A PHYSICALLY BASED CONCEPTUAL MODEL OF FLOW AND SEDIMENT DYNAMICS IN RIVER MOUTH JET FLOW

by

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ABSTRACT

A PHYSICALLY BASED CONCEPTUAL MODEL OF FLOW AND SEDIMENT DYNAMICS IN RIVER MOUTH JET FLOW

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River mouth areas, located in the “river-sea” contact zones, are complex natural objects which an abrupt restructuring occurs from the river-type hydrological regime to the regime of a receiving water body. The most characteristic feature is attenuation of the river jet (reduction of flow velocities) as it proceeds into the receiving water body. This process is accompanied by rapid deposition of suspended sediments of the river runoff. Such transformation occurs within the limits of very short distance equal averagely to 10 widths of the river channel in the mouth gauge. Measurements are made, using multiple methods, in the mouths of the Jordan River flowing into Lake Kinneret, and Kura River flowing into the Caspian Sea.

The results of field measurements as well as theoretical analysis, have led to revealing a number of special features of mouth currents. Using both theoretical analyses based on the equations of motion of a free turbulent jet with a variable mass and the results of measurements, it was shown that velocity attenuation follows the exponential law. Accordingly, the volume of suspended material carried by the river jet is decreasing. The longitudinal dimensions of turbulent eddies get smaller with the distance from the

mouth gauge, while their orientation is changing from the predominantly vertical-longitudinal rotation with a horizontal axis to the predominantly horizontal-transversal rotation with a vertical axis. In the zone of mixing river and sea waters, the energy spectra become more narrow-band, their ordinates lowering as the river jet moves forward from the mouth, while the maximum spectral density shifts to the area of lower frequencies. The farther from the mouth, in the spectra of the river jet current there appear frequency intervals that can be described not by the Kolmogorov's "-5/3" law but by the "-7/3" law. As the river jet moves beyond the mouth bar, another frequency interval appears in the energy spectra; described by the "-3" law. This is attributed to the consumption of energy by the river jet flow for overcoming the ascending forces when the process of vertical mixing of river and sea water masses is going on beyond the bar.

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TABLE OF CONTENTS

TITLE **PAGE**

TABLE OF CONTENTS....vii

LIST OF TABLES ix

LIST OF FIGURES....x

CHAPTER 1: INTRODUCTION 1

1.1 Motivation of the Study....1

1.2 Objective of the Study....4

1.3 Organization of the Study....4

CHAPTER 2: BACKGROUND INFORMATION 7

2.1 Characteristics of Turbulence 8

2.1.1 Mean velocity....8

2.1.2 Turbulent intensity....9

2.1.3 Reynolds' stresses 9

2.1.4 Eddy viscosity 10

2.1.5 Correlation function....10

2.1.6 Energy spectrum....11

2.2 Regression Analysis 11

2.3 Free Turbulence 14

2.4 Sedimentation Processes in Rivers....14

2.5 Sedimentation Processes in Lakes 17

CHAPTER 3: LITERATURE REVIEW....21

3.1 Methodology....21

3.1.1 Field measurements 21

3.1.1.1 Establishment of distribution of main parameters of turbulent in the flow 21

3.1.1.2 Influence of turbulence on sediment....31

3.1.1.3 Obtaining data for calibration of different numerical models 37

3.1.2 Theoretical studies....40

3.2 River Mouths 43
3.3 Experimental Sites 43
3.3.1 Jordan River 46
3.3.2 Lake Kinneret 47
3.3.3 Kura River 49
CHAPTER 4: SITE DESCRIPTIONS 50
4.1 Lake Kinneret – Jordan River 50
4.2 Caspian Sea – Kura River 55
4.3 Hydrodynamic Sectors of River Mouths 61
CHAPTER 5: FIELD AND LABORATORY MEASUREMENTS AND DATA PROCESSING 64
CHAPTER 6: VELOCITY FIELDS IN RIVER MOUTH JET FLOW 74
6.1 Average Velocity Attenuations 76
6.2 Turbulent Velocity Fluctuations 84
6.2.1 Pulsations of the velocity module and the intensity of turbulence 85
6.2.2 Statistical tools to study the turbulence in river mouths 90
6.2.3 Velocity vector pulsations 95
CHAPTER 7: SEDIMENT TRANSPORT PROPERTIES IN THE RIVER MOUTH JET FLOW 102
CHAPTER 8: TURBULENT FEATURES IN RIVER MOUTH JET FLOW 117
8.1 Turbulent Scale and Eddies Structure 117
8.2 Turbulent Spectra and Balance of Energy 124
CHAPTER 9: SUMMARY, CONCLUSIONS AND FUTURE RECOMMENDATIONS 132
9.1 Physical Conceptual Model Summary 132
9.2 Conclusions 137
9.3 Recommendations for Future Research 143
APPENDIX A: AVERAGE VELOCITY ATTENUATIONS 145
APPENDIX B: SUSPENDED PARTICULATE MATTER CONCENTRATION 247
REFERENCES 380

LIST OF TABLES

TABLE	TITLE	PAGE
4.1	Morphometric parameters of Lake Kinneret (level -209 m)	53
4.2	Morphometric parameters of Caspian Sea (level -28 m)	56
6.1	Experiment #1 – Streamwise mean velocities at Q = 46.8 m^3/s	78
6.2	Experiment #5 – Streamwise mean velocities at Q = 12.5 m^3/s	80
6.3	Experiment #6 – Streamwise mean velocities at Q = 10.3 m^3/s	82
6.4	Experiment #8 – Streamwise mean velocities at Q = 6.9 m^3/s	83
6.5	Correlation tensor function invariants *I* and *D* (mouth section of the Kura River – gauge#4, experiment#10)	97
6.6	Correlation tensor function invariants *I* and *D* (mouth section of the Kura River – gauge#7, experiment#10)	97
6.7	Correlation tensor function invariants *I* and *D* (mouth section of the Kura River – gauge#8, experiment#10)	98
7.1	Experiment #1 – SPMC values for Q = 46.8 m^3/s	104
7.2	Experiment #5 – SPMC values for Q = 12.5 m^3/s	108
7.3	Experiment #6 – SPMC Values for Q = 10.3 m^3/s	110
7.4	Experiment #8 – SPMC Values for Q = 6.9 m^3/s	112
8.1	Changes in the depth (h) and width (B) of the flow, mean current velocity (V), average diameter of the bottom sediments (D), longitudinal dimensions of turbulent eddies (λ) and of bottom ridges (L_r) along the axis of the jet flow at various distances (S) from the Jordan River mouth, Experiment #1	120
8.2	Energy characteristics of the turbulent jet-flow in the Jordan River mouth	125

LIST OF FIGURES

FIG	TITLE	PAGE
2.1	Velocity fluctuations at a fixed point.	8
2.2	Lake response to various forms of physical output	20
3.1	Distribution of turbulence characteristics a) along the stream, b) across the stream	25
3.2	(a) Time correlation functions (b) Space correlation functions 1- Δx = 0.5 m, 2- Δx = 1.0 m, 3- Δx = 1.5 m, 4- R(uτ/h), 5- R(Δx/h, $\tau = \tau_M$), 5- R(Δx/h, $\tau = 0$)	27
3.3	Power spectrum (numbers indicate the micropeller) a) longitudinal direction, b) transversal direction	29
3.4	The energy cascade according to the 1941 Kolmogorov theory	42
4.1	Lake Kinneret and its watershed	51
4.2	Lake Kinneret air picture	52
4.3	Geographical location of Jordan River areas and Lake Isobaths	55
4.4	The main rivers inflowing directly to Caspian Sea	58
4.5	Kura River and Caspian Sea from world atlas	59
4.6	Kura River air picture	60
4.7	Schematic map of the Kura River Mouth area	61
4.8	Hydrodynamic Zoning of the Jordan and Kura River Mouth Area	63
5.1	Results of checking up the stability of the fluorescent cover of the sediment samples dyed green (fluoresecein) and red (rhodamine); the numbers mean the days of flushing	65
5.2	Preparation of fluorescently tagged particles (1), analysis of sediment samples with UV microscope (2) and under UV illumination (3)	66
5.3	Detailed picture of UV microscope	67

5.4 The set-up of the traps 69
5.5 Jordan River mouth area and points of measurement 72
5.6 Scheme of the Kura River mouth area and stations for measurements of the river flow velocity field 72
5.7 3-D turbulent current fluctuation meter 73
5.8 Measuring micropropeller meter and micropropeller's size 73

6.1 Attenuation of velocities at jet flow for 3 transects at Q = 46.8 m^3/s 79
6.2 Attenuation of velocities at jet flow for 3 transects at Q = 12.5 m^3/s 81
6.3 Attenuation of velocities at jet flow for 3 transects at Q = 10.3 m^3/s 83
6.4 Attenuation of velocities at jet flow for 3 transects at Q = 6.9 m^3/s 84
6.5 A sample recording of the longitudinal component of vector velocity fluctuations, exit cross section, Experiment #1 (surface layer, dynamical axis of the flow) 85
6.6 Relationship between turbulence intensity and intensity of attenuation of the longitudinal velocity along the axis of the jet flow at various distances in Kura River from the mouth (1- 200 m, 2- 500 m, 3- 800 m, 4- 1,400 m).........86
6.7 Variability of the intensity of turbulence with the jet flow depth at various distances from the Kura river mouth (a- mouth gauge, b- bar crest (500 m from the mouth), c- deeping beyond the bar (800 m from the mouth – zone of detachment of the river jet from the bottom). Curves 1, 2 and 3 correspond to the flow velocities in the mouth equal to 1.58, 2.10, and 2.46 m/s respectively 88
6.8 Distribution of turbulence intensity over the cross section of the jet flow at various distances from the Kura River Mouth: (1- mouth gage, 2- 200 m, 3- 500 m, 4- 800 m, 5- 1,100 m) 89
6.9 α, the angle between turbulent eddy rotation axis and each orthogonal plane 94
6.10 An example of changing statistical parameters of flow turbulence (the Kura River mouth area, experiment #10, dynamic axis of the flow relative depth 0.6) 100

6.11 Changing invariants of the correlation between the fluctuations of the orthogonal components of the vector along the flow (numbered are observation gauges in Kura River mouth: 4-mouth gauge, 5-7-transitional area between mouth and bar, 8-free turbulent jet beyond the bar- A-correlation of components $u^{'}$, $v^{'}$; B- correlation of components $u^{'}$, $w^{'}$; C-correlation of components $v^{'}$, $w^{'}$. 101

7.1 SPM concentrations at jet flow for 3 transects at Q = 46.8 m^3/s 107
7.2 SPM concentrations at jet flow for 3 transects at Q = 12.5 m^3/s 109
7.3 SPM concentrations at jet flow for 3 transects at Q = 10.3 m^3/s 111
7.4 SPM concentrations at jet flow for 3 transects at Q = 6.9 m^3/s 113
7.5 Examples of bottom relief in Kura River mouth area (Channel is 2 m by 200 m) a) 100 m from mouth b) 300 m from mouth........ 116

8.1 Examples of empirical longitudinal time-autocorrelation functions of flow velocity at the mouth gauge (1) and at distances of 100 m (2) and 300 m (3) from the Jordan River mouth........ 120
8.2 General scheme of the kinematic field of the flow above the bottom ridges........ 122
8.3 Changing rate of mass resuspension in Jordab River mouth (transfer of bottom sediments to the suspended state), V_{res}, with changing relative height of bottom ridges, h/H, (H- depth, 1- fraction 1.0-0.5 mm; 2- fraction 0.5-0.2 mm; 3- fraction 0.2-0.1 mm, 4- fraction 0.1-0.05 mm)........ 123
8.4 An example of empirical pulsation spectra of the vertical component of velocity at different areas of the flow in the Kura River mouth. Dynamic axis of the flow, relative depth 0.6. Numbered are the hydrometric gauges........ 129
9.1 Turbulent eddies spinning as described by rotational velocity vectors in two vertical (*uv*, *wv*) and one horizontal (*uw*) planes. Indexes: 1=*u*, 2=*w*, 3=*v*........ 135
9.2 The hydrodynamic field of eddies of different scales in initial section........ 139
9.3 The hydrodynamic field of eddies of different scales in transit section........ 140
9.4 The hydrodynamic field of eddies of different scales in free jet flow section........ 140

CHAPTER 1

INTRODUCTION

1.1 MOTIVATION OF THE STUDY

River mouth regions are specific zones of transition from the river hydrological regime to the reservoir-acceptor hydrological regime. This transition zone is very short compared with the length of the river. Consequently, the water flowing through the transition zone undergoes significant changes hydrodynamically, hydrophysically, chemically, and biologically. Physical evidence of these river mouth processes is the formation of rather stable forms of relief, such as the above-water and under-water deltas, mouth bar, and spits (Mikhailov, 1971, 1996; Shteinman and Kamenir, 1998; Shteinman et. al., 2000).

Bars and jet currents are the most important characteristics of river mouths. Therefore, studies conducted on river mouth processes are quite extensive. These studies include research conducted by (Samoilov, 1952; Bates, 1953; Leopold and Maddick, 1953; Takano, 1954a, 1954b; Einstein and Krone, 1961; Crickmay and Bates, 1955; Koshiwamura and Yoshida, 1967, 1969; Ibad-Zade and Shteinman, 1970; Wright and Coleman 1971, 1974; Mikhailov 1971, 1996; Serruya, 1974; Engelhardt et al., 1995; Shteinman and Parparov, 1997; Shteinman and Kamenir, 1998; Elford et al., 1999; Shteinman et al., 1993, 1998, 2000).

The relationship between the kinematics of river flow and the dynamics of sedimentation has been well investigated through both analytical and experimental studies for rivers, lakes, and seas. Two- and three-dimensional models have been developed, such as NASTD, TARGET, GWERD, GSTARS, HEC-RAS, SEDIFLOW, and theoretical schemes have been suggested. However, a literature review reveals that the study and development of a physically based conceptual model of flow and sediment dynamics of river mouth jet flow has not been considered extensively. The mouth areas are essential for drinking water supplies, places of fish spawning, and major centers of human activities. Studying flow dynamics and the characteristics of sedimentation processes for river mouth is necessary for physical and environmental planning. Mouth areas represent the final stage of the transport of sediments by a river. In the development of regional environmental protection measures, accumulated pollutants as well as suspended matter carried by the river has to be taken in account.

Flows in river mouths have some fundamental distinctions from the river flows. They are inertial jet currents because the river jet is moving outside of the river banks by inertia. When the river flow enters the lake or the sea, it induces a subsidiary flow in the bordering water mass. Unlike the river conditions, the jet flow is a flow with variable mass because it results in the participation of the adjacent mass of water in the motion as it enters the reception reservoir. Consequently, the river inherits some characteristics of the jet flow with growing water discharge along the stream. Furthermore, the river gradually loses its channel flow properties. The shore influence ends and the slope diminishes with a decrease in the influence of gravity. In the contact zone, "river-reception basin", specific accumulative topography is formed (river bars, spits), which affects the flow dynamics significantly. After the mouth bar, the jet flow is detached from the river bottom and the flow concentrates in the upper jet. The slope of the river flow becomes negligible and the flow becomes inertial, turbulent, and free of friction from banks and the bottom. This change leads to a rapid degradation of the river turbulence structure, attenuation of the river discharge flow, and intensive sedimentation of the river suspended material. Along the river jet flow, the structure of river turbulence degrades abruptly, which results in many features of sediment transport.

River mouths are dynamic dispersal points of river-derived sediments which contribute to delta formation. Consequently, they are the most fundamental elements of deltaic systems. River-mouth processes involve a variety of interactions between riverine and marine waters. These processes, acting in combination, determine patterns by which effluents from river mouths spread, decelerate, and deposit the sediment load (Wright, 1977).

The features of sediment transport, scour and deposition, have been the subject of earlier studies, and constitute a complex and dynamic problem that is yet to be completely understood. In most natural rivers, sediments are mainly transported as suspended load. Suspended load refers to sediment supported by the upward components of turbulent currents which remains in suspension for an appreciable length of time (Yang, 1996). Deposition of sediments is one of the most characteristic features of the river-receptor contact zone. In such a transition zone, a pronounced decline in the migration intensity of chemical elements occurs within a very short distance. This results in an increased sedimentation of these chemical elements which are producing a high local concentration in the bottom sediments.

1.2 OBJECTIVE OF THE STUDY

The main objective of this study is to develop a physically based conceptual model of flow and sediment dynamics in river mouths. The study is specifically focused on jet flow dynamics in the contact zone “river-lake (sea)”. The following processes were considered in the development of the proposed model:

a) attenuation of averaged velocities
b) vertical and horizontal velocity distribution and its variation along jet flow
c) sediment carrying capacity of the flow in the contact zone “river-sea (lake)”
d) accumulation of suspended particulate matter, cease of bed load transport
e) water discharges and sedimentation along jet flow
f) restructuring of turbulence along jet flow (fluctuations of velocity, autocorrelation functions, coherence functions, linear dimensions of turbulent eddies, coherent structures)

1.3 ORGANIZATION OF THE STUDY

In Chapter 2, background information about the river turbulence and lake turbulence is provided. General characteristics of turbulence such as mean velocity, Reynolds’ stresses, eddy viscosity, correlation function, and energy spectrum are discussed. Information on free turbulence and sedimentation processes in rivers and lakes are also included in this chapter.

A brief literature review related to the structure of turbulence and sediment dynamics in rivers, reservoirs, and river mouths is presented in Chapter 3.

Chapter 4 provides information about the two selected sites which were used to test the theoretical considerations. Experimental measurements were obtained at these two different river mouth areas: Lake Kinneret-Jordan River mouth (fresh water) and Caspian Sea-Kura River mouth (salinity water).

Chapter 5 demonstrates the combination of methods which were used to study the velocity structure of the flow and the transport of sediments in the Jordan River – Lake Kinneret and Kura River – Caspian Sea river mouths.

The results from the velocity structure study for the flow in the Jordan River – Lake Kinneret contact zone are given in Chapter 6. These results are explained by using the data obtained from field measurements along with the jet flow theory. Turbulent velocity fluctuations, which include pulsations of the velocity module, the intensity of turbulence, and velocity vector pulsations are also evaluated. The statistical tools used to evaluate the results obtained in this study are also discussed in this chapter. These statistical tools include the theory of random processes, the method of structural averaging for studying coherent structures, and the theory of random functions and fields to study hydrodynamic fields. SIGMAPLOT 8.0 is used for regression analysis.

In Chapter 7, sediment transport processes in the river mouth jet flow are formulated. The velocity effect is examined and the results are analyzed by SIGMAPLOT 8.0.

In Chapter 8, the turbulence energy balance and turbulent energy characteristics, as well as turbulent scale and eddies structures, are discussed by using the statistical tools described in Chapter 6. The discussions are based on the measurements made in the

Jordan River mouth inflowing into Lake Kinneret (Israel) and in the Kura River mouth inflowing into the Caspian Sea.

A summary of this study and the conclusions are provided in Chapter 9 together with recommendations for future work.

CHAPTER 2

BACKGROUND INFORMATION

The existence of two sharply differing types of flow called laminar and turbulent was initially noted in the first half of the XIX century, but the theory of turbulence appeared first together within the remarkable works of Osborn Reynolds (1883-1895).

Most flows encountered in nature and in engineering practice are turbulent. It is therefore important to understand the fundamental mechanisms and applications in such flows, many of which are still unresolved. Turbulence flows have therefore continued to be the subject of intensive research over a period that has lasted more than a century, and interest in this field shows no signs of abating.

Hinze (1959) thus described turbulence, “Turbulent fluid motion is an irregular condition of flow in which the various quantities show a random variation with time and space coordinates, so that statistically distinct average values can be discerned.”

To describe a turbulent motion quantitatively, it is first necessary to introduce some of its characteristics. By using mean values of characteristics such as eddy size and velocity fluctuation, the turbulent motion’s properties can be statistically analyzed, thus saving it from indeterminacy.

An important characteristic of turbulent motion is the richness of scales of eddy motion present in such flows: In a fully developed turbulent flow all scales appear to be fully occupied or saturated in a sense; from the largest ones that can fit within the size of the flow region, down to smallest scale allowed by dissipative processes. Turbulent flows are also highly vortical, a consequence of vortex stretching and tilting by larger random vorticity fields.

2.1 CHARACTERISTICS OF TURBULENCE

2.1.1 Mean velocity

In a particular direction, the instantaneous value of velocity U can be written as:

$$U = \overline{U} + u \tag{2.1}$$

Where $\overline{U}$ is the average velocity and u is the velocity fluctuations as shown in Figure 2.1.

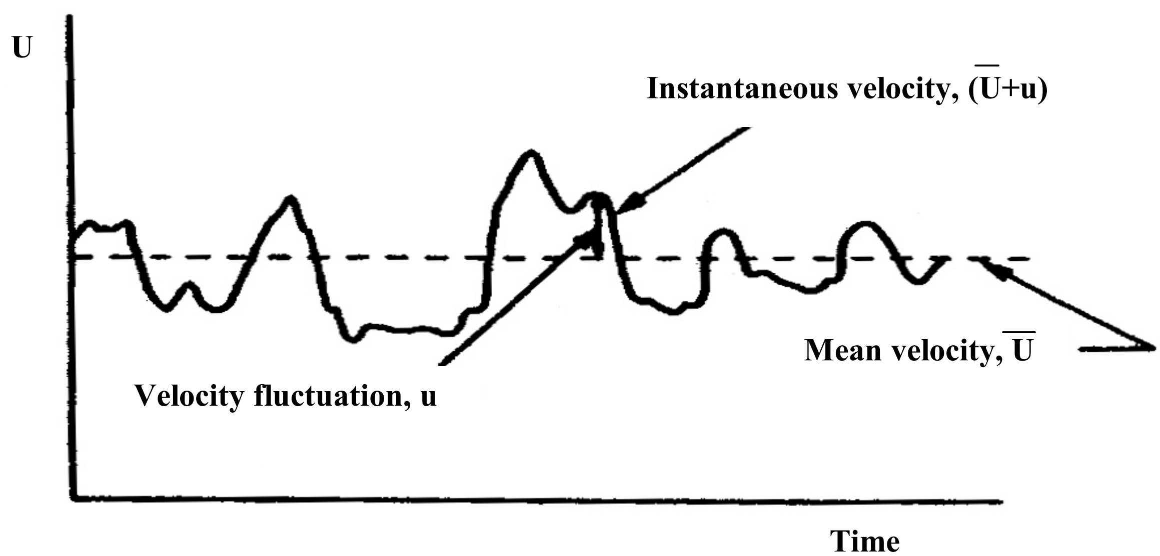

Figure 2.1: Velocity fluctuations at a fixed point (Smith, 1975)

Average velocity with respect to a time interval T is defined by:

$$\overline{U} = \lim_{T \to \infty} \frac{1}{T} \int_0^T U(t+\tau) d\tau \tag{2.2}$$

2.1.2 Turbulent intensity

The turbulent intensity u' is the root-mean-square of the velocity fluctuations:

$$u' = \sqrt{\overline{u^2}} \qquad (2.3)$$

The relative intensity will then be defined by the ratio of the turbulent intensity and the mean velocity $u'/\overline{U}$.

2.1.3 Reynolds' stresses

Newton's Second Law indicates that the change in momentum with time is equal to the resultant force acting on the mass. Therefore, if there is a velocity gradient in the mean motion and there are velocity fluctuations, there must be a shear force or stress because there will be a change in momentum in the fluid transported by these fluctuations (Smith, 1975). If the mean motion is in the x direction, these stresses, usually referred to as the Reynolds stresses, are given by

$$\tau_{yx}^{R} = \rho\overline{uv} \text{ and } \tau_{zx}^{R} = \rho\overline{uw} \qquad (2.4)$$

Where ρ = density,

$\overline{uv}$ and $\overline{uw}$ =mean products of the velocity fluctuations,

τ_{yx}^{R} = stress resulting from the transport of u-momentum by the v component of the flow,

and τ_{zx}^{R} = stress due to the w component.

The stress τ_{yx}^{R} due to the lateral cross-current fluctuations is of less importance in subsequent developments and the suffices are of the dropped, τ^{R} alone implying the stress due to the vertical fluctuations.

2.1.4 Eddy viscosity

In purely viscous flow, the shear stress associated with a velocity gradient is given by

$$\tau^{R} = \mu \frac{dU}{dz} \qquad (2.5)$$

Where μ is the coefficient of absolute or dynamic viscosity.

$$\tau_{zx}^{R} = \rho\overline{uw} = N \frac{dU}{dz} \qquad (2.6)$$

Where N is the coefficient of eddy viscosity.

2.1.5 Correlation function

The autocorrelation is given by:

$$R(\tau) = \frac{\overline{u(t)u(t+\tau)}}{u'^{2}} \qquad (2.7)$$

Where τ is the time lag and the over bar denotes time-averaged quantities. From correlation function an indication of the structure of the turbulence can be obtained.

2.1.6 Energy spectrum

The energy spectrum provides information on how the energy is distributed with respect to frequency. According to Kolmogoroff's theory, energy enters the spectrum through the larger eddies and is then transferred through the spectrum to the smaller eddies where it is finally dissipated (McQuivey and Richardson, 1969).

The relationship between the spectrum function and $\overline{u^2}$ is given by:

$$\overline{u^2} = \int_0^\infty E(n)dn \tag{2.8}$$

Let $\overline{u^2}$ be the sum of the energy contributed from all frequencies *n*. *E(n)* is the contribution of the frequencies between *n* and *n+dn*. The spectra can then be normalized by:

$$F(n) = \frac{E(n)}{\overline{u'}} \tag{2.9}$$

So that:

$$\int_0^\infty F(n)dn = 1 \tag{2.10}$$

2.2 REGRESSION ANALYSIS

The process of monitoring two variables and deciding if they vary simultaneously is an experience, for much of human learning involves drawing conclusions based on associating the variation in one set of events with that of another. The analysis of data in the search for cause-and-effect or any other kind of relationship between variables is important in our research activity, and Allen (1997) recognize that as a basic type of research.

Regression involves the analysis of the variation in the variables in order to:

1) derive a mathematical expression for the joint variation in the variables,
2) provide some information to decide whether the variables are related,
3) explain or account for the variations in a variable, and
4) provide an equation which predicts the values of a variable.

Regression enables to analyze the relationship between two variables, X and Y. The goal of regression analysis is to determine the values of parameters for a function, which represents the set of data provided. The relationship in which a dependent variable, Y, can be determined exactly from a selected value of the independent variable, X, is defined by the following expression:

$$Y = f(X) \tag{2.11}$$

A simple example of a regression model is the straight-line relationship between a pair of variables denoted by X and Y. If the relationship between two variables were exact, as determined by some physical law, Y could be expressed in terms of X as follows:

$$Y = \alpha + \beta X \tag{2.12}$$

where, α and β are called the parameters, which are known physical constants correlating X and Y. However, in applied sciences, generally variables are related through empirical relationships rather than exact physical relationships (Ratkowsky, 1990). Regression analysis is primarily used for the purpose of prediction. The goal in regression analysis is the development of a statistical model that can be used to predict the values of a dependent or response variable from the values of at least one explanatory or independent variable (Bates, 1988).

In linear regression, for each subject (or experimental unit), both X and Y are known and the goal is to find the best straight line that relates the available data. More precisely, the linear regression program provides values for the slope and intercept that define the line, which minimizes the sum of the square of the vertical distances between the points and the line. In some cases, the slope and/or the intercept have a scientific meaning. In other cases, the linear regression line is used as a standard curve to find new values of X from Y, or Y from X.

Nonlinear regression analysis is a common technique used to define a curve that represents the data available. It enables to represent data by any equation that defines Y as a function of X and one or more parameters. More simply, the goal is to find the curve that comes closest to the points. The accuracy of representing the available data using a curve is ensured by minimizing the sum of the squares of the vertical distances between the data points and the curve. Therefore, linear and nonlinear regression analyses are sometimes referred to as the least squares methods. In general, it is not possible to directly derive an equation to compute the best-fit values from the data. Instead, a computationally intensive iterative approach is needed for nonlinear regression analysis.

2.3 FREE TURBULENCE

The flow condition referred to as free turbulence occurs when there is a distinct interface or surface of discontinuity between two fluids having different velocities or densities. The most important kinds of free turbulent flows are turbulent wakes behind rigid bodies placed in a constant velocity flow (or moving through fluid at rest), turbulent jets, and turbulent mixing layers, (a boundary between streams of different velocities without any rigid walls between them) (Monin and Yaglom 1971; Favre, 1964). Flows of this type occur, for example, when a fast-flowing river enters a lake, or a sea.

The known methods of describing free turbulence are based first upon certain hypotheses of self-preservation of corresponding flows and second on the use of more special semi-empirical hypotheses. The self-preservation hypotheses may usually be justified with the aid of general similarity and dimensional arguments. However, the semi-empirical theories of free turbulence use, in addition to general laws of physics, some additional hypotheses if a more speculative character, the deductions thus obtained are important, primarily for practical applications.

2.4 SEDIMENTATION PROCESSES IN RIVERS

Every sediment particle which passes a particular cross section of a river must satisfy the following two conditions (Chow, 1964): (1) It must have been eroded somewhere in the watershed above the cross-section; (2) It must be transported by the flow from the place of erosion to the cross-section. Each of these two conditions may limit the sediment rate at the cross-section depending on the relative magnitude of two controls: the availability of the material in the watershed and the transporting ability of the river. In most rivers the finer part of the load, the part that can be easily carried in large quantities, is limited by its availability in the watershed. This part of the load is designated as *wash load*. Smaller grains (clay, silt, and very fine sand) generally travel within the flow, supported by fluid turbulence directed upward against their tendency to settle. As it consists in case of clay particles with settling velocities of less than 10^{-6} ms^{-1}, the wash load is often assumed to remain suspended in the flow (Reid and Frostick, 1994). These grains, the suspended load, travel at approximately the same speed as the surrounding fluid because they are not being decelerated by intermittent collisions with the bed. Maintenance of a suspended-sediment load requires the existence of a net upward-directed fluid stress to balance immersed weight of the suspended grains, which can only arise if the vertical component of turbulence is anisotropic. However, sediment is also suspended in vortices generated by eddy shedding from the separated boundary layer in the trough regions of ripples and dunes. Ripples and dunes are transverse, wave-like structures, which occur in trains of similar individuals wherever flow conditions are sufficiently uniform. Both types of structure are asymmetrical in vertical profile parallel to flow and they are characterized by its height H and wavelength λx. Dunes are those structures which exceed 60 cm in wavelength and 4 cm in height; ripples are less than 4 cm in height and 60 cm in wavelength (Allen, 1970). As long as a sediment grain experiences more upward-directed turbulent motions than the combination of downward-directed turbulent motions and gravitational settling, it will remain in suspension (Bridge, 2003; Boggs, 2001).

The coarser part of the load, the part that is more difficult to move by flowing water, is limited in its rate by the transporting ability of the flow between the source and the section. This part of the load is designated as *bed-material load*. Sediment grains with diameters greater than approximately 0.1 mm (sand or gravel) generally move close to the boundary (within ten grain diameters) by rolling, sliding, and saltating (jumping). These grains move more slowly than the surrounding fluid because of their intermittent collisions with bed and each other. The continuing movement of bed-load grains requires the existence of an upward dispersive force that must be exactly balanced by the immersed weight of the moving grains' steady bed-load transport.

Both turbulent and non-turbulent fluid lift forces can act on bed-load grains. Non-turbulent lift forces are pressures arising from a net relative velocity between grains and surrounding fluid. They are caused by asymmetrical flow around near-bed grains, the reduced grain velocity relative to the velocity gradient in the surrounding fluid (shear drift), and the effects of grain rotation (Bridge, 2003).

As turbulence originates very close to the bed of a stream, bed-load grains are undoubtedly affected by turbulent lift as well as by drag. As near-bed turbulent fluctuations increase with bed shear stress (or shear velocity), grain saltations are expected to be modified more and more by turbulence as bed shear stress and sediment transport rate increase. Turbulence affects different sized grains in different ways. For example, at the low sediment transport rate of gravel, most of the movement occurs during sweeps and to a lesser extent during outward interactions. Ejections and inward interactions have little effect on coarse-sediment movement, because even the largest values of turbulent lift are much less than the immersed weight of the gravel grains. Furthermore, the mean grain size of the bed load increases with turbulent shear stress associated with sweeps. With smaller (in fact lighter) grains or larger bed shear stresses, ejections have much more influence on bed-load movement.

One of the most striking and important characteristics of sediment transport over a bed of loose sediment is the development of bed forms. A bed form is defined as a single geometrical element, such as a ripple or a dune. Bed forms have been classified as microforms, mesoforms and macroforms by Jackson (1975).

2.5 SEDIMENTATION PROCESSES IN LAKES

The deposition, erosion, and transport of sediments in lakes is of interest in many fields of investigation including lake productivity and nutrient dynamics, aquatic habitat, contaminant transport and pathways, sediment/water and sediment/biota interactions, and also quantitative assessments related to shore erosion, longshore drift, resource extraction, dredging and water-storage capacity (Sly, 1994).

The processes of sedimentation in lakes are closely related to the hydrological flow patterns and to the topography of the basin, which influences the hydrodynamical regime. The formation and behavior of lacustrine sediments is dominated by the interaction of a number of physical processes whose relative importance is influenced particularly by the form of the basin, its orientation and size, and by climatic conditions. The form of existing lakes depends not only upon the form of the original basin but upon subsequent tectonic and isostatic movements, and upon the accumulation of infilling material. Changes which affect the physical regime lakes may be separated into four distinct types: (1) basin-wide effects which are caused by climatic change; (2) basin-wide effects which are produced by changes in water level; (3) basin-wide effects, which due to natural erosion-accumulation trends are related to expansion or shallowing; (4) local changes which affect only part of a basin, such as the migration of deltas, formation of spits and bars, or modification of inflow due to drainage change.

The range of lake types and their sedimentary characteristics are widely diverse. Despite apparent differences, however, it is important to realize that essentially the same relationships may be used to express sediment response to dynamics forces in almost all lake systems.

Sedimentary processes in lake systems differ from those of marine systems in three major aspects (Sly, 1978):

1) Despite the great size of a few lakes, the small size of most lakes significantly limits the generation of long-period waves and therefore maintains such energy levels much below that of marine systems; the occurrence of sorted coarse sands and gravels is largely confined to shallow water areas.
2) Lakes are essentially closed, or nearly closed systems; with respect to sediment transport and, because the ratio between land drainage and lake area is often high, sediment loadings and sedimentation rates appear substantially higher than in marine environments, typically mid-lake sedimentation rates are at least 10 times that of oceanic environments. Geologically speaking, therefore, most lakes are transitory features.
3) Lakes are almost tideless, tidal currents are generally negligible, and littoral zones are much reduces or absent.

The physical processes that interact in lakes to bring about sediment transport and deposition include wind, river inflow, atmospheric heating, surface barometric pressure, and gravity (Figure 2.2). Surface barometric pressure and gravity effects are of the least importance (Sly, 1978). Except in very large lakes, tides commonly play only a relatively minor role in lake processes. Wind processes are of major importance because winds create waves and currents may help generate seiches (periodic rocking back and forth of water in lake basins). River inflow may generate plumes of fine sediment that extend in surface waters far out into a lake, or it may generate density underflows, or turbidity currents, that carry sediment along the bottom toward the basin center. River inflow can also create currents that flow along the margins of lakes.

In lake sedimentological contexts, it is often useful to distinguish between areas dominated by river action and areas dominated by wind/wave action. Delta sedimentation and river plume sedimentation are exclusive for areas dominated by river action, while "pelagic" sedimentation and turbiditic sedimentation (i.e., sedimentation connected to various mass movements of already deposited material) are not restricted to river-mouth areas. The following four factors regulate the rate of deposition in lakes (Hakanson and Jansson, 1983):

1) A *deposition* factor describing the capacity of a given lake to act as a sediment trap – the larger the lake volume the higher the entrapment capacity, if all factors are held constant.
2) A *production* factor describing the autochthonous production, i.e., the total internal bioproduction.
3) A *pre-trapping* factor describing the fact that lakes "downstream" received less allochthonous materials than lakes "upstream", which act as sediment traps for suspended particles/aggregates.

4) A *load factor* describing the natural load of allochthonous materials (bed load, saltation and suspended load) and the anthropogenic load (from industries, urban areas and agricultural activities) on a given lake.

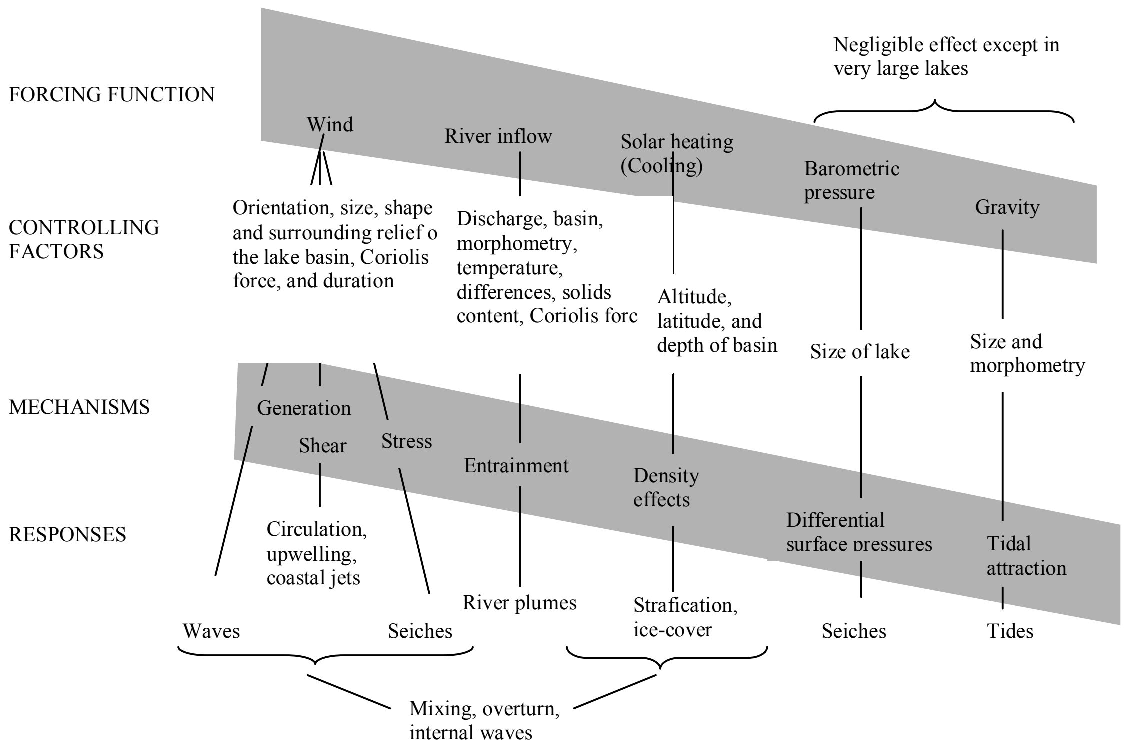

Figure 2.2: Lake response to various forms of physical output (Sly, 1978)

CHAPTER 3

LITERATURE REVIEW

There have been numerous theoretical, numerical, laboratory and field studies of rivers and reservoirs. The literature review is a summary of publications on structure of turbulence and sediment dynamics in rivers, reservoirs and river mouths.

3.1 METHODOLOGY

3.1.1 Field measurements

3.1.1.1 Establishment of distribution of main parameters of turbulent in the flow

Turbulence has great influence on mixing and transport processes in rivers. Researchers made many attempts to measure turbulence. Turbulence intensity is a simple and widely investigated river turbulence characteristic. It is often used in both basic research and practical applications. Many researchers, such as Grinval'd, 1974; Iwasa and Asano, 1980; Nezu and Nakagawa, 1993; among others, have tried to develop some universal functions to describe its vertical distribution in open channel flows by using both empirical models and semi-empirical models (Nikora and Smart, 1996).

Grinval'd (1972) used a small, low-inertia microimpeller to measure rapid velocity measurements. Having used the data obtained from field measurements he conducted in Turunchuk and Dnester rivers and plotted velocity distribution curves. It was shown that in most cases the longitudinal component of the velocity completely follows normal law: The turbulent intensity increases from the surface toward the base of the flow. The method of structure functions was used to investigate the flow structure and developed the inertia integral on a fixed band of frequencies, for which he applied "-2/3-law" of Kolmogorov-Obukhov for the structure function and the "-5/3-law" for the spectral function. The energy dissipation is computed directly from the spectrum and it also uses the structure function.

Barrage (1979) has developed a probe, which permits measurements of the instantaneous velocity in rivers. The purpose of the measurements is to determine the character of the turbulence in a natural channel and to compare it with measurements in laboratory flumes. As a result, he found that the flow in natural channels seems to be heavily influenced by secondary flow phenomena. The distribution of the mean velocity reflected the flow. Suitable conditional sampling of the velocity signal offers a better insight characterized by periods of low and high turbulence intensity of random duration. The scale of the smallest element corresponding to these periods appears to be an order of magnitude larger than the microscale.

Iwasa and Asano (1980) used two locations of the Yodo River and one location of the Tone River in Japan to find out the hydrodynamic characteristics of the turbulence in rivers and conveyance channels. The authors focused their investigations on three characteristic parameters of the turbulence, which are, the turbulence intensity u' the Eulerian mean time scale T_E and the energy dissipation rate of turbulence per unit mass and unit time ε. The main results they obtained through the study are as follows: Vertical distributions of the three characteristic parameters of turbulence in rivers and conveyance channels can also be represented in forms of universal functions, which have been obtained in the laboratory experiments. The depth of the flow, the local mean velocity and the friction velocity are used to normalize the three characteristic parameters of turbulence.

Anwar (1986) carried out a field experiment in a river bend, measured velocity components in the longitudinal, lateral and vertical directions at various cross sections within the bend and determined the bed topography. The following results based on the velocity components in three directions around river bend were obtained: (1) The curved flow affects equal contours of the normal stresses, in three directions, at the bend entrance. The stress contours changes greatly within the bend, with maxima near the free surface of the outer bank, and also in the deepest parts of the sections. (2) The Reynolds shear stress in the mean flow direction at the bend entrance is sensitive to the curved flow; the contours of constant shear stress are distorted within the bend.

Nikora (1991) presented the generalized results of observations in nature regarding fluvial turbulence in river sections featuring diverse bed macro-roughness (flat bed, sand dunes, shingle-cobblestone bed, aquatics). An empirical dependency for the rate of turbulence and power dissipation was derived. He proposed a velocity fluctuations spectrum model by considering the fluvial turbulence scales and revealed specific properties of fluvial turbulence. This model included (1) Empirical functions of probabilities distribution for all three components of velocity vectors (2) The distribution of averaged velocities by depth (3) Turbulence energy (4) Relative turbulence intensity (5) Correlation and coherence functions (6) Model of fluvial turbulence spectrum and classification of turbulence motion (7) Scales of turbulence (8) Turbulent energy dissipation. The obtained results yield foundations to isolate the following main properties of fluvial turbulence, which is considered as feasible in mathematical modeling of hydrophysical processes in rivers:

- Structurality expresses in velocity spectra by energy supply zones hierarchy, the scales of which correspond to characteristic sized of bed forms of various structural levels;
- Discreteness manifested through a discrete character of energy supply of turbulence as well as through possibility of existence of varyscale coherent structures;
- Spatial-time modulation of velocity pulsations taking place under stationary and non-stationary external conditions.

Nikora et al. (1993) performed the measurements of the macroturbulence characteristics in the middle part of the Swider River at low levels of water. They summarized their conclusions as follow:

- The integral characteristics of turbulence: Mean velocities u, velocity dispersion σ^2, intensity of turbulence σ/u, skewness A and kurtosis E of the fluctuating velocity represents the turbulence characteristics of the flow. These parameters characterize the probability distributions of the longitudinal velocities and they have very clear physical interpretation. The distribution of u, σ^2, and σ/u in direction of flow and within the cross-section are shown in Figure 3.1. The mean velocity u, velocity dispersion σ^2 and σ/u vary in the range of 15 to 18 percent and it does not exceed the range of precision of their determination. The tendency to increase in the longitudinal direction, what is caused by the widening of the stream as well as by the bed sand waves, characterizes the variability of σ^2 and σ/u.

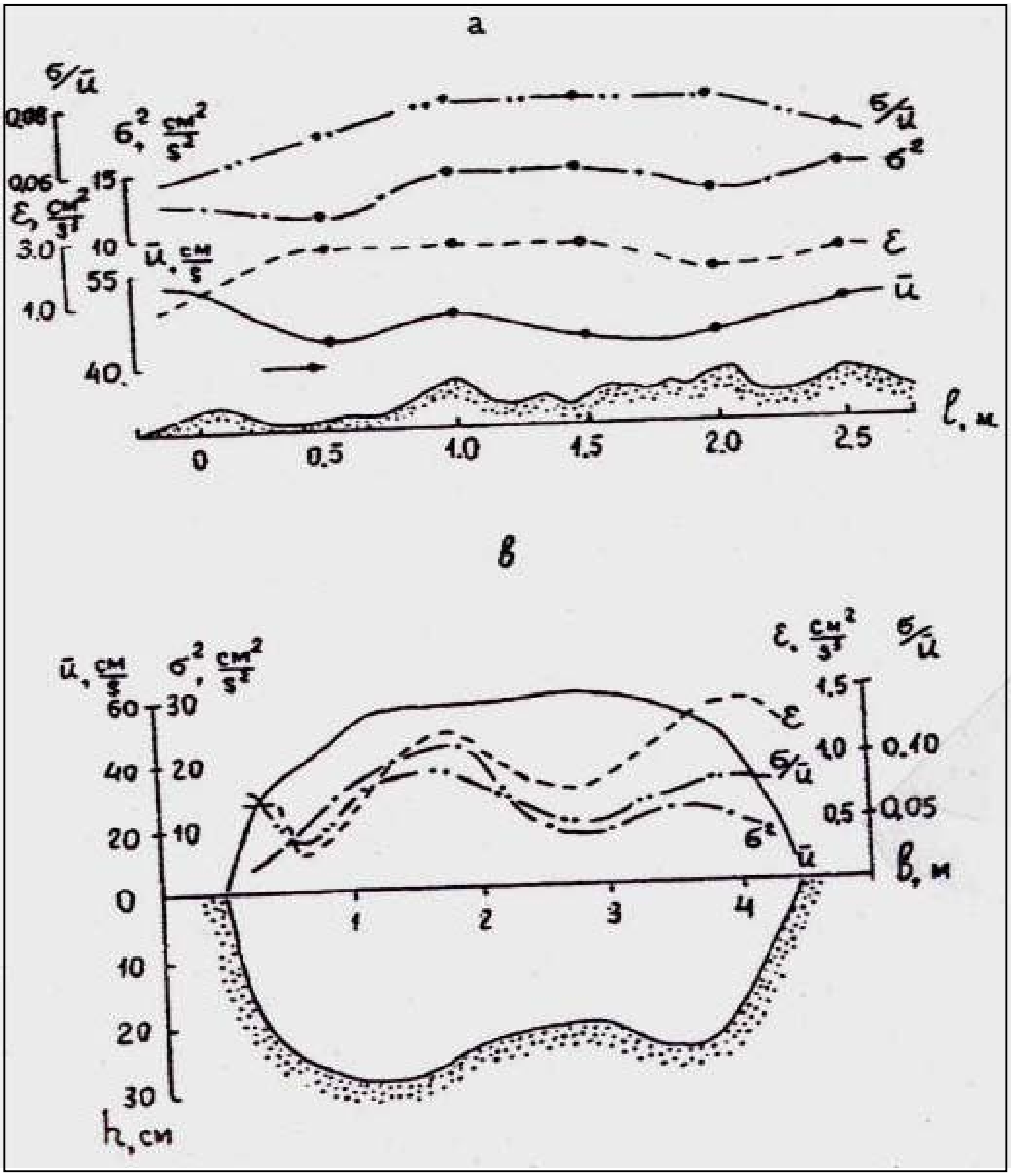

Figure 3.1: Distribution of turbulence characteristics a) along the stream, b) across the stream (Nikora et al., 1993)

- <u>Spatial-time and spectral characteristics of turbulence</u>: The analysis of spatial-time structure of turbulence concerns correlation and spectral functions of the velocity in the fixed points of the flow as well as two-point correlation and coherence functions. The time-autocorrelation functions R(τ) have a very similar form in all measuring points – they decrease to zero rapidly and further are characterized by the alternation of the domains of the positive and negative values. The apparent periodicity of the R(τ) varies in the range of 2 to 5 sec. The lateral correlation functions R(Δy, τ) are statistically insignificant for all Δy_i and τ what is caused by the nonoccurrence of the lateral velocity correlations for Δy ≥ 2h in the considered stream (Δy – the distance between the measuring points at the cross-section). In contradiction to R(Δy, τ), the longitudinal correlation functions R(Δx, τ) are characterized by many significant maxima for non-zero values of τ (Figure 3.2). Using the methodological approach described in Nikora and Ekhnich (1990), they calculated the transport rate of the turbulent eddies and evaluated the correctness of the formula R(τ) = R(Δx).

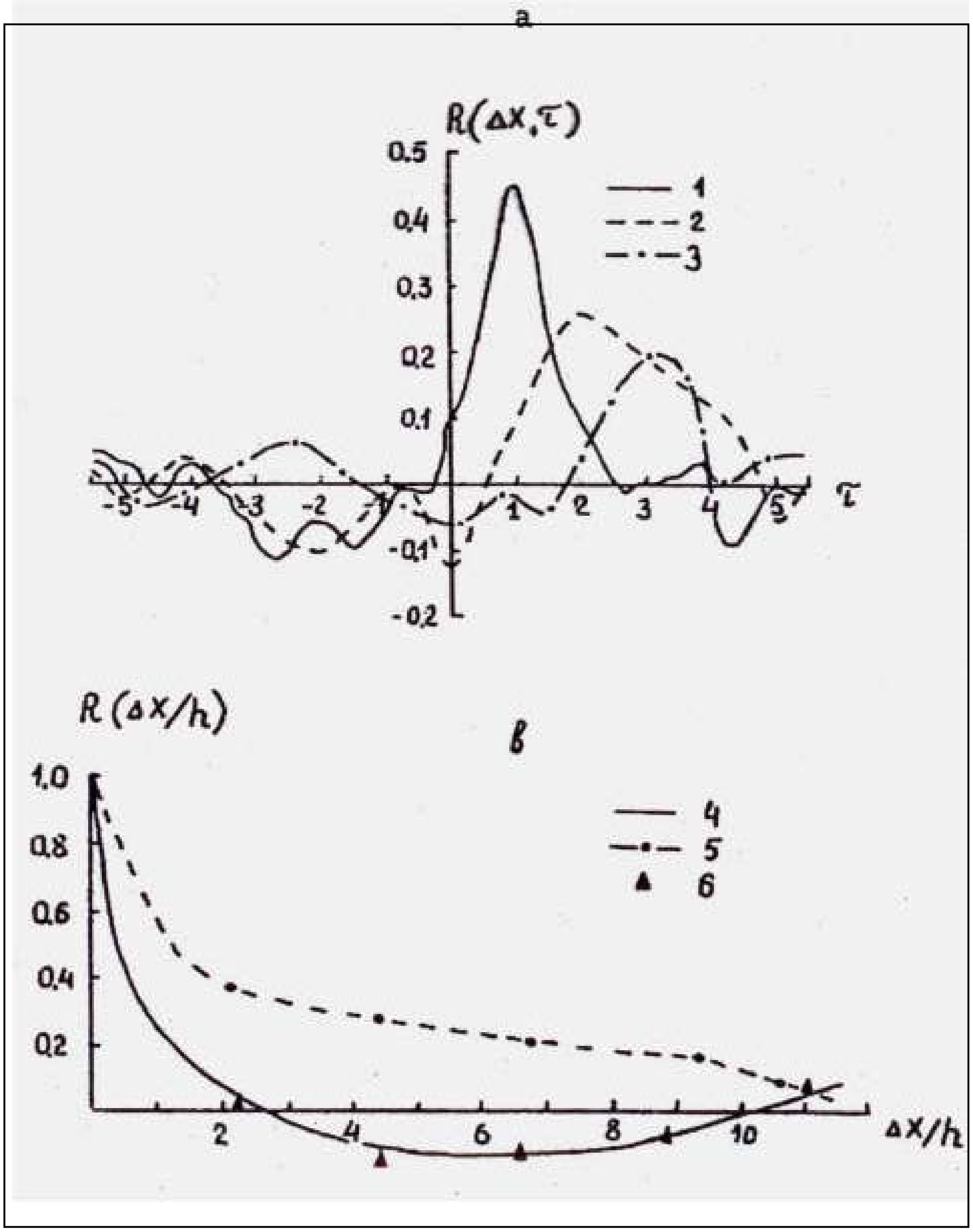

Figure 3.2: (a) Time correlation functions (b) Space correlation functions (Nikora et al., 1993) 1- Δx = 0.5 m, 2- Δx = 1.0 m, 3- Δx = 1.5 m, 4- R(uτ/h), 5- R(Δx/h, $\tau = \tau_M$), 5- R(Δx/h, $\tau = 0$)

The authors examined the frequency spectra of the longitudinal velocities within the frequency intervals from 0.5 to 62 rad/s and it corresponds to the intervals of the spatial scales from the lowest depth to the 15-30 depth of the flow (Figure

3.3). In spite of the small Reynolds numbers (10^4 to 10^5), they observed the inertial intervals in all spectra in the domains of high frequencies. In these intervals the spectral curves can be approximated by the power of "-5/3". The spatial scales, from which the low "-5/3" is satisfied; vary in the range of the 2 – 3 depths near the bank of those 8 – 10 times the depth of the stream in the central part. A very characteristic feature of the considered spectra is the existence of the maxima within the scales corresponding to the sizes of the sand-waves. They interpreted the layout of these maxima in the inertial interval of the scales as discrete zones of the sources of energy, which are additional sources of transmission of energy from the mean flow to the pulsating one as a balance of the independency of the stream and sand-waves. In the range of low frequencies, they showed that the spectrum could be approximated by the power function with the power close to "-1" (Figure 3.3).

