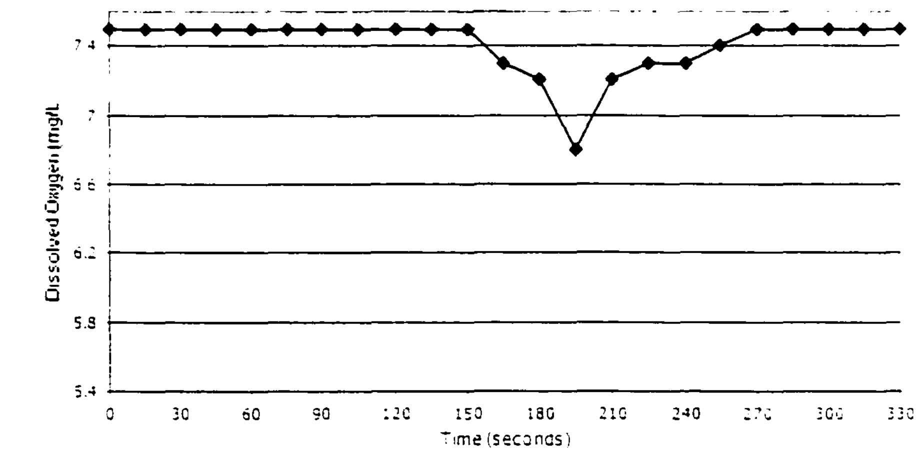

Figure D-8. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 4) (downstream), Sg. Selangor River, Malaysia.

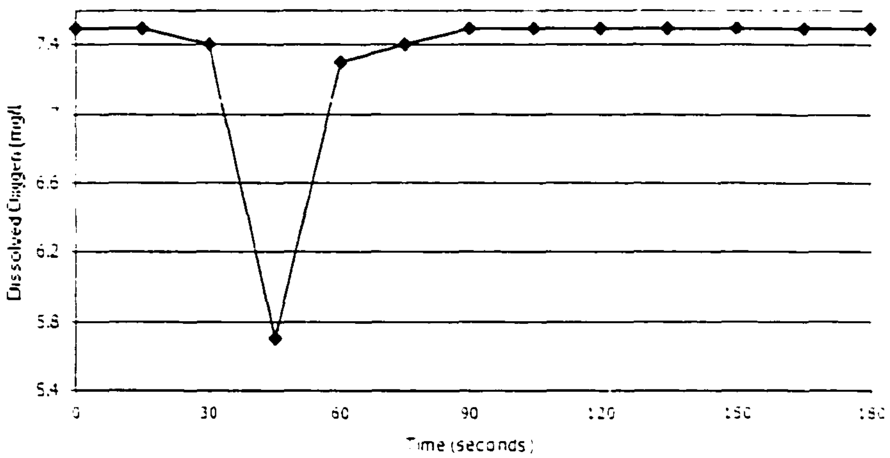

Figure D-9. DO Temporal Profile of a Disturbed Equilibrium at Alor Lempah (Run 5) (upstream), Sg. Selangor River, Malaysia.

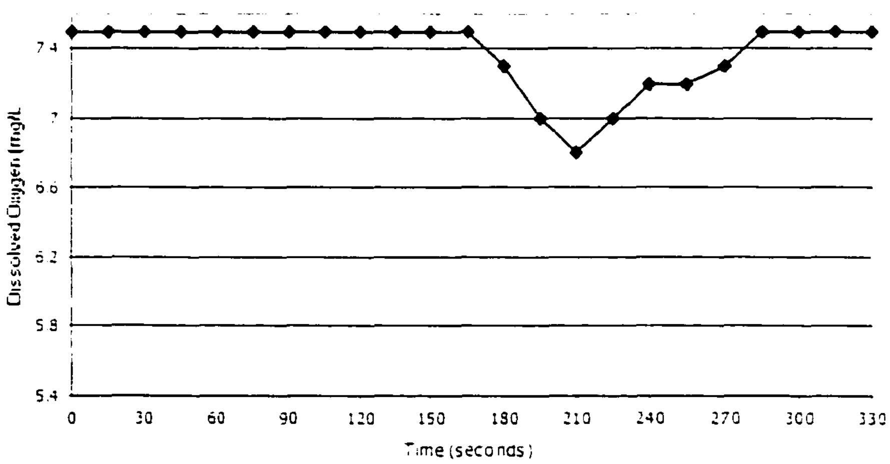

Figure D-10. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 5) (downstream), Sg. Selangor River, Malaysia.

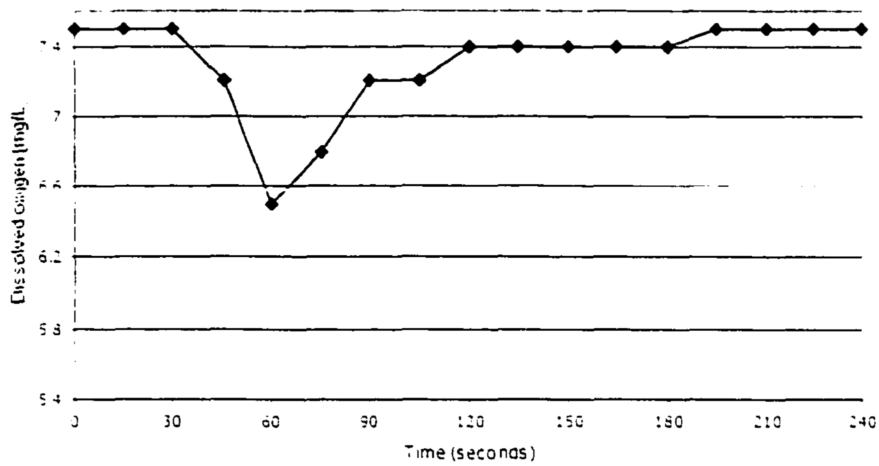

Figure D-11. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 6) (upstream), Sg. Selangor River, Malaysia.

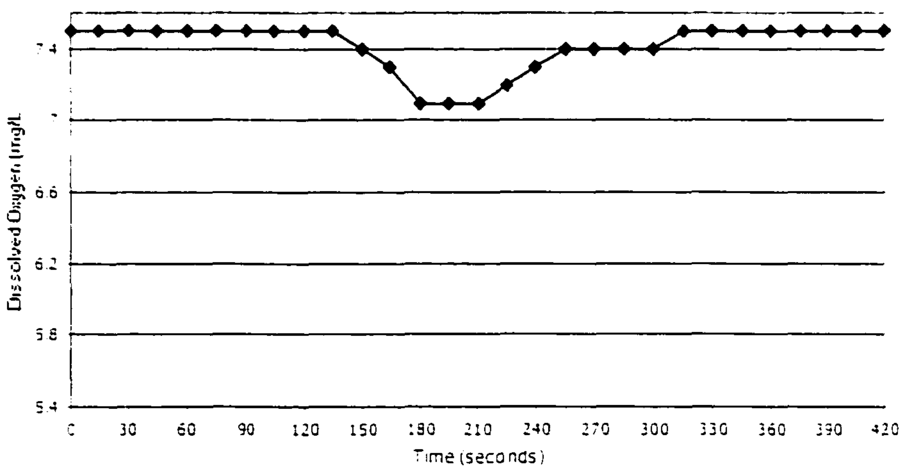

Figure D-12. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 6) (downstream), Sg. Selangor River, Malaysia.

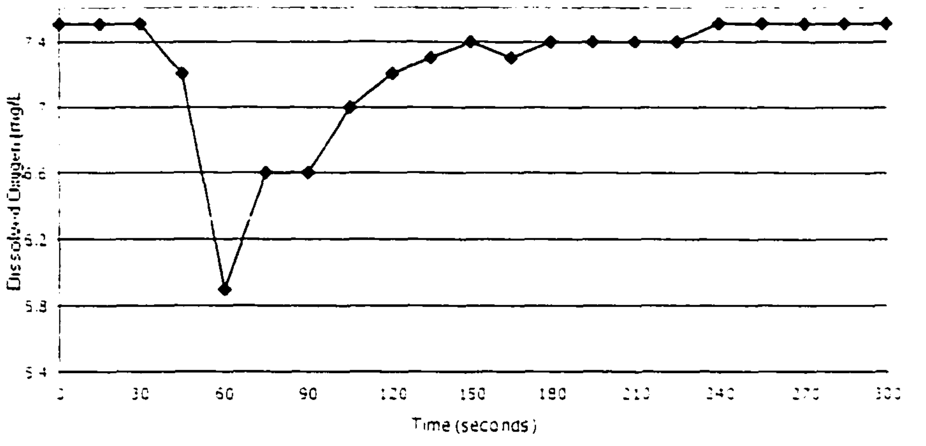

Figure D-13. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 7) (upstream), Sg. Selangor River, Malaysia.

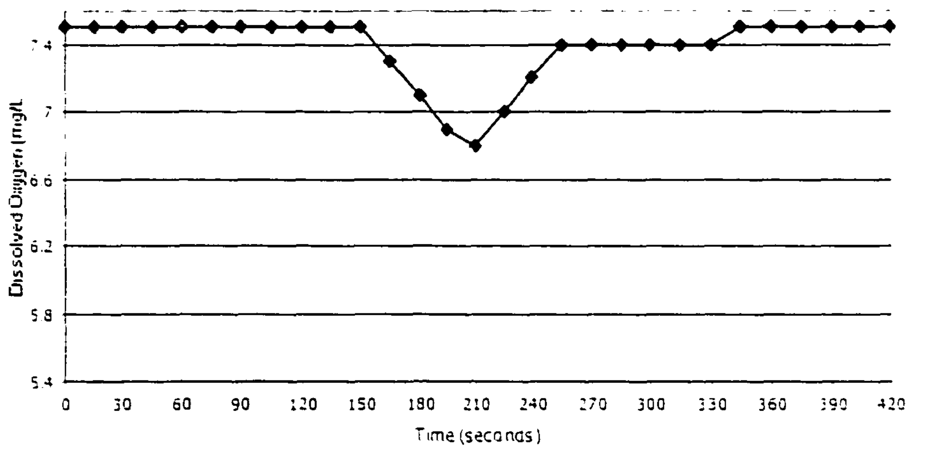

Figure D-14. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 7) (downstream), Sg. Selangor River, Malaysia.

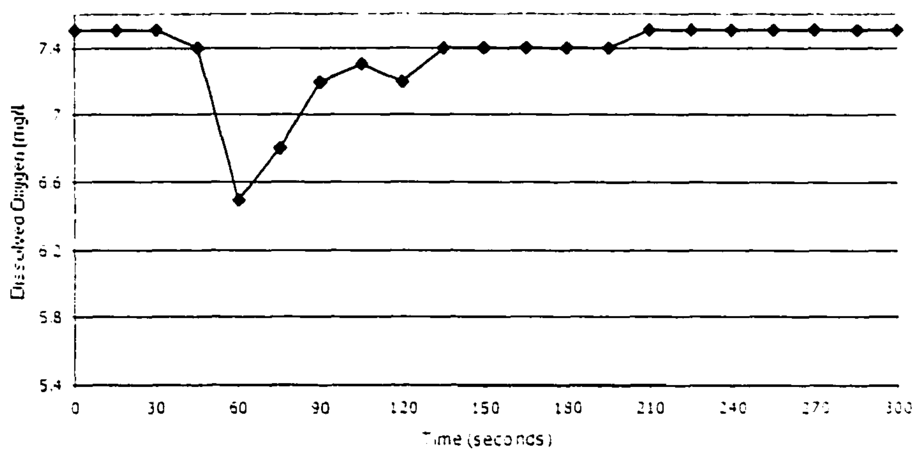

Figure D-15. DO Temporal Profile for Disturbed Equilibrium at Alor Lempah (Run 8) (upstream), Sg. Selangor River, Malaysia.

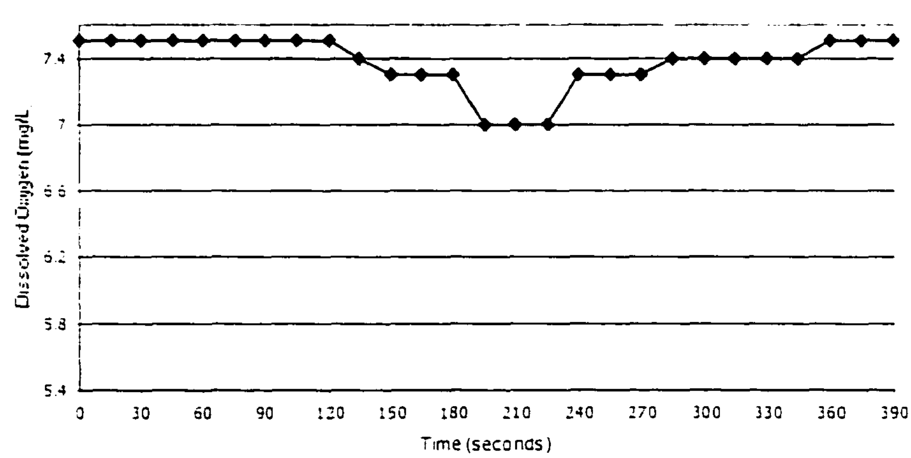

Figure D-16. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 8) (downstream), Sg. Selangor River, Malaysia.

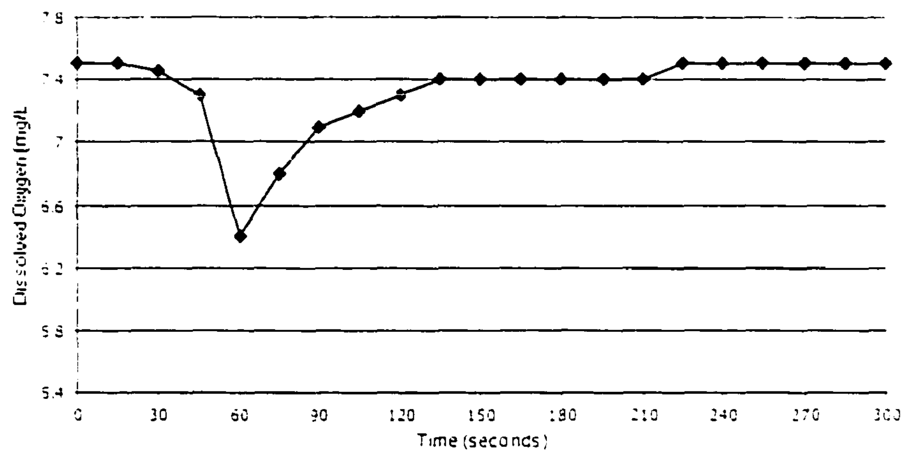

Figure D-17. DO Temporal Profile for Disturbed Equilibrium at Alor Lempah (Run 9) (upstream), Sg. Selangor River, Malaysia.

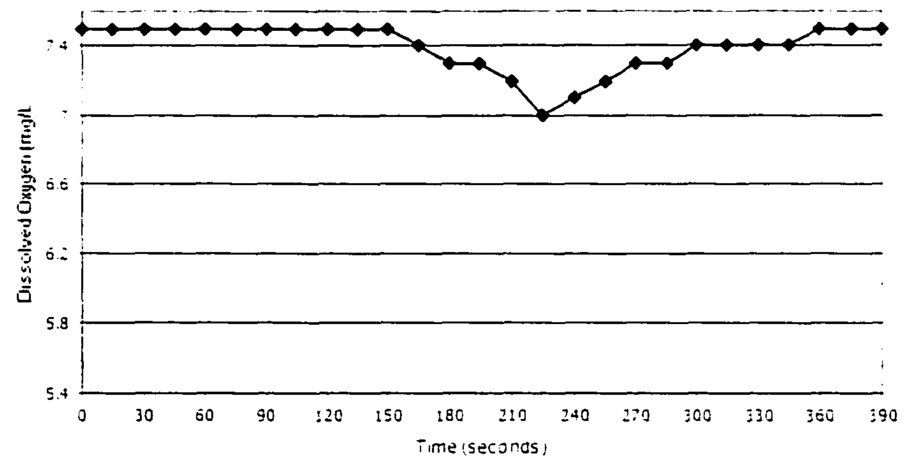

Figure D-18. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 9) (downstream), Sg. Selangor River, Malaysia.

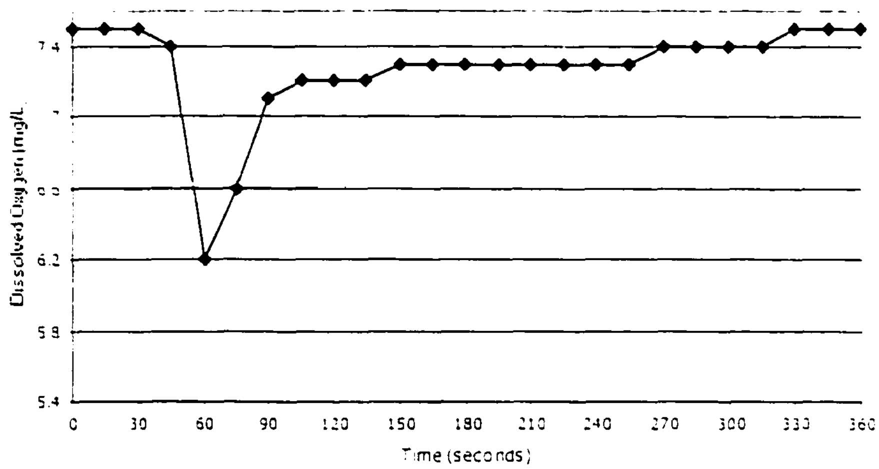

Figure D-19. DO Temporal Profile for Disturbed Equilibrium at Alor Lempah (Run 10) (upstream), Sg. Selangor River, Malaysia.

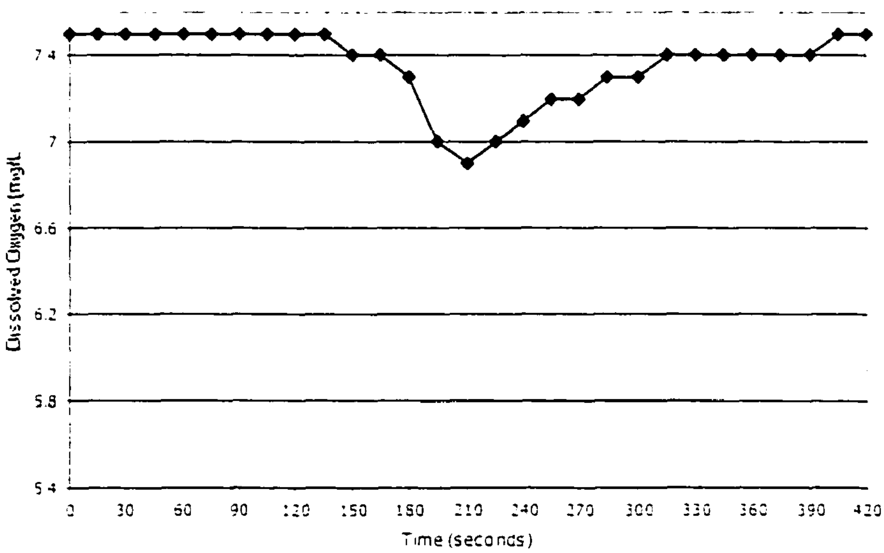

Figure D-20. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 10) (downstream), Sg. Selangor River, Malaysia.

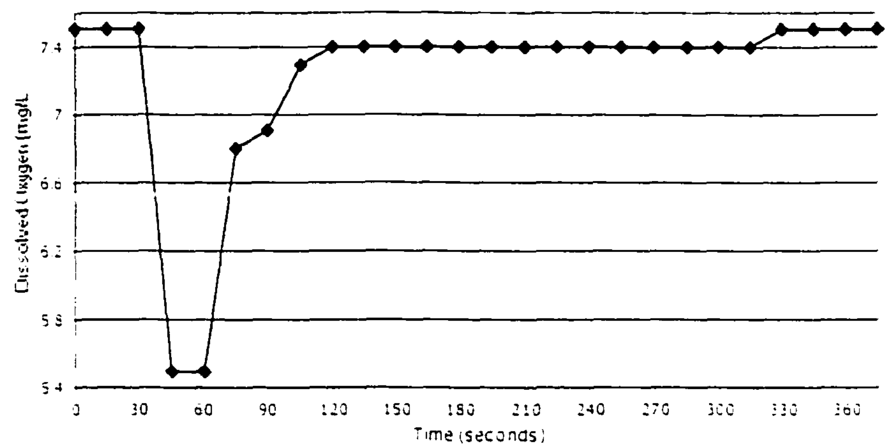

Figure D-21. DO Temporal Profile for Disturbed Equilibrium at Alor Lempah (Run 11) (upstream). Sg. Selangor River, Malaysia.

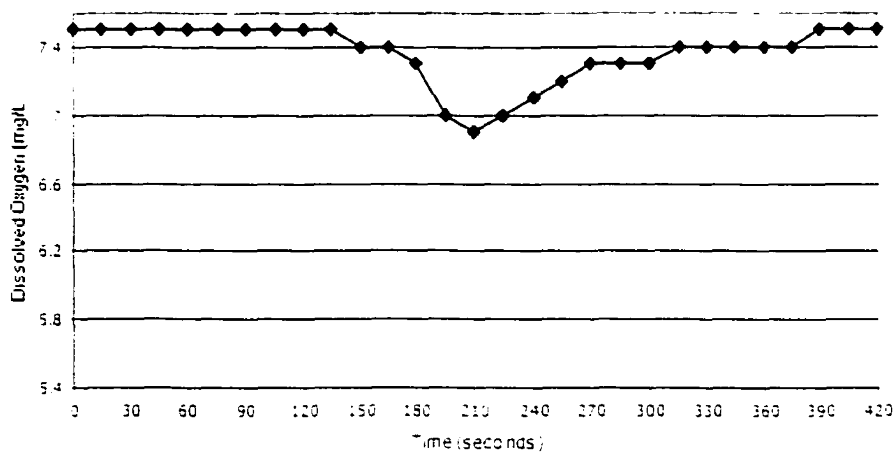

Figure D-22. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 11) (downstream), Sg. Selangor River, Malaysia.

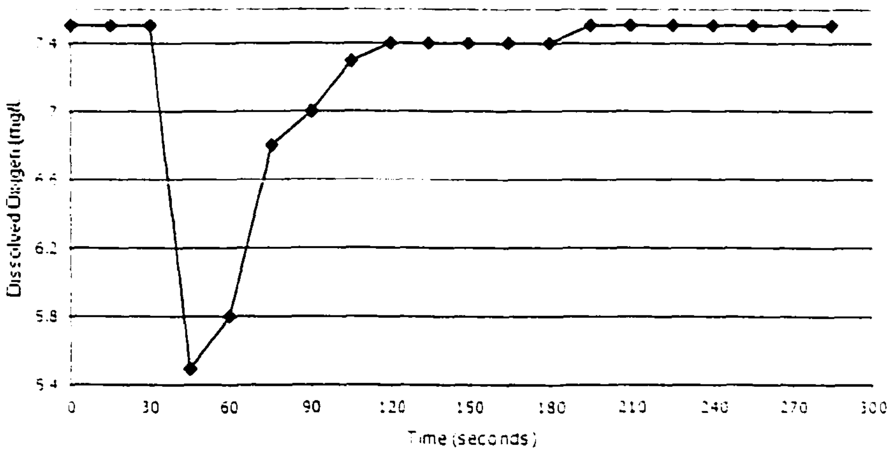

Figure D-23. DO Profile for a Disturbed Equilibrium at Alor Lempah (Run 12) (upstream), Sg. Selangor River, Malaysia.

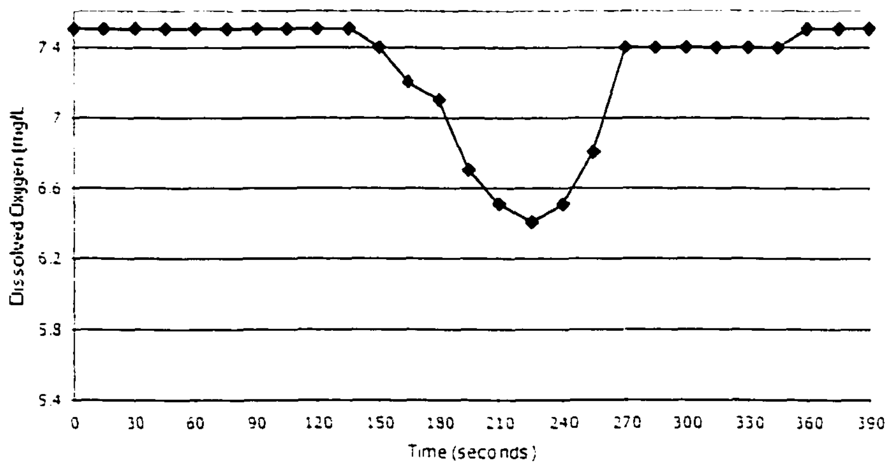

Figure D-24. DO Temporal Profile for a Disturbed Equilibrium at Alor Lempah (Run 12) (downstream), Sg. Selangor River, Malaysia.

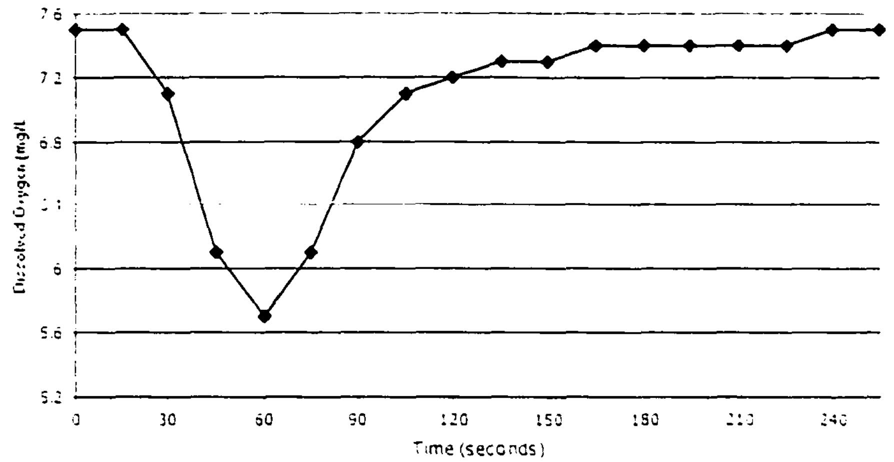

Figure D-25. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 1) (upstream), Serendah, Malaysia.

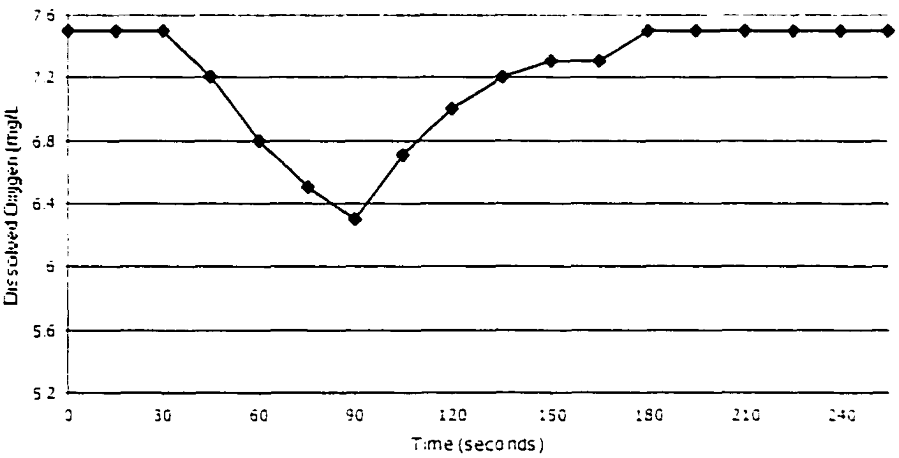

Figure D-26. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 1) (downstream), Serendah, Malaysia.

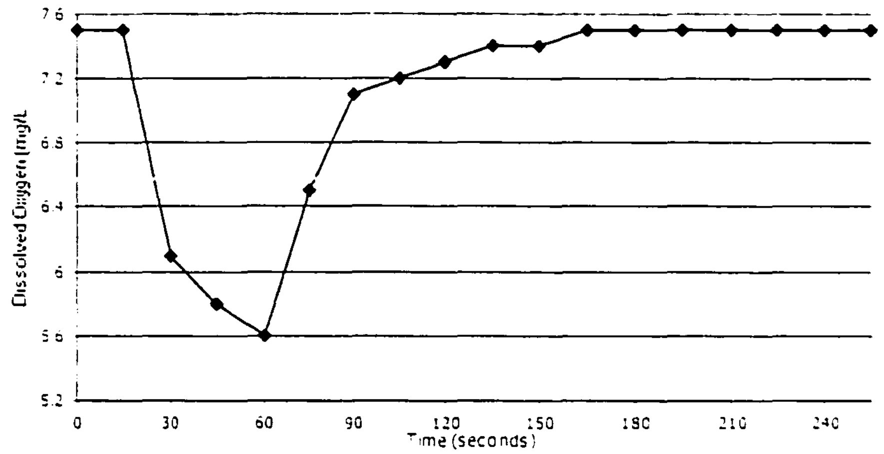

Figure D-27. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 2) (upstream), Serendah, Malaysia.

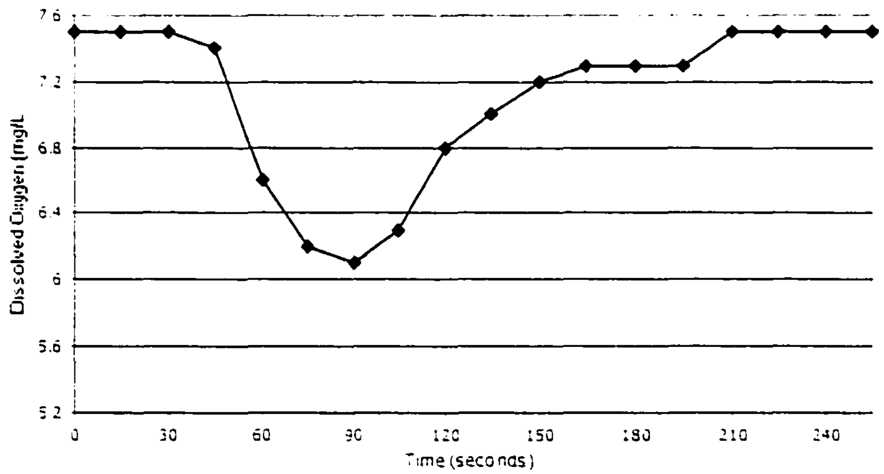

Figure D-28. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 2) (downstream), Serendah, Malaysia.

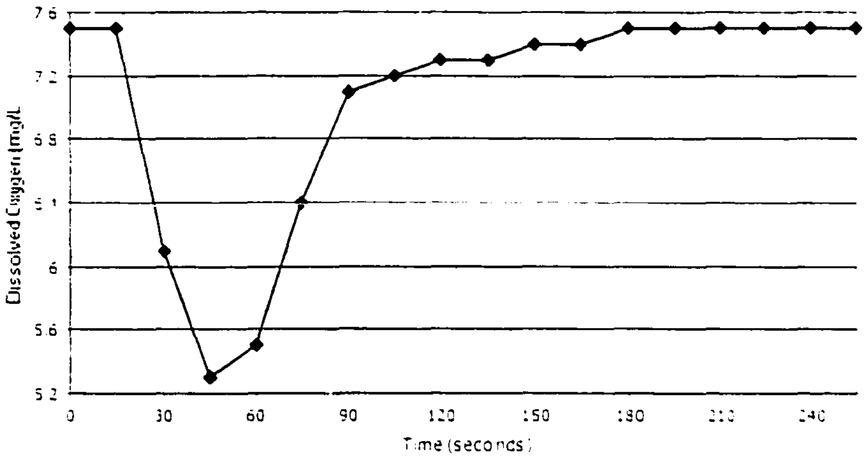

Figure D-29. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 3) (upstream), Serendah, Malaysia.

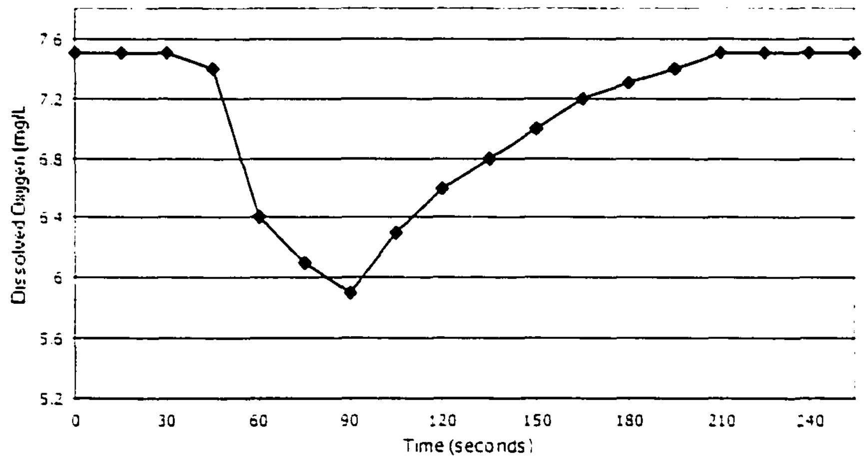

Figure D-30. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 3) (downstream), Serendah, Malaysia.

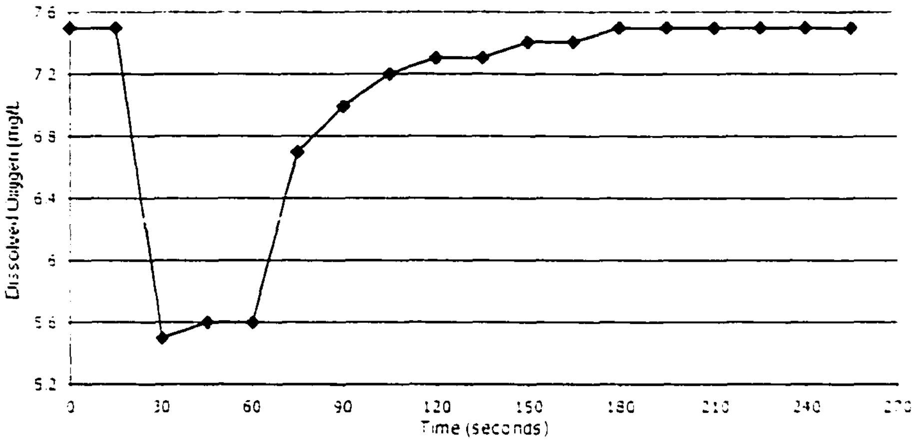

Figure D-31. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 4) (upstream), Serendah, Malaysia.

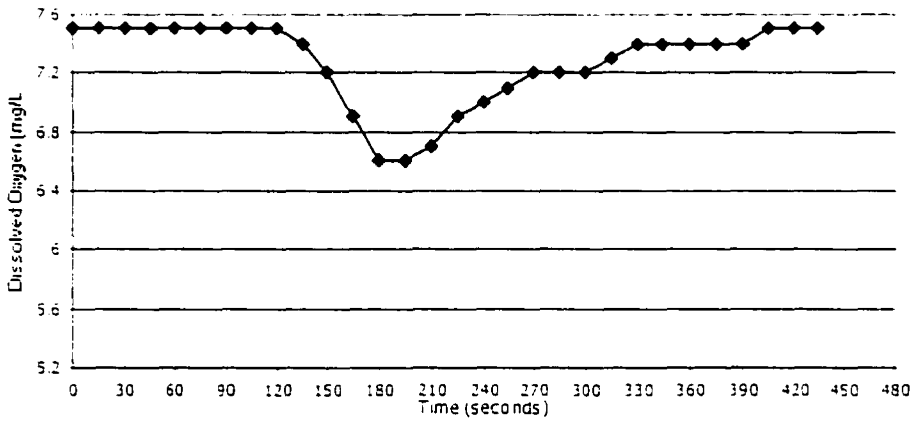

Figure D-32. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 4) (downstream), Serendah, Malaysia.

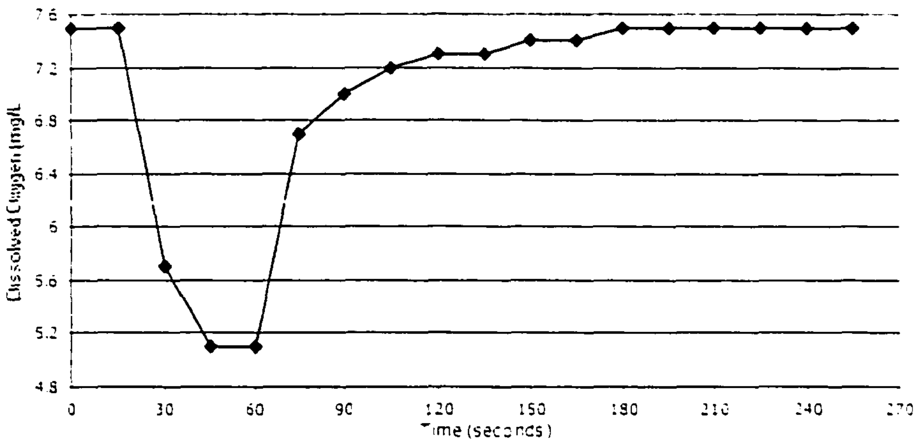

Figure D-33. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 5) (upstream), Serendah, Malaysia.

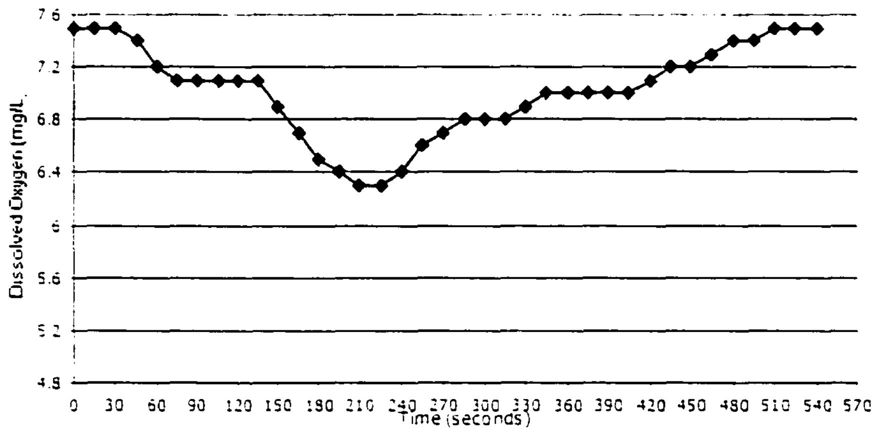

Figure D-34. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 5) (downstream), Serendah, Malaysia.

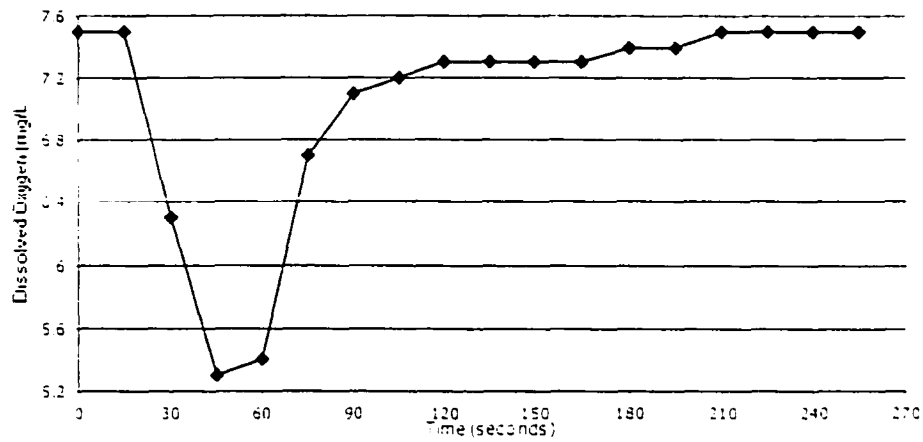

Figure D-35. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 6) (upstream), Serendah, Malaysia.

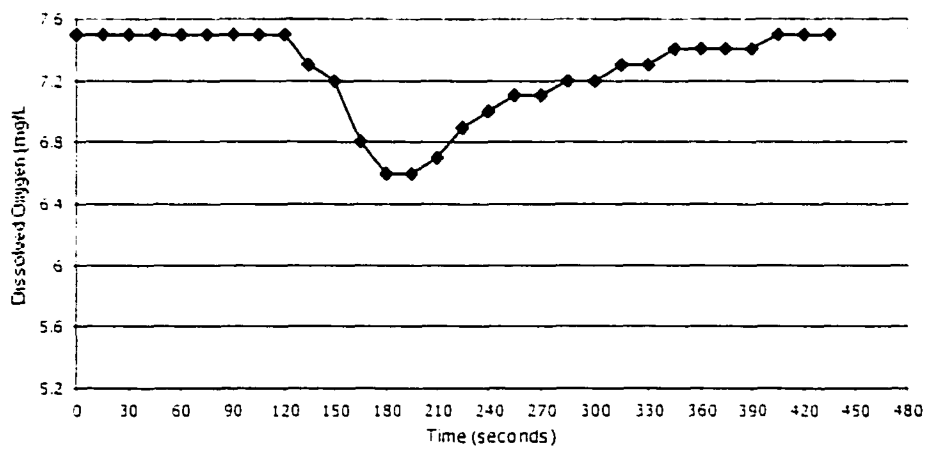

Figure D-36. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 6) (downstream), Serendah, Malaysia.

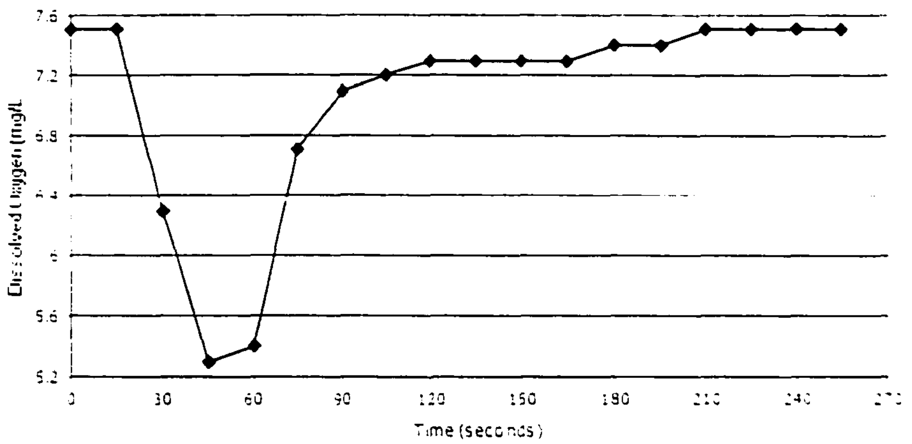

Figure D-37. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 7) (upstream), Serendah, Malaysia.

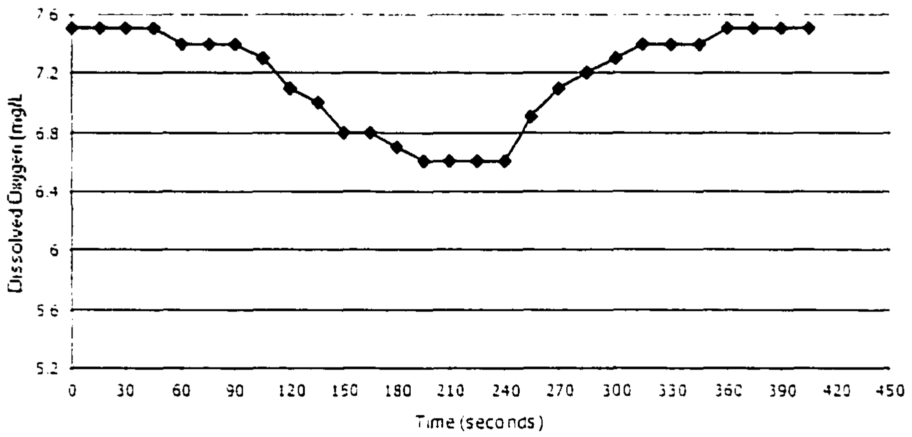

Figure D-38. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 7) (downstream), Serendah, Malaysia.

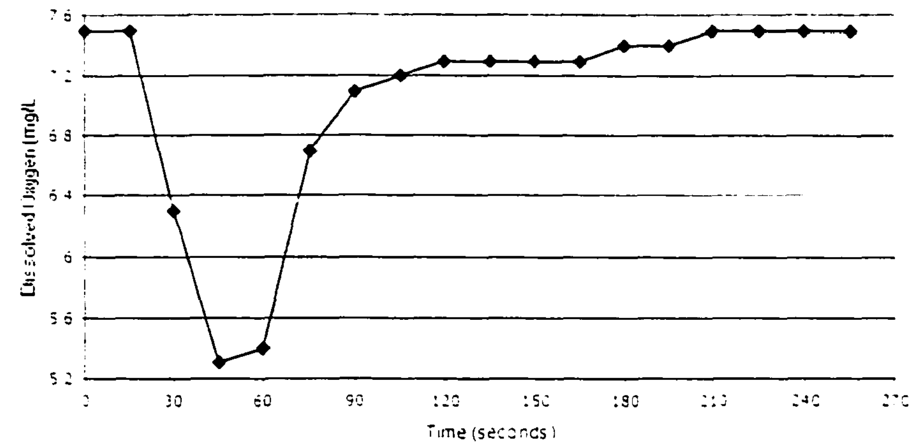

Figure D-39. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 8) (upstream), Serendah, Malaysia.

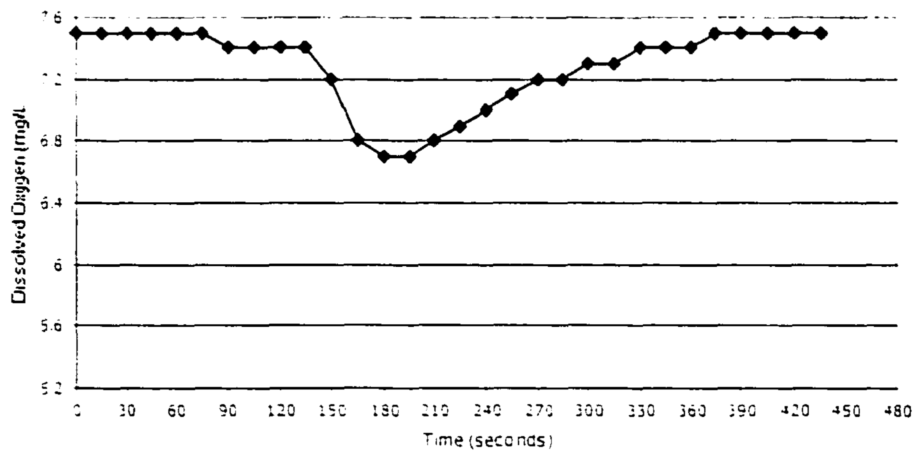

Figure D-40. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 8) (downstream), Serendah, Malaysia.

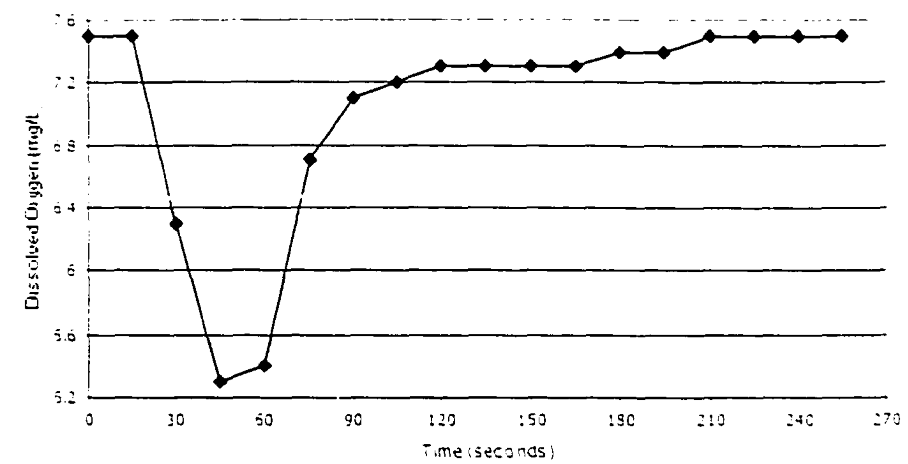

Figure D-41. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 9) (upstream), Serendah, Malaysia.

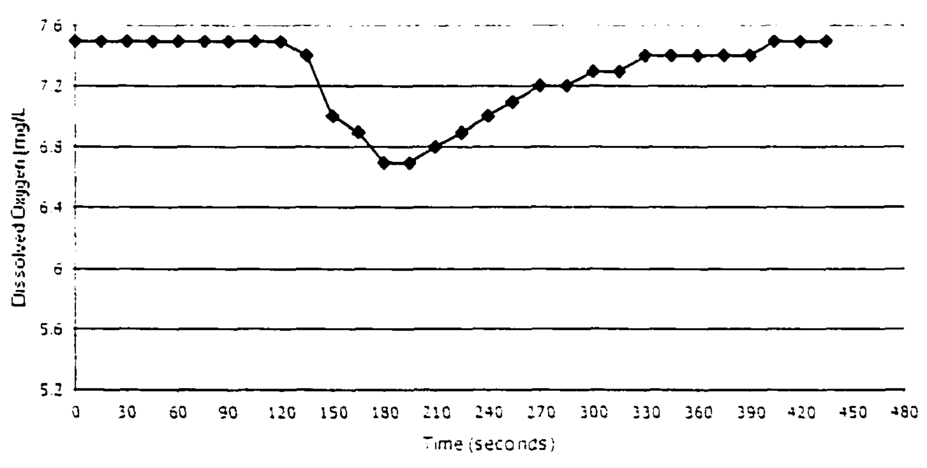

Figure D-42. DO Temporal Profile for a Disturbed Equilibrium at Sg. Serendah River (Run 9) (downstream), Serendah, Malaysia.

APPENDIX E

Sensitivity Analysis Results

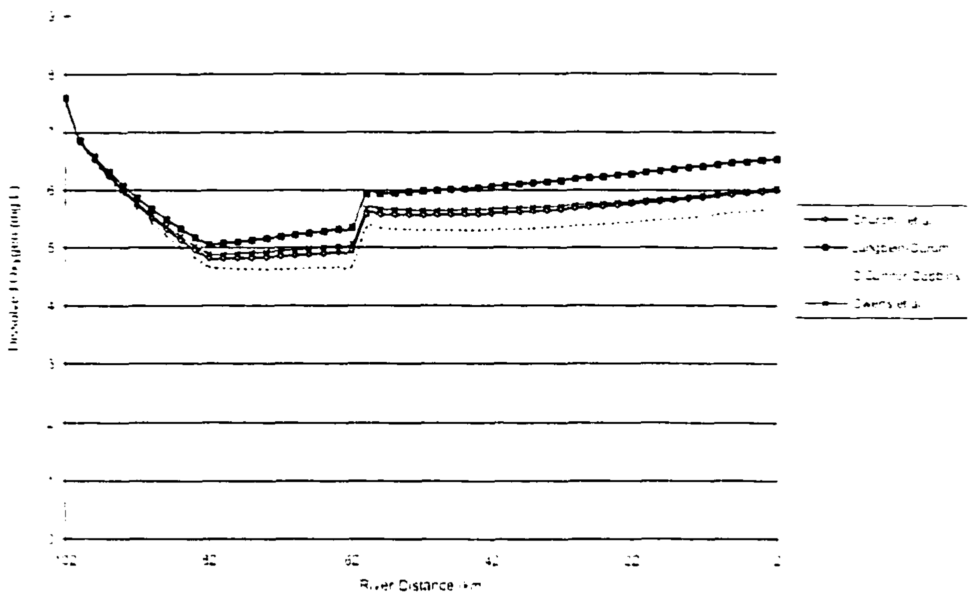

Figure E-1. Sensitivity Analysis: Simulated DO in QUAL2E by Predictive Equations (Headwater Q = 5.787 m^3/s)

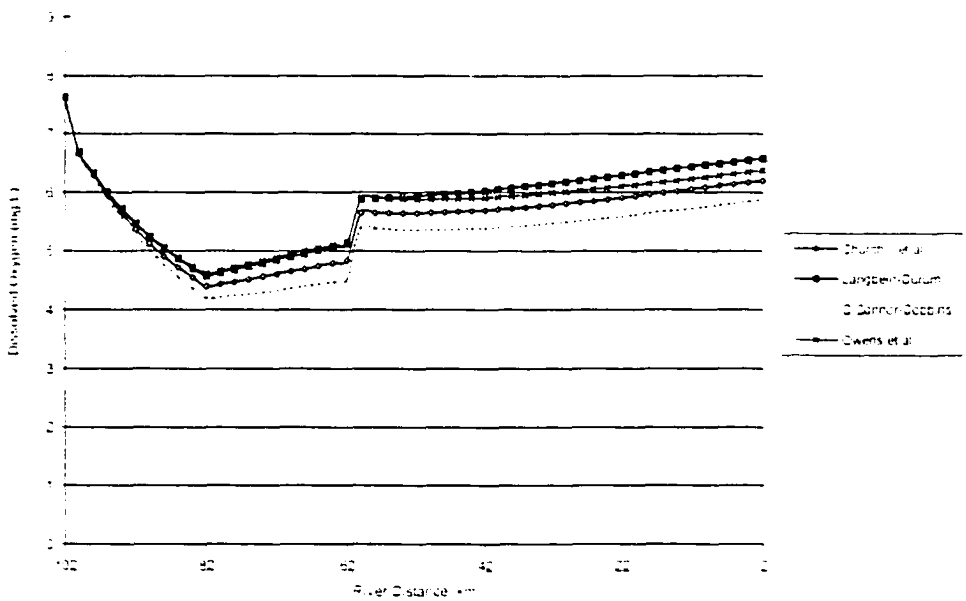

Figure E-2. Sensitivity Analysis: Simulated DO in QUAL2E by Predictive Equations (Headwater Q = 4.34 m^3/s) (25 percent reduction)

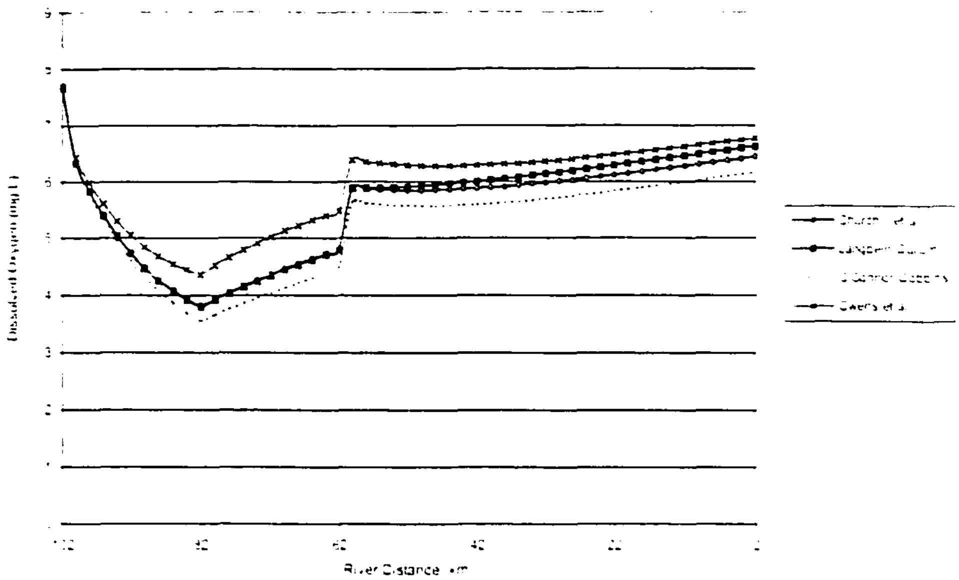

Figure E-3. Sensitivity Analysis: Simulated DO in QUAL2E by Predictive Equations (Headwater Q = 2.89 m^3/s) (50 percent reduction)

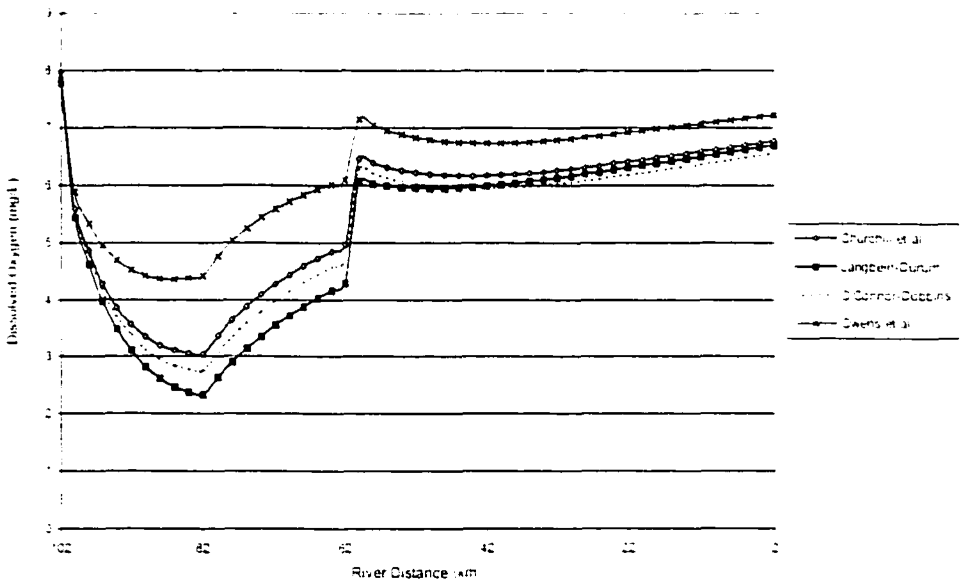

Figure E-4. Sensitivity Analysis: Simulated DO in QUAL2E by Predictive Equations (Headwater Q = 1.45 m^3/s) (75 percent reduction)

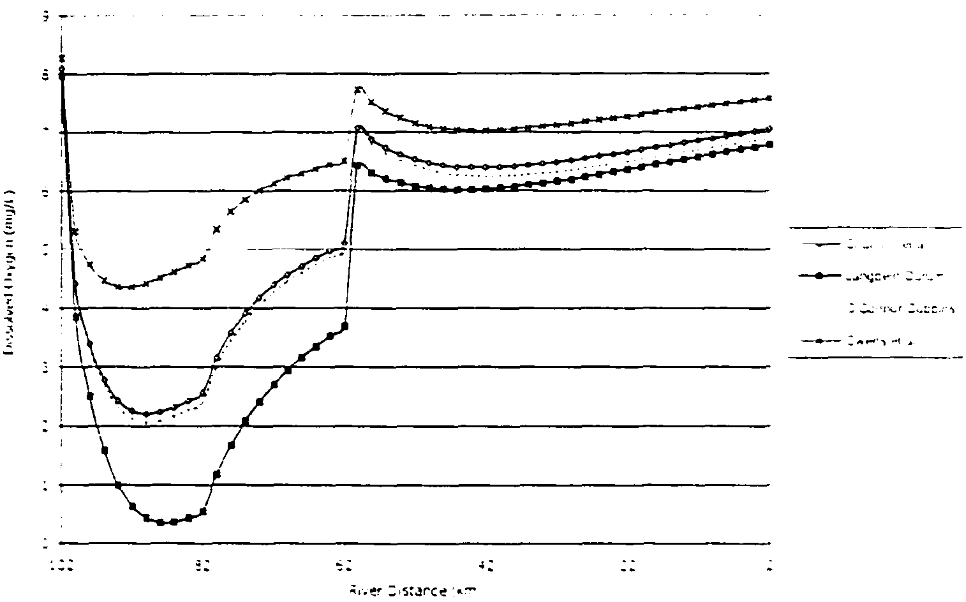

Figure E-5. Sensitivity Analysis: Simulated DO in QUAL2E by Predictive Equations (Headwater Q = 0.58 m^3/s) (90 percent reduction)

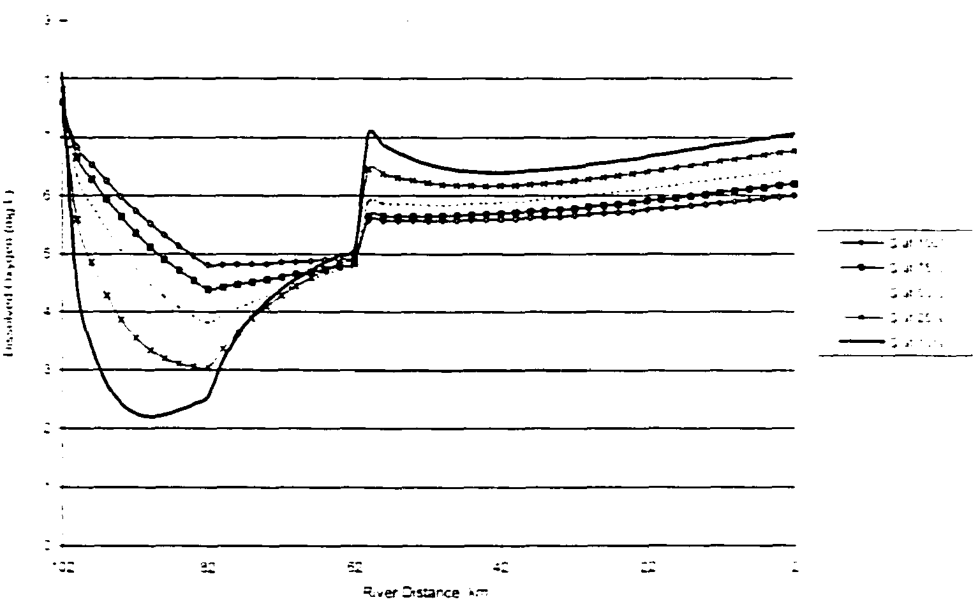

Figure E-6. Sensitivity Analysis: Simulated DO Sensitivity to Discharge in QUAL2E (Churchill et al. Predictive Equation)

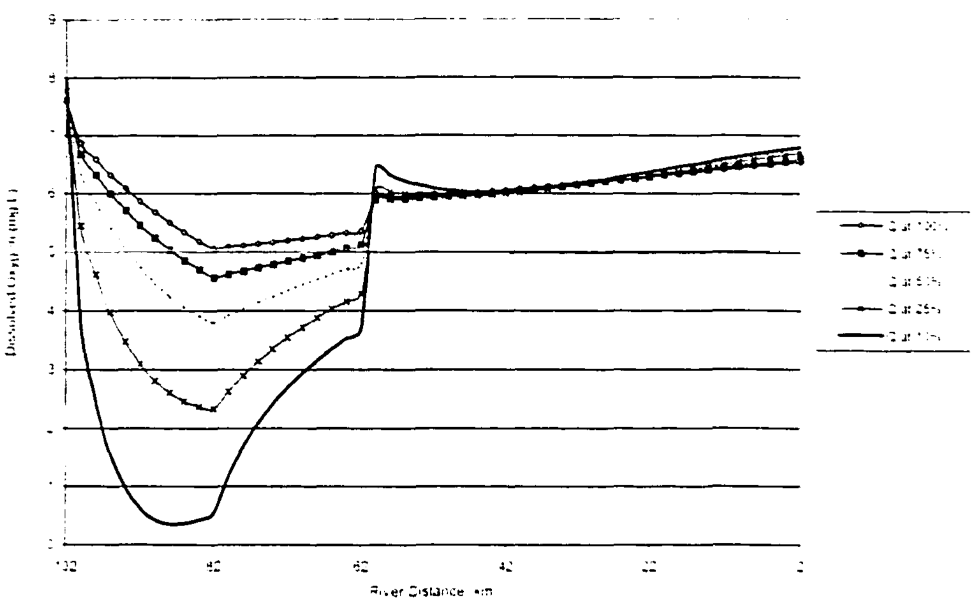

Figure E-7. Sensitivity Analysis: Simulated DO Sensitivity to Discharge in QUAL2E (Langbein-Durum Predictive Equation)

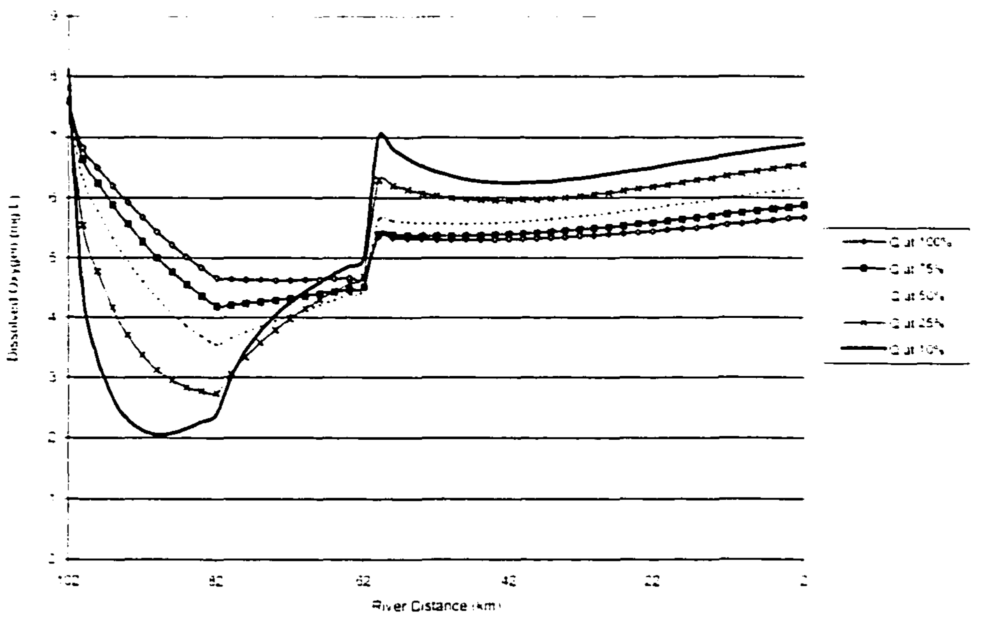

Figure E-8. Sensitivity Analysis: Simulated DO Sensitivity to Discharge in QUAL2E (O'Connor-Dobbins Predictive Equation)

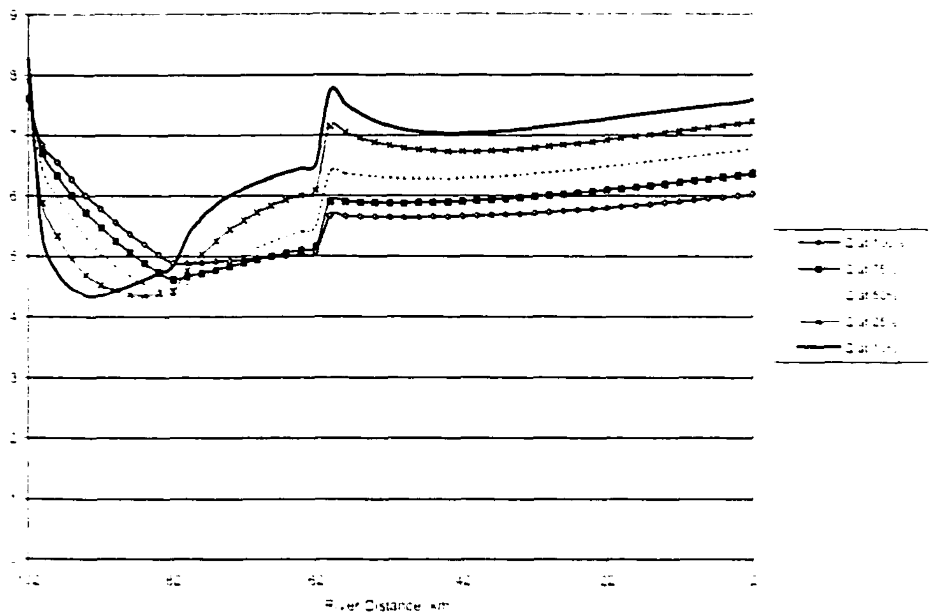

Figure E-9. Sensitivity Analysis: Simulated DO Sensitivity to Discharge in QUAL2E (Owens et al. Predictive Equation)

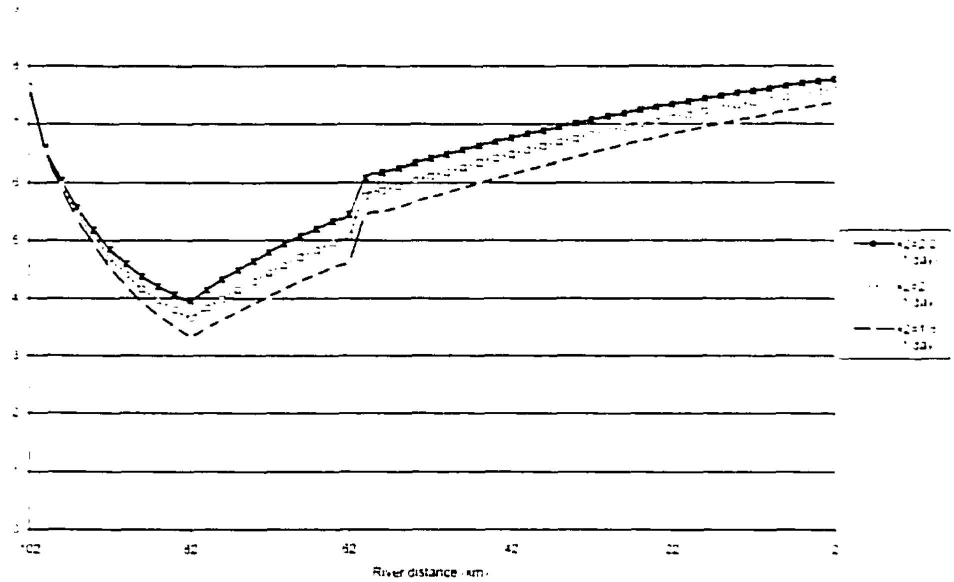

Figure E-10. Sensitivity Analysis: Simulated DO Sensitivity to Reaeration Coefficient (k_2) (10 percent change)

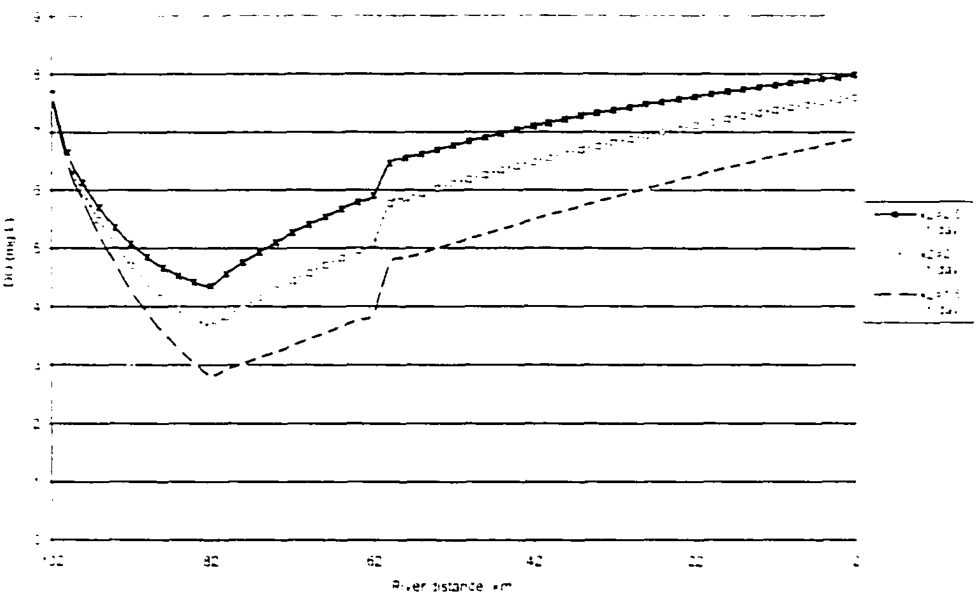

Figure E-11. Sensitivity Analysis: Simulated DO Sensitivity to Reaeration Coefficient (k_2) (25 percent change)

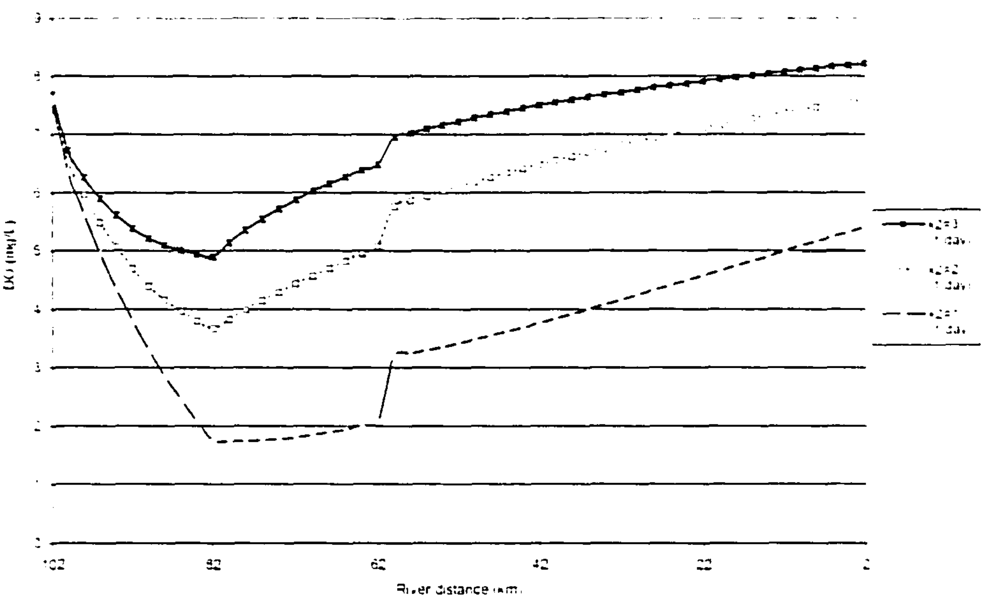

Figure E-12. Sensitivity Analysis: Simulated DO Sensitivity to Reaeration Coefficient (k_2) (50percent change)

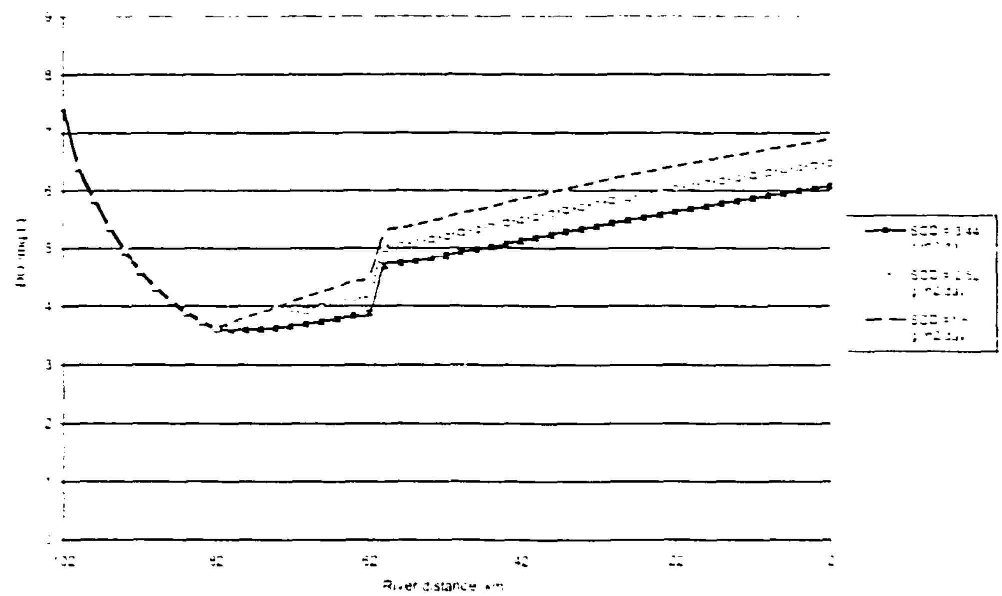

Figure E-13. Sensitivity Analysis: Simulated DO Sensitivity to Sediment Oxygen Demand (1 Std. Deviation Change)

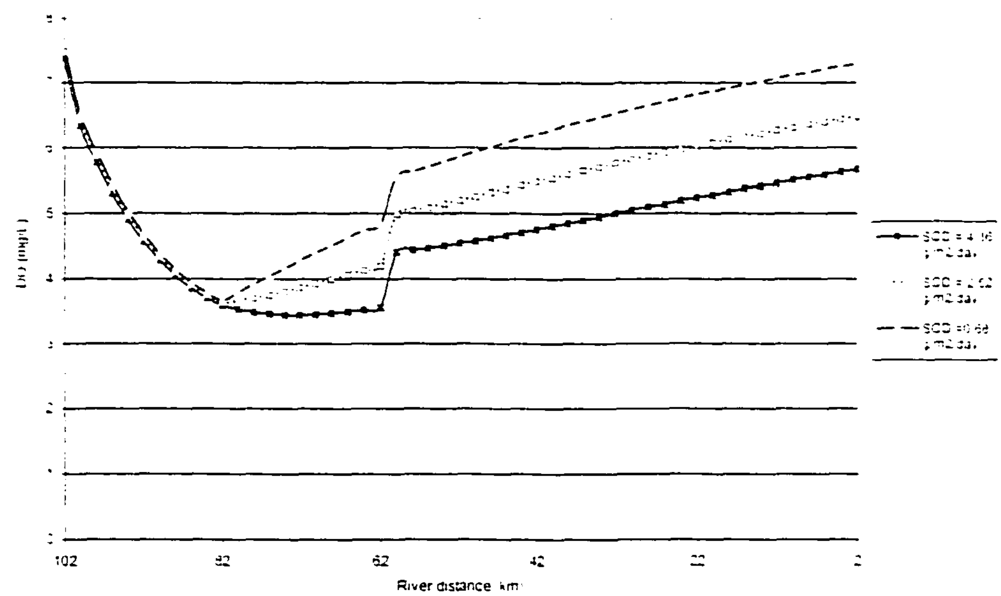

Figure E-14. Sensitivity Analysis: Simulated DO Sensitivity to Sediment Oxygen Demand (2 Std. Deviation Change)

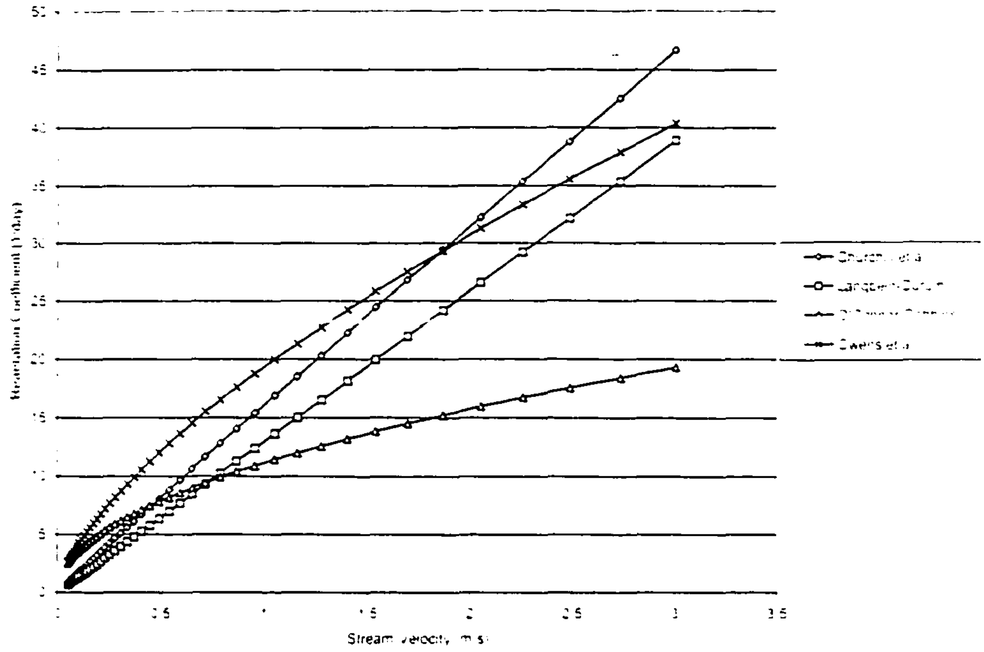

Figure E-15. Sensitivity Analysis: Reaeration Coefficient (k_2) Sensitivity to Stream Velocity

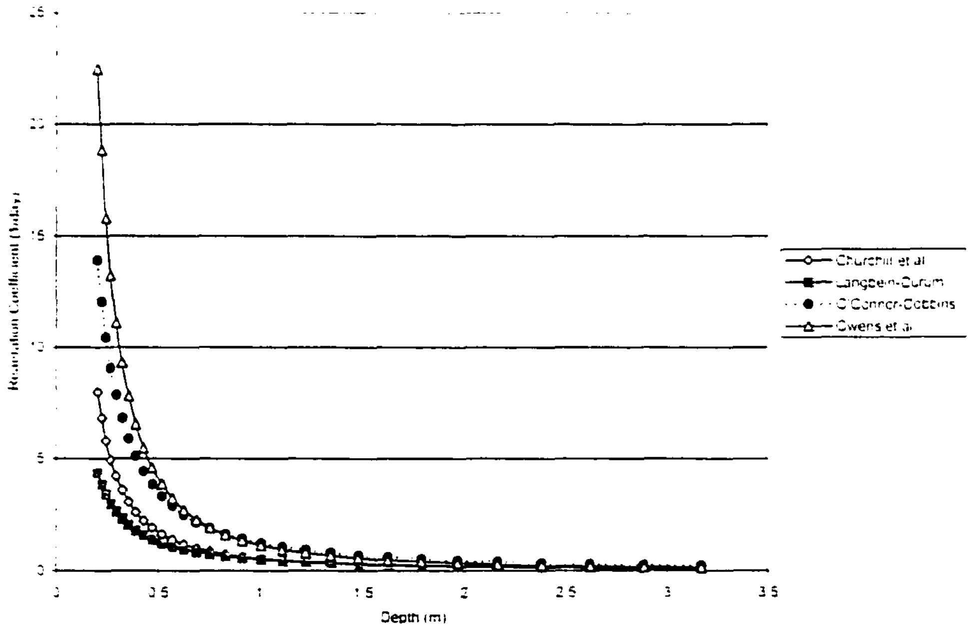

Figure E-16. Sensitivity Analysis: Reaeration Coefficient (k_2) Sensitivity to Stream Depth

APPENDIX F

Water Quality Error Analysis Results for Sg. Selangor

Table F-1. Error Analysis Results of Calibration1 for Temperature and BOD (Temperature, BOD and DO Simulation only) using March 4, 1986 Low-Flow Data

Reach #	Squared Error Temperature	Squared Error BOD
1	8.7764	0.2611
2	40.4860	0.1444
3	2.6334	0.2995
4	18.7056	0.2500
5	32.7756	0.0225
6	4.1718	0.1731
7	27.3878	0.1167
8	34.0472	0.0215
9	17.2059	0.1768
10	0.2052	0.1498
11	5.9130	0.1089
12	8.3810	0.0529
13	22.6259	0.1887
14	44.7561	0.2328
15	9.4727	1.8496
16	1.0671	4.4016
17	3.7636	0.6926
18	2.8561	3.5910
19	5.6549	0.1798
20	1.2063	1.8906
21	0.0315	0.2280
22	11.1823	0.1888
23	4.9729	1.1881
24	0.8190	0.0008
SSE =	309.0974	16.4096
MSE =	12.8791	0.6837
SE =	3.5887	0.8269
CV =	13.9821	77.8241

Table F-2. Error Analysis Results of Validation 1.1 for Temperature and BOD (Temperature, BOD and DO Simulation only) using Jan. 13, 1987 Low-Flow Data

Reach #	Squared Error Temperature	Squared Error BOD
1	2.8291	0.3776
2	26.7363	0.2450
3	0.0047	0.4261
4	12.4433	1.2210
5	29.3764	0.6202
6	8.9102	0.3618
7	34.3787	0.2417
8	34.0570	0.5538
9	13.5829	1.0252
10	1.3053	0.9073
11	8.6044	0.7569
12	9.1658	0.6521
13	28.1253	1.0461
14	45.8329	1.1289
15	10.1336	1.7822
16	0.1300	7.2522
17	1.4668	1.2309
18	1.0252	7.6591
19	1.2133	0.9594
20	0.4400	1.3728
21	0.0518	1.6320
22	9.1597	1.0558
23	3.6005	1.3283
24	0.5402	0.1743
SSE =	283.1133	34.0106
MSE =	11.7964	1.4171
SE =	3.4346	1.1904
CV =	13.3167	86.5762

Table F-3. Error Analysis Results of Validation 1.2 for Temperature and BOD (Temperature, BOD and DO Simulation only) using May 17, 1989 Low-Flow Data

Reach #	Squared Error Temperature	Squared Error BOD
1	0.0964	0.4020
2	10.0670	0.3489
3	0.0092	0.4261
4	6.2001	0.8190
5	10.0806	0.4970
6	0.7208	0.4096
7	0.8342	0.4096
8	0.4182	0.5402
9	11.7512	0.0538
10	0.1289	0.0681
11	2.2151	0.0676
12	0.3136	0.6360
13	2.0117	0.4290
14	19.8470	0.8464
15	0.8951	2.3290
16	7.4474	0.8372
17	13.2860	0.1361
18	17.5666	0.0002
19	21.0268	1.1046
20	10.2400	2.3256
21	6.0762	0.3969
22	21.6365	1.0983
23	18.9660	0.0900
24	8.6510	1.4762
SSE =	190.4857	15.7476
MSE =	7.9369	0.6562
SE =	2.8173	0.8100
CV =	10.9231	63.9499

Table F-4. Error Analysis Results of Calibration 1 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using March 4, 1986 Low-Flow Data

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.0729	0.1099	0.0829	0.0500	0.0765	0.2976	1.4388
2	2.5122	3.6508	2.8465	1.6512	1.8148	8.6520	30.8104
3	0.3080	0.3796	0.1985	0.1353	0.0018	0.9173	1.7571
4	0.0870	0.0400	0.0827	0.1225	0.0689	0.0431	2.2127
5	0.5588	1.3053	0.7526	0.1806	0.1936	6.9696	50.7300
6	0.1693	0.1170	0.1541	0.2130	0.1584	0.0112	0.4462
7	0.4624	0.8372	0.5700	0.2085	0.3422	2.3409	10.9561
8	1.5129	2.2575	1.7424	0.8160	0.0707	9.2416	54.3660
9	1.3283	1.3110	1.4232	1.5775	3.2148	0.8199	0.4173
10	0.9487	0.8492	0.9332	1.0650	1.1247	0.3600	0.2266
11	0.2791	0.5136	0.3501	0.1067	0.1035	1.6770	11.0889
12	1.8023	2.4336	2.0164	1.0151	0.0400	9.4403	57.7600
13	0.0147	0.0332	0.0182	0.0083	0.0756	0.1406	2.8038
14	0.0001	0.0064	0.0008	0.0006	0.0248	0.1089	9.1658
15	0.3580	0.5658	0.4385	0.0699	0.6119	5.5329	44.8900
16	0.7709	0.8892	0.5476	0.3832	0.0036	1.9853	3.6443
17	2.0275	2.5725	1.1616	0.6525	0.6127	6.8848	13.3103
18	4.2539	2.0880	3.9651	6.9762	6.8382	0.5910	16.8921
19	10.4846	10.0902	10.3781	10.7322	10.1188	8.8328	4.2457
20	5.1529	3.5532	4.6584	6.5110	4.0871	0.8899	3.7056
21	4.6225	2.6488	4.0200	6.4009	5.9658	0.2233	20.2500
22	1.2780	0.8345	2.3241	3.2906	9.6721	0.0891	2.3701
23	4.2436	2.6732	4.0905	6.4643	9.5327	0.3875	16.8100
24	0.3292	0.4456	0.3630	0.0546	1.4400	6.8579	39.6900
SSE =	43.5778	40.2053	43.1184	48.6858	56.1931	73.2944	399.9877
MSE =	1.8157	1.6752	1.7966	2.0286	2.3414	3.0539	16.6662
SE =	1.3475	1.2943	1.3404	1.4243	1.5302	1.7476	4.0824
CV =	19.6475	18.8720	19.5437	20.7671	22.3109	25.4807	59.5250

Table F-5. Error Analysis Results of Validation 1.1 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Jan. 13, 1987 Low-Flow Data

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.0011	0.0093	0.0027	0.0002	0.0008	0.0977	0.8724
2	1.8574	2.7651	2.1253	1.1526	1.1556	6.8944	24.9144
3	0.0653	0.0910	0.0270	0.0079	0.0711	0.3775	0.9036
4	0.0100	0.0003	0.0095	0.0256	0.0156	0.1425	1.9600
5	1.0661	1.9113	1.2996	0.5220	0.4001	7.5900	43.7582
6	0.4802	0.3856	0.4523	0.5417	0.4020	0.1556	0.2772
7	0.1369	0.4830	0.2209	0.0125	0.1980	2.2500	15.2230
8	2.3129	3.2460	2.5948	1.4181	0.3259	11.4300	59.4056
9	1.1751	1.1353	1.2905	1.4520	2.9447	0.6504	0.2788
10	0.7788	0.6699	0.7560	0.8789	0.8798	0.2367	0.6634
11	0.8311	1.3728	0.9933	0.4556	0.6669	3.5469	20.1751
12	2.7390	3.6195	3.0363	1.6835	0.2943	12.4962	62.4100
13	0.0857	0.1288	0.0951	0.0702	0.2601	0.3142	5.2670
14	0.0961	0.1502	0.1089	0.0784	0.2678	0.4064	17.7873
15	0.3217	0.5895	0.4189	0.0474	0.5650	6.1697	44.8900
16	1.4030	1.6577	0.9821	0.7081	0.0079	3.4932	6.1034
17	3.8569	5.0725	2.1316	1.2494	0.4096	13.1245	21.5451
18	4.2746	1.6673	3.8563	7.0557	5.0850	1.9600	20.2500
19	9.4895	9.0691	9.3850	9.6814	8.4536	7.8288	1.3783
20	5.3824	3.1270	4.7234	6.8121	1.6943	0.1296	16.4160
21	4.9395	2.6163	4.2539	6.7470	4.2436	0.7183	20.2500
22	0.8290	0.4058	1.9099	2.9002	9.2203	0.5730	4.0401
23	4.4310	2.4728	4.1923	6.8906	8.1368	1.0506	16.8100
24	0.0016	0.0302	0.0068	0.1016	2.7101	5.1189	33.6400
SSE =	46.5650	42.6763	44.8724	50.4928	48.4090	86.7553	439.2187
MSE =	1.9402	1.7782	1.8697	2.1039	2.0170	3.6148	18.3008
SE =	1.3929	1.3335	1.3674	1.4505	1.4202	1.9013	4.2779
CV =	20.3098	19.4433	19.9373	21.1490	20.7080	27.7220	62.3758

Table F-6. Error Analysis Results of Validation 1.2 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using May 17, 1989 Low-Flow Data

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	19.0052	18.4986	18.8269	19.6293	20.2455	16.4066	13.0755
2	10.1442	9.4556	9.9045	11.2752	13.5950	6.3901	1.7784
3	15.5937	15.2360	16.3126	16.9332	19.9958	12.8921	10.6059
4	1.0100	0.8418	1.0050	1.1289	1.0609	0.2809	0.2352
5	0.0002	0.0529	0.0077	0.0756	0.3906	1.3631	10.3684
6	1.4982	1.3561	1.4472	1.7358	2.1580	0.7534	0.1693
7	0.3844	0.3230	0.3600	0.4853	0.8070	0.0413	0.4334
8	0.0452	0.0841	0.0604	0.0002	0.7084	1.2882	9.4147
9	18.4213	18.6192	18.3955	18.7922	25.0350	17.0610	15.4056
10	18.4943	18.4642	18.4084	19.0270	20.5798	15.8683	11.3333
11	13.8260	13.6653	13.7517	14.3515	16.2812	11.2784	5.9455
12	0.0676	0.0743	0.0756	0.0095	0.8145	1.1130	8.4972
13	17.6820	17.1995	17.5375	18.0767	17.8600	15.4580	11.3120
14	0.8055	0.7482	0.7877	0.8464	0.8372	0.5220	0.0324
15	0.0400	0.0237	0.0393	0.0026	1.4440	0.9259	8.9401
16	0.0983	0.1008	0.0754	0.0402	0.1616	0.3528	0.7957
17	0.1233	0.1406	0.0667	0.0156	1.2358	0.7206	1.7600
18	5.5814	5.0120	5.6704	7.3103	12.2325	1.5813	0.0110
19	11.8922	11.4955	11.7649	12.3166	12.5848	9.8942	7.0172
20	6.8819	6.3672	6.6995	7.5900	8.3617	4.5227	1.1201
21	5.1529	4.4310	4.9506	6.6178	10.4652	1.1881	0.5700
22	3.8084	3.6100	4.3995	5.1438	11.5770	1.5713	0.3243
23	5.4639	4.9506	5.4873	7.0889	13.7085	1.1610	0.9458
24	0.1702	0.2438	0.1892	0.3600	4.8290	0.2743	8.0372
SSE =	156.1902	150.9941	156.2236	168.8527	216.9692	122.9086	128.1283
MSE =	6.5079	6.2914	6.5093	7.0355	9.0404	5.1212	5.3387
SE =	2.5511	2.5083	2.5513	2.6525	3.0067	2.2630	2.3106
CV =	45.9996	45.2280	46.0046	47.8279	54.2159	40.8055	41.6630