- Scales of turbulence and dissipation of energy: The existence of the inertial intervals in the frequency spectra allows to calculate the dissipation of turbulent energy on the basis of the famous Obukhov (Kolmogorov) law:

$$S(\omega) = C\varepsilon^{2/3}u^{2/3}\omega^{-5/3} \tag{3.1}$$

Sand-waves influence the longitudinal and lateral distributions of ε as well as other characteristics of turbulence. Nikora et al. (1993) investigated the Eulerian integral scale, L, the scales L_M (corresponding to the maxima in the velocity spectra) and also the Kolgomorov microscale η within the characteristic scales of turbulence. It varies in the ranges of 0.2 to 0.4 mm, which is comparable in order with the diameter of the bed particles.

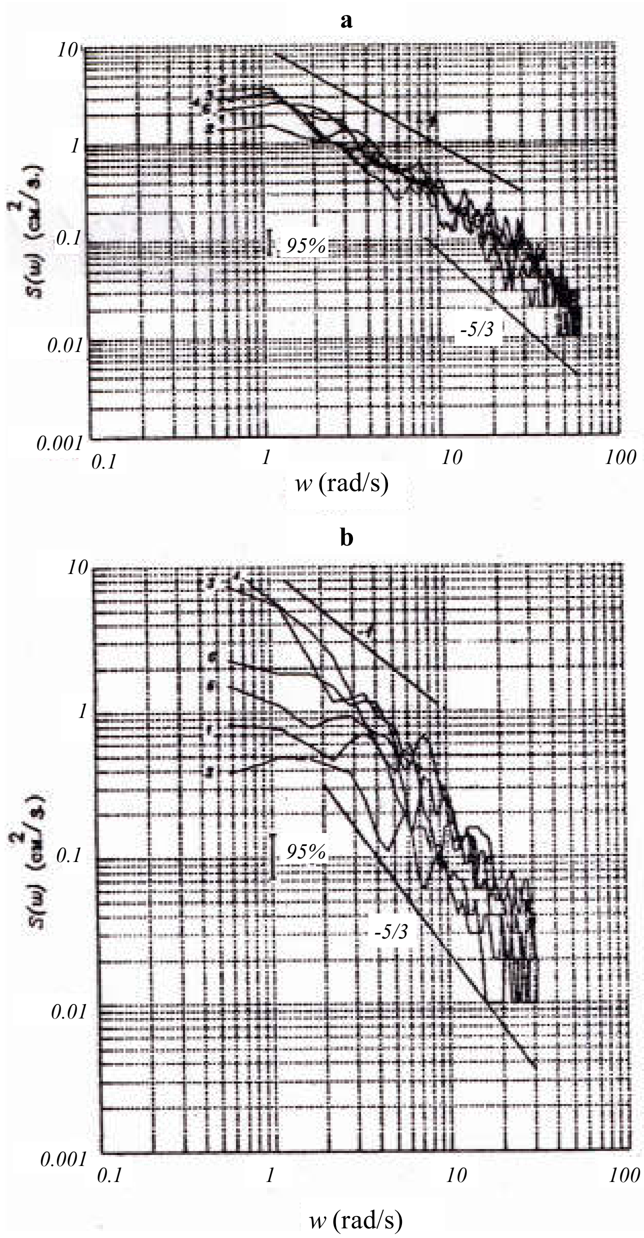

Figure 3.3: Power spectrum (numbers indicate the micropeller) a) longitudinal direction, b) transversal direction (Nikora et al., 1993)

The longitudinal and transverse components of flow velocity, as well as the normal and tangential stresses, must be expected to fluctuate with time and space when flow at high Reynolds number moves between fixed boundaries. Although these non-periodic fluctuations are generally secondary in magnitude compared to the mean motion.

Bhowmik and Xia (1993) and Bhowmik et al. (1995) from Illinois State Water Survey collected and analyzed detailed velocity data from the Illinois and Mississippi Rivers by using 2-D electromagnetic current meters. The goal of their research was to understand and evaluate the turbulent structure in natural river systems, especially near the channel border areas. They analyzed the fluctuation characteristics of flow velocity systemically and measured flow velocities with time at six different lateral locations and at three different vertical elevations. Analyses of the velocity data included the cross-sectional and vertical distributions of longitudinal and transverse velocity components (u, v), the fluctuating velocity components (u', v') and their frequency-distribution curves, turbulent intensities (σ_x, σ_y), turbulent shear stress ($-\rho u'v'$), and turbulent kinetic energy. They found that all of these components are relatively high within the main channel. Besides, all of these flow parameters decrease in the channel border areas. Thus, the main channel area above the riverbed appears to be the most active zone in the river.

3.1.1.2 Influence of turbulence on sediment

The influence of turbulence on sediment transport has received much attention in the past (Grass, 1971; 1982; Grass and Ayoub, 1982). Many experimental studies have been conducted to find out velocity fluctuations' effect on sedimentation concentration.

Smart (1999) investigated vertical profiles of turbulent streamwise velocities in several New Zealand gravel bed rivers. He conducted field measurements at high and low flows with electronic pitot tubes, which show logarithmic velocity profiles to extend over much of the flow depth. For the gravel bed rivers, he studied the velocity at 0.6 of the total depth and the velocity was generally a good indicator of depth-averaged flow velocity. He adopted an unambiguous definition of flow depth to deal with situations where the bed is uneven or moving. The results indicate that the profile origin offset below tops of the bed roughness elements is proportional to hydraulic roughness (Z_0). For mobile beds the offset does not appear to be related to bed-material size and also hydraulic roughness is appeared to be independent of bed-material size. Under movable bed conditions, field data indicates that hydraulic roughness may be proportional to the log profile parameter of square of the characteristic velocity (U^{*2}). For uniform flow conditions, this implies a linear relation between Z_0 and bed-shear stress.

Nikora and Goring (2002) worked on fluctuations of suspended sediment concentration and turbulent sediment fluxes in an open-channel flow. They aimed to solve a complex problem of turbulent-sediment interactions in an open-channel flow by approaching experimentally, using specially designed field experiments in an irrigation channel. The experimental design included synchronous measurements of instantaneous three-dimensional (3D) velocities and suspended sediment concentration using Acoustic Doppler Velocimeters (ADV) and a water sampling system. They considered various statistical measures of sediment concentration fluctuations, turbulent sediment fluxes, and diffusion coefficients for fluid momentum and sediment. By using quadrant analysis, they evaluated statistics, fractal behavior, and contributions of bursting events to vertical fluxes or fluid momentum and sediment. They advised that both turbulence and sediment events are organized in fractal clusters, which introduce additional characteristic time and spatial scales into the problem. They also showed that Barenblatt's theory of sediment-laden flows appears to be a good approximation of the experimental data.

Velocity fluctuations not only influences suspended sediment concentration but also bed load concentration. Bonham-Carter and Sutherland (1967) developed one of the oldest mathematical simulation models for studying delta formation. They wrote a FORTRAN IV computer program for simulating the diffusion and settling of suspended sediment at river mouths. Water and sediment discharge, sediment grain size distribution, sediment density, the porosity of the resulting sediment, width and depth of the river channel and the geometry of the basin govern the rate of sediment accumulation at any point in front of the channel mouth. They used a plane jet model for determining the velocity field and the rates of sediment diffusion. By adjusting the input parameters, they hypothesized that a variety of "delta" deposits may be created. Bonham-Carter and Sutherland found that the shape and foreset slope of the delta fan is closely controlled by grain size and discharge. They allowed the model to respond dynamically to build up sediment at the channel mouth, a distributary mouth bar and submerged levees can be formed. They monitored the delta simulation experiments by printing maps, showing the rates of sedimentation for each grain size at every cell in a digital accounting grid, and facies maps using alphabetic symbols. They used a digital plotter to draw maps and stratigraphic cross sections.

Grinval'd and Ekhnich (1977) suggested that it might be helpful to consider first the turbulent kinetic energy carried eddies of various scales in studying the variability of bottom relief under the action of turbulent flow. He reported the results of long-term field studies of the energy aspect of stream flow turbulence on sections from Turunchuk River with various channel forms and various bottom topographies. From the data, he verified that the energy contributions of small and medium eddies are equal, on the average over the vertical, to the energy contribution from large eddies for a straight section with a nonerodible or slightly erodible bottom. About 70% of all of the energy on the vertical, or nearly twice the contribution from large eddies, is in the small and medium sized eddies. He concluded that the shaping of channel-relief microforms is related to the medium-sized turbulent formations, i.e. eddies whose dimensions are comparable to the depth of the stream.

Grinval'd and Ekhnich (1980) studied coherence functions in turbulence structure analysis for river flows. The space-time cross spectra allows to correlate stationary random processes in the frequency domain and to determine frequencies (high to low) that are responsible for the linear relation between the processes. They applied spectral analysis to the turbulent eddies in rivers. The coherence graphs show that as a rule coherence level falls as the distance increases. In the study, the correlation became weaker as the distance between points increased for flat beds and for sand-ridge beds. However, the correlation was associated with different frequency components of the different types of bed relief. In the presence of sand ridges, the correlation was usually due to high-frequency components, which indicated that medium-scale and small vortices predominate. This finding agrees with the determination of the predominant vortices by dispersion analysis. The part with the flat bed (where large vortices predominate) had the highest correlation level occurring at low frequencies, which correspond to large-scale perturbations. It indicates that turbulent perturbations interact by different mechanisms in accordance with the relief of the river bed, and also that eddies of each type are involved in producing the relief.

Grinval'd and Nikora (1982) applied statistical methods to the microforms, which combine ridges and ripples, which are most abundant riverbed forms. They examined the variability of the correlation and structural functions along with that of the spectral densities of the longitudinal profiles from point to point across the river and on passage of floods. They pointed out the following conclusions from the statistical functions:

1) The form of the correlation and structural functions is dependent on the form of the cross section of the river bed. The period and amplitude of the oscillations are related to the characteristic length and height of the profile waves, and they vary with the depth over the width of the flow.
2) The -3 law is confirmed for the spectrum in the region of large wave numbers.
3) $f(\alpha)$ in Hino's formula for the sand-wave spectrum has been estimated for natural rivers and is found to be dependent on the Froude number.

Hwang and Yang (1990) studied the state of the flow field and the diffusion of concentration under the interaction of a stream debounchment and sea currents at a river mouth. They used three-dimensional unsteady conservation equations to describe the interaction of the flow field and consider the dynamic factors, which include the effects of buoyancy, inertia, hydrostatic pressure and mixing turbulence. They modeled turbulent effects by using an eddy viscosity through the Reynolds Approximation. In the numerical process, the conservation equations are solved by an explicit method of central difference scheme with time-iteration, until the flow field variables are continuously adjusted with the time-dependent finite difference technique to steady state. Hwang and Yang used the

DuFort-Frankel formula to modify the terms of viscosity to make sure that the steady state model is correct. To avoid the negative values, they applied the second upwind method to convective terms of concentration. Results of the computations showed that the phenomena of vortex, secondary flow and wall jet exist downstream of the stream and sea current. Also they concluded that the diffusion of sediment concentration decreases with increases in depth.

Sumer et al. (2003) studied the influence of turbulence on bed load sediment transport in an open channel by experimentally. The external turbulence was generated by (1) a horizontal pipe places halfway through the depth *h*; (2) a series of grids with a clearance of about one-third of the depth from the bed, and extending over a finite length of flume; and (3) a series of grids with a clearance in the range (0.1-1.0)*h* from the bed, but extending over the entire length of flume. They conducted two kinds of experiments: plane-bed experiments and ripple-covered-bed experiments. In the former case, Sumer et al. adjusted the flow in the presence of the turbulence generator so that the mean bed shear stress was the same as in the case without the turbulence generator in order to single out the effect of the external turbulence on the sediment transport. In the latter case, they measured the mean and turbulence quantities of the streamwise component of the velocity and determined the Shields parameter, due to skin friction. Based on these experiments, the authors noted the Shields parameter, together with the RMS value of the streamwise velocity fluctuations, was correlated with the sediment transport rate. As a result, the sediment transport increases markedly with increasing turbulence level. Not only turbulence influences on sand bed but also sand bed influences turbulent structure. McLean and Smith (1979) analyzed the data produced with small mechanical current meters above 2 m high 96 m long sand waves in Columbia River for turbulent structure of flow over regular sets of bed forms. The high-frequency resolution of the flow sensors and the collected half hour record showed that they are sufficient to yield reliable Reynolds stresses. They presented an expression from which the sampling error in Reynolds shear stresses can be estimated from the sampling frequency, the local flow speed, and the distance from the boundary. Although they found the $\kappa^{-5/3}$ range of the energy spectrum, the conditions for isotropy were not satisfied anywhere within the measured band. Furthermore, they found that the Reynolds shear stress varies with the structure of the variance of the vertical velocity component rather than with that of turbulent kinetic energy as assumed in the simple closure models that have been used so far in theories for flow over such bed forms.

Grinval'd et al. (1981) attempted to determine the dimension of sand-wave relief by a mathematical model of correlation and spectral analysis. He analyzed that the spectral density curves have well-defined peaks; at large wave numbers, the spectrum has the form of a power-law function, generally with an exponent of -3.

Sukhodolov et al. (1998) presented the measurements and analysis of the three-dimensional turbulence structure in a straight lowland river reach. They took accurate measurements of velocity profiles with acoustic Doppler velocimeter (ADV) and a multichannel micropeller-based system. They showed that analytical expressions derived from investigations of laboratory open-channel flows agree well with the measured data only in central part of the river where flow can be considered weakly three-dimensional. At the same time, they detected clear differences of empirical parameters between river and laboratory flows and reported that river turbulence is isotropic for spatial scales smaller than the river depth. The data also allowed the detection and analysis of the turbulence anisotrophy impact on the formation of secondary currents. They advised special attention to be paid to the investigation of coherent structures. By applying the conditional-average procedure based on *uw* quadrant analysis, they were able to evaluate their spatial scales. On average, the scales of ejection and sweep events are as large as 1.5 times the flow depth.

3.1.1.3 Obtaining data for calibration of different numerical models

Theory of turbulence has not been fully developed. However, by using numerical models, it is possible to define turbulence. Turbulence influences sediment in river mouth more strongly. As a result of these influences, some of the formations such as ripple forms at the bottom, sand bar forms as well as other sedimentation forms are created.

Oziransky and Shteinman (1993) used the two dimensional reservoir water quality model "BETTER" for assessment of turbulent processes in Lake Kinneret. The simulation processes reproduce observed water quality patterns on the basis of 6, 12 or 24 h time intervals. Input data to the model include daily inflow and outflow volumes, meteorological conditions and concentrations of dissolved oxygen, nutrients, pH etc., in the inflow and in the lake water at the start of the model run. The Jordan River inflow is considered to be input to the surface layer. Lake geometry, flows and thermal stratification determine flow and mixing patterns within the water body. They simulated all processes within each box and calculated the resulting two-dimensional concentration patterns and displayed the results graphically. Based on the output, they evaluated the relationship between the main diffusion parameters and the turbulent scale. The main conclusion is that the greatest decrease in the scale of the vortices in the lake occurs close to the mouth of the river. The kinetic turbulent power also declines when moving away from the flow source, and macroturbulent processes are replaced by microturbulent processes. The coefficient of turbulent diffusion changes respectively. According to modeling results and the filed survey, they pointed out that the dispersion characteristics of turbulent flux are mostly determined by the scale of turbulence and this relationship is close to linear.

Natale (1996) presented a mathematical model for studying the hydrodynamic dispersion of pollutants discharged in coastal areas near a river mouth during flooding. She represented the hydrodynamic process in a two-dimensional depth integrated system and assumed the solute is non-reactive. Natale solved the model numerically by using finite differences characterized by an appropriate algorithm, which is explicit to describe the field of motion and implicit to integrate the transport equation.

Egashira et al. (1997) developed a depth integrated mathematical model for evaluating sand-bar flushing during floods. In addition, they reproduced flow velocities and bed variations correctly in upstream river bends as well as in the mouth region. The primary purpose of modeling, both numerically and physically, is to mirror exactly or duplicate the phenomena on compressed scales, which cannot be practically observed in prototype.

Wu et al. (1997) presented a 3-D numerical procedure for river flow with free surface and rough bed, which uses the k-ε turbulence model as well as a finite-volume method on an adaptive non-staggered grid for solving the full Reynolds-averaged Navier Stokes equations. They calculated the water level with the aid of a 2-D Poisson equation derived from 2-D depth-averaged momentum equations. The test calculations for a strongly curved open channel flow and a natural river flow show that the model can predict the important features of main and secondary flows in rivers.

Bungartz et al. (1998, 2000) used the three-dimensional numerical model SEDIFLOW to simulate the floodplain effected turbulent flow and the suspended sediment transport in the Jordan River cross-section upstream from Lake Kinneret. Based on Reynolds eqs. and convection-diffusion eqs. for suspended sediment transport, the package SEDIFLOW predicts the mean flow velocities and the coupled suspended sediment transport in natural rivers. The authors used standard k-ε turbulence closure to predict the distribution of vertical turbulent momentum exchange and utilized a constant-coefficient model to describe the transverse mixing. By comparing filed data of flow velocity and suspended particulate matter concentration with predicted numerical results for different discharge situations, they could estimate unknown model parameters like the coefficient of transverse turbulent exchange, the effective bed roughness and the mean particle settling velocity dependent on water discharge. Streamwise flow velocities predicted by the model were in good agreement with field measurements for six considered hydraulic situations. The applied turbulence closure seems to be a suitable approach for describing turbulent flow and particle mixing over the river cross section studied.

3.1.2 Theoretical studies

Researchers have been interested in turbulence on rivers, lakes and seas for a long time. One of the main fundamental books was written by Hinze (1959), who presented current notions and theories about turbulent fluid flow and tried to explain sufficient theoretical basis not only for studying the specialized literature on turbulence but also for theoretical investigations on engineering problems, for which turbulence plays essential part, such as mixing, heat and mass transfer. He gave a general introduction to various specific turbulence theories and derived some general basic formulas about turbulence. He mentioned isotropic turbulence theories and used them as a starting point for further theoretical studies on turbulence. Hinze also described turbulence statistical theory and applied statistic to turbulence description. He showed appliance of Navier-Stokes equations and modified these equations to apply to local turbulence. He also showed processes of mass and heat transfer in turbulence. The originality of his research was nonisotropic free turbulence. He used self-preservation to indicate that the turbulence maintains its structure during the development of the turbulent region in the downstream direction of main flow. Based on the application of tensor and correlation functions, he described mass and heat transfer in turbulence flows.

Andrei Nikolaevich Kolmogorov was perhaps the foremost contemporary Soviet mathematician who also had outstanding knowledge of turbulence. Hinze observed isotropic turbulence but Kolmogorov in contrast applied isotropic turbulence to rivers, streams, sea and lakes. He created local isotropic model of turbulence. Basically, in rivers and river mouths, turbulence is not isotropic. He also showed that in limited volume, isotropic turbulence theory could be applied which is why the theory is called local isotropic. In 1941 Andrea Kolmogorov published a paper (Kolmogorov, 1941) in which he derived a formula for the energy spectrum of turbulence. This spectrum gave the distribution of energy among turbulence vortices as a function of vortex size. In this work

Kolmogorov founded the field of mathematical analysis of turbulence. There were other attempts at such analysis before but never with such a striking result. Kolmogorov used dimensional analysis to qualitatively predict a relationship between the control parameters and the flow property concerned. Based on the theory analysis, he showed that the turbulent velocity field can be thought of as being made of many eddies of different sizes, where the biggest eddy is compared to the river channel. The energy spectrum *E(k)* is defined as the kinetic energy per unit mass and per unit wavenumber *k*. Kolmogorov's (1941) theory is based on the notion that that large eddies can feed energy to the smaller eddies and these in turn feed even smaller eddies, resulting in a cascade of energy from the largest eddies to the smallest ones as illustrated in Figure 3.4. After the turbulent flow reaches to steady state, the energy is injected into the flow at the largest scale ~ l_0 (the largest eddy) and then is transferred successively to smaller eddies of sizes ~ l_1, ~ l_2 ... until the dissipation cut-off length l_{min} is reached. The smaller eddies are exposed to the strain-rate field of the larger eddies. By increasing their vorticity, the smaller eddies gain their own energy at the expense of the energy of the larger eddies. As a result, there is an energy flux, ε, transferred from the larger eddies to the smaller ones. For simplicity, Kolmogorov theory assumes that $\varepsilon_n \cong \varepsilon$ is a constant. At the length scale l_{min}, the kinetic energy will dissipate into heat, and the eddies can not further cascade into any smaller sizes. In accordance with the time range, where $t_{diss} >> t_n >> t_0$, there exists an inertial range, where $l_{min} << l_n << l_0$, in which one may ignore the dissipation and the boundary effect. In this inertial range, the energy ε per unit mass per unit time is transferred to the smaller eddies (i.e. larger wavenumbers, where wavenumber $k_n=1/l_n$).

Hence in the inertial range *E(k)* is expected to depend only on the two quantities ε *and k*. Dimensional considerations again dictate that this dependence can only be of the form

$$E(k) = C\varepsilon^{2/3}k^{-5/3} \qquad (3.2)$$

in the inertial range (Shen, 1996). The dependence of *E(k)* on *k* gives the Kolmogorov -5/3 law.

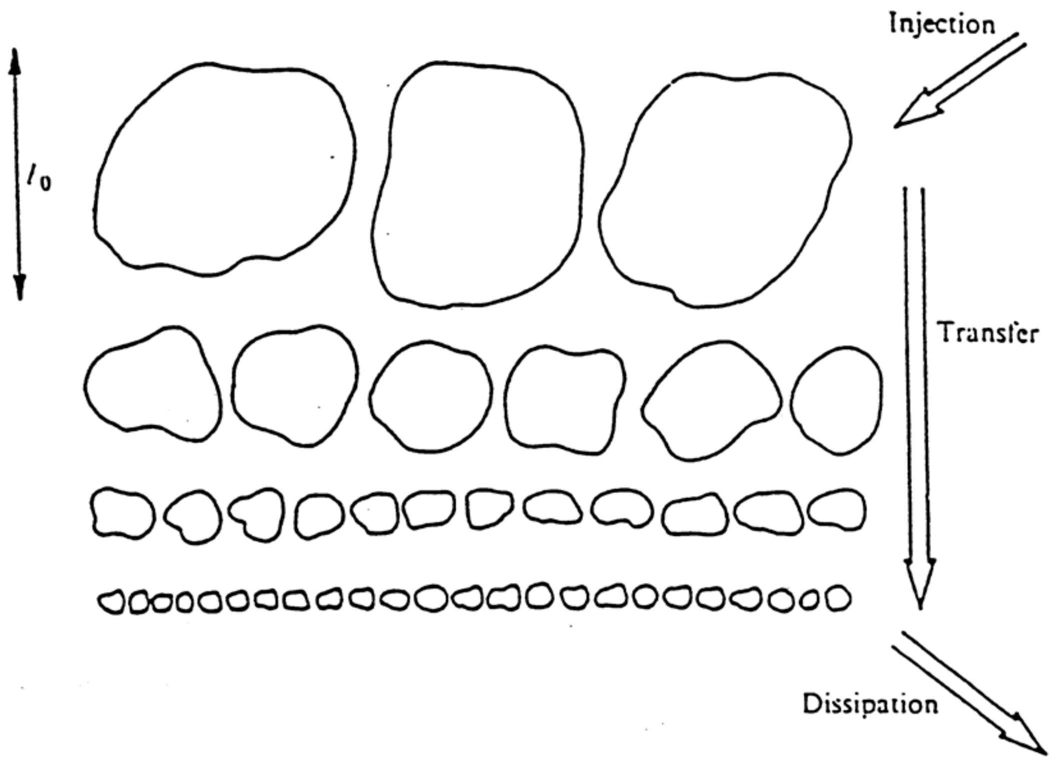

Figure 3.4: The energy cascade according to the 1941 Kolmogorov theory (Shen, 1996)

In spite of a long history of sediment transport theory and channel mechanics, the structure of mobile bed flows has attracted much less attention than sediment transport itself. Most researchers have implicitly assumed in their sediment transport studies that flows over mobile beds have the same structure and follow the same scaling laws as those over fixed beds. To study the processes of flow structure over sand and gravel mobile beds, Grinval'd (1988) used the theory of Hinze and Kolmogorov. He created a theory of suspended matter in rivers and also the relationship between turbulence and the bottom of the river channel. He formed a theory to explain how turbulence effected the bottom relief in rivers by using the correlation and spectral characteristics of velocity and turbidity of a natural stream channel.

3.2 RIVER MOUTHS

Mikhailov (1966) studied hydrology and formation of river-mouth bars. He mentioned that the formation of a bar, its size and shape depend on the intensity of sea and freshwater interaction processes taking place at the river mouth. Further, to form a bar in the mouth of river, it is sufficient to have a water flow that can transfer river sediments. Other factors (wave action, tidal currents, growth of vegetation, coagulation of suspended sediments, etc.) deform or shape the bar formed by the river flow, and facilitate or retard its development.

Ibad-Zade and Shteinman (1970) used tracer methods to study the processes of sedimentation and redistribution of river sediments in river mouth area. The results of field studies show that the process of sediments accumulation in the river mouths and formation of delta bar depends on the discharge of suspended sediments and sediments along the river flow in the offshore zone. Up to the bar crest the bed sediment transport is carried in the form of fulls, whose linear dimensions rapidly decrease with the distance from the exit mouth section, while the rate of their movement decreases in accordance with extinguishing of the river flow rate. Also, when wave motions are superimposed on the river flow the turbulence intensity decreases by a factor of 1.5 to 2, resulting in accumulation of fine sediment fractions.

Wright (1977) studied sediment transport and deposition at river mouths. He suggested that sediment dispersal and accumulation patterns are governed by three basic effluent forces and by tide- or wave-induced patterns. These three basic forces are (1) outflow inertia, (2) turbulent bed friction seaward of the mouth, and (3) outflow buoyancy.

Most complex turbulence in river mouths are in tidal mouths (estuaries) due to tidal oscillations associated with changes in depth, mean velocity, direction of flow and density gradients affected by salt, heat and suspended particles. Kereselidze et al. (1991) observed the velocity distribution and sediment transport in the region of river estuaries in the presence of waves and currents on a 12.8 m long flume. They devoted their main attention to bottom velocities determining sediment transport in the bottom layer (most saturated with solid fraction). A comparison of the intensity of turbulent velocity fluctuations showed that when waves propagate over the surface of a turbulent flow, turbulent intensity decreases. The authors analyzed results of 80 experiments to find the empirical relation for the quantity of noncohesive material being transported by waves.

Shteinman et al. (1992) simulated the turbulent structure of a river jet flowing into a lake in the laboratory. Based on experiments, the main purpose of the study was to look for the turbulent coherent structures at a river mouth up to the point where the river defined turbulent ceases to exist. They conducted the experiments at the Caucasia Regional Institute at Baku and performed the final analysis of the data at Kinneret Limnological Laboratory in Israel. To model the river outgoing jet properly, they had to apply a sand bottom, which formed the ripples and the bar as in natural conditions. Several days after the beginning of the laboratory experiment, the ripples and the bar has reached a quasi steady state, the turbulent measurements began. Experimental data were gathered by simultaneous recording of longitudinal velocities at different distances between the channel outlet and the sand bar. Shteinman et al. calculated values of mean velocities, water depths along the jet axis, spectrum of joint velocities at chosen frequencies, and maximal and average size of the coherent structures. The patterns of these parameters enable the description of the decay process of a turbulent jet flowing out of a channel.

Kawanisi and Yokosi (1994) performed simultaneous measurements of longitudinal and vertical components of instantaneous velocities and salinities continuously during two spring tides in the Ota River estuary. Their main purpose was to elucidate the behavior of turbulence, tidal current and salinity over the tidal cycle. They found that the characteristics of mean flow and turbulence are strongly affected by the longitudinal and vertical salinity gradient. Also, the turbulent intensities, correlation coefficient, and vertical eddy viscosity decreased rapidly as the flux Richardson number increased.

3.3 EXPERIMENTAL SITES

3.3.1 Jordan River

Shteinman and Imbar (1995) used luminescent sand to trace sediment transport at the outlet of the Jordan River to Lake Kinneret in ten experiments during 1991-1992 rainy seasons. They found out that bedload discharge is proportional to water discharge raised to fourth power and thus, most of the total bedload is carried during short time flow events.

Shteinman et al. (1996) conducted special experiments in the Jordan River to validate the "frozen" turbulence hypothesis for river flows. The measurements were performed by a 3D velocity meter made up of three piezo-electric slabs. Their main conclusions were (a) the presentation of turbulent eddies as "frozen" for river flow conditions is physically unjustified; (b) the "frozen" turbulence hypothesis can be applied to mean velocity quantities (correlation functions, spectra and structure functions) in the flow region which is not very close to the bottom.

Nikora and Shteinman (1996) measured instant longitudinal velocities by micropeller meters and five verticals located along the midstream region of the flow. They presented some additional information about river turbulence, which includes the analysis of long and short period velocity fluctuations, velocity vertical distribution, turbulence intensity, velocity structure functions and spectra, turbulence scales and turbulent energy dissipation.

Shteinman et al. (1997, 2000) used fluorescent tracer methods in Jordan River mouth to study the sediment transport. They used three methods for quantitative measurements as visual scanning and counting, excitation-emission fluorescence spectroscopy and optical absorption of extracts in organic solutions. The principal results of the study are as follows: The fluorescent tracer method is reliable for measuring bedload discharge at the mouth of the Jordan River. During floods, bedload discharge was much higher than suspended load discharge, which usually accounts for 95% or more of the total sediment discharge of the Jordan River. The bedload discharge was proportional to the fourth power of the water discharge.

3.3.2 Lake Kinneret

Shteinman and Gutman (1993) investigated the distribution of turbulent energy in the river mouth and its role in the transport of the matter within the flow. They generalized the results to formulate a conceptual model of the turbulent energy characteristics, specific for the river mouth. In another study, they measured the fluctuations of the velocity vector along the centerline of the river jet in the Jordan River mouth. Their evaluations were turbulent energy, full and streamwise intensities, 3D scales and intensity of rotations of large coherent structures in orthogonal planes for different regions of the river mouth (Shteinman and Gutman, 1994).

The sediment balance in jet flow at the mouth of the Jordan River near its entrance to Lake Kinneret was studied via application of dynamics equations and experimental measurements by Shteinman et al (2000), Shteinman and Kamenir (1998). Field experimental measurements made at the Jordan River mouth in Lake Kinneret show that the suspended matter concentration (SMC) decreases along the jet flow. This SMC decrease is governed by two main factors: sedimentation due to flow velocity attenuation along the jet flow, and SMC-dilution due to turbulent mixing of the jet (river) water (having a high SMC) with the lake water mass (with a much lower SMC), which takes place in the contact zones at the jet boundaries. Their measurements show that the flow attenuation proceeds according to exponential law.

Koren and Klein (2000) measured the rate of sedimentation in Lake Kinneret, Israel over several years by means of sediment traps, in up to seven different locations. The aim of their study was to determine the seasonal and spatial patterns of sedimentation. The rate of sedimentation decreases southward along the coasts, as a result of the increasing distance from the river mouth and the decreasing in fetch length. The rate of sedimentation is lowest at the centre of the lake. The sedimentation rate along the eastern coast is also higher than western coast as a result of re-suspension along the coast.

Shteinman (2001) studied some aspects of the relationships between water turbulence structure and patchiness formation by using Lake Kinneret as an example. The study was carried out via synchronous measurements of turbulent fluctuations of the velocity and the fluctuations in chlorophyll *a in vivo* fluorescence (IVF). Kolmogorov's theory of locally isotropic turbulence is used for theoretical considerations. Correlation-spectral analysis of the data obtained was performed using standard statistical programs. Shteinman proved that patch development depends not only from numerous biologic factors, but also from the turbulent structure of water masses.

3.3.3 Kura River

The Kura River mouth area is one of the best-studied river mouths in the world. This is related to the fact that since 1960 a specialized hydrological station has been functioning in the mouth. The station performs regular measurements of liquid and solid runoff, studying their long-term and seasonal variability, delta dynamics and other river mouth processes. By the direction of its work, the station became essentially a natural laboratory to study the delta formation processes. The first publication that summarized the results of stationary hydrological observations was the book by Shteinman and Tsitsarev (1971) where main features of the hydrological regime in the Kura River mouth area and of its delta formation. In addition, this was the first region where the method of fluorescent tracers was used to study the dynamics of sediments in river mouths (Shteinman, 1966; Shteinman et al., 1968; Shteinman and Tsitsarev, 1970, Ibad-Zade and Shteinman, 1970). In subsequent publications (Rustamov and Shteinman, 1968; Ibad-Zade and Shteinman, 1971; 1972; 1973) some particular features of the regime such as the bedload, the delta's seacoast dynamics, and the bar formation were described.

Despite a rather high level of knowledge of the region in question, it should be noted that, concerning the scope of problems considered in this work, the Kura mouth area has not been seriously studied. For instance, there is only one publication dealing with the dynamics of the free river turbulent jet in the river-sea contact zone and the structure of its turbulence (Shteinman, 1968), where regularities of the changes in the turbulence scale along the river jet was analyzed. At the same time, the primary field measurements related to the turbulent structure of the river flow in the delta and in the river-sea contact zone are available and were used in this work.

CHAPTER 4

SITE DESCRIPTIONS

In order to check the theoretical suggestions, experimental measurements were carried out at two different river mouth areas: Lake Kinneret-Jordan River mouth (fresh water) and Caspian Sea-Kura River mouth (salinity water). The data for Lake Kinneret-Jordan River is collected between 1991-2003, and the data for Caspian Sea-Kura River is collected between 1978-1990. The principal advantage of using these sites is the existing large database of measurements, which were compiled over a long period of time that included all amplitude of water and sediment discharge variability. In addition, very modern measurement methods have been employed in collecting data in this site, among which are tracers, PIV systems, Anderra series, and velocity fluctuation meter.

4.1 LAKE KINNERET - JORDAN RIVER

Lake Kinneret is located in the central part of the Jordan Rift Valley but the lake's watershed (2,730 km^2) extends over the geographical units of the Upper Galilee in northeastern Israel and southern Anti-Lebanon in Lebanon. The whole watershed (Figure 4.1) is situated between 32^o 40' N and 33^o 38' N which corresponds approximately to the latitude of San Diego, California. The Watershed is 110 km long in N-S direction. Its maximum width is 50 km in the lake area and 15 km in its northernmost portion.

The Kinneret is fed by a number of fresh water streams in addition to few salty springs at the lake bottom and along its shores. These add to the salt concentration (salinity) of the water that is further intensified by the high evaporation rate during hot climate. The amount of water in the lake fluctuates a great deal with the shift from rainy to drought years. Until the winter of 1973/74, several years of drought had lowered the surface considerably but that exceedingly rainy winter restored it to its average. In 1964 the National Water Carrier was completed to bring sweet water to the more southern sections of Israel; Lake Kinneret is the main reservoir from which the water is taken. Therefore, it is utilized for recreation, tourism, commercial fishery, and water supply. As a natural water reservoir, it supplies 25% of the country's annual freshwater consumption, including 50% of the drinking water demand and consequently, the water quality is of prime national importance (Berman, 1985; Gophen, 1993; Hadas, 1988).

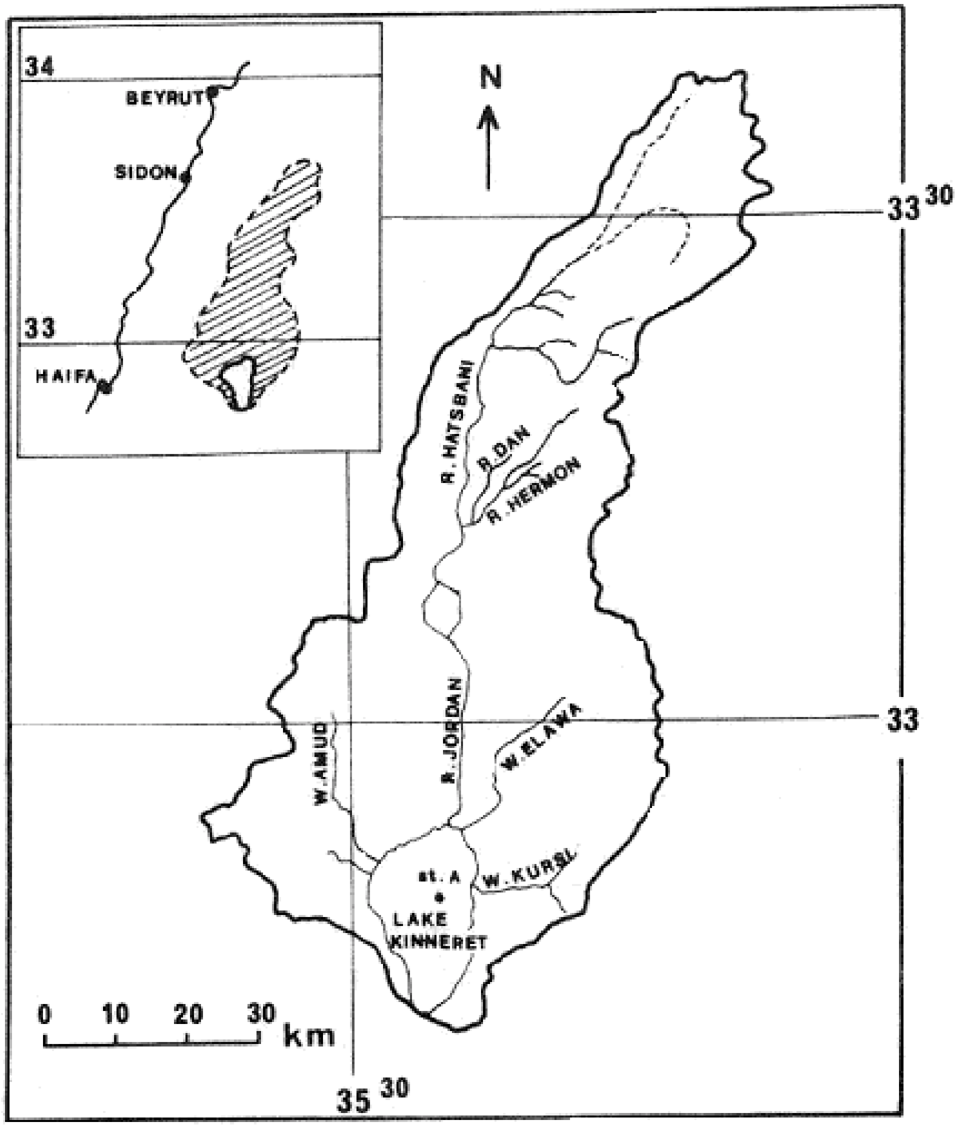

Figure 4.1: Lake Kinneret and its watershed

The watershed of the Litani River occupies the northern border of the Kinneret drainage area and the Mounts of Meron limit its extension to the west. The Mounts of Meron are also the water divide between the drainage systems of the Mediterranean Sea and of the Rift Valley. The water divide with the northern tributaries of the Yamouk River constitutes the eastern frontier of the Jordan watershed on the Golan Heights, and the northern limit of the watershed of the southern Jordan River is the southern limit of the Lake Kinneret drainage area. This relatively small area has an unusual variety of landscapes and vegetation partly due to the large range of altitudes encountered (+2,814 m to -210 m) (Figure 4.2).

Figure 4.2: Lake Kinneret air picture

In Table 4.1 described are the morphometric parameters of Lake Kinneret. D_L represents the ratio of the length of the shore line to the length of the circumference of a circle of an area equal to that lake. The parameter roughly quantifies the potential effect of the littoral processes on the lake (Serruya, 1978).

Table 4.1: Morphometric parameters of Lake Kinneret (level -209 m)

	Kinneret
1. Surface A (m^2)	$167.87x10^6$
2. Maximum depth Z_m (m)	43
3. Mean depth z (m)	25.6
4. Depth of cryptodepressions z^c (m)	253
5. $z:Z_m$	0.59
6. Volume V (m^3)	$4.301x10^9$
7. Length l (m)	$22x10^3$ NS
8. Width w (m)	$12x10^3$ EW
9. Shore line L (m)	$53x10^3$
10. Development of shore line D_L	1.16

The main tributary of Lake Kinneret is the Jordan River. The Jordan River is a mountain river, with a hydrological regime characterized by heavy rainfalls and floods. The Jordan catchment is approximately 12,431 km^2 and the Jordan River rises from Lake Tiberias. Jordan has its source in three headstreams whose waters are drawn mainly from the precipitation on top of Mount Hermon as well as from scores of springs. The three streams- Nahal Senir, issuing from the foot of the Hermon, Nahal Hermon emerging from the cave of Banias, and Nahal Dan from Tel Dan, all merge into one river in the Huleh Valley. The Northern Jordan River drains catchment area of ca. 1,560 km^2 and has its rise at Mount Hernon about 350 m above mean sea level. The total length of the Jordan from its sources is about 104 miles in a straight line, during which it falls 2,380 feet. The length of the northern section of the river is about 40 km and the mean annual discharge is 0.6×10^9 m^3. Some 80% of the annual water and sediment runoff come within the flood period (December-February) (Bungartz et al., 2000; Shteinman et al, 2000).

Within its mouth area (Figure 4.3), Jordan River retains its mountain-river properties, with the slopes up to 50 cm per km and the river-bed formed by coarse gravel. Only within the last kilometer before the lake entrance, the water surface slope diminishes some 5-6 times, the flow becomes calmer, and the bottom becomes sandy-silty sediment formations. The depths along the river midstream are less than 1 m, but during the floods they rise up to 3-4 m; the flow velocities during these periods are 2 m/s or higher. The river mouth has one bayou. The delta, formed in the Jordan-Kinneret contact zone, protrudes some 100 m into the lake, and ends up as a lunar-shaped bar connecting the ends of the mouth spits. The body of the bar is formed by clayey-silty mud, with its length at approximately 50-70 m (depending on the sediments runoff) and the depths near the bar crest at less than 1 m.

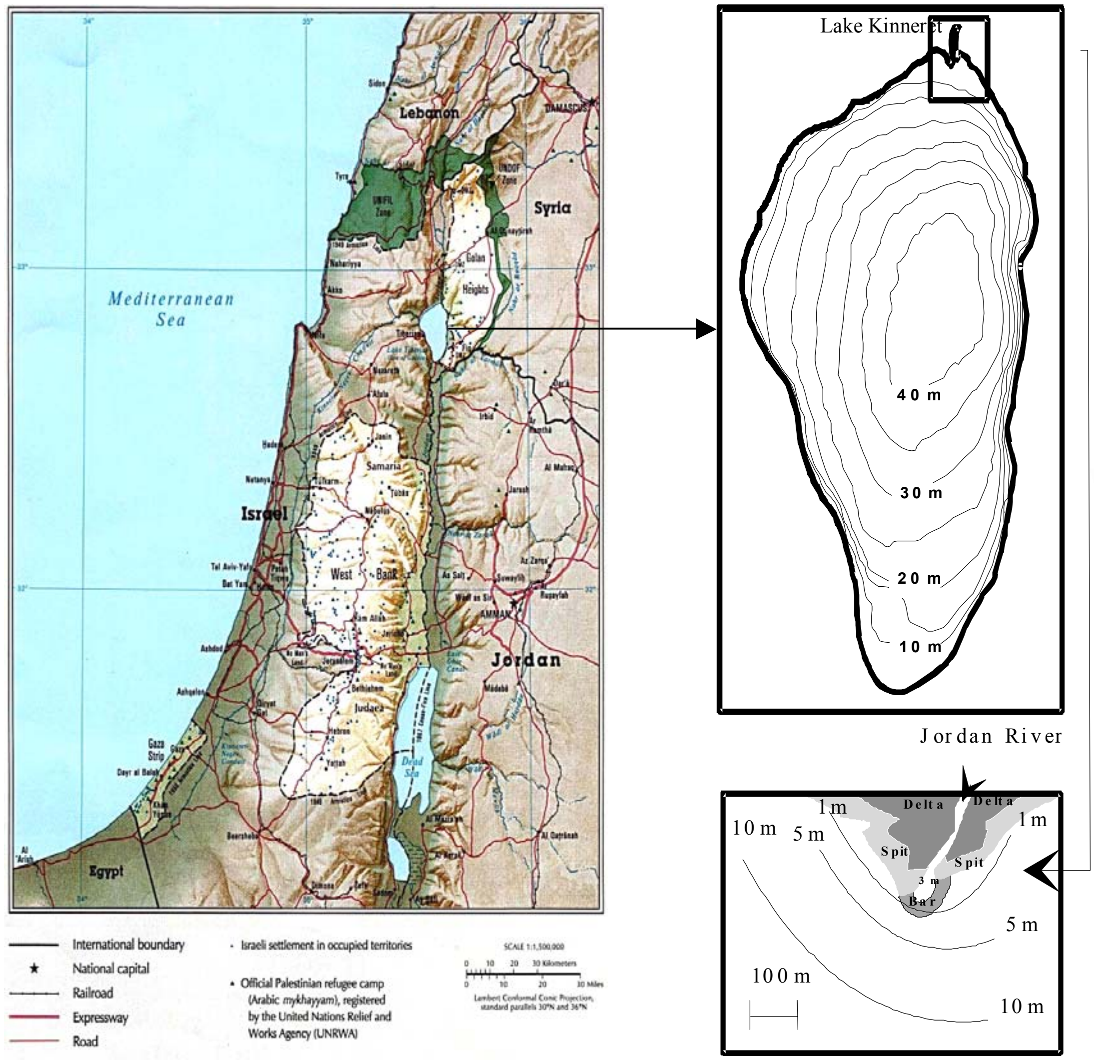

Figure 4.3: Geographical location of Jordan River areas and Lake Isobaths

4.2 CASPIAN SEA – KURA RIVER

Caspian Sea (ancient Caspium Mare or Hyrcanium Mare), a saltwater lake in southeastern Europe and southwestern Asia, constitutes the largest inland body of water in the world. It borders Azerbaijan and Russia on the west, Kazakhstan on the northeast and east, Turkmenistan on the east and Iran on the south. The Caspian Sea lies between 47°13' and 36°34' 35" north latitude and between 46°38' 39" and 54°44' 19" east longitude. The shoreline length is about 6,000 km and it extends about 1,210 km (about 750 mi) in a north-south direction and about 210 to 466 km (about 130 to 271 mi) in an east-west direction. The average breadth of the Caspian from the west to the east is 330 km and in the region of the Absheron Peninsula, its breadth narrows down to only 204 km. It has an area of about 378,400 km^2 (about 144,250 mi^2) and its volume is about 78,000 km^3 (approx. 40% of the world's continental surface water) (Shteinman, 1971). In comparison with other larger natural lakes of the world, the Caspian Sea ranks first in surface area and lake volume, and both the 3-d in average and maximum depths (after Lakes Baikal and Tanganyika). In Table 4.2, the morphometric parameters of Caspian Sea are summarized.

Table 4.2: Morphometric parameters of Caspian Sea (level -28 m)

	Caspian Sea
1. Surface A (km^2)	378,400
2. Maximum depth Z_m (m)	1025
3. Mean depth z (m)	184
4. Volume development $z{:}Z_m$	0.18
5. Volume V (km^3)	$7.8x10^3$
6. Length l (km)	1210 NS
7. Width w (km)	210 to 466 EW
8. Shore line L (m)	$6x10^3$
9. Development of shore line D_L	2.75

The Caspian Sea is conventionally divided into three parts: the northern, middle and southern parts. The northern part of the sea covers about 80,000 km^2. It is relatively shallow, averaging about 5-6 m in depth. The Ural Furrow is a slightly deeper (8-10m) structure extending the Ural River trend across the shallow northeast shelf. The middle part of the Caspian Sea is a separate depression totaling about 138,000 km^2 area. The western slope of this depression is quite steep, whereas the eastern slope is more gradual. The bottom is a gently sloped plain with depths of 400-600 m. The average depth of the Middle Caspian is 190 m, and its greatest depth is 788 m. The southern part of the Caspian Sea, having a total area of about 168,400 sq. km, is separated from the middle by the Absheron ridge which is a continuation of the main Caucasus range.

The Caspian coastline is irregular, with large gulfs on the east, including Krasnovodsk Gulf and the very shallow Garabogazköl Gulf, which acts as an evaporation basin and is the site of a major chemical plant that extracts salts from the deposits. In the 1960s and 1970s the level fell substantially, partly because water was withdrawn from tributary rivers for irrigation and other purposes. In 1980, a dike was built across the mouth of Garabogazköz Gulf to reduce water loss, creating a lake that was expected to last for several years. Instead, the gulf dried up completely by 1983. In the meantime, the level of the Caspian Sea began rising again at a rate of about 14 to 20 cm (about 6 to 8 in) annually. To restore water flow into Garabogazköz Gulf an aqueduct was built.

About 130 rivers of various sizes drain into the Caspian with an annual input of about 300 km^3. The main rivers are Volga (Russia), Kura (Azerbaijan/Georgia), Ural (Kazakhstan/Russia), Emba (Kazakhstan), Kuma (Astrakhan/Kalmik, Russia), Terek (Dagestan, Russia), Sumgayit (Azerbaijan), Atrek (Iran/Turkmenistan), Sulak (Dagestan, Russia), Samur (Azerbaijan/Russia), Shafa-Rud (Iran), Safid (Iran), and some others. Length of the main rivers inflowing the sea is given by Figure 4.4. It should be noticed that almost all inflowing rivers are strongly regulated and affected by anthropogenic activity (mainly agricultural irrigation and hydropower plants). Particularly, River Volga is strongly regulated by valley dam reservoirs and contributes 237 km^3/year on average. The Kura River is second in line and discharges only 16.8 km^3/year; the Ural River is third, with a discharge of 8.1 km^3/year on average.

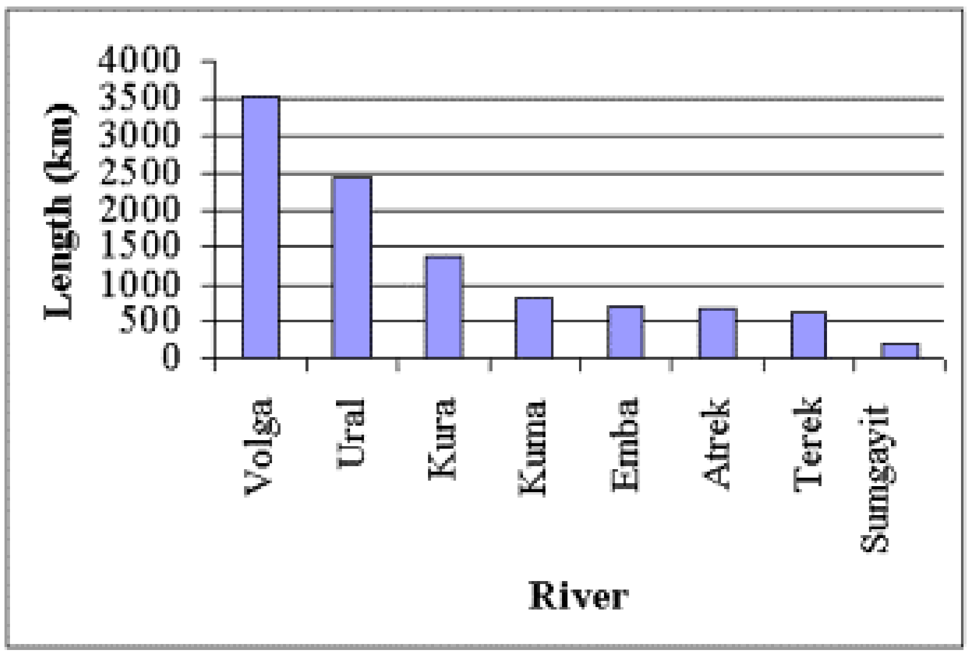

Figure 4.4: The main rivers inflowing directly to Caspian Sea

Kura River is the largest hydrological watercourse in the Southern Caucasus. It originates in the springs located at the 2,720 meters above the sea level on the northeast slopes of Kizil-Giadik (Turkey). It flows through territory of Georgia with the lower reaches in Azerbaijan and finally flowing into the Caspian Sea (Figure 4.5). The Kura River's length is 1,515 km, the total watershed area is 188,000 km^2 and average annual discharge is about 16 km^3. The national and local economy is quite dependent on the river, as it is the primary source of drinking water, hydropower energy generation and irrigation.

Figure 4.5: Kura River and Caspian Sea from world atlas

The total area of the Kura's delta amounts now to some 75 km^2. The river bifurcates, within its delta, into two branches – northern and southern, and the bulk of river runoff (up to 80%) is entering the sea through the southern one (Figure 4.6).

The average annual discharge of suspended sediments in the mouth of the southern branch is 280 kg per sec. The predominant grain size in the suspended sediments is <0.05 mm, and it is the biggest in the period of high water (April-June), when up to 75% of the annual runoff enters the sea. The river sediments coming to the mouth coastal waters have formed a crescent-shaped sand bar and mouth spits (Figure 4.7). The bar crest averages a distance of about 1 km from the mouth, experiencing insignificant seasonal oscillations corresponding to the sediment balance at different stages of the hydrological regime. At the stage of rising high waters, the bar moves seaward causing the water depth at its crest falling down to 0.7-0.5 m. At the low water stage, the bar gets gradually eroded from its seaward slope. Current velocities at the mouth reach 1.5-2.5 m/s in the high-water periods, while in low-water periods they are 0.5 m/s on the average.