Table F-7. Error Analysis Results of Calibration 1 for Dissolved Oxygen (All Parameters Simulation) using March 4, 1986 Low-Flow Data

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.0729	0.1099	0.0829	0.0500	0.0765	0.2976	1.4388
2	2.5168	3.6508	2.8465	1.6512	1.8148	8.6646	30.8104
3	0.3093	0.3803	0.1985	0.1353	0.0018	0.9184	1.7571
4	0.0870	0.0400	0.0827	0.1225	0.0689	0.0431	2.2127
5	0.5588	1.3168	0.7613	0.1806	0.1936	6.9960	50.7300
6	0.1689	0.1170	0.1537	0.2130	0.1580	0.0112	0.4462
7	0.4624	0.8372	0.5700	0.2085	0.3422	2.3511	10.9561
8	1.5170	2.2650	1.7446	0.8175	0.0716	9.2568	54.3660
9	1.3283	1.3110	1.4232	1.5775	3.2148	0.8199	0.4173
10	0.9487	0.8492	0.9322	1.0640	1.1247	0.3594	0.2266
11	0.2791	0.5136	0.3520	0.1067	0.1035	1.6813	11.0889
12	1.8090	2.4414	2.0235	1.0151	0.0410	9.4864	57.7600
13	0.0147	0.0332	0.0182	0.0083	0.0756	0.1406	2.8038
14	0.0001	0.0068	0.0008	0.0006	0.0248	0.1089	9.1658
15	0.3633	0.5734	0.4467	0.0723	0.6119	5.5670	44.8900
16	0.7859	0.9101	0.5625	0.3919	0.0033	2.0207	3.6443
17	2.0370	2.5832	1.1700	0.6561	0.6119	6.9052	13.3103
18	4.2333	2.0485	3.9254	6.9432	6.8056	0.6241	16.8921
19	10.4846	10.0902	10.3781	10.7322	10.1188	8.8328	4.2457
20	5.1529	3.5532	4.6512	6.5110	4.0871	0.8867	3.7056
21	4.6010	2.6244	4.0000	6.3883	5.9658	0.2377	20.2500
22	1.2780	0.8336	2.3211	3.2888	9.6721	0.0900	2.3701
23	4.2436	2.6488	4.0602	6.4389	9.5327	0.4064	16.8100
24	0.3379	0.4556	0.3736	0.0570	1.4370	6.9169	39.6900
SSE =	43.5904	40.1931	43.0788	48.6305	56.1579	73.6229	399.9877
MSE =	1.8163	1.6747	1.7949	2.0263	2.3399	3.0676	16.6662
SE =	1.3477	1.2941	1.3398	1.4235	1.5297	1.7515	4.0824
CV =	19.6504	18.8691	19.5347	20.7553	22.3039	25.5377	59.5250

Table F-8. Error Analysis Results of Validation 1.1 for Dissolved Oxygen (All Parameters Simulation) using Jan. 13, 1987 Low-Flow Data

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.0011	0.0093	0.0027	0.0002	0.0008	0.0977	0.8742
2	1.8613	2.7675	2.1295	1.1526	1.1556	6.9019	24.9714
3	0.0653	0.0913	0.0272	0.0079	0.0711	0.3782	0.9057
4	0.0095	0.0003	0.0095	0.0256	0.0156	0.1425	1.9600
5	1.0661	1.9113	1.2996	0.5256	0.4001	7.6038	43.8244
6	0.4802	0.3850	0.4523	0.5417	0.4020	0.1556	0.2777
7	0.1381	0.4830	0.2225	0.0125	0.1980	2.2500	15.2490
8	2.3180	3.2610	2.6109	1.4221	0.3259	11.4582	59.4184
9	1.1740	1.1353	1.2905	1.4508	2.9447	0.6488	0.2777
10	0.7779	0.6699	0.7560	0.8789	0.8798	0.2343	0.6659
11	0.8403	1.3728	0.9933	0.4556	0.6669	3.5532	20.1751
12	2.7390	3.6290	3.0363	1.6900	0.2970	12.5139	62.4100
13	0.0857	0.1288	0.0951	0.0702	0.2601	0.3142	5.2670
14	0.0961	0.1502	0.1089	0.0784	0.2678	0.4064	17.7873
15	0.3287	0.5938	0.4247	0.0494	0.5642	6.2084	44.8900
16	1.4364	1.6952	1.0070	0.7293	0.0086	3.5664	6.2076
17	3.8809	5.1001	2.1462	1.2594	0.4096	13.1688	21.5760
18	4.2333	1.6320	3.8220	7.0291	5.0681	2.0485	20.2500
19	9.4895	9.0661	9.3850	9.6814	8.4536	7.8288	1.3748
20	5.3824	3.1270	4.7234	6.8121	1.6943	0.1296	16.4295
21	4.9284	2.6002	4.2333	6.7211	4.2436	0.7526	20.2500
22	0.8290	0.4058	1.9099	2.9002	9.2173	0.5746	4.0401
23	4.4100	2.4414	4.1718	6.8775	8.1083	1.0920	16.8100
24	0.0023	0.0333	0.0086	0.0984	2.7101	5.1813	33.6400
SSE =	46.5735	42.6896	44.8662	50.4700	48.3631	87.2098	439.5318
MSE =	1.9406	1.7787	1.8694	2.1029	2.0151	3.6337	18.3138
SE =	1.3930	1.3337	1.3673	1.4501	1.4196	1.9062	4.2795
CV =	20.3117	19.4463	19.9359	21.1443	20.6982	27.7945	62.3980

Table F-9. Error Analysis Results of Validation 1.2 for Dissolved Oxygen (All Parameters Simulation) using May 17, 1989 Low-Flow Data

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	18.9965	18.4943	18.8269	19.6293	20.2455	16.4066	13.0718
2	10.1351	9.4556	9.8955	11.2752	13.5950	6.3865	1.7746
3	15.5937	15.2317	16.3081	16.9241	19.9958	12.8921	10.5986
4	1.0100	0.8418	1.0050	1.1289	1.0609	0.2783	0.2352
5	0.0002	0.0541	0.0077	0.0743	0.3906	1.3748	10.3845
6	1.4982	1.3561	1.4472	1.7358	2.1580	0.7526	0.1693
7	0.3823	0.3230	0.3600	0.4853	0.8070	0.0413	0.4334
8	0.0452	0.0860	0.0617	0.0002	0.7070	1.2958	9.4403
9	18.4213	18.6106	18.3955	18.7922	25.0350	17.0610	15.4056
10	18.4943	18.4642	18.4041	19.0270	20.5798	15.8643	11.3266
11	13.8260	13.6407	13.7517	14.3515	16.2812	11.2784	5.9049
12	0.0689	0.0756	0.0784	0.0100	0.8145	1.1183	8.5410
13	17.6820	17.1948	17.5375	18.0767	17.8600	15.4536	11.3120
14	0.8055	0.7482	0.7877	0.8464	0.8372	0.5220	0.0324
15	0.0411	0.0244	0.0407	0.0028	1.4427	0.9334	8.9700
16	0.0999	0.1024	0.0767	0.0412	0.1604	0.3558	0.8037
17	0.1245	0.1415	0.0673	0.0159	1.2358	0.7225	1.7659
18	5.5519	4.9729	5.6347	7.2968	12.2238	1.5531	0.0141
19	11.8887	11.4955	11.7649	12.3166	12.5812	9.8910	7.0172
20	6.8819	6.3672	6.6995	7.5900	8.3617	4.5227	1.1201
21	5.1189	4.4100	4.9284	6.5921	10.4491	1.1718	0.5891
22	3.8064	3.6081	4.3995	5.1438	11.5770	1.5713	0.3238
23	5.4289	4.9173	5.4756	7.0756	13.7085	1.1396	0.9653
24	0.1671	0.2389	0.1892	0.3525	4.8180	0.2836	8.0940
SSE =	156.0685	150.8549	156.1435	168.7843	216.9258	122.8702	128.2935
MSE =	6.5029	6.2856	6.5060	7.0327	9.0386	5.1196	5.3456
SE =	2.5501	2.5071	2.5507	2.6519	3.0064	2.2627	2.3120
CV =	45.9817	45.2072	45.9928	47.8182	54.2105	40.7991	41.6898

Table F-10. Error Analysis Calibration 1 Results for Other Parameters (All Parameters Simulation) using March 4, 1986 Low-Flow Data

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	8.7764	0.2611	0.4020	0.0032	0.0424	0.0000	0.0145	0.0751	0.0001	0.0004	0.0009	4557465	7.1637
2	40.4860	0.1444	11.5940	0.0147	0.0086	0.0003	0.0011	0.0005	0.0004	0.0052	0.0025	524631	0.0284
3	2.6334	0.2995	1.3611	0.0033	0.0418	0.0000	0.0135	0.0706	0.0001	0.0004	0.0009	3960414	7.5137
4	18.7056	0.2500	23.2083	0.0036	0.0361	0.0000	0.0020	0.0303	0.0001	0.0004	0.0009	1660026	1.7623
5	32.7756	0.0225	104.7552	0.0072	0.0000	0.0008	0.1681	0.1211	0.0004	0.0000	0.0003	114169973	147.6225
6	4.1718	0.1731	1.0650	0.0032	0.0137	0.0000	0.8584	0.9781	0.0001	0.0000	0.0001	1910812949	2187.3861
7	27.3878	0.1167	3.4782	0.0004	0.0030	0.0008	0.7482	0.8581	0.0000	0.0003	0.0007	1780728875	2057.9832
8	34.0472	0.0215	65.9750	0.0068	0.0000	0.0008	0.3896	0.3245	0.0004	0.0000	0.0003	106736982	155.6256
9	17.2059	0.1768	21.6225	0.0032	0.0352	0.0000	0.1879	0.3226	0.0001	0.0009	0.0004	4484776	24.2753
10	0.2052	0.1498	1.2466	0.0046	0.0279	0.0000	0.2162	0.3226	0.0001	0.0008	0.0003	629	12.5848
11	5.9130	0.1089	0.0064	0.0001	0.0225	0.0000	0.1980	0.3509	0.0000	0.0004	0.0004	1546529	7.4075
12	8.3810	0.0529	69.5973	0.0036	0.0016	0.0008	0.3875	0.3913	0.0001	0.0001	0.0000	103075033	160.3389
13	22.6259	0.1887	0.1713	0.0032	0.0139	0.0000	0.0175	0.0387	0.0001	0.0000	0.0001	4610210	8.4132
14	44.7561	0.2328	12.7271	0.0036	0.0116	0.0000	0.0049	0.0130	0.0001	0.0000	0.0001	86537	3.8416
15	9.4727	1.8496	61.7098	0.0039	0.0014	0.0008	0.3865	0.3873	0.0001	0.0968	0.0883	109043625	161.9115
16	1.0671	4.4016	54.6860	0.2034	0.3888	0.0007	0.3684	0.1971	0.0116	0.0363	0.0888	1760523	268.9764
17	3.7636	0.6926	47.9787	0.0367	0.0134	0.0003	0.5216	0.1857	0.0015	0.0027	0.0079	1792929	305.7447
18	2.8561	3.5910	10.7994	0.4193	1.0481	0.0007	1.5345	0.1667	0.0225	0.0992	0.2151	17640000	49.8436
19	5.6549	0.1798	14.5352	0.0032	0.0132	0.0008	0.5738	0.7081	0.0001	0.0000	0.0002	4742628	208.3548
20	1.2063	1.8906	0.0003	0.0000	0.0256	0.0014	0.5065	0.8305	0.0000	0.0023	0.0016	135740869	930.8601
21	0.0315	0.2280	84.7781	0.1388	0.2025	0.0008	1.5813	0.2121	0.0081	0.0289	0.0663	31315720	707.2940
22	11.1823	0.1888	134.5948	0.0034	0.0689	0.0003	0.2570	0.5285	0.0001	0.0000	0.0001	12974292	102.4144
23	4.9729	1.1881	1.0302	0.0961	0.1156	0.0001	1.1025	0.1648	0.0049	0.0016	0.0121	2268868632	2840.3570
24	0.8190	0.0008	27.5231	0.0196	0.0004	0.0007	0.1056	0.0388	0.0009	0.0036	0.0009	2639029086	4475.1083
SSE =	309.0974	16.4096	754.8457	0.9851	2.1360	0.0102	10.1453	7.3170	0.0519	0.2803	0.4892	9259863332	14832.8115
MSE =	12.8791	0.6837	31.4519	0.0410	0.0890	0.0004	0.4227	0.3049	0.0022	0.0117	0.0204	385827639	618.0338
SE =	3.5887	0.8269	5.6082	0.2026	0.2983	0.0206	0.6502	0.5522	0.0465	0.1081	0.1428	19642	24.8603
CV =	13.9821	77.8241	16.4343	631.4870	145.8239	108.8881	84.3462	53.7923	1014.8257	117.3631	147.6925	137	77.1859

Table F-11. Error Analysis Results of Validation 1.1 for Other Parameters (All Parameters Simulation) using Jan. 13, 1987 Low-Flow Data

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	2.8291	0.3776	77.5016	0.00325	0.00325	0.00001	0.0160	0.01677	0.00010	0.00040	0.00090	1492818	52.0707
2	26.7363	0.2450	24.7293	0.01372	0.00257	0.00029	0.0018	0.01151	0.00043	0.67945	0.64458	17186	91.6533
3	0.0047	0.4261	62.7000	0.00315	0.00340	0.00001	0.0193	0.02061	0.00010	0.00040	0.00090	20040942	47.3115
4	12.4433	1.2210	25.1252	0.00360	0.00250	0.00002	0.0064	0.00511	0.00010	0.00040	0.00090	14913519	63.2423
5	29.3764	0.6202	171.6100	0.00563	0.02641	0.00078	0.1849	0.04752	0.00040	0.64803	0.62016	120774660	5.3477
6	8.9102	0.3618	38.2357	0.00342	0.00016	0.00002	0.8199	0.74391	0.00010	0.01000	0.00810	7812700882	69.8812
7	34.3787	0.2417	7.2540	0.00080	0.00401	0.00078	0.6917	0.58472	0.00004	0.00538	0.00467	7497376107	43.6040
8	34.0570	0.5538	108.0560	0.00708	0.03180	0.00078	0.3875	0.14861	0.00040	0.64133	0.61231	105909569	6.6092
9	13.5829	1.0252	162.7410	0.00331	0.00021	0.00002	0.1718	0.14025	0.00010	0.00640	0.00490	16432200	40.9280
10	1.9600	0.8920	71.5528	0.00490	0.00015	0.00002	0.1868	0.12453	0.00010	0.00579	0.00437	1913919	66.8397
11	8.6044	0.7569	52.1765	0.00010	0.00090	0.00002	0.1695	0.13988	0.00000	0.00490	0.00490	25286	82.9921
12	9.1658	0.6521	98.6546	0.00490	0.02250	0.00078	0.3721	0.17472	0.00010	0.65610	0.63601	98785510	7.0756
13	28.1253	1.0461	44.0970	0.00327	0.00019	0.00002	0.0128	0.00523	0.00010	0.01000	0.00810	16519356	55.7926
14	45.8329	1.1289	8.2369	0.00423	0.00000	0.00002	0.0014	0.00055	0.00010	0.01000	0.00810	3350273	74.7793
15	10.1336	1.7822	85.5933	0.00467	0.02351	0.00084	0.3694	0.16910	0.00010	0.65071	0.62938	104130993	7.1022
16	0.1300	7.2522	7.5625	0.33756	0.93606	0.00055	0.3295	0.90726	0.01918	0.07344	0.16728	112393	710.4624
17	1.4668	1.2309	0.6760	0.06030	0.09541	0.00022	0.4776	0.02294	0.00213	0.00111	0.00658	5593532	802.3056
18	1.0252	7.6591	49.7201	0.70560	2.38703	0.00032	1.4191	1.37945	0.03610	0.14156	0.03469	17640000	560.2689
19	1.2133	0.9594	7.5845	0.00410	0.00001	0.00078	0.5235	0.47610	0.00010	0.00931	0.00748	14685439	565.3220
20	0.4400	1.3728	10.3577	0.00010	0.00090	0.00144	0.4247	0.41345	0.00000	0.00160	0.00160	103807842	48.0249
21	0.0518	1.6320	84.0431	0.28891	0.66423	0.00042	1.4340	0.01742	0.01440	0.28623	0.16810	17640000	163.9680
22	9.1597	1.0558	0.4658	0.00360	0.06708	0.00029	0.2391	0.49491	0.00010	0.01000	0.00810	5287903	770.1458
23	3.6005	1.3283	4.1923	0.18490	0.31923	0.00004	0.9900	0.00000	0.01000	0.01210	0.04410	2114528256	1141.5952
24	0.5402	0.1743	33.1920	0.02600	0.00439	0.00073	0.0900	0.00941	0.00160	0.00250	0.00010	2588427919	2412.6516
SSE =	283.7680	33.9953	1236.0580	1.67709	4.59588	0.00919	9.3388	6.05396	0.08588	3.86714	3.62630	20682106503	7889.9735
MSE =	11.8237	1.4165	51.5024	0.06988	0.19150	0.00038	0.3891	0.25225	0.00358	0.16113	0.15110	861754438	328.7489
SE =	3.4386	1.1902	7.1765	0.26435	0.43760	0.01957	0.6238	0.50224	0.05982	0.40141	0.38871	29356	18.1314
CV =	13.3320	86.5567	17.7930	823.93558	530.42617	103.23337	80.9245	55.53486	1305.16085	116.63277	111.45816	154	124.6861

Table F-12. Error Analysis Results of Validation 1.2 for Other Parameters (All Parameters Simulation) using May 17, 1989 Data

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	0.0964	0.4020	3109.3449	0.0029	0.0018	0.0000	0.0253	0.0224	0.0001	0.0004	0.0009	3161192151	14495.1968
2	10.0670	0.3489	2844.0889	0.0082	0.0006	0.0003	0.0110	0.0000	0.0002	0.4069	0.3871	3057371774	14163.7201
3	0.0092	0.4261	2911.5017	0.0031	0.0015	0.0000	0.0193	0.0155	0.0001	0.0004	0.0009	20137247	14432.4182
4	6.2001	0.8190	2609.1664	0.0036	0.0009	0.0000	0.0064	0.0029	0.0001	0.0004	0.0009	15029171	14178.2603
5	10.0806	0.4970	2260.0516	0.0020	0.0196	0.0008	0.2304	0.3636	0.0001	0.2704	0.2601	75099296	178263.3952
6	0.7208	0.4096	1500.5164	0.0026	0.0130	0.0000	0.9380	1.0692	0.0001	0.0144	0.0121	594584479	231922.6675
7	0.8342	0.4096	1394.6490	0.0000	0.0072	0.0008	0.8836	1.1088	0.0000	0.0125	0.0117	557697508	231389.8609
8	0.4182	0.5402	2093.8251	0.0013	0.0245	0.0008	0.4935	0.7219	0.0001	0.2791	0.2687	75573450	178753.4981
9	11.7512	0.0538	2876.8205	0.0025	0.0132	0.0000	0.2233	0.2911	0.0001	0.0100	0.0081	24388698	312071.3873
10	0.1289	0.0681	2701.0888	0.0031	0.0112	0.0000	0.2921	0.3499	0.0001	0.0100	0.0081	14986778	311520.2596
11	2.2151	0.0676	2635.2822	0.0001	0.0100	0.0000	0.2809	0.4083	0.0000	0.0100	0.0100	10170072	311191.0440
12	0.3136	0.6360	2176.6890	0.0004	0.0324	0.0008	0.5041	0.7974	0.0001	0.2889	0.2809	74935685	179005.1481
13	2.0117	0.4290	3118.5399	0.0025	0.0134	0.0000	0.0312	0.0598	0.0001	0.0144	0.0121	25350391	14582.3067
14	19.8470	0.8464	2981.1600	0.0025	0.0121	0.0000	0.0233	0.0447	0.0001	0.0144	0.0121	18445930	14526.8783
15	0.8951	2.3290	2178.2445	0.0004	0.0334	0.0008	0.5041	0.8072	0.0001	0.2856	0.2809	78181465	179133.0381
16	7.4474	0.8372	2791.7486	0.0445	0.0329	0.0008	0.4396	0.0897	0.0024	0.0020	0.0088	6672450	10222.8277
17	13.2860	0.1361	2509.9543	0.0110	0.0006	0.0003	0.5938	0.4998	0.0004	0.0047	0.0023	5247864	10151.2342
18	17.5666	0.0002	1784.2176	0.0709	0.1630	0.0014	1.7722	0.4802	0.0042	0.1610	0.1131	19561879	163182.6717
19	21.0268	1.1046	2625.7426	0.0029	0.0132	0.0008	0.6115	0.7569	0.0001	0.0144	0.0121	22887584	10409.5087
20	10.2400	2.3256	1462.4251	0.0001	0.0100	0.0014	0.5801	0.8366	0.0000	0.0025	0.0025	93434810	215212.4881
21	6.0762	0.3969	1231.1327	0.0233	0.0689	0.0014	1.7956	0.9082	0.0016	0.2116	0.1764	43610703	213705.1098
22	21.6365	1.0983	2456.8875	0.0028	0.0028	0.0003	0.3136	0.3295	0.0001	0.0144	0.0121	3920248	196750.7964
23	18.9660	0.0900	1845.3468	0.0169	0.0484	0.0004	1.2769	0.6416	0.0009	0.0729	0.0576	2660827038	211301.1056
24	8.6510	1.4762	1098.2596	0.0036	0.0081	0.0014	0.1691	0.0897	0.0003	0.0961	0.0900	2841998748	1983.3662
SSE =	190.4857	15.7476	55196.6837	0.2111	0.5428	0.0127	12.0189	10.6951	0.0114	2.1975	2.0295	13501305419	3232548.1876
MSE =	7.9369	0.6562	2299.8618	0.0088	0.0226	0.0005	0.5008	0.4456	0.0005	0.0916	0.0846	562554392	134689.5078
SE =	2.8173	0.8100	47.9569	0.0938	0.1504	0.0230	0.7077	0.6676	0.0218	0.3026	0.2908	23718	367.0007
CV =	10.9231	63.9499	61.4176	292.3136	114.2220	121.5335	91.8050	70.0079	475.8882	105.8629	100.1308	138	109.0641

Table F-13. Error Analysis Results of Calibration 2 for Temperature and BOD (Temperature, BOD and DO Simulation only) using March 4, 1986 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error Temperature	Squared Error BOD
1	25.8521	0.2176
2	52.2522	0.0503
3	12.5316	0.2635
4	32.4615	0.2048
5	40.4178	0.0081
6	30.0030	0.1669
7	45.8780	0.0051
8	42.7062	0.0462
9	3.1241	0.1932
10	9.9477	0.0384
11	14.3641	0.0044
12	13.1951	0.0182
13	37.0475	0.1444
14	46.2400	0.1620
15	13.6653	1.1544
16	0.3153	14.7763
17	0.1839	2.1251
18	0.0763	16.4938
19	0.0128	0.0729
20	0.3211	0.5017
21	0.3452	5.8928
22	2.8426	0.2098
23	1.9391	7.4666
24	0.0722	0.3466
SSE =	425.7948	50.5632
MSE =	17.7415	2.1068
SE =	4.2121	1.4515
CV =	16.4106	136.6100

Table F-14 Error Analysis Results of Validation 2.1 for Temperature and BOD (Temperature, BOD and DO Simulation only) using Jan. 13, 1987 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error Temperature	Squared Error BOD
1	16.6831	0.3209
2	38.7951	0.1052
3	6.4516	0.3762
4	32.4615	1.1078
5	40.4178	0.2601
6	30.0030	0.3703
7	45.8780	0.0738
8	42.7062	0.1482
9	3.1241	1.0806
10	9.9477	0.6336
11	14.3641	0.2844
12	13.1951	0.2162
13	37.0475	0.9604
14	46.2400	1.0050
15	13.6653	1.1544
16	0.3153	14.7763
17	0.1839	2.1251
18	0.0763	16.4938
19	0.0128	0.7569
20	0.3211	0.5017
21	0.3452	5.8928
22	2.8426	1.1194
23	1.9391	4.9841
24	0.0722	0.7899
SSE =	397.0887	55.5370
MSE =	16.5454	2.3140
SE =	4.0676	1.5212
CV =	15.7710	110.6325

Table F-15. Error Analysis Results of Validation 2.2 for Temperature and BOD (Temperature, BOD and DO Simulation only) using May 17, 1989 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error Temperature	Squared Error BOD
1	16.6831	0.3209
2	38.7951	0.1052
3	6.4516	0.3762
4	22.0665	0.7268
5	28.7028	0.0961
6	30.0030	0.3703
7	33.3314	0.0738
8	12.4962	0.0342
9	0.0541	0.0574
10	26.5637	0.0000
11	33.5241	0.0711
12	13.1951	0.0702
13	37.0475	0.3364
14	46.2400	0.6440
15	13.6653	1.1544
16	0.3153	14.7763
17	0.1839	2.1251
18	0.0763	16.4938
19	0.0128	0.7569
20	0.3211	0.5017
21	0.3452	5.8928
22	2.8426	1.1194
23	1.9391	4.9841
24	0.0722	0.0969
SSE =	364.9280	51.1839
MSE =	15.2053	2.1327
SE =	3.8994	1.4604
CV =	15.1188	115.2918

Table F-16. Error Analysis Results of Calibration 2 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using March 4, 1986 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.3064	0.3925	0.3266	0.2627	0.4442	0.7217	3.8573
2	2.5646	4.3980	3.0400	1.6165	3.4862	12.9857	55.7049
3	0.8525	1.0793	0.5650	0.4349	0.1276	2.2634	4.0446
4	0.0163	0.0002	0.0127	0.0281	0.0068	0.1892	7.8540
5	0.4761	1.4400	0.6848	0.1425	0.7569	9.2873	57.7600
6	0.0003	0.0074	0.0011	0.0001	0.0697	0.0888	5.8903
7	0.5088	1.7205	0.7396	0.1878	4.7451	8.2944	57.1284
8	1.1899	2.4362	1.5088	0.5041	0.5017	13.6346	57.7600
9	0.8046	0.6964	1.0040	1.1546	2.0178	0.2515	0.0172
10	0.4258	0.3170	0.4026	0.4823	0.2455	0.0578	7.2307
11	0.3403	1.2882	0.5329	0.0851	2.4284	6.5110	55.0317
12	1.2045	2.5202	1.5500	0.4865	0.4193	14.8033	57.7600
13	0.0860	0.1328	0.0954	0.0726	0.4923	0.3338	14.3936
14	0.0000	0.0064	0.0004	0.0005	0.1156	0.1024	39.5327
15	0.1482	0.5468	0.2472	0.0003	0.2315	8.4293	44.8900
16	2.6002	3.1952	1.7384	1.2724	0.0829	6.5869	11.3401
17	6.7745	9.3772	3.4990	2.0736	0.2358	23.1521	29.8237
18	4.7143	1.5283	4.1616	7.4529	2.7806	4.1057	20.2500
19	8.7942	8.3810	8.7055	8.9281	6.2750	7.1530	1.9881
20	6.1174	3.2701	5.3824	7.4165	0.0584	0.0011	22.0900
21	5.5932	2.8900	4.8071	7.3441	1.9460	0.7656	20.2500
22	0.0613	0.9477	0.5837	1.5713	7.2981	9.4188	12.1383
23	5.3361	2.5043	4.8400	8.0514	5.3708	1.9881	16.8100
24	0.0638	0.3525	0.1287	0.0268	0.8055	9.5945	39.6900
SSE =	48.9792	49.4281	44.5575	49.5956	40.9419	140.7199	643.2354
MSE =	2.0408	2.0595	1.8566	2.0665	1.7059	5.8633	26.8015
SE =	1.4286	1.4351	1.3626	1.4375	1.3061	2.4214	5.1770
CV =	20.8296	20.9249	19.8672	20.9603	19.0441	35.3064	75.4850

Table F-17 Error Analysis Results of Validation 2.1 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Jan. 13, 1987 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.1250	0.1819	0.1380	0.0977	0.2176	0.4219	3.1117
2	1.9640	3.5992	2.3826	1.1480	2.7794	11.5843	52.7595
3	0.5232	0.7037	0.3043	0.2111	0.0247	1.7016	3.2801
4	0.0298	0.0827	0.0352	0.0176	0.1463	0.5402	9.6255
5	0.9801	2.2500	1.2713	0.4590	1.3689	11.2058	62.4100
6	0.1463	0.0986	0.1343	0.1685	0.0185	0.0104	4.1087
7	0.0982	0.8311	0.2116	0.0011	3.1625	6.1504	51.2417
8	1.9344	3.4627	2.3358	1.0201	1.0167	15.9401	62.4100
9	0.8046	0.6964	1.0040	1.1546	2.0178	0.2515	0.0172
10	0.4258	0.3170	0.4026	0.4823	0.2455	0.0578	7.2307
11	0.7803	2.0592	1.0609	0.3501	3.4534	8.1320	59.5727
12	1.9530	3.5627	2.3870	0.9950	0.8978	17.2018	62.4100
13	0.1547	0.2157	0.1672	0.1365	0.6427	0.4594	15.1624
14	0.0900	0.1444	0.1024	0.0770	0.4096	0.3844	43.3952
15	0.1482	0.5468	0.2472	0.0003	0.2315	8.4293	44.8900
16	2.6002	3.1952	1.7384	1.2724	0.0829	6.5869	11.3401
17	6.7745	9.3772	3.4990	2.0736	0.2358	23.1521	29.8237
18	4.7143	1.5283	4.1616	7.4529	2.7806	4.1057	20.2500
19	8.7942	8.3810	8.7055	8.9281	6.2750	7.1530	1.9881
20	6.1174	3.2701	5.3824	7.4165	0.0584	0.0011	22.0900
21	5.5932	2.8900	4.8071	7.3441	1.9460	0.7656	20.2500
22	0.0613	0.9477	0.5837	1.5713	7.2981	9.4188	12.1383
23	5.3361	2.5043	4.8400	8.0514	5.3708	1.9881	16.8100
24	0.0613	0.0088	0.0200	0.4406	1.9530	6.7470	33.6400
SSE =	50.2099	50.8546	45.9220	50.8696	42.6335	142.3891	649.9555
MSE =	2.0921	2.1189	1.9134	2.1196	1.7764	5.9329	27.0815
SE =	1.4464	1.4557	1.3833	1.4559	1.3328	2.4358	5.2040
CV =	21.0897	21.2247	20.1691	21.2278	19.4335	35.5152	75.8783

Table F-18 Error Analysis Results of Validation 2.2 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using May 17, 1989 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	14.7956	14.2393	14.6574	15.1127	13.9390	12.6061	5.9341
2	7.8320	5.3032	7.0566	9.7880	6.4154	0.6343	9.3855
3	12.0872	11.2971	13.3103	13.9918	16.3441	8.3842	5.7068
4	0.5293	0.3752	0.5077	0.5891	0.2678	0.0272	4.8510
5	0.0081	0.3600	0.0518	0.0495	0.0729	5.9903	49.0000
6	0.3393	0.2642	0.3209	0.3727	0.1129	0.0912	3.3379
7	0.0128	0.5065	0.0676	0.0278	2.4911	5.1984	48.4184
8	0.2409	0.9232	0.3948	0.0121	0.0117	9.5636	49.0000
9	15.1866	14.7034	16.0160	16.6016	19.5408	12.2605	9.8032
10	13.3408	12.6950	13.2096	13.6493	12.2185	10.5008	0.0967
11	9.1003	6.0762	8.2369	10.9451	4.1684	1.0990	14.5797
12	0.2475	0.9752	0.4160	0.0095	0.0023	10.5463	49.0000
13	13.0080	12.5002	12.8961	13.1809	10.2293	11.0372	0.0113
14	0.3600	0.2704	0.3364	0.3875	0.0676	0.0784	32.3477
15	0.1482	0.5468	0.2472	0.0003	0.2315	8.4293	44.8900
16	2.6002	3.1952	1.7384	1.2724	0.0829	6.5869	11.3401
17	6.7745	9.3772	3.4990	2.0736	0.2358	23.1521	29.8237
18	4.7143	1.5283	4.1616	7.4529	2.7806	4.1057	20.2500
19	8.7942	8.3810	8.7055	8.9281	6.2750	7.1530	1.9881
20	6.1174	3.2701	5.3824	7.4165	0.0584	0.0011	22.0900
21	5.5932	2.8900	4.8071	7.3441	1.9460	0.7656	20.2500
22	0.0613	0.9477	0.5837	1.5713	7.2981	9.4188	12.1383
23	5.3361	2.5043	4.8400	8.0514	5.3708	1.9881	16.8100
24	0.1208	0.0000	0.0582	0.5833	2.2425	6.2375	32.4900
SSE =	127.3485	113.1294	121.5012	139.4114	112.4034	155.8555	493.5423
MSE =	5.3062	4.7137	5.0625	5.8088	4.6835	6.4940	20.5643
SE =	2.3035	2.1711	2.2500	2.4101	2.1641	2.5483	4.5348
CV =	41.5360	39.1485	40.5712	43.4587	39.0227	45.9503	81.7692

Table F-19. Error Analysis Results of Calibration 2 for Dissolved Oxygen (All Parameters Simulation) using March 4, 1986 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.3064	0.3925	0.3266	0.2632	0.4456	0.7217	3.8593
2	2.5669	4.3980	3.0450	1.6202	3.4889	12.9960	55.7262
3	0.8536	1.0793	0.5650	0.4349	0.1284	2.2667	4.0557
4	0.0163	0.0002	0.0127	0.0281	0.0068	0.1892	7.8821
5	0.4761	1.4460	0.6848	0.1425	0.7569	9.3025	57.7600
6	0.0003	0.0075	0.0011	0.0001	0.0697	0.0891	5.8976
7	0.5088	1.7205	0.7453	0.1878	4.7451	8.2944	57.1284
8	1.1954	2.7945	1.8496	0.6588	0.3782	15.1580	57.7600
9	0.8046	0.6956	1.0040	1.1535	2.0178	0.2510	0.0168
10	0.4258	0.3170	0.4020	0.4823	0.2450	0.0574	7.2630
11	0.3422	1.2882	0.5329	0.0851	2.4336	6.5110	55.0317
12	1.2100	2.5361	1.5625	0.4900	0.4225	14.8803	57.7600
13	0.0860	0.1328	0.0954	0.0726	0.4931	0.3338	14.3936
14	0.0000	0.0064	0.0004	0.0004	0.1156	0.1040	39.5327
15	0.1491	0.5567	0.2506	0.0005	0.2304	8.4875	44.8900
16	2.6651	3.2761	1.7876	1.3053	0.0861	6.7366	11.5566
17	6.8208	9.4283	3.5198	2.0912	0.2336	23.1949	29.8359
18	4.6764	1.4884	4.1209	7.4324	2.7473	4.2282	20.2500
19	8.7942	8.3810	8.7055	8.9281	6.2750	7.1503	1.9937
20	6.1174	3.2701	5.3824	7.4165	0.0584	0.0011	22.0900
21	5.5578	2.8646	4.7961	7.3306	1.9252	0.7921	20.2500
22	0.0618	0.9487	0.5829	1.5713	7.2981	9.4188	12.1417
23	5.3130	2.4728	4.8071	8.0514	5.3592	2.0306	16.8100
24	0.0683	0.3630	0.1360	0.0248	0.8010	9.7032	39.6900
SSE =	49.0161	49.8640	44.9160	49.7715	40.7617	142.8985	643.5750
MSE =	2.0423	2.0777	1.8715	2.0738	1.6984	5.9541	26.8156
SE =	1.4291	1.4414	1.3680	1.4401	1.3032	2.4401	5.1784
CV =	20.8375	21.0169	19.9469	20.9974	19.0021	35.5787	75.5049

Table F-20. Error Analysis Results of Validation 2.1 for Dissolved Oxygen (All Parameters Simulation) using Jan. 13, 1987 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.1250	0.1819	0.1380	0.0980	0.2186	0.4219	3.1135
2	1.9660	3.5992	2.3870	1.1510	2.7817	11.5940	52.7802
3	0.5240	0.7037	0.3043	0.2111	0.0251	1.7045	3.2902
4	0.0298	0.0827	0.0352	0.0176	0.1463	0.5402	9.6566
5	0.9801	2.2575	1.2713	0.4590	1.3689	11.2225	62.4100
6	0.1463	0.0983	0.1343	0.1685	0.0185	0.0103	4.1148
7	0.0982	0.8311	0.2147	0.0011	3.1625	6.1504	51.2417
8	1.9414	3.8875	2.7556	1.2358	0.8372	17.5840	62.4100
9	0.8046	0.6956	1.0040	1.1535	2.0178	0.2510	0.0168
10	0.4258	0.3170	0.4020	0.4823	0.2450	0.0574	7.2630
11	0.7832	2.0592	1.0609	0.3501	3.4596	8.1320	59.5727
12	1.9600	3.5816	2.4025	1.0000	0.9025	17.2848	62.4100
13	0.1547	0.2157	0.1672	0.1365	0.6436	0.4594	15.1624
14	0.0900	0.1444	0.1024	0.0784	0.4096	0.3875	43.3952
15	0.1491	0.5567	0.2506	0.0005	0.2304	8.4875	44.8900
16	2.6651	3.2761	1.7876	1.3053	0.0861	6.7366	11.5566
17	6.8208	9.4283	3.5198	2.0912	0.2336	23.1949	29.8359
18	4.6764	1.4884	4.1209	7.4324	2.7473	4.2282	20.2500
19	8.7942	8.3810	8.7055	8.9281	6.2750	7.1503	1.9937
20	6.1174	3.2701	5.3824	7.4165	0.0584	0.0011	22.0900
21	5.5578	2.8646	4.7961	7.3306	1.9252	0.7921	20.2500
22	0.0618	0.9487	0.5829	1.5713	7.2981	9.4188	12.1417
23	5.3130	2.4728	4.8071	8.0514	5.3592	2.0306	16.8100
24	0.0570	0.0105	0.0172	0.4323	1.9460	6.8382	33.6400
SSE =	50.2415	51.3523	46.3493	51.1025	42.3963	144.6782	650.2949
MSE =	2.0934	2.1397	1.9312	2.1293	1.7665	6.0283	27.0956
SE =	1.4469	1.4628	1.3897	1.4592	1.3291	2.4553	5.2053
CV =	21.0963	21.3283	20.2627	21.2763	19.3794	35.7995	75.8981

Table F-21. Error Analysis Results of Validation 2.2 for Dissolved Oxygen (All Parameters Simulation) using May 17, 1989 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	14.7956	14.2393	14.6574	15.1088	13.9316	12.6061	5.9317
2	7.8280	5.3032	7.0490	9.7790	6.4117	0.6320	9.3942
3	12.0833	11.2971	13.3103	13.9918	16.3351	8.3778	5.6935
4	0.5293	0.3752	0.5077	0.5891	0.2678	0.0272	4.8731
5	0.0081	0.3630	0.0518	0.0495	0.0729	6.0025	49.0000
6	0.3393	0.2637	0.3209	0.3727	0.1129	0.0909	3.3434
7	0.0128	0.5065	0.0693	0.0278	2.4911	5.1984	48.4184
8	0.2434	1.1485	0.5776	0.0448	0.0002	10.8460	49.0000
9	15.1866	14.6996	16.0160	16.5975	19.5408	12.2570	9.7938
10	13.3408	12.6950	13.2060	13.6493	12.2150	10.4944	0.0930
11	9.1003	6.0762	8.2369	10.9451	4.1616	1.0990	14.5797
12	0.2500	0.9851	0.4225	0.0100	0.0025	10.6113	49.0000
13	13.0080	12.5002	12.8961	13.1809	10.2258	11.0372	0.0113
14	0.3600	0.2704	0.3364	0.3844	0.0676	0.0770	32.3477
15	0.1491	0.5567	0.2506	0.0005	0.2304	8.4875	44.8900
16	2.6651	3.2761	1.7876	1.3053	0.0861	6.7366	11.5566
17	6.8208	9.4283	3.5198	2.0912	0.2336	23.1949	29.8359
18	4.6764	1.4884	4.1209	7.4324	2.7473	4.2282	20.2500
19	8.7942	8.3810	8.7055	8.9281	6.2750	7.1503	1.9937
20	6.1174	3.2701	5.3824	7.4165	0.0584	0.0011	22.0900
21	5.5578	2.8646	4.7961	7.3306	1.9252	0.7921	20.2500
22	0.0618	0.9487	0.5829	1.5713	7.2981	9.4188	12.1417
23	5.3130	2.4728	4.8071	8.0514	5.3592	2.0306	16.8100
24	0.1148	0.0000	0.0535	0.5738	2.2350	6.3252	32.4900
SSE =	127.3557	113.4092	121.6641	139.4318	112.2851	157.7221	493.7876
MSE =	5.3065	4.7254	5.0693	5.8097	4.6785	6.5718	20.5745
SE =	2.3036	2.1738	2.2515	2.4103	2.1630	2.5635	4.5359
CV =	41.5372	39.1969	40.5984	43.4619	39.0022	46.2247	81.7895

Table F-22. Error Analysis Calibration 2 Results for Other Parameters (All Parameters Simulation) using March 4, 1986 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	25.8521	0.2176	1.5302	0.0041	0.0378	0.0000	0.0034	0.0372	0.0001	0.0004	0.0009	1409098	2.1389
2	52.2522	0.0503	49.1701	0.0261	0.0005	0.0003	0.0038	0.0340	0.0007	0.0026	0.0005	391666	5.2539
3	12.5316	0.2635	33.3506	0.0043	0.0351	0.0000	0.0006	0.0221	0.0001	0.0004	0.0009	804307	1.1796
4	32.4615	0.2048	125.9445	0.0064	0.0289	0.0000	0.0072	0.0001	0.0001	0.0004	0.0009	34740	1.5314
5	40.4178	0.0081	29.1330	0.0225	0.0121	0.0008	0.0961	0.0061	0.0009	0.0012	0.0039	81715634	83.0377
6	30.0030	0.1669	0.3175	0.0037	0.0120	0.0000	0.7841	0.8798	0.0001	0.0000	0.0001	1865191640	2118.3927
7	45.8780	0.0051	30.9878	0.0064	0.0042	0.0008	0.6320	0.4552	0.0003	0.0034	0.0067	1568293059	1848.1401
8	42.7062	0.0462	8.7074	0.0286	0.0243	0.0008	0.2678	0.0483	0.0011	0.0026	0.0074	61359309	77.4547
9	3.1241	0.1932	5.7816	0.0037	0.0322	0.0000	0.1505	0.2601	0.0001	0.0009	0.0004	2676754	17.9691
10	9.9477	0.0384	13.2387	0.0072	0.0178	0.0000	0.1403	0.1836	0.0002	0.0007	0.0002	10942484	1.4197
11	14.3641	0.0044	38.1924	0.0016	0.0081	0.0000	0.1122	0.1526	0.0001	0.0004	0.0001	40071116	1.5792
12	13.1951	0.0182	4.8952	0.0218	0.0138	0.0008	0.2601	0.0787	0.0009	0.0016	0.0042	51717708	73.7022
13	37.0475	0.1444	17.2225	0.0041	0.0109	0.0000	0.0032	0.0104	0.0001	0.0000	0.0001	1065144	2.0433
14	46.2400	0.1620	84.5480	0.0049	0.0072	0.0000	0.0018	0.0008	0.0001	0.0000	0.0001	4323904	0.0588
15	13.6653	1.1544	3.0431	0.0184	0.0104	0.0008	0.2618	0.0917	0.0009	0.0705	0.0576	68729277	80.4908
16	0.3153	14.7763	256.6885	0.6186	1.5265	0.0004	0.2998	2.1083	0.0339	0.1362	0.3053	4682928	333.6468
17	0.1839	2.1251	123.0620	0.0992	0.1093	0.0003	0.4385	0.0010	0.0038	0.0145	0.0328	27574897	373.8207
18	0.0763	16.4938	276.5985	1.2656	3.5721	0.0008	1.3514	3.3197	0.0619	0.2970	0.6261	17640000	144.0300
19	0.0128	0.0729	63.0198	0.0066	0.0057	0.0008	0.4389	0.4692	0.0002	0.0000	0.0004	347085	160.9980
20	0.3211	0.5017	56.3000	0.0017	0.0072	0.0014	0.3080	0.4007	0.0001	0.0013	0.0009	52257019	980.8380
21	0.3452	5.8928	526.9320	0.6084	1.4520	0.0008	1.3053	0.6634	0.0289	0.1444	0.3080	17640000	500.1932
22	2.8426	0.2098	204.1612	0.0039	0.0643	0.0003	0.2134	0.4476	0.0001	0.0000	0.0001	24747640	125.2721
23	1.9391	7.4666	135.3732	0.4456	1.0151	0.0001	0.8836	0.5206	0.0218	0.0529	0.1369	2114528256	2529.3356
24	0.0722	0.3466	6.2938	0.0784	0.0870	0.0014	0.0473	0.1068	0.0036	0.0004	0.0064	2411237434	4091.8411
SSE =	425.7948	50.5632	2094.4917	3.2917	8.0945	0.0107	8.0112	10.2979	0.1600	0.7319	1.5008	8429381102	13554.3675
MSE =	17.7415	2.1068	87.2705	0.1372	0.3373	0.0004	0.3338	0.4291	0.0067	0.0305	0.0625	351224213	564.7653
SE =	4.2121	1.4515	9.3419	0.3703	0.5808	0.0211	0.5778	0.6550	0.0817	0.1746	0.2501	18741	23.7648
CV =	16.4106	136.6100	27.3754	1154.3136	283.8702	111.3798	74.9519	63.8156	1781.6700	189.6431	258.6884	130	73.7846

Table F-23. Error Analysis Results of Validation 2.1 for Other Parameters (All Parameters Simulation) using Jan. 13, 1987 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	16.6831	0.3209	45.7382	0.00410	0.00198	0.00001	0.0034	0.00185	0.00010	0.00040	0.00090	34989	72.8889
2	38.7951	0.1052	0.9759	0.02606	0.01635	0.00029	0.0038	0.11184	0.00074	0.64114	0.59731	2643330	151.0968
3	6.4516	0.3762	4.9506	0.00430	0.00139	0.00001	0.0006	0.00000	0.00010	0.00040	0.00090	9590366	79.4574
4	32.4615	1.1078	10.3845	0.00640	0.00040	0.00002	0.0072	0.01988	0.00010	0.00040	0.00090	5694845	126.2814
5	40.4178	0.2601	54.7230	0.02250	0.08410	0.00078	0.0961	0.01040	0.00090	0.58523	0.54391	81715634	34.6627
6	30.0030	0.3703	29.5555	0.00372	0.00009	0.00002	0.7841	0.70224	0.00010	0.01000	0.00810	7777099445	64.4167
7	45.8780	0.0738	0.1878	0.00640	0.02723	0.00078	0.6320	0.33024	0.00034	0.00174	0.00034	7157444259	24.9001
8	42.7062	0.1482	24.5108	0.02862	0.11278	0.00078	0.2678	0.00157	0.00111	0.56125	0.51003	61359309	38.4297
9	3.1241	1.0806	130.0626	0.00366	0.00009	0.00002	0.1505	0.11560	0.00010	0.00640	0.00490	14715502	45.7111
10	9.9477	0.6336	28.7457	0.00723	0.00133	0.00002	0.1403	0.06682	0.00018	0.00578	0.00391	1227537	96.2067
11	14.3641	0.2844	7.9524	0.00160	0.00640	0.00002	0.1122	0.04869	0.00010	0.00490	0.00360	17058346	150.2259
12	13.1951	0.2162	17.7452	0.02176	0.08851	0.00078	0.2601	0.01010	0.00090	0.57760	0.54023	51717708	41.1522
13	37.0475	0.9604	14.8225	0.00408	0.00002	0.00002	0.0032	0.00000	0.00010	0.01000	0.00810	10446201	73.4544
14	46.2400	1.0050	1.4280	0.00490	0.00023	0.00002	0.0018	0.01651	0.00010	0.01000	0.00810	14544	104.9088
15	13.6653	1.1544	14.0209	0.01838	0.07965	0.00084	0.2618	0.01510	0.00090	0.58608	0.54760	68729277	36.3408
16	0.3153	14.7763	64.3445	0.61858	1.78356	0.00044	0.2998	2.40870	0.03386	0.13616	0.30526	1295	798.9668
17	0.1839	2.1251	9.5687	0.09923	0.18538	0.00029	0.4385	0.00470	0.00380	0.00498	0.01719	9309703	860.5096
18	0.0763	16.4938	214.0735	1.26563	4.24360	0.00078	1.3514	3.96806	0.06188	0.06503	0.00008	17640000	729.0675
19	0.0128	0.7569	0.0038	0.00656	0.00060	0.00078	0.4389	0.34223	0.00018	0.00865	0.00648	7779299	514.7680
20	0.3211	0.5017	2.2600	0.00174	0.00723	0.00144	0.3080	0.21437	0.00010	0.00134	0.00090	52257019	44.6447
21	0.3452	5.8928	287.4720	0.60840	1.60023	0.00078	1.3053	0.76475	0.02890	0.17640	0.06003	17640000	244.4532
22	2.8426	1.1194	5.2372	0.00391	0.06426	0.00029	0.2134	0.44756	0.00010	0.01000	0.00810	7698960	718.6421
23	1.9391	4.9841	92.8332	0.44556	1.01506	0.00012	0.8836	0.52056	0.02176	0.05290	0.13690	2114528256	1042.8056
24	0.0722	0.7899	0.2588	0.07840	0.08703	0.00137	0.0473	0.10677	0.00360	0.00040	0.00640	2411237434	2113.0111
SSE =	397.0887	55.5370	1061.8552	3.29168	9.40747	0.01070	8.0112	10.22857	0.16004	3.45716	3.32014	19897583260	8207.0020
MSE =	16.5454	2.3140	44.2440	0.13715	0.39198	0.00045	0.3338	0.42619	0.00667	0.14405	0.13834	829065969	341.9584
SE =	4.0676	1.5212	6.6516	0.37034	0.62608	0.02112	0.5778	0.65283	0.08166	0.37954	0.37194	28794	18.4921
CV =	15.7710	110.6325	16.4916	1154.31357	758.88644	111.37979	74.9519	72.18606	1781.67002	110.27716	106.64945	151	127.1664

Table F-24. Error Analysis Results of Validation 2.2 for Other Parameters (All Parameters Simulation) using May 17, 1989 Water Quality Data and 7Q10 Discharge

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	16.6831	0.3209	2783.9342	0.0041	0.0006	0.0000	0.0034	0.0005	0.0001	0.0004	0.0009	2990673930	14033.3639
2	38.7951	0.1052	2207.8587	0.0261	0.0214	0.0003	0.0038	0.1256	0.0007	0.3609	0.3282	2795677627	13157.8925
3	6.4516	0.3762	2325.6506	0.0043	0.0003	0.0000	0.0006	0.0005	0.0001	0.0004	0.0009	9590366	13944.3296
4	22.0665	0.7268	1829.9145	0.0064	0.0000	0.0000	0.0072	0.0259	0.0001	0.0004	0.0009	5694845	13400.9564
5	28.7028	0.0961	1552.1630	0.0225	0.0012	0.0008	0.0961	0.0219	0.0009	0.2162	0.1914	34101746	173982.8377
6	30.0030	0.3703	1255.7455	0.0037	0.0099	0.0000	0.7841	0.8612	0.0001	0.0144	0.0121	537677060	230424.9607
7	33.3314	0.0738	926.1878	0.0064	0.0056	0.0008	0.6320	0.4418	0.0003	0.0038	0.0015	384225859	227519.4601
8	12.4962	0.0342	1365.3641	0.0286	0.0067	0.0006	0.2669	0.0839	0.0011	0.2018	0.1715	21466712	173722.9347
9	0.0541	0.0574	2440.8046	0.0037	0.0099	0.0000	0.1505	0.1849	0.0001	0.0100	0.0081	14715502	310515.3031
10	26.5637	0.0000	1880.2197	0.0072	0.0029	0.0000	0.1403	0.1215	0.0002	0.0092	0.0068	1227537	307128.2187
11	33.5241	0.0711	1666.2724	0.0016	0.0001	0.0000	0.1122	0.0965	0.0001	0.0081	0.0064	17058346	304420.7059
12	13.1951	0.0702	1311.3452	0.0218	0.0016	0.0003	0.2601	0.1229	0.0009	0.2116	0.1892	15932092	173543.0622
13	37.0475	0.3364	2485.0225	0.0041	0.0089	0.0000	0.0032	0.0084	0.0001	0.0144	0.0121	10446201	14025.5333
14	46.2400	0.6440	2007.4880	0.0049	0.0056	0.0000	0.0018	0.0015	0.0001	0.0144	0.0121	14544	13632.3138
15	13.6653	1.1544	1277.6653	0.0184	0.0006	0.0004	0.2612	0.1390	0.0009	0.2167	0.1936	25911279	173865.3708
16	0.3153	14.7763	1442.3665	0.6186	1.5475	0.0004	0.2998	2.1374	0.0339	0.1362	0.3053	1295	9748.4028
17	0.1839	2.1251	1840.9820	0.0992	0.1133	0.0002	0.4385	0.0005	0.0038	0.0026	0.0123	9309703	9538.5607
18	0.0763	16.4938	301.6735	1.2656	3.7976	0.0001	1.3485	3.6176	0.0619	0.0020	0.0848	1000000	156815.0100
19	0.0128	0.7569	2121.6618	0.0066	0.0043	0.0008	0.4389	0.4556	0.0002	0.0128	0.0101	7779299	10880.8890
20	0.3211	0.5017	812.0600	0.0017	0.0000	0.0014	0.3080	0.3058	0.0001	0.0013	0.0009	16232049	216521.1513
21	0.3452	5.8928	170.1720	0.6084	1.9740	0.0001	1.2996	1.0702	0.0289	0.0144	0.0030	1000000	208269.0132
22	2.8426	1.1194	1910.6952	0.0039	0.0012	0.0003	0.2134	0.2016	0.0001	0.0144	0.0121	7698960	198196.3621
23	1.9391	4.9841	500.1932	0.4456	1.4520	0.0000	0.8836	0.8864	0.0218	0.0009	0.0289	2114528256	207291.2606
24	0.0722	0.0969	379.9088	0.0784	0.2500	0.0004	0.0441	0.2989	0.0036	0.0324	0.0144	2411237434	1597.4011
SSE =	364.9280	51.1839	36795.3492	3.2917	9.2155	0.0070	7.9980	11.2101	0.1600	1.4996	1.6076	11433200642	3176175.2941
MSE =	15.2053	2.1327	1533.1395	0.1372	0.3840	0.0003	0.3332	0.4671	0.0067	0.0625	0.0670	476383360	132340.6373
SE =	3.8994	1.4604	39.1553	0.3703	0.6197	0.0171	0.5773	0.6834	0.0817	0.2500	0.2588	21826	363.7865
CV =	15.1188	115.2918	50.1456	1154.3136	470.6275	90.0765	74.8899	71.6735	1781.6700	87.4533	89.1162	127	108.1089

Table F-25. Error Analysis Results of Calibration for Temperature and BOD (Temperature, BOD and DO Simulation only) using Sept. 27, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error Temperature	Squared Error BOD
1	7.3984	0.0028
2	0.9189	0.0004
3	5.4341	0.0027
4	28.6760	0.0100
5	26.3426	0.0182
6	7.9270	0.0581
7	42.4452	0.0552
8	29.4125	0.0270
9	10.0679	0.1772
10	44.9168	0.2057
11	33.5627	0.2010
12	28.4089	0.0256
13	0.7019	0.1975
14	14.6689	0.2304
15	24.5245	0.0207
16	12.8021	0.2495
17	20.8798	0.0608
18	35.9850	0.9458
19	37.2344	0.0210
20	31.4347	0.0306
21	22.7529	0.5077
22	31.7532	0.1932
23	43.4611	0.0053
24	40.6885	0.1081
SSE =	582.3980	3.3544
MSE =	24.2666	0.1398
SE =	4.9261	0.3739
CV =	18.2167	66.9592

Table F-26. Error Analysis Results of Validation for Temperature and BOD (Temperature, BOD and DO Simulation only) using Nov. 14, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error Temperature	Squared Error BOD
1	4.1148	2.0938
2	0.4041	2.2158
3	2.3870	2.0864
4	3.2580	2.5440
5	3.5532	2.5122
6	4.0421	1.0847
7	8.4003	1.0955
8	4.1311	2.4232
9	5.0873	0.8482
10	8.6554	0.9168
11	4.5369	0.9184
12	3.4876	2.4336
13	0.3640	0.8983
14	1.3631	0.9801
15	2.5052	2.4859
16	14.6115	1.2122
17	23.8524	1.7088
18	43.0500	0.8860
19	40.2019	2.4227
20	36.6227	2.3716
21	29.2681	1.2656
22	35.4442	0.8789
23	52.2368	0.0380
24	25.1753	0.4556
SSE =	356.7529	36.7765
MSE =	14.8647	1.5324
SE =	3.8555	1.2379
CV =	15.2945	72.2852

Table F-27. Error Analysis Results of Validation for Temperature and BOD (Temperature, BOD and DO Simulation only) using Nov. 12, 1993 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error Temperature	Squared Error BOD
1	6.6075	2.7093
2	0.4188	2.7985
3	4.8449	2.7225
4	1.1772	1.6900
5	0.6162	1.5750
6	11.4955	2.7011
7	13.4811	2.7778
8	5.6525	1.5834
9	29.9209	1.2555
10	20.8255	1.3572
11	16.1202	1.3963
12	12.0930	1.6256
13	3.7507	0.2010
14	7.8260	0.2401
15	10.3720	1.6641
16	17.5980	0.0702
17	26.8497	0.0220
18	52.9256	0.7678
19	47.8726	0.0204
20	52.1765	1.6341
21	40.4496	1.0506
22	39.3443	0.1879
23	66.4633	1.1396
24	13.6900	2.9584
SSE =	502.5716	34.1486
MSE =	20.9405	1.4229
SE =	4.5761	1.1928
CV =	17.8289	78.2188

Table F-28. Error Analysis Results of Calibration 3 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Sept. 27, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.0093	0.0166	0.0105	0.0159	0.6154	0.0009	0.0404
2	0.0676	0.0380	0.0597	0.0417	0.2429	0.2616	0.8796
3	0.0004	0.0010	0.0011	0.0084	0.4923	0.0376	0.1878
4	0.7613	0.7396	0.7656	0.9458	1.4702	0.2500	0.0006
5	0.0473	0.0743	0.0529	0.0870	1.1078	0.0176	0.5402
6	0.1505	0.1892	0.1576	0.1706	1.6091	0.0721	0.0087
7	0.0521	0.0961	0.0608	0.0720	1.2100	0.0001	0.1237
8	0.0003	0.0130	0.0014	0.0049	1.2525	0.0793	0.7382
9	0.0781	0.1053	0.0615	0.0737	1.2133	0.0376	0.0013
10	0.0737	0.1285	0.0555	0.0710	0.8492	0.0090	0.0853
11	0.2704	0.3844	0.2500	0.2739	1.4082	0.0971	0.0374
12	0.0006	0.0100	0.0001	0.0001	1.2432	0.0827	0.7921
13	0.1035	0.0828	0.0947	0.1686	0.4415	0.0011	0.0841
14	0.5663	0.5256	0.5513	0.6642	0.8418	0.1806	0.0233
15	0.0289	0.0016	0.0230	0.0196	1.1556	0.1946	1.1966
16	0.0640	0.0504	0.0679	0.0441	0.2616	0.1888	0.4456
17	0.0088	0.0141	0.0098	0.0283	1.6299	0.0225	0.1863
18	7.5556	7.8821	7.5488	8.1653	15.7609	5.2843	2.7184
19	11.0623	11.0457	11.0357	11.4989	14.2431	9.6721	8.1339
20	9.0802	9.0701	9.0601	9.5893	12.0062	7.1467	4.5796
21	6.9169	7.1958	6.9301	7.4802	14.1941	4.6872	1.9952
22	6.2575	6.3605	6.3529	6.8121	12.9996	4.7263	3.2238
23	7.9524	8.3666	8.0231	8.5996	17.3889	5.3824	2.2425
24	14.2129	15.3272	14.4400	14.5829	27.8652	11.8594	7.2294
SSE =	65.3209	67.7186	65.6139	69.4181	131.5025	50.2916	35.4938
MSE =	2.7217	2.8216	2.7339	2.8924	5.4793	2.0955	1.4789
SE =	1.6498	1.6798	1.6535	1.7007	2.3408	1.4476	1.2161
CV =	24.3507	24.7936	24.4052	25.1028	34.5503	21.3665	17.9499

Table F-29. Error Analysis Results of Validation 3.1 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Nov. 14, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.4376	0.3813	0.4232	0.4206	0.0173	0.5469	0.7560
2	0.8984	0.7310	0.8556	0.8556	0.0045	1.2608	2.1066
3	0.4632	0.4371	0.4594	0.3879	0.0007	0.7656	1.2161
4	0.0144	0.0127	0.0150	0.0011	0.0827	0.2162	0.9120
5	0.5112	0.3938	0.4865	0.4489	0.0400	0.9555	2.1170
6	0.1215	0.1604	0.1307	0.1303	1.6887	0.0686	0.0132
7	0.0407	0.0900	0.0506	0.0499	1.3963	0.0015	0.0729
8	0.8464	0.6413	0.7906	0.7906	0.0560	1.3053	2.5921
9	0.0138	0.0052	0.0233	0.0169	0.5077	0.0380	0.1208
10	0.0158	0.0010	0.0277	0.0199	0.3181	0.0790	0.4173
11	0.2085	0.1179	0.2304	0.2162	0.0642	0.4032	1.2210
12	0.9025	0.6683	0.8742	0.8836	0.0462	1.3456	2.7806
13	0.0413	0.0372	0.0413	0.0218	0.1452	0.1521	0.3694
14	0.0702	0.0625	0.0702	0.0380	0.0225	0.3053	0.9312
15	1.1342	0.8525	1.0874	1.1025	0.0353	1.6327	3.2942
16	0.8181	0.7552	0.8473	0.7718	0.0221	1.1162	1.6116
17	0.5559	0.5041	0.5725	0.5002	0.1130	0.8556	1.3417
18	8.6951	9.1658	8.5849	9.0300	16.8408	6.8579	4.3733
19	10.6994	10.7912	10.7125	11.0290	14.5199	9.5914	8.3059
20	9.1910	9.3330	9.2112	9.6307	12.7330	7.4985	5.2060
21	7.7562	8.1939	7.7284	8.1368	15.2686	5.9171	3.3672
22	7.1022	7.2927	7.0490	7.4093	13.4359	5.8903	4.5114
23	9.0601	9.6255	9.0601	9.4864	18.4900	6.9564	3.9601
24	0.8649	1.1691	0.9025	0.9120	5.7121	0.4573	0.0049
SSE =	60.4627	61.4226	60.2347	62.2899	101.5606	54.2170	51.6028
MSE =	2.5193	2.5593	2.5098	2.5954	4.2317	2.2590	2.1501
SE =	1.5872	1.5998	1.5842	1.6110	2.0571	1.5030	1.4663
CV =	21.4490	21.6186	21.4085	21.7707	27.7988	20.3110	19.8152

Table F-30. Error Analysis Results of Validation 3.2 for Dissolved Oxygen (Temperature, BOD and DO Simulation only) using Nov. 12, 1993 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	6.3605	6.4898	6.3782	6.5587	10.0046	5.6359	4.7633
2	4.5187	4.7368	4.5613	4.8024	7.9968	3.3830	1.8769
3	5.8430	5.8752	5.9319	6.2361	9.5172	4.8156	3.7917
4	2.1389	2.0736	2.1609	2.4414	3.1064	1.1610	0.2809
5	0.5968	0.6602	0.6084	0.7439	2.4964	0.1482	0.0798
6	4.7393	4.9729	4.7961	4.7219	10.5788	4.6053	4.2354
7	4.1616	4.6082	4.2711	4.1209	10.5300	3.9204	3.1862
8	0.4160	0.5738	0.4511	0.4411	3.6132	0.2147	0.0021
9	9.5080	9.8188	9.2781	9.3697	15.4685	9.1779	8.3810
10	9.4679	10.1283	9.1385	9.2143	15.0040	8.8506	7.1289
11	1.4240	1.7512	1.3340	1.3225	4.1141	1.1700	0.5041
12	0.5112	0.7310	0.5184	0.4970	3.7249	0.3192	0.0189
13	8.5232	8.7091	8.5621	8.7091	13.1769	7.7996	6.8935
14	5.5460	5.8081	5.5932	5.7840	8.7616	4.5796	3.2761
15	2.9336	3.4575	2.9737	2.9146	9.0100	2.4284	1.2333
16	0.0219	0.0105	0.0322	0.0225	0.3546	0.0648	0.1888
17	0.9978	1.0781	0.9463	1.0145	3.9557	0.7617	0.4715
18	10.2640	10.8488	9.9777	10.2800	18.2116	8.9401	6.7016
19	9.6939	9.9666	9.7563	9.7157	15.1321	9.3422	8.7025
20	8.7616	9.2822	8.8804	8.8110	14.5797	8.0940	6.8121
21	8.9700	9.6100	8.9102	8.9700	16.8921	7.9242	5.9536
22	7.9609	8.2312	7.7869	8.0287	13.8235	7.1156	5.9219
23	10.6766	11.4244	10.5950	10.7256	20.1152	9.4096	7.0490
24	6.7081	7.5145	6.7470	6.6822	16.0801	5.8928	3.8711
SSE =	130.7434	138.3608	130.1892	132.1280	246.2479	115.7543	91.3243
MSE =	5.4476	5.7650	5.4245	5.5053	10.2603	4.8231	3.8052
SE =	2.3340	2.4010	2.3291	2.3463	3.2032	2.1962	1.9507
CV =	40.6801	41.8483	40.5937	40.8949	55.8288	38.2772	33.9989

Table F-31. Error Analysis Results of Calibration 3 for Dissolved Oxygen (All Parameters Simulation) using Sept. 27, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.0093	0.0166	0.0105	0.0159	0.6154	0.0009	0.0404
2	0.0676	0.0380	0.0600	0.0426	0.2429	0.2623	0.8796
3	0.0004	0.0010	0.0011	0.0083	0.4923	0.0376	0.1883
4	0.7613	0.7396	0.7656	0.9458	1.4641	0.2500	0.0006
5	0.0462	0.0729	0.0529	0.0870	1.1078	0.0176	0.5439
6	0.1505	0.1888	0.1576	0.1702	1.6091	0.0721	0.0086
7	0.0521	0.0961	0.0608	0.0711	1.2100	0.0001	0.1248
8	0.0002	0.0125	0.0013	0.0047	1.2525	0.0803	0.7382
9	0.0781	0.1053	0.0615	0.0737	1.2133	0.0376	0.0013
10	0.0737	0.1285	0.0550	0.0710	0.8492	0.0089	0.0858
11	0.2687	0.3844	0.2500	0.2739	1.4082	0.0961	0.0380
12	0.0006	0.0100	0.0001	0.0001	1.2432	0.0856	0.7966
13	0.1035	0.0828	0.0944	0.1686	0.4407	0.0011	0.0847
14	0.5663	0.5256	0.5513	0.6642	0.8418	0.1806	0.0233
15	0.0299	0.0019	0.0235	0.0204	1.1556	0.1965	1.2039
16	0.0648	0.0506	0.0684	0.0445	0.2611	0.1905	0.4496
17	0.0088	0.0139	0.0096	0.0281	1.6285	0.0227	0.1883
18	7.5350	7.8750	7.5419	8.1368	15.7609	5.2670	2.6978
19	11.0623	11.0423	11.0324	11.4989	14.2431	9.6721	8.1339
20	9.0802	9.0701	9.0601	9.5893	12.0062	7.1467	4.5796
21	6.8906	7.1824	6.9169	7.4802	14.1752	4.6764	1.9740
22	6.2575	6.3605	6.3529	6.8121	12.9996	4.7263	3.2238
23	7.9102	8.3232	7.9948	8.5849	17.3889	5.3477	2.2201
24	14.2129	15.3077	14.3641	14.5542	27.8652	11.8336	7.2025
SSE =	65.2306	67.6298	65.4867	69.3465	131.4750	50.2104	35.4277
MSE =	2.7179	2.8179	2.7286	2.8894	5.4781	2.0921	1.4762
SE =	1.6486	1.6787	1.6519	1.6998	2.3405	1.4464	1.2150
CV =	24.3338	24.7773	24.3816	25.0898	34.5467	21.3492	17.9331

Table F-32. Error Analysis Results of Validation 3.1 for Dissolved Oxygen (All Parameters Simulation) using Nov. 14, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	0.4376	0.3819	0.4232	0.4212	0.0173	0.5469	0.7578
2	0.8998	0.7335	0.8583	0.8556	0.0045	1.2624	2.1087
3	0.4632	0.4371	0.4594	0.3879	0.0007	0.7656	1.2161
4	0.0144	0.0127	0.0150	0.0011	0.0827	0.2162	0.9120
5	0.5184	0.3969	0.4865	0.4489	0.0400	0.9555	2.1243
6	0.1215	0.1604	0.1307	0.1303	1.6887	0.0684	0.0132
7	0.0400	0.0890	0.0506	0.0499	1.3963	0.0015	0.0729
8	0.8495	0.6427	0.7936	0.7906	0.0560	1.3091	2.5921
9	0.0138	0.0052	0.0233	0.0169	0.5077	0.0380	0.1208
10	0.0158	0.0010	0.0279	0.0200	0.3181	0.0792	0.4173
11	0.2085	0.1190	0.2304	0.2178	0.0642	0.4032	1.2210
12	0.9120	0.6724	0.8789	0.8836	0.0462	1.3456	2.7889
13	0.0413	0.0374	0.0416	0.0218	0.1452	0.1521	0.3694
14	0.0702	0.0625	0.0702	0.0380	0.0225	0.3053	0.9312
15	1.1366	0.8546	1.0909	1.1025	0.0353	1.6384	3.3023
16	0.8181	0.7569	0.8501	0.7735	0.0225	1.1183	1.6129
17	0.5559	0.5041	0.5725	0.5017	0.1130	0.8577	1.3430
18	8.6878	9.1582	8.5703	9.0150	16.8408	6.8382	4.3577
19	10.6962	10.7912	10.7093	11.0290	14.5199	9.5883	8.3059
20	9.1910	9.3330	9.2112	9.6307	12.7330	7.4985	5.2060
21	7.7284	8.1653	7.7284	8.1083	15.2490	5.9049	3.3489
22	7.1022	7.2927	7.0490	7.4093	13.4359	5.8903	4.5114
23	9.0451	9.6100	9.0300	9.4710	18.4685	6.9432	3.9402
24	0.8579	1.1610	0.8978	0.9073	5.7121	0.4556	0.0041
SSE =	60.4251	61.3787	60.1989	62.2319	101.5200	54.1825	51.5781
MSE =	2.5177	2.5574	2.5083	2.5930	4.2300	2.2576	2.1491
SE =	1.5867	1.5992	1.5838	1.6103	2.0567	1.5025	1.4660
CV =	21.4423	21.6108	21.4021	21.7605	27.7932	20.3045	19.8105

Table F-33. Error Analysis Results of Validation 3.2 for Dissolved Oxygen (All Parameters Simulation) using Nov. 12, 1993 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error using Churchill et. al Predictive Equation	Squared Error using Langbein-Durum Predictive Equation	Squared Error using O'Connor-Dobbins Predictive Equation	Squared Error using Owens et. al Predictive Equation	Squared Error using Single Coefficient (measured)	Squared Error using Thackston-Krenkel Predictive Equation	Squared Error using Tsivoglou-Wallace Predictive Equation
1	6.3580	6.4872	6.3782	6.5587	10.0046	5.6335	4.7633
2	4.5156	4.7368	4.5613	4.7992	7.9968	3.3803	1.8769
3	5.8430	5.8752	5.9319	6.2361	9.5172	4.8156	3.7917
4	2.1316	2.0736	2.1609	2.4414	3.1064	1.1556	0.2809
5	0.5968	0.6602	0.6084	0.7439	2.4964	0.1482	0.0798
6	4.7393	4.9729	4.7961	4.7219	10.5788	4.6032	4.2354
7	4.1616	4.6082	4.2711	4.1209	10.5300	3.9204	3.1803
8	0.4160	0.5738	0.4511	0.4400	3.6132	0.2124	0.0020
9	9.5080	9.8157	9.2781	9.3697	15.4685	9.1779	8.3810
10	9.4679	10.1188	9.1385	9.2112	15.0040	8.8506	7.1262
11	1.4240	1.7512	1.3340	1.3225	4.1141	1.1700	0.5041
12	0.5077	0.7268	0.5184	0.4935	3.7249	0.3164	0.0176
13	8.5232	8.7091	8.5621	8.7091	13.1769	7.7965	6.8935
14	5.5460	5.8081	5.5932	5.7840	8.7616	4.5796	3.2761
15	2.9317	3.4451	2.9699	2.9108	9.0067	2.4249	1.2309
16	0.0221	0.0106	0.0324	0.0228	0.3546	0.0648	0.1892
17	0.9978	1.0781	0.9463	1.0145	3.9557	0.7617	0.4715
18	10.2560	10.8323	9.9777	10.2720	18.2116	8.9401	6.6822
19	9.6939	9.9666	9.7531	9.7126	15.1321	9.3422	8.7025
20	8.7517	9.2720	8.8804	8.8011	14.5797	8.0940	6.8121
21	8.9401	9.6100	8.8953	8.9700	16.8921	7.9102	5.9414
22	7.9580	8.2312	7.7869	8.0287	13.8235	7.1156	5.9219
23	10.6602	11.4244	10.5788	10.7256	20.1152	9.3942	7.0358
24	6.7081	7.5076	6.7340	6.6758	16.0801	5.8806	3.8661
SSE =	130.6583	138.2956	130.1382	132.0862	246.2446	115.6886	91.2624
MSE =	5.4441	5.7623	5.4224	5.5036	10.2602	4.8204	3.8026
SE =	2.3333	2.4005	2.3286	2.3460	3.2032	2.1955	1.9500
CV =	40.6668	41.8385	40.5858	40.8884	55.8284	38.2663	33.9874

Table F-34. Error Analysis Calibration 3 Results for Other Parameters (All Parameters Simulation) using Sept. 27, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	7.3984	0.0028	1648.8066	0.0025	0.0004	0.0000	0.0350	0.0245	0.0001	0.0036	0.0025	278453816	3711.4292
2	0.9189	0.0004	1579.5515	0.0040	0.0000	0.0003	0.0277	0.0130	0.0001	0.0107	0.0081	266609112	3672.1003
3	5.4341	0.0027	1620.2414	0.0025	0.0004	0.0000	0.0344	0.0238	0.0001	0.0036	0.0025	186527519	3707.5244
4	28.6760	0.0100	1554.3306	0.0025	0.0001	0.0000	0.0289	0.0180	0.0001	0.0036	0.0025	180524282	3685.4006
5	26.3426	0.0182	2131.8998	0.0000	0.0016	0.0008	0.3136	0.3913	0.0000	0.0025	0.0016	65566875	15228.7940
6	7.9270	0.0581	298.4775	0.0025	0.0827	0.0000	0.9643	1.4921	0.0001	0.0000	0.0001	605132867	24591.8851
7	42.4452	0.0552	261.1995	0.0000	0.0617	0.0008	0.9184	1.5285	0.0000	0.0002	0.0004	558063216	24410.9376
8	29.4125	0.0270	1872.0044	0.0001	0.0004	0.0008	0.5688	0.6288	0.0001	0.0016	0.0009	55404253	15152.7893
9	10.0679	0.1772	682.4634	0.0025	0.0096	0.0000	0.2328	0.2825	0.0001	0.0001	0.0004	184682650	10766.9677
10	44.9168	0.2057	625.3250	0.0029	0.0081	0.0000	0.3147	0.3618	0.0001	0.0001	0.0004	163703542	10702.7301
11	33.5627	0.2010	595.1160	0.0001	0.0081	0.0000	0.3025	0.4255	0.0000	0.0001	0.0001	141651018	10622.3942
12	28.4089	0.0256	1905.5408	0.0000	0.0009	0.0008	0.5625	0.6488	0.0000	0.0016	0.0016	49331273	15114.8583
13	0.7019	0.1975	676.9537	0.0025	0.0822	0.0000	0.0328	0.1756	0.0001	0.0000	0.0001	184387823	3696.3022
14	14.6689	0.2304	595.9702	0.0028	0.0784	0.0000	0.0225	0.1436	0.0001	0.0000	0.0001	139545020	3644.8388
15	24.5245	0.0207	1889.7375	0.0000	0.0009	0.0008	0.5525	0.6402	0.0000	0.0016	0.0016	48389685	15119.5715
16	12.8021	0.2495	1476.6343	0.0222	0.0128	0.0008	0.4456	0.1888	0.0013	0.0003	0.0030	153849963	1730.5184
17	20.8798	0.0608	1205.4784	0.0069	0.0005	0.0003	0.6006	0.5318	0.0002	0.0010	0.0023	130930043	1669.6758
18	35.9850	0.9458	1648.2585	0.0210	0.0462	0.0014	1.7990	1.0389	0.0016	0.0024	0.0079	22289127	10840.9744
19	37.2344	0.0210	1264.1580	0.0025	0.0821	0.0008	0.6225	1.1067	0.0001	0.0000	0.0001	179682564	1748.8706
20	31.4347	0.0306	281.6243	0.0003	0.0081	0.0014	0.5980	0.8397	0.0000	0.0025	0.0025	57452256	19149.0244
21	22.7529	0.5077	229.9772	0.0077	0.0240	0.0014	1.8158	1.3007	0.0008	0.0002	0.0014	30224458	18931.6961
22	31.7532	0.1932	1739.0985	0.0025	0.0021	0.0003	0.3352	0.3475	0.0001	0.0000	0.0001	138726443	13943.9491
23	43.4611	0.0053	3472.1556	0.0049	0.0169	0.0004	1.3110	0.9235	0.0004	0.2475	0.2209	29508281	76524.1569
24	40.6885	0.1081	3744.3691	0.0009	0.0016	0.0014	0.1936	0.1667	0.0001	0.2809	0.2704	2871186114	85134.1095
SSE =	582.3980	3.3544	32999.3718	0.0936	0.5297	0.0127	12.6328	13.2422	0.0056	0.5641	0.5315	6721822200	393501.4985
MSE =	24.2666	0.1398	1374.9738	0.0039	0.0221	0.0005	0.5264	0.5518	0.0002	0.0235	0.0221	280075925	16395.8958
SE =	4.9261	0.3739	37.0806	0.0625	0.1486	0.0230	0.7255	0.7428	0.0153	0.1533	0.1488	16735	128.0465
CV =	18.2167	66.9592	57.9385	194.6989	120.8636	121.5335	94.1203	78.6209	333.8498	131.8844	123.1621	110	99.0050

Table F-35. Error Analysis Results of Validation 3.1 for Other Parameters (All Parameters Simulation) using Nov. 14, 1989 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	4.1148	2.0938	470.9117	0.00250	0.00010	0.00001	0.0361	0.02280	0.00010	0.01000	0.00810	27465377	1598.2005
2	0.4041	2.2158	442.5914	0.00377	0.00010	0.00029	0.0306	0.01488	0.00010	0.00903	0.00710	24646133	1582.8462
3	2.3870	2.0864	457.6985	0.00250	0.00010	0.00001	0.0353	0.02174	0.00010	0.01000	0.00810	1969532	1594.5380
4	3.2580	2.5440	429.3184	0.00250	0.00003	0.00002	0.0298	0.01729	0.00010	0.01000	0.00810	1487796	1584.6371
5	3.5532	2.5122	760.5185	0.00000	0.00250	0.00078	0.3249	0.41990	0.00000	0.04410	0.04410	176197881	17329.0896
6	4.0421	1.0847	1115.2260	0.00250	0.00000	0.00002	0.9702	0.87423	0.00010	0.00810	0.00640	562720	284.7150
7	8.4003	1.0955	1053.3270	0.00001	0.00123	0.00078	0.9312	0.92737	0.00001	0.00614	0.00563	5471	269.4522
8	4.1311	2.4232	616.0324	0.00001	0.00095	0.00078	0.5789	0.66912	0.00001	0.04000	0.04000	161697525	17258.0769
9	5.0873	0.8482	202.8630	0.00250	0.00476	0.00002	0.2352	0.25503	0.00010	0.01440	0.01210	1773120	19545.4380
10	8.6554	0.9168	176.0796	0.00250	0.00360	0.00002	0.3198	0.33524	0.00010	0.01440	0.01210	404833	19477.2727
11	4.5369	0.9184	162.1378	0.00018	0.00360	0.00002	0.3080	0.39985	0.00000	0.01440	0.01440	22545	19389.1700
12	3.4876	2.4336	632.7740	0.00000	0.00160	0.00078	0.5776	0.68558	0.00000	0.04410	0.04000	151990063	17218.6884
13	0.3640	0.8983	206.8483	0.00250	0.00000	0.00002	0.0353	0.01901	0.00010	0.00810	0.00640	1961027	1594.4493
14	1.3631	0.9801	177.7556	0.00250	0.00010	0.00002	0.0272	0.01243	0.00010	0.00810	0.00640	62823	1577.0827
15	2.5052	2.4859	632.5504	0.00000	0.00160	0.00084	0.5709	0.67989	0.00000	0.04340	0.04000	151558382	17235.6054
16	14.6115	1.2122	401.5214	0.01575	0.00456	0.00084	0.4570	0.26214	0.00084	0.00000	0.00106	200426	421.3167
17	23.8524	1.7088	259.6932	0.00530	0.00156	0.00029	0.6127	0.58659	0.00023	0.00063	0.00160	15490	399.7556
18	43.0500	0.8860	522.0083	0.01051	0.02600	0.00144	1.8394	1.27521	0.00090	0.00040	0.00250	115479632	12607.6405
19	40.2019	2.4227	276.7565	0.00250	0.00001	0.00078	0.6265	0.58599	0.00010	0.00000	0.00010	1289026	431.2891
20	36.6227	2.3716	1088.4501	0.00040	0.00360	0.00144	0.6032	0.79745	0.00000	0.00250	0.00250	162902423	455.6090
21	29.2681	1.2656	1034.9089	0.00391	0.01210	0.00144	1.8496	1.49573	0.00040	0.00001	0.00031	125260640	428.8006
22	35.4442	0.8789	535.4365	0.00250	0.00240	0.00029	0.3428	0.35820	0.00010	0.00000	0.00010	2406	0.8547
23	52.2368	0.0380	2022.7506	0.00250	0.00810	0.00044	1.3456	1.08368	0.00040	0.04410	0.03610	2828393463	154665.2256
24	25.1753	0.4556	2207.2379	0.00040	0.00160	0.00137	0.2025	0.18662	0.00010	0.05290	0.05290	2917385940	166969.2829
SSE =	356.7529	36.7765	15885.3961	0.06773	0.08019	0.01274	12.8903	11.98598	0.00399	0.38480	0.35609	6852734674	473919.0366
MSE =	14.8647	1.5324	661.8915	0.00282	0.00334	0.00053	0.5371	0.49942	0.00017	0.01603	0.01484	285530611	19746.6265
SE =	3.8555	1.2379	25.7273	0.05312	0.05780	0.02304	0.7329	0.70669	0.01289	0.12662	0.12181	16898	140.5227
CV =	15.2945	72.2852	48.8879	165.57658	107.54123	121.53349	95.0747	80.70734	281.25653	82.35620	76.93127	168	126.5020

Table F-36. Error Analysis Results of Validation 3.2 for Other Parameters (All Parameters Simulation) using Nov. 12, 1993 Water Quality and Discharge Data (High-Flow)

Reach #	Squared Error Temperature	Squared Error BOD	Squared Error TDS	Squared Error Organic-N	Squared Error NH_3N	Squared Error NO_2N	Squared Error NO_3N	Squared Error Total-N	Squared Error Organic-P	Squared Error Dissolved-P	Squared Error Total-P	Squared Error Fecal Coliform	Squared Error SS
1	6.6075	2.7093	554.9558	0.0025	0.0001	0.0000	0.0344	0.0207	0.0001	0.0036	0.0025	4247754	48353.3712
2	0.4188	2.7985	510.8569	0.0043	0.0004	0.0003	0.0270	0.0095	0.0001	0.0027	0.0015	2768437	48183.6993
3	4.8449	2.7225	536.3856	0.0025	0.0001	0.0000	0.0336	0.0200	0.0001	0.0036	0.0025	79710474	48339.6411
4	1.1772	1.6900	494.6176	0.0025	0.0000	0.0000	0.0272	0.0142	0.0001	0.0036	0.0025	75395574	48242.8278
5	0.6162	1.5750	1761.2711	0.0000	0.0006	0.0008	0.3136	0.3636	0.0000	0.0023	0.0016	169271289	48085.9112
6	11.4955	2.7011	346.9093	0.0025	0.0001	0.0000	0.9811	0.9073	0.0001	0.0036	0.0025	4616067	48389.6606
7	13.4811	2.7778	325.0208	0.0001	0.0001	0.0008	0.9604	1.0060	0.0000	0.0028	0.0025	2649548	48290.7950
8	5.6525	1.5834	1521.5851	0.0000	0.0007	0.0008	0.5916	0.6705	0.0000	0.0018	0.0016	164496550	48156.8395
9	29.9209	1.2555	20.4892	0.0025	0.0144	0.0000	0.2406	0.3158	0.0001	0.0036	0.0025	81573312	118.7882
10	20.8255	1.3572	15.2334	0.0025	0.0135	0.0000	0.3358	0.4167	0.0001	0.0036	0.0025	73694610	116.8993
11	16.1202	1.3963	12.6025	0.0004	0.0121	0.0000	0.3249	0.4956	0.0000	0.0036	0.0036	65099832	113.8133
12	12.0930	1.6256	1620.0625	0.0000	0.0016	0.0008	0.5929	0.7022	0.0000	0.0025	0.0025	159763280	48164.8862
13	3.7507	0.2010	20.5310	0.0025	0.0001	0.0000	0.0363	0.0230	0.0001	0.0036	0.0025	81922582	48392.6669
14	7.8260	0.2401	13.8570	0.0025	0.0000	0.0000	0.0306	0.0173	0.0001	0.0036	0.0025	66738075	48336.2210
15	10.3720	1.6641	1628.9296	0.0000	0.0016	0.0008	0.5827	0.6993	0.0000	0.0025	0.0025	159388787	48197.0798
16	17.5980	0.0702	522.4424	0.0088	0.0057	0.0008	0.4699	0.2965	0.0004	0.0004	0.0000	72595291	40163.7673
17	26.8497	0.0220	340.0131	0.0042	0.0030	0.0003	0.6232	0.6334	0.0001	0.0004	0.0010	65425827	40034.6742
18	52.9256	0.7678	1556.4998	0.0030	0.0005	0.0014	1.8803	1.7802	0.0004	0.0001	0.0001	142014055	40169.6796
19	47.8726	0.0204	354.1359	0.0025	0.0001	0.0008	0.6336	0.6123	0.0001	0.0000	0.0001	77543162	40252.7982
20	52.1765	1.6341	342.0034	0.0004	0.0140	0.0014	0.6241	0.9210	0.0000	0.0025	0.0025	174271417	40491.5006
21	40.4496	1.0506	345.9600	0.0009	0.0016	0.0014	1.9044	1.8104	0.0001	0.0009	0.0003	150671022	40346.7482
22	39.3443	0.1879	1482.6350	0.0025	0.0025	0.0003	0.3511	0.3672	0.0001	0.0000	0.0001	66225677	32669.6588
23	66.4633	1.1396	1968.2532	0.0004	0.0009	0.0004	1.3924	1.3248	0.0001	0.0009	0.0004	149794528	38977.6178
24	13.6900	2.9584	2066.6116	0.0001	0.0324	0.0014	0.2209	0.4583	0.0001	0.0016	0.0016	22053872764	211813.9541
SSE =	502.5716	34.1486	18361.8617	0.0477	0.1060	0.0127	13.2127	13.8859	0.0023	0.0538	0.0419	24143749915	1104403.4992
MSE =	20.9405	1.4229	765.0776	0.0020	0.0044	0.0005	0.5505	0.5786	0.0001	0.0022	0.0017	1005989580	46016.8125
SE =	4.5761	1.1928	27.6600	0.0446	0.0665	0.0230	0.7420	0.7606	0.0099	0.0474	0.0418	31717	214.5153
CV =	17.8289	78.2188	52.9801	139.0198	94.9580	121.5335	96.2564	85.2859	215.1315	51.8987	43.5959	204	100.1238

APPENDIX G

Regression Analysis Results for Sg. Selangor River (Main-Stem Reaches)

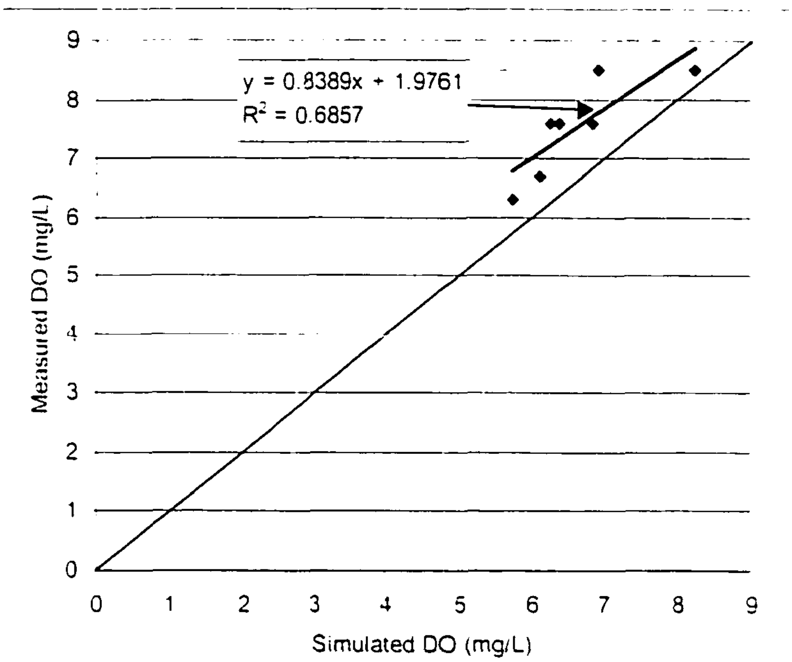

Figure G-1. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 1 (Temp., BOD and DO only Simulation) using March 4, 1986 Data (Low-Flow) (Sg. Selangor River, Malaysia)

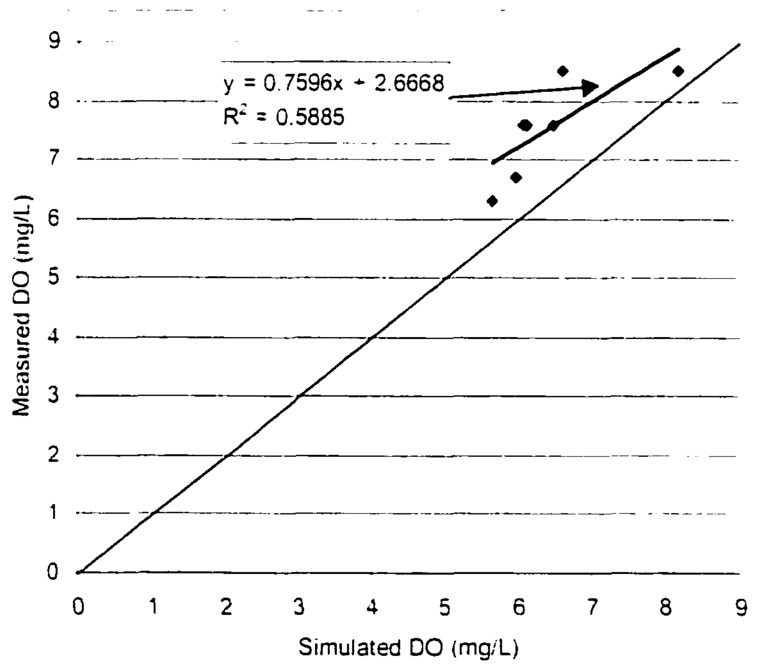

Figure G-2. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO during Calibration 1 (Temp., BOD and DO only Simulation) using March 4, 1986 Data (Low-Flow) (Sg. Selangor River, Malaysia)