Figure 4.6: Kura River air picture

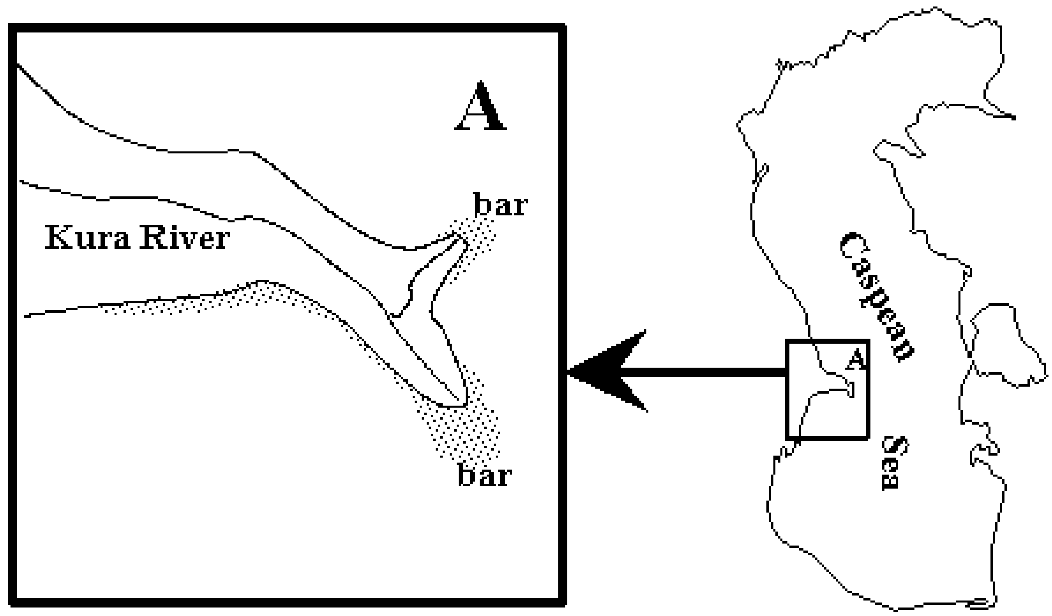

Figure 4.7: Schematic map of the Kura River Mouth area

4.3 HYDRODYNAMIC SECTORS OF RIVER MOUTHS

River mouth areas are peculiar natural formations occupying an intermediate geographical position between rivers and seas. They demonstrate significant and often irreversible changes in hydrological, hydrochemical and morphological characteristics. River mouth areas, including deltas, act as crucial natural formations for the development of navigation, port construction, agriculture, fishery etc. Observations and measurements in river mouths, and systematization of their results have led to segmentation of the river mouth areas into the following three hydrodynamic sectors (Shteinman and Gutman, 1993):

1) *Initial flow:* Where the flow's hydrodynamic properties are practically the same as the river flow ones.

2) *Transition sector:* The sector that starts from the final cross section of the previous sector and ends at the crest of the mouth bar (the latter is typical for almost all rivers with large sediment discharge). This sector is characterized by the widening flow accompanied by the attenuation of river discharging currents. Eddy zones are being formed at the boundaries of the river jet flow. An important feature is that within the first two sectors, the water discharge remains constant. Besides, within the transition sector, the free surface jet flow finally flattens; the slope angle of the flow becomes zero, and the flow stops movement caused by the gravity force component parallel to its free surface. Current within the first two sectors embraces the entire depth, from the surface to the bottom.
3) *Free flow section:* Sector that begins at the crest of the mouth bar and ends in the lake or sea, where full attenuation of the runoff flow is observed. Since within this sector the slope angle of the water surface is practically zero, the flow here becomes an inertial turbulent free jet. The jet flow here detaches from the bottom, and is gradually thinning out, its depth decreasing. The jet abruptly widens in area, involving in movement the adjacent mass of the receiving water body. As a result, water discharge along the flow grows up. Eddies are being formed on the lower boundary of the runoff current, in the zone of contact of the river flow and the adjacent water mass, and on the lateral boundaries of the jet.

The above hydraulic characteristics of jet flows in the river mouths determine to a great extent the specifics of the interaction of the flow and the mobile bottom. We have studied this kind of interaction within the mouth of the Jordan River, where it inflows into Lake Kinneret (Israel) and within Kura River, where it flows into Caspian Sea.

According to this information, the entry of the Jordan River mouth and Kura River mouth can be split into four sections (Figure 4.8):

1. The River itself, representing the river hydrologic and hydrodynamic regime
2. A transition zone between river and lake (sea) regimes, represented by a rapid drop in flow velocity, with a consequent sharp increase in settling intensity over a short distance (~100 m for Jordan River, ~500 for Kura River)
3. Free flow section zone (~600 m for Jordan River, ~ 3,000 for Kura River) where there is no influence of friction from the banks and bottom on the jet flow and where the jet flow slope is zero
4. Lake (Sea) zone

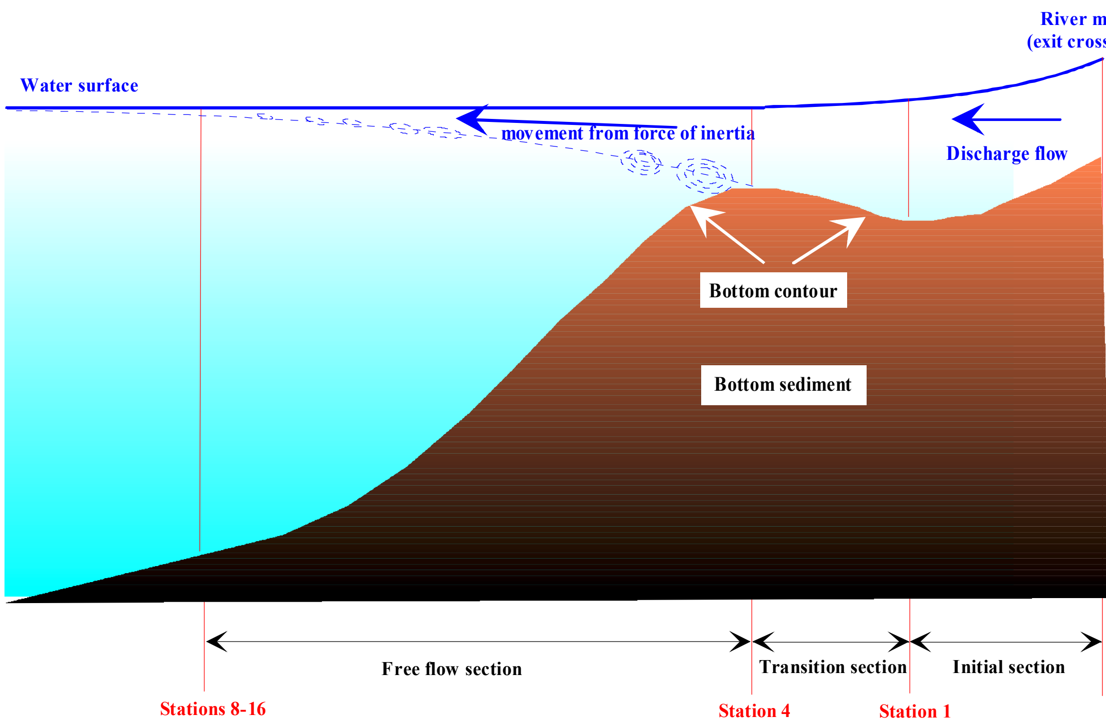

Figure 4.8: Hydrodynamic zoning of the Jordan and Kura River Mouth area

CHAPTER 5

FIELD AND LABORATORY MEASUREMENTS AND DATA PROCESSING

A combination of methods has been used for the study of the velocity structure of the flow and the transport of sediments in the Jordan River – Lake Kinneret and Kura River – Caspian Sea river mouths.

Tracer methods have been used to study the processes of sedimentation and redistribution of river sediments in the river mouth area. The FT method has been used to determine the bed load and study the resuspension processes. The method of fluorescent tracers (FT) is based on the use of flourescently tagged sediment particles (tracers) placed on the bottom to measure the transport of sediments and the bed load. The bed load samples were taken from the river or the lakebed after some interval (days or weeks) and then analyzed for their content of flourescently labeled particles (Shteinman et al., 2002). A modified fluorescent tracer (FT) method was used to determine the sediment transfer at the Jordan River mouth. This method is not only used for the studies of river sediment bed load transport, but also for a broad range of other investigations into the water and suspended particle movements.

Scuba divers had taken sediments from the bottom of the Jordan River canal. After thorough air-drying, the particulate material was mixed with one of the following dyes to obtain particles with the indicated colored fluorescence: rhodamine (red), anthracine (blue violet), auromine (yellow), fluorescein (green), eosine (green-yellow), primulin (dark blue). Depending on the specific dye and the desired lifetime of the fluorescent particles, one of the following solutions was added as a fixative:

methoxidiethanol, chloroform, acetone or ethanol, together with small amounts of resin, agar or gelatine (Figure 5.1). Depending on the fixative, the “lifetimes” of these particles could be varied from 10 days to 6-7 months.

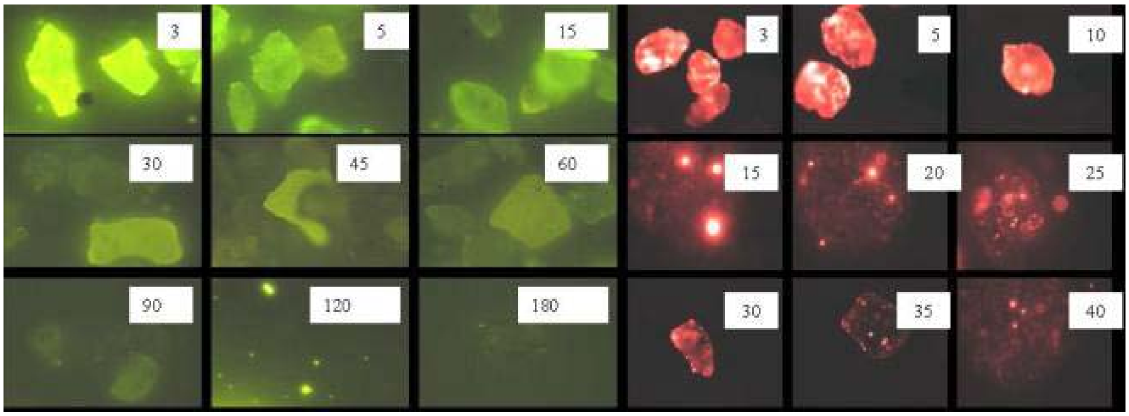

Figure 5.1: Results of checking up the stability of the fluorescent cover of the sediment samples dyed green (fluoresecein) and red (rhodamine); the numbers mean the days of flushing

The fluorescent labeling process did not change the hydrodynamic properties of the original particles. Using Particle Image Velocimetry (TSI Inc., Laser Diagnostics Division), an optical imaging technique that simultaneously measures fluid or particle velocity vectors at many points in a flow filed (Grant and Smith, 1988; Particle Image Velocimetry, 2001) showed that labeled and unlabeled particles had identical settling velocities.

For most experimental purposes, scuba drivers replaced the fluorescently tagged sediments at their original sites. After some time, interval (days or weeks, depending on the experiment) bedload samples were taken by scuba divers from the original sampling site and analyzed for their content of fluorescently tagged particles.

Prior to laboratory analysis, the collected material was carefully air-dried by forced ventilation and thoroughly mixed in a revolving drum to give a uniform distribution of FT's within the bulk, non-fluorescing, particles (Figure 5.2A). For the initial visual evaluation and counting, the dried material was examined under a UV lamp to check the bed sediments for the presence of tracer particles (Figure 5.2C) and also to check via a microscope (Figure 5.2B, Figure 5.3) of the sediments left on the filter after filtration for presence of tracer particles.

Figure 5.2: Preparation of fluorescently tagged particles (1), analysis of sediment samples with UV microscope (2) and under UV illumination (3)

Three methods were used to obtain a quantitative analysis of the concentrations of colored FT's based either on their fluorescence emission or on their specific spectral absorption. In the first technique, a thin layer of dried sediment sample was placed 20 cm from an excitation monochromator (150 W Xenon lamp with 90^{o} geometry), which gave an excitation range from 275 to 400 nm. The emitted fluorescence from FT's in the sample was collected by focused lens and passed through a second monochromator set for a wide spectral range from 400-500 nm. The monochromator slits (16 and 4 mm) and photomultiplier voltage (900 V) was held constant throughout the measurements.

Variation of the amplifier gain from 1 to 100 permitted detection of fluorescence intensities over a range of three orders of magnitude. Calibration was made by placing measured amounts of FT's under the excitation beam and recording the peak heights of the emitted fluorescence.

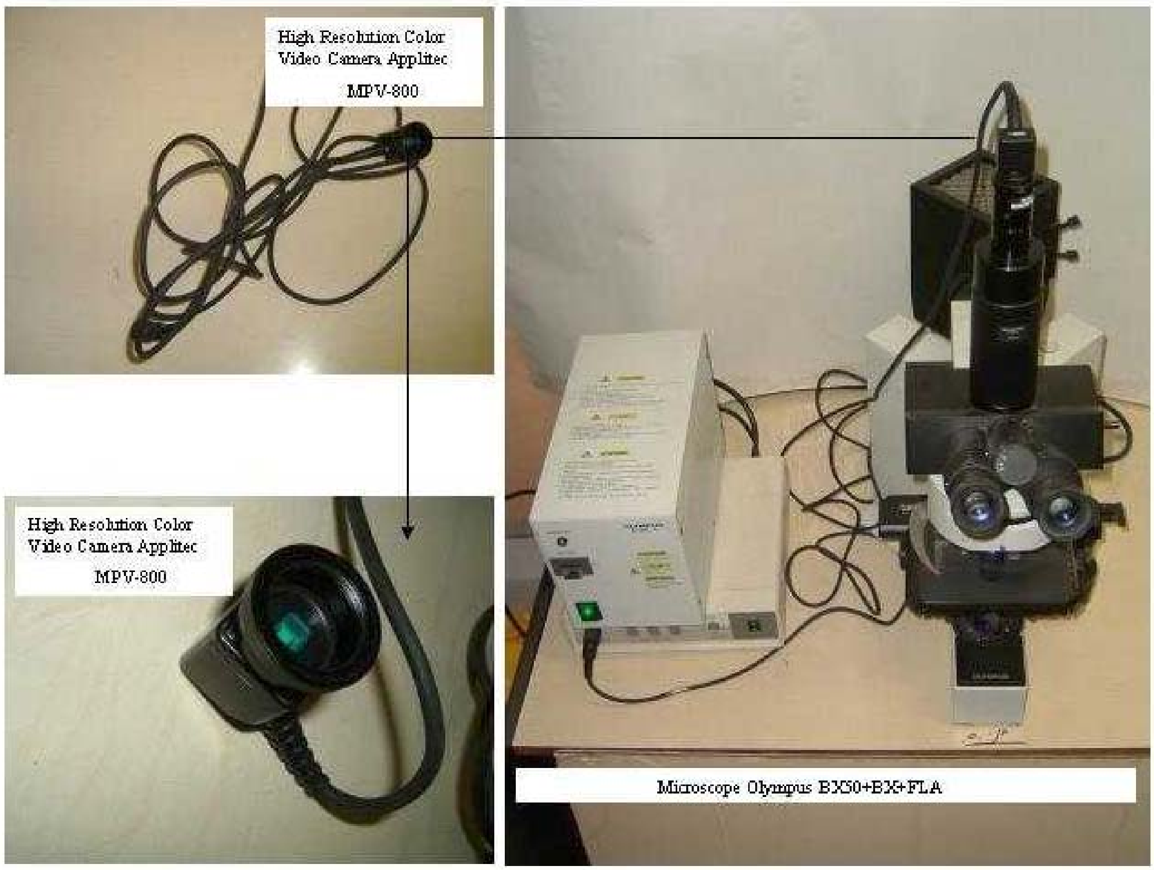

Figure 5.3: Detailed picture of UV microscope

As an alternative to this approach, quantitative determinations of FT's concentrations were also made by analysis of acetone or ethanol extracts of weighted dry sediment samples. Spectral scans of these extracts (in the range 300-600 nm) were made on a Kontron UV-KON 930 spectorophometer. For calibration, known quantities of the various dyes were dissolved in acetone or ethanol and their spectra were determined. Concentrations of FT's in experiments were then quantified by comparison with the calibrated samples. The effects of overlapping absorption were taken into account in determining the concentrations of a mixture of different colored FT's.

A third method was also used to quantify the numbers of FT's within sediment samples. Batches of dried material were spread a thin layer over a 400-cm^2 board. The board was then completely scanned with a Sony camera, which detected the labeled particles in color and recorded them in a PCX equipped with a Targa+ frame grabber. The total number of different colored FT's in each scan was evaluated using image analysis (Image-Pro Software). In this manner, an exact count could be made of total FT's within a weighed dry sample of sediment (Shteinman et al., 1998; Shteinman et al., 2002).

To obtain samples of suspended particulate matter, arrays of sediment traps were used at various depths deployed at known distances from the initial site of labeled particle deposition. Gardner (1980) identified three conditions for the design of an effective sediment trap: (i) a tube diameter, (ii) a constant diameter along the tube, (iii) an aspect ratio (the ratio between length of tube and its diameter) ranging between 3 and 15. The sediment traps were used in this study met all three conditions. Each consisted of four PVC tubes, 5.3 cm in diameter and 60 cm long. A bottle was screwed to the bottom of each tube in order to collect settling sediment (Figure 5.4). Field investigations were carried out on different depths (up to 23 m depth) of transects directed athwart to the lake shoreline. SPC was determined by sampling water using standard bathometers, then filtration. By double weighing (before and after filtration) solid residual was determined. Its weight was divided by the volume of the sample (Koren and Klein, 2000).

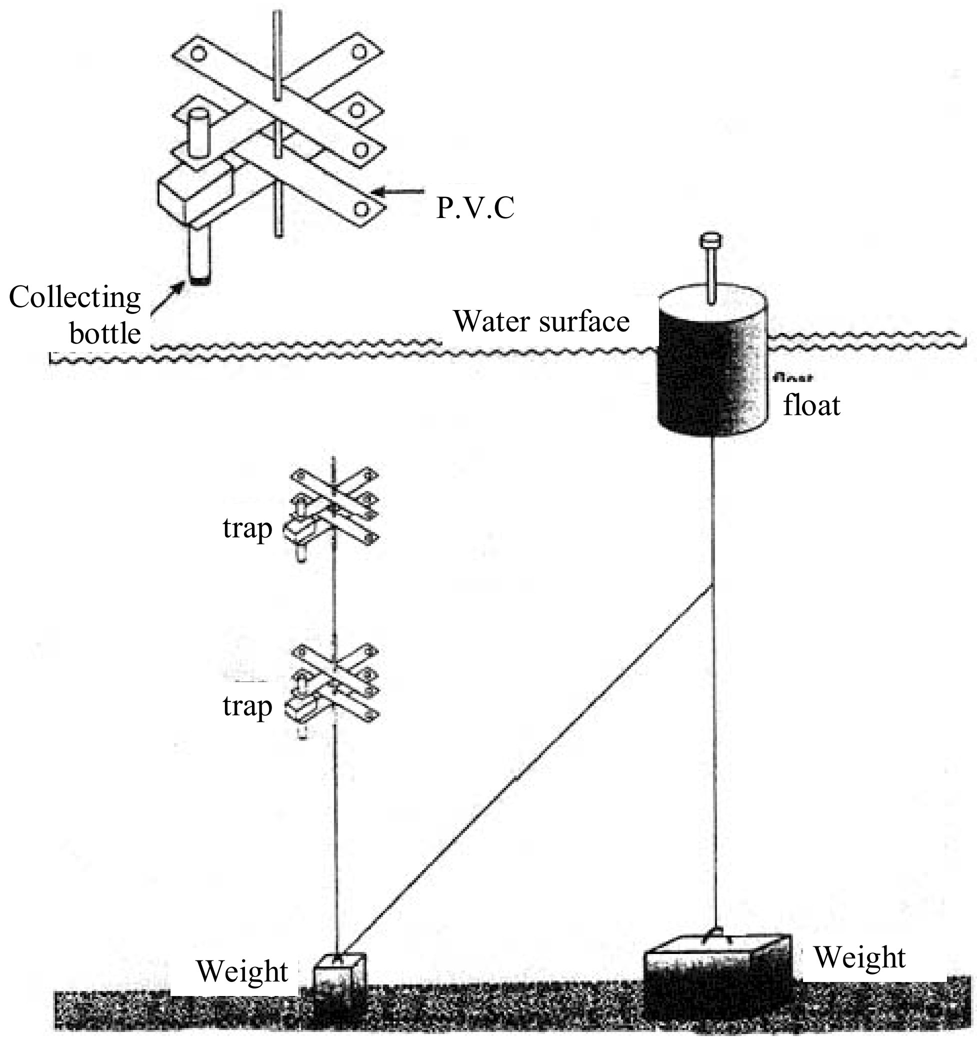

Figure 5.4: The set-up of the traps

Field measurements were conducted on the mouth of Jordan River in the conditions of surface waves that were superimposing on the contradirectional jet current, which was forming wave-driven currents superimpose on the discharging river flow. The river width at the flow exit cross-section was about 50 m, the depth about 2.5 m, and water discharge 20-50 m^3/s. The field of mean velocities was measured using standard meters of the flow Anderra series. Three transects were chosen in accordance with the direction of predominant water discharge spreading inside the lake. Measurements were conducted along the dynamic axis of the jet flow starting from the mouth cross-section and ending at the zone of full attenuation of the runoff current, at every 10, 25, 50 or 100 m (Figure 5.5). In total, a series of 10 preliminary experiments was carried out. SIGMAPLOT 8.0 (SYSTAT Softwater Inc.) is used for statistical analysis.

To measure the structure of the flow turbulence in the river itself and in the river-sea contact zone, 8 stations had been selected in Kura River Mouth that embraced the mouth areas (Figure 5.6) characterized by various hydrodynamic regimes. The hydrometric gauge #1 was located at a distance of 19 km upstream from the mouth, outside the zone of the dynamic impact of the sea, and measurements there characterized "purely river" flow. The hydrometric gauges #1 and #3 were located at the distances of 8 km and 4 km upstream from the mouth respectively; they were within the zone of the dynamic impact of the sea, and measurements there characterized the "transitional" river flow. The hydrometric gauge #4 was located within the mouth, in the zone of considerable dynamic impact of the sea, closing the river area. The hydrometric gauges #5 and #6 were located at the distances of 200 m and 500 m seaward from the mouth gauge respectively, in the zone of expanding river jet that flows within "liquid banks", but maintaining contact with the bottom. The hydrometric gauge #7 was located at a distance of 800 m seaward from the mouth gauge, at the crest of the mouth bar, in the zone of rapidly expanding river jet that had been losing its contact with the bottom. The river flow in this zone was a free turbulent jet with attenuating velocity. Flow velocity fluctuations were measured along the flow dynamic axis. In total, a series of 18 experiments were carried out.

The measuring devices included velocity fluctuation meters (Figure 5.7), consisting of three piezoelectric slabs mounted on a 5x5x5 cm cubic frame (Shteinman and Gutman, 1993, 1994). Measurements of streamwise mean velocities were also made with custom-made equipment consisting of six micropropeller meters (Figure 5.8) a converter-amplifier and a laptop computer. In each micropropeller (with a diameter of 10 mm) there were five blades. The blades rotate in an agate fulcrum installed in the frame. They were protected against mechanical disturbances by a metal ring. An electrode jack was attached to the upper part of the ring and consists of a stainless wire 0.5 mm in diameter. The upper edges of the propeller blades passed the electrode at the distance of 0.05 to 0.1 mm. The inertial filter in the recording equipment was adjusted in such a way that velocity pulsations with periods less than 0.5 sec. were suppressed. The detailed description of this measuring system was presented in Nikora et al. (1994). The measuring sites were located along the jet flow.

Some measurements were performed in a flume where a constant discharge was created. After the current stabilization, the field of mean velocities was measured, as well as their turbulent fluctuations, and then regular progressive wave were generated on the flow surface by a wave generator. After this, kinematical characteristics were measured again.

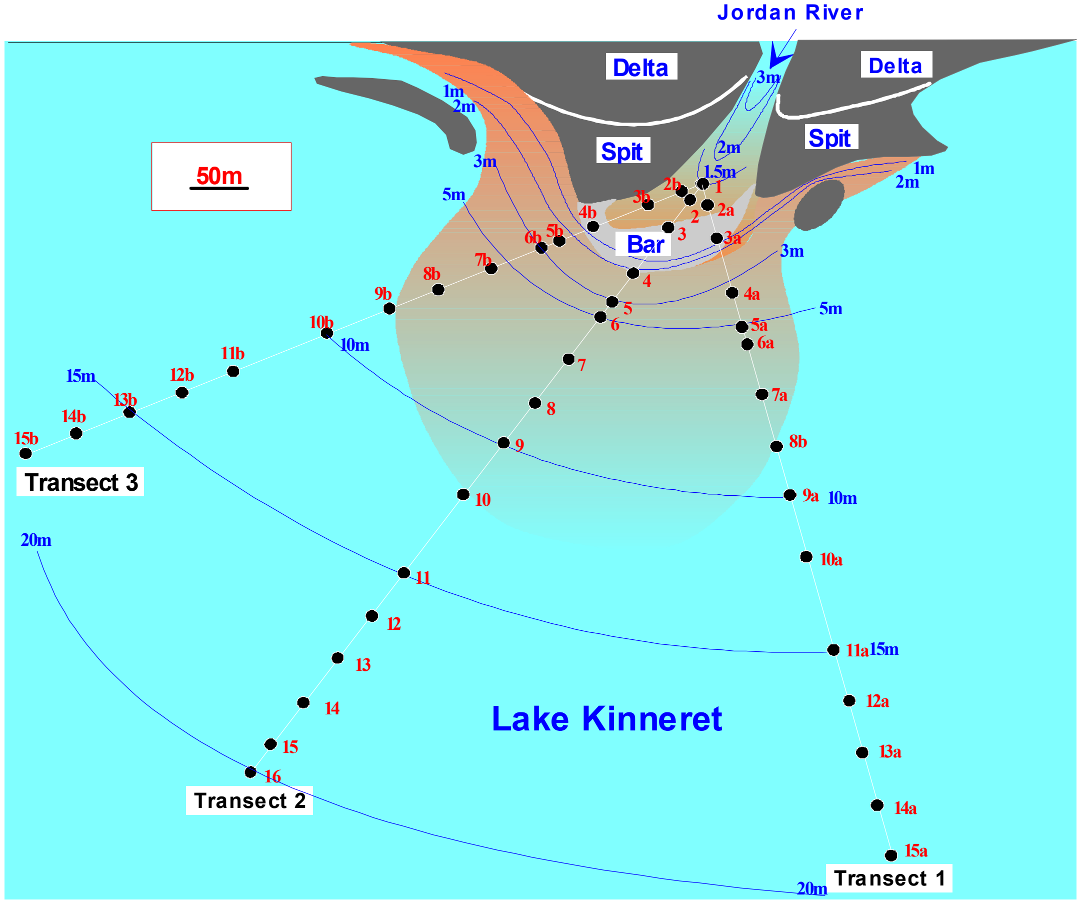

Figure 5.5: Jordan River mouth area and points of measurement

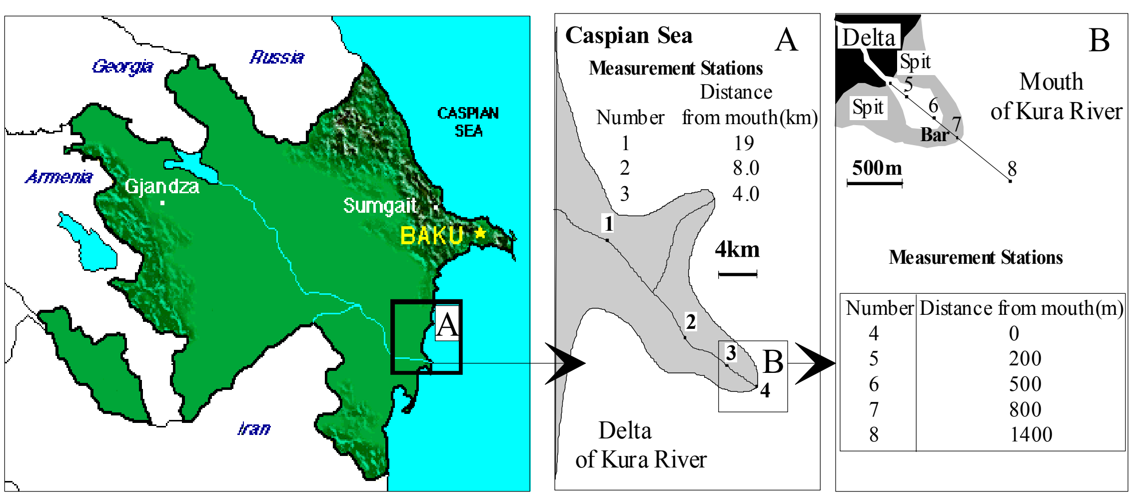

Figure 5.6: Scheme of the Kura River mouth area and stations for measurements of the river flow velocity field

Figure 5.7: 3-D turbulent current fluctuation meter

Figure 5.8: Measuring micropropeller meter and micropropeller's

CHAPTER 6

VELOCITY FIELDS IN RIVER MOUTH JET FLOW

Data obtained from field measurements and jet flow theory was used to study the velocity structure of the flow in the Jordan River – Lake Kinneret contact zone.

Theoretically, the river flow induces subsidiary flow in the bordering water mass upon entering the reservoir-acceptor. As a result, the stream obtains some characteristics of the jet flow with growing water discharge along the stream. At the bar crest, the jet stall occurs at the river bottom and the flux concentrates in the upper jet. Furthermore, vortex zones develop at the jet boundaries due to boundary friction (Shteinman and Kamenir, 1998).

An integral equation for the variable discharge flow (growing from the river mouth gauge) may have the following form proposed by Makkaveev and Konovalov (1940):

$$\frac{1}{2g}\int \frac{d(Q^2)}{w^2}) + \frac{V^2}{2g} + \frac{P}{\gamma} = const. \qquad (6.1)$$

where, g is the acceleration of gravity; Q is the water discharge; w is the discharge section area; V is the current speed; P is the air pressure, and γ is the air density.

The above equation was simplified by Simonov (1960) to:

$$\frac{dV}{V} + \frac{k}{2h}dx = 0 \qquad (6.2)$$

where, h is the depth, k is the coefficient of friction, and x is the distance from the mouth gauge.

The following expression was obtained by Shteinman and Kamenir (1998) by modifying equation (6.2):

$$\int \frac{dV(x)}{V(x)} = -\frac{1}{2}\int \frac{k}{h} dx + c \qquad (6.3)$$

It is important to note that, equation (6.3) contains an arbitrary constant that can be estimated using the following equation:

$$\int_{V(x_0)}^{V(x)} \frac{dV(x)}{V(x)} = -\frac{1}{2}\int_{x_0}^{x} \frac{k}{h} dx \qquad (6.4)$$

Solving for the unknown velocity yields:

$$V(x) = V(x_0)\exp\{-\frac{1}{2}\int_{x_0}^{x} \frac{k}{h} dx\} \qquad (6.5)$$

In the case when k and h are independent of x, the following expression can be obtained using equation (6.5):

$$V(x) = V(x_0)^{-\frac{k}{2}\frac{(x-x_0)}{h}} \qquad (6.6)$$

Assuming x_0 to be equal to zero yields:

$$V_x = V_0 e^{\frac{-kx}{2h}} \qquad (6.7)$$

where, V_0 and V_x are the average flow velocities over the cross section at an initial section and at a distance x away from initial section, respectively; with $k/2h=c$.

In a dimensionless form equation (6.7) becomes:

$$\frac{V_x}{V_0} = e^{-cx} \tag{6.8}$$

where, c is the empirical coefficient. The velocity equation along the length of the jet flow in the river mouth area shows that the attenuation follows an exponential law.

6.1 AVERAGE VELOCITY ATTENUATIONS

The Jordan inlet (entrance to lake) is characterized by a spit and a bar (100 m from the entrance), which are the results of the accumulation of river material. In this study, three fan-shaped transects which are 1,000 m each were considered, to check the theoretical considerations. The transects are in accordance with the direction of predominant water discharge, diverging from the mouth into receiving water body (shown in Fig.5.9). Distances between the stations (points of measurement) were decided to be equal to the river width in the mouth gauge (Shteinman et al., 2004). Measurements of the streamwise mean velocities were taken with special equipment consisting of six micro-propeller meters (Nikora et al. 1994), which was discussed in Chapter 5. It is important to note that all measurements were taken in calm waters, with almost no waves or alongshore movement of sediments, which made it possible to investigate various models of free spreading of the river jet on the river mouth area in its pure form (undisturbed state). Measurements were taken under steady hydraulic conditions and embraced the entire cross section of the flow. The duration of measurements in each point was 15 minutes, in order to keep the background hydrological and hydraulic conditions practically unchanged during each experiment (Khanbilvardi et al., 2004a).

Measurements were performed at the river mouth cross section and at distances of 25, 50, 75, 100, 150, 200, 300, 400, and 500 meters from the river mouth along the jet's dynamic axis, at its boundaries, as well as in the area of its free spreading beyond the bar.

Accordingly, ten sets of measurements were carried out. The streamwise mean velocity values measured at three transects for discharge flows of 46.8 m^3/s, 12.5 m^3/s, 10.3 m^3/s and 6.9 m^3/s are summarized in Tables 6.1 through 6.4. The corresponding flow velocity attenuations are shown in Figures 6.1 through.

It was observed that, the jet flow rapidly attenuates when the Jordan River enters Lake Kinneret. In order to define the velocity attenuation, SIGMAPLOT 8.0 (SYSTAT Software Inc.) was used for non-linear regression analysis. The data was observed to have a simple exponential decay with the form, $f = a*exp(-b*x)$, which is very similar to that of equation (6.8). When the non-regression analysis is used for all three transects, the constants "*a*" and "*b*" in this equation form can be found and it's possible to check if the value for "*a*" corresponds to V_0 value (in the tables indicating the velocity at a distance "0 meter" away from the river mouth), whereas "*b*" corresponds to constant value "*c*" in equation (6.8). All the R-values and R^2-values in non-regression analysis are close to 1, which shows that the chosen plot is appropriate for all ten sets of data. It can also be seen that the graphs validate the equation (6.8). As an example, the recorded values at Q = 46.8 m^3/s are shown below. The full non-linear regression analyses, tabulated streamwise mean velocities, and velocity attenuation graphs can be found in Appendix A for all cases.

Table 6.1: Experiment #1 – Streamwise mean velocities at Q = 46.8 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	1.74	1.74	1.74
2	25	1.61	1.64	1.63
3	50	1.56	1.58	1.58
4	100	1.41	1.45	1.43
5	150	1.23	1.36	1.30
6	175	1.09	1.16	1.12
7	200	1.07	1.10	1.07
8	250	1.03	1.08	1.05
9	300	0.80	0.93	0.91
10	350	0.75	0.90	0.83
11	425	0.60	0.77	0.66
12	475	0.55	0.70	0.61
13	525	0.50	0.68	0.59
14	575	0.41	0.6	0.51
15	625	0.35	0.51	0.43
16	1000	0.19	0.22	0.19

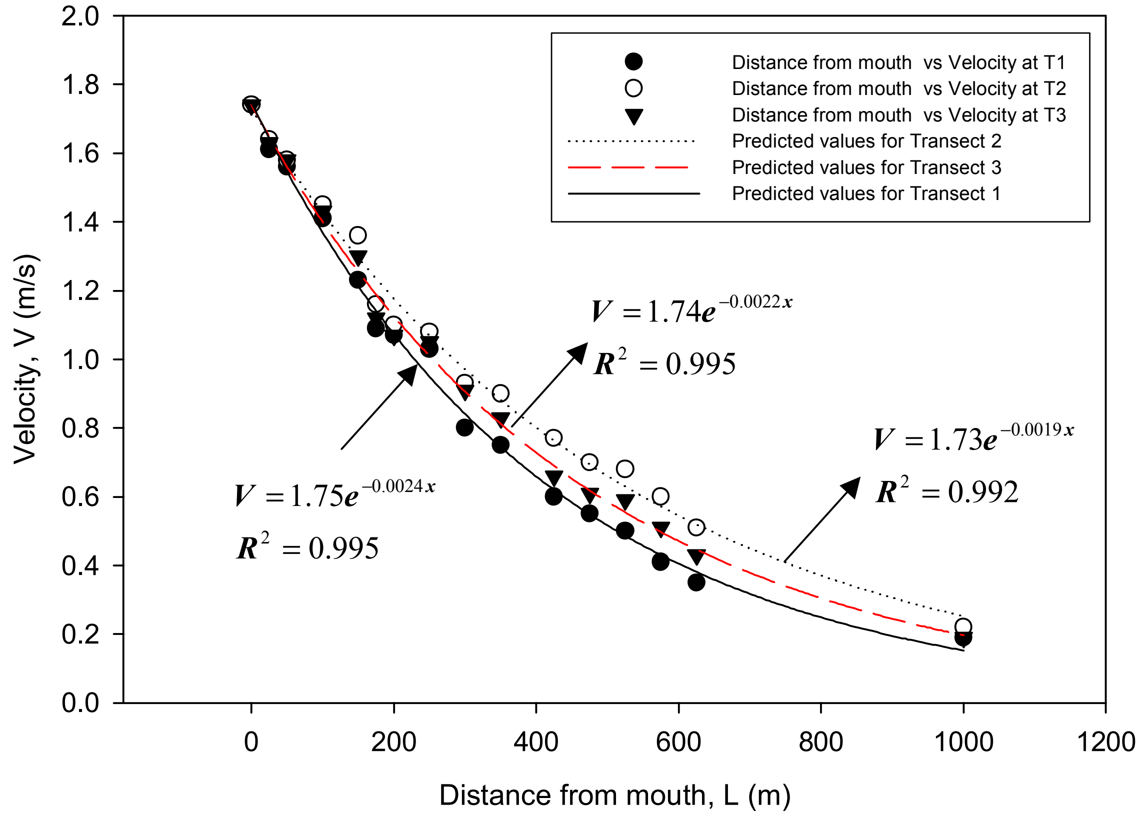

Figure 6.1: Attenuation of velocities at jet flow for 3 transects at Q = 46.8 m^3/s

From the regression analysis, the following values can be seen in Appendix A for:

- Transect 1, a =1.75; b = 0.0024 and R^2 = 0.995,
- Transect 2, a =1.73; b = 0.0019 and R^2 = 0.992, and
- Transect 3, a =1.74; b = 0.0022 and R^2 = 0.995.

If all three values obtained for "a" are compared to the V_0 values (Table 6.1), it is observed that the values are approximately the same. The corresponding velocity attenuation equations are shown in Figure 6.1 for all three transects.

Table 6.2: Experiment #5 – Streamwise mean velocities at Q = 12.5 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	0.98	0.98	0.98
2	25	0.85	0.88	0.86
3	50	0.70	0.73	0.71
3′	75	0.66	0.72	0.68
4	100	0.60	0.68	0.63
4′	125	0.52	0.57	0.55
5	150	0.50	0.53	0.52
6	175	0.40	0.46	0.42
7	200	0.38	0.42	0.41
8	250	0.27	0.30	0.28
9	300	0.20	0.25	0.21
9′	325	0.19	0.22	0.20
10	350	0.18	0.20	0.19
10′	400	0.15	0.19	0.17
11	425	0.13	0.17	0.15
11′	450	0.08	0.1	0.09
12	475	0.07	0.09	0.08
12′	500	0.06	0.09	0.08
13	525	0.05	0.09	0.06
13′	550	0.04	0.08	0.05
14	575	0.03	0.06	0.04

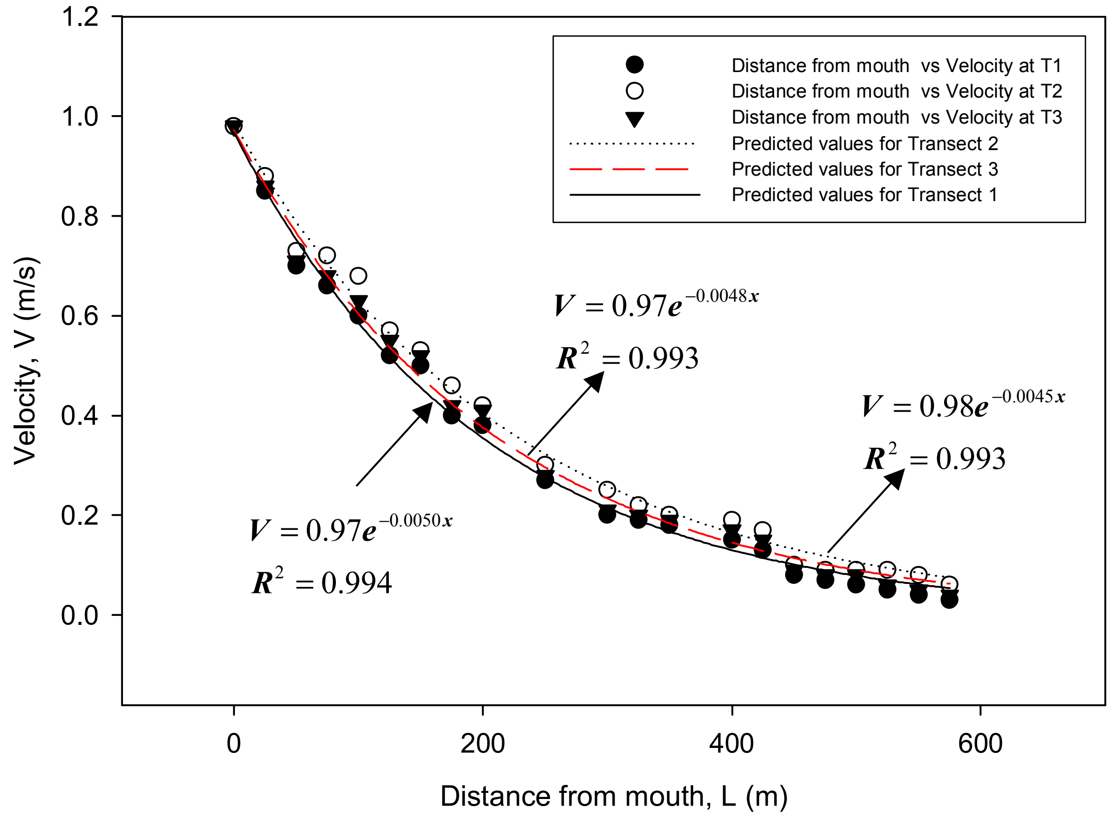

Figure 6.2: Attenuation of velocities at jet flow for 3 transects at Q = 12.5 m^3/s

For Q = 12.5 m^3/s, when the $f = a*exp\ (-b*x)$ is chosen to fit the data, the following values are obtained for:

- Transect 1, a = 0.97; b = 0.0050 and R^2= 0.994,

- Transect 2, a = 0.98; b = 0.0045 and R^2= 0.993,

- Transect 3, a = 0.97; b = 0.0048 and R^2= 0.993.

It was noted that the values computed for "a" using regression analysis are comparable to V_0 values summarized in Table 6.2. The velocity attenuation equations obtained by using SIGMAPLOT 8.0 for these transects are shown in Figure 6.2.

The same procedure was followed for Q = 10.3 m^3/s and Q = 6.9 m^3/s as well as for the remaining six sets of data. As one can see, the computed values for "*a*" compare well with V_0 values for the corresponding transects at different water discharge values, Q. The velocity attenuation values obtained as discussed above follow equation (6.8) and it proves that the velocity attenuation at the Jordan River mouth follows an exponential law.

Table 6.3: Experiment #6 – Streamwise mean velocities at Q = 10.3 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	0.83	0.83	0.83
2	25	0.71	0.73	0.72
3	50	0.60	0.63	0.61
3′	75	0.59	0.60	0.57
4	100	0.47	0.50	0.48
4′	125	0.38	0.40	0.38
5	150	0.36	0.38	0.37
6	175	0.31	0.35	0.33
7	200	0.27	0.29	0.26
8	250	0.21	0.25	0.23
9	300	0.12	0.17	0.15
9′	325	0.14	0.15	0.16
10	350	0.10	0.12	0.09
10′	400	0.10	0.10	0.10
11	425	0.08	0.08	0.08
11′	450	0.06	0.06	0.06
12	475	0.05	0.06	0.05

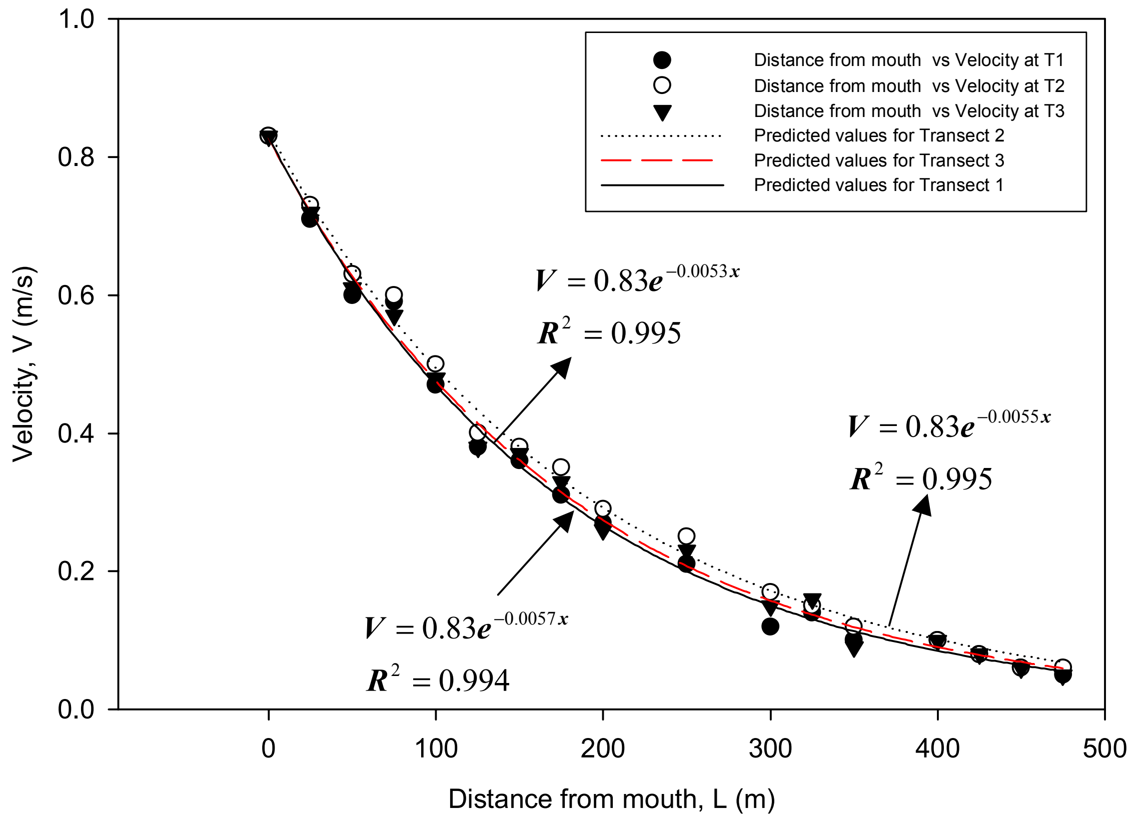

Figure 6.3: Attenuation of velocities at jet flow for 3 transects at Q = 10.3 m^3/s

Table 6.4: Experiment #8 – Streamwise mean velocities at Q = 6.9 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	0.55	0.55	0.55
2	25	0.39	0.39	0.41
3	50	0.3	0.3	0.35
3′	75	0.19	0.19	0.22
4	100	0.15	0.15	0.15
4′	125	0.1	0.1	0.12
5	150	0.05	0.05	0.07

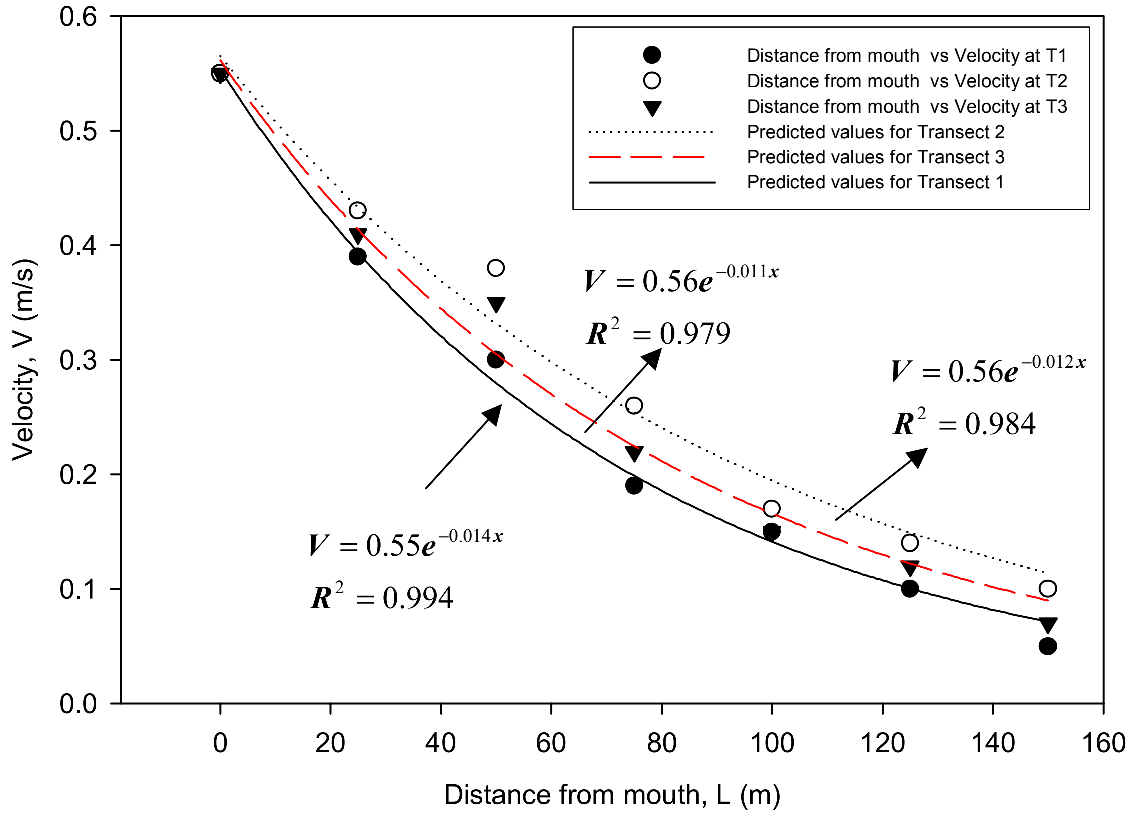

Figure 6.4: Attenuation of velocities at jet flow for 3 transects at $Q = 6.9\ m^3/s$

6.2 TURBULENT VELOCITY FLUCTUATIONS

An example of turbulent velocity fluctuations of the longitudinal velocity in the Jordan River mouth is presented in Figure 6.5. The recordings were measured by velocity fluctuation meter as described in Chapter 5.

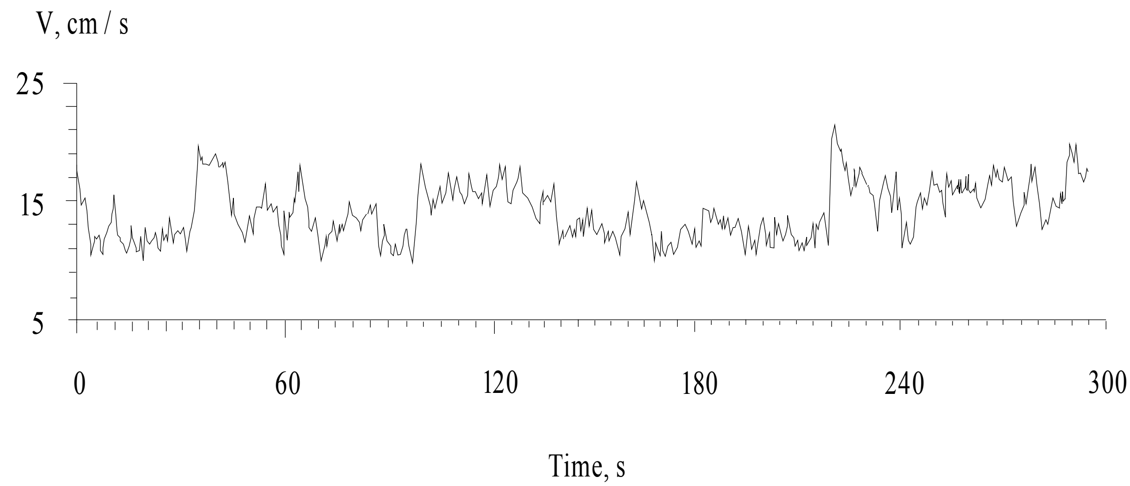

Figure 6.5: A sample recording of the longitudinal component of vector velocity fluctuations, exit cross section, Experiment #1 (surface layer, dynamical axis of the flow) (Khanbilvardi et al., 2003a)

6.2.1 Pulsations of the velocity module and the intensity of turbulence

Based on multiple theoretical and experimental studies, it has been established that the intensity of turbulence on rectilinear portions of the river channels with a smooth, poorly erodible bottom is evenly increasing from the water surface to the bottom of the flow, where main generation of the turbulence energy takes place.

At the area of inflow of a jet river flow into a receiving water body, the main factor determining the changes in the turbulence intensity is the intensity of dissipation of the longitudinal current velocity (Figure 6.6).

The turbulence intensity grows the fastest at the river mouth section, where the flow is abruptly getting wider. Away from the mouth, relative dissipation of velocity remains the same and the turbulence intensity grows slower. It should be emphasized that, only the longitudinal component of velocity is considered in the above discussions.

The relationship shown in Figure 6.6. is possible due to the fact that, the farther from the mouth the section is and the wider the flow is, the greater the part of pulsations energy associated with the transversal (between the mouth and the bar) and vertical (beyond the bar crest) components of velocity.

Pulsations of the longitudinal component of velocity in the jet flow first grow with the distance from the mouth. At a distance equal to the width of the river channel, the intensity of longitudinal turbulence on the jet axis is approximately the same as in the channel, and then grows in the areas of increased longitudinal gradients of velocity (Figure 6.6). Here, K_u is the intensity of turbulence and $\Delta U/U$ is the intensity of the attenuation velocity between two consecutive cross sections.

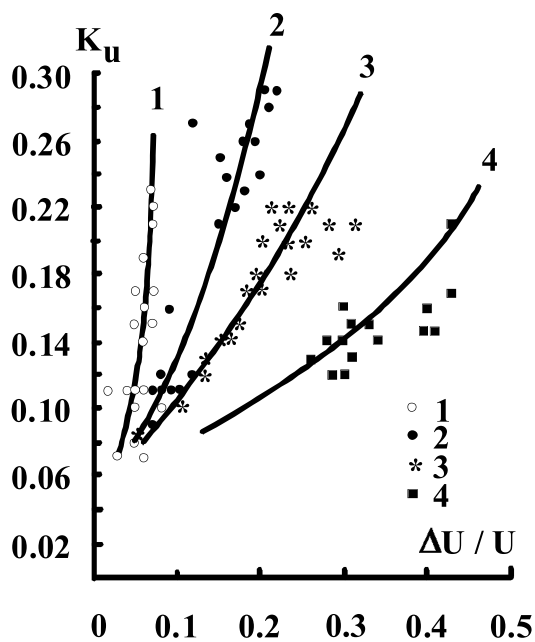

Figure 6.6: Relationship between turbulence intensity and intensity of attenuation of the longitudinal velocity along the axis of the jet flow at various distances in Kura River from the mouth (1- 200 m, 2- 500 m, 3- 800 m, 4- 1,400 m)

Levels of turbulence in the diffusion current are significantly higher than that in the steady current because of a higher velocity gradient, thus, higher generation of turbulence. Within a length of the river equal to two to three times the width, in the river mouth, abrupt flow deceleration occurs. This results in considerable growth of the level of pulsations. The greater the river water discharge, thus, the flow velocities, the farther from the river mouth gauge the zone of highest turbulent pulsations occurs.

Findings from previous studies show that, the intensity of turbulence in the river flow increases from the water surface to the bottom. However, in the conditions of free spreading of the jet flow, starting from the bar crest where the jet detaches itself from the bottom (so-called detached flow), the highest intensity of turbulence is observed within the contact zone between the upper layer of fresh river water and the underlying layer of denser sea water mass (Figure 6.7). As the velocity of the river jet increases, the layer of maximum turbulence shifts deeper.

The influence of the bottom topography on the velocity pulsations and on the distribution of turbulence intensity is felt in the jet flow in the same manner as in the river channel. Results from previous studies (Ozkurt et al., 2003, Khanbilvardi et al., 2003) have indicated that, in the area between the river mouth gauge and the bar crest, the linear dimensions of the bottom ridges diminish rapidly along the flow. This leads, first, to the faster decrease in the standard deviation of the longitudinal pulsations of velocity, and second, to a more uniform distribution of turbulence intensity over the depth of the flow.

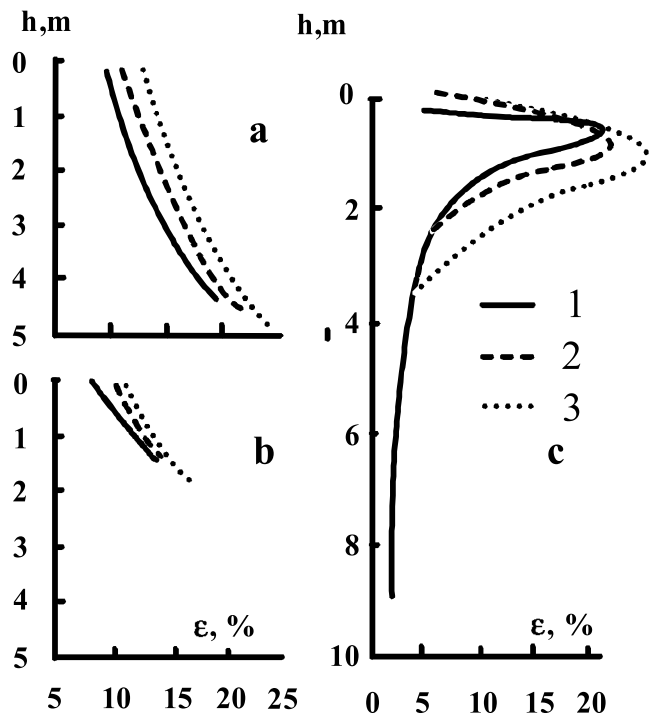

Figure 6.7: Variability of the intensity of turbulence with the jet flow depth at various distances from the Kura river mouth (a- mouth gauge, b- bar crest (500 m from the mouth), c- deeping beyond the bar (800 m from the mouth – zone of detachment of the river jet from the bottom). Curves 1, 2 and 3 correspond to the flow velocities in the mouth equal to 1.58, 2.10, and 2.46 m/s respectively)

The mouth bar has also the shape of a large ridge composed of river sediments. According to findings from an experimental study conducted by Petrosyan (1984), maximum values of the standard deviation of pulsations on the vertical lines beyond the bar crest occur at the crest level. In this study, similarity with the channel flow having a ridged bottom is observed. Furthermore, it was decided that the assumption concerning the trend of changes in the turbulence intensity beyond the bar being similar to that of the area below the bar of a moving sand wave, cannot be extrapolated to the field conditions.

In laboratory conditions, an unstratified flow is observed beyond the bar, while in natural river mouths fresh waters are pinching out to the flow surface as the river jet is moving into the sea. This is why the distribution of velocity pulsations and turbulence intensity on the vertical lines beyond the bar crest has specific features as shown in Figure 6.7. The river mouth bar, from the point of view of its influence on turbulence, can be considered not as a bottom ridge characteristic of a river, but as a practically immobile large bottom ridge generating a detached current. Examples of the distribution of turbulence intensity over the cross section of a jet flow at various distances from the river mouth are given in Figure 6.8.

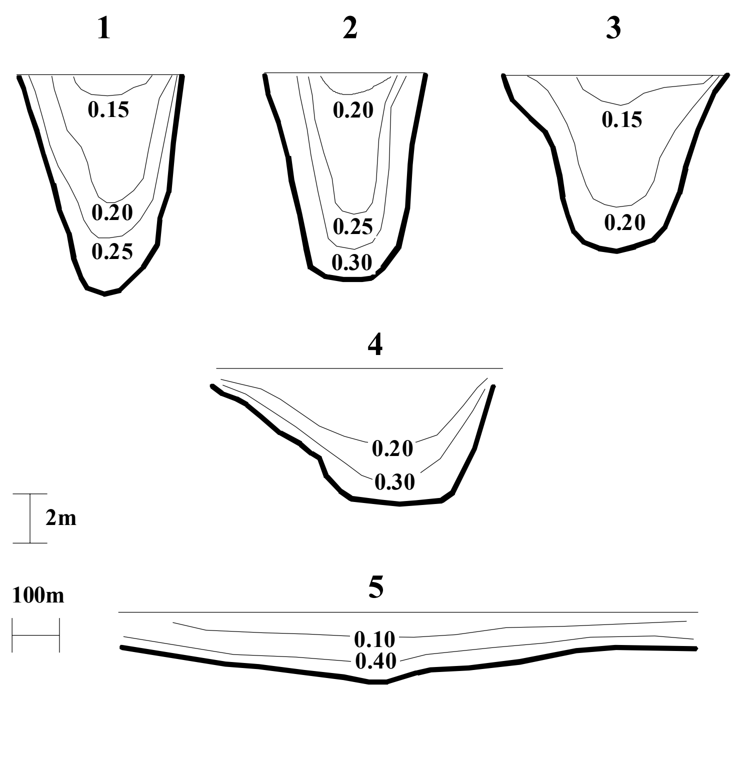

Figure 6.8: Distribution of turbulence intensity over the cross section of the jet flow at various distances from the Kura River Mouth: (1- mouth gage, 2- 200 m, 3-500 m, 4- 800 m, 5- 1,100 m)

6.2.2 Statistical tools to study the turbulence in river mouths

The characteristic feature of turbulent motion is the presence of disordered fluctuations of the fluid dynamic variables of the flow. As a result, both the spatial coordinates and temporal dependence of the instantaneous values of the hydrodynamic fields have a very complex and confused nature. The distributions of instantaneous values of the fluid dynamic variables in space have a similar nature; they constitute a disordered set or three-dimensional fluctuations of diverse amplitude, wavelength and orientation. Due to this extreme disorder and the sharp variation in time and space of the fields of all the fluid dynamic quantities, in the study of turbulence it is necessary to use some methods of averaging. This will enable passing from the initial fluid dynamic fields to smoother, more regular mean values of flow variables (Monin and Yaglom, 1966).

The main mechanisms used to describe the results for this research were the theory of random processes, the method of structural averaging when studying coherent structures, and the theory of random functions and fields when studying hydrodynamic fields (Grinvald and Nikora, 1988; Grinvald, 1974; Nikora, 1991; Sukhodolov et al. 1998; Monin and Yaglom, 1965, 1966, 1967). The analysis of spatial-time structure of turbulence concerns correlation and spectral functions of velocity in the fixed points of the flow as well as two-point correlation and coherence functions. The space-time cross spectra allow one to correlate stationary random processes in the frequency domain and to determine which frequencies (high or low) are responsible for the linear correlation between the processes.

<u>Moments of Hydrodynamic Fields</u>**:** If we have a system of N random variables u_1, u_2, u_3, ..., u_N with an N-dimensional probability density ρ(u_1, u_2, u_3, ..., u_N), then the moments of these variables are defined by the expression:

$$b_{k_1k_2...k_N} = u_1^{k_1}u_2^{k_2}...u_N^{k_N} = \int\int_{-\infty}^{\infty}...\int u_1^{k_1}u_2^{k_2}...u_N^{k_N}\,\rho(u_1^{k_1}u_2^{k_2}...u_N^{k_N})du_1du_2...du_N \qquad (6.9)$$

Where k_1, k_2, ..., k_N are nonnegative integers, the sum which gives the order of the moment (Monin and Yaglom 1975). In particular, the moments of first order are the mean values of the quantities u_1, u_2, u_3, ..., u_N.

Central moment, i.e., the moment of the deviations of u_1, u_2, u_3, ..., u_N from their corresponding mean values is often used.

$$B_{k_1k_2...k_N} = \overline{(u_1-\overline{u_1})^{k_1}(u_2-\overline{u_2})^{k_2}...(u_N-\overline{u_N})^{k_N}} \qquad (6.10)$$

The moment B_2 is called the variance of u and at a specific time, it is expressed as:

$$\sigma^2(t) = \overline{\left|u(t)-\overline{u}(t)\right|^2} \qquad (6.11)$$

The general second central moment is called the covariance of variables of u_1 and u_2 and

$$B_{11} = \overline{(u_1-\overline{u_1})(u_2-\overline{u_2})} \qquad (6.12)$$

Also, if we call u as velocity quantity and substitute $u' = u - \overline{u}$ in Eq. 7.12, where u' is the velocity fluctuation quantity, the correlation function of $u(t)$ becomes

$$B(t_1,t_2) = \overline{u'(t_1)u'(t_2)} \qquad (6.13)$$

where

$$\bar{u} = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} u(t)dt \tag{6.14}$$

Auto correlation function then can be expressed as:

$$R(t_1, t_2) = \frac{B(t_1, t_2)}{\sigma(t_1)\sigma(t_2)} \tag{6.15}$$

When considering jointly the three velocity components, the vector fields of velocity, the vector-algebraic method of analysis was used (Rozhkov, 1979). This method provides important information under conditions of commensurability of the three velocity components. The main element of this analysis is analyzing the correlation tensor of the vector process

$$K_{\vec{v}}(t,\tau) = \begin{pmatrix} K_{v_1 v_1} & K_{v_1 v_2} \\ K_{v_2 v_1} & K_{v_2 v_2} \end{pmatrix} \tag{6.16}$$

which is a dyadic tensor function of the arguments (t, τ) where τ is temporal lag. This function characterizes the interrelation of the directional changes of the flow velocity vectors at the moments of time t, $t+\tau$, and provides numerical assessment of the intensity of these changes and of their orientation in the given system of coordinates.

The invariant D of the skew-symmetric part of the tensor K_v, called by Rozhkov (1979) the indicator of spinning (rotational movement of turbulent eddies), can be determined by the relation

$$D_{1,2} = K_{v_1 v_2} - K_{v_2 v_1} \tag{6.17}$$

It is composed of the orthogonal components of the vectors $\vec{v}(t)$ and $\vec{v}(t+\tau)$. If $D>0$, then the vector $\vec{v}(t+\tau)$ is predominantly oriented to the right of the vector $\vec{v}(t)$, and if $D<0$, then to the left. This means that in the first case the vector's rotation is clockwise, while in the second case it is counterclockwise.

In equation (6.17), the basis unit vectors of the tensor $K_{\vec{v}}$ depend on the arguments (t, τ) are oriented, with respect to the reference system of coordinates, in the direction

$$\alpha^{(K)} = 0.5arctg\left[\frac{K_{v_1v_2} + K_{v_2v_1}}{K_{v_1v_1} - K_{v_2v_2}}\right] \tag{6.18}$$

where α is the angle between turbulent eddy rotation axis and each orthogonal plane (Figure 6.8).

In our experiments, the spatial structure of the correlation characteristics is conducted successively for the vertical (u, v), horizontal (u, w), and transversal (v, w) planes in the left system of coordinates (the X-axis goes with the current, the Y-axis is oriented perpendicular to the gravity vector in the direction of the right edge of the current, and the positive Z-semiaxis goes upward, perpendicular to the bottom plane). The invariants $D_{i,j}$ characterize the intensity of spinning of the velocity vector in various planes.

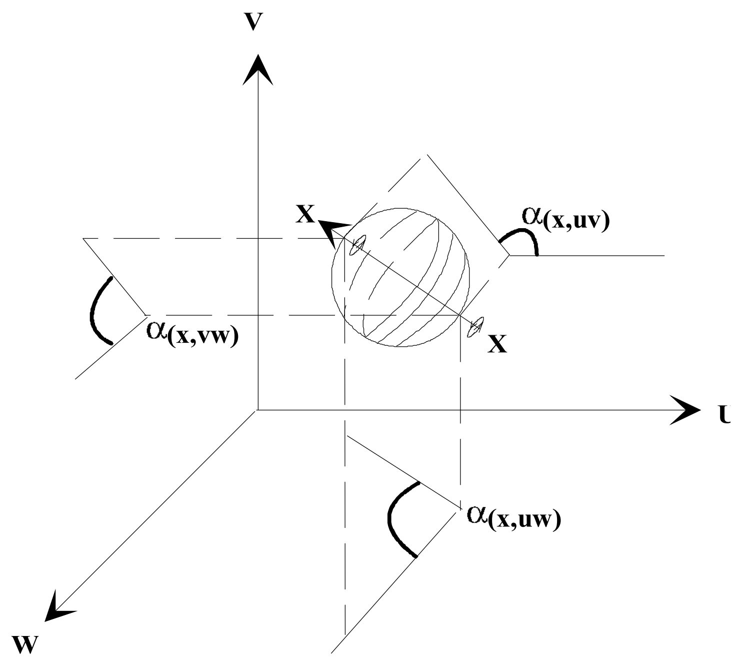

Figure 6.9: α, the angle between turbulent eddy rotation axis and each orthogonal plane

For a more complete analysis, the so-called linear invariant *I* was considered, which can be determined by the equation

$$I = K_{v_1 v_2} + K_{v_2 v_2} \tag{6.19}$$

composed of the collinear vector components $\vec{v}(t)$ and $\vec{v}(t+\tau)$. If *I>0*, the collinear vector components are unidirectional, if *I<0*, they have opposite directions, and if *I=0*, the vectors are orthogonal.

A joint analysis of the invariants *I* and *D* helps to get results for, regardless of the chosen system of coordinates, the structure of collinear and orthogonal alterations of the flow velocity vectors, the intensity of spinning of the turbulent eddies in various planes, as well as the spatial orientation of the axes of such spinning.

6.2.3 Velocity vector pulsations

Pulsations of the transversal (*w*') and vertical (*v*') velocity differ from the pulsations of the longitudinal component (*u*'). Within the river area, the ratio $\overline{u'^2}/\overline{v'^2}$ generally displays regular growth from the bottom to the flow surface; the ratio $\overline{u'^2}/\overline{w'^2}$ is also growing, resulting in a ratio greater than that given by $\overline{u'^2}/\overline{v'^2}$. In the river mouth jet flow, spatial distribution of the velocity components has some specific features. In the jet flow, at a distance from the mouth equal to the width of the river, $\overline{u'^2}$ starts its regular growth with the distance from the bottom. This is related to the fact that friction at the side boundaries of the jet is six to nine times higher than friction at the bottom (Mikhailov et al., 1986). Therefore, when the river flow exits the mouth gauge, its surface layer acquires intense additional turbulization compared with the near-bottom layers experiencing basic friction on the bottom due to minimal transversal velocity gradient. Beyond the bar, where the river jet possessing insignificant energy, detaches from the bottom and spreads freely, all three components of the velocity have the highest values of pulsation in the surface layer. However, if the jet has significant energy, the $\overline{u'^2}$, $\overline{v'^2}$ and $\overline{w'^2}$ decrease from the bottom to the surface, which is due to high vertical gradients of velocity in the near-bottom zone.

Eddy zones on the jet boundaries are the sources of the elevated turbulence, with the velocity of translational motion five to ten times lower than the velocity in the main body of the jet. In this study, the highest values of turbulent pulsation and commensurable components *u', v'* and *w*' were observed. The intensity of transversal pulsations can be as high as 60 percent, while the intensity of longitudinal pulsations is on the order of 25 to 35 percent. The transversal pulsations of velocity at a distance equal to five to six times the river width are 10 to 20 times higher than those in the jet axis.

Figure 6.10 gives an example of changing statistical parameters of turbulence along the river jet within the river-sea contact zone – invariants of the correlation between orthogonal components of the turbulent functions of velocity. As can be seen, the functions $D_{uv}(\tau)$, $D_{uw}(\tau)$ and $D_{vw}(\tau)$, which correspond to the river flow (Table 6.5, Figure 6.10A) exhibit both positive and negative values, and lower amplitudes of oscillation compared to $I(\tau)$. The highest values belong to $D_{uw}(\tau)$ (spinning in a vertical plane), while the lowest to D_{vw}. In the initial 200 meter-area of river inflow into the sea (gauge 5), the highest positive values belong to $D_{uv}(\tau)$, while $D_{uw}(\tau)$ exhibits the lowest negative values (Figure 6.10B). At a distance of 500 meter from the mouth (gauge 6), the invariant $D_{uw}(\tau)$ has the highest positive values, which testifies to the restructuring of the flow structure from the predominant rotation in the vertical-longitudinal plane (u, v) to the predominant rotation in the horizontal-transversal plane (Figure 6.10C). At the mouth bar (Table 6.6), approximately 800 meter from the mouth gauge, the predominance of the component $D_{uw}(\tau)$ over other components is higher than in areas located upstream, while the component $D_{uv}(\tau)$ has the smallest value and amplitude (Figure 6.10D). Beyond the bar (gauge 8), the value of the component $D_{uv}(\tau)$ characterizing rotation of turbulent eddies in the longitudinal vertical plane (u, v) is close to zero (Table 6.7); the most intense spinning of eddies is observed in the horizontal plane (u,w).

Table 6.5: Correlation tensor function invariants *I* and *D* (mouth section of the Kura River – gauge# 4, experiment# 10)

τ, s	B_{uu} cm^2 s^{-2}	B_{vv} cm^2 s^{-2}	B_{ww} cm^2 s^{-2}	$\alpha°_{uv}$	$\alpha°_{uw}$	I cm^2 s^{-2}	D_{uv} cm^2 s^{-2}	D_{uw} cm^2 s^{-2}	D_{vw} cm^2 s^{-2}
0	1345	56	840	11	31	2241	287	641	96
1	1037	43	648	23	32	1728	533	567	258
2	679	28	424	32	30	1131	821	292	282
3	338	14	211	41	29	563	1397	141	253
4	57	2	36	8	37	95	8	51	69
5	-143	-6	-90	23	24	-239	-73	-41	5
6	-260	-11	-162	43	26	-433	-2004	-87	1
7	-303	-13	-189	22	27	-505	-162	-110	10
8	-289	-12	-181	14	27	-482	-89	-108	19
9	-239	-10	-149	36	27	-398	-423	-88	17
10	-171	-7	-107	40	29	-285	-488	-72	70
11	-100	-4	-62	2	24	-166	-4	-29	3
12	-37	-1	-23	11	23	-61	-7	-11	1
13	11	1	7	36	35	19	15	7	5
14	42	2	26	40	33	70	129	24	19
15	58	2	36	31	35	96	62	40	2

Table 6.6: Correlation tensor function invariants *I* and *D* (section on the bar, Kura River – gauge# 7, experiment# 10)

τ, s	B_{uu} cm^2 s^{-2}	B_{vv} cm^2 s^{-2}	B_{ww} cm^2 s^{-2}	$\alpha°_{uv}$	$\alpha°_{uw}$	I cm^2 s^{-2}	D_{uv} cm^2 s^{-2}	D_{uw} cm^2 s^{-2}	D_{vw} cm^2 s^{-2}
0	1088	31	558	10	39	1677	212	1729	650
1	823	23	422	11	42	1268	167	2599	1340
2	559	16	287	15	44	862	193	5511	1400
3	326	9	167	18	44	502	130	3315	1100
4	141	4	72	14	40	217	38	265	74
5	-7	0.2	4	8	17	11	1	1	2
6	-78	-2	-40	7	31	-120	-11	-50	35
7	-122	-3	-63	10	42	-188	-24	-403	84
8	-136	-4	-70	14	43	-210	-42	-690	123
9	-129	-4	-66	18	44	-199	-55	-1361	370
10	-109	-3	-56	20	44	-168	-46	-1065	140
11	-84	-2	-43	24	43	-129	-47	-408	90
12	-58	-1	-29	12	43	-88	-13	-298	66
13	-34	-1	-18	16	43	-53	-12	-155	35

Table 6.7: Correlation tensor function invariants *I* and *D* (section beyond the bar, Kura River – gauge# 8, experiment# 10)

τ, s	B_{uu} $cm^2\,s^{-2}$	B_{vv} $cm^2\,s^{-2}$	B_{ww} $cm^2\,s^{-2}$	$\alpha°_{uv}$	$\alpha°_{uw}$	I $cm^2\,s^{-2}$	D_{uv} $cm^2\,s^{-2}$	D_{uw} $cm^2\,s^{-2}$	D_{vw} $cm^2\,s^{-2}$
0	207	44	13288	3	5	13539	9	-1600	-440
1	21	4	1326	5	8	1351	2	-252	-164
2	-18	-4	-1150	6	9	-1172	-2	-220	-73
3	-6	-1	-370	6	5	-377	-0.6	-43	-19
4	0.7	0.2	48	15	4	49	0.2	5	-1
5	0.8	0.2	49	9	4	50	0.1	5	-1
6	0.1	0.01	5	24	6	5	0.06	0.7	-1

The analysis of invariants $I(\tau)$, parameters $\alpha^o(\tau)$ and rotation indicators $D(\tau)$ in various planes has shown that flow circulation within the experimental river area was observed in the form of a right-handed screw (clockwise), while within the jet part of the flow, the farther from the mouth gauge and the closer to the bar, what happens is turnover (reorientation) of the turbulent eddies so that beyond the bar counterclockwise rotation becomes predominant.

As proven by the values of the angle $\alpha^o(\tau)$ in Figure 6.10, the direction of the longer axis of the tensor curve (the direction of the predominant variability of the velocity vector) is changing cyclically: mostly in the (u,v) plane within the channel area, mainly in the (u,w) plane within the jet area between the mouth gauge and the bar, and again in the (u,v) plane beyond the bar. Furthermore, while within the channel area (mouth gauge) the entire flow is involved in vertical circulation, beyond the bar it is localized (concentrated) in the surface layer where intense mixing of fresh river water masses and saline seawater masses occurs.

Comparison of the values of the correlation function *I(τ)* of the collinear components of the pulsation velocity vector with the function *D(τ)* of the orthogonal components shows that *I(τ)* > *D(τ)* before the bar, and *I(τ)* < *D(τ)* on the bar. This indicates that while at the beginning of the jet the interrelation of the collinear components is predominant, around the bar the interrelation of the orthogonal components is stronger, that is the influence of the changing flow direction is greater than the influence of the changing velocity module. Similar conclusions can be made when analyzing the changes in invariants *D(τ)* along the river, transitional and jet areas of the flow (Figure 6.11).

From the analysis of the spectral functions (distribution of the kinetic energy by frequencies of turbulent pulsations), it was concluded that the pulsation spectra for the channel flow contain a considerable interval where the ordinates are changing in proportion to the frequency in the power of -5/3, which corresponds to the Kolmogorov's model of local-isotropic turbulence (Kolmogorov, 1941).

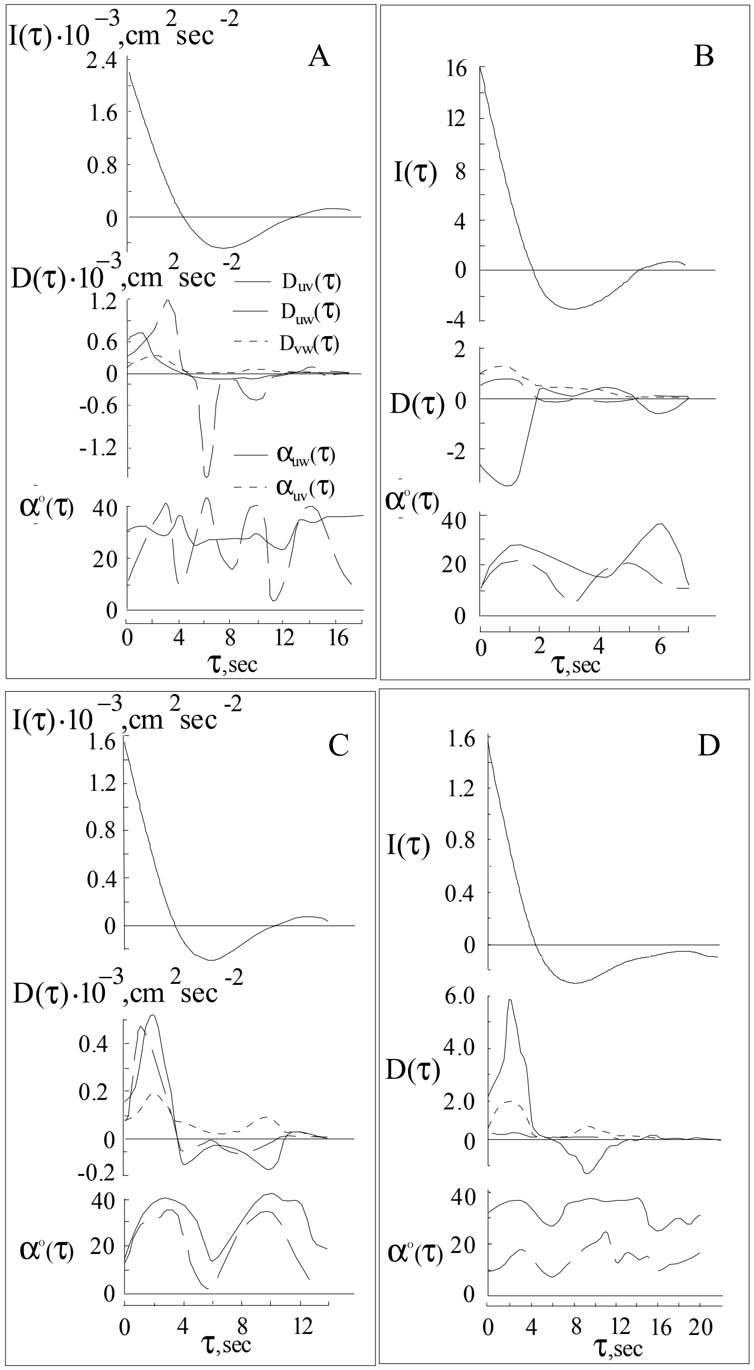

Figure 6.10: Changing statistical parameters of flow turbulence (the Kura River mouth area, experiment #10, dynamic axis of the flow relative depth 0.6)

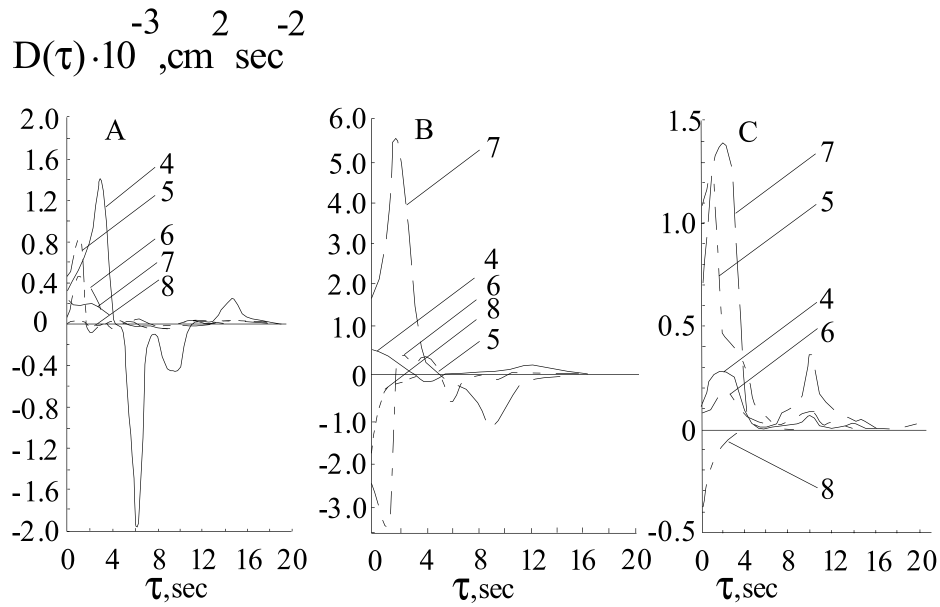

Figure 6.11: Changing invariants of the correlation between the fluctuations of the orthogonal components of the vector along the flow (numbered are observation gauges in Kura River mouth: 4-mouth gauge, 5-7-transitional area between mouth and bar, 8-free turbulent jet beyond the bar- A-correlation of components u', v'; B- correlation of components u', w'; C-correlation of components v', w'

CHAPTER 7

SEDIMENT TRANSPORT PROPERTIES IN THE RIVER MOUTH JET FLOW

The velocity attenuation of the river flow in the mouth region produces a decline in its transportation capacity of suspended matter, which results in suspended particulate matter (SPM) sedimentation. The decrease of the suspended particulate matter concentration (SPMC) along the jet flow is not only due to the transportation capacity drop, but also due to the dilution of the river water (having high SPMC) with the reservoir water (as a rule, less turbid). The first process predominates in the zone where the river jet flows between the mouth spits, while the second one predominates after the bar crest where only the finest SPM fractions, with negligible sedimentation velocities, are left in the jet (Shteinman and Kamenir, 1998).

The concentration of suspended sandy-silty particles carried by the river to the mouth is rapidly diminishing along the river jet, the highest gradient being observed between the mouth and the bar crest. The latter is typically located at a distance of about 5 river widths in the mouth. SPM size spectrum was determined using image analysis (Image Pro. Plus, 1997). For all grain sizes larger than 0.05 mm, the SPMC decrease can be described by the approximated equation

$$V_x = V_0 e^{-3cx} \tag{7.1}$$

corresponding to the case of predominant processes of sedimentation [Image Pro. Plus 1997, Simonov 1960, Mikhailov 1971), where V_0 and V_x are average (over the cross-section) flow velocities in the initial cross-section and at the distance x, respectively, c is an empirical coefficient.

Starting from the bar crest, the SPMC decrease can be described by

$$V_x = V_0 e^{-cx} \tag{7.2}$$

corresponding to the case of predominant process of dilution of the river water by the water mass of the receiving water body.

For the grain sizes smaller than 0.05 mm, the SPMC decrease can be described by a relationship close to equation (7.2). This testifies to the low rates of deposition of these particles in addition to the decrease in their concentration that is caused by the dilution processes. While the average SPMC decrease before the bar crest for grain sizes >0.05 mm is 70%, for grain sizes <0.05 mm it is just 8-10% (Shteinman et al., 2004).

Both equations (7.1) and (7.2) follow from the dynamic equilibrium equation obtained by Makkaveev and Konovalov (1940) and transformed by Simonov (1960) in the form:

$$QV = const. \tag{7.3}$$

where Q is the water discharge and V is the velocity averaged over the cross-section.

To verify the theoretical considerations, the same 10 sets of measurements that were collected from the Jordan River-Lake Kinneret are used. The 10 sets of measurements were carried out during calm conditions in the water discharge range of 3.8-46.8 m^3/s. The tables show the Suspended Particulate Matter Concentration (SPMC) values at three transects (shown in Figure 5.9) for discharge flows of 46.8 m^3/s, 12.5

m^3/s, 10.3 m^3/s and 6.9 m^3/s in Tables 7.1 - 7.4. These SPMC values are illustrated in Figures 7.1 – 7.4. Further sets of tables, graphs and corresponding reports for non-regression analysis are presented in Appendix B.

Table 7.1: Experiment #1 – SPMC values for Q = 46.8 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	4810	4810	4810
2	25	3620	4150	3900
3	50	3210	3440	3610
4	100	2180	2830	2470
5	150	2000	2460	2140
6	175	1830	2400	2100
7	200	1790	2170	2000
8	250	1650	2050	1870
9	300	1430	1910	1610
10	350	1200	1750	1490
11	425	1050	1480	1360
12	475	930	1350	1100
13	525	740	1290	970
14	575	650	1160	910
15	625	610	960	860
16	1000	230	590	370

SIGMAPLOT 8.0 analyzes the data. All the non-linear regression analysis can be found in Appendix B.

It's shown that the velocity attenuation of the runoff flow follows the law described by equation as shown in Chapter 6:

$$\frac{V_x}{V_0} = e^{-cx} \tag{7.4}$$

The SPMC decline produced by the particles sedimentation should follow the equation:

$$SPMC_x = SPMC_0 e^{-3cx} \tag{7.5}$$

until the bar and the following equation:

$$SPMC_x = SPMC_0 e^{-cx} \tag{7.6}$$

if the SPMC decline is provided only by the river water dilution where $SPMC_0$ and $SPMC_x$ are suspended particulate matter concentration over the cross section at an initial section and at a distance x away from initial section and c is the empirical coefficient.

From Figure 7.1, it's possible to compare the results of coefficient a before bar found by SIGMAPLOT 8.0 with the experimental values of $SPMC_0$ and coefficient a after bar with the experimental values of $SPMC_{100}$ at Q = 46.8 m^3/s. All the R-values and R^2-values in non-regression analysis are close to 1, which show that the chosen plot is appropriate for all ten sets of data. It can also be seen that the graphs validate the equations (7.5; 7.6). From the regression analysis, the following values can be seen in Appendix B for Q = 46.8 m^3/s:

- Transect 1, a = 4690; b = 0.0079; R^2 = 0.979 before bar and a = 2243; b = 0.0024; R^2 = 0.993 after bar;

- Transect 2, a = 4756; b = 0.0056; R^2 = 0.982 before bar and a = 2737; b = 0.0019; R^2 = 0.992 after bar, and

- Transect 3, a = 4763; b = 0.0064; R^2 = 0.981 before bar and a = 2451; b = 0.0020; R^2 = 0.994 after bar.

These values for each transect are approximately close to the $SPMC_0$ and $SPMC_{100}$ values and coefficient *b* found by SIGMAPLOT 8.0 corresponds to the *c* value and it's almost the same as the velocity attenuation constant. One main reason why these values are not the same is because of the predominant processes. Although the predominant process before the bar is sedimentation, there is still a small percentage of dilution processes that is taking place. After the bar, the dilution processes are predominant but there is still some sedimentation occurring with a small percentage. The equations for these values are shown in the Figure 7.1 -7.4. The same results can also be seen for the remaining nine sets of data. As an exception, for Q = 6.9 m^3/s, Q = 5.5 m^3/s and Q = 3.8 m^3/s there are almost no sedimentation processes after 100 meters; and hence the analysis and the graphs are only accurate until 100 meters for these values.

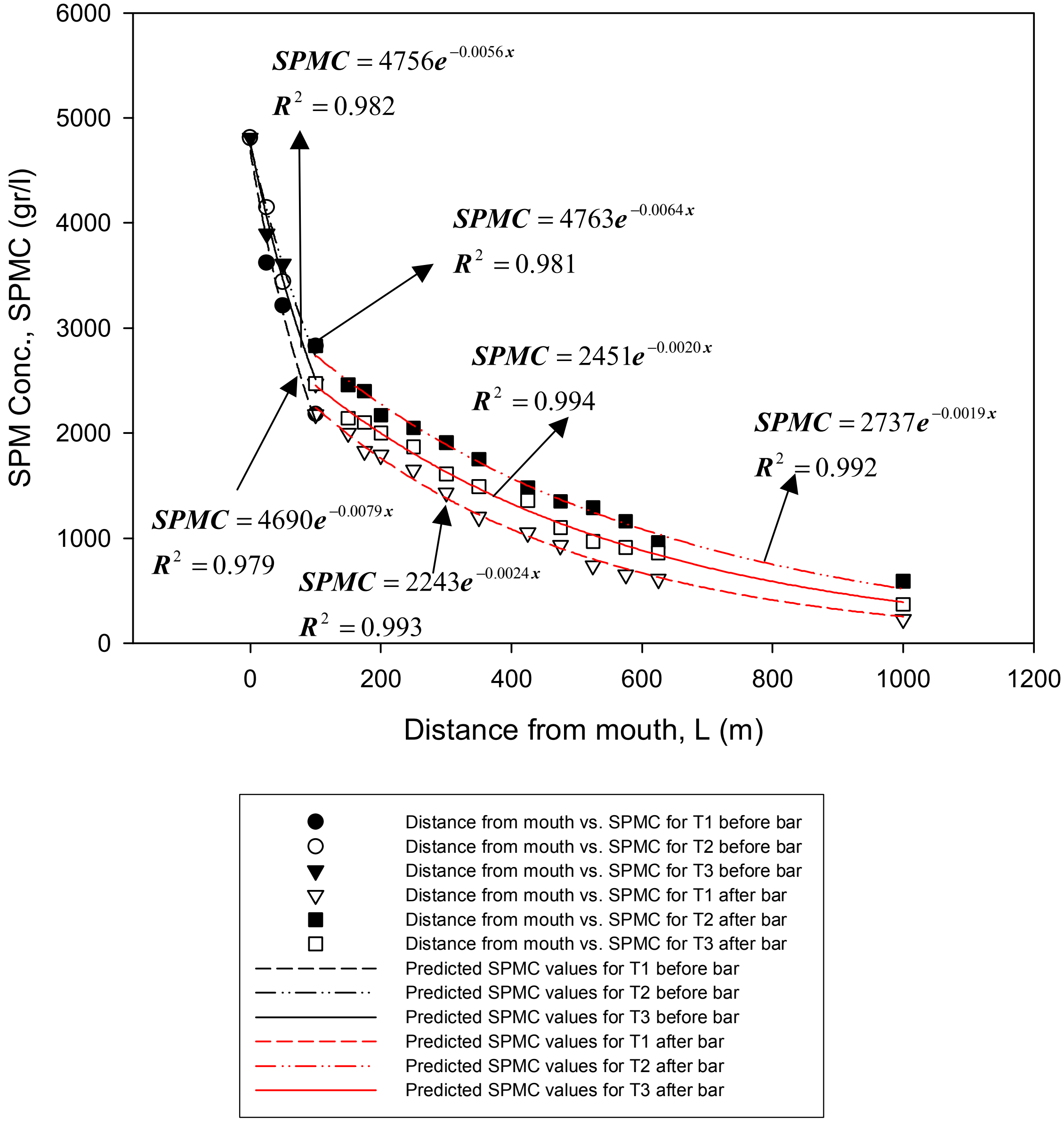

Figure 7.1: SPM concentrations at jet flow for 3 transects at Q = 46.8 m^3/s

Table 7.2: Experiment #5 – SPMC values for Q = 12.5 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	830	830	830
2	25	580	610	600
3	50	390	460	420
3′	75	270	350	300
4	100	200	230	220
4′	125	190	210	190
5	150	170	190	170
6	175	150	170	150
7	200	110	160	140
8	250	100	140	120
9	300	83	110	90
9′	325	66	73	75
10	350	61	70	68
10′	400	39	66	60
11	425	35	60	55
11′	450	34	55	51
12	475	31	47	40
12′	500	29	41	36
13	525	26	39	33
13′	550	24	30	29
14	575	19	27	25

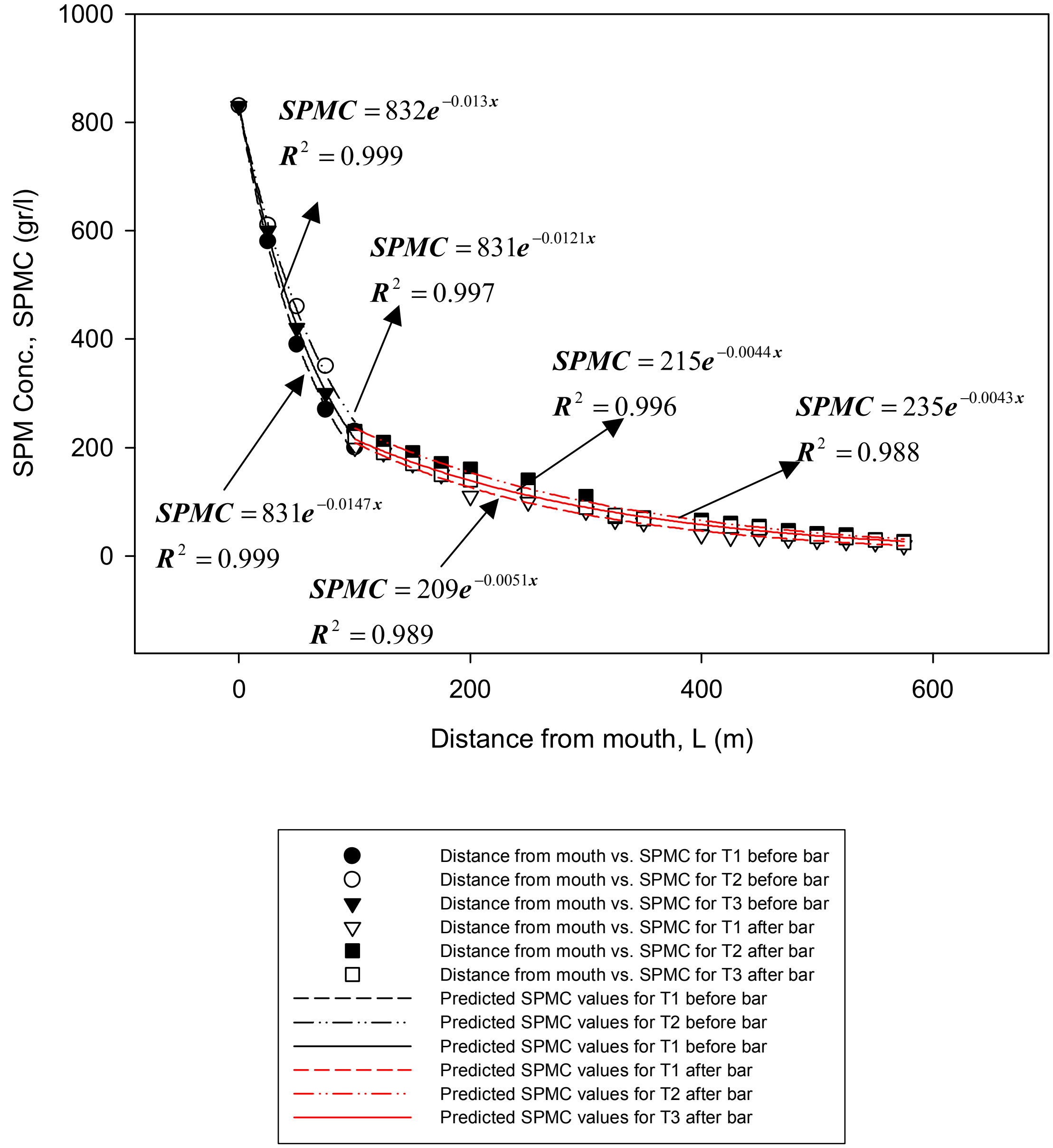

Figure 7.2: SPM concentrations at jet flow for 3 transects at Q = 12.5 m^3/s

Table 7.3: Experiment #6 – SPMC values for Q = 10.3 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	510	510	510
2	25	340	350	350
3	50	200	230	220
3′	75	160	180	170
4	100	95	120	110
4′	125	84	110	92
5	150	70	91	78
6	175	61	85	73
7	200	58	75	62
8	250	45	52	50
9	300	30	41	33
9′	325	28	40	31
10	350	21	33	30
10′	400	19	30	26
11	425	18	21	22
11′	450	16	20	19
12	475	11	19	13

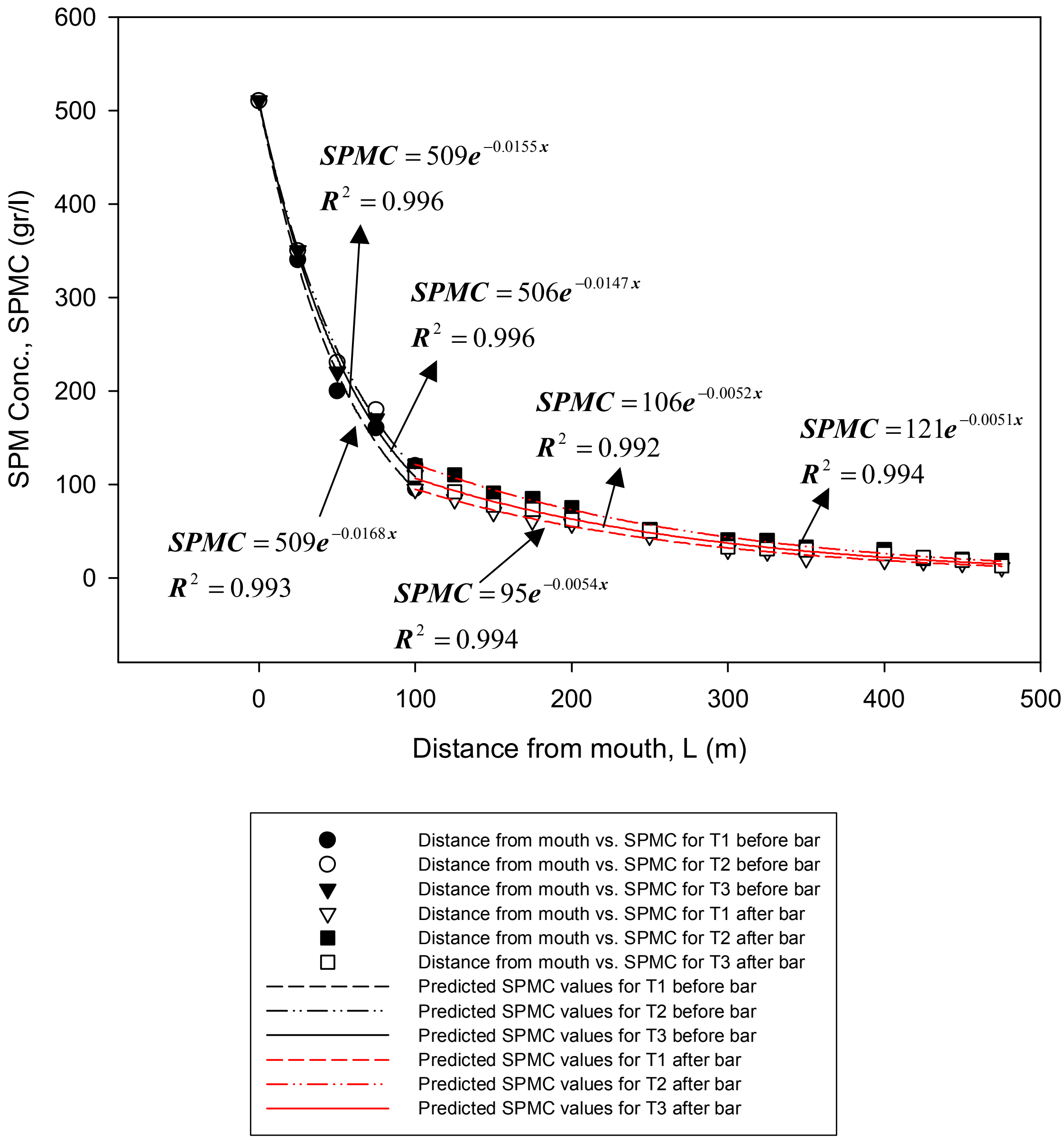

Figure7.3: SPM concentrations at jet flow for 3 transects at Q = 10.3 m^3/s

Table 7.4: Experiment #8 – SPMC values for Q = 6.9 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	150	150	150
2	25	66	72	69
3	50	22	38	29
3′	75	6	12	10
4	100	3	8	6
4′	125	0	2	1
5	150	0	1	0

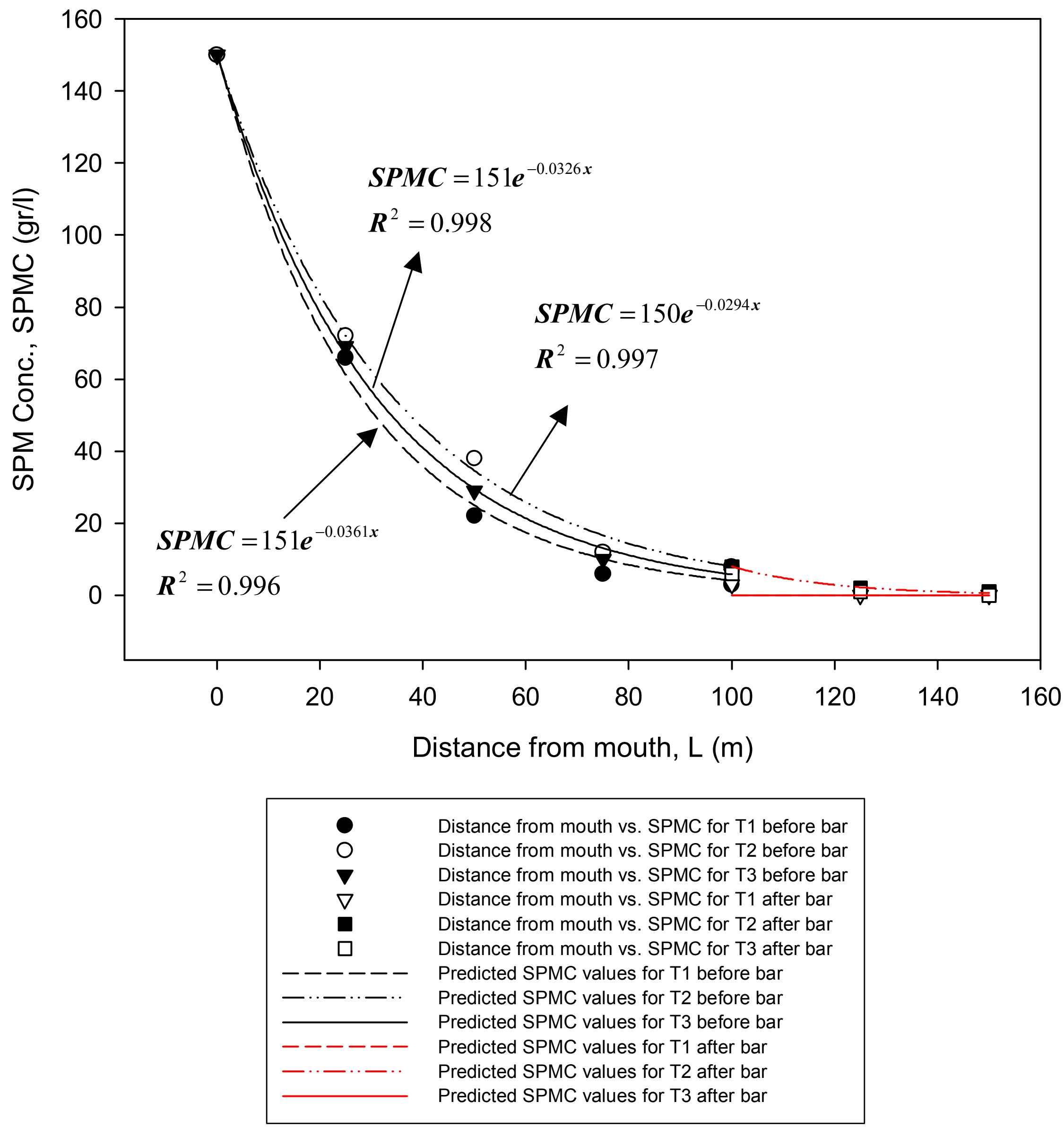

Figure 7.4: SPM concentrations at jet flow for 3 transects at Q = 6.9 m^3/s

The interaction between turbulent flows and erodible bottom is a complicated nonlinear process where, under the influence of turbulent fluctuations of velocity (and pressure), sand waves and ripples are forming on the sand bottom. These forms, in turn, exert substantial adverse influences on the structure of the turbulent flow. This nonlinear process is particularly complicated at the river mouths. The concern is that, besides usual hydro and morphodynamic factor characteristic of river flows, certain factors specific of river mouths manifest themselves at the river mouths only. These factors are caused by the following particular hydro and morphodynamic features of the river mouths (Ozkurt et al., 2003).

Within these natural objects at relatively short distances, the restructuring occurs of the hydrodynamic structure characteristic to the river flows, transforming into the structure characteristic of the hydrodynamics of the receiving water body (Mikhailov, 1971; 1995; 1996). In general, this restructuring may be summed up by the following process:

The most universal process, characteristic of mouths of all rivers, is fast attenuation of the river flow and the runoff currents with moving away from the mouth into the receiving water body. This attenuation is related to the flow slope becoming gentler, up to zero. In accordance to this, further movement of the flow into the receiving water body (a lake or a sea) occurs under the influence of inertia, not the component of gravity parallel to the flow surface as in the river. Besides, in this area the banks are no longer a factor of influence, and the bottom too – at some distance from the mouth – on the hydrodynamics of the flow.

As a result of these factors and changing conditions of flow, the river flow is transforming into the free turbulent jet that flows by way of inertia in the conditions of "liquid banks and bottom". This is highly distinguished by the river flow.

Very important characteristic of the mouth areas of the rivers is the process of energy dissipation: the kinetic energy of the river jet is gradually, in the course of dissipation, decreasing to zero, and the energy of the waves is dissipating when they break on the shallow water. This causes the predominance of accumulation processes in the river mouths – the intense sedimentation of suspended matter and the gradual reduction of bottom sediments along the jet. As a result of these processes, the most characteristic feature of the river mouths is formed – the mouth sand bar. This bar, on one hand, is the last structural bottom formation characteristic of the river channels, and on the other hand, the first morphological element characteristic of the river mouths (Mikhailov, 1995; 1996; Mikhailova, 1993; Butakov, 1971; Shteinman et al., 1993; Hitoshi and Kyozo, 1993). It is only beyond the bar that intense mixing of the river water with the water of the receiving water body starts (Mikhailov, 1995). Figure 7.1 to Figure 7.4 show that 90% of suspended load transport is before the bar and follows the "*-3cx*" formula. The distance of the bar from the mouth in Jordan River-Lake Kinneret river mouth is approximately 100 m. and for Kura River-Caspian Sea this distance is 500 m., which is schematized in Figure 4.8 in Chapter 4.