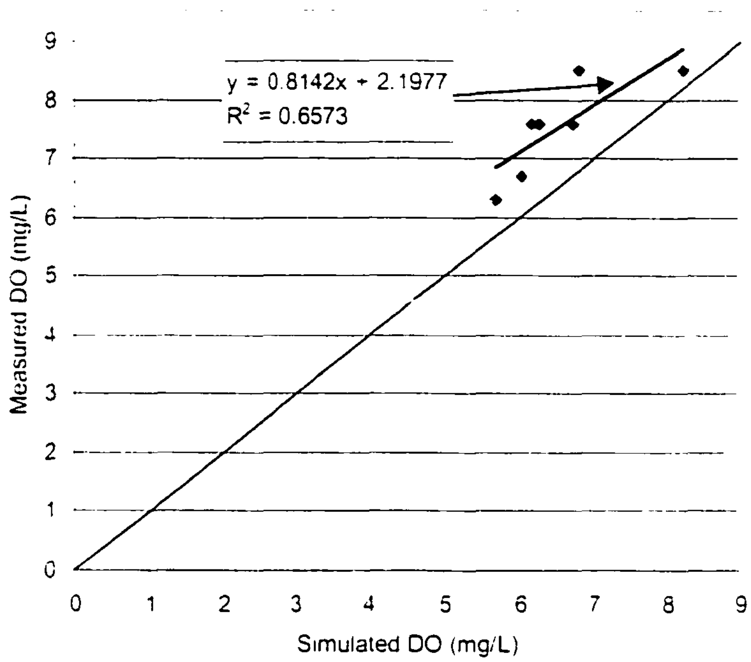

Figure G-3. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO during Calibration 1 (Temp., BOD and DO only Simulation) using March 4, 1986 Data (Low-Flow)

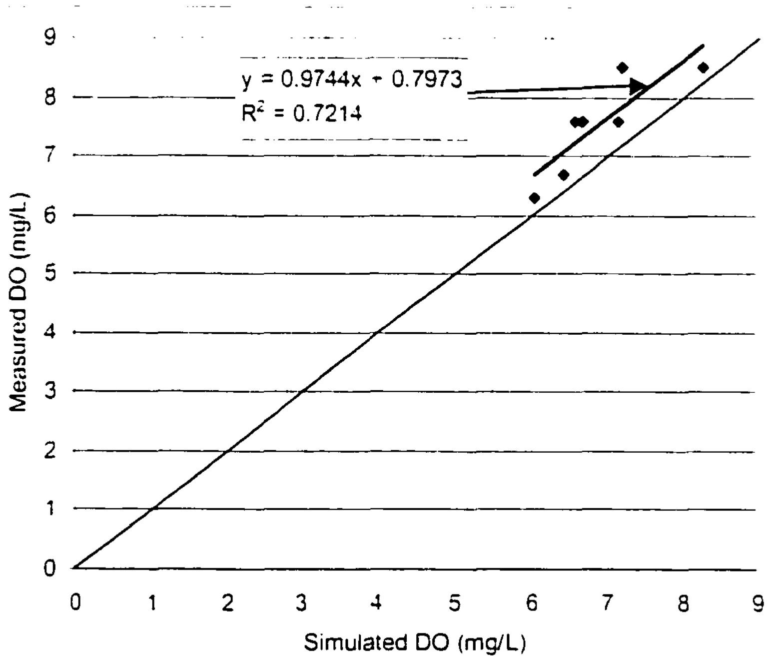

Figure G-4. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 1 (Temp., BOD and DO only Simulation) using March 4, 1986 Data (Low-Flow)

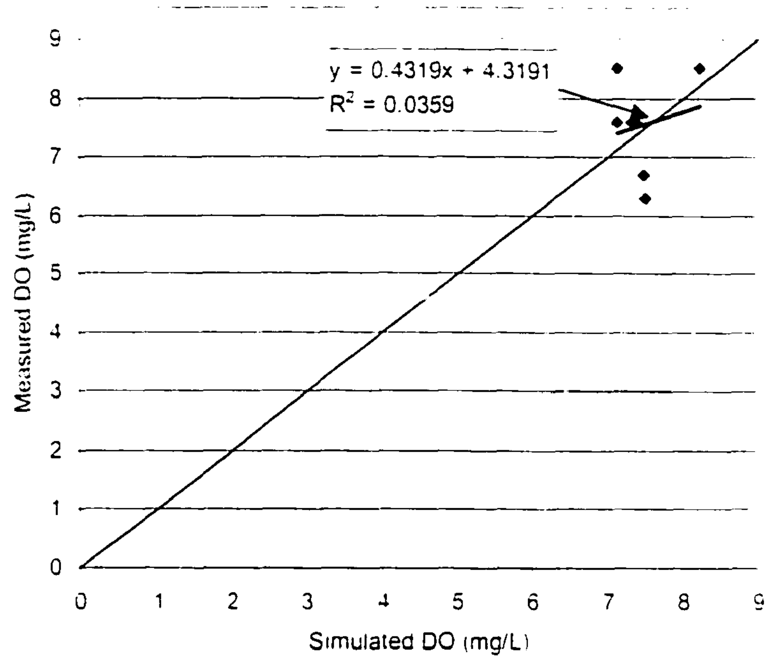

Figure G-5. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO during Calibration 1 (Temp., BOD and DO only Simulation) using March 4, 1986 Data (Low-Flow) (Sg. Selangor, Malaysia)

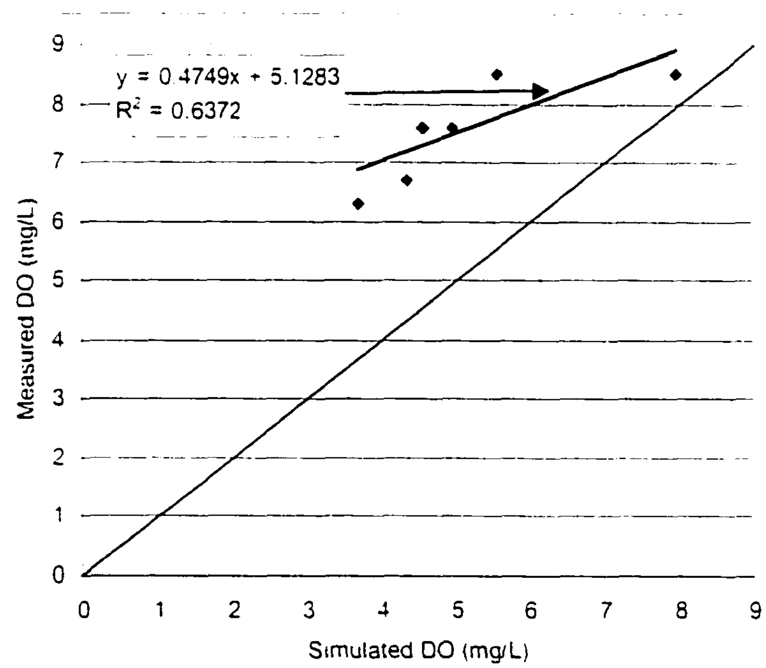

Figure G-6. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO during Calibration 1 (Temp., BOD and DO only Simulation) using March 4, 1986 Data (Low-Flow) (Sg. Selangor, Malaysia)

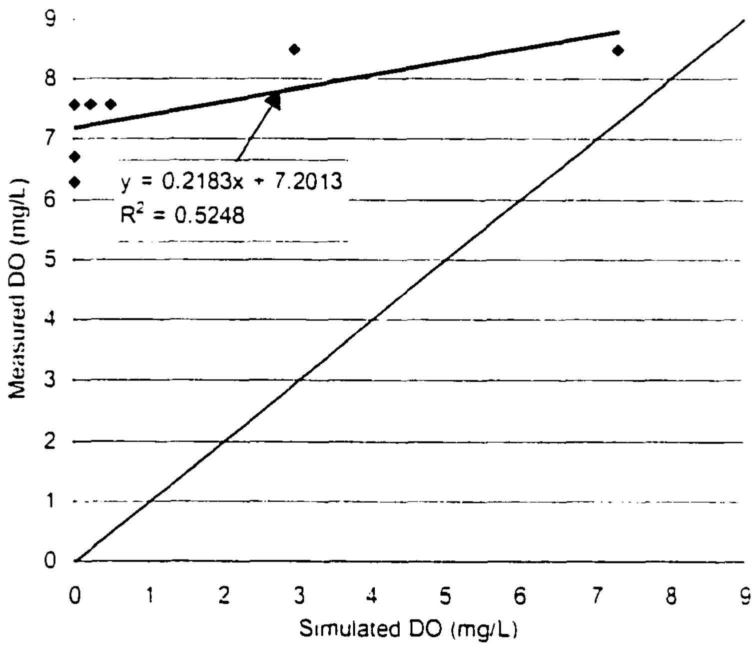

Figure G-7. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO during Calibration 1 (Temp., BOD and DO only Simulation) using March 4, 1986 Data (Low-Flow) (Sg. Selangor, Malaysia)

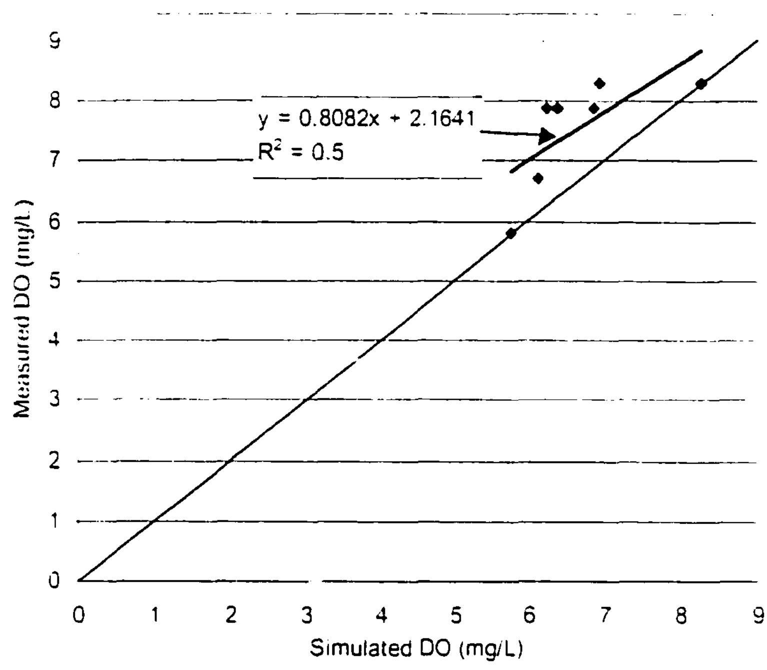

Figure G-8. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO During Validation 1.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Data (Low-Flow) (Sg. Selangor, Malaysia)

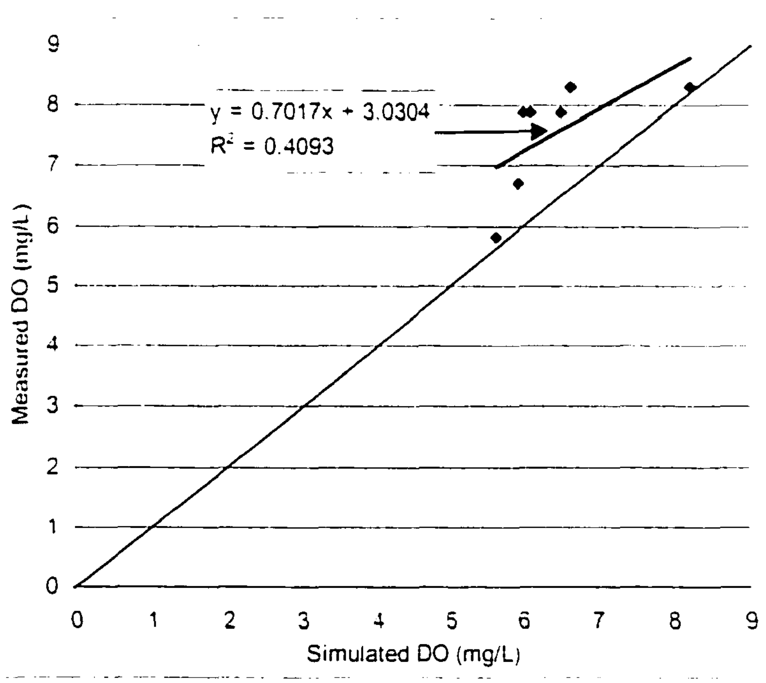

Figure G-9. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO During Validation 1.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Data (Low-Flow) (Sg. Selangor, Malaysia)

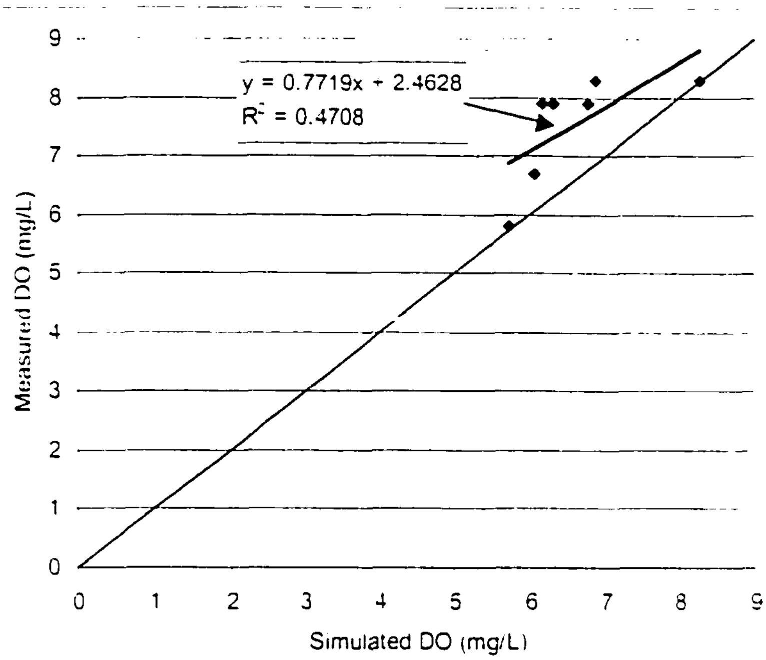

Figure G-10. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO During Validation 1.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Data (Low-Flow) (Sg. Selangor, Malaysia)

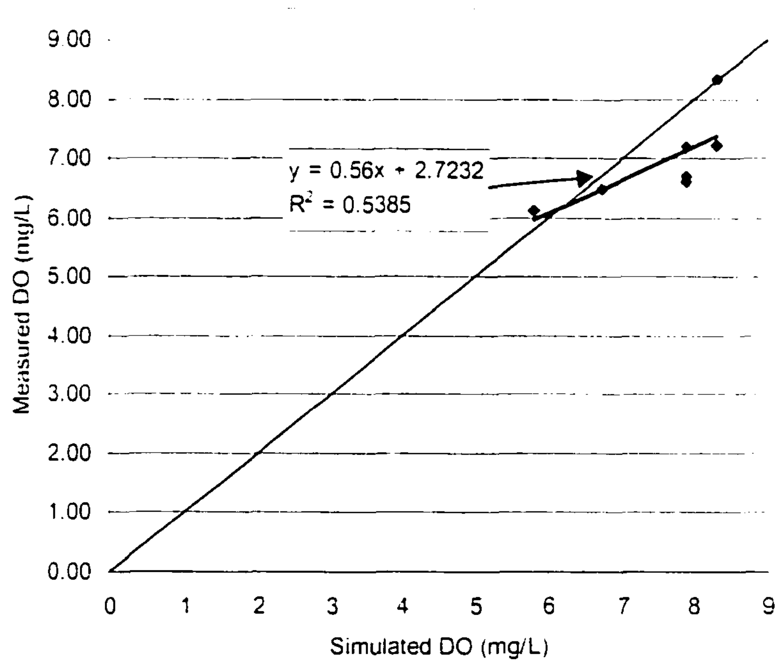

Figure G-11. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO During Validation 1.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Data (Low-Flow) (Sg. Selangor, Malaysia)

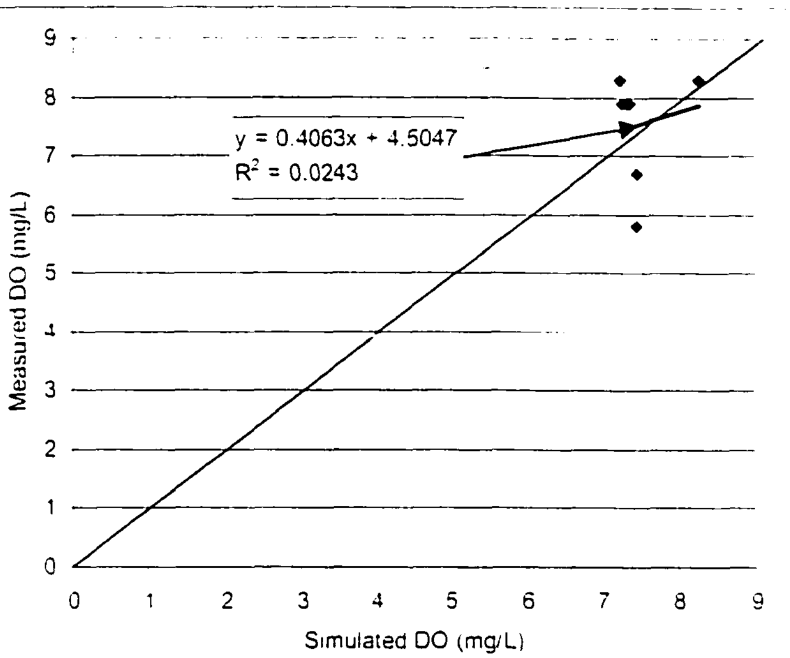

Figure G-12. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO During Validation 1.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Data (Low-Flow) (Sg. Selangor, Malaysia)

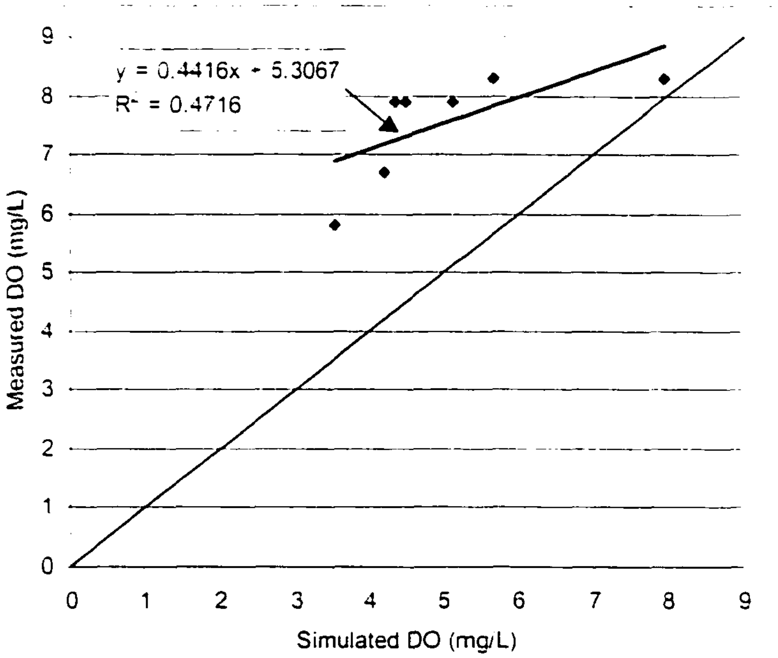

Figure G-13. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO During Validation 1.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Data (Low-Flow) (Sg. Selangor, Malaysia)

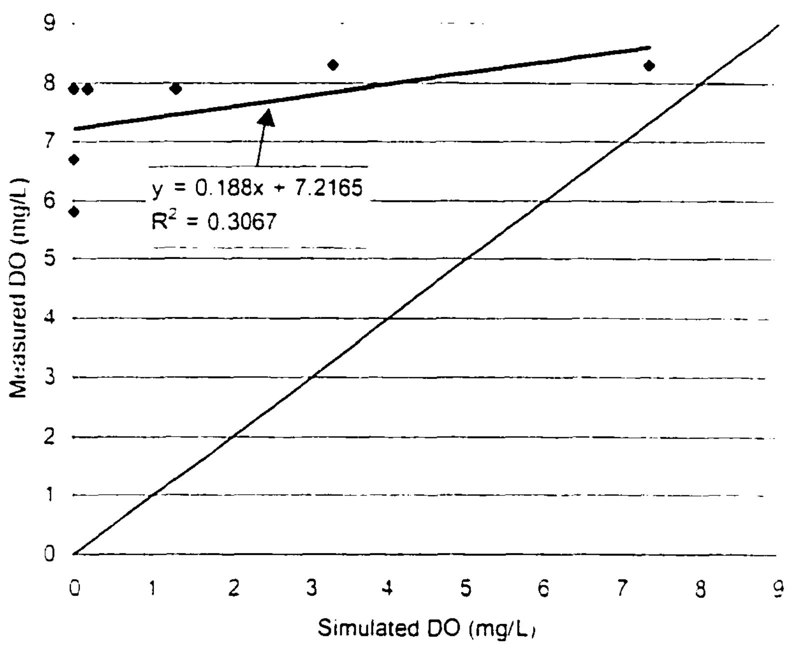

Figure G-14. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO During Validation 1.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Data (Low-Flow) (Sg. Selangor, Malaysia)

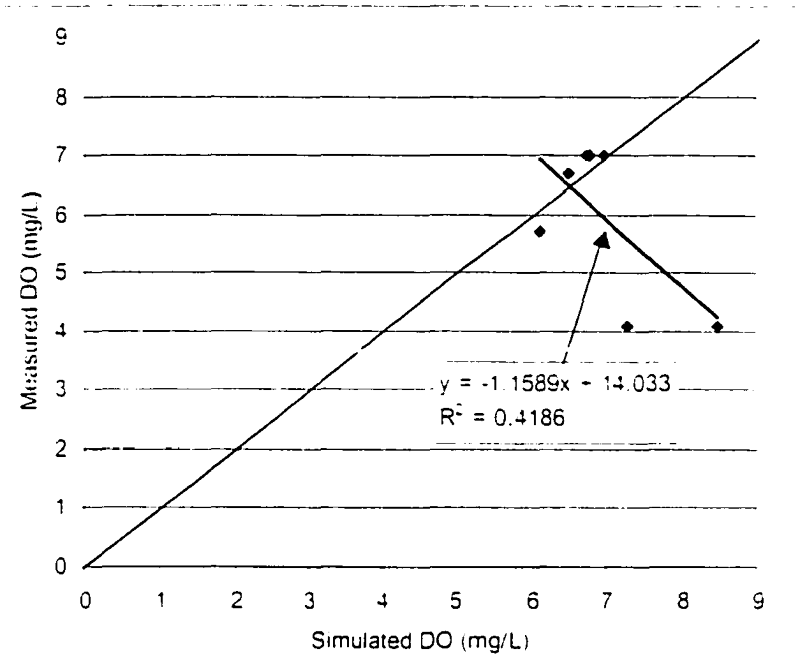

Figure G-15. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO during Validation 1.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Data (Low-Flow) (Sg. Selangor, Malaysia)

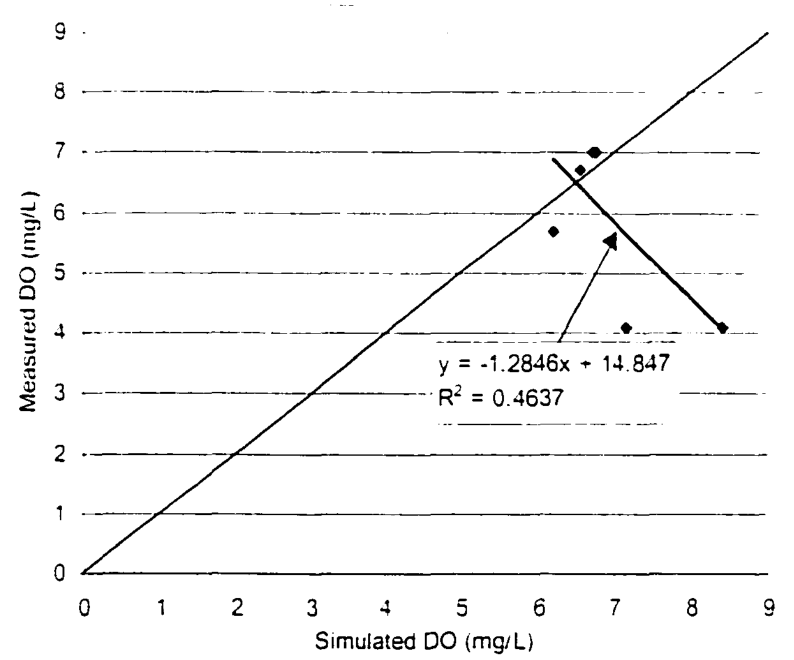

Figure G-16. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO during Validation 1.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Data (Low-Flow) (Sg. Selangor, Malaysia)

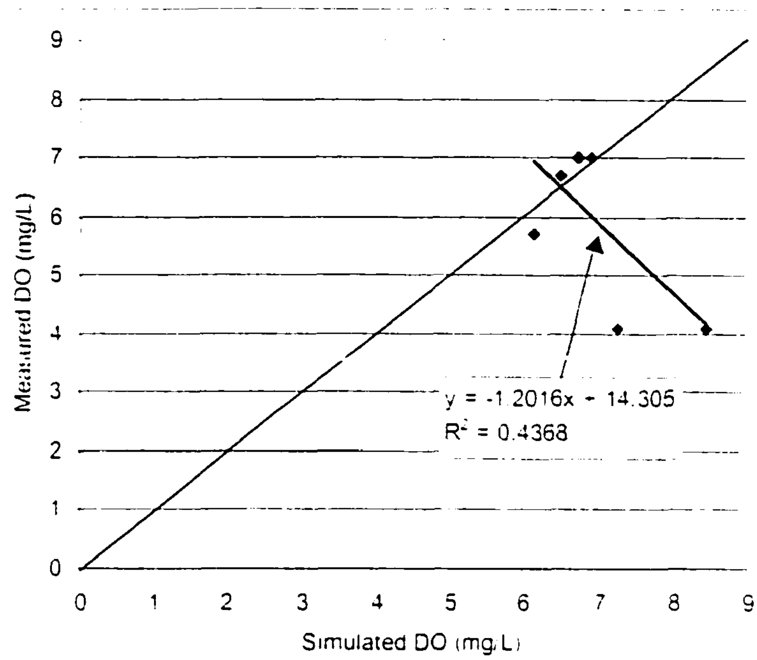

Figure G-17. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO during Validation 1.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Data (Low-Flow) (Sg. Selangor, Malaysia)

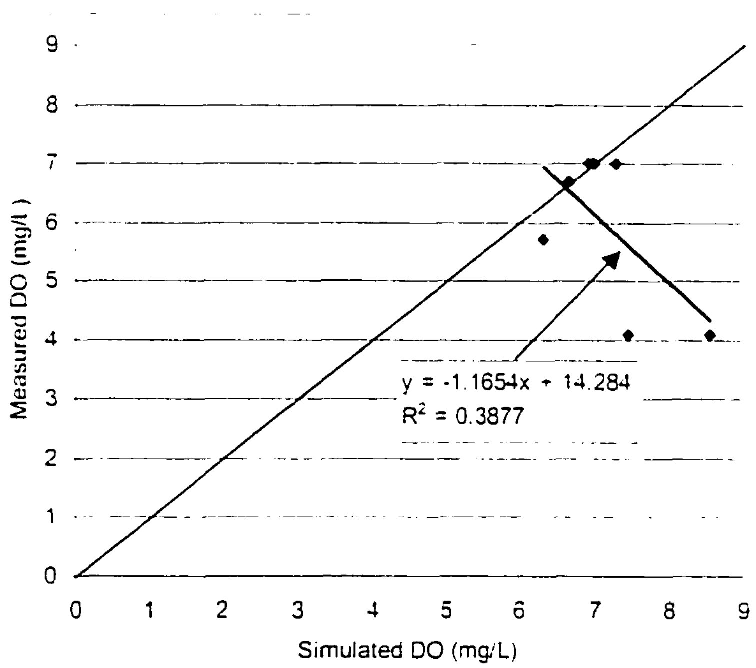

Figure G-18. Regression Analysis: Owens et al Predictive Equation DO Simulation vs. Measured DO during Validation 1.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Data (Low-Flow) (Sg. Selangor, Malaysia)

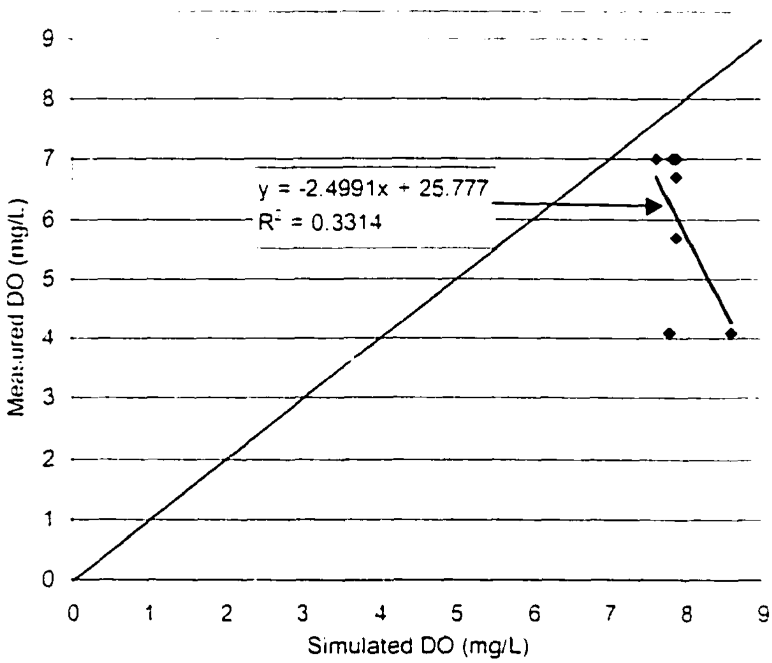

Figure G-19. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO during Validation 1.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Data (Low-Flow) (Sg. Selangor, Malaysia)

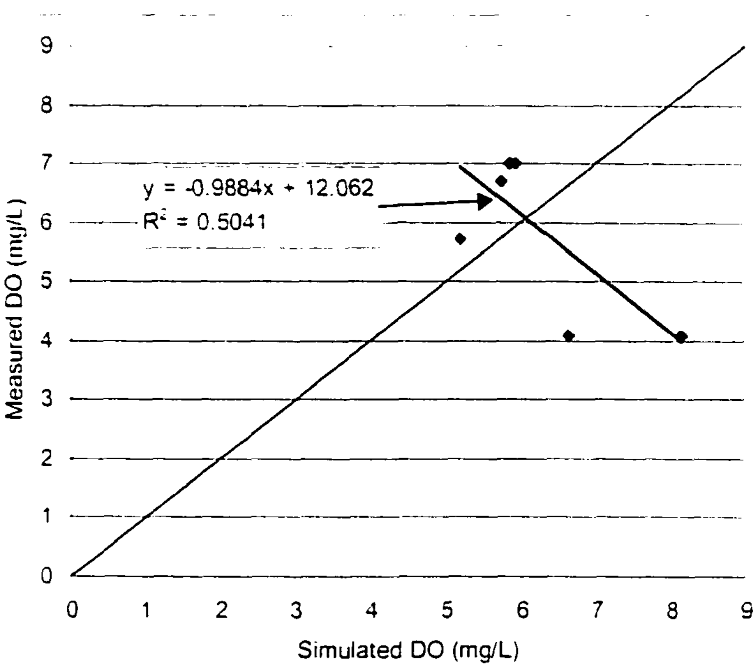

Figure G-20. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO during Validation 1.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Data (Low-Flow) (Sg. Selangor, Malaysia)

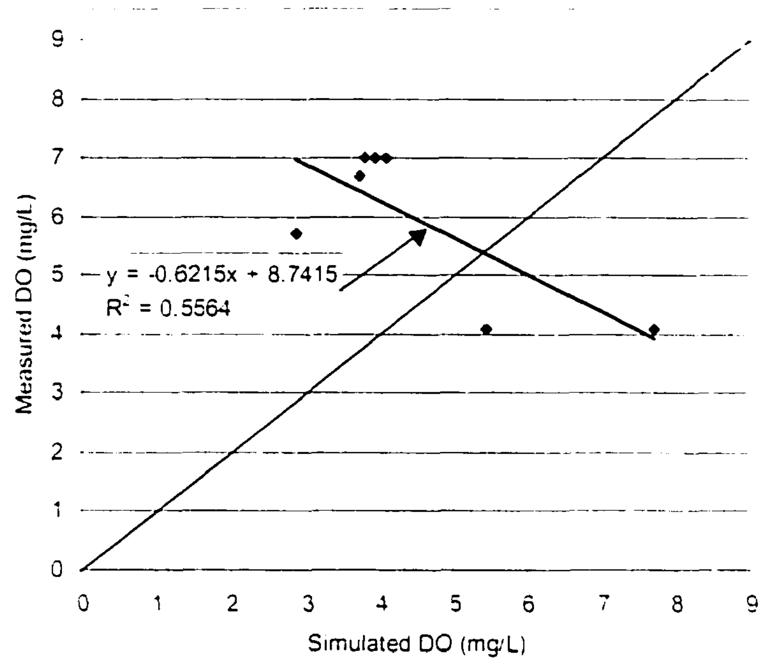

Figure G-21. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO during Validation 1.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Data (Low-Flow) (Sg. Selangor, Malaysia)

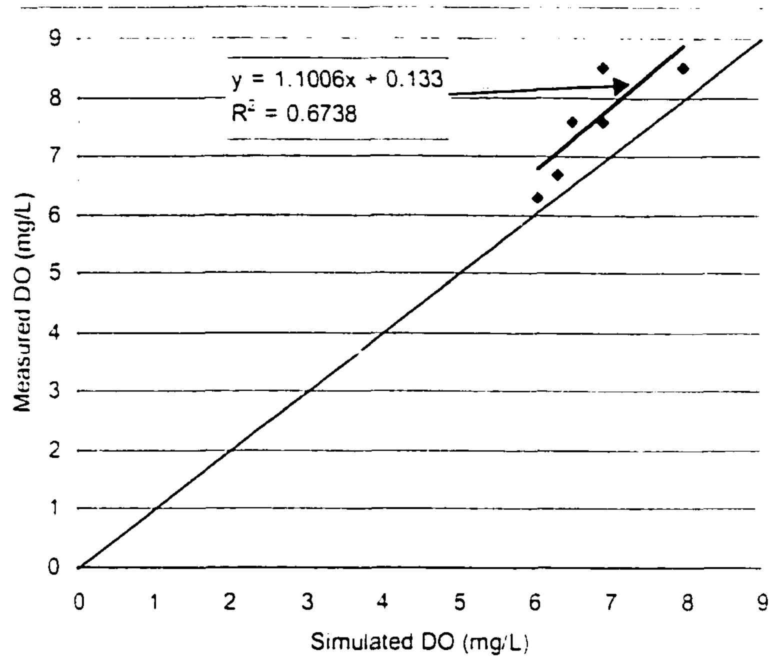

Figure G-22. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

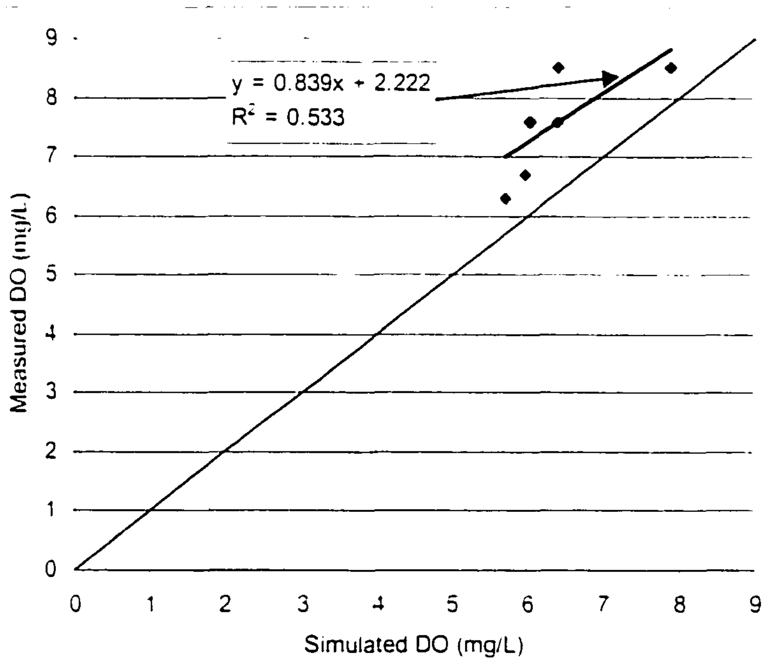

Figure G-23. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

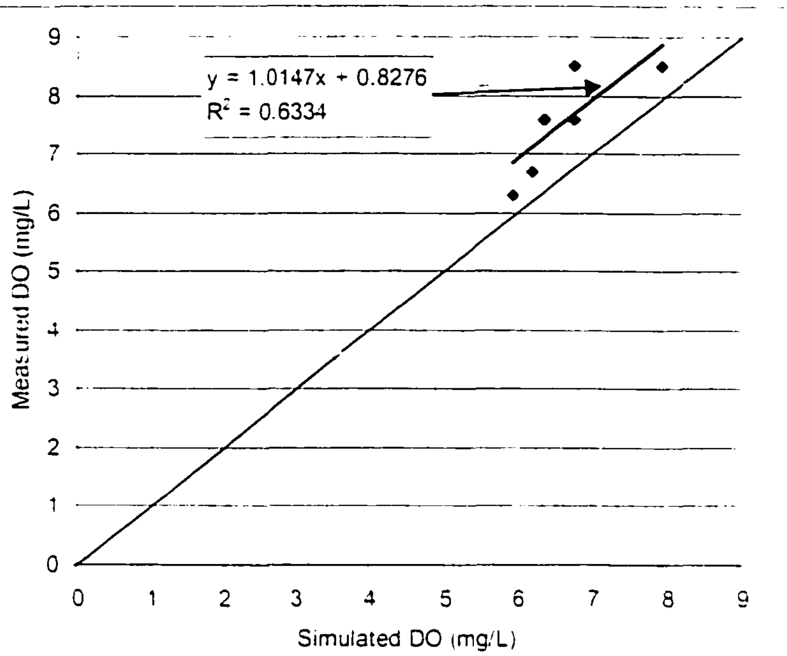

Figure G-24. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

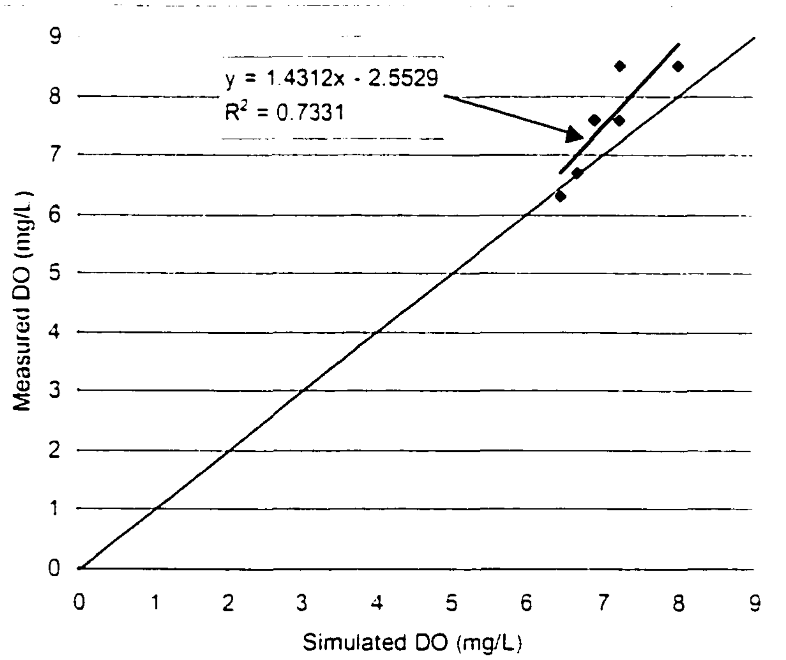

Figure G-25. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

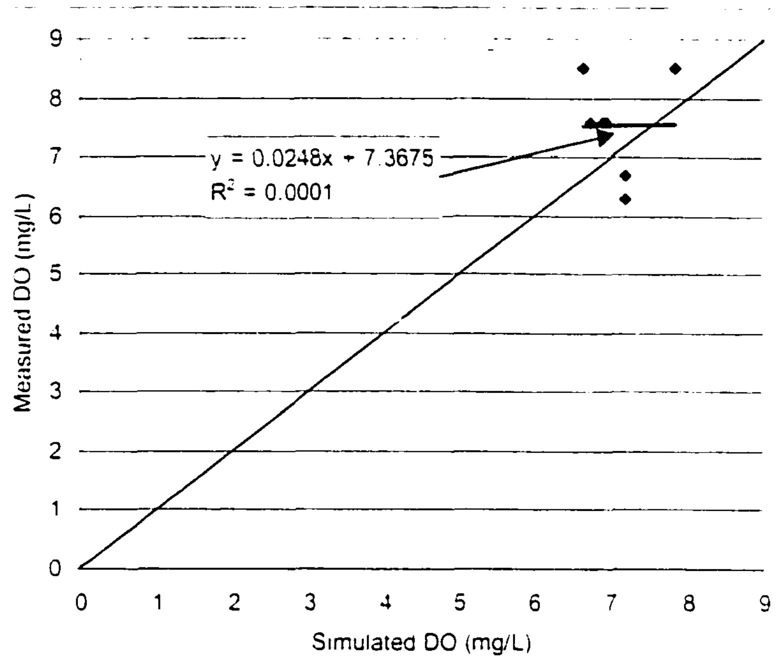

Figure G-26. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

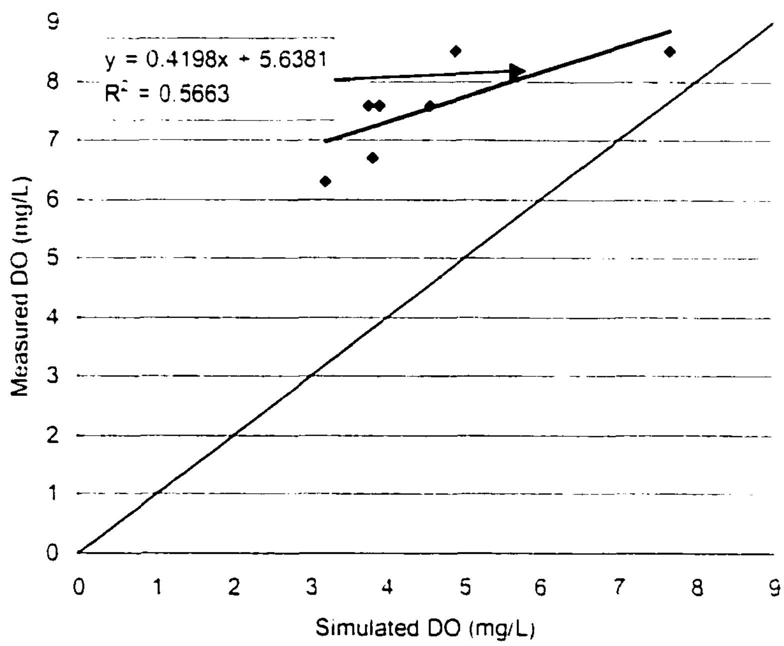

Figure G-27. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

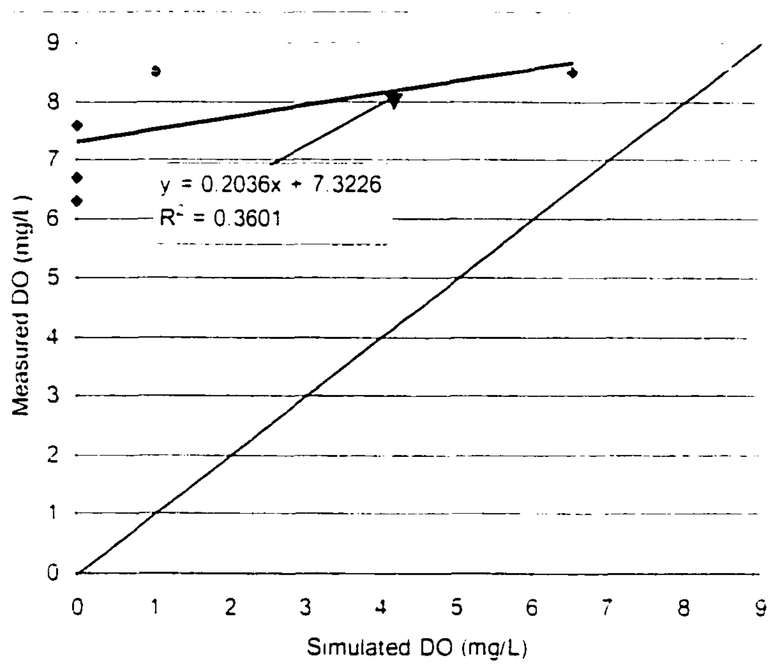

Figure G-28. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO during Calibration 2 (Temp., BOD and DO only Simulation) using March 4, 1986 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

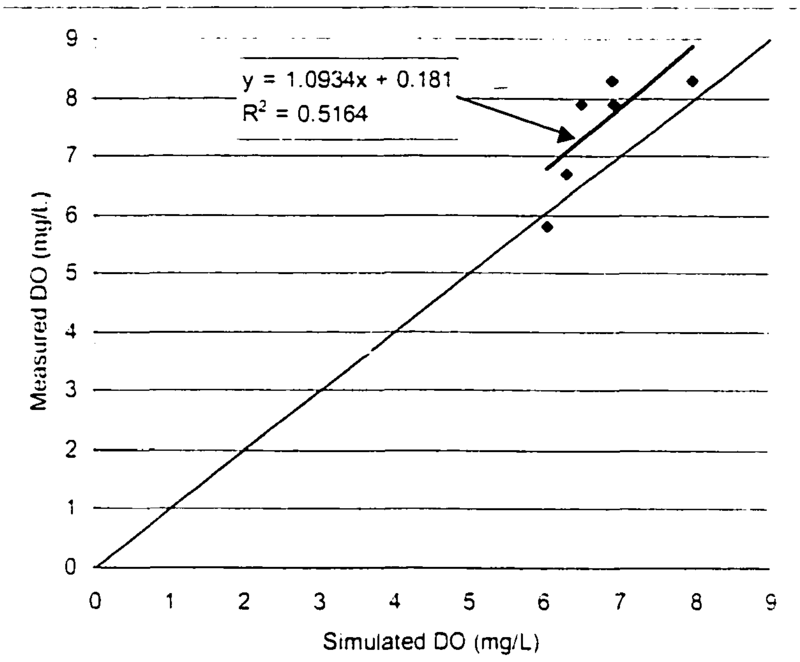

Figure G-29. Regression Analysis: Churchill et al Predictive Equation DO Simulation vs. Measured DO During Validation 2.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