Bed load transforms in the formation of ripples. The two main reasons for bed load deposition are decreasing of linear dimensions of ripples and decreasing of moving velocity. As shown in Figure 7.5, the longitudinal dimension of ripples in river mouths is dropping approximately 10 times after the bar. The bed load transport before the bar is almost 100%. After 300 m from the mouth, there are no ripples because of the turbulence in the Kura River mouth.

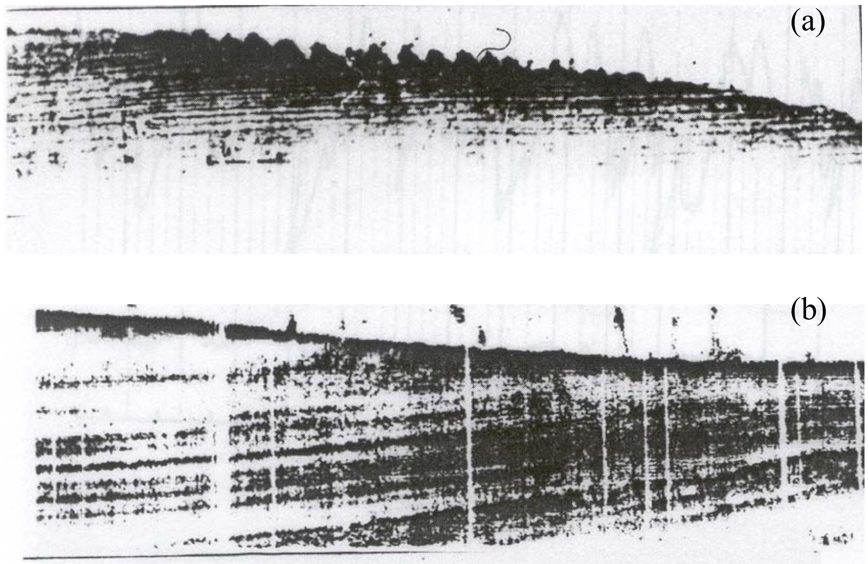

Figure 7.5: Examples of bottom relief in Kura River mouth area (Channel is 2 m by 200 m) a) 100 m from mouth b) 300 m from mouth

CHAPTER 8

TURBULENT FEATURES IN RIVER MOUTH JETFLOW

8.1 TURBULENT SCALE AND EDDIES STRUCTURE

Solving the problem of interaction of turbulent jet currents with the erodible bottom is possible on the basis of the theory of river turbulence (Ikeda, 1998; Ashworth et al., 1996, Mckernan and Gaskin, 2000; Bradbury, 1965), taking into account the specific conditions of the river mouths (Totok and Akira, 2001; Hitoshi and Hyun-Seok, 2001; Tanaka and Shuto, 1992; Dalrymple and Rhodes, 1995; Chu et al., 1997).

The main property of flow, important in terms of the interaction of the turbulent current with the erodible bottom, is the presence of coherent structures in it. The hydrodynamic field of such flows shows up as a cascade of eddies of different scales that move along the flow and interact with the bottom (Nikora et al., 1993; 2001; 2002; McLean et al., 1994; Ferreira et al., 2002). This cascade of eddies forms a corresponding spectrum of sand waves and ripples (Fedelle and Garcia, 2001; Reynolds, 1965; Masato, 2001; Xiaonan and Knight, 2001; Nikora et al., 1997), which in turn exerts an inverse influence on the structure of the flow and on the redistribution of mean velocities.

Multiple theoretical and experimental studies have established that sand ridges are formed because of quasi-periodic turbulent pulsations of flow velocity. Assuming that the large-scale elements of the internal structure of the turbulent channel flow look as large eddies with the axes normal to the plane of averaged motion, and the transverse dimensions of these eddies look as an eddy chain, Grishanin and Snishchenko (1970;

1971) concluded that the shape taken by the bottom as a result of the initial deformation is fully determined by the geometric parameter of the eddy path. The shape taken by the ridges in their further development also depends on the speed of motion of the eddies. Under the conditions of stabilized ridges, they exert adverse influence on the flow structure.

To study how these general laws take shape in the specific conditions of the river mouths, we have conducted a series of experimental measurements in the mouth of the Jordan River, at its inflow in the Lake Kinneret. As a result of the measurements of flow velocity fluctuations, the time auto-correlation functions have been calculated, an example of which is presented in Figure 8.1. The analytical approximation of these curves can be represented as:

$$R(\tau) = e^{-\alpha\tau} \cos \beta\tau \tag{8.1}$$

With the function set as above, the curve (Eq. 8.1) will satisfy all the requirements the correlation functions must satisfy. Indeed,

$$-1 \leq R(\tau) \leq 1 \tag{8.2}$$

$$\lim_{\tau \to 0} R(\tau) = 1 \tag{8.3}$$

$$\lim_{\tau \to 0} \frac{dR(\tau)}{dt} = 0 \tag{8.4}$$

The parameter β characterizes the transition of the correlation function through zero (the correlation radius), and has the dimension of frequency. The parameter α characterizes the maximum ordinate of the spectral density. The fluctuation period, T=1/ β, characterizes the time of passage of two successive eddies rotating in the opposite direction, or the "double eddy" period. If one assumes that the eddies are moving at a forward speed equal to the average flow velocity, *V*, then the linear longitudinal scale of these eddies may be expressed as:

$$\lambda = \frac{V}{2\beta} \tag{8.5}$$

As shown in Figure 8.1, all auto-correlation functions constitute attenuating curves passing through zero. Negative correlation is the result of the predominance of low-frequency fluctuations in the spectrum.

Results showing longitudinal dimensions of turbulent eddies, linear dimensions of bottom ridges, and hydro-morphological characteristics of the jet current at various distances from the river mouth are presented in Table 8.1 for one of the experiments. The measurements were performed when the mean water discharge in the river was 21.7 m^3/s, and the average flow velocity in the cross section in the river mouth was 1.28 m/s.

The main conclusion that can be made from these data is that maximum longitudinal dimensions of the turbulent eddies more or less correspond to the linear dimensions of bottom ridges.

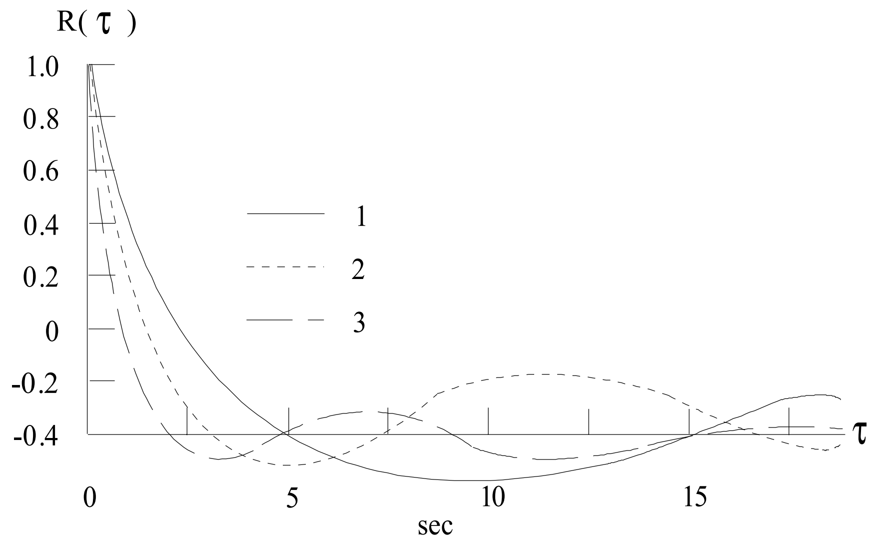

Figure 8.1: Examples of empirical longitudinal time-autocorrelation functions of flow velocity at the mouth gauge (1) and at distances of 100 m (2) and 300 m (3) from the Jordan River mouth

Table 8.1: Changes in the depth (h) and width (B) of the flow, mean current velocity (V), average diameter of the bottom sediments (D), longitudinal dimensions of turbulent eddies (λ) and of bottom ridges (L_r) along the axis of the jet flow at various distances (S) from the Jordan River mouth, Experiment #1.

S, m	h, m	B, m	V, m/s	D, mm	λ, m	L, r
0	3.4	55	1.74	0.28	2.6	2.8
50	2.8	85	1.58	0.22	1.5	1.6
100	1.2	120	1.45	0.19	0.8	0.5
150	4.1	190	1.36	0.08	0.5	0.3
200	6.6	290	1.10	0.05	0.2	0.2

The correspondence of the dimensions of bottom ridges to those of the eddies and to the scale of turbulence were studied in each experiment under conditions of steady regime, when the hydraulic characteristics of the flow did not change for a prolonged period of time. This allowed us to come to a conclusion about the correspondence of channel morphology to the hydraulic conditions observed, i.e. that these ridges are not relics from the previous regime. Besides, a proof of the end of formation of a ridge was the change of the grain size of sediments along the ridge (decreasing the >0.05 mm fraction content and increasing content of the finer fractions by 30-50% from the wave hollow to the crest of the ridge), which is also an indicator of the steady character of the ridge (Grishanin and Snishchenko, 1970, Grishanin, 1971; Dymshits et al., 1970; Debolsky, 1970).

The analysis of samples of suspended sediments has shown that with growing length (and hence height) of the bottom ridges, a transition of bottom sediments to the suspended state was even more pronounced; i.e. the eroding capacity of the flow was increasing. This was shown by fluorescent analysis of the samples. Tagged particles placed on the bottom were found in the water column, with a clear trend of growing percentage of these particles in the water samples.

The growing eroding capacity of the flow, given the presence of large ridges on its bottom, cannot be theoretically explained at the moment. One possible explanation for this phenomenon may be the periodic compression and expansion of the transit flow above the ridges, which is accompanied by significant distortions of the flow lines and by large angles of their convergence and divergence (Lyapin, 1959). The "expansion-compression" of the hydraulic cycles constitutes a rapidly changing motion in which the vertical distribution of pressure deviates from the hydrostatic law (Figure 8.2). The distortion of flow lines above the ridges and the deviation of pressure from the hydrostatic one cause the emerging tangential accelerations to exceed the acceleration of gravity by hundreds of times.

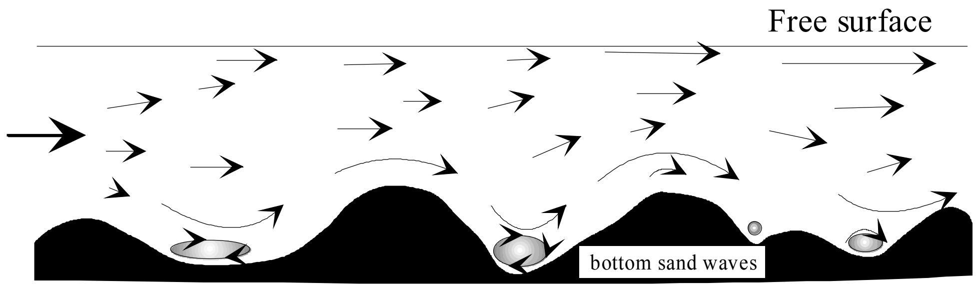

Figure 8.2: General scheme of the kinematic field of the flow above the bottom ridges

As mentioned above, the higher the bottom ridges, the smaller velocity is needed to cause suspension of the bottom sediments (Figure 8.3), and it does not matter in which stage of development – active or passive – are the channel forms when they are relics of the previous regime. What is important is just the fact of their belonging to the previous hydraulic regime. From Figure 8.3, it can be seen that with distance from the mouth along the jet flow, growth of the velocity V_{res} is observed. Also, transition of the bottom particles into the state of suspension begins, in accordance with the reduction of linear dimensions of the bottom ridges.

With the river jet flow moving away from the mouth into the receiving water body, rapid collapse of the river turbulence structure occurs, and linear dimensions of turbulent eddies decrease. Since there is a clear correlation between the scale of turbulence and the sizes of bottom ridges, gradual length and height reduction of these ridges is observed accordingly.

The collapse of the structure of channel turbulence takes place on the background of attenuation of the runoff current along the jet flow, which causes a decrease in the speed of motion of the bottom ridges. The above-mentioned reduction of the linear dimensions of the ridges leads to the slowing of the resuspension process of bottom particles.

As a result of these processes, along with the accumulation of suspended sediments, a large accumulative form is created in the mouth – a bar. The fact that the main contribution in the formation of the mouth bar is provided by the bed load has been previously shown (see, e.g., (Mikhailov, 1971; Mikhailova, 1971)). Our studies have established some features of the mechanism of this process.

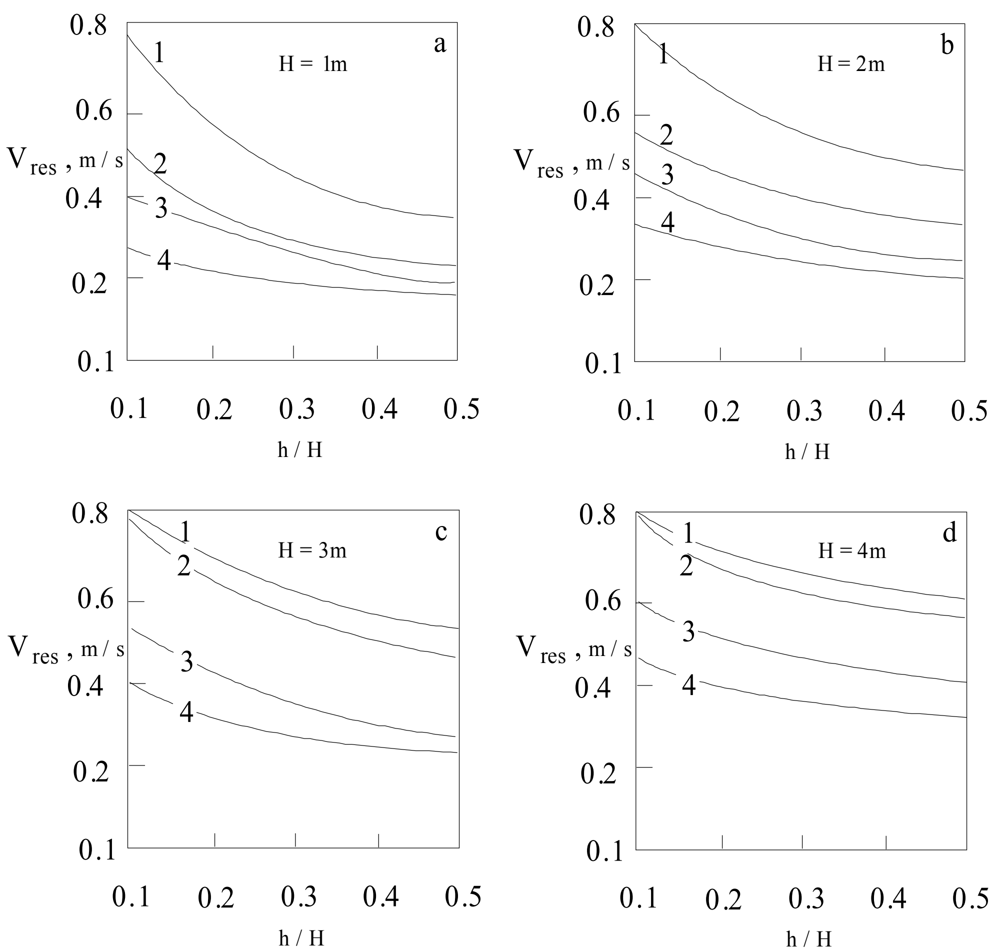

Figure 8.3: Changing rate of mass resuspension in Jordan River mouth (transfer of bottom sediments to the suspended state), V_{res}, with changing relative height of bottom ridges, h/H, (H- depth, 1- fraction 1.0-0.5 mm; 2- fraction 0.5-0.2 mm; 3- fraction 0.2-0.1 mm, 4- fraction 0.1-0.05 mm)

8.2 TURBULENT SPECTRA AND BALANCE OF ENERGY

In this section, the turbulence energy balance and turbulent energy characteristics based on the measurements made in the Jordan River mouth inflowing into Lake Kinneret (Israel) and in the Kura River mouth inflowing into the Caspian Sea is discussed by using the statistical tools described in Chapter 6.

Turbulence kinetic energy (TKE) is estimated using the following approximate relationship:

$$E = \frac{1}{2}(\sigma_u^2 + \sigma_v^2 + \sigma_w^2) \qquad (8.6)$$

Where σ_u, σ_v, σ_w are standard deviations of longitudinal, lateral and vertical components of the velocity. This parameter increases along the section from the mouth down to the bar crest (100 m at the Jordan River mouth, and 500 m at the Kura River mouth) and from the flow surface to the bottom (Table 8.2). Beyond the bar crest, σ_u or TKE decreases along the flow. The maximum value of TKE in this section occurred in the surface layer, unlike the section before the bar where the maximum energy was observed near the bottom.

It is known that cascade transfer of turbulent energy from large-scale eddies to small-scale eddies occurs in an inertial frequency subrange. In our work, we used a direct method to estimate the rate of TKE dissipation based on the analysis of energy spectra and relationship as postulated in the "-5/3" Kolmogorov's law:

$$S(\omega) = a\omega^{-5/3}, \quad a = cu^{-2/3}\varepsilon^{-2/3} \qquad (8.7)$$

Where ω is pulsation frequency, u is time-average velocity at a given point, $S(\omega)$ is spectral density of energy, ε is the mean rate of TKE dissipation due to viscosity at dissipative scales, c = 0.48 is Kolmogorov's constant. The inertial subranges, where the spectrum satisfies the Kolmogorov law "-5/3", demonstrate the existence of the local isotropy of turbulence within a wide spatial scale range. It is worth noting that the existence of the inertial subrange in the velocity spectra is usually expected if the flow is characterized by a sufficiently large Reynolds number. The existence of the inertial subrange in the spectra suggests that Eq. (8.7) should be used to estimate the mean rate of TKE dissipation and the balance of energy (Khanbilvardi et al., 2004b).

Table 8.2: Energy characteristics of the turbulent jet-flow in the Jordan River mouth

S (m)	H (m)	h (m)	U (m/s)	σ_u (m/s)	σ_w (m/s)	σ_v (m/s)	TKE (m^2/s^2)	ε_1 (cm^2/s^3)	ε_2 (cm^2/s^3)	ε_3 (cm^2/s^3)	Π (cm^2/s^3)
0	1.6	0.3	1.56	0.14	0.12	0.06	0.0188	0.39	12.2	12.6	13.7
		1.0	1.35	0.15	0.12	0.08	0.0216	0.62	22.3	22.9	26.1
25	1.8	0.3	1.51	0.14	0.14	0.07	0.0220	0.31	7.32	7.63	9.08
		1.0	1.30	0.16	0.15	0.08	0.0272	0.30	11.0	11.5	13.8
50	1.6	0.3	1.46	0.16	0.15	0.11	0.0301	0.23	1.95	2.18	2.64
		1.0	1.26	0.18	0.15	0.13	0.0408	0.38	4.22	4.60	5.75
		1.5	0.93	0.18	0.18	0.15	0.0436	1.03	12.6	13.6	NA*
75	1.6	0.3	1.39	0.23	0.31	0.17	0.0890	0.12	1.03	1.15	1.50
		1.0	1.19	0.26	0.38	0.22	0.1302	0.29	3.07	3.36	4.60
		1.5	0.80	0.27	0.40	0.25	0.1477	0.49	5.52	6.01	9.98
100	1.9	0.3	1.25	0.24	0.43	0.21	0.1433	1.11	1.15	1.26	1.85
		1.0	1.02	0.26	0.51	0.25	0.1951	0.28	2.77	3.05	4.97
		1.5	0.72	0.28	0.55	0.32	0.2416	0.45	4.80	5.25	7.93
125	1.9	0.3	1.10	0.12	0.34	0.11	0.0710	0.11	2.40	2.51	4.04
		1.0	0.91	0.13	0.36	0.14	0.0830	0.27	4.02	4.29	6.56
		1.5	0.66	0.15	0.45	0.18	0.1287	0.44	7.66	8.10	11.3
150	2.6	0.3	0.95	0.10	0.33	0.04	0.0602	NA*	NA*	6.32	10.5
		1.0	0.79	0.10	0.32	0.08	0.0594	NA*	NA*	7.22	11.7
		1.5	0.51	0.11	0.17	0.14	0.0303	NA*	NA*	7.23	14.6
200	2.8	0.3	0.70	0.05	0.20	0.05	0.0225	NA*	NA*	8.55	18.3
		1.0	0.61	0.05	0.18	0.06	0.0192	NA*	NA*	9.36	18.9

*unavailable; the coherent turbulent structure did not appear.

In our experiments the main source of energy is flow of the river currents. As applied to jet flows in river mouths, sources of turbulence energy in zones of energy supply can be divided into two basic groups. The first group includes sources stimulated, as mentioned, by hydrodynamic instability of averaged flow at scales of the flow width. The second group of turbulent energy sources relates to the generation mechanisms of the jet's mixing with water masses from the receiving reservoir. Two maximums of spectral density, corresponding to the above-mentioned groups of factors is found.

Turbulent energy is related to other sources. The density stratification, which produce a weak wavy form of the spectra is one of them. However, the influence of these secondary factors on the energy balance of the flow is minimal, compared to the influence of the above-mentioned two groups of basic factors. Hence spectra obtained in the experiments may be schematized into two basic discrete energy supply zones with frequencies ω_{max1} and ω_{max2} and their respective spectral densities $S(\omega_{max1})$ and $S(\omega_{max2})$. The first inertial subrange at intermediate frequencies separates these energy supply zones. The second inertial subrange takes place at high frequencies. Taking into account the relationship Eq. (8.7), the values of energy dissipation for both discrete zones of the energy supply (ε_1 and ε_2) and total dissipation (ε_3) are calculated. For that purpose a physical pattern is accepted, according to which the rate of energy transfer through the frequency cascade (ε_1) in the first (left) inertial interval represents generation of the turbulent energy at scales of the flow width. For the second inertial interval, the rate of energy transfer ε_2 is a sum of ε_1, and the rate of energy generation at the second discrete energy supply zone, which corresponds to the flow depth. The rate of energy transfer through the frequency cascade in the right inertial interval is equal to the rate of dissipation of energy into heat within the viscous interval.

Inertial intervals in the turbulence energy spectra satisfying the Kolmogorov's "-5/3" law are observed only in those spectra which were measured in the flow region from the initial mouth cross section to the cross section near the crest of the bar, where flow begins to break away from the bottom. The results of the experiment given in Table 8.1 do not confirm the model of local-isotropic turbulence and, accordingly, the relationship Eq. (8.2) for the cross-sections at 150 m and 200 m.

Therefore, an indirect procedure is used to calculate the energy dissipation rate. For the cross-sections that are closer than 125 m from the mouth cross-section, the generation of turbulent energy is calculated by using the formula:

$$\prod = -\overline{u'v'}(\Delta u / \Delta z) \qquad (8.8)$$

Where u and v are longitudinal and vertical components of the flow velocity. The ratio of turbulent energy generation to its dissipation, $\prod/\varepsilon$, is calculated. Subsequently, this ratio is related to the intensity of the averaged longitudinal flow velocity attenuation (Δu) between two consecutive cross-sections. The relationship $\prod/\varepsilon = f(\Delta u/u)$ is linear, and can be approximated by the equation:

$$\prod / \varepsilon = 4.0(\Delta u) / u + 1.1 \qquad (8.9)$$

Here Δu is the velocity attenuation between two consecutive cross-sections S_1 and S_2, and u is velocity in the previously located cross-section S_1. After the energy generation was calculated, using Eq. (8.8) and extrapolation of Eq. (8.9), the value of $\prod/\varepsilon$ is determined for the cross-sections beyond the bar, 150-200 m from the mouth (Table 8.2).

In Figure 8.4, an example from Kura River mouth is presented of the pulsation spectra of the vertical component of velocity for different areas of the flow: channel (gauges 1-4) and jet (gauges 5-8). On these spectra, as well as on those of the horizontal component of velocity, an inertial interval can be visualized, within which the spectrum is quite reliably approximated by the power function -5/3. Besides, two main zones of energy supply characterize all three-velocity components. The scales of additional zones of energy supply correspond to the scales of turbulent eddies that are commensurate to the flow depth.

In the jet area of the river current the inertial interval for the entire range of the frequencies studied is observed before the bar (gauges 5 and 6), while on the bar (gauge 7) and beyond it (gauge 8) the ordinates of the spectrum are decreasing faster by the "-7/3" law in the range of frequencies 0.2-0.6 rad/sec, and "-9/3" in the range of frequencies higher than 0.6 rad/sec. The inertial interval of frequencies is followed by the intervals in which the flow can no longer be considered isotropic and the ordinates of the spectra decreases by the "-7/3" law because of high-energy consumption on the bar. This consumption is related to the increasing friction on the lateral boundaries of the jet as well as at the bottom. Still farther another interval of frequencies is observed where the spectra drops by the "-9/3" law, which is related to the additional energy consumption on overcoming the Archimedean forces when vertical mixing of river and seawater masses occurs.

With the distance away from the mouth and closer to the bar the ordinates of the frequency spectra decreases, while the frequencies corresponding to the maximum ordinates increases. This is related to the destruction of the structure of channel turbulence as the river jet is progressing into the sea.

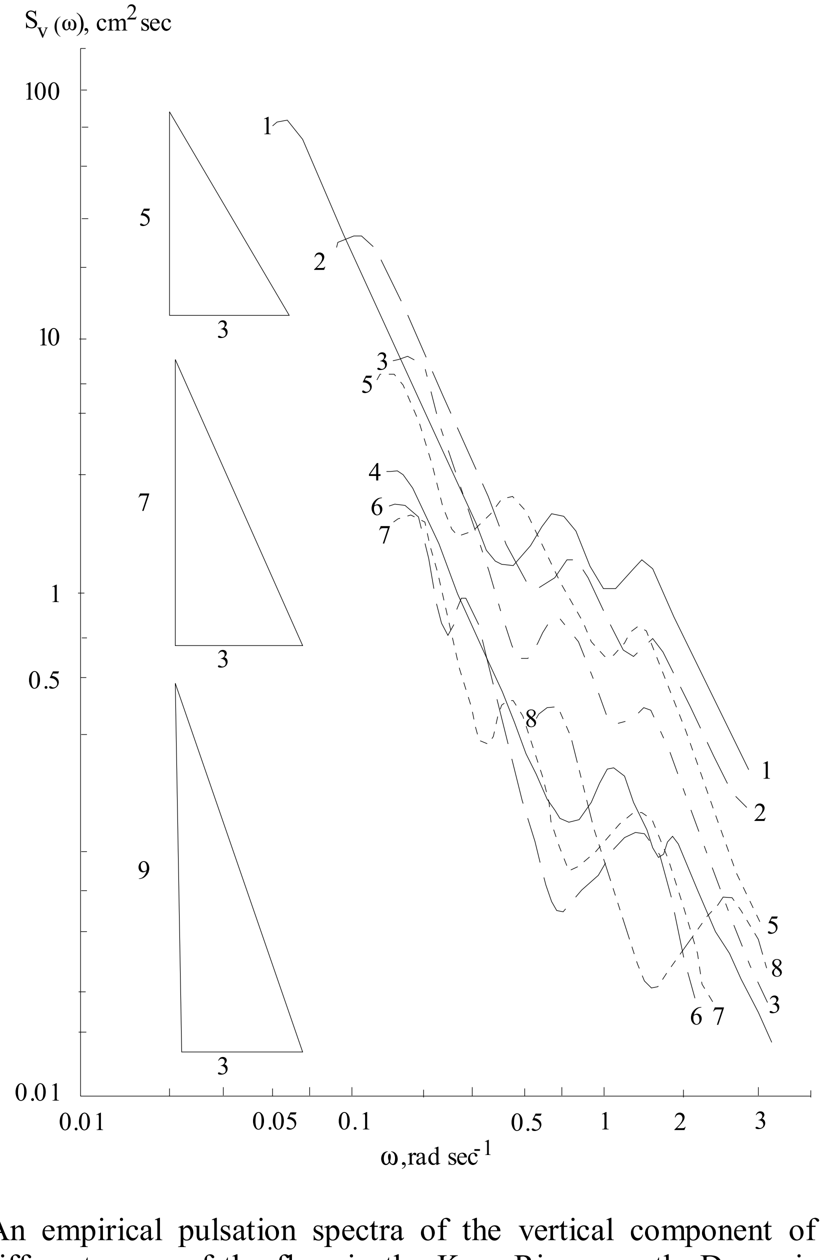

Figure 8.4: An empirical pulsation spectra of the vertical component of velocity at different areas of the flow in the Kura River mouth. Dynamic axis of the flow, relative depth 0.6. Numbered are the hydrometric gauges.

The obtained results lead to following conclusions:

Spatial distribution of the turbulent energy generation has two maxima: the first one is in the initial section of the river jet at its discharge into the reservoir, and the second one is in the last section, within the zone of full attenuation of the runoff flow. In the cross-section at about five flow widths from the outlet, where the river jet spreads only within the surface layer, velocity measurements did not confirm the existence of a turbulence-ordered structure of the Kolmogorov's model. In particular, temporal auto-correlation functions and spectra of the velocity pulsation appeared to be similar to those of "white noise".

The Kolmogorov-Obukhov model of local-isotropic turbulence could approximately describe jet flows in the river mouth, within 2-3 flow widths away from the mouth. The presence of inertial intervals is detected in the energy spectra of such flows; in these intervals, turbulent energy was transferred through a frequency cascade without dissipation and additional generation. Energy spectra is characterized by the presence of two basic discrete zones of energy supply, which related to the hydrodynamic instability of the averaged flow and to the increased friction on the river jet boundaries, respectively. These discrete zones are separated by the inertial interval. Beyond the mouth bar, the energy spectrum drops more steeply than postulated by the "-5/3" law, and turbulence energy of the jet flow cannot be described by using the local-isotropic turbulence model.

Analysis of distribution of the components of the river jet velocity vector at its inflow into the sea show that the structure of channel turbulence rapidly degenerates. Turbulent eddies change their orientation from the predominantly vertical-longitudinal spinning with a horizontal axis to the predominantly horizontal-transversal spinning with a vertical axis. At the same time, substantial additional turbulent energy is being generated in the zones of contact between the jet flow and the adjacent mass of seawater.

CHAPTER 9

SUMMARY, CONCLUSIONS AND FUTURE RECOMMENDATIONS

9.1 PHYSICAL CONCEPTUAL MODEL SUMMARY

The results of measurements performed in multiple river mouths, as well as theoretical analysis, led to a number of special features of mouth currents. This exposure made it possible to formulate a conceptual physical model of free jet current turbulence in a river mouth. The model describes averaged hydrodynamic characteristic of flow, sediment transport and distribution of turbulence characteristics.

The most characteristic feature of such flows is gradual attenuation of the runoff current, accompanied by the corresponding decrease in its kinetic energy. These laws stems, first of all, from attenuation of the river current velocity at the inflow to a sea or lake. The attenuation of the averaged flow velocities follow the exponential law which can be expressed by:

$$\frac{V_x}{V_0} = e^{-cx} \tag{9.1}$$

where V_0 and V_x are the average flow velocities over the cross section at an initial section (shown in Figure 4.8) and at a distance x away from exit cross section of initial section, respectively; and c is the empirical coefficient.

Accordingly, the concentration of suspended particulate material carried by the river jet is changing due to the attenuation of the averaged velocities. This change also follows exponential law. Before the bar, the SPMC (Suspended Particulate Matter Concentration) decrease can be described by the approximated equation:

$$SPMC_x = SPMC_0 e^{-3cx} \tag{9.2}$$

and after the bar, by the following equation:

$$SPMC_x = SPMC_0 e^{-cx} \tag{9.3}$$

where $SPMC_x$ and $SPMC_0$ are suspended particulate matter concentration over the cross section at an initial section and at a distance x away from exit cross section of initial section and c is the empirical coefficient.

Three-dimensional turbulence structure of the obtained data is described by using a statistical vector analysis. Linear invariant I and rotation invariant D equations are used for describing the overturning intensity of the eddies. The equations are:

$$K_{\vec{v}}(t,\tau) = \begin{bmatrix} K_{uu} & K_{uv} & K_{uw} \\ K_{vu} & K_{vv} & K_{vw} \\ K_{wu} & K_{wv} & K_{ww} \end{bmatrix} \tag{9.4}$$

$$D_{uv} = K_{uv} - K_{vu} \qquad D_{uw} = K_{uw} - K_{wu} \qquad D_{vw} = K_{vw} - K_{wv} \tag{9.5}$$

$$I = K_{uu} + K_{vv} + K_{ww} \tag{9.6}$$

where K is a dyadic tensor function of the arguments (t, τ), where τ is temporal lag. This function characterizes the interrelation of the directional changes of the flow velocity vectors at the moments of time t, $t+\tau$, and provides numerical assessment of the intensity of these changes and of their orientation in the given system of coordinates. The antisymmetrical part of the tensor $D_{ij}(\tau)$ components describes the spinning of the turbulent eddies in the 3 orthogonal planes, the indices *i,j* relate to the components *u*, *v* and *w* of the velocity vector (Figure 9.1). These components of the invariant D_{ij} characterize the intensity of rotation in 3 orthogonal planes. The linear invariant $I(\tau)$ composed of the collinear vector components $\vec{v}(t)$ and $\vec{v}(t+\tau)$. The invariant $I(\tau)$ may be interpreted as auto-correlation functions of the fluctuations of the vector instantaneous velocity. Taken together, they completely describe the intensity of spinning of the turbulent eddies in various planes, as well as the direction of the eddy rotation.

The model describes, for any moment in time, the position of rotation axes of the turbulent eddies. The position of rotation axes also changes in any moment. This rotation is found by:

$$\alpha^{(B)} = 0.5arctg\left[\frac{K_{uv} + K_{vu}}{K_{uu} - K_{vv}}\right] \tag{9.7}$$

where α is the angle between turbulent eddy rotation axis and each orthogonal plane (shown in Figure 6.8).

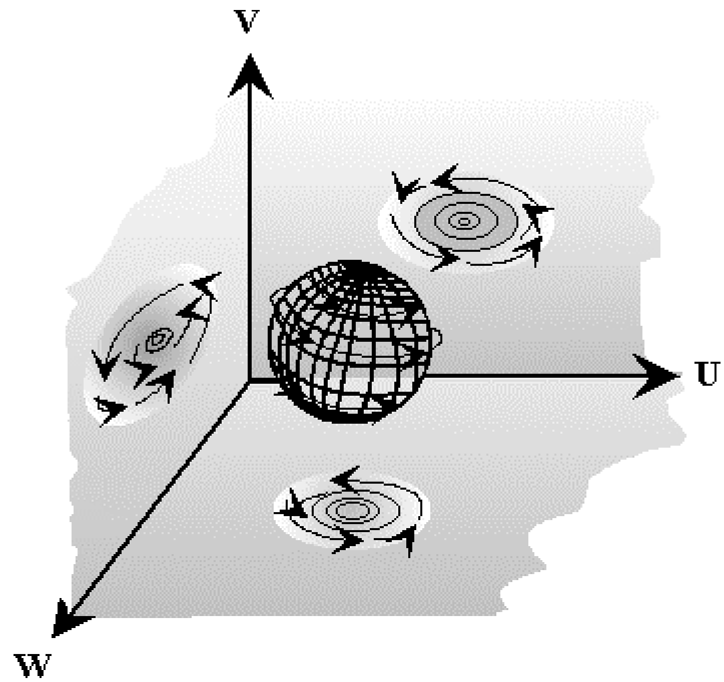

Figure 9.1: Turbulent eddies spinning as described by rotational velocity vectors in two vertical (*uv*, *wv*) and one horizontal (*uw*) planes. Indexes: 1=*u*, 2=*w*, 3=*v*.

In addition, as a result of the measurements of flow velocity fluctuations, the time auto-correlation functions have been calculated. The model describes changes in linear dimensions of the eddies and the analytical approximation of these curves can be represented as:

$$R(\tau) = e^{-\alpha\tau} \cos \beta\tau \tag{9.8}$$

where the parameter α characterizes the maximum ordinate of the spectral density and the parameter β characterizes the transition of the correlation function through zero (the correlation radius), and has the dimension of frequency.

In order to estimate the rate of TKE (Turbulent Kinetic Energy) dissipation in the model, a direct method is used based on the analysis of energy spectra and relationship as postulated in the “-5/3” Kolmogorov’s law where the equation is as following:

$$S(\omega) = cu^{-2/3}\varepsilon^{-2/3}\omega^{-5/3} \tag{9.9}$$

where ω is velocity pulsation frequency, u is time-average velocity at a given point, $S(\omega)$ is spectral density of energy, ε is the mean rate of TKE dissipation due to viscosity at dissipative scales, c = 0.48 is Kolmogorov’s constant. Apart from Kolmogorov’s local isotropic turbulence model, this model takes into account the fact that in river mouths the jet flow turbulence is not local isotropic. On these spectra, as well as on those of the horizontal component of velocity, an inertial interval can be visualized, within which the spectrum is quite reliably approximated by the power function -5/3. Besides, this model describes the energy spectra of turbulence by using two additional main zones of energy supply that characterize all three-velocity components. The scales of additional zones of energy supply correspond to the scales of turbulent eddies that are commensurate to the flow depth. The inertial interval of frequencies is followed by the intervals in which the flow can no longer be considered isotropic and the ordinates of the spectra decreases by the "-7/3" law because of high-energy consumption on the bar. This consumption is related to the increasing friction on the lateral boundaries of the jet. Still farther, another interval of frequencies is observed where the spectra drops by the "-9/3" law, which is related to the additional energy consumption on overcoming the Archimedean forces when vertical mixing of river and seawater masses occurs.

Therefore, an indirect procedure is used to calculate the energy dissipation rate. For the cross-sections that are closer than 125m from the mouth cross-section, the generation of turbulent energy is calculated by using the formula:

$$\prod = -\overline{u'v'}(\Delta u / \Delta z) \tag{9.10}$$

where u and v are longitudinal and vertical components of the flow velocity, respectively. The ratio of turbulent energy generation to its dissipation, $\prod/\varepsilon$, is calculated. The relationship $\prod/\varepsilon = f(\Delta u/u)$ is linear, and can be approximated by the equation:

$$\prod / \varepsilon = 4.0(\Delta u) / u + 1.1 \tag{9.11}$$

Here Δu is the velocity attenuation between two consecutive cross-sections S_1 and S_2, and u is velocity in the previously located cross-section S_1.

9.2 CONCLUSIONS

As a result of theoretical analysis conducted and measured data processed, the following laws, governing of flow and sediment dynamics in river mouth jet flow have been established:

- Based on the solution of equations of the motion of a free turbulent jet with a variable mass (described by Eq. 6.7 and Eq. 6.8) and the results of measurements (Tables 6.1-6.4, Figures 6.1-6.4), the exponential law of attenuation of velocities is verified. The very retardation of the river jet on its boundaries, along with the diminishing flow gradient, are the main causes of its attenuation.

- Consequently, the volume of suspended material carried by the river jet decreases since the velocity decreases. The concentration of suspended particulate matter carried by the river to the mouth rapidly diminishes along the river jet. It also follows the exponential law which is described by Eq. 7.5 and Eq. 7.6 and confirmed by experiments (Tables 7.1-7.4, Figures 7.1-7.4). Before the bar, the SPMC decline is produced by the particles sedimentation, whereas after the bar the SPMC decline is provided only by the river water dilution.
- Simultaneously with the attenuation of averaged velocities, the pulsation of the velocity module gets higher as well as the intensity of turbulence which can be seen in Figure 6.6. The turbulence intensity grows the fastest at the river mouth section, where the flow abruptly gets wider. Away from the mouth, relative dissipation of velocity remains the same and the turbulence intensity grows slower. If the attenuation of averaged velocities curves faster, the intensity of turbulence curves faster as well due to the fact that the energy of averaged flow is transformed to the energy of turbulence.
- Because of the higher velocity gradient, thus, higher generation of turbulence, levels of turbulence in the diffusion current are significantly higher than that of the steady current. In the river mouth, within a length of the river equal to two to three times the width, rapid flow deceleration occurs. This results in considerable growth of the level of pulsations. As the river water discharge becomes greater, thus, the flow velocities, the zone of highest turbulent pulsations occurs farther from the river mouth gauge.

- In the conditions of free spreading of the jet flow, starting from the bar crest where the jet detaches itself from the bottom (so-called detached flow), the highest intensity of turbulence is observed within the contact zone between the upper layer of fresh river water and the underlying layer of denser sea water mass (Figure 6.7). As the velocity of the river jet increases, the layer of maximum turbulence shifts deeper.

- The influence of the bottom topography on the velocity pulsations and on the distribution of turbulence intensity is shown in the jet flow in the same manner as in the river channel. The hydrodynamic field of such flows shows up as a cascade of eddies of different scales that move along the flow. In the area between the river mouth gauge and the bar crest, the linear dimensions of the bottom ridges diminish rapidly along the flow (Figure 9.2 - 9.4). This leads, first, to the faster decrease in the standard deviation of the longitudinal pulsations of velocity, and second, to a more uniform distribution of turbulence intensity over the depth of the flow.

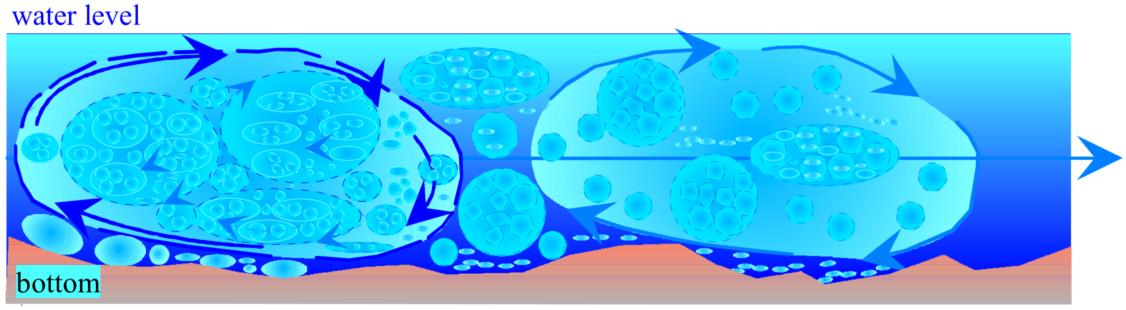

Figure 9.2: The hydrodynamic field of eddies of different scales in initial section

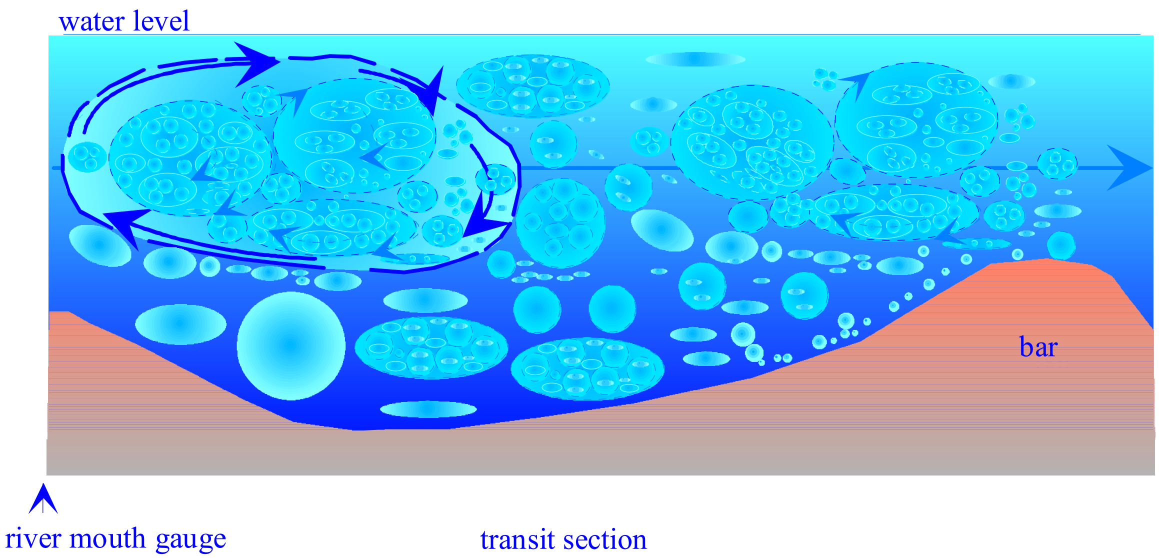

Figure 9.3: The hydrodynamic field of eddies of different scales in transit section

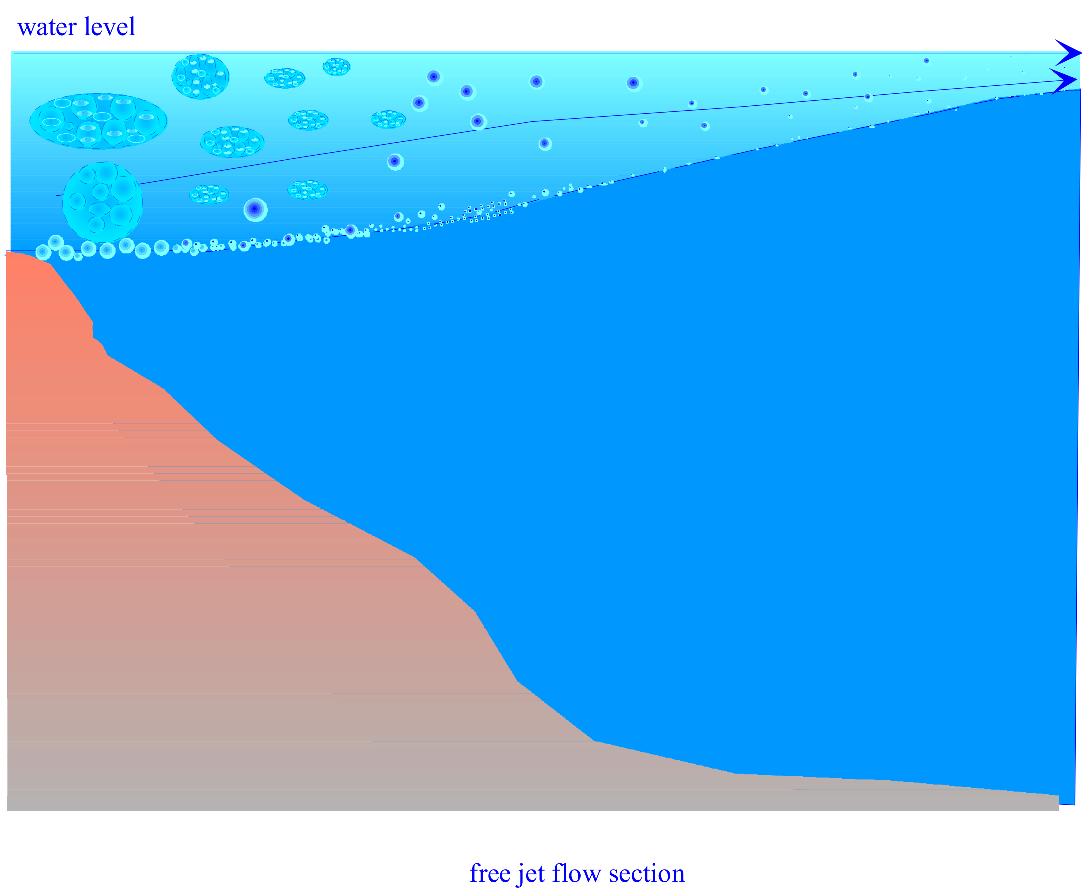

Figure 9.4: The hydrodynamic field of eddies of different scales in free jet flow section

- The functions $D_{uv}(\tau)$, $D_{uw}(\tau)$ and $D_{vw}(\tau)$, which correspond to the river flow exhibit both positive and negative values, and lower amplitudes of oscillation compared to $I(\tau)$ (Tables 6.5-6.7, Figure 6.9). Comparison of the values of the correlation function $I(\tau)$ of the collinear components of the pulsation velocity vector with the function $D(\tau)$ of the orthogonal components shows that $I(\tau) > D(\tau)$ before the bar, and $I(\tau) < D(\tau)$ on the bar. This indicates that while at the beginning of the jet, the interrelation of the collinear components is predominant; the interrelation of the orthogonal components is stronger around the bar. Thus, the influence of the changing flow direction is greater than the influence of the changing velocity module. Similar conclusions can be made when analyzing the changes in invariants $D(\tau)$ along the river, transitional and jet areas of the flow. In the initial river area of the flow, the highest positive values belong to $D_{uv}(\tau)$, while $D_{uw}(\tau)$ exhibits the lowest negative values. Before the bar, the invariant $D_{uw}(\tau)$ has the highest positive values, which testifies to the restructuring of the flow structure from the predominant rotation in the vertical-longitudinal plane (u,v) to the predominant rotation in the horizontal-transversal plane. At the mouth bar, the predominance of the component $D_{uw}(\tau)$ over other components is higher than in areas located upstream, while the component $D_{uv}(\tau)$ has the smallest value and amplitude. Beyond the bar, the value of the component $D_{uv}(\tau)$ characterizing rotation of turbulent eddies in the longitudinal vertical plane (u,v) is close to zero, the most intense spinning of eddies is observed in the horizontal plane (u,w).

- In its turn, the bar influences upon the restructing of velocity field. The direction of the longer axis of the tensor curve (the direction of the predominant variability of the velocity vector) changes cyclically: mostly in the *(u,v)* plane within the channel area, mainly in the *(u,w)* plane within the jet area between the mouth gauge and the bar, and again in the *(u,v)* plane beyond the bar. Furthermore, while within the channel area (mouth gauge) the entire flow is involved in vertical circulation, beyond the bar, it is localized (concentrated) in the surface layer where intense mixing of fresh river water masses and saline seawater masses occurs.
- As a result of above processes, intense sedimentation takes place as well as gradual decrease in the bed-load transport, resulting deformation of large accumulative form the bar. Bed load decreases because of two main processes: (a) Attenuation of velocities and (b) Decreasing of linear dimensions of ripples and the rate of the motion. The linear longitudinal scale of these eddies is found by using Eq. 8.5. The main conclusion that can be made from these data (shown in Table 8.1, Figure 8.1) is that maximum longitudinal dimensions of the turbulent eddies more or less correspond to the linear dimensions of bottom ridges.
- Along the jet flow, the energy spectrum of turbulence changes. Spatial distribution of the turbulent energy generation has two maxima: the first one is in the initial section of the river jet at its discharge into the reservoir, and the second one is in the last section, within the zone of full attenuation of the runoff flow. In the cross-section at about five flow widths from the outlet, where the river jet

spreads only within the surface layer, velocity measurements did not confirm the existence of a turbulence-ordered structure of the Kolmogorov's model. In particular, temporal auto-correlation functions and spectra of the velocity pulsation appeared to be similar to those of "white noise".

- Analysis of distribution of the components of the river jet velocity vector at its inflow into the sea show that the structure of channel turbulence rapidly degenerates. Turbulent eddies change their orientation from the predominantly vertical-longitudinal spinning with a horizontal axis to the predominantly horizontal-transversal spinning with a vertical axis. At the same time, substantial additional turbulent energy is being generated in the zones of contact between the jet flow and the adjacent mass of seawater.

9.3 RECOMMENDATIONS FOR FUTURE RESEARCH

In this study, the physically based conceptual model consists of many equations. Consideration of the possibility of a universal equation for the whole processes should be addressed. The model also doesn't consider the bottom profile of the river channel because the bottom relief immediately affects the surface profile which this process is non-linear. The growing eroding capacity of the flow, given the presence of large ridges on its bottom, cannot be theoretically explained at the moment. An extension of the study considering the bottom profile is recommended. Meanwhile, waves play an important role in the formation of the turbulence structure. Additional research to measure turbulence in the conditions of waves superimposed on the contradirectional and parallel jet flows are required. The parameters and structure of turbulence also depend on wind stress. Thus, wind stresses must be investigated in future studies.

APPENDIX A: AVERAGE VELOCITY ATTENUATIONS

Ten sets of measurements were used to study the velocity structure of the flow in the Jordan River – Lake Kinneret contact zone. The experimental streamwise mean velocity values and corresponding velocity attenuation graphs for Q = 46.8 m^3/s, Q = 12.5 m^3/s, Q = 10.3 m^3/s and Q = 6.9 m^3/s can be found in Chapter 6. Their full non-linear regression analyses are at the end of Appendix A.

The tabulated streamwise mean velocities, full non-linear regression analyses, and velocity attenuation graphs for all other six cases can be found in Appendix A.

Table A.1: Experiment #2 – Streamwise mean velocities at Q = 39.1 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	1.53	1.53	1.53
2	25	1.40	1.40	1.40
3	50	1.33	1.35	1.33
4	100	1.10	1.18	1.12
5	150	0.93	1.03	1.05
6	175	0.90	1.00	0.93
7	200	0.80	0.94	0.91
8	250	0.75	0.83	0.73
9	300	0.62	0.77	0.65
10	350	0.55	0.7	0.53
11	425	0.36	0.57	0.44
12	475	0.30	0.53	0.42
13	525	0.24	0.45	0.30
14	575	0.23	0.41	0.26
15	625	0.19	0.35	0.22
16	1000	0.10	0.14	0.12

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 39.1 m^3/s - Transect 1

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.53615}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00319325}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99756550
Rsqr = 0.99513693
Adj Rsqr = 0.99478957

Standard Error of Estimate = 0.0333

	Coefficient	**Std. Error**	**t**	**P**
a	1.5361	0.0203	75.5117	<0.0001
b	0.0032	0.0001	39.3098	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	3.1817	3.1817	2864.8387	<0.0001
Residual	14	0.0155	0.0011		
Total	15	3.1972	0.2131		

PRESS = 0.0193

Durbin-Watson Statistic = 1.4819

Normality Test:
K-S Statistic = 0.2007
Significance Level = 0.4922

Constant Variance Test: P = 0.0843

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	1.5361	-0.0061	-0.1845	-0.2329	-0.2249
2	1.4183	-0.0183	-0.5486	-0.6381	-0.6240
3	1.3095	0.0205	0.6163	0.6834	0.6698
4	1.1162	-0.0162	-0.4869	-0.5165	-0.5026
5	0.9515	-0.0215	-0.6453	-0.6767	-0.6630
6	0.8785	0.0215	0.6452	0.6763	0.6626
7	0.8111	-0.0111	-0.3329	-0.3493	-0.3381
8	0.6914	0.0586	1.7584	1.8538	2.0566
9	0.5894	0.0306	0.9191	0.9728	0.9708
10	0.5024	0.0476	1.4284	1.5147	1.5962
11	0.3954	-0.0354	-1.0623	-1.1245	-1.1361
12	0.3371	-0.0371	-1.1118	-1.1728	-1.1901
13	0.2873	-0.0473	-1.4197	-1.4906	-1.5660
14	0.2449	-0.0149	-0.4476	-0.4674	-0.4540
15	0.2088	-0.0188	-0.5633	-0.5852	-0.5709
16	0.0630	0.0370	1.1090	1.1198	1.1309

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0161	0.3726	-0.1733
2	0.0719	0.2609	-0.3707
3	0.0536	0.1867	0.3209
4	0.0168	0.1116	-0.1781
5	0.0228	0.0905	-0.2092
6	0.0226	0.0898	0.2081
7	0.0062	0.0922	-0.1077
8	0.1916	0.1003	0.6868
9	0.0570	0.1075	0.3369
10	0.1428	0.1107	0.5632
11	0.0762	0.1076	-0.3944
12	0.0775	0.1013	-0.3995
13	0.1137	0.0928	-0.5009
14	0.0099	0.0832	-0.1368
15	0.0135	0.0732	-0.1605
16	0.0122	0.0191	0.1580

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	1.5361	1.4925	1.5798	1.4524	1.6199
2	1.4183	1.3818	1.4548	1.3380	1.4985
3	1.3095	1.2786	1.3403	1.2316	1.3873
4	1.1162	1.0923	1.1401	1.0409	1.1916
5	0.9515	0.9300	0.9730	0.8769	1.0261
6	0.8785	0.8571	0.8999	0.8039	0.9531
7	0.8111	0.7894	0.8328	0.7364	0.8858
8	0.6914	0.6688	0.7140	0.6164	0.7664
9	0.5894	0.5659	0.6128	0.5142	0.6646
10	0.5024	0.4786	0.5262	0.4271	0.5777
11	0.3954	0.3720	0.4188	0.3202	0.4706
12	0.3371	0.3143	0.3598	0.2620	0.4121
13	0.2873	0.2655	0.3091	0.2126	0.3620
14	0.2449	0.2243	0.2655	0.1705	0.3193
15	0.2088	0.1894	0.2281	0.1347	0.2828
16	0.0630	0.0531	0.0729	-0.0091	0.1352

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 39.1 m³/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.49906}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00228468}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99902612
Rsqr = 0.99805318
Adj Rsqr = 0.99791412

Standard Error of Estimate = 0.0186

	Coefficient	**Std. Error**	**t**	**P**
a	1.4991	0.0105	142.7986	<0.0001
b	0.0023	0.0000	67.0724	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2.4887	2.4887	7177.2180	<0.0001
Residual	14	0.0049	0.0003		
Total	15	2.4936	0.1662		

PRESS = 0.0070

Durbin-Watson Statistic = 1.6847

Normality Test:
K-S Statistic = 0.1337
Significance Level = 0.9184

Constant Variance Test: P = 0.0821

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.4991	0.0309	1.6615	2.0117	2.2990
2	1.4158	-0.0158	-0.8505	-0.9759	-0.9741
3	1.3372	0.0128	0.6855	0.7586	0.7465
4	1.1929	-0.0129	-0.6916	-0.7351	-0.7224
5	1.0641	-0.0341	-1.8316	-1.9150	-2.1479
6	1.0050	-0.0050	-0.2702	-0.2816	-0.2722
7	0.9492	-0.0092	-0.4960	-0.5165	-0.5025
8	0.8468	-0.0168	-0.9003	-0.9398	-0.9356
9	0.7554	0.0146	0.7864	0.8249	0.8149
10	0.6738	0.0262	1.4062	1.4826	1.5561
11	0.5677	0.0023	0.1232	0.1307	0.1260
12	0.5064	0.0236	1.2662	1.3460	1.3901
13	0.4518	-0.0018	-0.0941	-0.1001	-0.0965
14	0.4030	0.0070	0.3767	0.4003	0.3880
15	0.3595	-0.0095	-0.5092	-0.5401	-0.5260
16	0.1526	-0.0126	-0.6774	-0.6984	-0.6850

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.9426	0.3178	1.5692
2	0.1507	0.2404	-0.5480
3	0.0647	0.1835	0.3539
4	0.0350	0.1146	-0.2599
5	0.1707	0.0852	-0.6553
6	0.0034	0.0796	-0.0800
7	0.0113	0.0780	-0.1462
8	0.0396	0.0822	-0.2801
9	0.0341	0.0910	0.2579
10	0.1227	0.1004	0.5199
11	0.0011	0.1112	0.0446
12	0.1177	0.1150	0.5011
13	0.0007	0.1160	-0.0350
14	0.0104	0.1146	0.1396
15	0.0182	0.1110	-0.1859
16	0.0154	0.0593	-0.1720

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	1.4991	1.4765	1.5216	1.4532	1.5449
2	1.4158	1.3963	1.4354	1.3714	1.4603
3	1.3372	1.3201	1.3543	1.2938	1.3807
4	1.1929	1.1794	1.2064	1.1507	1.2350
5	1.0641	1.0525	1.0758	1.0225	1.1057
6	1.0050	0.9938	1.0163	0.9635	1.0465
7	0.9492	0.9381	0.9604	0.9078	0.9907
8	0.8468	0.8353	0.8582	0.8052	0.8883
9	0.7554	0.7433	0.7674	0.7136	0.7971
10	0.6738	0.6612	0.6865	0.6319	0.7157
11	0.5677	0.5544	0.5810	0.5256	0.6098
12	0.5064	0.4929	0.5200	0.4642	0.5486
13	0.4518	0.4381	0.4654	0.4096	0.4939
14	0.4030	0.3895	0.4165	0.3608	0.4452
15	0.3595	0.3462	0.3728	0.3174	0.4016
16	0.1526	0.1429	0.1623	0.1115	0.1937

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 39.1 m³/s - Transect 3

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.53372}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00289849}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99773541
Rsqr = 0.99547594
Adj Rsqr = 0.99515279

Standard Error of Estimate = 0.0313

	Coefficient	**Std. Error**	**t**	**P**
a	1.5337	0.0187	82.1436	<0.0001
b	0.0029	0.0001	41.7274	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	3.0224	3.0224	3080.5645	<0.0001
Residual	14	0.0137	0.0010		
Total	15	3.0362	0.2024		

PRESS = 0.0170

Durbin-Watson Statistic = 2.2352

Normality Test:
K-S Statistic = 0.1810
Significance Level = 0.6260

Constant Variance Test: P = 0.0735

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.5337	-0.0037	-0.1189	-0.1480	-0.1428
2	1.4265	-0.0265	-0.8466	-0.9809	-0.9795
3	1.3268	0.0032	0.1020	0.1131	0.1090
4	1.1478	-0.0278	-0.8876	-0.9421	-0.9380
5	0.9930	0.0570	1.8213	1.9071	2.1360
6	0.9235	0.0065	0.2061	0.2156	0.2081
7	0.8590	0.0510	1.6286	1.7043	1.8447
8	0.7431	-0.0131	-0.4182	-0.4395	-0.4265
9	0.6428	0.0072	0.2284	0.2411	0.2328
10	0.5561	-0.0261	-0.8339	-0.8832	-0.8758
11	0.4475	-0.0075	-0.2383	-0.2526	-0.2440
12	0.3871	0.0329	1.0505	1.1116	1.1219
13	0.3349	-0.0349	-1.1133	-1.1743	-1.1918
14	0.2897	-0.0297	-0.9480	-0.9957	-0.9954
15	0.2506	-0.0306	-0.9772	-1.0216	-1.0233
16	0.0845	0.0355	1.1328	1.1490	1.1634

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0060	0.3553	-0.1060
2	0.1648	0.2551	-0.5732
3	0.0015	0.1863	0.0522
4	0.0561	0.1123	-0.3336
5	0.1753	0.0879	0.6632
6	0.0022	0.0856	0.0637
7	0.1382	0.0869	0.5690
8	0.0101	0.0944	-0.1376
9	0.0033	0.1027	0.0788
10	0.0475	0.1085	-0.3056
11	0.0040	0.1102	-0.0859
12	0.0740	0.1070	0.3884
13	0.0776	0.1012	-0.3999
14	0.0512	0.0936	-0.3199
15	0.0485	0.0850	-0.3118
16	0.0190	0.0280	0.1974

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.5337	1.4937	1.5738	1.4555	1.6119
2	1.4265	1.3926	1.4605	1.3513	1.5018
3	1.3268	1.2978	1.3558	1.2536	1.4000
4	1.1478	1.1253	1.1703	1.0770	1.2187
5	0.9930	0.9730	1.0129	0.9229	1.0630
6	0.9235	0.9039	0.9432	0.8535	0.9935
7	0.8590	0.8392	0.8788	0.7890	0.9290
8	0.7431	0.7225	0.7637	0.6728	0.8134
9	0.6428	0.6213	0.6644	0.5723	0.7134
10	0.5561	0.5340	0.5782	0.4854	0.6269
11	0.4475	0.4252	0.4698	0.3767	0.5183
12	0.3871	0.3651	0.4091	0.3164	0.4578
13	0.3349	0.3135	0.3562	0.2644	0.4054
14	0.2897	0.2691	0.3102	0.2194	0.3599
15	0.2506	0.2310	0.2702	0.1806	0.3206
16	0.0845	0.0733	0.0958	0.0164	0.1526

$R^2 = 0.994$

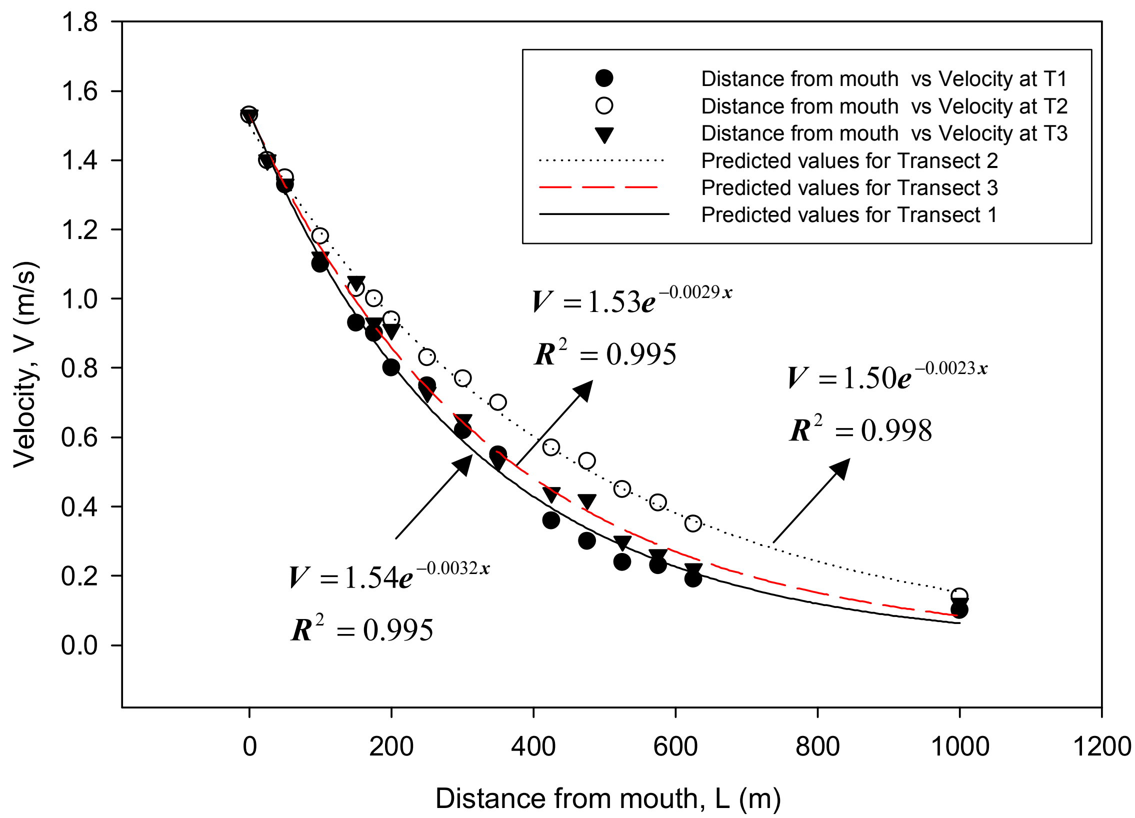

Figure A.1: Attenuation of velocities at jet flow for 3 transects at Q = 39.1 m^3/s

Table A.2: Experiment #3 – Streamwise mean velocities at Q = 32.7 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	1.23	1.23	1.23
2	25	1.12	1.13	1.13
3	50	0.96	0.98	0.96
4	100	0.84	0.9	0.88
5	150	0.68	0.73	0.7
6	175	0.63	0.71	0.69
7	200	0.6	0.66	0.63
8	250	0.47	0.52	0.51
9	300	0.4	0.48	0.45
10	350	0.32	0.45	0.36
11	425	0.28	0.38	0.3
12	475	0.2	0.3	0.23
13	525	0.18	0.21	0.2
14	575	0.14	0.19	0.18
15	625	0.1	0.15	0.14
16	1000	0.04	0.06	0.05

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 32.7 m^3/s - Transect 1

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.21178}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00372036}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99875676
Rsqr = 0.99751506
Adj Rsqr = 0.99733756

Standard Error of Estimate = 0.0192

	Coefficient	**Std. Error**	**t**	**P**
a	1.2118	0.0122	99.2481	<0.0001
b	0.0037	0.0001	53.2422	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2.0817	2.0817	5619.9392	<0.0001
Residual	14	0.0052	0.0004		
Total	15	2.0868	0.1391		

PRESS = 0.0076

Durbin-Watson Statistic = 2.5791

Normality Test:
K-S Statistic = 0.1162
Significance Level = 0.9743

Constant Variance Test: P = 0.4625

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	1.2118	0.0182	0.9466	1.2246	1.2489
2	1.1042	0.0158	0.8232	0.9630	0.9603
3	1.0061	-0.0461	-2.3949	-2.6550	-3.6308
4	0.8353	0.0047	0.2434	0.2582	0.2494
5	0.6935	-0.0135	-0.7029	-0.7397	-0.7272
6	0.6319	-0.0019	-0.1004	-0.1058	-0.1020
7	0.5758	0.0242	1.2570	1.3269	1.3675
8	0.4781	-0.0081	-0.4193	-0.4445	-0.4314
9	0.3969	0.0031	0.1600	0.1699	0.1639
10	0.3295	-0.0095	-0.4961	-0.5263	-0.5123
11	0.2493	0.0307	1.5947	1.6810	1.8131
12	0.2070	-0.0070	-0.3632	-0.3806	-0.3687
13	0.1719	0.0081	0.4232	0.4405	0.4275
14	0.1427	-0.0027	-0.1395	-0.1443	-0.1392
15	0.1185	-0.0185	-0.9594	-0.9867	-0.9857
16	0.0294	0.0106	0.5531	0.5557	0.5415

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.5050	0.4025	1.0249
2	0.1708	0.2692	0.5829
3	0.8071	0.1863	-1.7375
4	0.0042	0.1116	0.0884
5	0.0294	0.0971	-0.2384
6	0.0006	0.0988	-0.0338
7	0.1007	0.1026	0.4624
8	0.0123	0.1104	-0.1520
9	0.0019	0.1138	0.0588
10	0.0174	0.1116	-0.1816
11	0.1571	0.1001	0.6045
12	0.0071	0.0891	-0.1153
13	0.0081	0.0773	0.1237
14	0.0007	0.0655	-0.0368
15	0.0281	0.0545	-0.2367
16	0.0015	0.0095	0.0530

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.2118	1.1856	1.2380	1.1629	1.2607
2	1.1042	1.0827	1.1256	1.0577	1.1507
3	1.0061	0.9883	1.0239	0.9611	1.0511
4	0.8353	0.8215	0.8491	0.7918	0.8788
5	0.6935	0.6807	0.7064	0.6503	0.7368
6	0.6319	0.6190	0.6449	0.5887	0.6752
7	0.5758	0.5626	0.5890	0.5325	0.6192
8	0.4781	0.4644	0.4918	0.4346	0.5216
9	0.3969	0.3830	0.4108	0.3534	0.4405
10	0.3295	0.3158	0.3433	0.2860	0.3731
11	0.2493	0.2363	0.2624	0.2060	0.2926
12	0.2070	0.1947	0.2193	0.1639	0.2501
13	0.1719	0.1604	0.1833	0.1290	0.2147
14	0.1427	0.1321	0.1533	0.1001	0.1853
15	0.1185	0.1088	0.1281	0.0761	0.1609
16	0.0294	0.0253	0.0334	-0.0121	0.0708

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 32.7 m^3/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.20363}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00307206}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99660398
Rsqr = 0.99321949
Adj Rsqr = 0.99273517

Standard Error of Estimate = 0.0305

	Coefficient	**Std. Error**	**t**	**P**
a	1.2036	0.0185	65.2171	<0.0001
b	0.0031	0.0001	33.6384	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1.9109	1.9109	2050.7407	<0.0001
Residual	14	0.0130	0.0009		
Total	15	1.9239	0.1283		

PRESS = 0.0179

Durbin-Watson Statistic = 1.7466

Normality Test:
K-S Statistic = 0.1399
Significance Level = 0.8891

Constant Variance Test: P = 0.9258

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	1.2036	0.0264	0.8638	1.0845	1.0919
2	1.1147	0.0153	0.5028	0.5839	0.5697
3	1.0323	-0.0523	-1.7117	-1.8979	-2.1222
4	0.8853	0.0147	0.4825	0.5120	0.4981
5	0.7592	-0.0292	-0.9572	-1.0031	-1.0033
6	0.7031	0.0069	0.2263	0.2369	0.2288
7	0.6511	0.0089	0.2911	0.3051	0.2950
8	0.5584	-0.0384	-1.2581	-1.3246	-1.3648
9	0.4789	0.0011	0.0362	0.0383	0.0369
10	0.4107	0.0393	1.2873	1.3644	1.4121
11	0.3262	0.0538	1.7629	1.8674	2.0766
12	0.2797	0.0203	0.6636	0.7010	0.6877
13	0.2399	-0.0299	-0.9799	-1.0308	-1.0333
14	0.2058	-0.0158	-0.5160	-0.5401	-0.5260
15	0.1765	-0.0265	-0.8666	-0.9025	-0.8962
16	0.0558	0.0042	0.1389	0.1405	0.1355

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.3388	0.3656	0.8288
2	0.0595	0.2586	0.3364
3	0.4132	0.1866	-1.0165
4	0.0165	0.1118	0.1767
5	0.0494	0.0894	-0.3143
6	0.0027	0.0880	0.0711
7	0.0046	0.0899	0.0927
8	0.0952	0.0979	-0.4496
9	0.0001	0.1056	0.0127
10	0.1150	0.1099	0.4963
11	0.2129	0.1088	0.7256
12	0.0284	0.1038	0.2340
13	0.0566	0.0963	-0.3374
14	0.0140	0.0875	-0.1629
15	0.0344	0.0780	-0.2606
16	0.0002	0.0224	0.0205

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.2036	1.1640	1.2432	1.1271	1.2801
2	1.1147	1.0814	1.1479	1.0412	1.1881
3	1.0323	1.0040	1.0605	0.9609	1.1036
4	0.8853	0.8634	0.9072	0.8162	0.9543
5	0.7592	0.7396	0.7788	0.6909	0.8276
6	0.7031	0.6837	0.7225	0.6348	0.7714
7	0.6511	0.6315	0.6707	0.5828	0.7195
8	0.5584	0.5379	0.5789	0.4898	0.6270
9	0.4789	0.4576	0.5002	0.4101	0.5477
10	0.4107	0.3890	0.4324	0.3417	0.4797
11	0.3262	0.3046	0.3478	0.2572	0.3951
12	0.2797	0.2587	0.3008	0.2110	0.3485
13	0.2399	0.2196	0.2602	0.1714	0.3085
14	0.2058	0.1864	0.2251	0.1375	0.2740
15	0.1765	0.1582	0.1947	0.1085	0.2444
16	0.0558	0.0460	0.0656	-0.0104	0.1220

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 32.7 m³/s - Transect 3

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.20975}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00338818}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99822975
Rsqr = 0.99646263
Adj Rsqr = 0.99620996

Standard Error of Estimate = 0.0226

	Coefficient	**Std. Error**	**t**	**P**
a	1.2098	0.0140	86.5866	<0.0001
b	0.0034	0.0001	45.6635	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2.0057	2.0057	3943.7404	<0.0001
Residual	14	0.0071	0.0005		
Total	15	2.0128	0.1342		

PRESS = 0.0106

Durbin-Watson Statistic = 2.8656

Normality Test:
K-S Statistic = 0.1985
Significance Level = 0.5069

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.2098	0.0202	0.8979	1.1438	1.1576
2	1.1115	0.0185	0.8203	0.9564	0.9532
3	1.0212	-0.0612	-2.7150	-3.0106	-4.8857
4	0.8621	0.0179	0.7945	0.8428	0.8336
5	0.7277	-0.0277	-1.2300	-1.2913	-1.3258
6	0.6686	0.0214	0.9474	0.9947	0.9943
7	0.6143	0.0157	0.6948	0.7307	0.7180
8	0.5186	-0.0086	-0.3812	-0.4027	-0.3903
9	0.4378	0.0122	0.5419	0.5744	0.5602
10	0.3696	-0.0096	-0.4238	-0.4496	-0.4364
11	0.2866	0.0134	0.5929	0.6267	0.6126
12	0.2420	-0.0120	-0.5305	-0.5582	-0.5440
13	0.2043	-0.0043	-0.1887	-0.1975	-0.1906
14	0.1724	0.0076	0.3359	0.3495	0.3383
15	0.1456	-0.0056	-0.2463	-0.2549	-0.2462
16	0.0409	0.0091	0.4056	0.4086	0.3961

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.4075	0.3838	0.9137
2	0.1642	0.2642	0.5713
3	1.0404	0.1867	-2.3410
4	0.0445	0.1114	0.2952
5	0.0852	0.0927	-0.4237
6	0.0507	0.0929	0.3182
7	0.0283	0.0959	0.2338
8	0.0094	0.1042	-0.1331
9	0.0204	0.1102	0.1971
10	0.0127	0.1115	-0.1546
11	0.0231	0.1052	0.2100
12	0.0167	0.0970	-0.1783
13	0.0019	0.0871	-0.0589
14	0.0051	0.0765	0.0973
15	0.0023	0.0659	-0.0654
16	0.0013	0.0148	0.0486

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.2098	1.1798	1.2397	1.1529	1.2667
2	1.1115	1.0866	1.1364	1.0571	1.1659
3	1.0212	1.0003	1.0421	0.9685	1.0739
4	0.8621	0.8459	0.8782	0.8111	0.9131
5	0.7277	0.7130	0.7425	0.6772	0.7783
6	0.6686	0.6539	0.6834	0.6181	0.7192
7	0.6143	0.5994	0.6293	0.5637	0.6650
8	0.5186	0.5030	0.5342	0.4678	0.5694
9	0.4378	0.4217	0.4538	0.3868	0.4887
10	0.3696	0.3534	0.3857	0.3186	0.4206
11	0.2866	0.2709	0.3023	0.2358	0.3375
12	0.2420	0.2269	0.2570	0.1913	0.2926
13	0.2043	0.1900	0.2185	0.1538	0.2547
14	0.1724	0.1590	0.1858	0.1222	0.2226
15	0.1456	0.1331	0.1580	0.0956	0.1955
16	0.0409	0.0350	0.0467	-0.0079	0.0896

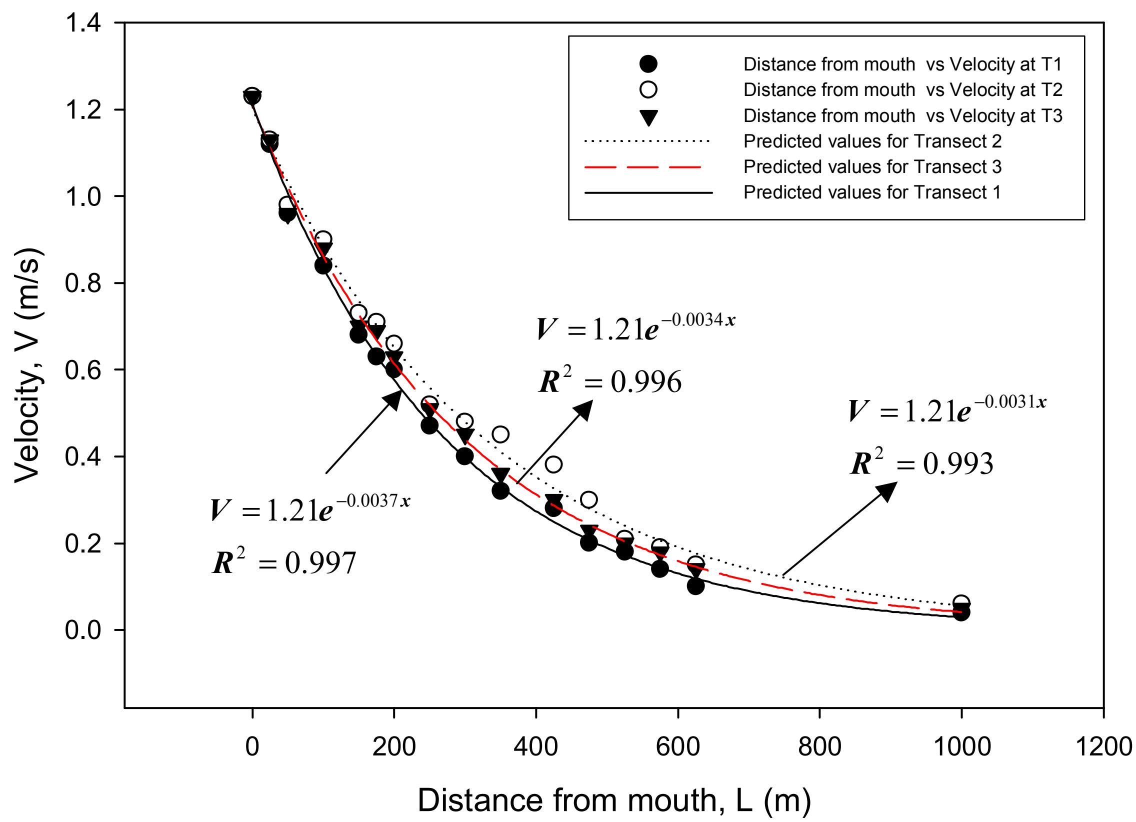

Figure A.2: Attenuation of velocities at jet flow for 3 transects at Q = 32.7 m^3/s

Table A.3: Experiment #4– Streamwise mean velocities at Q = 31.4 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	1.46	1.46	1.46
2	25	1.35	1.36	1.36
3	50	1.20	1.22	1.22
4	100	0.98	1.03	1.00
5	150	0.85	0.88	0.86
6	175	0.80	0.82	0.80
7	200	0.71	0.75	0.73
8	250	0.58	0.60	0.60
9	300	0.53	0.54	0.54
10	350	0.41	0.46	0.43
11	425	0.30	0.40	0.36
12	475	0.28	0.35	0.32
13	525	0.25	0.28	0.27
14	575	0.21	0.22	0.22
15	625	0.17	0.18	0.18
16	1000	0.04	0.06	0.05

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 31.4 m^3/s - Transect 1

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.4485}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00352482}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99903367
Rsqr = 0.99806827
Adj Rsqr = 0.99793029

Standard Error of Estimate = 0.0200

	Coefficient	**Std. Error**	**t**	**P**
a	1.4485	0.0125	115.4955	<0.0001
b	0.0035	0.0001	61.3820	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2.9055	2.9055	7233.3923	<0.0001
Residual	14	0.0056	0.0004		
Total	15	2.9111	0.1941		

PRESS = 0.0076

Durbin-Watson Statistic = 1.7725

Normality Test:
K-S Statistic = 0.1699
Significance Level = 0.7037

Constant Variance Test: P = 0.4422

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.4485	0.0115	0.5740	0.7358	0.7232
2	1.3263	0.0237	1.1817	1.3797	1.4303
3	1.2144	-0.0144	-0.7206	-0.7990	-0.7881
4	1.0182	-0.0382	-1.9064	-2.0224	-2.3164
5	0.8537	-0.0037	-0.1837	-0.1930	-0.1863
6	0.7817	0.0183	0.9144	0.9613	0.9585
7	0.7157	-0.0057	-0.2864	-0.3017	-0.2917
8	0.6001	-0.0201	-1.0023	-1.0606	-1.0657
9	0.5031	0.0269	1.3410	1.4229	1.4826
10	0.4218	-0.0118	-0.5901	-0.6261	-0.6120
11	0.3238	-0.0238	-1.1893	-1.2558	-1.2846
12	0.2715	0.0085	0.4237	0.4451	0.4320
13	0.2276	0.0224	1.1158	1.1652	1.1816
14	0.1909	0.0191	0.9553	0.9916	0.9909
15	0.1600	0.0100	0.4982	0.5141	0.5002
16	0.0427	-0.0027	-0.1331	-0.1340	-0.1292

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.1742	0.3916	0.5802
2	0.3456	0.2664	0.8619
3	0.0732	0.1866	-0.3775
4	0.2565	0.1114	-0.8203
5	0.0019	0.0944	-0.0601
6	0.0486	0.0953	0.3110
7	0.0050	0.0986	-0.0965
8	0.0673	0.1068	-0.3686
9	0.1275	0.1118	0.5261
10	0.0247	0.1117	-0.2170
11	0.0907	0.1032	-0.4358
12	0.0103	0.0938	0.1390
13	0.0615	0.0830	0.3556
14	0.0381	0.0719	0.2757
15	0.0086	0.0611	0.1275
16	0.0001	0.0123	-0.0144

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.4485	1.4216	1.4754	1.3978	1.4992
2	1.3263	1.3041	1.3485	1.2779	1.3747
3	1.2144	1.1959	1.2330	1.1676	1.2613
4	1.0182	1.0039	1.0326	0.9729	1.0635
5	0.8537	0.8405	0.8669	0.8087	0.8986
6	0.7817	0.7684	0.7949	0.7367	0.8267
7	0.7157	0.7022	0.7292	0.6707	0.7608
8	0.6001	0.5860	0.6141	0.5549	0.6453
9	0.5031	0.4887	0.5175	0.4578	0.5484
10	0.4218	0.4075	0.4362	0.3765	0.4672
11	0.3238	0.3100	0.3376	0.2787	0.3690
12	0.2715	0.2583	0.2847	0.2266	0.3165
13	0.2276	0.2153	0.2400	0.1829	0.2724
14	0.1909	0.1793	0.2024	0.1464	0.2354
15	0.1600	0.1494	0.1706	0.1157	0.2043
16	0.0427	0.0379	0.0474	-0.0006	0.0859

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 31.4 m^3/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.44839}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00324975}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99883974
Rsqr = 0.99768084
Adj Rsqr = 0.99751518

Standard Error of Estimate = 0.0216

	Coefficient	**Std. Error**	**t**	**P**
a	1.4484	0.0132	109.4491	<0.0001
b	0.0032	0.0001	57.2066	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2.8060	2.8060	6022.6578	<0.0001
Residual	14	0.0065	0.0005		
Total	15	2.8125	0.1875		

PRESS = 0.0087

Durbin-Watson Statistic = 1.1025

Normality Test:
K-S Statistic = 0.1706
Significance Level = 0.6985

Constant Variance Test: P = 0.4694

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.4484	0.0116	0.5379	0.6808	0.6672
2	1.3354	0.0246	1.1410	1.3281	1.3689
3	1.2312	-0.0112	-0.5175	-0.5739	-0.5596
4	1.0465	-0.0165	-0.7657	-0.8124	-0.8019
5	0.8896	-0.0096	-0.4437	-0.4654	-0.4520
6	0.8202	-0.0002	-0.0075	-0.0079	-0.0076
7	0.7562	-0.0062	-0.2856	-0.2999	-0.2899
8	0.6428	-0.0428	-1.9810	-2.0899	-2.4278
9	0.5464	-0.0064	-0.2948	-0.3122	-0.3019
10	0.4644	-0.0044	-0.2049	-0.2173	-0.2098
11	0.3640	0.0360	1.6693	1.7664	1.9309
12	0.3094	0.0406	1.8817	1.9836	2.2543
13	0.2630	0.0170	0.7883	0.8270	0.8171
14	0.2235	-0.0035	-0.1641	-0.1712	-0.1652
15	0.1900	-0.0100	-0.4641	-0.4815	-0.4679
16	0.0562	0.0038	0.1772	0.1788	0.1725

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.1396	0.3759	0.5178
2	0.3129	0.2619	0.8154
3	0.0378	0.1867	-0.2682
4	0.0414	0.1115	-0.2841
5	0.0109	0.0911	-0.1431
6	0.0000	0.0906	-0.0024
7	0.0046	0.0932	-0.0930
8	0.2466	0.1015	-0.8158
9	0.0059	0.1083	-0.1052
10	0.0029	0.1110	-0.0741
11	0.1868	0.1069	0.6681
12	0.2188	0.1001	0.7517
13	0.0343	0.0912	0.2588
14	0.0013	0.0813	-0.0491
15	0.0089	0.0711	-0.1294
16	0.0003	0.0178	0.0232

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	1.4484	1.4200	1.4768	1.3941	1.5027
2	1.3354	1.3117	1.3591	1.2834	1.3874
3	1.2312	1.2112	1.2512	1.1807	1.2816
4	1.0465	1.0311	1.0620	0.9977	1.0953
5	0.8896	0.8756	0.9036	0.8412	0.9379
6	0.8202	0.8062	0.8341	0.7718	0.8685
7	0.7562	0.7420	0.7703	0.7078	0.8046
8	0.6428	0.6280	0.6575	0.5942	0.6913
9	0.5464	0.5311	0.5616	0.4976	0.5951
10	0.4644	0.4490	0.4798	0.4156	0.5132
11	0.3640	0.3488	0.3791	0.3153	0.4127
12	0.3094	0.2947	0.3240	0.2608	0.3579
13	0.2630	0.2490	0.2770	0.2146	0.3113
14	0.2235	0.2103	0.2367	0.1754	0.2717
15	0.1900	0.1777	0.2024	0.1421	0.2379
16	0.0562	0.0500	0.0623	0.0095	0.1029

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 31.4 m^3/s - Transect 3

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.44831}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00336776}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99912048
Rsqr = 0.99824174
Adj Rsqr = 0.99811615

Standard Error of Estimate = 0.0189

	Coefficient	Std. Error	t	P
a	1.4483	0.0117	123.8239	<0.0001
b	0.0034	0.0001	65.2171	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	2.8418	2.8418	7948.4189	<0.0001
Residual	14	0.0050	0.0004		
Total	15	2.8468	0.1898		

PRESS = 0.0069

Durbin-Watson Statistic = 1.2954

Normality Test:
K-S Statistic = 0.1674
Significance Level = 0.7205

Constant Variance Test: P = 0.3029

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	1.4483	0.0117	0.6182	0.7868	0.7756
2	1.3314	0.0286	1.5145	1.7652	1.9292
3	1.2239	-0.0039	-0.2041	-0.2264	-0.2185
4	1.0342	-0.0342	-1.8084	-1.9184	-2.1532
5	0.8739	-0.0139	-0.7362	-0.7728	-0.7611
6	0.8034	-0.0034	-0.1774	-0.1862	-0.1796
7	0.7385	-0.0085	-0.4488	-0.4719	-0.4583
8	0.6240	-0.0240	-1.2713	-1.3429	-1.3865
9	0.5273	0.0127	0.6701	0.7103	0.6971
10	0.4456	-0.0156	-0.8254	-0.8756	-0.8679
11	0.3461	0.0139	0.7328	0.7748	0.7631
12	0.2925	0.0275	1.4543	1.5308	1.6167
13	0.2472	0.0228	1.2074	1.2641	1.2942
14	0.2089	0.0111	0.5888	0.6130	0.5988
15	0.1765	0.0035	0.1853	0.1918	0.1850
16	0.0499	0.0001	0.0043	0.0043	0.0042

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.1919	0.3827	0.6106
2	0.5585	0.2639	1.1551
3	0.0059	0.1867	-0.1047
4	0.2308	0.1114	-0.7625
5	0.0304	0.0924	-0.2429
6	0.0018	0.0925	-0.0574
7	0.0118	0.0955	-0.1489
8	0.1044	0.1038	-0.4718
9	0.0311	0.1099	0.2449
10	0.0481	0.1114	-0.3073
11	0.0354	0.1054	0.2620
12	0.1265	0.0975	0.5313
13	0.0768	0.0877	0.4013
14	0.0157	0.0772	0.1732
15	0.0013	0.0667	0.0495
16	0.0000	0.0152	0.0005

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.4483	1.4232	1.4734	1.4006	1.4960
2	1.3314	1.3105	1.3522	1.2858	1.3770
3	1.2239	1.2063	1.2414	1.1797	1.2680
4	1.0342	1.0207	1.0477	0.9914	1.0769
5	0.8739	0.8616	0.8862	0.8315	0.9163
6	0.8034	0.7910	0.8157	0.7610	0.8457
7	0.7385	0.7260	0.7510	0.6960	0.7809
8	0.6240	0.6110	0.6371	0.5814	0.6666
9	0.5273	0.5139	0.5408	0.4846	0.5701
10	0.4456	0.4321	0.4591	0.4029	0.4884
11	0.3461	0.3330	0.3593	0.3035	0.3888
12	0.2925	0.2798	0.3052	0.2500	0.3350
13	0.2472	0.2352	0.2592	0.2049	0.2895
14	0.2089	0.1976	0.2201	0.1668	0.2510
15	0.1765	0.1660	0.1870	0.1346	0.2184
16	0.0499	0.0449	0.0549	0.0091	0.0908

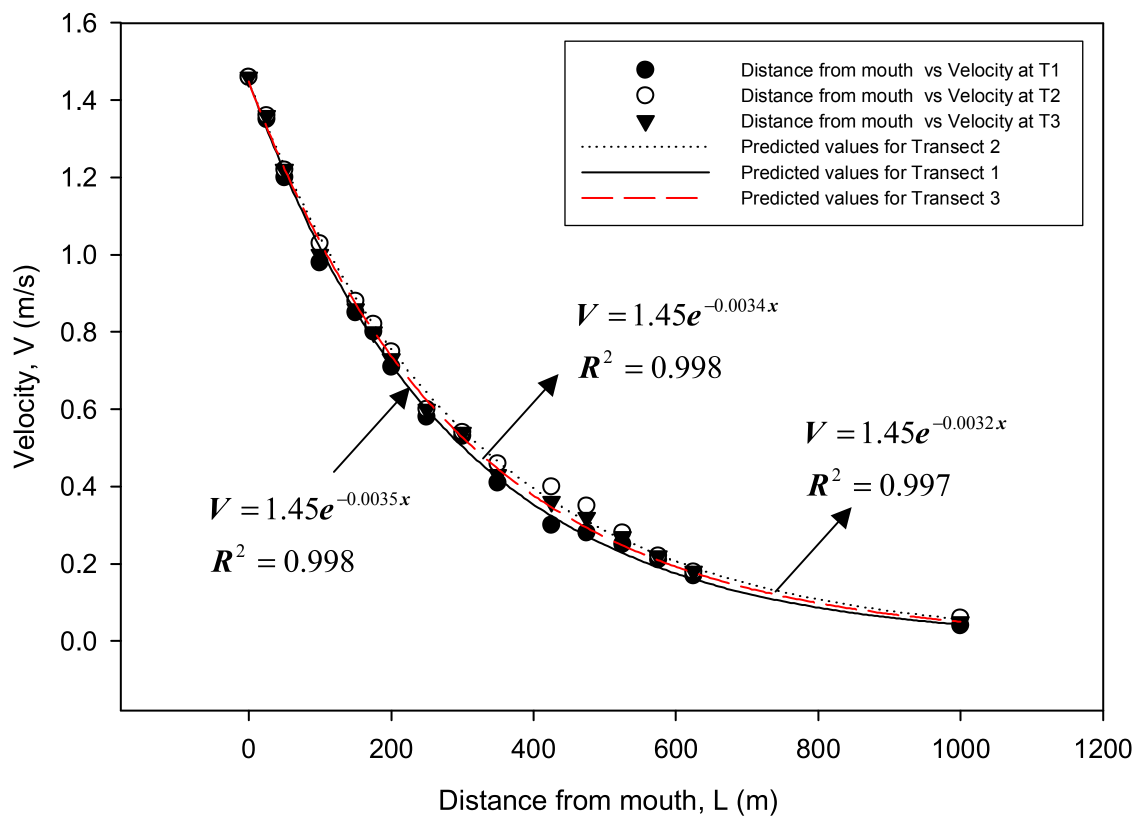

Figure A.3: Attenuation of velocities at jet flow for 3 transects at Q = 31.4 m^3/s

Table A.4: Experiment #7 – Streamwise mean velocities at Q = 8.5 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	0.68	0.68	0.68
2	25	0.50	0.56	0.52
3	50	0.35	0.49	0.41
3′	75	0.30	0.33	0.30
4	100	0.25	0.30	0.28
4′	125	0.14	0.25	0.20
5	150	0.10	0.22	0.14
6	175	0.08	0.18	0.11
7	200	0.04	0.12	0.10
7′	225	0.03	0.09	0.05
8	250	~	0.07	0.04
8′	275		0.04	

<u>Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 8.5 m^3/s - Transect 1</u>

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.681663}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0121284}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99437923
Rsqr = 0.98879006
Adj Rsqr = 0.98754451

Standard Error of Estimate = 0.0242

	Coefficient	**Std. Error**	**t**	**P**
a	0.6817	0.0205	33.3231	<0.0001
b	0.0121	0.0006	19.9207	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.4660	0.4660	793.8591	<0.0001
Residual	9	0.0053	0.0006		
Total	10	0.4713	0.0471		

PRESS = 0.0071

Durbin-Watson Statistic = 1.3420

Normality Test:
K-S Statistic = 0.3467
Significance Level = 0.1106

Constant Variance Test: P = 0.4495

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.6817	-0.0017	-0.0686	-0.1281	-0.1209
2	0.5034	-0.0034	-0.1391	-0.1608	-0.1518
3	0.3717	-0.0217	-0.8961	-0.9845	-0.9826
4	0.2745	0.0255	1.0530	1.1571	1.1824
5	0.2027	0.0473	1.9526	2.1415	2.8830
6	0.1497	-0.0097	-0.3994	-0.4334	-0.4129
7	0.1105	-0.0105	-0.4346	-0.4642	-0.4430
8	0.0816	-0.0016	-0.0668	-0.0703	-0.0663
9	0.0603	-0.0203	-0.8367	-0.8676	-0.8545
10	0.0445	-0.0145	-0.5988	-0.6142	-0.5916
11	0.0329	-0.0329	-1.3565	-1.3803	-1.4657

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0204	0.7129	-0.1904
2	0.0043	0.2517	-0.0880
3	0.1004	0.1716	-0.4472
4	0.1388	0.1717	0.5384
5	0.4653	0.1687	1.2987
6	0.0166	0.1506	-0.1739
7	0.0152	0.1237	-0.1664
8	0.0003	0.0954	-0.0215
9	0.0284	0.0701	-0.2346
10	0.0099	0.0496	-0.1352
11	0.0337	0.0341	-0.2756

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.6817	0.6354	0.7279	0.6099	0.7534
2	0.5034	0.4759	0.5309	0.4421	0.5647
3	0.3717	0.3490	0.3944	0.3124	0.4310
4	0.2745	0.2518	0.2972	0.2152	0.3338
5	0.2027	0.1802	0.2252	0.1434	0.2619
6	0.1497	0.1284	0.1709	0.0909	0.2085
7	0.1105	0.0913	0.1298	0.0524	0.1686
8	0.0816	0.0647	0.0985	0.0243	0.1390
9	0.0603	0.0458	0.0748	0.0036	0.1170
10	0.0445	0.0323	0.0567	-0.0116	0.1007
11	0.0329	0.0227	0.0430	-0.0229	0.0886

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 8.5 m³/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.690909}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00840672}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99429764
Rsqr = 0.98862779
Adj Rsqr = 0.98749057

Standard Error of Estimate = 0.0230

	Coefficient	**Std. Error**	**t**	**P**
a	0.6909	0.0177	38.9711	<0.0001
b	0.0084	0.0004	23.1749	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.4580	0.4580	869.3367	<0.0001
Residual	10	0.0053	0.0005		
Total	11	0.4632	0.0421		

PRESS = 0.0074

Durbin-Watson Statistic = 1.8792

Normality Test:
K-S Statistic = 0.1533
Significance Level = 0.9184

Constant Variance Test: P = 0.5126

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	0.6909	-0.0109	-0.4753	-0.7484	-0.7307
2	0.5599	0.0001	0.0024	0.0027	0.0026
3	0.4538	0.0362	1.5769	1.7103	1.9290
4	0.3678	-0.0378	-1.6464	-1.7615	-2.0123
5	0.2981	0.0019	0.0840	0.0900	0.0854
6	0.2416	0.0084	0.3672	0.3945	0.3772
7	0.1958	0.0242	1.0552	1.1322	1.1504
8	0.1587	0.0213	0.9293	0.9923	0.9915
9	0.1286	-0.0086	-0.3745	-0.3969	-0.3796
10	0.1042	-0.0142	-0.6195	-0.6512	-0.6313
11	0.0845	-0.0145	-0.6302	-0.6568	-0.6370
12	0.0685	-0.0285	-1.2397	-1.2819	-1.3303

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.4143	0.5966	-0.8888
2	0.0000	0.2611	0.0015
3	0.2579	0.1499	0.8099
4	0.2247	0.1265	-0.7658
5	0.0006	0.1292	0.0329
6	0.0120	0.1334	0.1480
7	0.0970	0.1314	0.4475
8	0.0690	0.1230	0.3712
9	0.0097	0.1100	-0.1334
10	0.0222	0.0948	-0.2043
11	0.0186	0.0793	-0.1869
12	0.0569	0.0647	-0.3500

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.6909	0.6514	0.7304	0.6263	0.7555
2	0.5599	0.5338	0.5861	0.5025	0.6174
3	0.4538	0.4340	0.4736	0.3990	0.5086
4	0.3678	0.3496	0.3860	0.3135	0.4221
5	0.2981	0.2797	0.3165	0.2437	0.3524
6	0.2416	0.2229	0.2603	0.1871	0.2960
7	0.1958	0.1772	0.2143	0.1414	0.2502
8	0.1587	0.1407	0.1766	0.1045	0.2129
9	0.1286	0.1116	0.1456	0.0747	0.1825
10	0.1042	0.0885	0.1200	0.0507	0.1577
11	0.0845	0.0701	0.0989	0.0313	0.1376
12	0.0685	0.0554	0.0815	0.0157	0.1212

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 8.5 m^3/s - Transect 3

[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x) "Auto {{previous: 0.678289}}
b = if(x50(x,y)-min(x)=0, 1, -ln(.5)/(x50(x,y)-min(x))) "Auto {{previous: 0.0101365}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100

R = 0.99725724
Rsqr = 0.99452200
Adj Rsqr = 0.99391333

Standard Error of Estimate = 0.0161

	Coefficient	**Std. Error**	**t**	**P**
a	0.6783	0.0131	51.8725	<0.0001
b	0.0101	0.0003	30.8781	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.4247	0.4247	1633.9340	<0.0001
Residual	9	0.0023	0.0003		
Total	10	0.4270	0.0427		

PRESS = 0.0031

Durbin-Watson Statistic = 2.2137

Normality Test:
K-S Statistic = 0.1826
Significance Level = 0.8171

Constant Variance Test: P = 0.1162

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	0.6783	0.0017	0.1061	0.1814	0.1714
2	0.5265	-0.0065	-0.4002	-0.4642	-0.4429
3	0.4086	0.0014	0.0865	0.0942	0.0889
4	0.3171	-0.0171	-1.0630	-1.1516	-1.1759
5	0.2461	0.0339	2.0999	2.2814	3.3123
6	0.1910	0.0090	0.5554	0.6022	0.5795
7	0.1483	-0.0083	-0.5136	-0.5524	-0.5299
8	0.1151	-0.0051	-0.3155	-0.3356	-0.3184
9	0.0893	0.0107	0.6622	0.6961	0.6747
10	0.0693	-0.0193	-1.1989	-1.2464	-1.2919
11	0.0538	-0.0138	-0.8566	-0.8821	-0.8701

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0317	0.6579	0.2376
2	0.0372	0.2565	-0.2602
3	0.0008	0.1568	0.0383
4	0.1152	0.1480	-0.4901
5	0.4693	0.1528	1.4066
6	0.0318	0.1493	0.2428
7	0.0240	0.1358	-0.2100
8	0.0074	0.1163	-0.1155
9	0.0254	0.0950	0.2185
10	0.0627	0.0747	-0.3670
11	0.0235	0.0570	-0.2140

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.6783	0.6487	0.7079	0.6313	0.7252
2	0.5265	0.5080	0.5449	0.4856	0.5673
3	0.4086	0.3942	0.4230	0.3694	0.4478
4	0.3171	0.3031	0.3312	0.2781	0.3562
5	0.2461	0.2319	0.2604	0.2070	0.2853
6	0.1910	0.1770	0.2051	0.1519	0.2301
7	0.1483	0.1348	0.1617	0.1094	0.1871
8	0.1151	0.1027	0.1275	0.0766	0.1536
9	0.0893	0.0781	0.1006	0.0512	0.1275
10	0.0693	0.0594	0.0793	0.0315	0.1071
11	0.0538	0.0451	0.0625	0.0163	0.0913

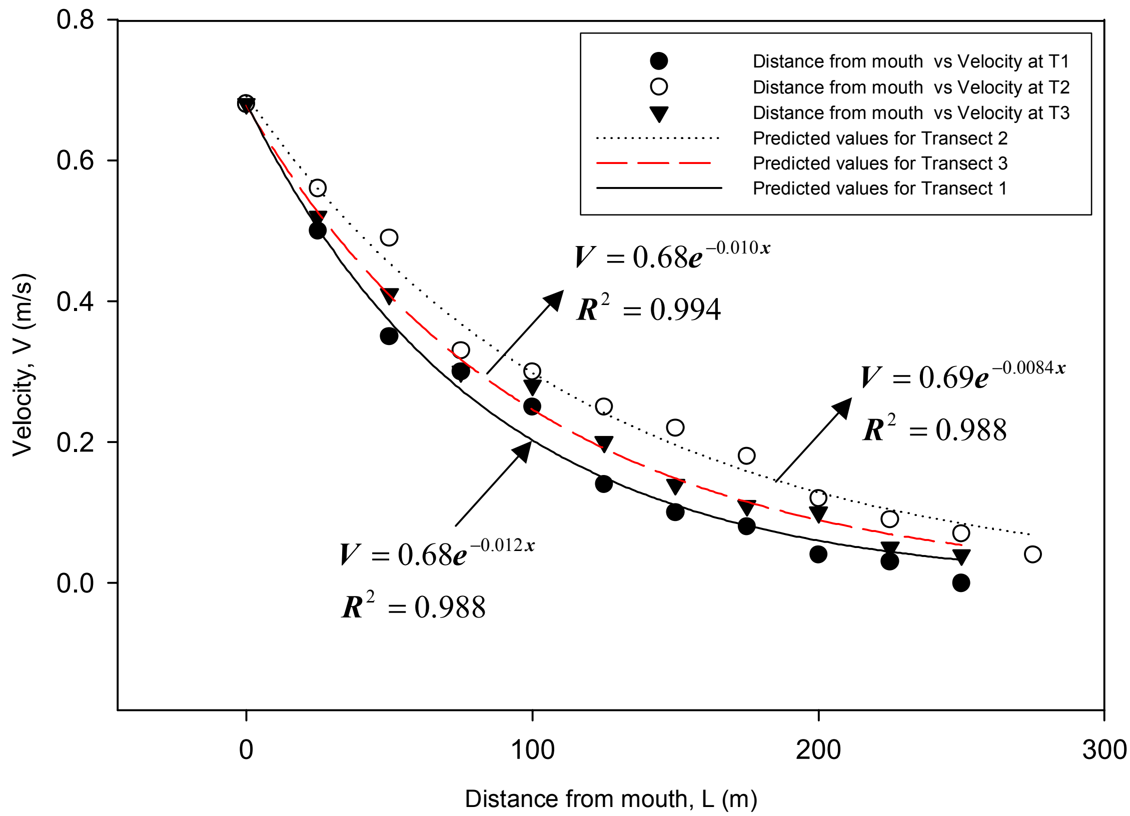

Figure A.4: Attenuation of velocities at jet flow for 3 transects at Q = 8.5 m^3/s

Table A.5: Experiment #9 – Streamwise mean velocities at Q = 5.5 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	0.41	0.41	0.41
1′	10	0.32	0.34	0.32
2	25	0.21	0.25	0.22
2′	35	0.16	0.18	0.18
3	50	0.12	0.16	0.14
3′	60	0.1	0.1	0.1
3″	70	0.03	0.09	0.06
3‴	80	~	0.08	0.05
3⁗	90		0.05	0.03
4	100		0.03	~

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 5.5 m³/s - Transect 1

[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x) "Auto {{previous: 0.417902}}
b = if(x50(x,y)-min(x)=0, 1, -ln(.5)/(x50(x,y)-min(x))) "Auto {{previous: 0.0282823}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100

R = 0.98657460
Rsqr = 0.97332944
Adj Rsqr = 0.96888435

Standard Error of Estimate = 0.0247

	Coefficient	**Std. Error**	**t**	**P**
a	0.4179	0.0211	19.7924	<0.0001
b	0.0283	0.0026	11.0457	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.1340	0.1340	218.9672	<0.0001
Residual	6	0.0037	0.0006		
Total	7	0.1377	0.0197		

PRESS = 0.0056

Durbin-Watson Statistic = 0.8840

Normality Test:
K-S Statistic = 0.1939
Significance Level = 0.8906

Constant Variance Test: P = 0.0149

Power of performed test with alpha = 0.0500: 0.9999

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.4179	-0.0079	-0.3194	-0.6129	-0.5778
2	0.3150	0.0050	0.2040	0.2398	0.2200
3	0.2061	0.0039	0.1591	0.1779	0.1629
4	0.1553	0.0047	0.1899	0.2136	0.1958
5	0.1016	0.0184	0.7434	0.8270	0.8020
6	0.0766	0.0234	0.9468	1.0350	1.0424
7	0.0577	-0.0277	-1.1202	-1.2013	-1.2583
8	0.0435	-0.0435	-1.7582	-1.8527	-2.5855