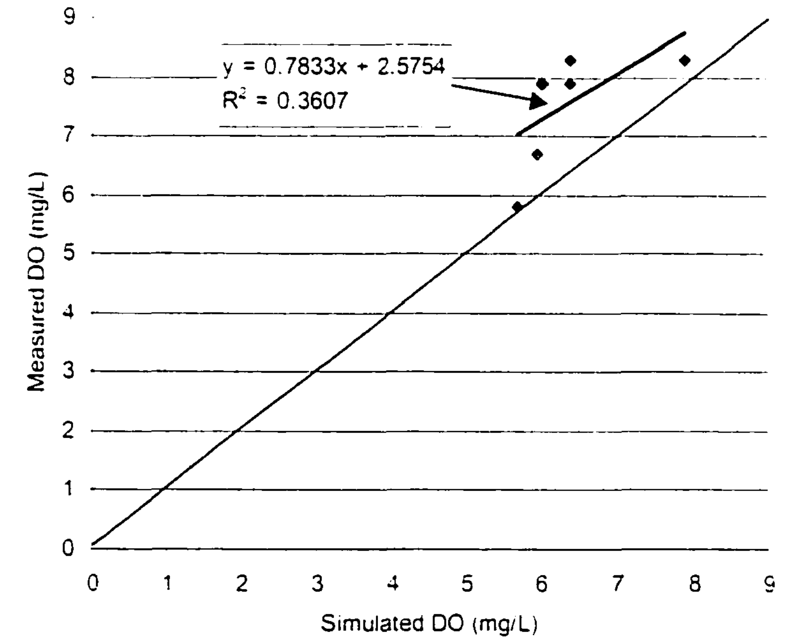

Figure G-30. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO During Validation 2.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

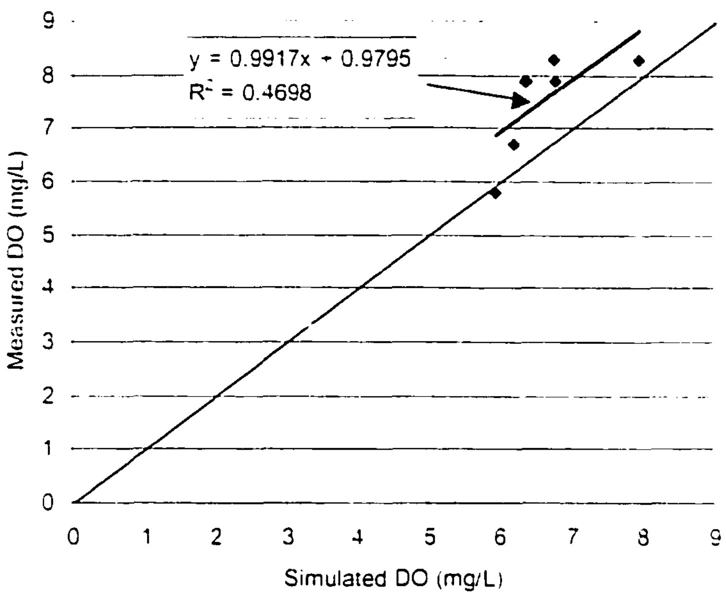

Figure G-31. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO During Validation 2.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

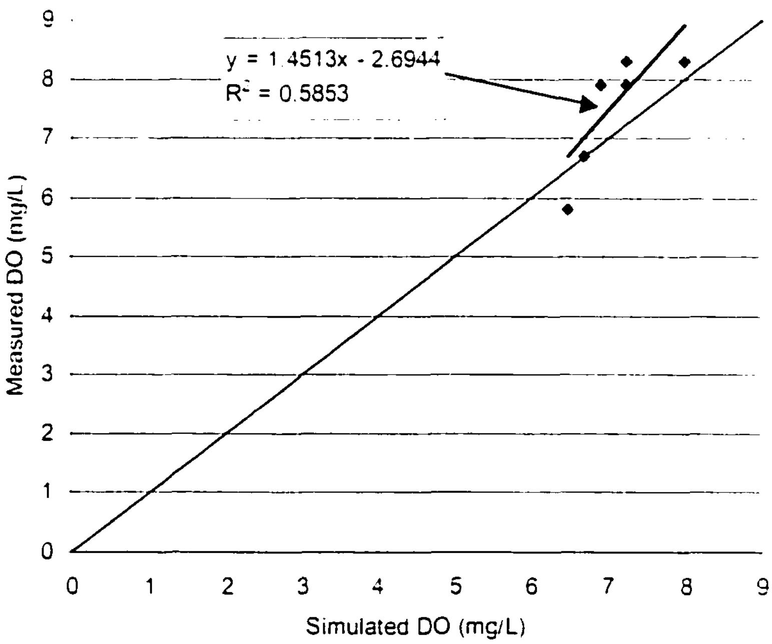

Figure G-32. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO During Validation 2.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

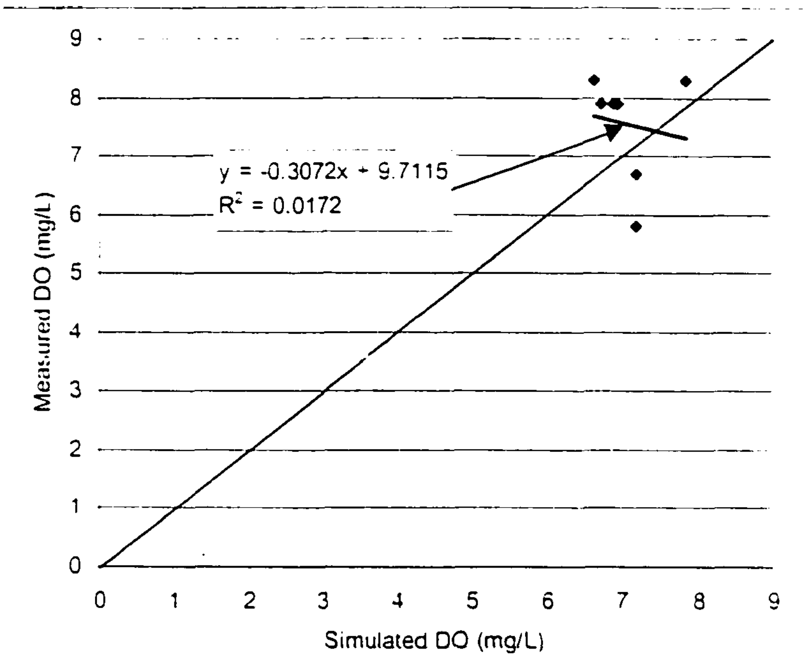

Figure G-33. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO During Validation 2.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

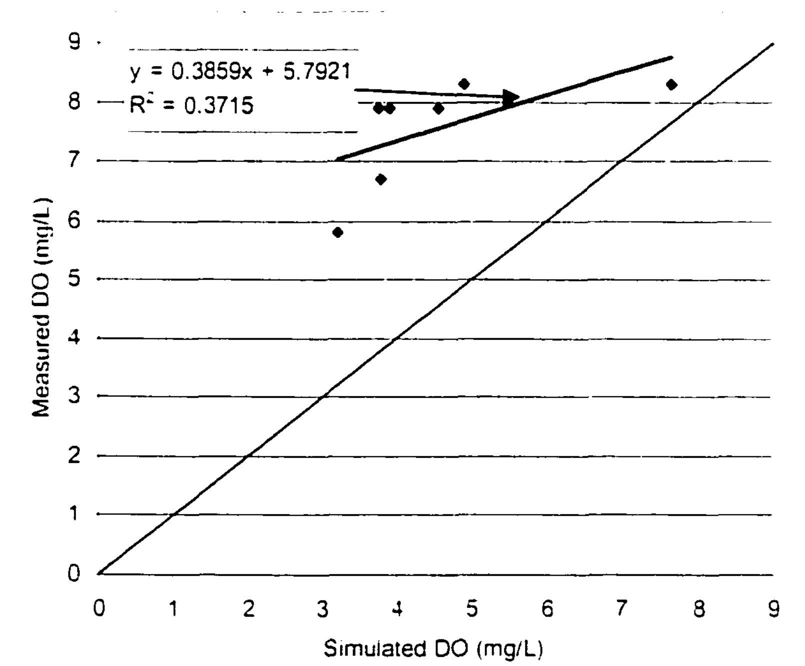

Figure G-34. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO During Validation 2.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

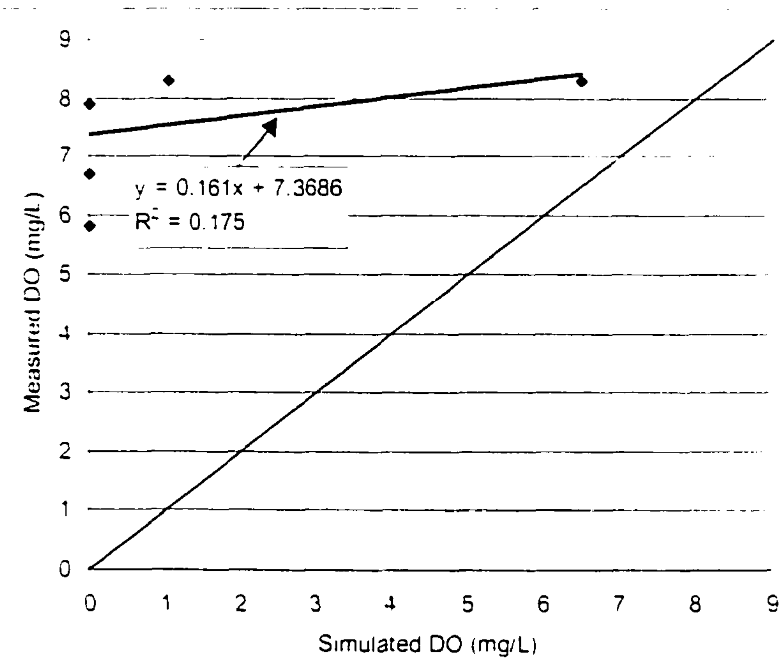

Figure G-35. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO During Validation 2.1 (Temp., BOD and DO only Simulation) using Jan. 13, 1987 Water Quality and 7Q10 Discharge Data (Sg. Selangor, Malaysia)

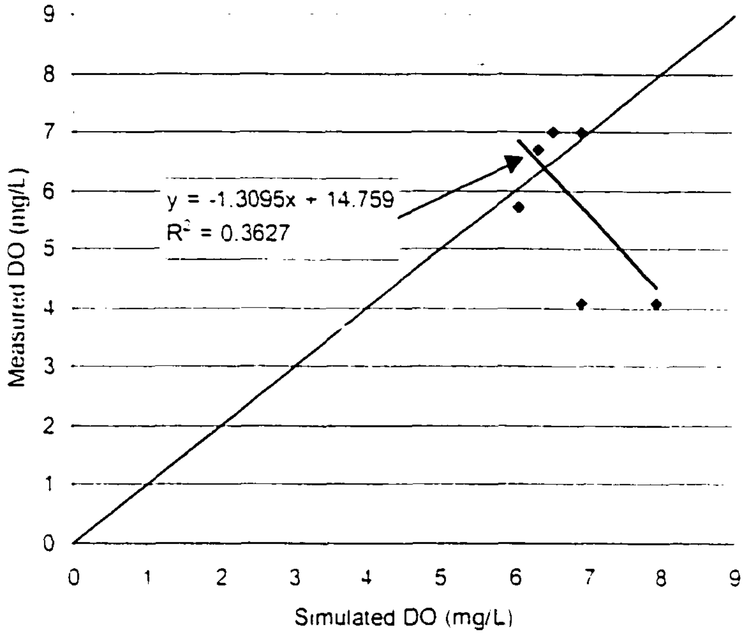

Figure G-36. Regression Analysis: Churchill et al. Predictive Equation Simulated DO vs. Measured DO During Validation 2.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Water Quality and 7Q10 Discharge Data

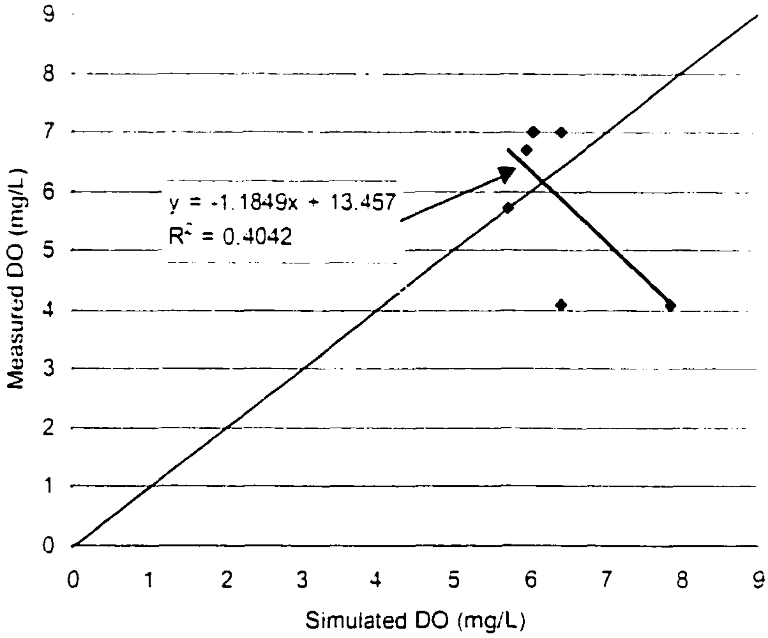

Figure G-37. Regression Analysis: Langbein-Durum Predictive Equation Simulated DO vs. Measured DO During Validation 2.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Water Quality and 7Q10 Discharge Data

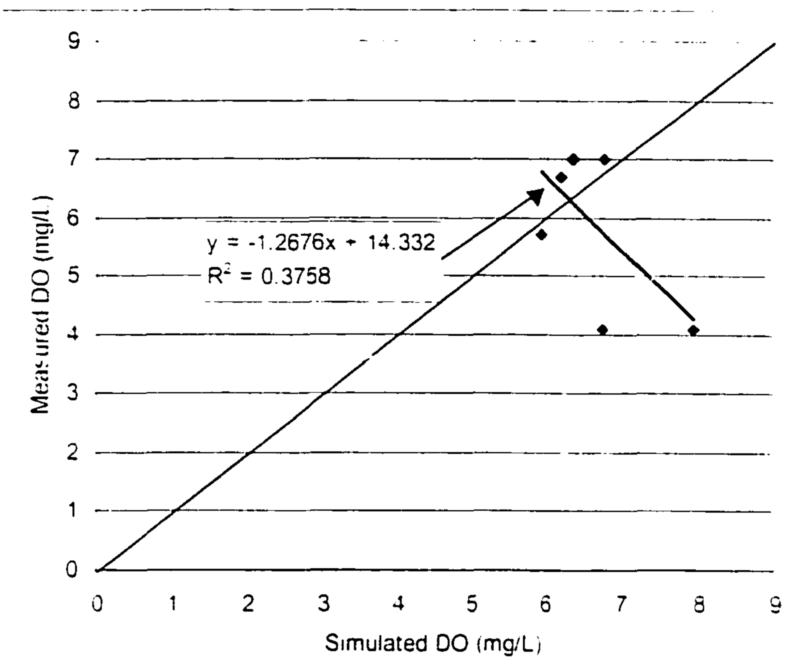

Figure G-38. Regression Analysis: O'Connor-Dobbins Predictive Equation Simulated DO vs. Measured DO During Validation 2.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Water Quality and 7Q10 Discharge Data

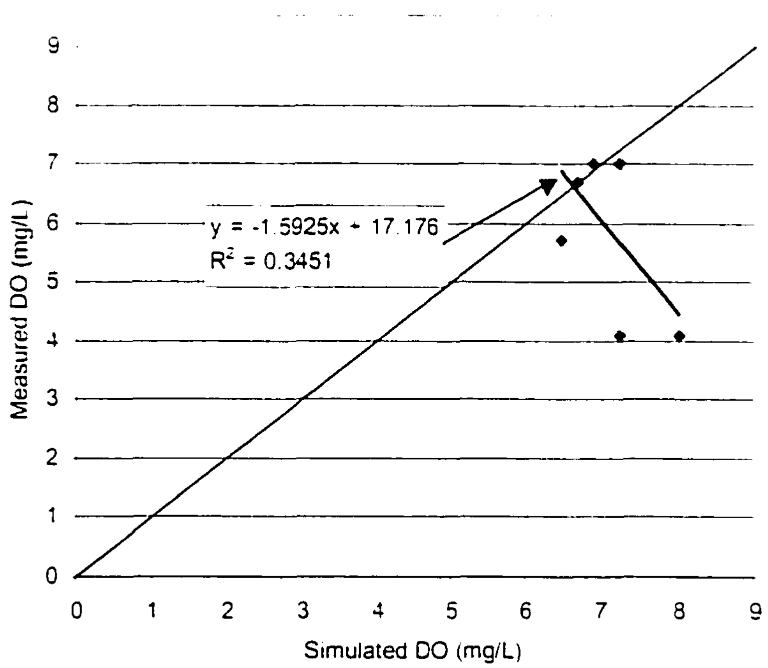

Figure G-39. Regression Analysis: Owens et al. Predictive Equation Simulated DO vs. Measured DO During Validation 2.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Water Quality and 7Q10 Discharge Data

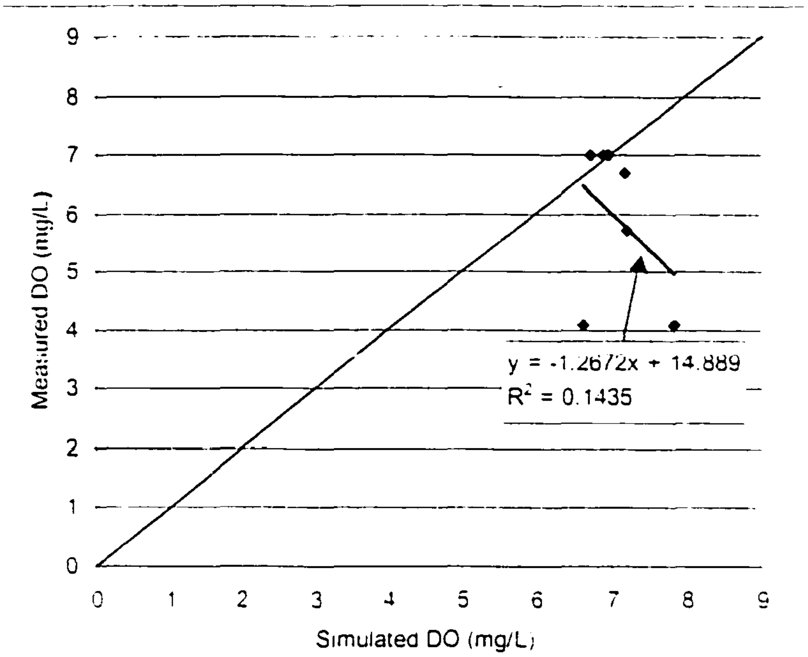

Figure G-40. Regression Analysis: Measured k_2 Simulated DO vs. Measured DO During Validation 2.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Water Quality and 7Q10 Discharge Data

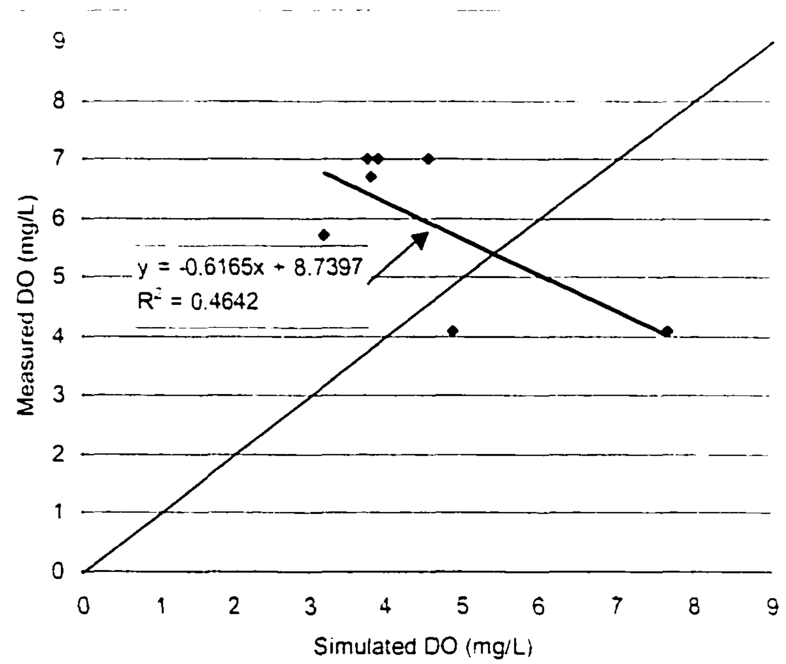

Figure G-41. Regression Analysis: Thackston-Krenkel Predictive Equation Simulated DO vs. Measured DO During Validation 2.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Water Quality and 7Q10 Discharge Data

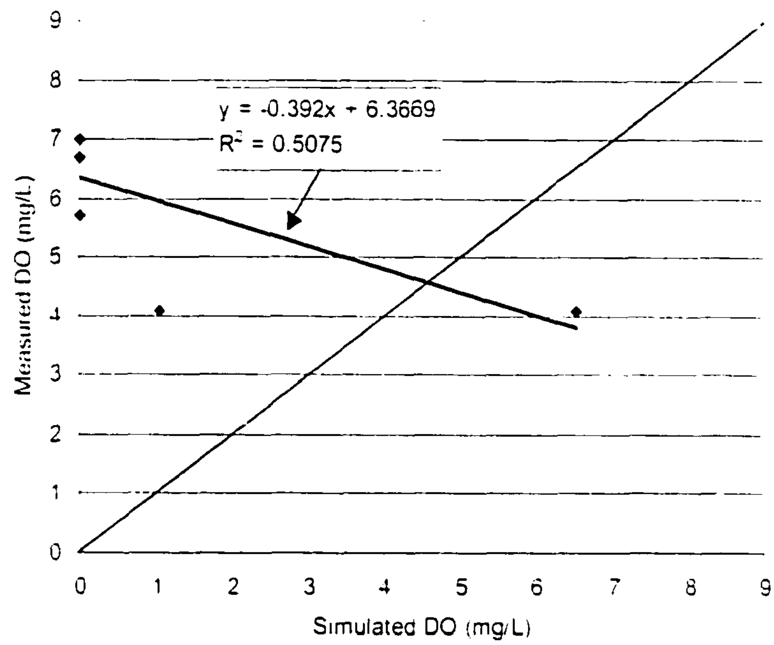

Figure G-42. Regression Analysis: Tsivoglou-Wallace Predictive Equation Simulated DO vs. Measured DO During Validation 2.2 (Temp., BOD and DO only Simulation) using May 17, 1989 Water Quality and 7Q10 Discharge Data

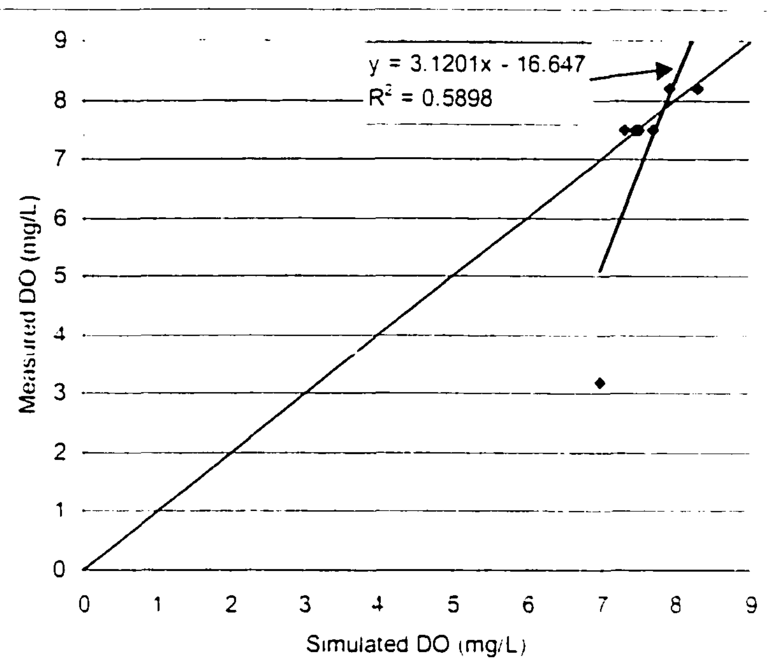

Figure G-43. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 3 (Temp., BOD and DO only Simulation) using Sept. 27, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

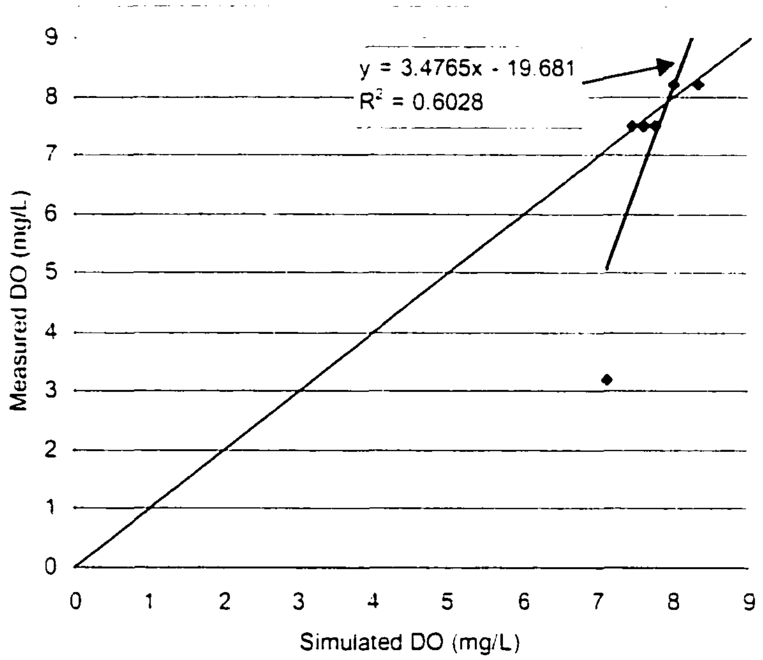

Figure G-44. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO during Calibration 3 (Temp., BOD and DO only Simulation) using Sept. 27, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

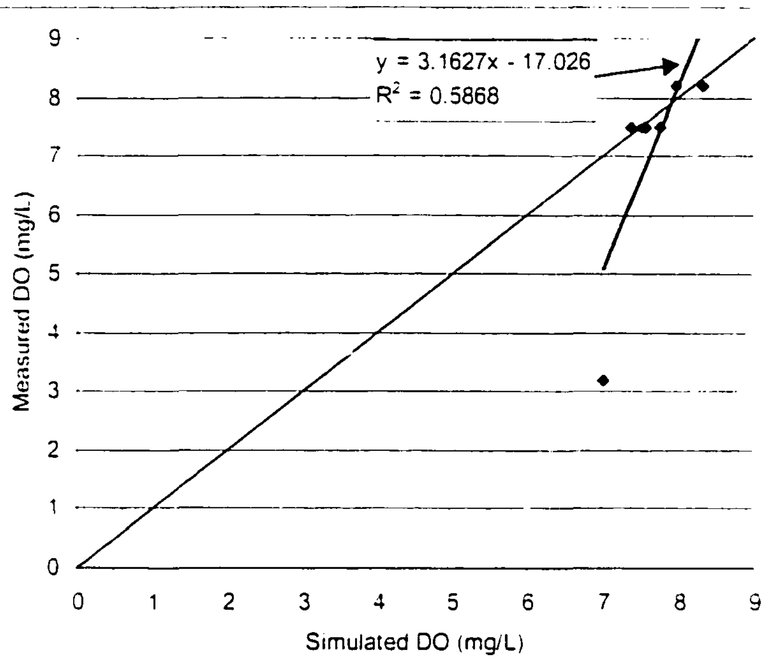

Figure G-45. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO during Calibration 3 (Temp., BOD and DO only Simulation) using Sept. 27, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

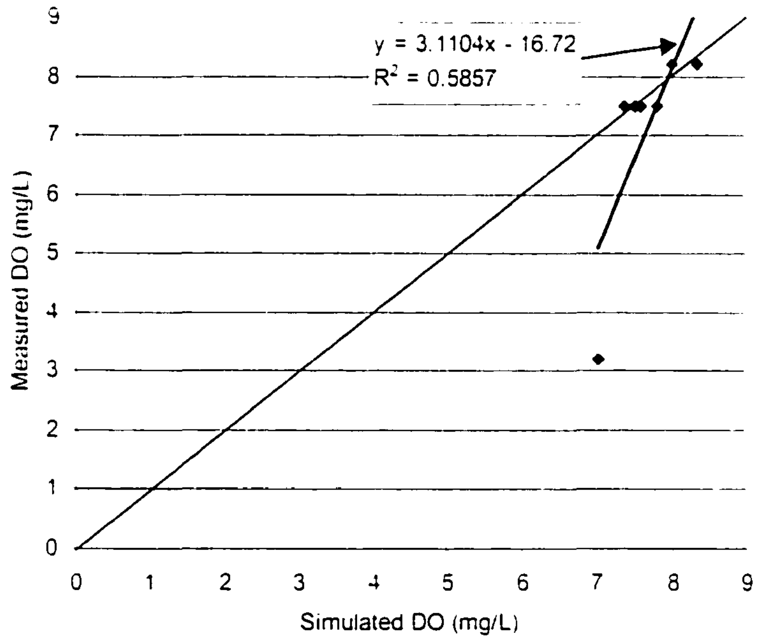

Figure G-46. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO during Calibration 3 (Temp., BOD and DO only Simulation) using Sept. 27, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

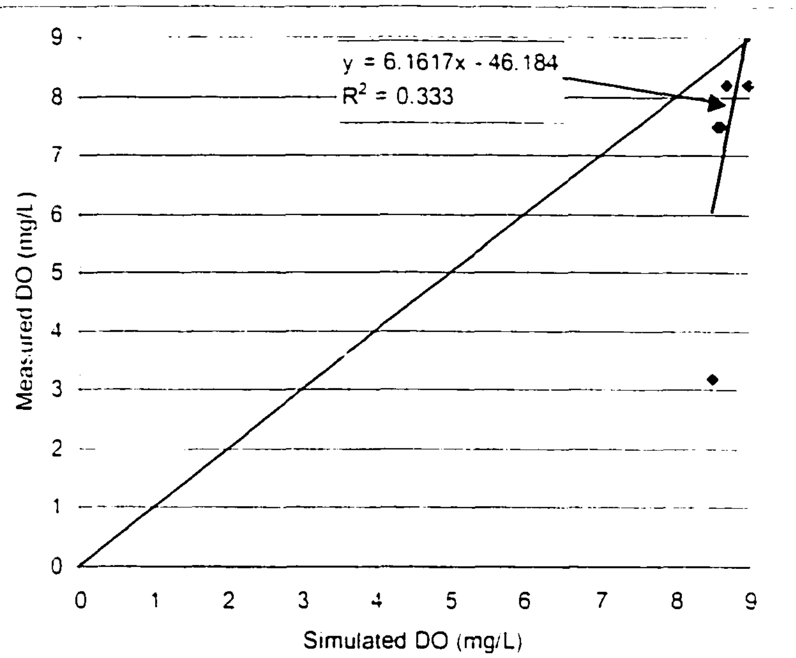

Figure G-47. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO during Calibration 3 (Temp., BOD and DO only Simulation) using Sept. 27, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

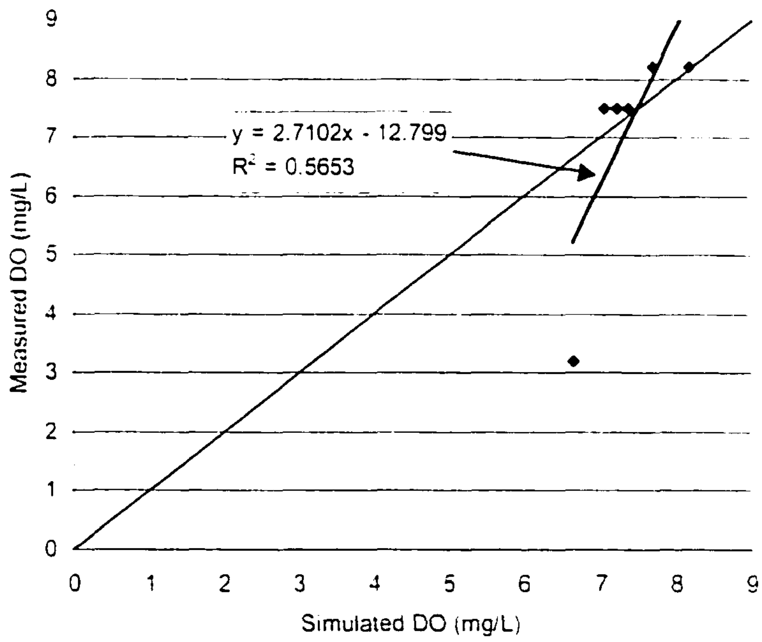

Figure G-48. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO during Calibration 3 (Temp., BOD and DO only Simulation) using Sept. 27, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

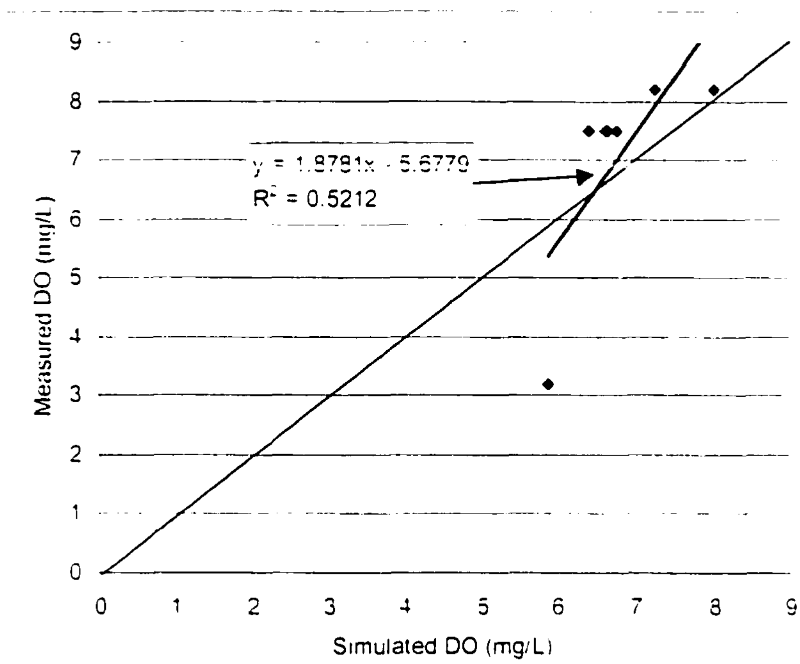

Figure G-49. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO during Calibration 3 (Temp., BOD and DO only Simulation) using Sept. 27, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

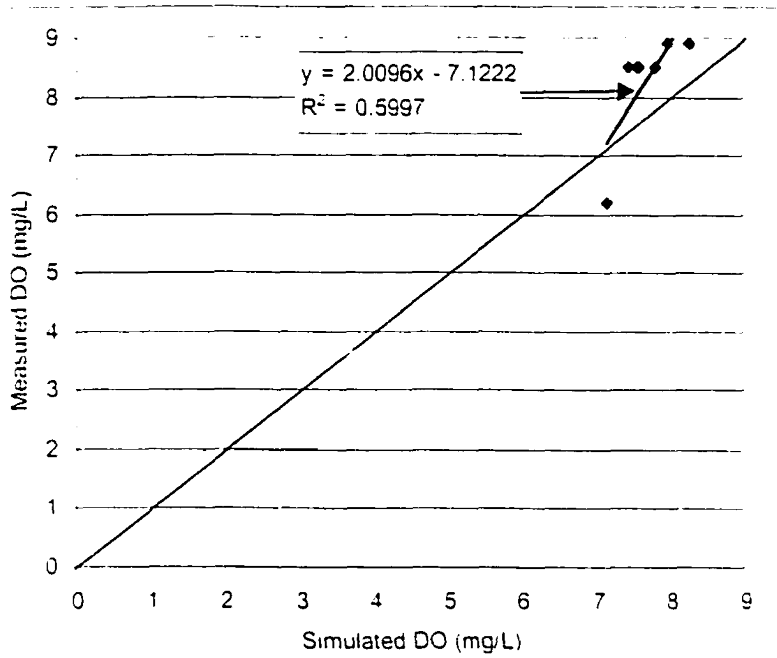

Figure G-50. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO during Validation 3.1 (Temp., BOD and DO only Simulation) using Nov. 14, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

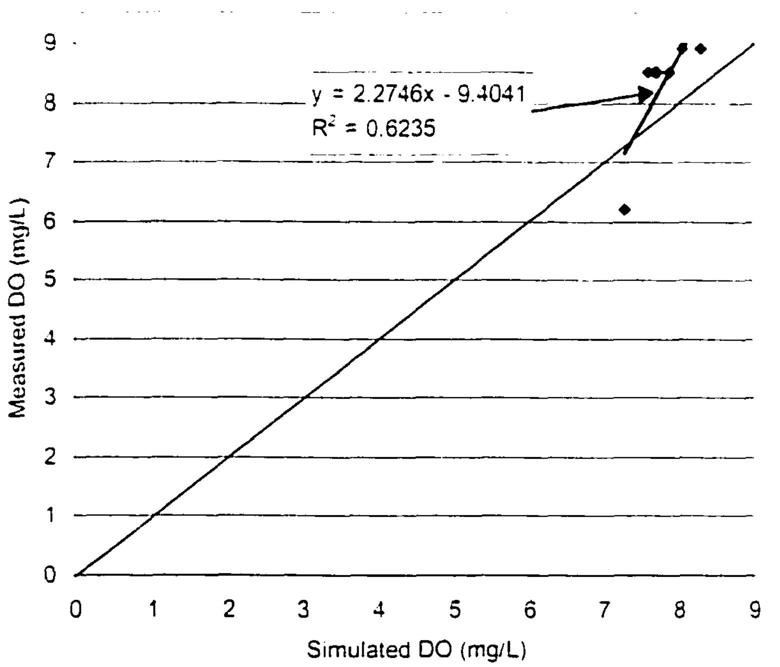

Figure G-51. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO during Validation 3.1 (Temp., BOD and DO only Simulation) using Nov. 14, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

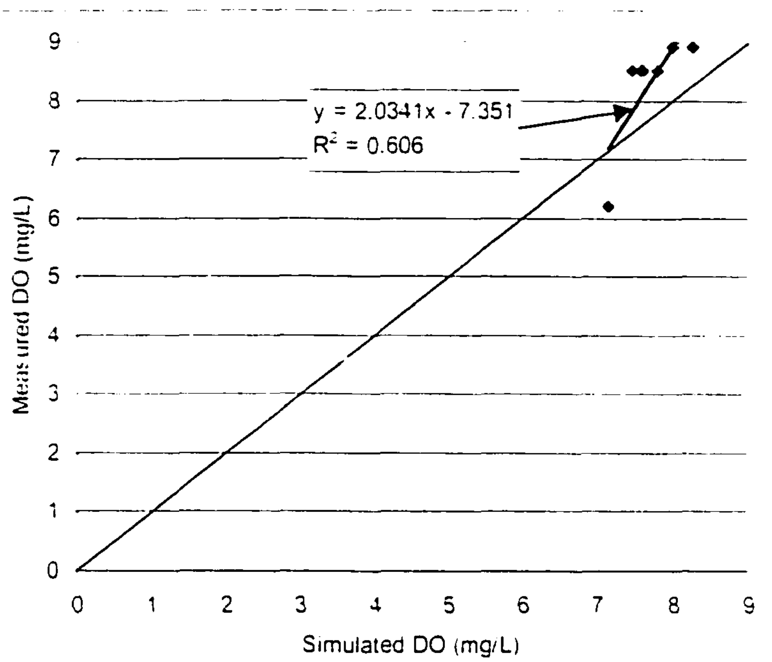

Figure G-52. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO during Validation 3.1 (Temp., BOD and DO only Simulation) using Nov. 14, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

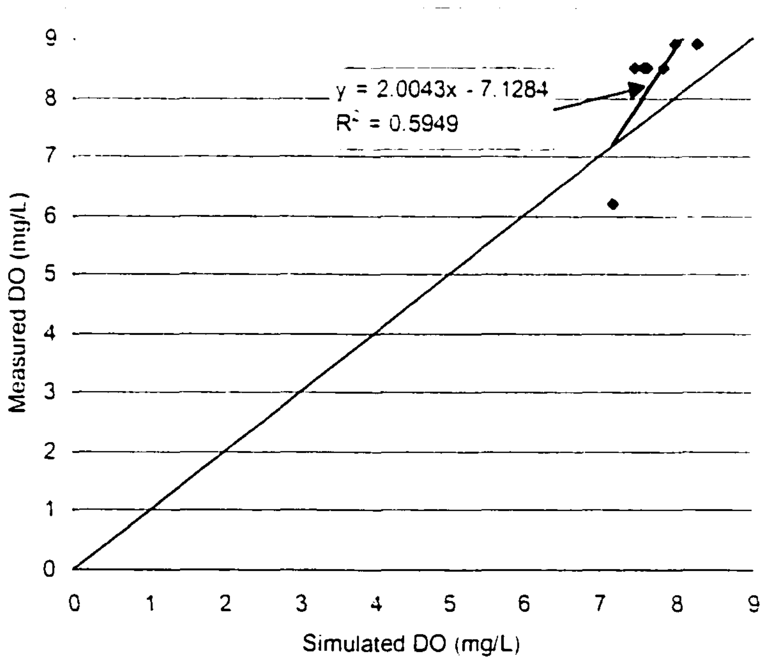

Figure G-53. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO during Validation 3.1 (Temp., BOD and DO only Simulation) using Nov. 14, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

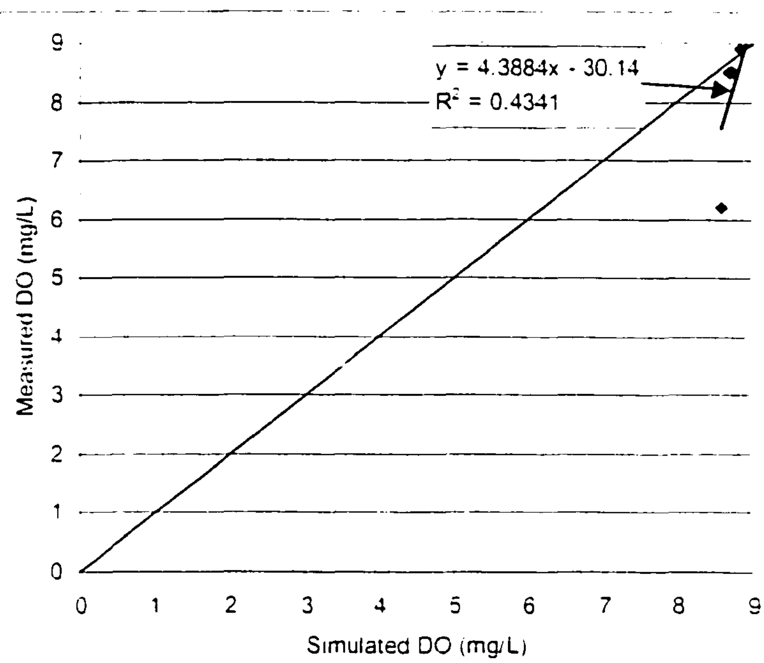

Figure G-54. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO during Validation 3.1 (Temp., BOD and DO only Simulation) using Nov. 14, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

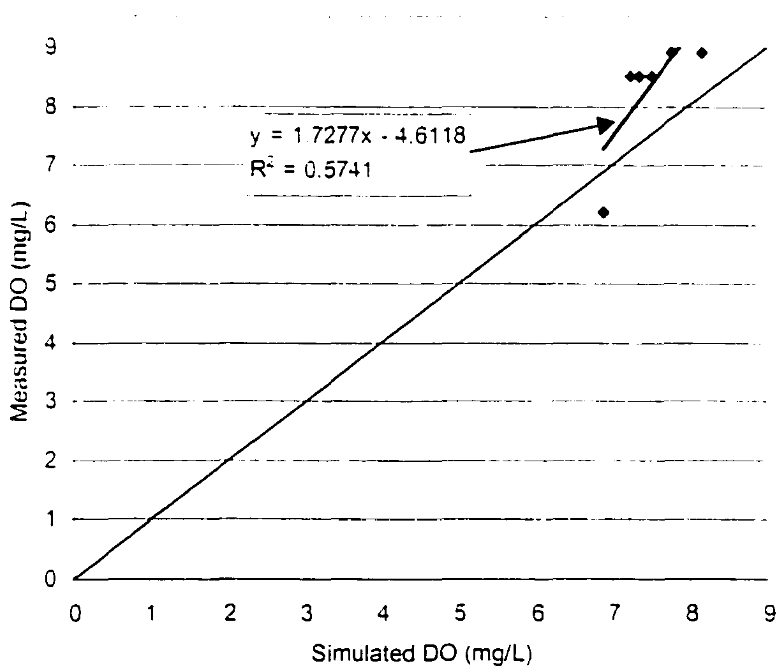

Figure G-55. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO during Validation 3.1 (Temp., BOD and DO only Simulation) using Nov. 14, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

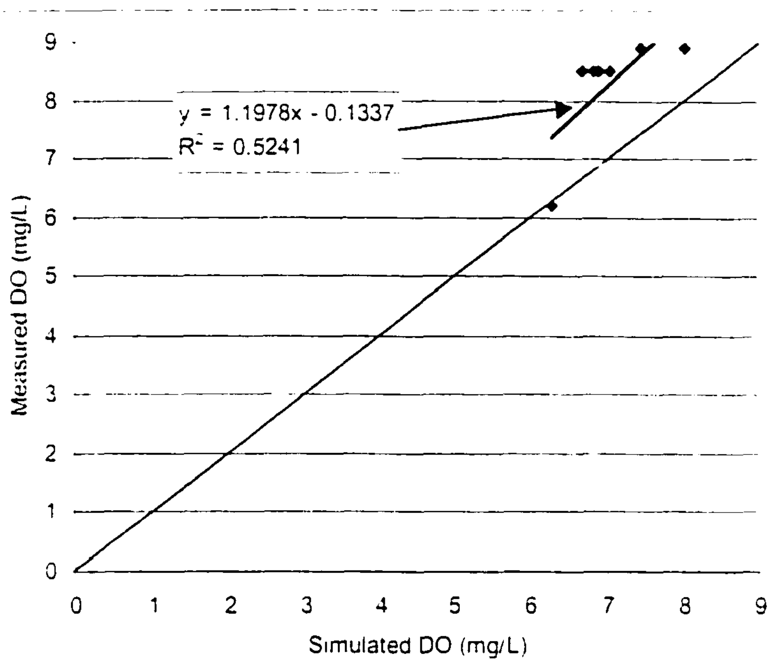

Figure G-56. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO during Validation 3.1 (Temp., BOD and DO only Simulation) using Nov. 14, 1989 Data (High-Flow) (Sg. Selangor, Malaysia)