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.5037	0.7284	-0.9463
2	0.0110	0.2764	0.1360
3	0.0040	0.2007	0.0816
4	0.0060	0.2094	0.1008
5	0.0812	0.1919	0.3909
6	0.1044	0.1632	0.4603
7	0.1082	0.1304	-0.4874
8	0.1896	0.0995	-0.8593

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.4179	0.3662	0.4696	0.3383	0.4975
2	0.3150	0.2831	0.3468	0.2466	0.3833
3	0.2061	0.1789	0.2332	0.1397	0.2724
4	0.1553	0.1276	0.1830	0.0887	0.2219
5	0.1016	0.0751	0.1281	0.0355	0.1677
6	0.0766	0.0521	0.1010	0.0113	0.1419
7	0.0577	0.0358	0.0796	-0.0066	0.1221
8	0.0435	0.0244	0.0626	-0.0200	0.1070

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 5.5 m^3/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.416812}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0220086}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99553737
Rsqr = 0.99109466
Adj Rsqr = 0.98998149

Standard Error of Estimate = 0.0128

	Coefficient	**Std. Error**	**t**	**P**
a	0.4168	0.0103	40.5468	<0.0001
b	0.0220	0.0009	23.7645	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.1452	0.1452	890.3369	<0.0001
Residual	8	0.0013	0.0002		
Total	9	0.1465	0.0163		

PRESS = 0.0021

Durbin-Watson Statistic = 2.6358

Normality Test:
K-S Statistic = 0.2149
Significance Level = 0.6900

Constant Variance Test: P = 0.4899
Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.4168	-0.0068	-0.5334	-0.8992	-0.8871
2	0.3345	0.0055	0.4330	0.5116	0.4865
3	0.2404	0.0096	0.7496	0.8163	0.7976
4	0.1929	-0.0129	-1.0126	-1.1012	-1.1183
5	0.1387	0.0213	1.6692	1.8202	2.2245
6	0.1113	-0.0113	-0.8839	-0.9603	-0.9550
7	0.0893	0.0007	0.0546	0.0588	0.0551
8	0.0717	0.0083	0.6530	0.6966	0.6723
9	0.0575	-0.0075	-0.5877	-0.6201	-0.5945
10	0.0461	-0.0161	-1.2643	-1.3204	-1.3966

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.7443	0.6480	-1.2037
2	0.0518	0.2835	0.3061
3	0.0620	0.1568	0.3440
4	0.1107	0.1544	-0.4778
5	0.3133	0.1590	0.9674
6	0.0831	0.1527	-0.4054
7	0.0003	0.1391	0.0221
8	0.0335	0.1212	0.2497
9	0.0218	0.1019	-0.2003
10	0.0791	0.0832	-0.4208

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.4168	0.3931	0.4405	0.3790	0.4546
2	0.3345	0.3188	0.3502	0.3011	0.3678
3	0.2404	0.2288	0.2521	0.2088	0.2721
4	0.1929	0.1814	0.2045	0.1613	0.2246
5	0.1387	0.1269	0.1504	0.1070	0.1704
6	0.1113	0.0998	0.1228	0.0797	0.1429
7	0.0893	0.0783	0.1003	0.0579	0.1207
8	0.0717	0.0614	0.0819	0.0405	0.1028
9	0.0575	0.0481	0.0669	0.0266	0.0884
10	0.0461	0.0376	0.0546	0.0155	0.0768

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 5.5 m³/s - Transect 3

[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x) "Auto {{previous: 0.414319}}
b = if(x50(x,y)-min(x)=0, 1, -ln(.5)/(x50(x,y)-min(x))) "Auto {{previous: 0.0252806}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100

R = 0.99341393
Rsqr = 0.98687124
Adj Rsqr = 0.98523015

Standard Error of Estimate = 0.0162

	Coefficient	**Std. Error**	**t**	**P**
a	0.4143	0.0134	30.9299	<0.0001
b	0.0253	0.0014	18.2166	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.1578	0.1578	601.3493	<0.0001
Residual	8	0.0021	0.0003		
Total	9	0.1599	0.0178		

PRESS = 0.0028

Durbin-Watson Statistic = 0.6582

Normality Test:
K-S Statistic = 0.2058
Significance Level = 0.7398

Constant Variance Test: P = 0.0108
Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	0.4143	-0.0043	-0.2666	-0.4742	-0.4499
2	0.3218	-0.0018	-0.1091	-0.1285	-0.1204
3	0.2202	-0.0002	-0.0135	-0.0148	-0.0139
4	0.1710	0.0090	0.5540	0.6090	0.5834
5	0.1171	0.0229	1.4167	1.5525	1.7373
6	0.0909	0.0091	0.5615	0.6093	0.5837
7	0.0706	-0.0106	-0.6542	-0.7007	-0.6765
8	0.0548	-0.0048	-0.2980	-0.3149	-0.2964
9	0.0426	-0.0126	-0.7766	-0.8104	-0.7912
10	0.0331	-0.0331	-2.0414	-2.1080	-2.9574

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.2432	0.6838	-0.6617
2	0.0032	0.2791	-0.0749
3	0.0000	0.1706	-0.0063
4	0.0387	0.1725	0.2664
5	0.2420	0.1672	0.7785
6	0.0329	0.1507	0.2458
7	0.0361	0.1281	-0.2593
8	0.0058	0.1041	-0.1010
9	0.0292	0.0816	-0.2358
10	0.1472	0.0621	-0.7612

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.4143	0.3834	0.4452	0.3658	0.4628
2	0.3218	0.3020	0.3415	0.2795	0.3640
3	0.2202	0.2048	0.2356	0.1798	0.2606
4	0.1710	0.1555	0.1865	0.1306	0.2115
5	0.1171	0.1018	0.1323	0.0767	0.1574
6	0.0909	0.0764	0.1054	0.0508	0.1310
7	0.0706	0.0572	0.0840	0.0309	0.1103
8	0.0548	0.0428	0.0669	0.0156	0.0941
9	0.0426	0.0319	0.0533	0.0037	0.0814
10	0.0331	0.0238	0.0424	-0.0054	0.0716

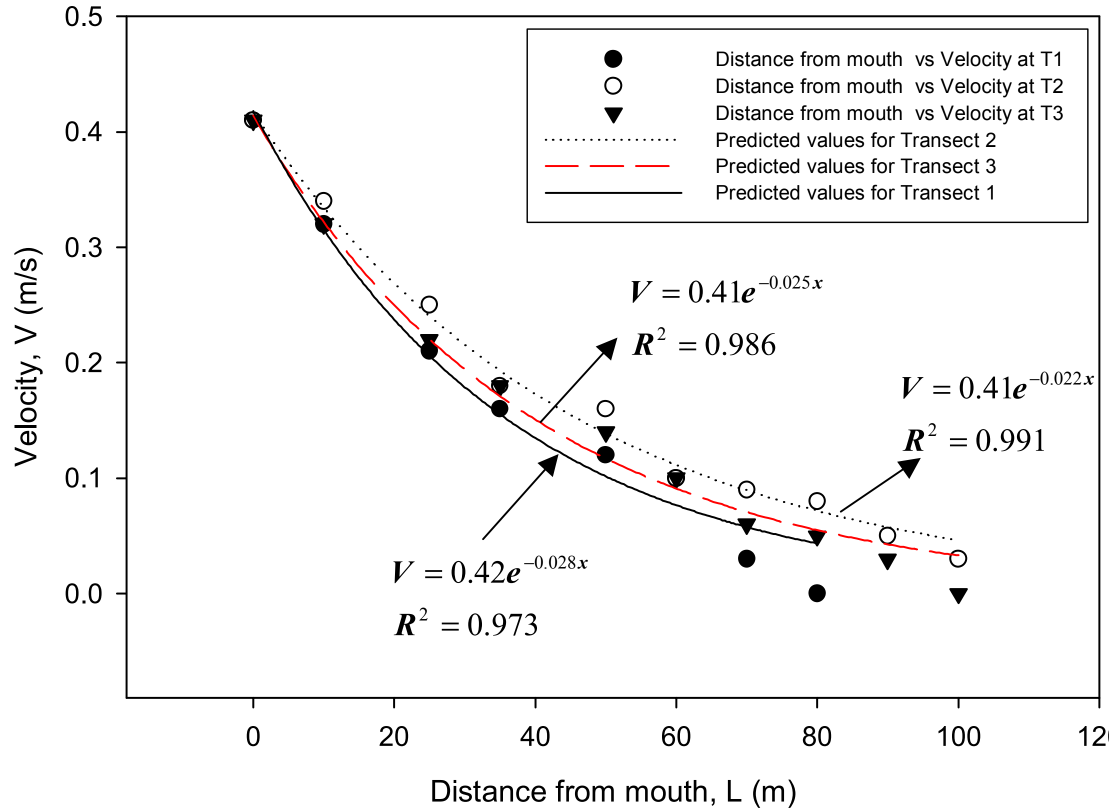

Figure A.5: Attenuation of velocities at jet flow for 3 transects at Q = 5.5 m^3/s

Table A.6: Experiment #10 – Streamwise mean velocities at Q = 3.8 m^3/s

Station No.	Distance, L (m)	Velocity at Transect 1 (m/s)	Velocity at Transect 2 (m/s)	Velocity at Transect 3 (m/s)
1	0	0.28	0.28	0.28
1′	10	0.18	0.2	0.2
2	25	0.07	0.11	0.09
2′	35	0.05	0.09	0.07
3	50	0.03	0.06	0.04

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 3.8 m^3/s - Transect 1

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.282456}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0498023}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99722539
Rsqr = 0.99445849
Adj Rsqr = 0.99261132

Standard Error of Estimate = 0.0091

	Coefficient	**Std. Error**	**t**	**P**
a	0.2825	0.0085	33.0580	<0.0001
b	0.0498	0.0031	16.1753	0.0005

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.0444	0.0444	538.3683	0.0002
Residual	3	0.0002	0.0001		
Total	4	0.0447	0.0112		

PRESS = 0.0010

Durbin-Watson Statistic = 2.7514

Normality Test:
K-S Statistic = 0.1990
Significance Level = 0.9760

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 0.9964

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.2825	-0.0025	-0.2703	-0.7956	-0.7314
2	0.1717	0.0083	0.9183	1.1293	1.2160
3	0.0813	-0.0113	-1.2467	-1.5654	-2.9868
4	0.0494	0.0006	0.0634	0.0745	0.0609
5	0.0234	0.0066	0.7248	0.7788	0.7119

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	2.4253	0.8846	-2.0245
2	0.3265	0.3387	0.8702
3	0.7066	0.3658	-2.2682
4	0.0011	0.2771	0.0377
5	0.0469	0.1339	0.2799

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.2825	0.2553	0.3096	0.2428	0.3221
2	0.1717	0.1548	0.1885	0.1382	0.2051
3	0.0813	0.0638	0.0988	0.0475	0.1151
4	0.0494	0.0342	0.0646	0.0168	0.0821
5	0.0234	0.0128	0.0340	-0.0074	0.0542

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 3.8 m^3/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.278413}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0334291}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99709890
Rsqr = 0.99420622
Adj Rsqr = 0.99227496

Standard Error of Estimate = 0.0079

	Coefficient	**Std. Error**	**t**	**P**
a	0.2784	0.0071	38.9498	<0.0001
b	0.0334	0.0018	18.6303	0.0003

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.0325	0.0325	514.7966	0.0002
Residual	3	0.0002	0.0001		
Total	4	0.0327	0.0082		

PRESS = 0.0005

Durbin-Watson Statistic = 1.8591

Normality Test:
K-S Statistic = 0.3406
Significance Level = 0.5130

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 0.9961

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	0.2784	0.0016	0.1997	0.4577	0.3875
2	0.1993	0.0007	0.0880	0.1042	0.0852
3	0.1207	-0.0107	-1.3479	-1.6265	-3.8641
4	0.0864	0.0036	0.4521	0.5510	0.4745
5	0.0523	0.0077	0.9649	1.1246	1.2074

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.4452	0.8096	0.7989
2	0.0022	0.2865	0.0540
3	0.6033	0.3132	-2.6096
4	0.0737	0.3269	0.3307
5	0.2267	0.2639	0.7228

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.2784	0.2557	0.3012	0.2444	0.3124
2	0.1993	0.1858	0.2128	0.1706	0.2280
3	0.1207	0.1066	0.1349	0.0917	0.1497
4	0.0864	0.0720	0.1009	0.0573	0.1155
5	0.0523	0.0393	0.0653	0.0239	0.0808

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 3.8 m³/s - Transect 3

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.283892}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0408102}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99620163
Rsqr = 0.99241769
Adj Rsqr = 0.98989026

Standard Error of Estimate = 0.0101

	Coefficient	**Std. Error**	**t**	**P**
a	0.2839	0.0093	30.4861	<0.0001
b	0.0408	0.0027	14.9591	0.0006

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.0402	0.0402	392.6580	0.0003
Residual	3	0.0003	0.0001		
Total	4	0.0405	0.0101		

PRESS = 0.0013

Durbin-Watson Statistic = 3.2243

Normality Test:
K-S Statistic = 0.1880
Significance Level = 0.9867

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 0.9932

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.2839	-0.0039	-0.3846	-0.9825	-0.9741
2	0.1888	0.0112	1.1104	1.3293	1.6929
3	0.1023	-0.0123	-1.2198	-1.5043	-2.4776
4	0.0680	0.0020	0.1927	0.2320	0.1912
5	0.0369	0.0031	0.3068	0.3426	0.2854

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	2.6667	0.8467	-2.2896
2	0.3826	0.3022	1.1141
3	0.5892	0.3425	-1.7880
4	0.0121	0.3103	0.1282
5	0.0145	0.1983	0.1420

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.2839	0.2543	0.3135	0.2401	0.3277
2	0.1888	0.1711	0.2065	0.1520	0.2255
3	0.1023	0.0835	0.1212	0.0650	0.1397
4	0.0680	0.0501	0.0860	0.0312	0.1049
5	0.0369	0.0226	0.0512	0.0016	0.0722

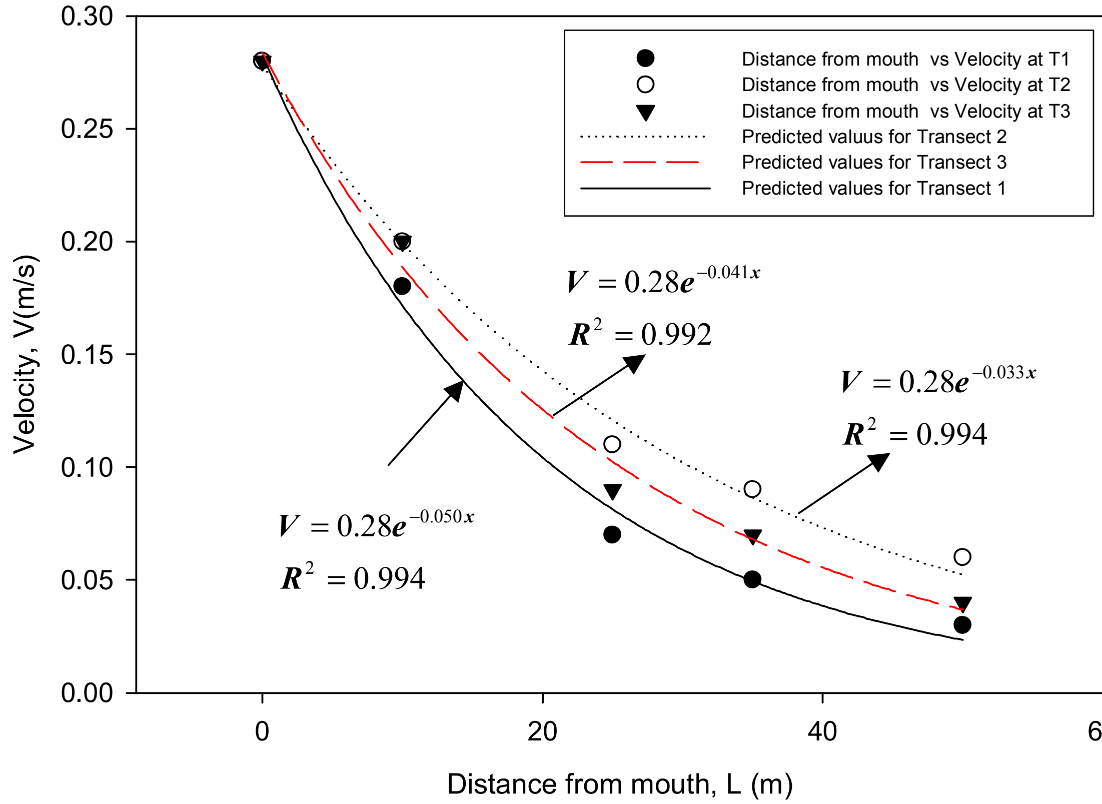

Figure A.6: Attenuation of velocities at jet flow for 3 transects at Q = 3.8 m^3/s

Nonlinear Regression Analysis for Velocity Attenuations with SIGMAPLOT 8.0 at Q=46.8 m^3/s - Transect 1

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.74635}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00243611}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99753687
Rsqr = 0.99507980
Adj Rsqr = 0.99472835

Standard Error of Estimate = 0.0352

	Coefficient	**Std. Error**	**t**	**P**
a	1.7464	0.0202	86.6318	<0.0001
b	0.0024	0.0001	41.6616	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	3.5155	3.5155	2831.4115	<0.0001
Residual	14	0.0174	0.0012		
Total	15	3.5329	0.2355		

PRESS = 0.0216

Durbin-Watson Statistic = 2.4192

Normality Test:
K-S Statistic = 0.1090
Significance Level = 0.9867

Constant Variance Test: P = 0.9869

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.7464	-0.0064	-0.1803	-0.2198	-0.2121
2	1.6432	-0.0332	-0.9413	-1.0829	-1.0902
3	1.5461	0.0139	0.3950	0.4374	0.4244
4	1.3688	0.0412	1.1699	1.2428	1.2697
5	1.2118	0.0182	0.5163	0.5399	0.5258
6	1.1402	-0.0502	-1.4249	-1.4861	-1.5604
7	1.0728	-0.0028	-0.0805	-0.0840	-0.0809
8	0.9498	0.0802	2.2759	2.3794	2.9710
9	0.8409	-0.0409	-1.1602	-1.2190	-1.2424
10	0.7445	0.0055	0.1575	0.1663	0.1604
11	0.6201	-0.0201	-0.5714	-0.6063	-0.5920
12	0.5490	0.0010	0.0278	0.0296	0.0285
13	0.4861	0.0139	0.3957	0.4201	0.4074
14	0.4303	-0.0203	-0.5766	-0.6111	-0.5968
15	0.3810	-0.0310	-0.8789	-0.9288	-0.9239
16	0.1528	0.0372	1.0555	1.0827	1.0899

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0117	0.3273	-0.1480
2	0.1897	0.2444	-0.6201
3	0.0216	0.1845	0.2019
4	0.0993	0.1140	0.4554
5	0.0136	0.0855	0.1608
6	0.0970	0.0807	-0.4624
7	0.0003	0.0799	-0.0238
8	0.2634	0.0851	0.9062
9	0.0772	0.0941	-0.4004
10	0.0016	0.1028	0.0543
11	0.0231	0.1115	-0.2098
12	0.0001	0.1136	0.0102
13	0.0112	0.1128	0.1453
14	0.0230	0.1096	-0.2094
15	0.0503	0.1045	-0.3157
16	0.0305	0.0495	0.2487

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.7464	1.7031	1.7896	1.6593	1.8334
2	1.6432	1.6058	1.6805	1.5589	1.7275
3	1.5461	1.5136	1.5785	1.4638	1.6283
4	1.3688	1.3433	1.3943	1.2890	1.4485
5	1.2118	1.1897	1.2339	1.1331	1.2905
6	1.1402	1.1187	1.1617	1.0616	1.2188
7	1.0728	1.0515	1.0942	0.9943	1.1514
8	0.9498	0.9278	0.9719	0.8711	1.0285
9	0.8409	0.8177	0.8641	0.7618	0.9199
10	0.7445	0.7202	0.7687	0.6651	0.8238
11	0.6201	0.5949	0.6454	0.5405	0.6998
12	0.5490	0.5235	0.5745	0.4693	0.6288
13	0.4861	0.4607	0.5114	0.4063	0.5658
14	0.4303	0.4053	0.4553	0.3507	0.5099
15	0.3810	0.3565	0.4054	0.3015	0.4604
16	0.1528	0.1360	0.1696	0.0754	0.2302

Nonlinear Regression Analysis for Velocity Attenuations with SIGMAPLOT 8.0 at Q=46.8 m³/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.72819}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00192465}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99603947
Rsqr = 0.99209462
Adj Rsqr = 0.99152995

Standard Error of Estimate = 0.0406

	Coefficient	**Std. Error**	**t**	**P**
a	1.7282	0.0221	78.3061	<0.0001
b	0.0019	0.0001	34.2233	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2.9022	2.9022	1756.9468	<0.0001
Residual	14	0.0231	0.0017		
Total	15	2.9254	0.1950		

PRESS = 0.0280

Durbin-Watson Statistic = 1.7416

Normality Test:
K-S Statistic = 0.1986
Significance Level = 0.5064

Constant Variance Test: P = 0.8136

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.7282	0.0118	0.2905	0.3459	0.3348
2	1.6470	-0.0070	-0.1725	-0.1965	-0.1896
3	1.5696	0.0104	0.2550	0.2816	0.2721
4	1.4256	0.0244	0.5997	0.6379	0.6238
5	1.2948	0.0652	1.6035	1.6764	1.8069
6	1.2340	-0.0740	-1.8208	-1.8961	-2.1195
7	1.1760	-0.0760	-1.8708	-1.9447	-2.1935
8	1.0681	0.0119	0.2919	0.3037	0.2936
9	0.9701	-0.0401	-0.9876	-1.0317	-1.0342
10	0.8811	0.0189	0.4643	0.4877	0.4740
11	0.7627	0.0073	0.1798	0.1904	0.1837
12	0.6927	0.0073	0.1792	0.1906	0.1839
13	0.6292	0.0508	1.2508	1.3348	1.3768
14	0.5714	0.0286	0.7027	0.7513	0.7390
15	0.5190	-0.0090	-0.2217	-0.2372	-0.2290
16	0.2522	-0.0322	-0.7920	-0.8301	-0.8203

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0250	0.2949	0.2165
2	0.0058	0.2299	-0.1036
3	0.0087	0.1803	0.1276
4	0.0268	0.1162	0.2262
5	0.1307	0.0851	0.5511
6	0.1518	0.0779	-0.6160
7	0.1524	0.0746	-0.6226
8	0.0038	0.0760	0.0842
9	0.0486	0.0837	-0.3126
10	0.0123	0.0938	0.1525
11	0.0022	0.1086	0.0641
12	0.0024	0.1164	0.0667
13	0.1237	0.1219	0.5130
14	0.0403	0.1251	0.2794
15	0.0041	0.1260	-0.0869
16	0.0339	0.0896	-0.2574

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.7282	1.6809	1.7755	1.6290	1.8274
2	1.6470	1.6052	1.6888	1.5503	1.7437
3	1.5696	1.5326	1.6066	1.4749	1.6643
4	1.4256	1.3959	1.4553	1.3335	1.5177
5	1.2948	1.2694	1.3203	1.2040	1.3856
6	1.2340	1.2097	1.2583	1.1435	1.3245
7	1.1760	1.1522	1.1998	1.0857	1.2664
8	1.0681	1.0441	1.0922	0.9777	1.1586
9	0.9701	0.9449	0.9954	0.8794	1.0609
10	0.8811	0.8544	0.9078	0.7900	0.9723
11	0.7627	0.7340	0.7914	0.6709	0.8545
12	0.6927	0.6630	0.7225	0.6006	0.7848
13	0.6292	0.5987	0.6596	0.5368	0.7215
14	0.5714	0.5406	0.6023	0.4790	0.6639
15	0.5190	0.4881	0.5500	0.4265	0.6115
16	0.2522	0.2261	0.2783	0.1612	0.3432

<u>Nonlinear Regression Analysis for Velocity Attenuations with SIGMAPLOT 8.0 at Q=46.8 m^3/s - Transect 3</u>

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1.74122}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00217981}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99753161
Rsqr = 0.99506931
Adj Rsqr = 0.99471712

Standard Error of Estimate = 0.0339

	Coefficient	**Std. Error**	**t**	**P**
a	1.7412	0.0189	92.0542	<0.0001
b	0.0022	0.0001	42.4405	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	3.2478	3.2478	2825.3619	<0.0001
Residual	14	0.0161	0.0011		
Total	15	3.2638	0.2176		

PRESS = 0.0197

Durbin-Watson Statistic = 1.9799

Normality Test:
K-S Statistic = 0.0948
Significance Level = 0.9978

Constant Variance Test: P = 0.3480

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1.7412	-0.0012	-0.0360	-0.0434	-0.0418
2	1.6489	-0.0189	-0.5566	-0.6375	-0.6234
3	1.5614	0.0186	0.5480	0.6062	0.5919
4	1.4002	0.0298	0.8794	0.9348	0.9303
5	1.2556	0.0444	1.3095	1.3690	1.4175
6	1.1890	-0.0690	-2.0354	-2.1208	-2.4807
7	1.1259	-0.0559	-1.6501	-1.7175	-1.8628
8	1.0097	0.0403	1.1892	1.2401	1.2666
9	0.9054	0.0046	0.1351	0.1416	0.1365
10	0.8119	0.0181	0.5331	0.5616	0.5473
11	0.6895	-0.0295	-0.8692	-0.9217	-0.9164
12	0.6183	-0.0083	-0.2440	-0.2595	-0.2506
13	0.5544	0.0356	1.0492	1.1171	1.1280
14	0.4972	0.0128	0.3782	0.4026	0.3903
15	0.4458	-0.0158	-0.4672	-0.4967	-0.4829
16	0.1969	-0.0069	-0.2025	-0.2097	-0.2024

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0004	0.3113	-0.0281
2	0.0633	0.2375	-0.3479
3	0.0411	0.1827	0.2799
4	0.0568	0.1151	0.3355
5	0.0871	0.0850	0.4321
6	0.1928	0.0790	-0.7263
7	0.1228	0.0769	-0.5376
8	0.0672	0.0804	0.3744
9	0.0010	0.0889	0.0426
10	0.0173	0.0986	0.1810
11	0.0529	0.1107	-0.3233
12	0.0044	0.1157	-0.0907
13	0.0835	0.1180	0.4126
14	0.0108	0.1178	0.1426
15	0.0161	0.1155	-0.1745
16	0.0016	0.0670	-0.0542

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1.7412	1.7007	1.7818	1.6580	1.8245
2	1.6489	1.6134	1.6843	1.5680	1.7298
3	1.5614	1.5303	1.5925	1.4823	1.6405
4	1.4002	1.3755	1.4249	1.3234	1.4770
5	1.2556	1.2344	1.2768	1.1799	1.3313
6	1.1890	1.1686	1.2094	1.1135	1.2645
7	1.1259	1.1058	1.1461	1.0505	1.2014
8	1.0097	0.9891	1.0303	0.9341	1.0853
9	0.9054	0.8837	0.9271	0.8295	0.9813
10	0.8119	0.7891	0.8348	0.7357	0.8881
11	0.6895	0.6653	0.7137	0.6128	0.7661
12	0.6183	0.5935	0.6430	0.5415	0.6951
13	0.5544	0.5294	0.5794	0.4775	0.6313
14	0.4972	0.4722	0.5221	0.4203	0.5741
15	0.4458	0.4211	0.4705	0.3690	0.5226
16	0.1969	0.1780	0.2157	0.1218	0.2720

<u>Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 12.5 m^3/s - Transect 1</u>

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.966512}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00501245}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99718408
Rsqr = 0.99437609
Adj Rsqr = 0.99408010

Standard Error of Estimate = 0.0223

	Coefficient	**Std. Error**	**t**	**P**
a	0.9665	0.0143	67.5591	<0.0001
b	0.0050	0.0001	40.2301	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1.6645	1.6645	3359.4332	<0.0001
Residual	19	0.0094	0.0005		
Total	20	1.6739	0.0837		

PRESS = 0.0118

Durbin-Watson Statistic = 1.3767
Normality Test:

K-S Statistic = 0.1427
Significance Level = 0.7529

Constant Variance Test: P = 0.1072

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.9665	0.0135	0.6059	0.7909	0.7828
2	0.8527	-0.0027	-0.1203	-0.1386	-0.1350
3	0.7523	-0.0523	-2.3474	-2.5539	-3.0674
4	0.6637	-0.0037	-0.1641	-0.1739	-0.1694
5	0.5855	0.0145	0.6519	0.6834	0.6735
6	0.5165	0.0035	0.1558	0.1628	0.1586
7	0.4557	0.0443	1.9904	2.0805	2.3045
8	0.4020	-0.0020	-0.0910	-0.0952	-0.0927
9	0.3547	0.0253	1.1377	1.1923	1.2065
10	0.2760	-0.0060	-0.2718	-0.2848	-0.2778
11	0.2149	-0.0149	-0.6673	-0.6967	-0.6869
12	0.1895	0.0005	0.0203	0.0211	0.0205
13	0.1672	0.0128	0.5739	0.5957	0.5853
14	0.1302	0.0198	0.8916	0.9192	0.9153
15	0.1148	0.0152	0.6818	0.7006	0.6909
16	0.1013	-0.0213	-0.9569	-0.9803	-0.9792
17	0.0894	-0.0194	-0.8702	-0.8888	-0.8837
18	0.0788	-0.0188	-0.8466	-0.8623	-0.8563
19	0.0696	-0.0196	-0.8786	-0.8928	-0.8878
20	0.0614	-0.0214	-0.9598	-0.9732	-0.9718
21	0.0541	-0.0241	-1.0844	-1.0973	-1.1036

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.2201	0.4131	0.6567
2	0.0031	0.2462	-0.0771
3	0.5988	0.1551	-1.3144
4	0.0019	0.1096	-0.0595
5	0.0231	0.0901	0.2119
6	0.0012	0.0843	0.0481
7	0.2005	0.0848	0.7015
8	0.0004	0.0873	-0.0287
9	0.0698	0.0894	0.3781
10	0.0040	0.0892	-0.0869
11	0.0218	0.0825	-0.2060
12	0.0000	0.0774	0.0059
13	0.0137	0.0717	0.1626
14	0.0266	0.0592	0.2296
15	0.0137	0.0530	0.1635
16	0.0237	0.0471	-0.2176
17	0.0171	0.0414	-0.1838
18	0.0140	0.0363	-0.1661
19	0.0130	0.0315	-0.1602
20	0.0133	0.0273	-0.1627
21	0.0145	0.0235	-0.1710

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.9665	0.9366	0.9965	0.9111	1.0219
2	0.8527	0.8296	0.8758	0.8007	0.9047
3	0.7523	0.7339	0.7706	0.7022	0.8023
4	0.6637	0.6482	0.6791	0.6146	0.7127
5	0.5855	0.5715	0.5995	0.5368	0.6341
6	0.5165	0.5030	0.5301	0.4680	0.5650
7	0.4557	0.4421	0.4693	0.4072	0.5042
8	0.4020	0.3883	0.4158	0.3534	0.4506
9	0.3547	0.3407	0.3686	0.3060	0.4033
10	0.2760	0.2621	0.2900	0.2274	0.3247
11	0.2149	0.2015	0.2282	0.1664	0.2633
12	0.1895	0.1766	0.2025	0.1412	0.2379
13	0.1672	0.1548	0.1797	0.1190	0.2155
14	0.1302	0.1188	0.1415	0.0822	0.1781
15	0.1148	0.1041	0.1256	0.0670	0.1626
16	0.1013	0.0912	0.1114	0.0536	0.1490
17	0.0894	0.0799	0.0989	0.0418	0.1369
18	0.0788	0.0700	0.0877	0.0314	0.1263
19	0.0696	0.0613	0.0778	0.0222	0.1169
20	0.0614	0.0537	0.0691	0.0141	0.1086
21	0.0541	0.0470	0.0613	0.0070	0.1013

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 12.5 m³/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.985435}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00446711}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99663043
Rsqr = 0.99327221
Adj Rsqr = 0.99291811

Standard Error of Estimate = 0.0244

	Coefficient	**Std. Error**	**t**	**P**
a	0.9854	0.0151	65.1855	<0.0001
b	0.0045	0.0001	38.4436	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1.6766	1.6766	2805.1065	<0.0001
Residual	19	0.0114	0.0006		
Total	20	1.6879	0.0844		

PRESS = 0.0141

Durbin-Watson Statistic = 1.6345
Normality Test:

K-S Statistic = 0.1454
Significance Level = 0.7320

Constant Variance Test: P = 0.9977

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.9854	-0.0054	-0.2223	-0.2829	-0.2759
2	0.8813	-0.0013	-0.0534	-0.0613	-0.0597
3	0.7882	-0.0582	-2.3798	-2.5905	-3.1351
4	0.7049	0.0151	0.6178	0.6550	0.6449
5	0.6304	0.0496	2.0284	2.1240	2.3674
6	0.5638	0.0062	0.2537	0.2644	0.2578
7	0.5042	0.0258	1.0544	1.0978	1.1041
8	0.4509	0.0091	0.3705	0.3861	0.3772
9	0.4033	0.0167	0.6834	0.7131	0.7035
10	0.3226	-0.0226	-0.9230	-0.9646	-0.9627
11	0.2580	-0.0080	-0.3271	-0.3415	-0.3334
12	0.2307	-0.0107	-0.4391	-0.4576	-0.4479
13	0.2064	-0.0064	-0.2599	-0.2703	-0.2636
14	0.1650	0.0250	1.0206	1.0560	1.0594
15	0.1476	0.0224	0.9159	0.9450	0.9422
16	0.1320	-0.0320	-1.3094	-1.3472	-1.3788
17	0.1181	-0.0281	-1.1478	-1.1778	-1.1907
18	0.1056	-0.0156	-0.6375	-0.6525	-0.6423
19	0.0944	-0.0044	-0.1812	-0.1850	-0.1802
20	0.0845	-0.0045	-0.1821	-0.1854	-0.1807
21	0.0755	-0.0155	-0.6351	-0.6455	-0.6353

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0248	0.3824	-0.2171
2	0.0006	0.2395	-0.0335
3	0.6203	0.1560	-1.3480
4	0.0266	0.1104	0.2272
5	0.2177	0.0880	0.7354
6	0.0030	0.0791	0.0756
7	0.0506	0.0775	0.3200
8	0.0064	0.0791	0.1105
9	0.0226	0.0815	0.2096
10	0.0428	0.0843	-0.2921
11	0.0052	0.0821	-0.0997
12	0.0090	0.0791	-0.1313
13	0.0030	0.0753	-0.0752
14	0.0393	0.0659	0.2813
15	0.0288	0.0607	0.2395
16	0.0532	0.0554	-0.3340
17	0.0367	0.0502	-0.2738
18	0.0101	0.0452	-0.1398
19	0.0007	0.0405	-0.0370
20	0.0006	0.0360	-0.0349
21	0.0069	0.0318	-0.1152

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.9854	0.9538	1.0171	0.9253	1.0456
2	0.8813	0.8563	0.9063	0.8243	0.9383
3	0.7882	0.7680	0.8084	0.7332	0.8432
4	0.7049	0.6879	0.7219	0.6510	0.7588
5	0.6304	0.6152	0.6456	0.5770	0.6838
6	0.5638	0.5494	0.5782	0.5106	0.6170
7	0.5042	0.4900	0.5185	0.4511	0.5573
8	0.4509	0.4366	0.4653	0.3978	0.5041
9	0.4033	0.3887	0.4179	0.3501	0.4565
10	0.3226	0.3077	0.3374	0.2693	0.3758
11	0.2580	0.2433	0.2727	0.2048	0.3112
12	0.2307	0.2163	0.2451	0.1776	0.2839
13	0.2064	0.1923	0.2204	0.1533	0.2594
14	0.1650	0.1519	0.1782	0.1122	0.2179
15	0.1476	0.1350	0.1602	0.0949	0.2003
16	0.1320	0.1200	0.1441	0.0794	0.1846
17	0.1181	0.1066	0.1295	0.0656	0.1705
18	0.1056	0.0947	0.1165	0.0533	0.1579
19	0.0944	0.0841	0.1047	0.0422	0.1466
20	0.0845	0.0747	0.0942	0.0324	0.1365
21	0.0755	0.0664	0.0847	0.0235	0.1275

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 12.5 m^3/s - Transect 3

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.972683}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00475694}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99650850
Rsqr = 0.99302920
Adj Rsqr = 0.99266231

Standard Error of Estimate = 0.0248

	Coefficient	Std. Error	t	P
a	0.9727	0.0157	62.0533	<0.0001
b	0.0048	0.0001	36.8230	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	1.6682	1.6682	2706.6540	<0.0001
Residual	19	0.0117	0.0006		
Total	20	1.6799	0.0840		

PRESS = 0.0144

Durbin-Watson Statistic = 1.4630

Normality Test:
K-S Statistic = 0.1325
Significance Level = 0.8275

Constant Variance Test: P = 0.5888

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.9727	0.0073	0.2947	0.3801	0.3714
2	0.8636	-0.0036	-0.1459	-0.1677	-0.1633
3	0.7668	-0.0568	-2.2875	-2.4893	-2.9516
4	0.6808	-0.0008	-0.0327	-0.0347	-0.0338
5	0.6045	0.0255	1.0281	1.0771	1.0819
6	0.5367	0.0133	0.5357	0.5590	0.5487
7	0.4765	0.0435	1.7513	1.8270	1.9587
8	0.4231	-0.0031	-0.1246	-0.1301	-0.1267
9	0.3757	0.0343	1.3835	1.4469	1.4929
10	0.2961	-0.0161	-0.6500	-0.6803	-0.6704
11	0.2335	-0.0235	-0.9446	-0.9862	-0.9855
12	0.2073	-0.0073	-0.2931	-0.3053	-0.2979
13	0.1840	0.0060	0.2403	0.2496	0.2434
14	0.1451	0.0249	1.0038	1.0367	1.0389
15	0.1288	0.0212	0.8534	0.8787	0.8732
16	0.1144	-0.0244	-0.9816	-1.0076	-1.0081
17	0.1015	-0.0215	-0.8679	-0.8883	-0.8832
18	0.0902	-0.0102	-0.4093	-0.4178	-0.4085
19	0.0801	-0.0201	-0.8077	-0.8224	-0.8151
20	0.0711	-0.0211	-0.8489	-0.8625	-0.8564
21	0.0631	-0.0231	-0.9307	-0.9436	-0.9408

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0479	0.3987	0.3024
2	0.0045	0.2432	-0.0926
3	0.5710	0.1556	-1.2671
4	0.0001	0.1099	-0.0119
5	0.0566	0.0889	0.3380
6	0.0139	0.0817	0.1636
7	0.1475	0.0812	0.5824
8	0.0008	0.0834	-0.0382
9	0.0982	0.0858	0.4572
10	0.0221	0.0871	-0.2071
11	0.0438	0.0826	-0.2957
12	0.0040	0.0785	-0.0869
13	0.0025	0.0736	0.0686
14	0.0358	0.0625	0.2681
15	0.0232	0.0567	0.2140
16	0.0273	0.0510	-0.2336
17	0.0188	0.0455	-0.1929
18	0.0037	0.0404	-0.0838
19	0.0125	0.0356	-0.1565
20	0.0120	0.0312	-0.1536
21	0.0124	0.0272	-0.1572

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.9727	0.9399	1.0055	0.9112	1.0341
2	0.8636	0.8380	0.8892	0.8057	0.9216
3	0.7668	0.7463	0.7873	0.7109	0.8226
4	0.6808	0.6636	0.6980	0.6261	0.7356
5	0.6045	0.5890	0.6200	0.5503	0.6587
6	0.5367	0.5218	0.5516	0.4827	0.5907
7	0.4765	0.4617	0.4913	0.4225	0.5306
8	0.4231	0.4081	0.4381	0.3690	0.4772
9	0.3757	0.3604	0.3909	0.3215	0.4298
10	0.2961	0.2808	0.3115	0.2420	0.3503
11	0.2335	0.2185	0.2484	0.1794	0.2875
12	0.2073	0.1927	0.2218	0.1533	0.2612
13	0.1840	0.1699	0.1981	0.1302	0.2379
14	0.1451	0.1321	0.1581	0.0915	0.1986
15	0.1288	0.1164	0.1412	0.0754	0.1822
16	0.1144	0.1026	0.1261	0.0611	0.1676
17	0.1015	0.0905	0.1126	0.0484	0.1547
18	0.0902	0.0797	0.1006	0.0372	0.1432
19	0.0801	0.0703	0.0898	0.0272	0.1329
20	0.0711	0.0619	0.0802	0.0183	0.1238
21	0.0631	0.0545	0.0717	0.0104	0.1158

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 10.3 m³/s - Transect 1

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.828147}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00568362}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99719384
Rsqr = 0.99439555
Adj Rsqr = 0.99402192

Standard Error of Estimate = 0.0191

	Coefficient	**Std. Error**	**t**	**P**
a	0.8281	0.0130	63.9141	<0.0001
b	0.0057	0.0002	37.0824	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.9675	0.9675	2661.4440	<0.0001
Residual	15	0.0055	0.0004		
Total	16	0.9730	0.0608		

PRESS = 0.0068

Durbin-Watson Statistic = 2.6813

Normality Test:
K-S Statistic = 0.1762
Significance Level = 0.6230

Constant Variance Test: P = 0.9059

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.8281	0.0019	0.0972	0.1325	0.1280
2	0.7185	-0.0085	-0.4433	-0.5137	-0.5007
3	0.6233	-0.0233	-1.2214	-1.3277	-1.3654
4	0.5407	0.0493	2.5841	2.7398	3.7449
5	0.4691	0.0009	0.0469	0.0493	0.0477
6	0.4070	-0.0270	-1.4145	-1.4884	-1.5575
7	0.3531	0.0069	0.3638	0.3837	0.3725
8	0.3063	0.0037	0.1942	0.2052	0.1985
9	0.2657	0.0043	0.2241	0.2370	0.2294
10	0.2000	0.0100	0.5248	0.5534	0.5401
11	0.1505	-0.0305	-1.6008	-1.6756	-1.7955
12	0.1306	0.0094	0.4939	0.5146	0.5016
13	0.1133	-0.0133	-0.6969	-0.7229	-0.7109
14	0.0853	0.0147	0.7729	0.7949	0.7846
15	0.0740	0.0060	0.3163	0.3240	0.3141
16	0.0642	-0.0042	-0.2188	-0.2233	-0.2161
17	0.0557	-0.0057	-0.2975	-0.3027	-0.2933

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0075	0.4618	0.1186
2	0.0452	0.2550	-0.2929
3	0.1600	0.1536	-0.5817
4	0.4659	0.1104	1.3194
5	0.0001	0.0970	0.0156
6	0.1187	0.0968	-0.5098
7	0.0083	0.1008	0.1247
8	0.0025	0.1045	0.0678
9	0.0033	0.1059	0.0790
10	0.0171	0.1006	0.1806
11	0.1342	0.0873	-0.5552
12	0.0114	0.0792	0.1471
13	0.0199	0.0707	-0.1962
14	0.0182	0.0545	0.1884
15	0.0026	0.0471	0.0698
16	0.0010	0.0404	-0.0443
17	0.0016	0.0343	-0.0553

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.8281	0.8005	0.8558	0.7790	0.8773
2	0.7185	0.6979	0.7390	0.6729	0.7640
3	0.6233	0.6074	0.6392	0.5796	0.6669
4	0.5407	0.5272	0.5542	0.4979	0.5836
5	0.4691	0.4565	0.4818	0.4265	0.5117
6	0.4070	0.3943	0.4196	0.3644	0.4495
7	0.3531	0.3402	0.3660	0.3104	0.3957
8	0.3063	0.2932	0.3194	0.2636	0.3490
9	0.2657	0.2525	0.2790	0.2230	0.3085
10	0.2000	0.1871	0.2129	0.1574	0.2426
11	0.1505	0.1385	0.1625	0.1081	0.1929
12	0.1306	0.1191	0.1420	0.0884	0.1728
13	0.1133	0.1025	0.1241	0.0712	0.1553
14	0.0853	0.0758	0.0948	0.0435	0.1270
15	0.0740	0.0651	0.0828	0.0324	0.1156
16	0.0642	0.0560	0.0723	0.0227	0.1056
17	0.0557	0.0481	0.0632	0.0143	0.0970

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 10.3 m³/s - Transect 2

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.836437}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00527036}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99780824
Rsqr = 0.99562128
Adj Rsqr = 0.99532936

Standard Error of Estimate = 0.0169

	Coefficient	**Std. Error**	**t**	**P**
a	0.8364	0.0112	74.4730	<0.0001
b	0.0053	0.0001	42.7554	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.9761	0.9761	3410.6556	<0.0001
Residual	15	0.0043	0.0003		
Total	16	0.9804	0.0613		

PRESS = 0.0054

Durbin-Watson Statistic = 2.0426

Normality Test:
K-S Statistic = 0.2501
Significance Level = 0.2042

Constant Variance Test: P = 0.7801

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.8364	-0.0064	-0.3805	-0.5088	-0.4959
2	0.7332	-0.0032	-0.1880	-0.2174	-0.2104
3	0.6427	-0.0127	-0.7490	-0.8147	-0.8051
4	0.5633	0.0367	2.1673	2.2973	2.7567
5	0.4938	0.0062	0.3669	0.3855	0.3743
6	0.4328	-0.0328	-1.9409	-2.0365	-2.3130
7	0.3794	0.0006	0.0353	0.0371	0.0359
8	0.3326	0.0174	1.0305	1.0859	1.0929
9	0.2915	-0.0015	-0.0893	-0.0943	-0.0911
10	0.2240	0.0260	1.5380	1.6218	1.7254
11	0.1721	-0.0021	-0.1238	-0.1299	-0.1255
12	0.1508	-0.0008	-0.0502	-0.0525	-0.0507
13	0.1322	-0.0122	-0.7228	-0.7524	-0.7410
14	0.1016	-0.0016	-0.0944	-0.0974	-0.0942
15	0.0891	-0.0091	-0.5352	-0.5505	-0.5373
16	0.0781	-0.0181	-1.0676	-1.0942	-1.1020
17	0.0684	-0.0084	-0.4980	-0.5087	-0.4957

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.1020	0.4408	-0.4402
2	0.0080	0.2522	-0.1222
3	0.0608	0.1547	-0.3445
4	0.3260	0.1100	0.9690
5	0.0077	0.0938	0.1204
6	0.2093	0.0917	-0.7349
7	0.0001	0.0951	0.0116
8	0.0650	0.0993	0.3628
9	0.0005	0.1021	-0.0307
10	0.1473	0.1007	0.5774
11	0.0008	0.0912	-0.0398
12	0.0001	0.0845	-0.0154
13	0.0237	0.0772	-0.2143
14	0.0003	0.0621	-0.0242
15	0.0088	0.0549	-0.1295
16	0.0302	0.0480	-0.2476
17	0.0056	0.0418	-0.1035

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.8364	0.8125	0.8604	0.7932	0.8797
2	0.7332	0.7151	0.7513	0.6928	0.7735
3	0.6427	0.6285	0.6569	0.6039	0.6814
4	0.5633	0.5514	0.5753	0.5253	0.6013
5	0.4938	0.4827	0.5048	0.4561	0.5315
6	0.4328	0.4219	0.4438	0.3952	0.4705
7	0.3794	0.3683	0.3905	0.3417	0.4171
8	0.3326	0.3212	0.3439	0.2948	0.3704
9	0.2915	0.2800	0.3030	0.2537	0.3294
10	0.2240	0.2125	0.2354	0.1861	0.2618
11	0.1721	0.1612	0.1830	0.1344	0.2098
12	0.1508	0.1404	0.1613	0.1133	0.1884
13	0.1322	0.1222	0.1422	0.0948	0.1697
14	0.1016	0.0926	0.1106	0.0644	0.1388
15	0.0891	0.0806	0.0975	0.0520	0.1261
16	0.0781	0.0702	0.0860	0.0411	0.1150
17	0.0684	0.0611	0.0758	0.0316	0.1052

<u>Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 10.3 m^3/s - Transect 3</u>

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.827153}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00553378}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99751043
Rsqr = 0.99502705
Adj Rsqr = 0.99469552

Standard Error of Estimate = 0.0179

	Coefficient	**Std. Error**	**t**	**P**
a	0.8272	0.0120	68.6527	<0.0001
b	0.0055	0.0001	39.6951	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.9593	0.9593	3001.3200	<0.0001
Residual	15	0.0048	0.0003		
Total	16	0.9640	0.0603		

PRESS = 0.0059

Durbin-Watson Statistic = 2.9562

Normality Test:
K-S Statistic = 0.0844
Significance Level = 0.9995

Constant Variance Test: P = 0.8094

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.8272	0.0028	0.1592	0.2155	0.2085
2	0.7203	-0.0003	-0.0159	-0.0184	-0.0178
3	0.6272	-0.0172	-0.9633	-1.0474	-1.0510
4	0.5462	0.0238	1.3321	1.4122	1.4652
5	0.4756	0.0044	0.2452	0.2578	0.2497
6	0.4142	-0.0342	-1.9111	-2.0088	-2.2699
7	0.3607	0.0093	0.5227	0.5506	0.5374
8	0.3141	0.0159	0.8917	0.9413	0.9375
9	0.2735	-0.0135	-0.7541	-0.7969	-0.7868
10	0.2074	0.0226	1.2654	1.3344	1.3732
11	0.1573	-0.0073	-0.4057	-0.4250	-0.4131
12	0.1369	0.0231	1.2901	1.3459	1.3867
13	0.1192	-0.0292	-1.6358	-1.6991	-1.8266
14	0.0904	0.0096	0.5358	0.5518	0.5386
15	0.0787	0.0013	0.0706	0.0724	0.0699
16	0.0686	-0.0086	-0.4791	-0.4898	-0.4770
17	0.0597	-0.0097	-0.5430	-0.5533	-0.5400

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0193	0.4542	0.1902
2	0.0001	0.2541	-0.0104
3	0.0999	0.1540	-0.4485
4	0.1235	0.1102	0.5156
5	0.0035	0.0957	0.0812
6	0.2115	0.0949	-0.7349
7	0.0166	0.0987	0.1778
8	0.0507	0.1027	0.3171
9	0.0371	0.1046	-0.2689
10	0.0997	0.1007	0.4596
11	0.0088	0.0888	-0.1290
12	0.0800	0.0812	0.4122
13	0.1139	0.0731	-0.5131
14	0.0092	0.0572	0.1327
15	0.0001	0.0499	0.0160
16	0.0054	0.0431	-0.1012
17	0.0059	0.0369	-0.1057

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.8272	0.8015	0.8528	0.7812	0.8731
2	0.7203	0.7011	0.7395	0.6776	0.7630
3	0.6272	0.6123	0.6422	0.5863	0.6682
4	0.5462	0.5335	0.5588	0.5060	0.5863
5	0.4756	0.4638	0.4874	0.4357	0.5155
6	0.4142	0.4024	0.4259	0.3743	0.4540
7	0.3607	0.3487	0.3726	0.3207	0.4006
8	0.3141	0.3018	0.3263	0.2740	0.3541
9	0.2735	0.2612	0.2858	0.2334	0.3135
10	0.2074	0.1953	0.2195	0.1674	0.2474
11	0.1573	0.1459	0.1686	0.1175	0.1970
12	0.1369	0.1261	0.1478	0.0973	0.1766
13	0.1192	0.1089	0.1295	0.0798	0.1587
14	0.0904	0.0813	0.0995	0.0512	0.1296
15	0.0787	0.0702	0.0872	0.0397	0.1178
16	0.0686	0.0607	0.0765	0.0296	0.1075
17	0.0597	0.0524	0.0670	0.0209	0.0985

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 6.9 m³/s - Transect 1

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.553773}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0136532}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99721005
Rsqr = 0.99442789
Adj Rsqr = 0.99331346

Standard Error of Estimate = 0.0145

	Coefficient	**Std. Error**	**t**	**P**
a	0.5538	0.0128	43.3207	<0.0001
b	0.0137	0.0006	23.7171	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.1871	0.1871	892.3255	<0.0001
Residual	5	0.0010	0.0002		
Total	6	0.1881	0.0314		

PRESS = 0.0018

Durbin-Watson Statistic = 2.1389

Normality Test:
K-S Statistic = 0.2293
Significance Level = 0.8017

Constant Variance Test: P = 0.4907

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	0.5538	-0.0038	-0.2606	-0.5547	-0.5122
2	0.3936	-0.0036	-0.2510	-0.2903	-0.2619
3	0.2798	0.0202	1.3947	1.5698	1.9717
4	0.1989	-0.0089	-0.6141	-0.6983	-0.6575
5	0.1414	0.0086	0.5955	0.6721	0.6303
6	0.1005	-0.0005	-0.0341	-0.0377	-0.0337
7	0.0714	-0.0214	-1.4802	-1.5929	-2.0302

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.5435	0.7794	-0.9626
2	0.0142	0.2523	-0.1521
3	0.3289	0.2107	1.0187
4	0.0715	0.2268	-0.3561
5	0.0619	0.2150	0.3298
6	0.0002	0.1794	-0.0158
7	0.2006	0.1365	-0.8073

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.5538	0.5209	0.5866	0.5041	0.6034
2	0.3936	0.3749	0.4123	0.3520	0.4353
3	0.2798	0.2627	0.2969	0.2388	0.3208
4	0.1989	0.1812	0.2166	0.1577	0.2401
5	0.1414	0.1241	0.1586	0.1003	0.1824
6	0.1005	0.0847	0.1163	0.0601	0.1409
7	0.0714	0.0577	0.0852	0.0318	0.1111

<u>Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 6.9 m³/s - Transect 2</u>

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.565217}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0106665}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.98959700
Rsqr = 0.97930222
Adj Rsqr = 0.97516266

Standard Error of Estimate = 0.0265

	Coefficient	**Std. Error**	**t**	**P**
a	0.5652	0.0225	25.1213	<0.0001
b	0.0107	0.0008	12.9884	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	0.1657	0.1657	236.5718	<0.0001
Residual	5	0.0035	0.0007		
Total	6	0.1692	0.0282		

PRESS = 0.0080

Durbin-Watson Statistic = 1.6516
Normality Test:

K-S Statistic = 0.2625
Significance Level = 0.6494

Constant Variance Test: P = 0.9684

Power of performed test with alpha = 0.0500: 0.9995

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	0.5652	-0.0152	-0.5750	-1.0920	-1.1192
2	0.4329	-0.0029	-0.1102	-0.1277	-0.1144
3	0.3316	0.0484	1.8294	2.0242	4.2609
4	0.2540	0.0060	0.2278	0.2554	0.2300
5	0.1945	-0.0245	-0.9267	-1.0510	-1.0650
6	0.1490	-0.0090	-0.3398	-0.3841	-0.3487
7	0.1141	-0.0141	-0.5334	-0.5942	-0.5513

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	1.5542	0.7228	-1.8071
2	0.0028	0.2553	-0.0670
3	0.4595	0.1832	2.0179
4	0.0084	0.2047	0.1167
5	0.1581	0.2226	-0.5698
6	0.0205	0.2174	-0.1838
7	0.0425	0.1941	-0.2706

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	0.5652	0.5074	0.6231	0.4759	0.6545
2	0.4329	0.3985	0.4673	0.3567	0.5091
3	0.3316	0.3025	0.3607	0.2576	0.4056
4	0.2540	0.2232	0.2847	0.1793	0.3286
5	0.1945	0.1624	0.2266	0.1193	0.2697
6	0.1490	0.1173	0.1807	0.0739	0.2241
7	0.1141	0.0841	0.1441	0.0398	0.1885

Nonlinear Regression Analysis for Velocity Attenuations with SigmaPlot 8.0 at Q = 6.9 m³/s - Transect 3

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 0.561354}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.012199}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99222931
Rsqr = 0.98451900
Adj Rsqr = 0.98142280

Standard Error of Estimate = 0.0239

	Coefficient	Std. Error	t	P
a	0.5614	0.0207	27.1207	<0.0001
b	0.0122	0.0008	14.5331	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	0.1809	0.1809	317.9765	<0.0001
Residual	5	0.0028	0.0006		
Total	6	0.1837	0.0306		

PRESS = 0.0063

Durbin-Watson Statistic = 1.9478

Normality Test:
K-S Statistic = 0.3971
Significance Level = 0.1664

Constant Variance Test: P = 0.8429

Power of performed test with alpha = 0.0500: 0.9998

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	0.5614	-0.0114	-0.4760	-0.9580	-0.9482
2	0.4138	-0.0038	-0.1592	-0.1842	-0.1653
3	0.3050	0.0450	1.8855	2.1032	5.5395
4	0.2248	-0.0048	-0.2033	-0.2297	-0.2065
5	0.1657	-0.0157	-0.6601	-0.7475	-0.7094
6	0.1222	-0.0022	-0.0913	-0.1020	-0.0913
7	0.0901	-0.0201	-0.8411	-0.9193	-0.9020

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	1.3993	0.7531	-1.6560
2	0.0057	0.2527	-0.0961
3	0.5402	0.1963	2.7376
4	0.0073	0.2168	-0.1087
5	0.0788	0.2201	-0.3768
6	0.0013	0.1982	-0.0454
7	0.0822	0.1628	-0.3978

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	0.5614	0.5081	0.6146	0.4802	0.6425
2	0.4138	0.3830	0.4446	0.3452	0.4824
3	0.3050	0.2779	0.3322	0.2380	0.3721
4	0.2248	0.1963	0.2534	0.1572	0.2925
5	0.1657	0.1370	0.1945	0.0980	0.2335
6	0.1222	0.0949	0.1495	0.0551	0.1893
7	0.0901	0.0653	0.1148	0.0239	0.1562

APPENDIX – B: SUSPENDED PARTICULATE MATTER CONCENTRATION

Ten sets of measurements, which are in the water discharge range of 3.8-46.8 m^3/s, were used to study the suspended particulate matter concentration (SPMC) structure in the Jordan River – Lake Kinneret contact zone. The experimental SPMC values and corresponding SPMC attenuation graphs for Q = 46.8 m^3/s, Q = 12.5 m^3/s, Q = 10.3 m^3/s and Q = 6.9 m^3/s can be found in Chapter 7. Their full non-linear regression analyses are at the end of Appendix B.