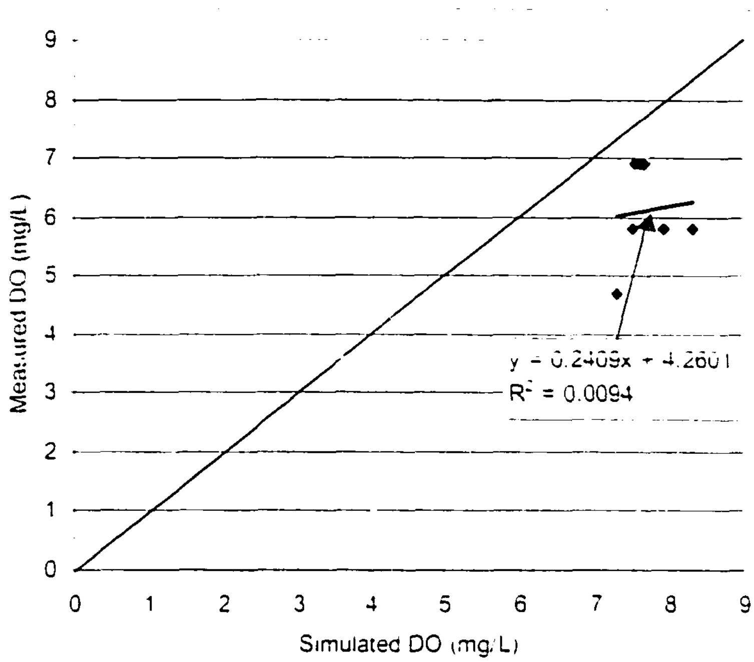

Figure G-57. Regression Analysis: Churchill et al. Predictive Equation DO Simulation vs. Measured DO during Validation 3.2 (Temp., BOD and DO only Simulation) using Nov. 12, 1993 Data (High-Flow) (Sg. Selangor, Malaysia)

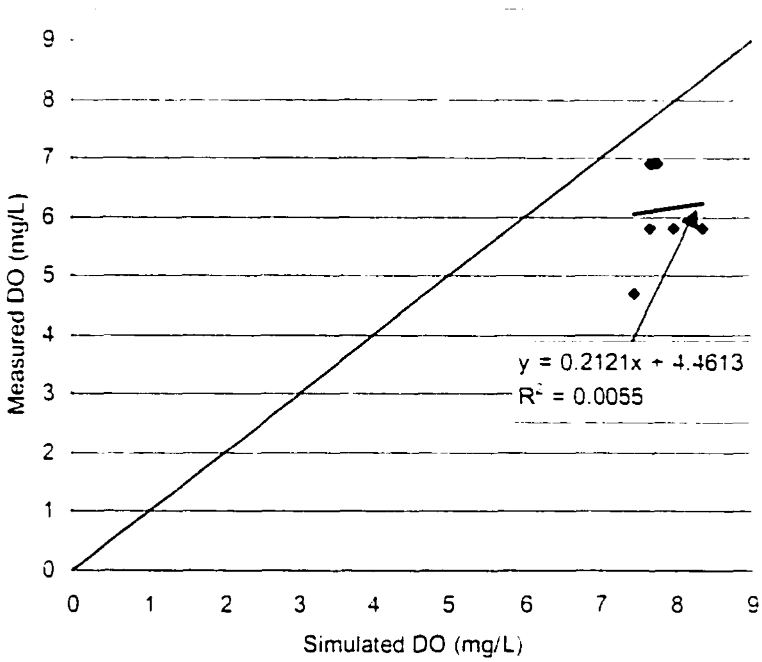

Figure G-58. Regression Analysis: Langbein-Durum Predictive Equation DO Simulation vs. Measured DO during Validation 3.2 (Temp., BOD and DO only Simulation) using Nov. 12, 1993 Data (High-Flow) (Sg. Selangor, Malaysia)

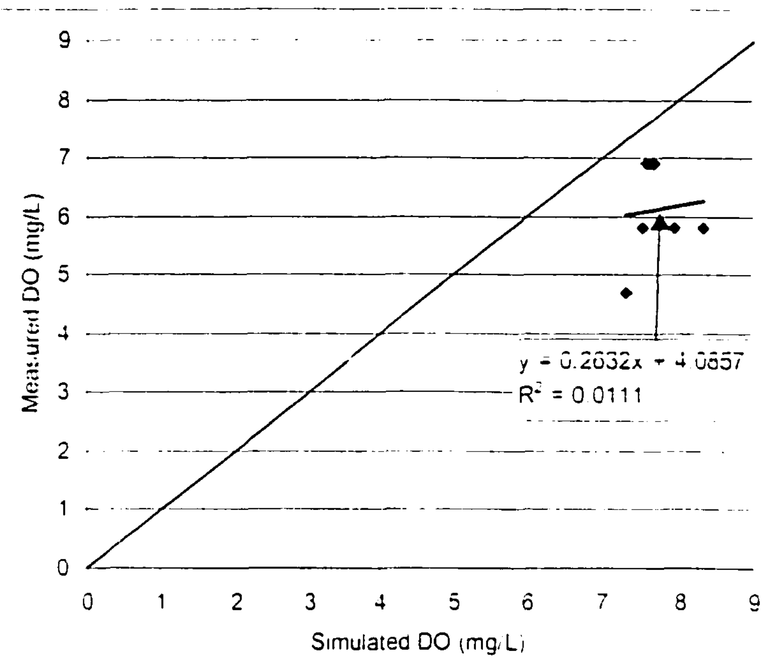

Figure G-59. Regression Analysis: O'Connor-Dobbins Predictive Equation DO Simulation vs. Measured DO during Validation 3.2 (Temp., BOD and DO only Simulation) using Nov. 12, 1993 Data (High-Flow) (Sg. Selangor, Malaysia)

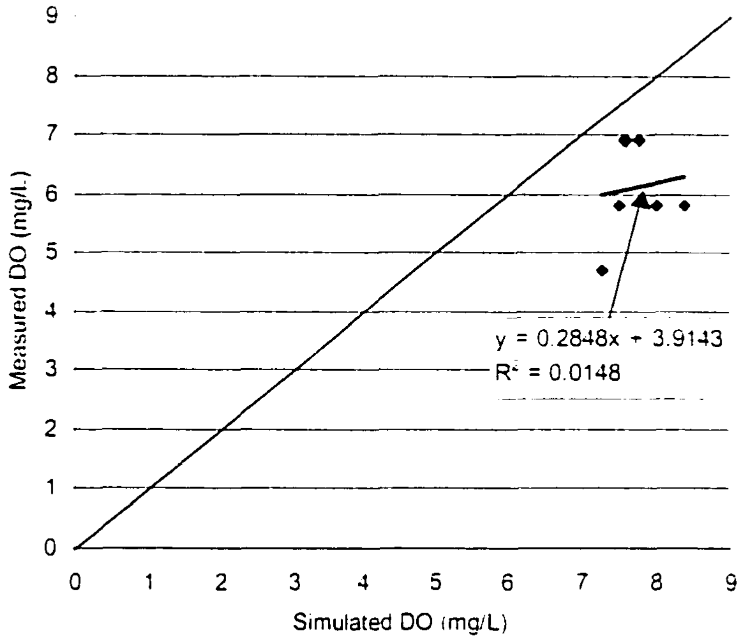

Figure G-60. Regression Analysis: Owens et al. Predictive Equation DO Simulation vs. Measured DO during Validation 3.2 (Temp., BOD and DO only Simulation) using Nov. 12, 1993 Data (High-Flow) (Sg. Selangor, Malaysia)

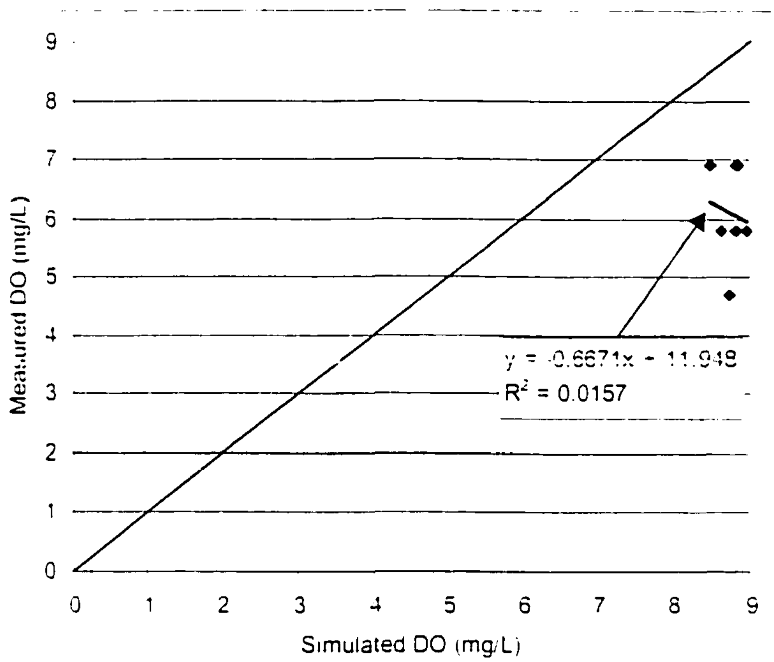

Figure G-61. Regression Analysis: Measured k_2 DO Simulation vs. Measured DO during Validation 3.2 (Temp., BOD and DO only Simulation) using Nov. 12, 1993 Data (High-Flow) (Sg. Selangor, Malaysia)

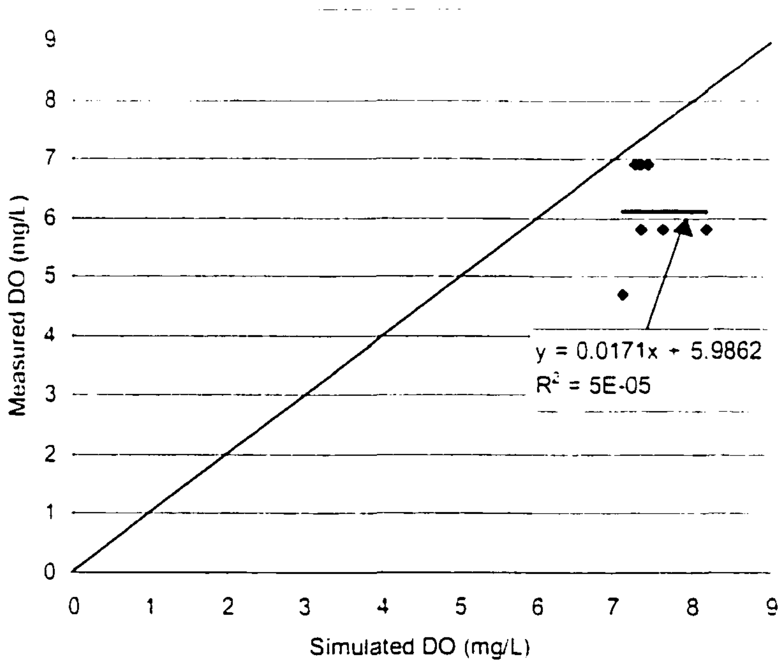

Figure G-62. Regression Analysis: Thackston-Krenkel Predictive Equation DO Simulation vs. Measured DO during Validation 3.2 (Temp., BOD and DO only Simulation) using Nov. 12, 1993 Data (High-Flow) (Sg. Selangor, Malaysia)

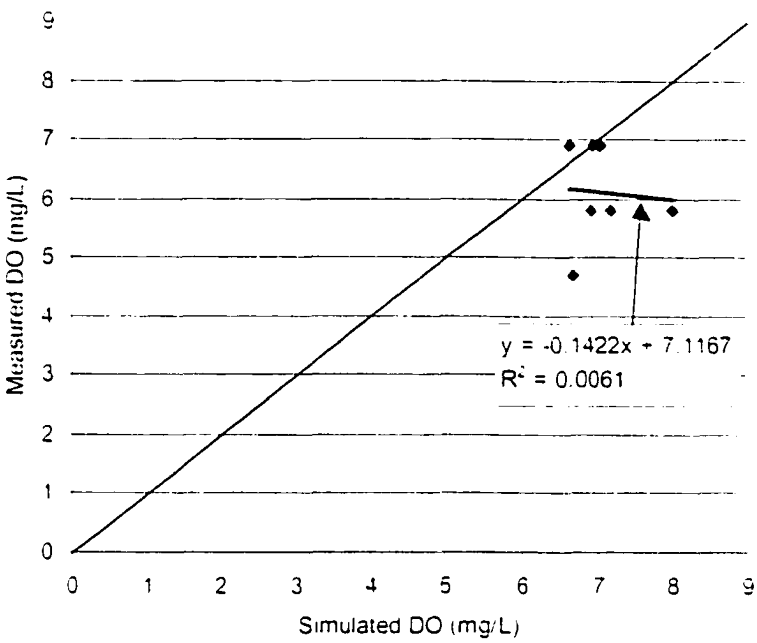

Figure G-63. Regression Analysis: Tsivoglou-Wallace Predictive Equation DO Simulation vs. Measured DO during Validation 3.2 (Temp., BOD and DO only Simulation) using Nov. 12, 1993 Data (High-Flow) (Sg. Selangor, Malaysia)

APPENDIX H

Comparison of Predicted to Measured Dissolved Oxygen Results by Main-Stem Reaches (Sg. Selangor River, Malaysia)

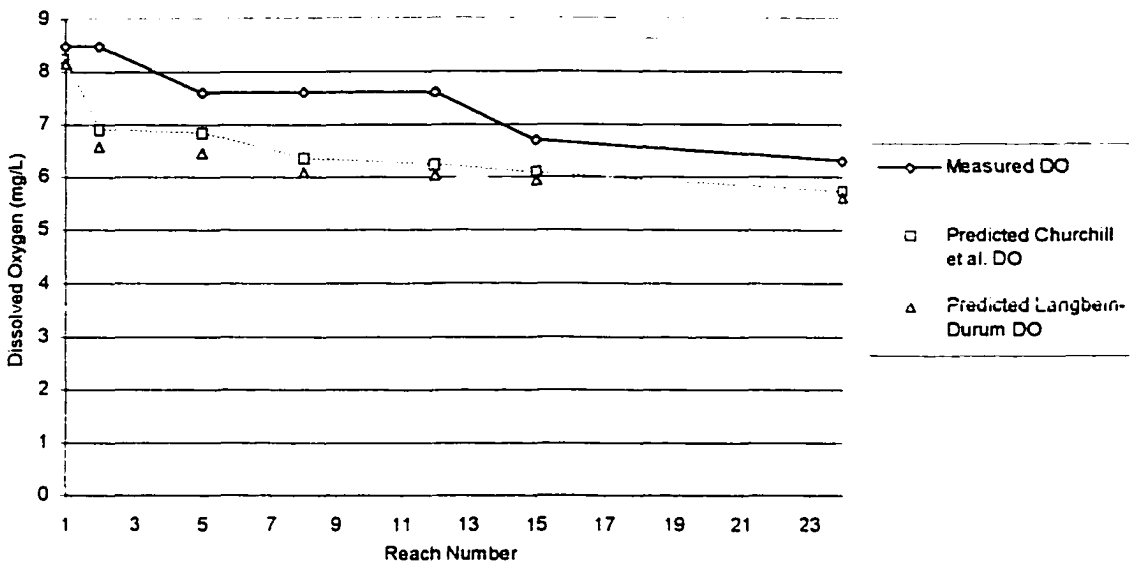

Figure H-1. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

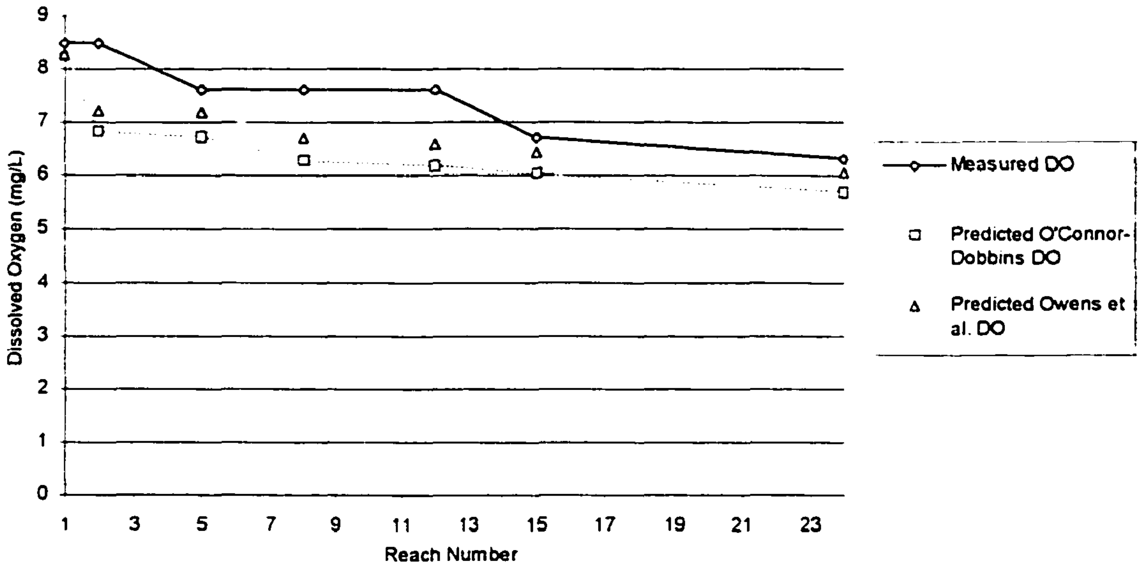

Figure H-2. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

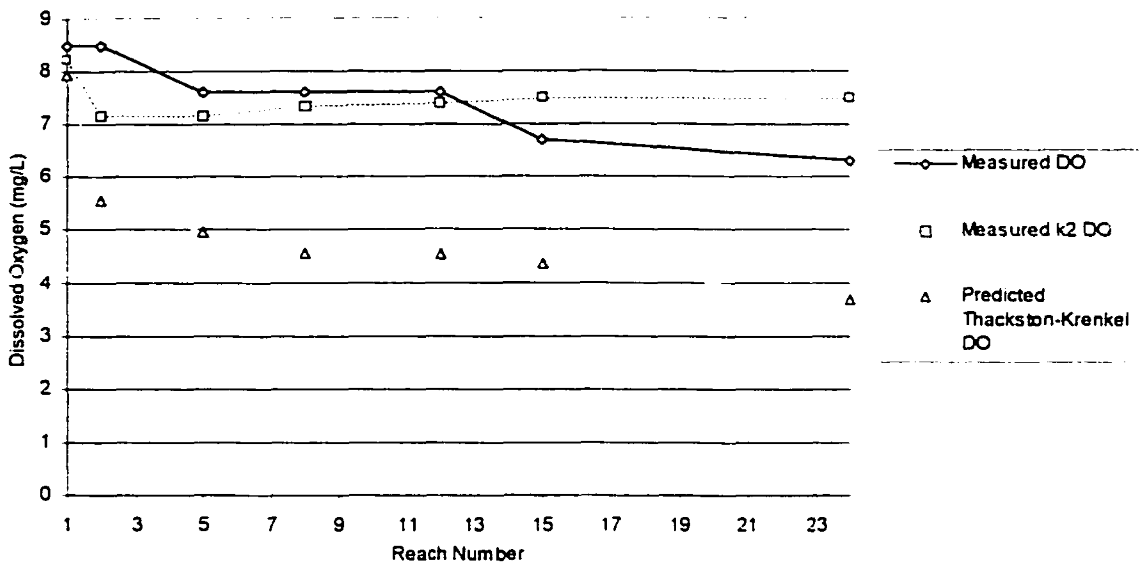

Figure H-3. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

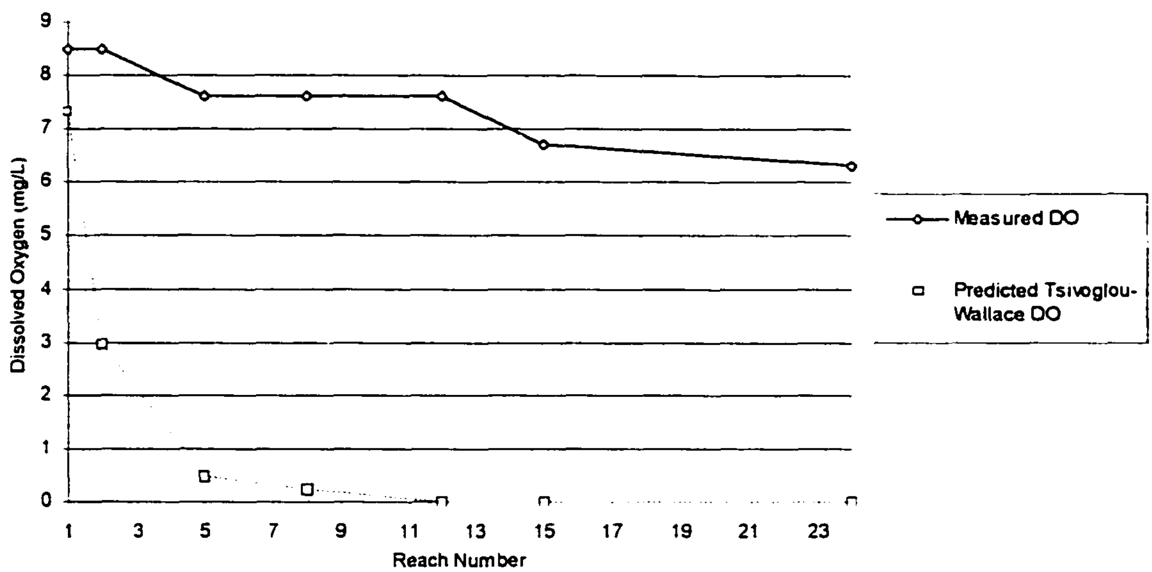

Figure H-4. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 1 (March 4, 1986 Data)

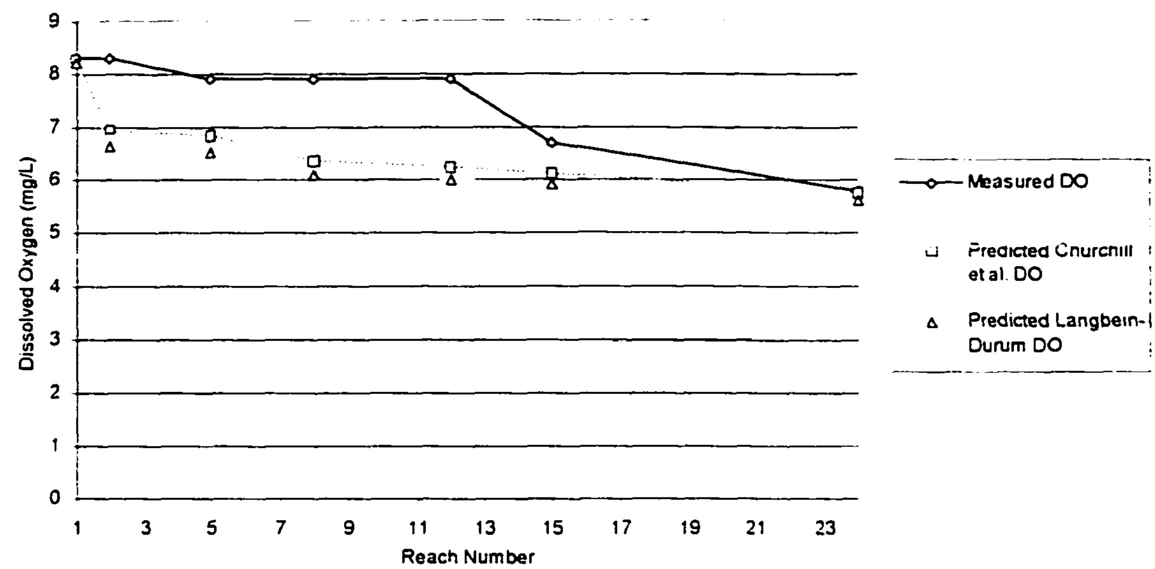

Figure H-5. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.1 (Jan. 13, 1987 Data)

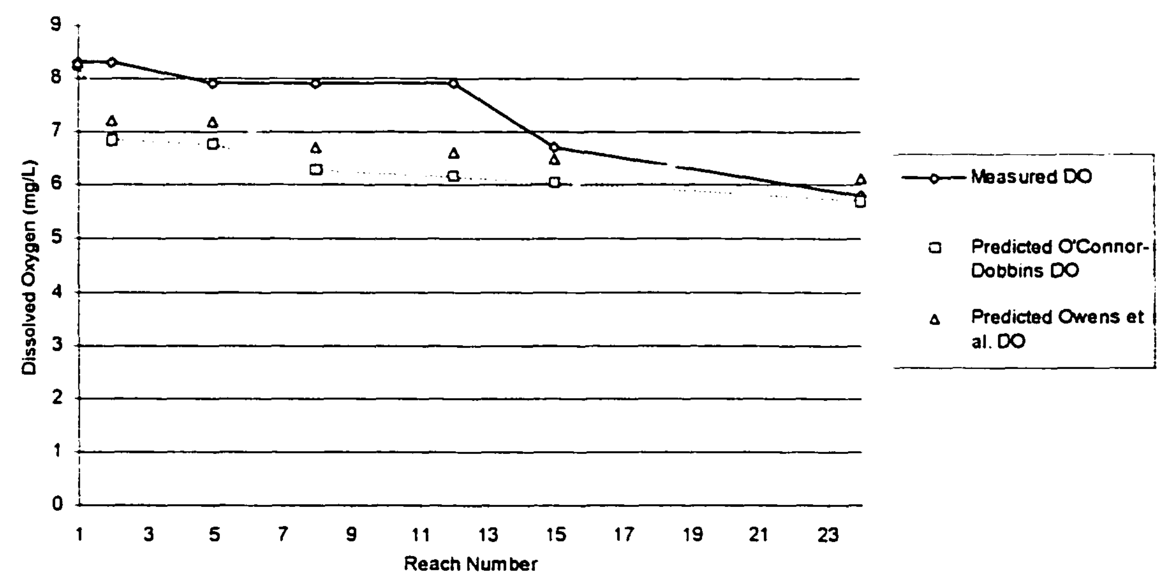

Figure H-6. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.1 (Jan. 13, 1987 Data)

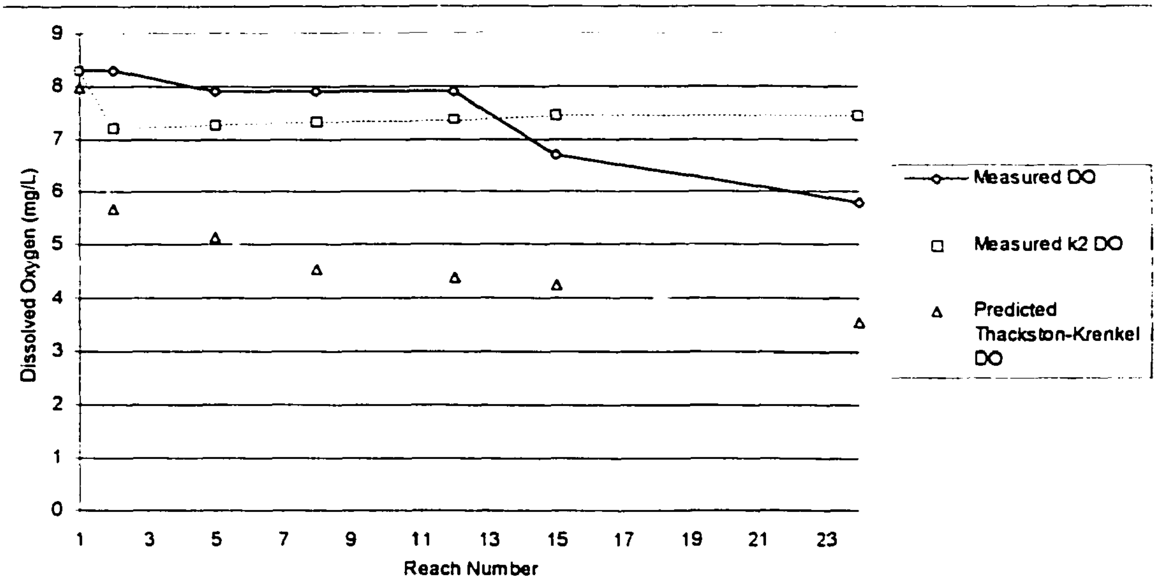

Figure H-7. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.1 (Jan. 13, 1987 Data)

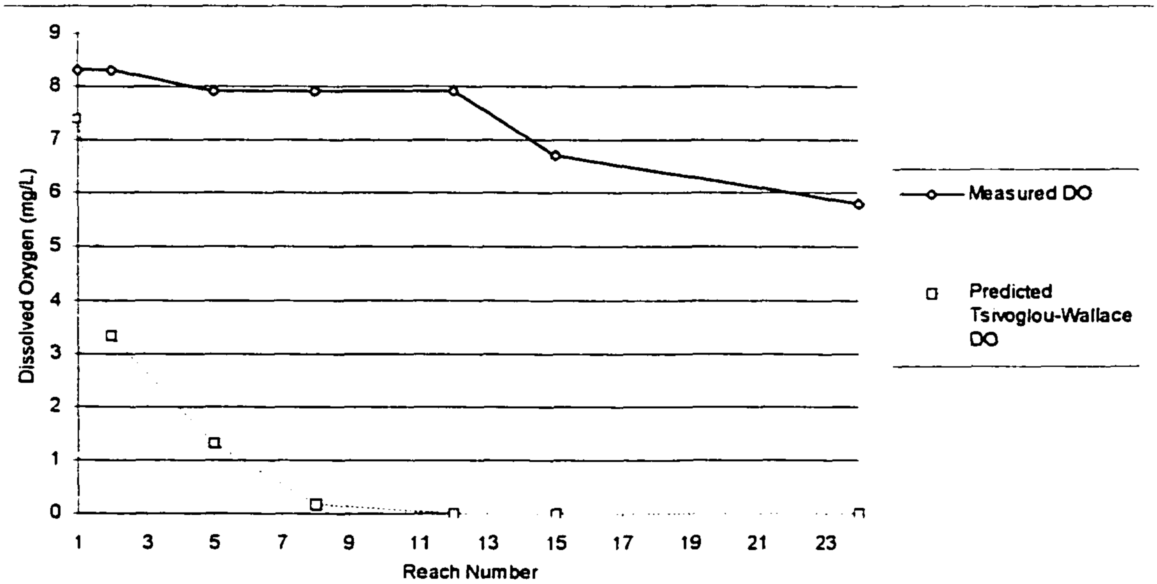

Figure H-8. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.1 (Jan. 13, 1987 Data)

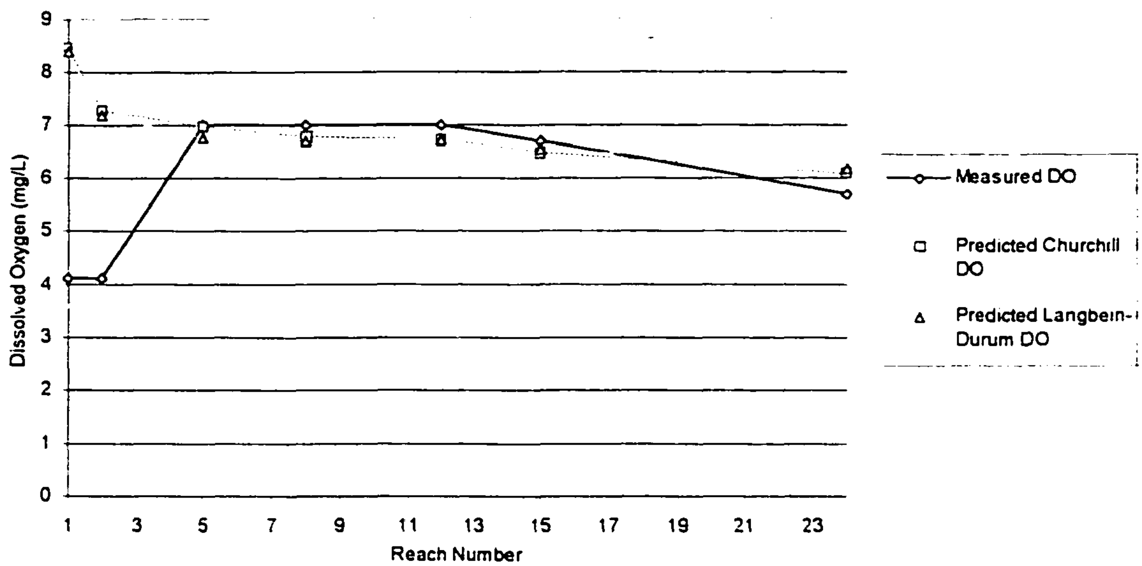

Figure H-9. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.2 (May 17, 1989 Data)

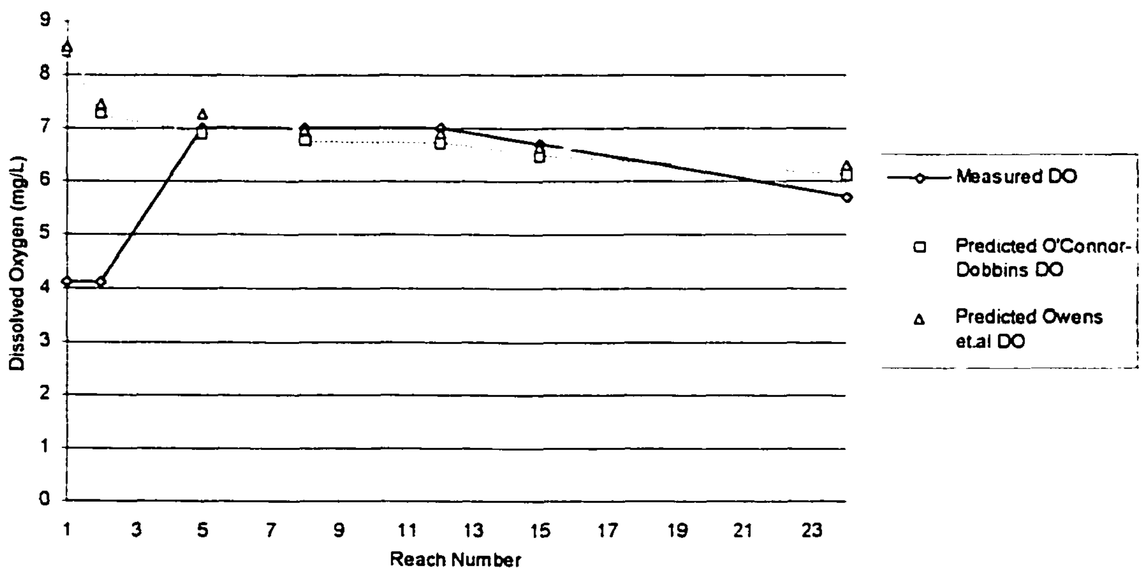

Figure H-10. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.2 (May 17, 1989 Data)

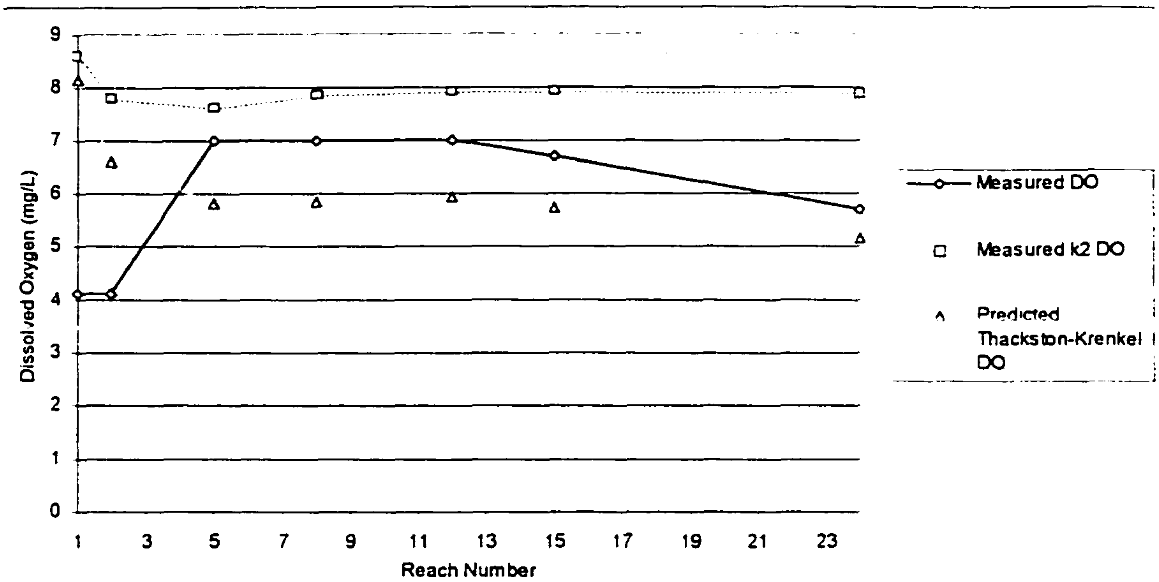

Figure H-11. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.2 (May 17, 1989 Data)

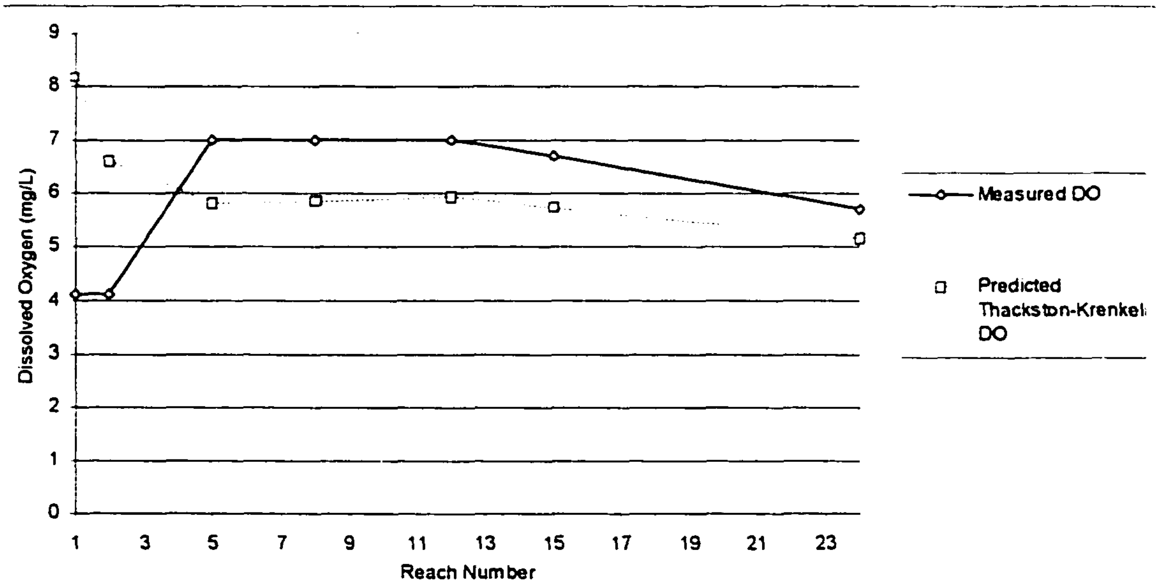

Figure H-12. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 1.2 (May 17, 1989 Data)

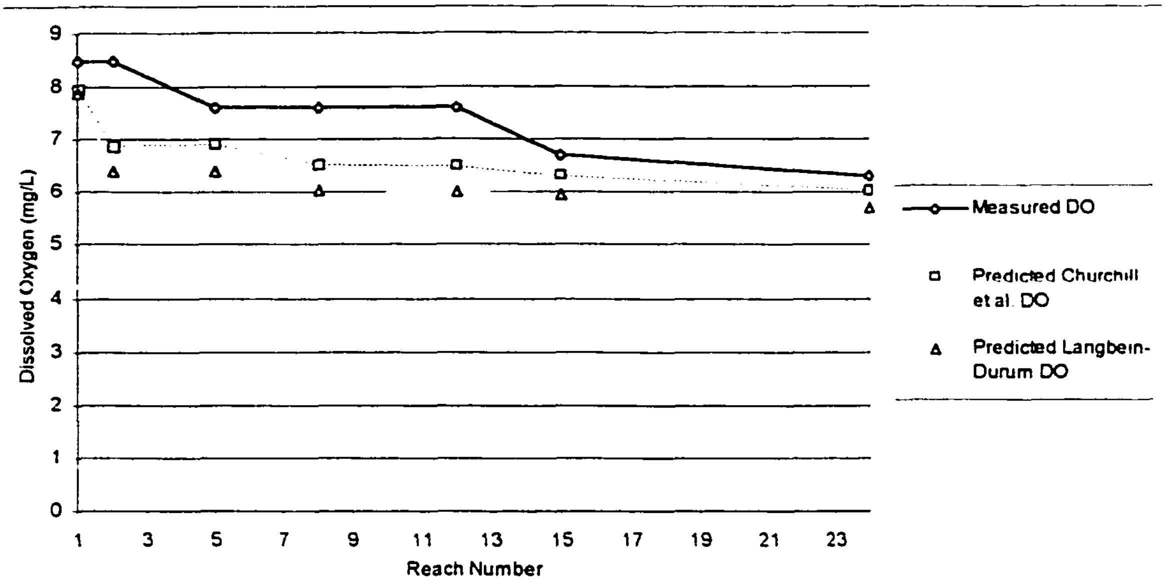

Figure H-13. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

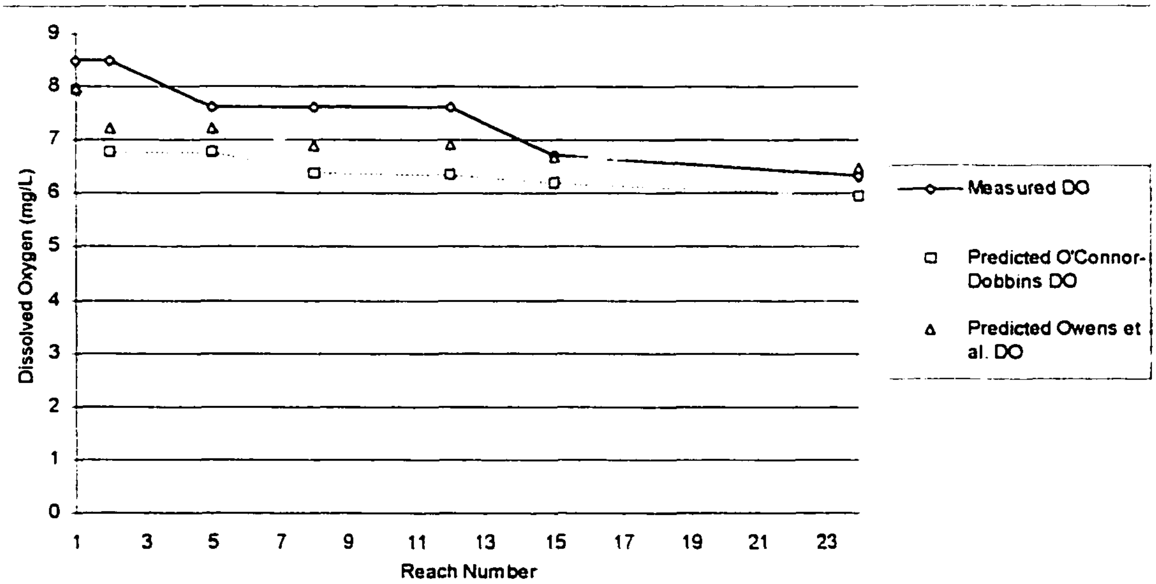

Figure H-14. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

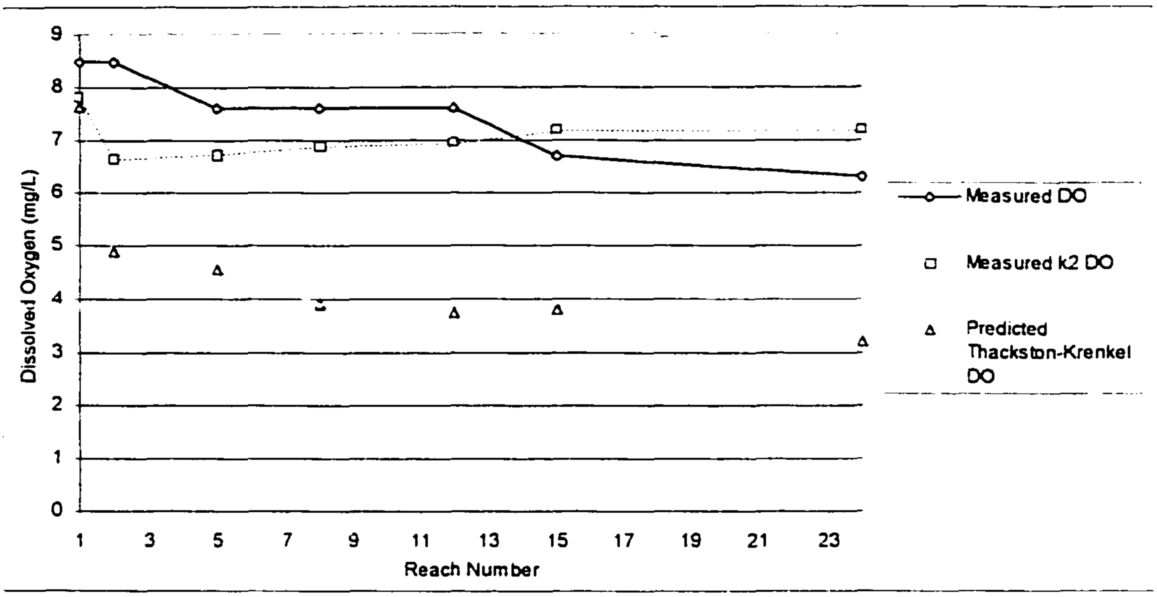

Figure H-15. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

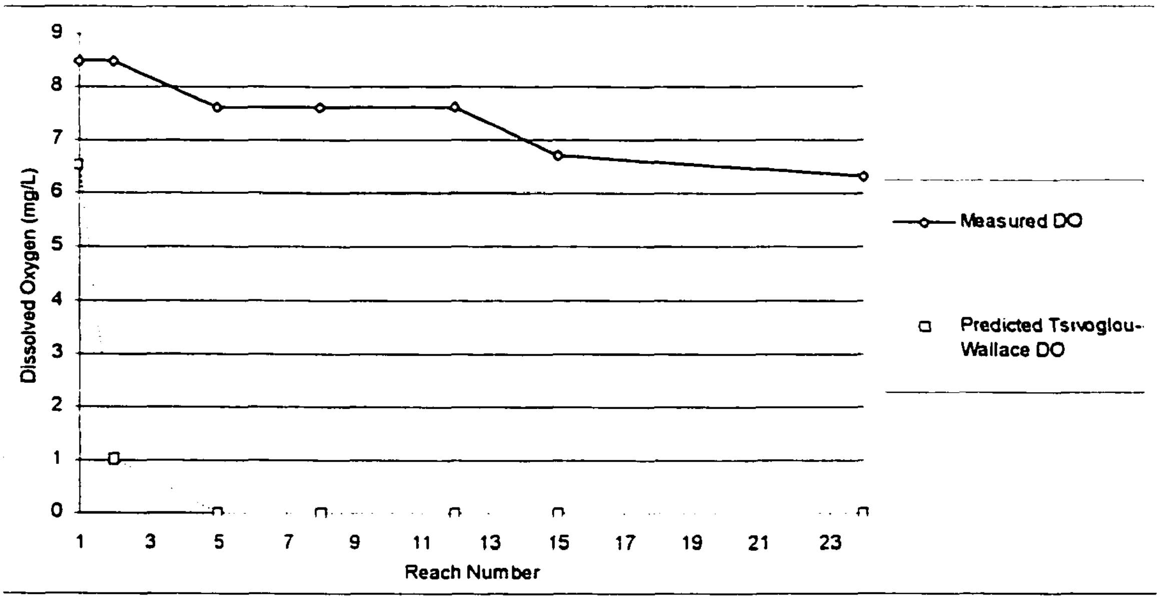

Figure H-16. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 2 (March 4, 1986 Water Quality Data and 7Q10 Discharge)

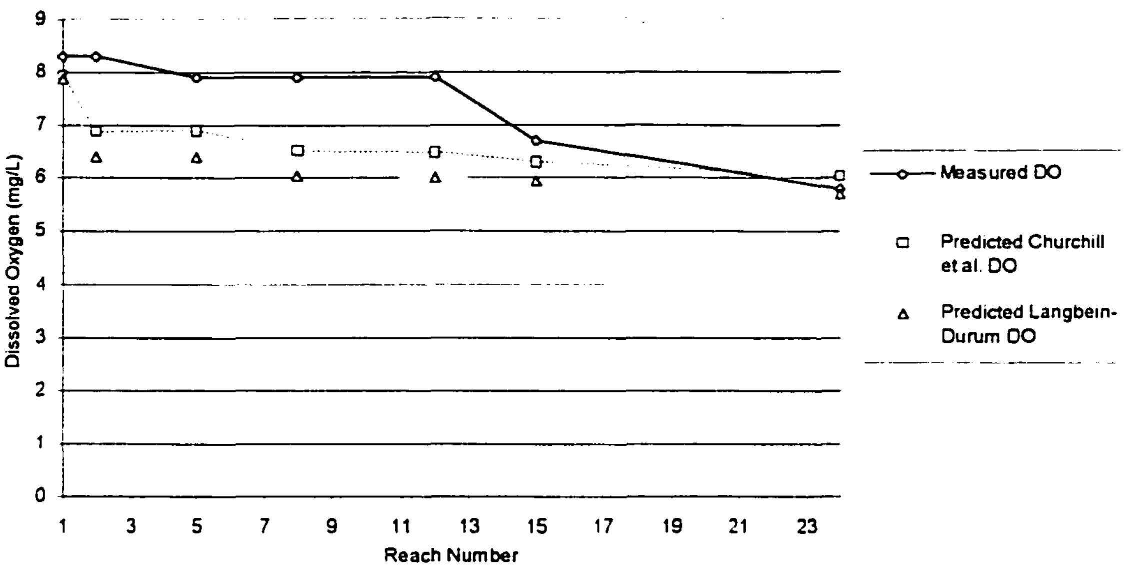

Figure H-17. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.1 (Jan. 13, 1987 Water Quality Data and 7Q10 Discharge)

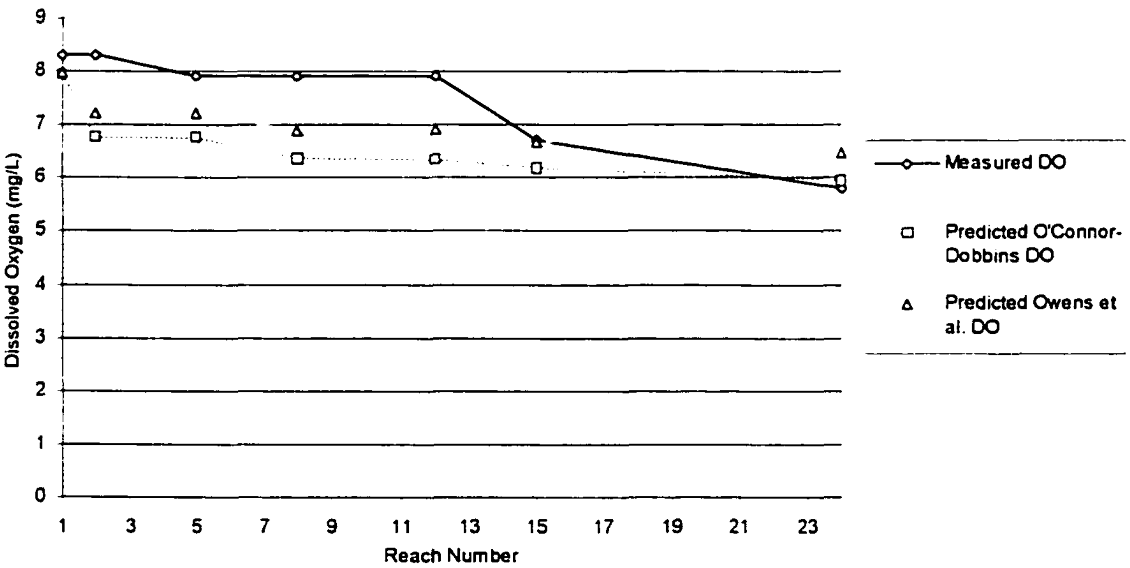

Figure H-18. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.1 (Jan. 13, 1987 Water Quality Data and 7Q10 Discharge)

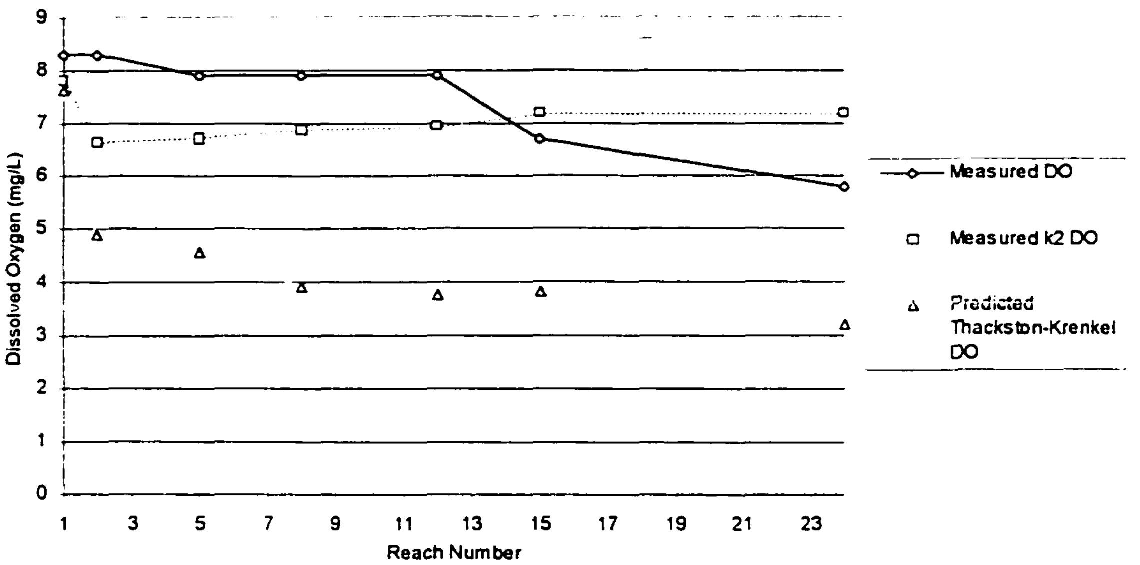

Figure H-19. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.1 (Jan. 13, 1987 Water Quality Data and 7Q10 Discharge)

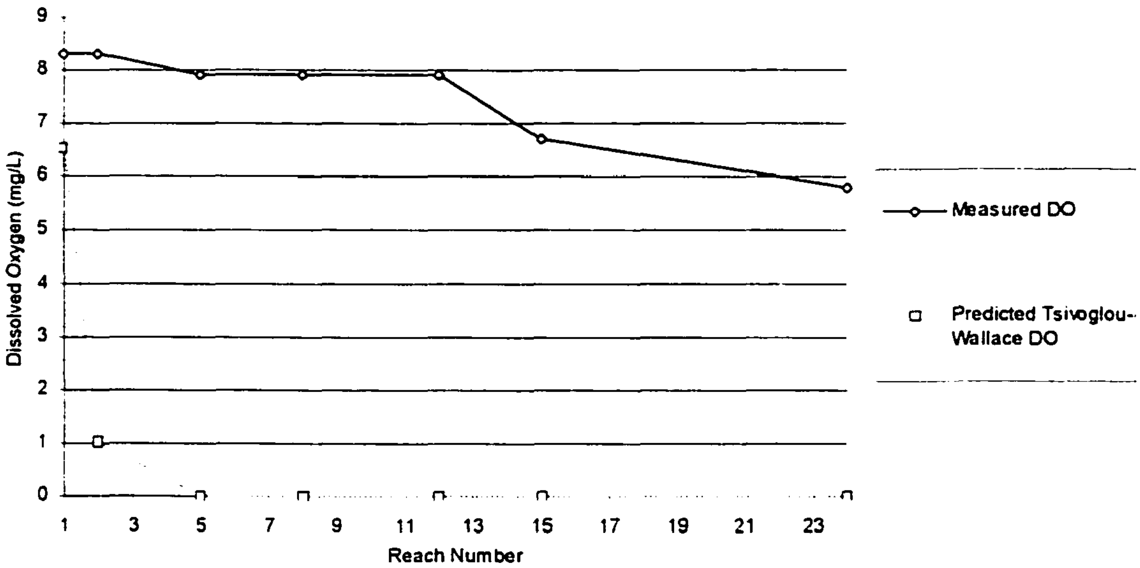

Figure H-20. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.1 (Jan. 13, 1987 Water Quality Data and 7Q10 Discharge)

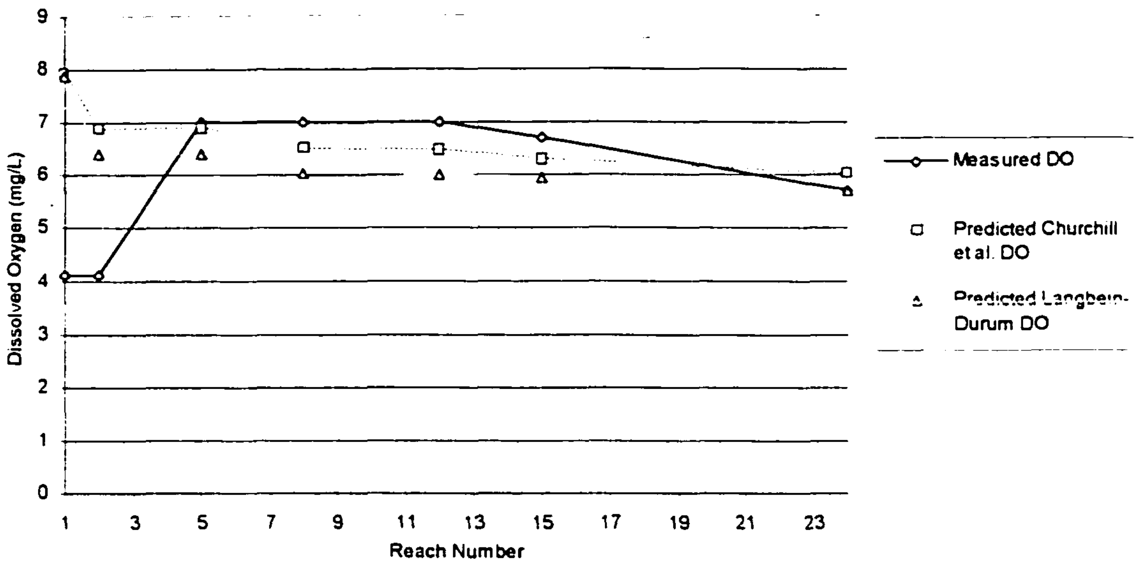

Figure H-21. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.2 (May 17, 1989 Water Quality Data and 7Q10 Discharge)

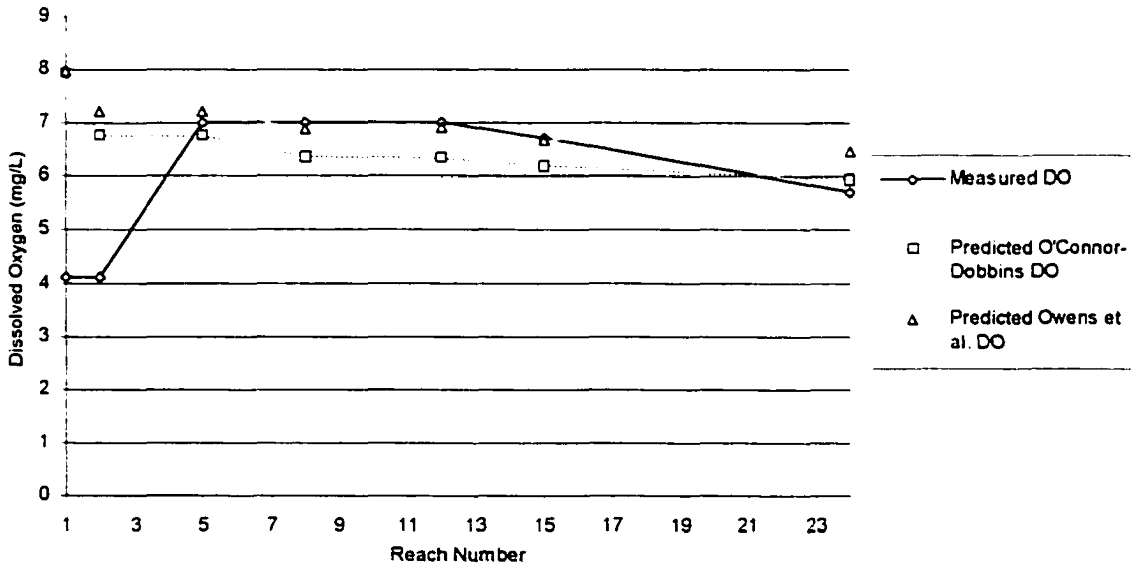

Figure H-22. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.2 (May 17, 1989 Water Quality Data and 7Q10 Discharge)

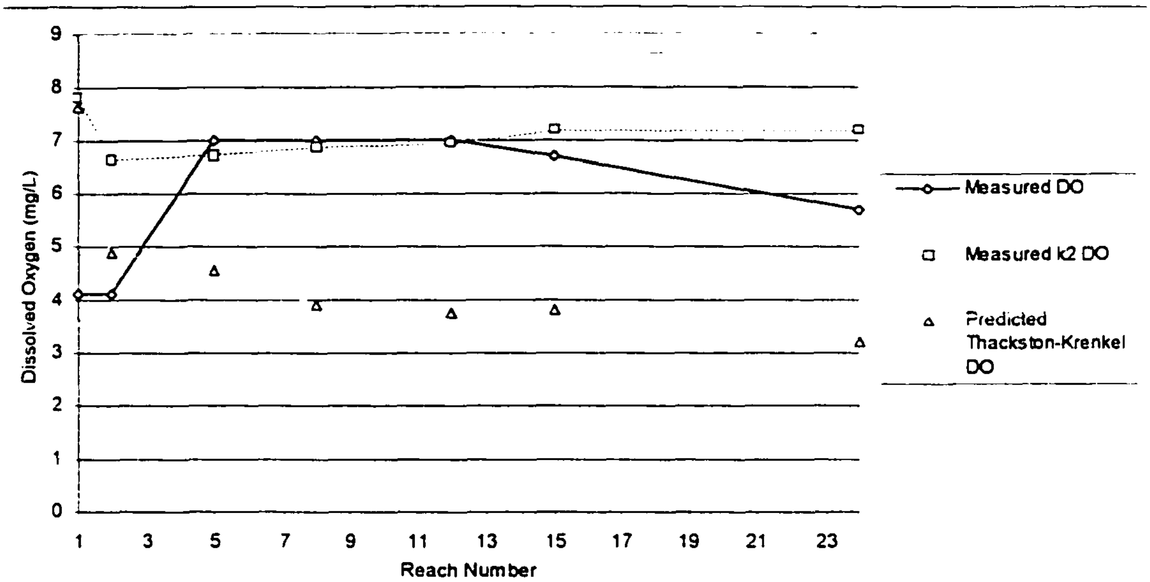

Figure H-23. Comparison of Predicted DO (Measured k_2 and Thackston-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.2 (May 17, 1989 Water Quality Data and 7Q10 Discharge)

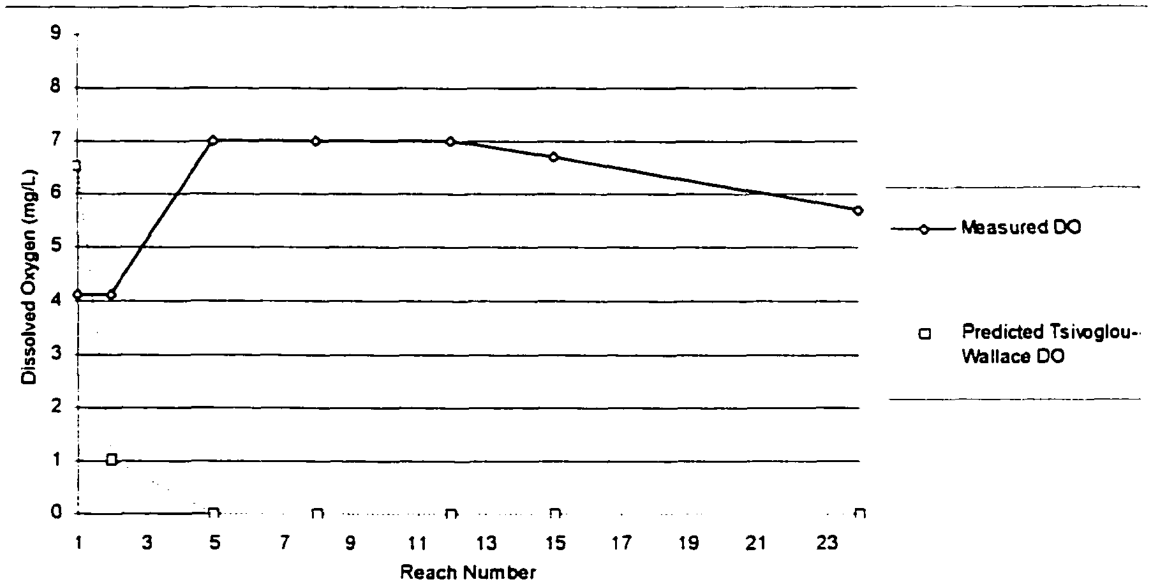

Figure H-24. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 2.2 (May 17, 1989 Water Quality Data and 7Q10 Discharge)

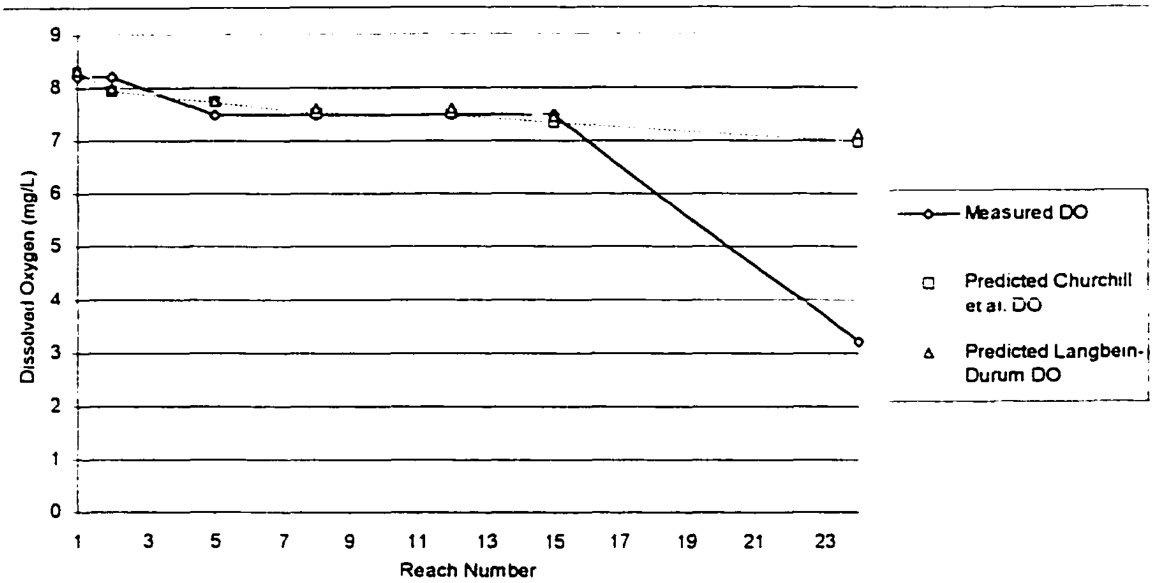

Figure H-25. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27,1989 Data)

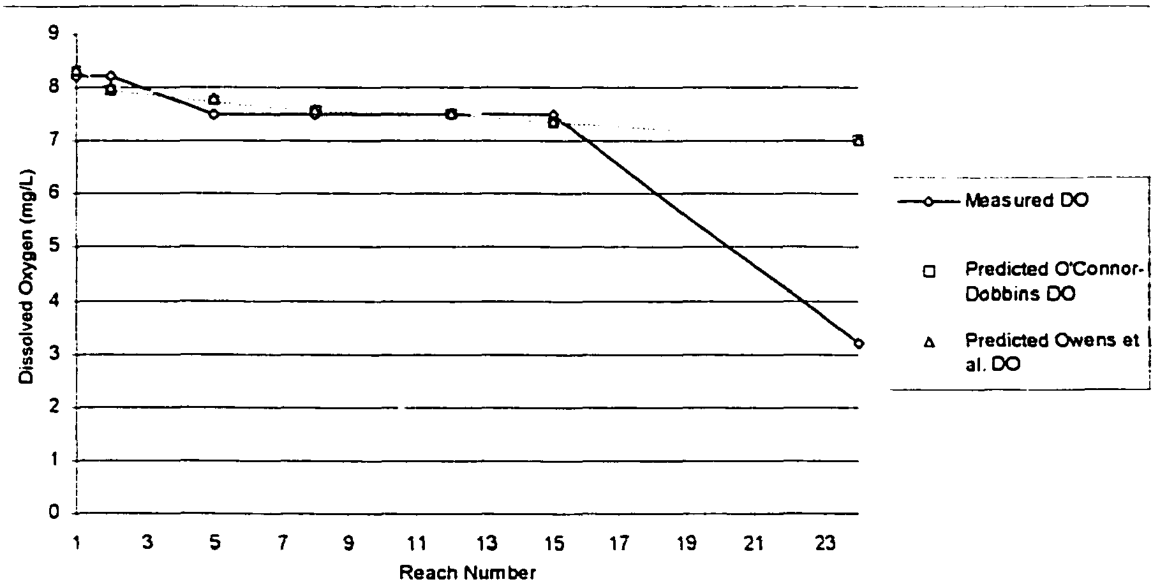

Figure H-26. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27, 1989 Data)

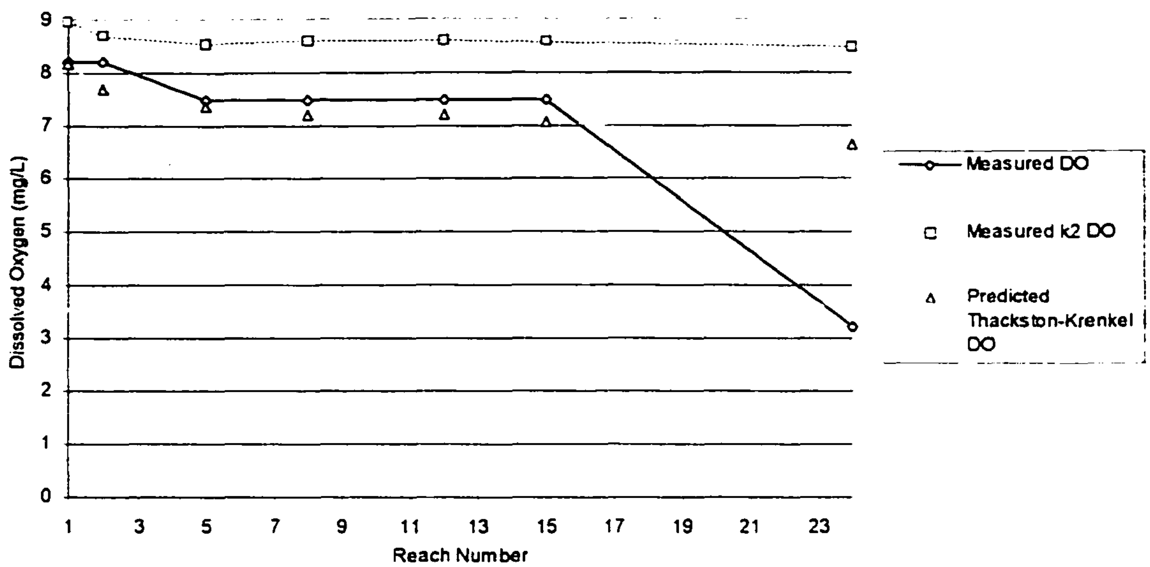

Figure H-27. Comparison of Predicted DO (Measured k_2 and Thackton-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27, 1989 Data)

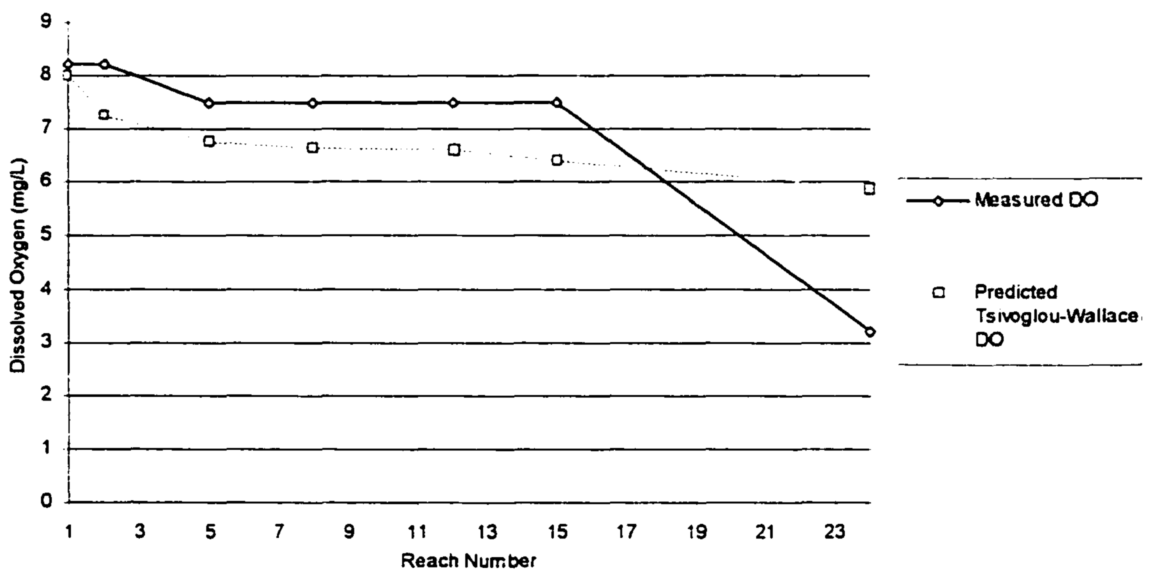

Figure H-28. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Calibration 3 (Sept. 27, 1989 Data)

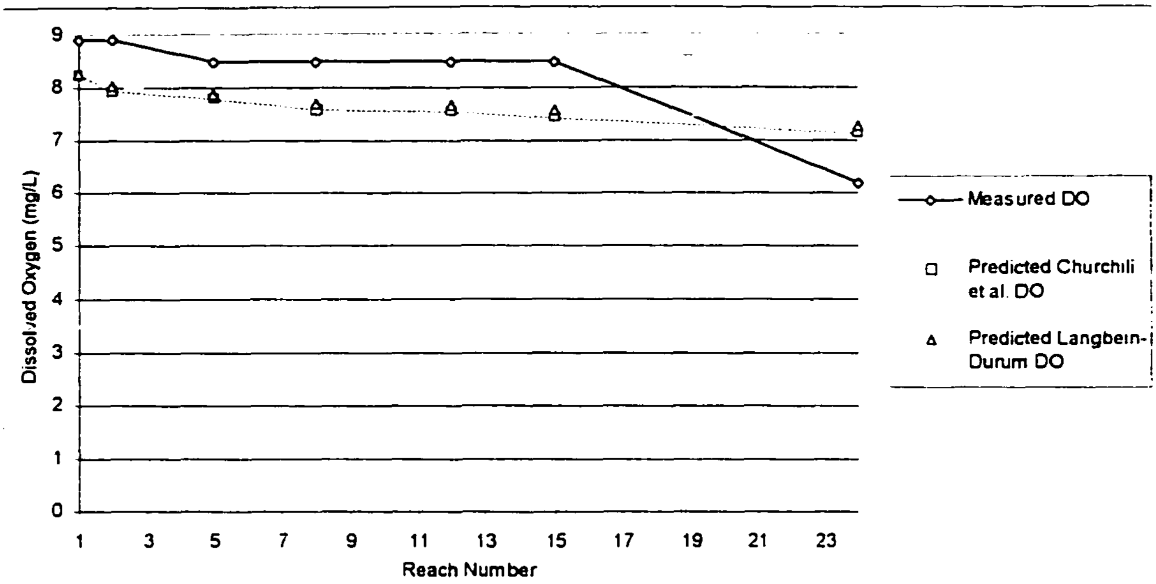

Figure H-29. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.1 (Nov. 14, 1989 Data)

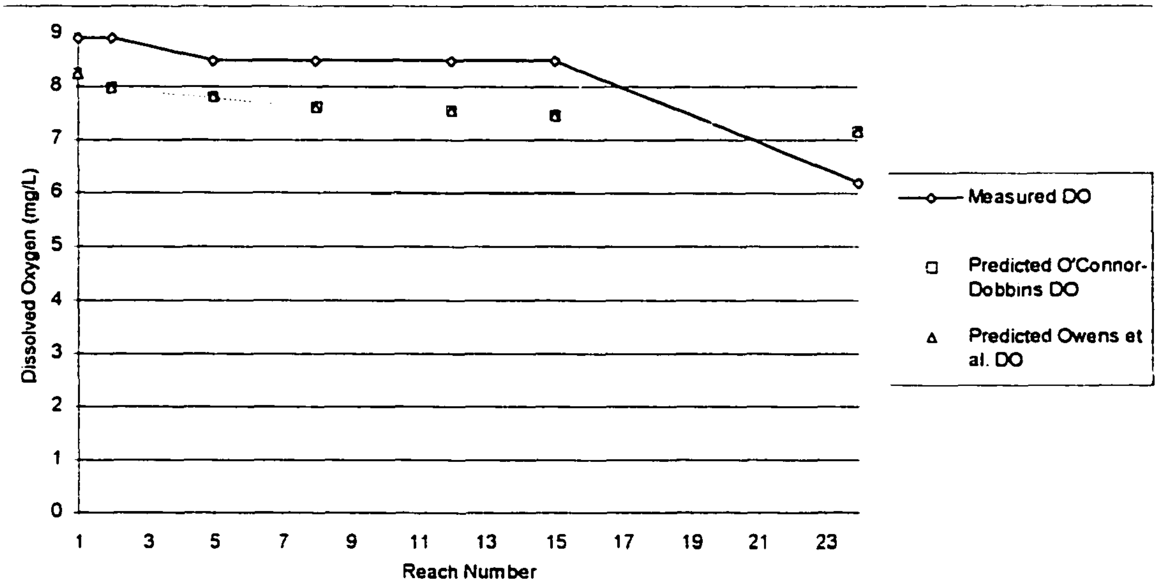

Figure H-30. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.1 (Nov. 14, 1989 Data)

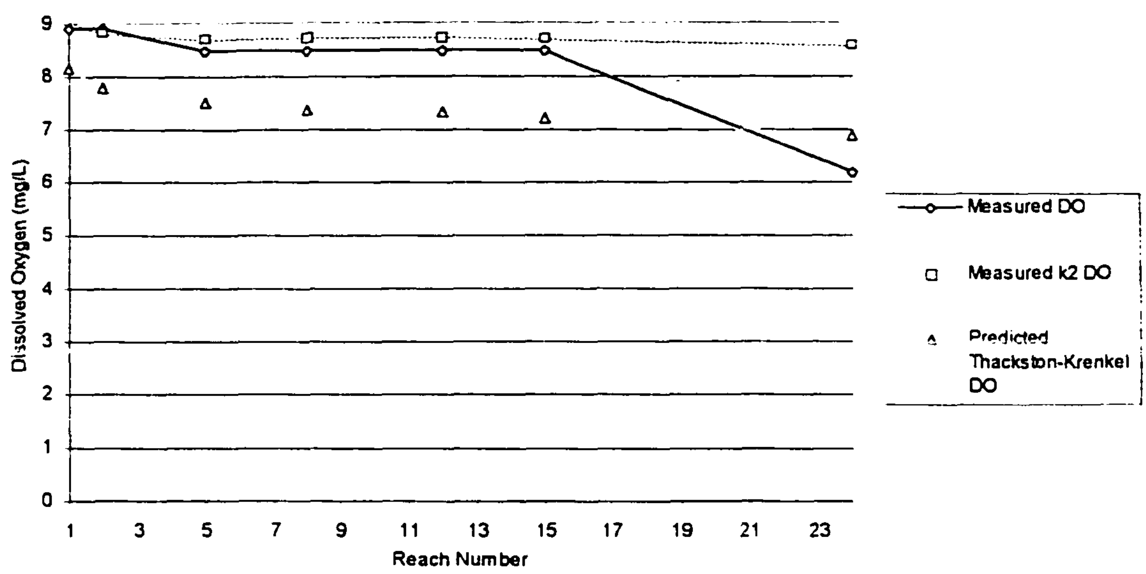

Figure H-31. Comparison of Predicted DO (Measured k_2 and Thackton-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.1 (Nov. 14, 1989 Data)

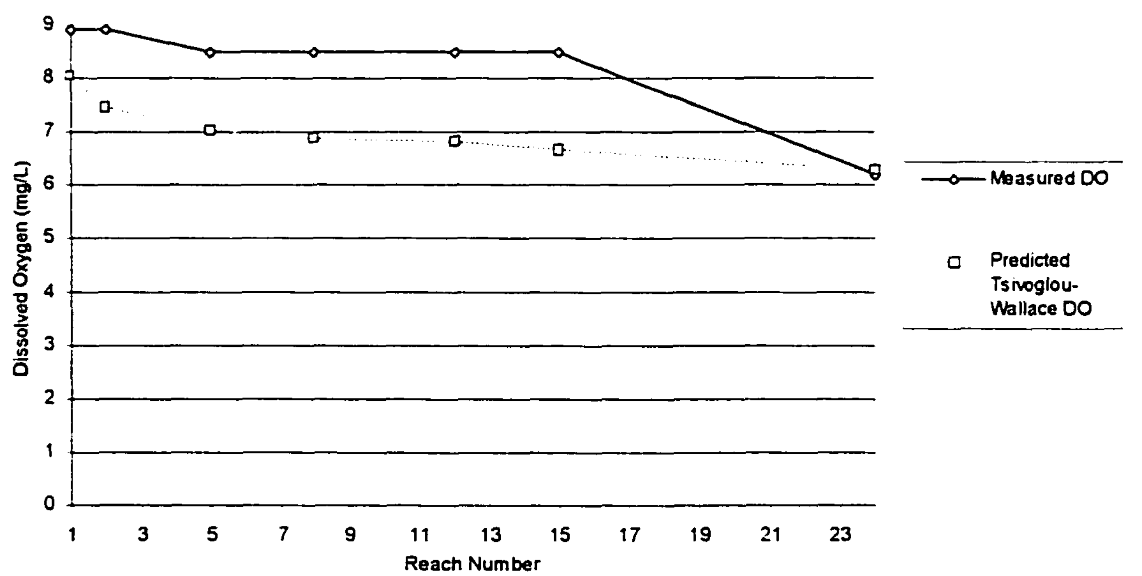

Figure H-32. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.1 (Nov. 14, 1989 Data)

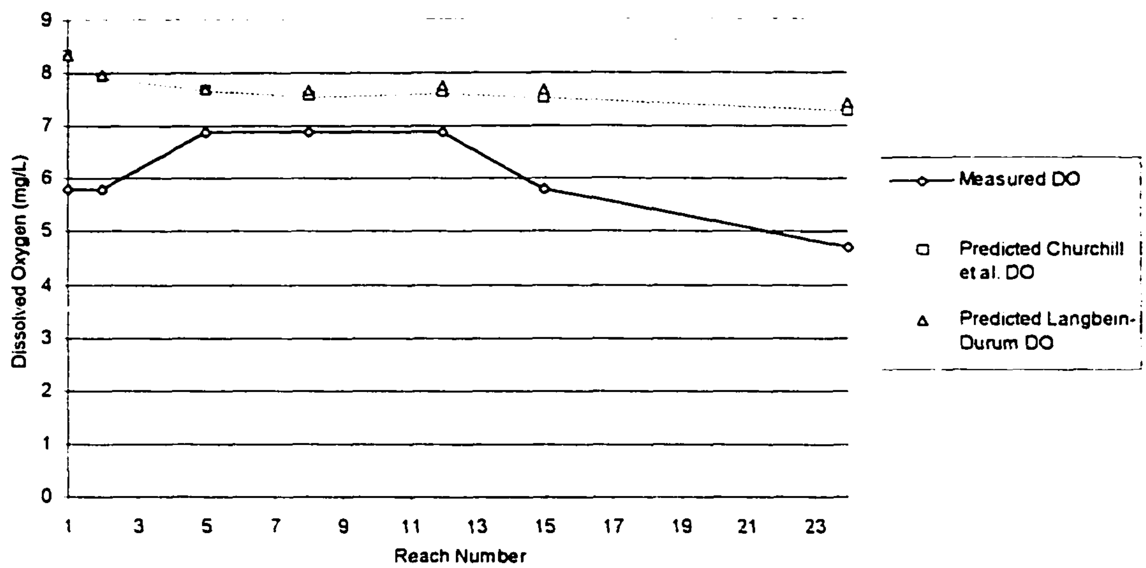

Figure H-33. Comparison of Predicted DO (Churchill et al. and Langbein-Durum Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.2 (Nov. 12, 1993 Data)

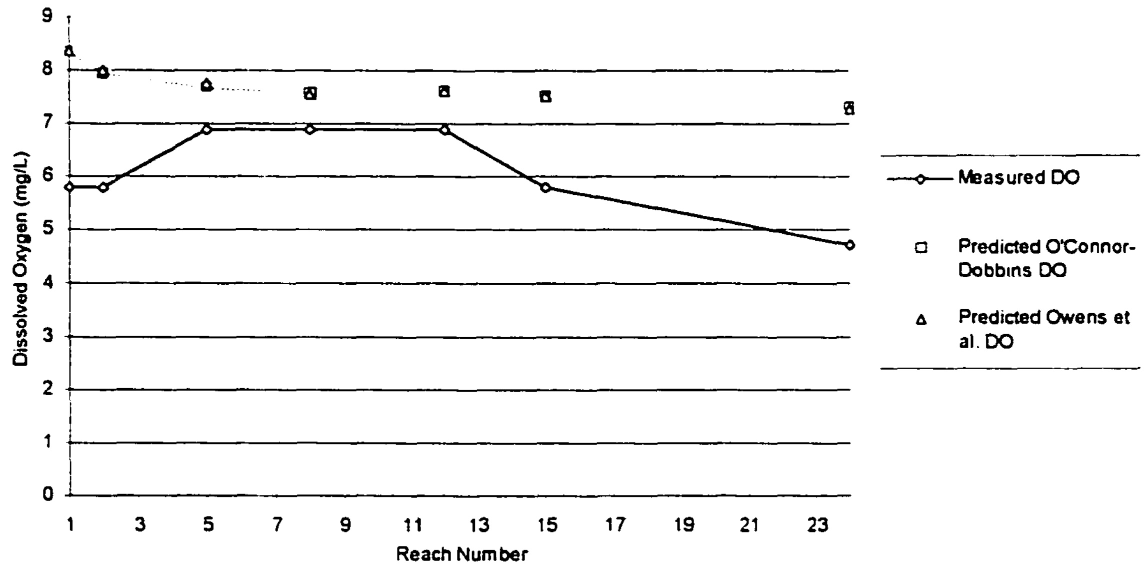

Figure H-34. Comparison of Predicted DO (O'Connor-Dobbins and Owens et al. Equations) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.2 (Nov. 12, 1993 Data)

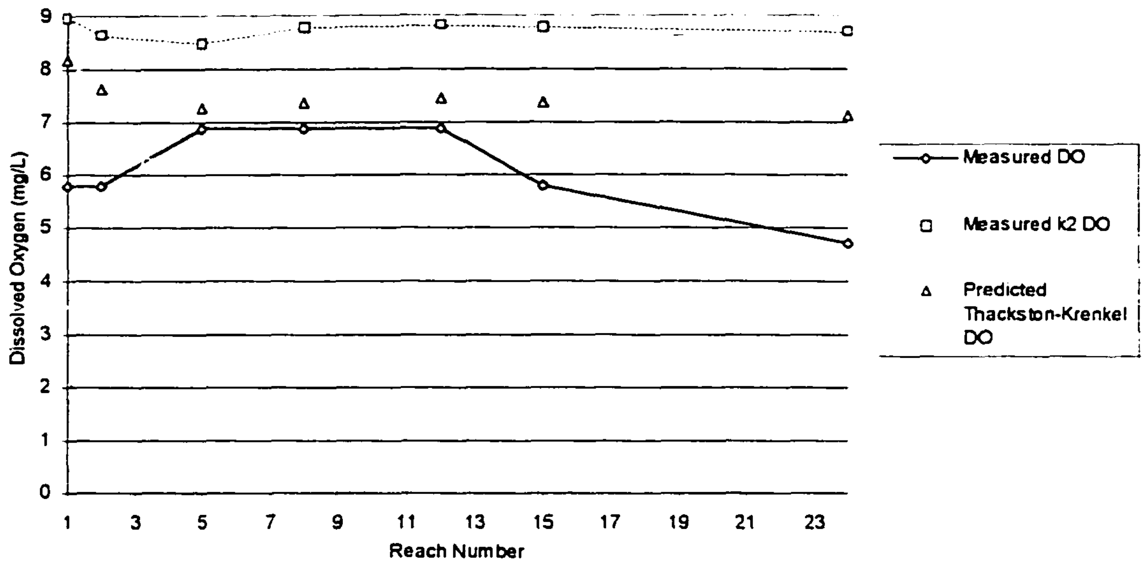

Figure H-35. Comparison of Predicted DO (Measured k_2 and Thackton-Krenkel Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.2 (Nov. 12, 1993 Data)

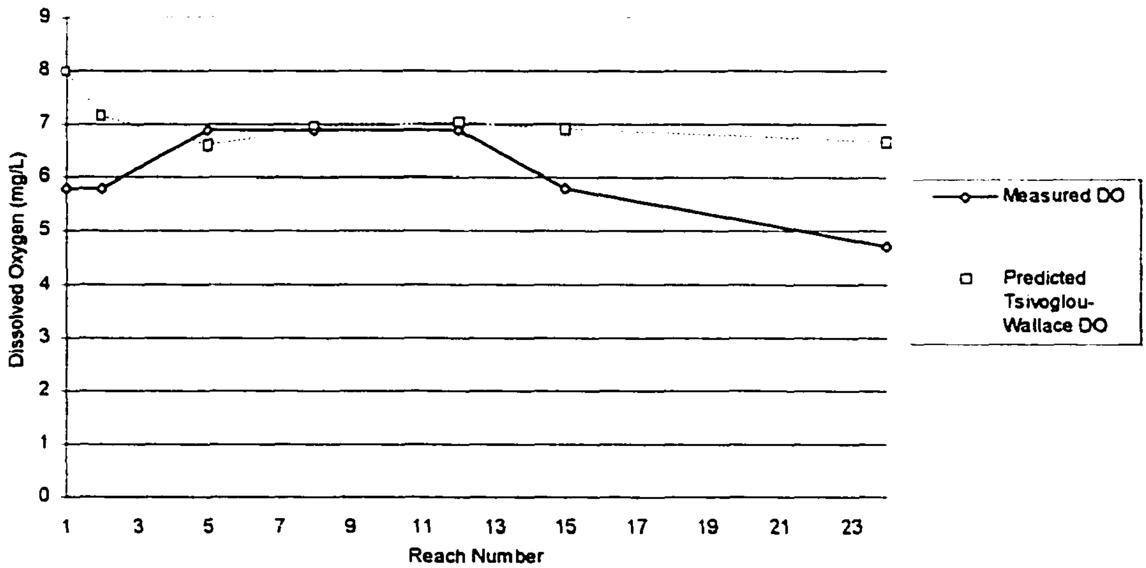

Figure H-36. Comparison of Predicted DO (Tsivoglou-Wallace Equation) to Measured DO by Main-Stem Reaches of Sg. Selangor River, Malaysia During Validation 3.2 (Nov. 12, 1993 Data)