The tabulated SPMC values, full non-linear regression analyses, and SPMC attenuation graphs for all other six cases can be found in Appendix B.

Table B.1: Experiment #2 – SPMC values for Q = 39.1 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	3150	3150	3150
2	25	2410	2680	2550
3	50	2100	2170	1990
4	100	1230	1640	1350
5	150	1100	1460	1240
6	175	980	1400	1090
7	200	870	1330	1010
8	250	760	1100	930
9	300	660	1050	770
10	350	520	930	630
11	425	490	810	510
12	475	330	740	470
13	525	310	620	400
14	575	300	590	330
15	625	240	520	310
16	1000	74	230	110

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=39.1 m^3/s Transect 1 before bar

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 3130.83}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00902442}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99443289
Rsqr = 0.98889678
Adj Rsqr = 0.98334517

Standard Error of Estimate = 102.5814

	Coefficient	**Std. Error**	**t**	**P**
a	3130.8300	89.9657	34.8003	0.0008
b	0.0090	0.0008	11.6880	0.0072

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1874429.1202	1874429.1202	178.1279	0.0056
Residual	2	21045.8798	10522.9399		
Total	3	1895475.0000	631825.0000		

PRESS = 58172.0684

Durbin-Watson Statistic = 3.3624

Normality Test:
K-S Statistic = 0.1827
Significance Level = 0.9975

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.8366

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	3130.8300	19.1700	0.1869	0.3890	0.2861
2	2498.4925	-88.4925	-0.8627	-1.0231	-1.0479
3	1993.8689	106.1311	1.0346	1.2713	2.0521
4	1269.7953	-39.7953	-0.3879	-0.6166	-0.4844

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.2520	0.7692	0.5222
2	0.2128	0.2890	-0.6681
3	0.4121	0.3377	1.4654
4	0.2900	0.6041	-0.5984

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	3130.8300	2743.7390	3517.9210	2543.7621	3717.8979
2	2498.4925	2261.2033	2735.7816	1997.3783	2999.6067
3	1993.8689	1737.3754	2250.3624	1483.3807	2504.3571
4	1269.7953	926.7442	1612.8464	710.7842	1828.8063

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=39.1 m^3/s Transect 2 before bar</u>

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 3140.94}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00674254}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99703249
Rsqr = 0.99407378
Adj Rsqr = 0.99111067

Standard Error of Estimate = 61.3687

	Coefficient	Std. Error	t	P
a	3140.9398	52.4151	59.9243	0.0003
b	0.0067	0.0004	16.8457	0.0035

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	1263467.7723	1263467.7723	335.4832	0.0030
Residual	2	7532.2277	3766.1138		
Total	3	1271000.0000	423666.6667		

PRESS = 27848.2099

Durbin-Watson Statistic = 2.9782

Normality Test:
K-S Statistic = 0.3218
Significance Level = 0.7115

Constant Variance Test: (P = <0.0001)

Power of performed test with alpha = 0.0500: 0.9025

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	3140.9398	9.0602	0.1476	0.2839	0.2049
2	2653.7098	26.2902	0.4284	0.5084	0.3853
3	2242.0602	-72.0602	-1.1742	-1.4132	-26.2538
4	1600.4235	39.5765	0.6449	1.1241	1.3101

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.1086	0.7295	0.3365
2	0.0528	0.2900	0.2462
3	0.4478	0.3096	-17.5812
4	1.2880	0.6709	1.8705

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	3140.9398	2915.4158	3366.4638	2793.6899	3488.1896
2	2653.7098	2511.5129	2795.9067	2353.8076	2953.6121
3	2242.0602	2095.1378	2388.9826	1939.8887	2544.2316
4	1600.4235	1384.1469	1816.7001	1259.1070	1941.7400

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=39.1 m^3/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 3145.13}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0086731}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99900789
Rsqr = 0.99801676
Adj Rsqr = 0.99702514

Standard Error of Estimate = 41.9798

	Coefficient	**Std. Error**	**t**	**P**
a	3145.1315	36.6752	85.7564	0.0001
b	0.0087	0.0003	28.1693	0.0013

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1773675.3890	1773675.3890	1006.4517	0.0010
Residual	2	3524.6110	1762.3055		
Total	3	1777200.0000	592400.0000		

PRESS = 11929.0212

Durbin-Watson Statistic = 2.9942

Normality Test:
K-S Statistic = 0.3065
Significance Level = 0.7658

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.9674

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	3145.1315	4.8685	0.1160	0.2383	0.1710
2	2532.0475	17.9525	0.4276	0.5071	0.3841
3	2038.4725	-48.4725	-1.1547	-1.4140	-61.5599
4	1321.2072	28.7928	0.6859	1.1050	1.2519

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0916	0.7632	0.3070
2	0.0522	0.2889	0.2448
3	0.4996	0.3332	-43.5164
4	0.9739	0.6147	1.5812

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	3145.1315	2987.3310	3302.9321	2905.2852	3384.9779
2	2532.0475	2434.9709	2629.1240	2326.9886	2737.1063
3	2038.4725	1934.2096	2142.7355	1829.9156	2247.0295
4	1321.2072	1179.5920	1462.8223	1091.6857	1550.7286

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=39.1 m^3/s Transect 1 after bar

```
[Variables]
x = col(6)
y = col(7)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1240.96}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.003204}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99681359
Rsqr = 0.99363733
Adj Rsqr = 0.99305891

Standard Error of Estimate = 30.0858

	Coefficient	**Std. Error**	**t**	**P**
a	1240.9638	20.3398	61.0116	<0.0001
b	0.0032	0.0001	31.0505	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1554904.2304	1554904.2304	1717.8341	<0.0001
Residual	11	9956.6927	905.1539		
Total	12	1564860.9231	130405.0769		

PRESS = 14056.4324

Durbin-Watson Statistic = 2.8318

Normality Test:
K-S Statistic = 0.1439
Significance Level = 0.9321

Constant Variance Test: Passed (P = 0.8065)

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1240.9638	-10.9638	-0.3644	-0.4946	-0.4769
2	1057.2682	42.7318	1.4203	1.6103	1.7563
3	975.8840	4.1160	0.1368	0.1496	0.1428
4	900.7644	-30.7644	-1.0226	-1.0958	-1.1070
5	767.4273	-7.4273	-0.2469	-0.2610	-0.2496
6	653.8277	6.1723	0.2052	0.2174	0.2078
7	557.0438	-37.0438	-1.2313	-1.3142	-1.3648
8	438.0548	51.9452	1.7266	1.8577	2.1382
9	373.2110	-43.2110	-1.4363	-1.5474	-1.6680
10	317.9659	-7.9659	-0.2648	-0.2847	-0.2725
11	270.8985	29.1015	0.9673	1.0356	1.0394
12	230.7983	9.2017	0.3058	0.3255	0.3119
13	69.4110	4.5890	0.1525	0.1554	0.1483

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.1030	0.4571	-0.4375
2	0.3700	0.2220	0.9382
3	0.0022	0.1634	0.0631
4	0.0891	0.1292	-0.4264
5	0.0040	0.1053	-0.0856
6	0.0029	0.1099	0.0730
7	0.1203	0.1223	-0.5094
8	0.2722	0.1362	0.8492
9	0.1924	0.1385	-0.6687
10	0.0063	0.1352	-0.1077
11	0.0784	0.1276	0.3975
12	0.0070	0.1171	0.1136
13	0.0005	0.0363	0.0288

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1240.9638	1196.1963	1285.7314	1161.0326	1320.8951
2	1057.2682	1026.0664	1088.4700	984.0670	1130.4695
3	975.8840	949.1152	1002.6528	904.4596	1047.3084
4	900.7644	876.9601	924.5687	830.3974	971.1314
5	767.4273	745.9436	788.9111	697.8111	837.0436
6	653.8277	631.8793	675.7761	584.0667	723.5887
7	557.0438	533.8883	580.1994	486.8936	627.1940
8	438.0548	413.6136	462.4960	367.4698	508.6398
9	373.2110	348.5712	397.8509	302.5570	443.8651
10	317.9659	293.6204	342.3114	247.4140	388.5178
11	270.8985	247.2451	294.5519	200.5824	341.2146
12	230.7983	208.1340	253.4626	160.8087	300.7879
13	69.4110	56.8006	82.0213	2.0026	136.8193

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=39.1 m^3/s Transect 2 after bar

```
[Variables]
x = col(6)
y = col(8)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1629.84}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0021966}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99817668
Rsqr = 0.99635669
Adj Rsqr = 0.99602548

Standard Error of Estimate = 26.5054

	Coefficient	Std. Error	t	P
a	1629.8362	16.3028	99.9727	<0.0001
b	0.0022	0.0000	44.1804	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	2113395.1620	2113395.1620	3008.2302	<0.0001
Residual	11	7727.9149	702.5377		
Total	12	2121123.0769	176760.2564		

PRESS = 9943.1313

Durbin-Watson Statistic = 2.4309

Normality Test:
K-S Statistic = 0.2631
Significance Level = 0.2827

Constant Variance Test: P = 0.9783

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	1629.8362	10.1638	0.3835	0.4863	0.4688
2	1460.3112	-0.3112	-0.0117	-0.0133	-0.0126
3	1382.2804	17.7196	0.6685	0.7324	0.7160
4	1308.4191	21.5809	0.8142	0.8745	0.8644
5	1172.3258	-72.3258	-2.7287	-2.8741	-5.4913
6	1050.3881	-0.3881	-0.0146	-0.0154	-0.0146
7	941.1335	-11.1335	-0.4200	-0.4427	-0.4259
8	798.1847	11.8153	0.4458	0.4754	0.4580
9	715.1627	24.8373	0.9371	1.0072	1.0079
10	640.7761	-20.7761	-0.7838	-0.8478	-0.8361
11	574.1267	15.8733	0.5989	0.6505	0.6325
12	514.4098	5.5902	0.2109	0.2295	0.2194
13	225.7200	4.2800	0.1615	0.1709	0.1631

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0720	0.3783	0.3657
2	0.0000	0.2160	-0.0066
3	0.0537	0.1668	0.3204
4	0.0587	0.1331	0.3386
5	0.4519	0.0986	-1.8164
6	0.0000	0.0920	-0.0047
7	0.0109	0.0998	-0.1418
8	0.0155	0.1207	0.1697
9	0.0788	0.1344	0.3972
10	0.0611	0.1452	-0.3447
11	0.0380	0.1524	0.2682
12	0.0049	0.1557	0.0942
13	0.0017	0.1069	0.0565

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1629.8362	1593.9540	1665.7185	1561.3464	1698.3261
2	1460.3112	1433.1985	1487.4239	1395.9806	1524.6418
3	1382.2804	1358.4527	1406.1081	1319.2638	1445.2970
4	1308.4191	1287.1379	1329.7003	1246.3206	1370.5175
5	1172.3258	1154.0049	1190.6467	1111.1786	1233.4730
6	1050.3881	1032.6929	1068.0832	989.4254	1111.3507
7	941.1335	922.7084	959.5586	879.9549	1002.3120
8	798.1847	777.9145	818.4549	736.4254	859.9440
9	715.1627	693.7754	736.5500	653.0278	777.2976
10	640.7761	618.5440	663.0082	578.3454	703.2068
11	574.1267	551.3541	596.8993	511.5015	636.7519
12	514.4098	491.3880	537.4315	451.6935	577.1260
13	225.7200	206.6422	244.7979	164.3417	287.0983

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=39.1 m^3/s Transect 3 after bar</u>

```
[Variables]
x = col(6)
y = col(9)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1377.08}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00292612}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99788987
Rsqr = 0.99578420
Adj Rsqr = 0.99540095

Standard Error of Estimate = 26.5619

	Coefficient	Std. Error	t	P
a	1377.0758	17.5313	78.5495	<0.0001
b	0.0029	0.0001	38.8558	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	1833146.7949	1833146.7949	2598.2324	<0.0001
Residual	11	7760.8974	705.5361		
Total	12	1840907.6923	53408.9744		

PRESS = 12241.7405

Durbin-Watson Statistic = 2.4409

Normality Test:
K-S Statistic = 0.1573
Significance Level = 0.8761

Constant Variance Test: P = 0.0254

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1377.0758	-27.0758	-1.0193	-1.3569	-1.4178
2	1189.6465	50.3535	1.8957	2.1481	2.6881
3	1105.7271	-15.7271	-0.5921	-0.6478	-0.6298
4	1027.7276	-17.7276	-0.6674	-0.7155	-0.6987
5	887.8469	42.1531	1.5870	1.6751	1.8505
6	767.0049	2.9951	0.1128	0.1191	0.1137
7	662.6104	-32.6104	-1.2277	-1.3058	-1.3545
8	532.0450	-22.0450	-0.8299	-0.8915	-0.8824
9	459.6301	10.3699	0.3904	0.4208	0.4045
10	397.0713	2.9287	0.1103	0.1189	0.1134
11	343.0272	-13.0272	-0.4904	-0.5276	-0.5095
12	296.3389	13.6611	0.5143	0.5509	0.5327
13	98.9098	11.0902	0.4175	0.4283	0.4118

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.7105	0.4356	-1.2456
2	0.6552	0.2212	1.4325
3	0.0413	0.1646	-0.2796
4	0.0382	0.1299	-0.2700
5	0.1601	0.1024	0.6252
6	0.0008	0.1042	0.0388
7	0.1120	0.1161	-0.4909
8	0.0611	0.1332	-0.3460
9	0.0143	0.1391	0.1626
10	0.0011	0.1398	0.0457
11	0.0219	0.1359	-0.2020
12	0.0224	0.1285	0.2045
13	0.0048	0.0495	0.0939

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	1377.0758	1338.4896	1415.6620	1307.0276	1447.1240
2	1189.6465	1162.1522	1217.1408	1125.0416	1254.2514
3	1105.7271	1082.0084	1129.4459	1042.6364	1168.8178
4	1027.7276	1006.6534	1048.8017	965.5828	1089.8723
5	887.8469	869.1349	906.5588	826.4629	949.2309
6	767.0049	748.1353	785.8746	705.5727	828.4371
7	662.6104	642.6916	682.5292	600.8478	724.3729
8	532.0450	510.7043	553.3857	469.8093	594.2806
9	459.6301	437.8245	481.4357	397.2334	522.0267
10	397.0713	375.2146	418.9280	334.6568	459.4858
11	343.0272	321.4778	364.5766	280.7197	405.3348
12	296.3389	275.3836	317.2942	234.2343	358.4435
13	98.9098	85.9061	111.9135	39.0186	158.8009

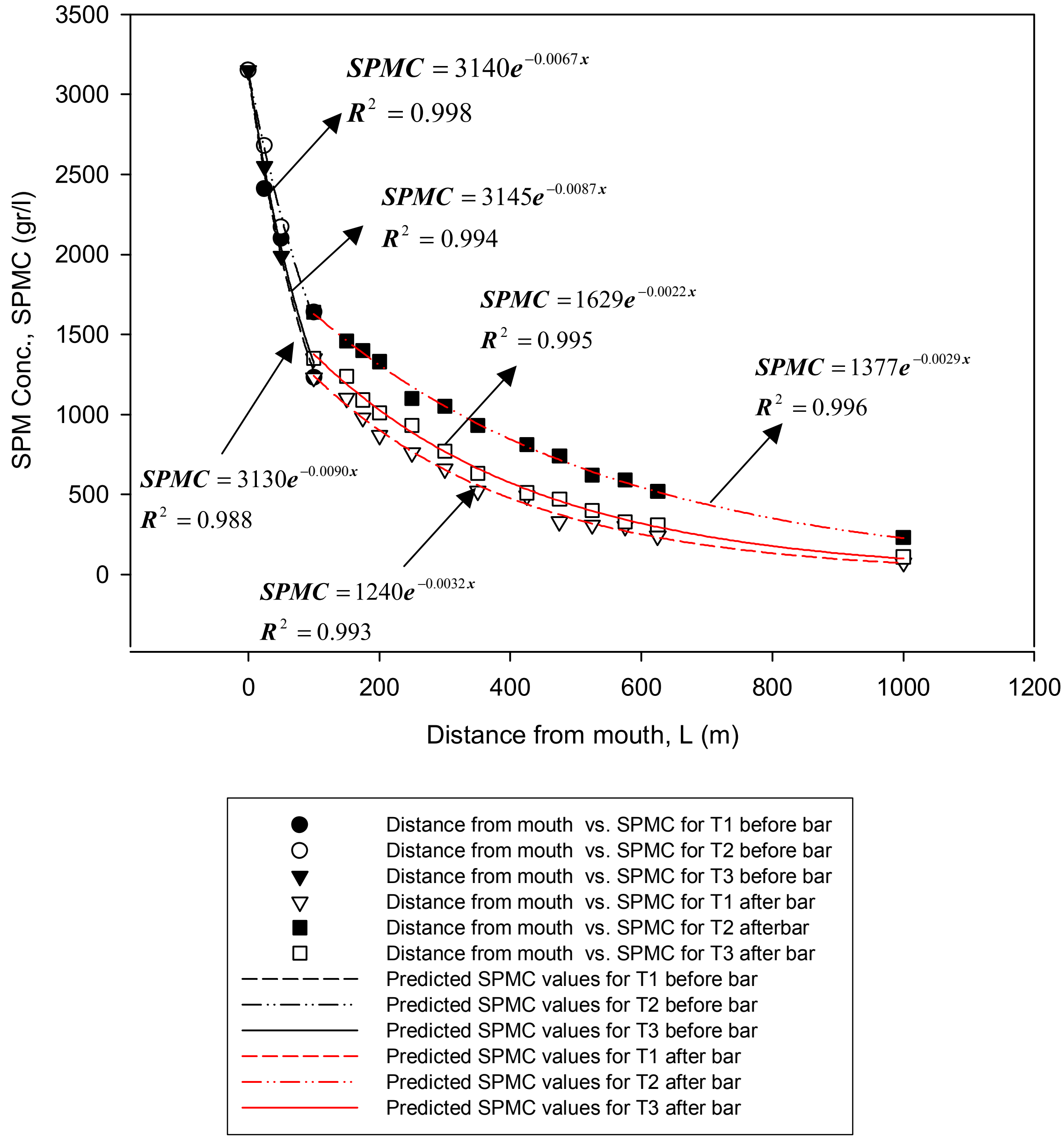

Figure B.1: SPM Concentrations at jet flow for 3 transects at Q = 39.1 m^3/s

Table B.2: Experiment #3 – SPMC values for Q = 32.7 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	1660	1660	1660
2	25	1280	1330	1290
3	50	960	1100	990
4	100	590	680	630
5	150	490	580	550
6	175	460	510	480
7	200	400	480	420
8	250	330	430	350
9	300	270	390	310
10	350	210	350	290
11	425	200	270	220
12	475	170	210	190
13	525	120	190	160
14	575	110	150	110
15	625	93	140	92
16	1000	25	49	33

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=32.7 m^3/s Transect 1 before bar

[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x) "Auto {{previous: 1658.06}}
b = if(x50(x,y)-min(x)=0, 1, -ln(.5)/(x50(x,y)-min(x))) "Auto {{previous: 0.0105449}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100

R = 0.99956504
Rsqr = 0.99913027
Adj Rsqr = 0.99869541

Standard Error of Estimate = 16.4686

	Coefficient	Std. Error	t	P
a	1658.0573	14.6727	113.0028	<0.0001
b	0.0105	0.0003	41.1268	0.0006

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	623132.5722	623132.5722	2297.5689	0.0004
Residual	2	542.4278	271.2139		
Total	3	623675.0000	207891.6667		

PRESS = 1788.2621

Durbin-Watson Statistic = 2.9411

Normality Test:
K-S Statistic = 0.3075
Significance Level = 0.7624

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.9880

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1658.0573	1.9427	0.1180	0.2598	0.1869
2	1273.8260	6.1740	0.3749	0.4453	0.3318
3	978.6349	-18.6349	-1.1315	-1.4117	-16.8158
4	577.6195	12.3805	0.7518	1.1299	1.3287

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.1299	0.7938	0.3666
2	0.0408	0.2913	0.2127
3	0.5546	0.3575	-12.5446
4	0.8038	0.5574	1.4909

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	1658.0573	1594.9257	1721.1889	1563.1546	1752.9601
2	1273.8260	1235.5816	1312.0705	1193.3054	1354.3467
3	978.6349	936.2652	1021.0046	896.0751	1061.1947
4	577.6195	524.7192	630.5199	489.1923	666.0468

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=32.7 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1663.4}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00872198}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99910989
Rsqr = 0.99822057
Adj Rsqr = 0.99733086

Standard Error of Estimate = 21.2738

	Coefficient	Std. Error	t	P
a	1663.3969	18.5957	89.4505	0.0001
b	0.0087	0.0003	29.4769	0.0011

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	507769.8500	507769.8500	1121.9574	0.0009
Residual	2	905.1500	452.5750		
Total	3	508675.0000	169558.3333		

PRESS = 3249.8760

Durbin-Watson Statistic = 2.9096

Normality Test:
K-S Statistic = 0.3276
Significance Level = 0.6905

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.9712

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	1663.3969	-3.3969	-0.1597	-0.3287	-0.2390
2	1337.5136	-7.5136	-0.3532	-0.4188	-0.3101
3	1075.4755	24.5245	1.1528	1.4124	19.7848
4	695.3528	-15.3528	-0.7217	-1.1604	-1.4355

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.1750	0.7641	-0.4301
2	0.0356	0.2889	-0.1976
3	0.4998	0.3338	14.0055
4	1.0675	0.6132	-1.8076

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1663.3969	1583.3859	1743.4078	1541.8231	1784.9707
2	1337.5136	1288.3173	1386.7099	1233.5967	1441.4305
3	1075.4755	1022.5893	1128.3618	969.7618	1181.1893
4	695.3528	623.6736	767.0319	579.0930	811.6125

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=32.7 m^3/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1653.78}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00989979}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99947192
Rsqr = 0.99894412
Adj Rsqr = 0.99841617

Standard Error of Estimate = 17.4304

	Coefficient	**Std. Error**	**t**	**P**
a	1653.7807	15.4292	107.1855	<0.0001
b	0.0099	0.0003	37.8085	0.0007

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	574867.3655	574867.3655	1892.1485	0.0005
Residual	2	607.6345	303.8172		
Total	3	575475.0000	191825.0000		

PRESS = 2943.6421

Durbin-Watson Statistic = 2.4178

Normality Test:
K-S Statistic = 0.2165
Significance Level = 0.9796

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.9846

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	1653.7807	6.2193	0.3568	0.7669	0.6455
2	1291.1964	-1.1964	-0.0686	-0.0815	-0.0577
3	1008.1071	-18.1071	-1.0388	-1.2876	-2.2016
4	614.5191	15.4809	0.8882	1.3661	3.7336

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	1.0647	0.7836	1.2281
2	0.0014	0.2900	-0.0369
3	0.4446	0.3491	-1.6124
4	1.2743	0.5773	4.3633

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95**	**Pop. 5%**	**Pop. 95%**
1	1653.7807	1587.3945	1720.1670	1553.6226	1753.9389
2	1291.1964	1250.8064	1331.5863	1206.0150	1376.3777
3	1008.1071	963.7952	1052.4189	920.9976	1095.2165
4	614.5191	557.5366	671.5015	520.3304	708.7078

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=32.7 m^3/s Transect 1 after bar

[Variables]
x = col(6)
y = col(7)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x) "Auto {{previous: 585.867}}
b = if(x50(x,y)-min(x)=0, 1, -ln(.5)/(x50(x,y)-min(x))) "Auto {{previous: 0.00363152}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100

R = 0.99707743
Rsqr = 0.99416340
Adj Rsqr = 0.99363280

Standard Error of Estimate = 13.9207

	Coefficient	**Std. Error**	**t**	**P**
a	585.8668	9.7418	60.1394	<0.0001
b	0.0036	0.0001	31.6464	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	363086.6735	363086.6735	1873.6580	<0.0001
Residual	11	2131.6342	193.7849		
Total	12	365218.3077	30434.8590		

PRESS = 2880.7281

Durbin-Watson Statistic = 1.7374

Normality Test:
K-S Statistic = 0.1577
Significance Level = 0.8742

Constant Variance Test: P = 0.9783

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	585.8668	4.1332	0.2969	0.4156	0.3995
2	488.5866	1.4134	0.1015	0.1151	0.1099
3	446.1828	13.8172	0.9926	1.0840	1.0936
4	407.4592	-7.4592	-0.5358	-0.5741	-0.5558
5	339.8026	-9.8026	-0.7042	-0.7468	-0.7308
6	283.3801	-13.3801	-0.9612	-1.0242	-1.0267
7	236.3262	-26.3262	-1.8912	-2.0290	-2.4455
8	179.9807	20.0193	1.4381	1.5496	1.6711
9	150.0958	19.9042	1.4298	1.5375	1.6544
10	125.1731	-5.1731	-0.3716	-0.3975	-0.3818
11	104.3887	5.6113	0.4031	0.4282	0.4117
12	87.0555	5.9445	0.4270	0.4501	0.4332
13	22.3031	2.6969	0.1937	0.1959	0.1871

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0829	0.4897	0.3913
2	0.0019	0.2224	0.0588
3	0.1132	0.1616	0.4801
4	0.0244	0.1289	-0.2138
5	0.0348	0.1110	-0.2582
6	0.0710	0.1193	-0.3778
7	0.3109	0.1312	-0.9504
8	0.1934	0.1387	0.6707
9	0.1846	0.1351	0.6539
10	0.0114	0.1261	-0.1451
11	0.0118	0.1138	0.1475
12	0.0112	0.0999	0.1443
13	0.0004	0.0222	0.0282

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	585.8668	564.4252	607.3084	548.4703	623.2634
2	488.5866	474.1359	503.0372	454.7106	522.4625
3	446.1828	433.8660	458.4996	413.1607	479.2049
4	407.4592	396.4577	418.4607	374.9048	440.0136
5	339.8026	329.5962	350.0091	307.5082	372.0971
6	283.3801	272.7984	293.9618	250.9651	315.7951
7	236.3262	225.2276	247.4249	203.7388	268.9137
8	179.9807	168.5684	191.3930	147.2851	212.6762
9	150.0958	138.8339	161.3576	117.4524	182.7391
10	125.1731	114.2911	136.0552	92.6588	157.6874
11	104.3887	94.0520	114.7255	72.0529	136.7246
12	87.0555	77.3723	96.7387	54.9226	119.1884
13	22.3031	17.7429	26.8633	-8.6735	53.2798

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=32.7 m^3/s Transect 2 after bar

```
[Variables]
x = col(6)
y = col(8)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 667.31}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00292456}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99664599
Rsqr = 0.99330323
Adj Rsqr = 0.99269443

Standard Error of Estimate = 16.3197

	Coefficient	**Std. Error**	**t**	**P**
a	667.3103	10.7709	61.9549	<0.0001
b	0.0029	0.0001	30.6372	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	434545.1004	434545.1004	1631.5824	<0.0001
Residual	11	2929.6688	266.3335		
Total	12	437474.7692	36456.2308		

PRESS = 4193.7933

Durbin-Watson Statistic = 1.0778

Normality Test:
K-S Statistic = 0.1044
Significance Level = 0.9979

Constant Variance Test: P = 0.3616

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	667.3103	12.6897	0.7776	1.0350	1.0387
2	576.5298	3.4702	0.2126	0.2409	0.2303
3	535.8814	-25.8814	-1.5859	-1.7351	-1.9412
4	498.0990	-18.0990	-1.1090	-1.1890	-1.2143
5	430.3379	-0.3379	-0.0207	-0.0219	-0.0208
6	371.7949	18.2051	1.1155	1.1786	1.2022
7	321.2162	28.7838	1.7637	1.8760	2.1690
8	257.9516	12.0484	0.7383	0.7930	0.7787
9	222.8600	-12.8600	-0.7880	-0.8493	-0.8377
10	192.5423	-2.5423	-0.1558	-0.1680	-0.1603
11	166.3489	-16.3489	-1.0018	-1.0777	-1.0865
12	143.7189	-3.7189	-0.2279	-0.2441	-0.2334
13	47.9975	1.0025	0.0614	0.0630	0.0601

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.4134	0.4356	0.9125
2	0.0082	0.2212	0.1228
3	0.2966	0.1646	-0.8617
4	0.1056	0.1299	-0.4693
5	0.0000	0.1024	-0.0070
6	0.0808	0.1042	0.4100
7	0.2311	0.1161	0.7860
8	0.0483	0.1332	0.3053
9	0.0583	0.1391	-0.3367
10	0.0023	0.1398	-0.0646
11	0.0913	0.1359	-0.4308
12	0.0044	0.1285	-0.0896
13	0.0001	0.0495	0.0137

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	667.3103	643.6037	691.0169	624.2729	710.3476
2	576.5298	559.6372	593.4223	536.8364	616.2232
3	535.8814	521.3085	550.4543	497.1183	574.6445
4	498.0990	485.1509	511.0471	459.9170	536.2809
5	430.3379	418.8414	441.8343	392.6234	468.0523
6	371.7949	360.2018	383.3881	334.0509	409.5389
7	321.2162	308.9785	333.4538	283.2692	359.1631
8	257.9516	244.8401	271.0631	219.7139	296.1893
9	222.8600	209.4626	236.2574	184.5234	261.1967
10	192.5423	179.1132	205.9714	154.1945	230.8900
11	166.3489	153.1084	179.5895	128.0668	204.6311
12	143.7189	130.8431	156.5947	105.5614	181.8764
13	47.9975	40.0062	55.9887	11.1998	84.7951

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=32.7 m^3/s Transect 3 after bar

```
[Variables]
x = col(6)
y = col(9)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 624.711}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0033913}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99592173
Rsqr = 0.99186010
Adj Rsqr = 0.99112010

Standard Error of Estimate = 17.4040

	Coefficient	**Std. Error**	**t**	**P**
a	624.7112	11.9486	52.2834	<0.0001
b	0.0034	0.0001	27.0409	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	405996.1093	405996.1093	1340.3673	<0.0001
Residual	11	3331.8907	302.8992		
Total	12	409328.0000	34110.6667		

PRESS = 4575.9013

Durbin-Watson Statistic = 1.1403

Normality Test:
K-S Statistic = 0.1523
Significance Level = 0.8992

Constant Variance Test: P = 0.5164

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	624.7112	5.2888	0.3039	0.4179	0.4017
2	527.2762	22.7238	1.3057	1.4806	1.5776
3	484.4151	-4.4151	-0.2537	-0.2772	-0.2652
4	445.0380	-25.0380	-1.4386	-1.5415	-1.6599
5	375.6263	-25.6263	-1.4724	-1.5586	-1.6836
6	317.0406	-7.0406	-0.4045	-0.4298	-0.4132
7	267.5924	22.4076	1.2875	1.3774	1.4437
8	207.4972	12.5028	0.7184	0.7736	0.7585
9	175.1343	14.8657	0.8542	0.9196	0.9126
10	147.8189	12.1811	0.6999	0.7510	0.7352
11	124.7639	-14.7639	-0.8483	-0.9052	-0.8971
12	105.3047	-13.3047	-0.7645	-0.8101	-0.7966
13	29.5216	3.4784	0.1999	0.2029	0.1938

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0779	0.4713	0.3793
2	0.3134	0.2223	0.8435
3	0.0075	0.1626	-0.1169
4	0.1759	0.1290	-0.6387
5	0.1464	0.1076	-0.5845
6	0.0119	0.1139	-0.1481
7	0.1371	0.1263	0.5489
8	0.0478	0.1376	0.3030
9	0.0673	0.1373	0.3641
10	0.0427	0.1315	0.2861
11	0.0568	0.1217	-0.3339
12	0.0404	0.1096	-0.2794
13	0.0006	0.0293	0.0337

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	624.7112	598.4126	651.0098	578.2466	671.1758
2	527.2762	509.2144	545.3381	484.9256	569.6269
3	484.4151	468.9682	499.8620	443.1119	525.7183
4	445.0380	431.2816	458.7945	404.3368	485.7392
5	375.6263	363.0639	388.1887	335.3131	415.9396
6	317.0406	304.1134	329.9679	276.6122	357.4691
7	267.5924	253.9797	281.2052	226.9396	308.2452
8	207.4972	193.2858	221.7086	166.6400	248.3544
9	175.1343	160.9390	189.3295	134.2827	215.9858
10	147.8189	133.9286	161.7093	107.0723	188.5655
11	124.7639	111.4006	138.1272	84.1939	165.3339
12	105.3047	92.6259	117.9835	64.9550	145.6544
13	29.5216	22.9626	36.0806	-9.3418	68.3850

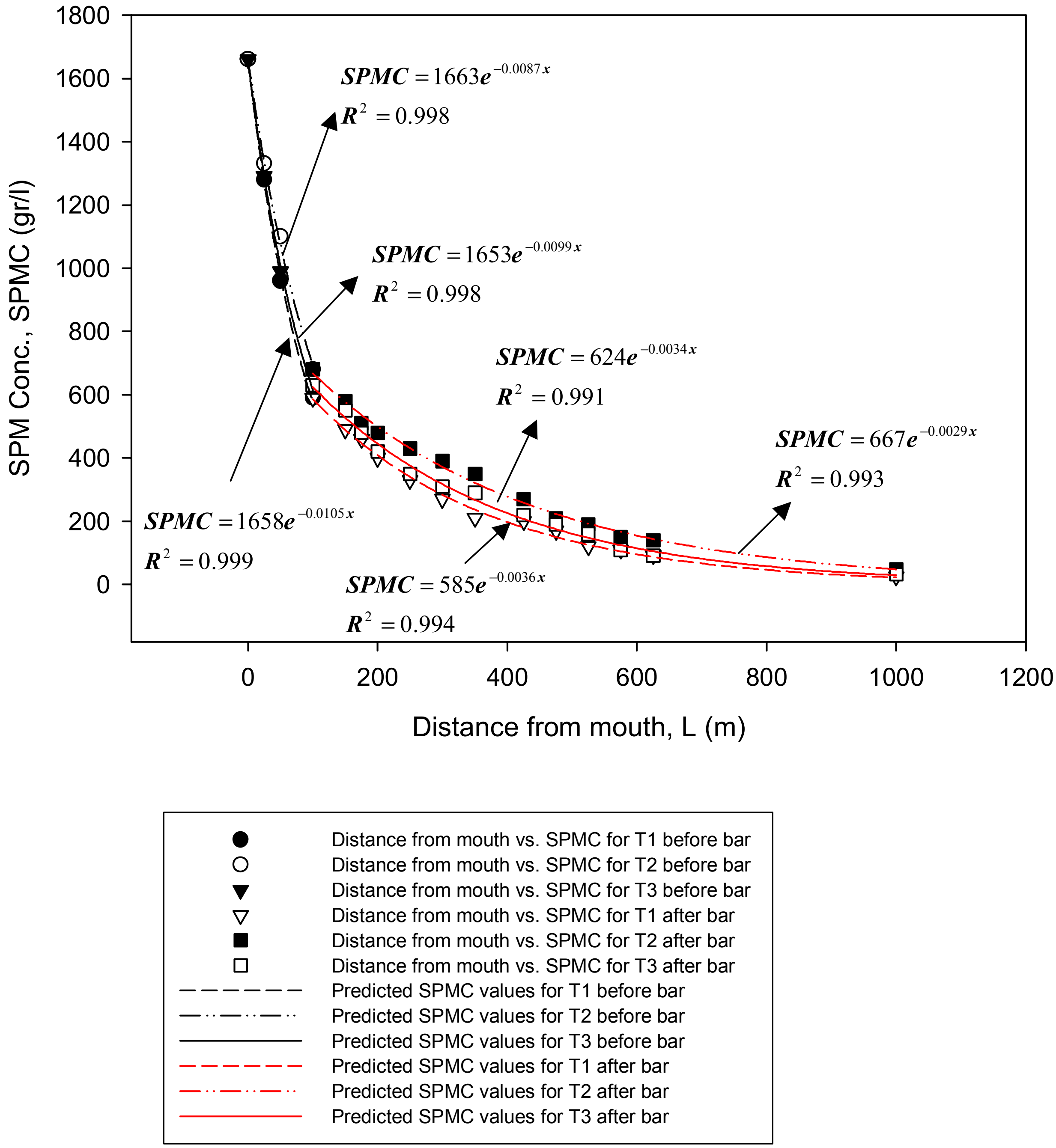

Figure B.2: SPM Concentrations at jet flow for 3 transects at Q = 32.7 m^3/s

Table B.3: Experiment #3 – SPMC values for Q = 31.4 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	2770	2770	2770
2	25	2140	2190	2160
3	50	1610	1790	1690
4	100	1010	1100	1020
5	150	815	890	840
6	175	750	810	780
7	200	610	730	680
8	250	530	650	560
9	300	490	560	530
10	350	430	490	450
11	425	300	390	330
12	475	240	310	290
13	525	210	260	230
14	575	190	230	200
15	625	150	180	170
16	1000	43	67	52

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=31.4 m^3/s Transect 1 before bar

```
Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 2762.71}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0103408}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99933071
Rsqr = 0.99866187
Adj Rsqr = 0.99799280

Standard Error of Estimate = 33.6210

	Coefficient	**Std. Error**	**t**	**P**
a	2762.7114	29.8932	92.4195	0.0001
b	0.0103	0.0003	33.3216	0.0009

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1687214.2584	1687214.2584	1492.6202	0.0007
Residual	2	2260.7416	1130.3708		
Total	3	1689475.0000	563158.3333		

PRESS = 8686.2886

Durbin-Watson Statistic = 2.7296

Normality Test:
K-S Statistic = 0.3458
Significance Level = 0.6235

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.9794

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	2762.7114	7.2886	0.2168	0.4737	0.3555
2	2133.3486	6.6514	0.1978	0.2349	0.1685
3	1647.3585	-37.3585	-1.1112	-1.3834	-4.7101
4	982.2922	27.7078	0.8241	1.2478	1.8746

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.4234	0.7905	0.6906
2	0.0113	0.2909	0.1079
3	0.5263	0.3548	-3.4930
4	1.0061	0.5638	2.1312

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	2762.7114	2634.0915	2891.3313	2569.1412	2956.2816
2	2133.3486	2055.3327	2211.3644	1968.9928	2297.7044
3	1647.3585	1561.1886	1733.5284	1478.9792	1815.7378
4	982.2922	873.6741	1090.9104	801.3938	1163.1907

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=31.4 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 2769.85}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00908669}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99947517
Rsqr = 0.99895061
Adj Rsqr = 0.99842592

Standard Error of Estimate = 27.8428

	Coefficient	Std. Error	t	P
a	2769.8514	24.4349	113.3565	<0.0001
b	0.0091	0.0002	38.2173	0.0007

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	1475924.5581	1475924.5581	1903.8760	0.0005
Residual	2	1550.4419	775.2209		
Total	3	1477475.0000	492491.6667		

PRESS = 4542.7421

Durbin-Watson Statistic = 3.1867

Normality Test:
K-S Statistic = 0.2650
Significance Level = 0.8940

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.9847

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	2769.8514	0.1486	0.0053	0.0111	0.0079
2	2206.9831	-16.9831	-0.6100	-0.7234	-0.5953
3	1758.4966	31.5034	1.1315	1.3912	5.4713
4	1116.4174	-16.4174	-0.5896	-0.9349	-0.8811

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0002	0.7702	0.0144
2	0.1064	0.2891	-0.3796
3	0.4952	0.3385	3.9139
4	0.6617	0.6022	-1.0842

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	2769.8514	2664.7167	2874.9862	2610.4625	2929.2404
2	2206.9831	2142.5728	2271.3934	2070.9676	2342.9986
3	1758.4966	1688.7973	1828.1960	1619.8982	1897.0951
4	1116.4174	1023.4494	1209.3854	964.7778	1268.0570

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=31.4 m^3/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 2771.24}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0099551}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99998554
Rsqr = 0.99997109
Adj Rsqr = 0.99995663

Standard Error of Estimate = 4.8732

	Coefficient	**Std. Error**	**t**	**P**
a	2771.2430	4.3161	642.0662	<0.0001
b	0.0100	0.0000	227.1225	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1642552.5045	1642552.5045	69166.6730	<0.0001
Residual	2	47.4955	23.7477		
Total	3	1642600.0000	547533.3333		

PRESS = 194.5799

Durbin-Watson Statistic = 2.6573

Normality Test:
K-S Statistic = 0.3169
Significance Level = 0.7289

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	2771.2430	-1.2430	-0.2551	-0.5494	-0.4216
2	2160.6700	-0.6700	-0.1375	-0.1632	-0.1162
3	1684.6213	5.3787	1.1037	1.3688	3.8524
4	1024.0707	-4.0707	-0.8353	-1.2822	-2.1493

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.5493	0.7845	-0.8043
2	0.0054	0.2901	-0.0743
3	0.5041	0.3498	2.8258
4	1.1148	0.5756	-2.5029

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	2771.2430	2752.6722	2789.8139	2743.2339	2799.2522
2	2160.6700	2149.3761	2171.9640	2136.8542	2184.4858
3	1684.6213	1672.2197	1697.0228	1660.2607	1708.9818
4	1024.0707	1008.1633	1039.9782	997.7518	1050.3896

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=31.4 m^3/s Transect 1 after bar</u>

```
[Variables]
x = col(6)
y = col(7)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 976.359}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00364604}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99542884
Rsqr = 0.99087858
Adj Rsqr = 0.99004936

Standard Error of Estimate = 29.0507

	Coefficient	**Std. Error**	**t**	**P**
a	976.3591	20.3500	47.9784	<0.0001
b	0.0036	0.0001	25.2769	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1008473.3821	1008473.3821	1194.9526	<0.0001
Residual	11	9283.3872	843.9443		
Total	12	1017756.7692	84813.0641		

PRESS = 15022.9914

Durbin-Watson Statistic = 1.3991

Normality Test:
K-S Statistic = 0.2886
Significance Level = 0.1904

Constant Variance Test: P = 0.3322

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	976.3591	33.6409	1.1580	1.6226	1.7739
2	813.6487	1.3513	0.0465	0.0528	0.0503
3	742.7636	7.2364	0.2491	0.2720	0.2603
4	678.0540	-68.0540	-2.3426	-2.5100	-3.6612
5	565.0561	-35.0561	-1.2067	-1.2800	-1.3229
6	470.8894	19.1106	0.6578	0.7011	0.6839
7	392.4156	37.5844	1.2938	1.3882	1.4574
8	298.5295	1.4705	0.0506	0.0545	0.0520
9	248.7795	-8.7795	-0.3022	-0.3249	-0.3113
10	207.3204	2.6796	0.0922	0.0987	0.0941
11	172.7704	17.2296	0.5931	0.6299	0.6117
12	143.9782	6.0218	0.2073	0.2184	0.2087
13	36.6861	6.3139	0.2173	0.2198	0.2100

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	1.2684	0.4907	1.7412
2	0.0004	0.2224	0.0269
3	0.0071	0.1615	0.1142
4	0.4663	0.1289	-1.4086
5	0.1024	0.1112	-0.4678
6	0.0334	0.1196	0.2520
7	0.1459	0.1315	0.5670
8	0.0002	0.1388	0.0209
9	0.0082	0.1350	-0.1230
10	0.0007	0.1258	0.0357
11	0.0254	0.1134	0.2188
12	0.0026	0.0994	0.0693
13	0.0005	0.0218	0.0314

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	976.3591	931.5691	1021.1492	898.2919	1054.4264
2	813.6487	783.4920	843.8054	742.9537	884.3436
3	742.7636	717.0641	768.4631	673.8519	811.6752
4	678.0540	655.0946	701.0133	610.1166	745.9913
5	565.0561	543.7380	586.3743	497.6558	632.4565
6	470.8894	448.7802	492.9987	403.2346	538.5442
7	392.4156	369.2321	415.5991	324.4022	460.4290
8	298.5295	274.7104	322.3486	230.2968	366.7622
9	248.7795	225.2896	272.2695	180.6610	316.8980
10	207.3204	184.6376	230.0031	139.4760	275.1647
11	172.7704	151.2387	194.3021	105.3021	240.2386
12	143.9782	123.8214	164.1350	76.9360	211.0203
13	36.6861	27.2402	46.1321	-27.9481	101.3203

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=31.4 m^3/s Transect 2 after bar

```
[Variables]
x = col(6)
y = col(8)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 1062.77}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00326583}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99799267
Rsqr = 0.99598936
Adj Rsqr = 0.99562476

Standard Error of Estimate = 20.5100

	Coefficient	Std. Error	t	P
a	1062.7731	13.9377	76.2517	<0.0001
b	0.0033	0.0001	39.0223	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	1149116.4442	1149116.4442	2731.7059	<0.0001
Residual	11	4627.2481	420.6589		
Total	12	53743.6923	96145.3077		

PRESS = 9132.5460

Durbin-Watson Statistic = 1.2449

Normality Test:
K-S Statistic = 0.1055
Significance Level = 0.9975

Constant Variance Test: P = 0.0776

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	1062.7731	37.2269	1.8151	2.4741	3.5421
2	902.6597	-12.6597	-0.6172	-0.6999	-0.6827
3	831.8897	-21.8897	-1.0673	-1.1667	-1.1883
4	766.6683	-36.6683	-1.7878	-1.9158	-2.2377
5	651.1649	-1.1649	-0.0568	-0.0601	-0.0573
6	553.0628	6.9372	0.3382	0.3588	0.3441
7	469.7404	20.2596	0.9878	1.0552	1.0612
8	367.6911	22.3089	1.0877	1.1707	1.1930
9	312.2961	-2.2961	-0.1120	-0.1206	-0.1151
10	265.2467	-5.2467	-0.2558	-0.2749	-0.2630
11	225.2856	4.7144	0.2299	0.2458	0.2350
12	191.3449	-11.3449	-0.5531	-0.5879	-0.5695
13	56.2268	10.7732	0.5253	0.5344	0.5163

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	2.6261	0.4618	3.2811
2	0.0699	0.2221	-0.3648
3	0.1327	0.1632	-0.5247
4	0.2721	0.1291	-0.8616
5	0.0002	0.1060	-0.0197
6	0.0081	0.1112	0.1217
7	0.0785	0.1236	0.3986
8	0.1086	0.1368	0.4748
9	0.0012	0.1381	-0.0461
10	0.0058	0.1340	-0.1035
11	0.0043	0.1257	0.0891
12	0.0224	0.1146	-0.2049
13	0.0050	0.0338	0.0966

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	1062.7731	1032.0965	1093.4498	1008.1941	1117.3522
2	902.6597	881.3830	923.9363	852.7547	952.5647
3	831.8897	813.6560	850.1235	783.2042	880.5753
4	766.6683	750.4472	782.8894	718.7002	814.6364
5	651.1649	636.4688	665.8610	603.6908	698.6390
6	553.0628	538.0107	568.1149	505.4773	600.6483
7	469.7404	453.8683	485.6125	421.8892	517.5916
8	367.6911	350.9974	384.3848	319.5611	415.8210
9	312.2961	295.5179	329.0743	264.1368	360.4554
10	265.2467	248.7221	281.7714	217.1752	313.3183
11	225.2856	209.2830	241.2883	177.3910	273.1803
12	191.3449	176.0616	206.6283	143.6858	239.0041
13	56.2268	47.9262	64.5273	10.3278	102.1257

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=31.4 m^3/s Transect 3 after bar

```
[Variables]
x = col(6)
y = col(9)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 998.933}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00339597}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99791804
Rsqr = 0.99584042
Adj Rsqr = 0.99546228

Standard Error of Estimate = 19.8204

	Coefficient	**Std. Error**	**t**	**P**
a	998.9334	13.6136	73.3774	<0.0001
b	0.0034	0.0001	37.9698	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	1034565.4403	1034565.4403	2633.5000	<0.0001
Residual	11	4321.3289	392.8481		
Total	12	1038886.7692	86573.8974		

PRESS = 6574.9170

Durbin-Watson Statistic = 1.6644

Normality Test:
K-S Statistic = 0.2240
Significance Level = 0.4785

Constant Variance Test: P = 0.1113

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	998.9334	21.0666	1.0629	1.4624	1.5535
2	842.9350	-2.9350	-0.1481	-0.1679	-0.1603
3	774.3243	5.6757	0.2864	0.3129	0.2997
4	711.2981	-31.2981	-1.5791	-1.6919	-1.8756
5	600.2183	-40.2183	-2.0291	-2.1480	-2.6879
6	506.4852	23.5148	1.1864	1.2604	1.2992
7	427.3900	22.6100	1.1407	1.2205	1.2515
8	331.2918	-1.2918	-0.0652	-0.0702	-0.0669
9	279.5556	10.4444	0.5270	0.5673	0.5490
10	235.8988	-5.8988	-0.2976	-0.3193	-0.3059
11	199.0597	0.9403	0.0474	0.0506	0.0483
12	167.9735	2.0265	0.1022	0.1083	0.1033
13	47.0081	4.9919	0.2519	0.2556	0.2444

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.9550	0.4718	1.4681
2	0.0040	0.2223	-0.0857
3	0.0095	0.1626	0.1321
4	0.2119	0.1290	-0.7217
5	0.2782	0.1076	-0.9335
6	0.1022	0.1140	0.4661
7	0.1078	0.1264	0.4761
8	0.0004	0.1377	-0.0267
9	0.0256	0.1373	0.2190
10	0.0077	0.1314	-0.1190
11	0.0002	0.1215	0.0180
12	0.0007	0.1093	0.0362
13	0.0010	0.0291	0.0423

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	998.9334	968.9700	1028.8969	946.0100	1051.8569
2	842.9350	822.3651	863.5049	794.7042	891.1658
3	774.3243	756.7340	791.9146	727.2870	821.3616
4	711.2981	695.6320	726.9642	664.9460	757.6502
5	600.2183	585.9069	614.5297	554.3063	646.1302
6	506.4852	491.7552	521.2152	460.4411	552.5293
7	427.3900	411.8800	442.8999	381.0904	473.6895
8	331.2918	315.1052	347.4783	284.7612	377.8223
9	279.5556	263.3919	295.7193	233.0330	326.0782
10	235.8988	220.0869	251.7107	189.4972	282.3004
11	199.0597	183.8521	214.2672	152.8606	245.2588
12	167.9735	153.5492	182.3978	122.0263	213.9208
13	47.0081	39.5623	54.4539	2.7528	91.2633

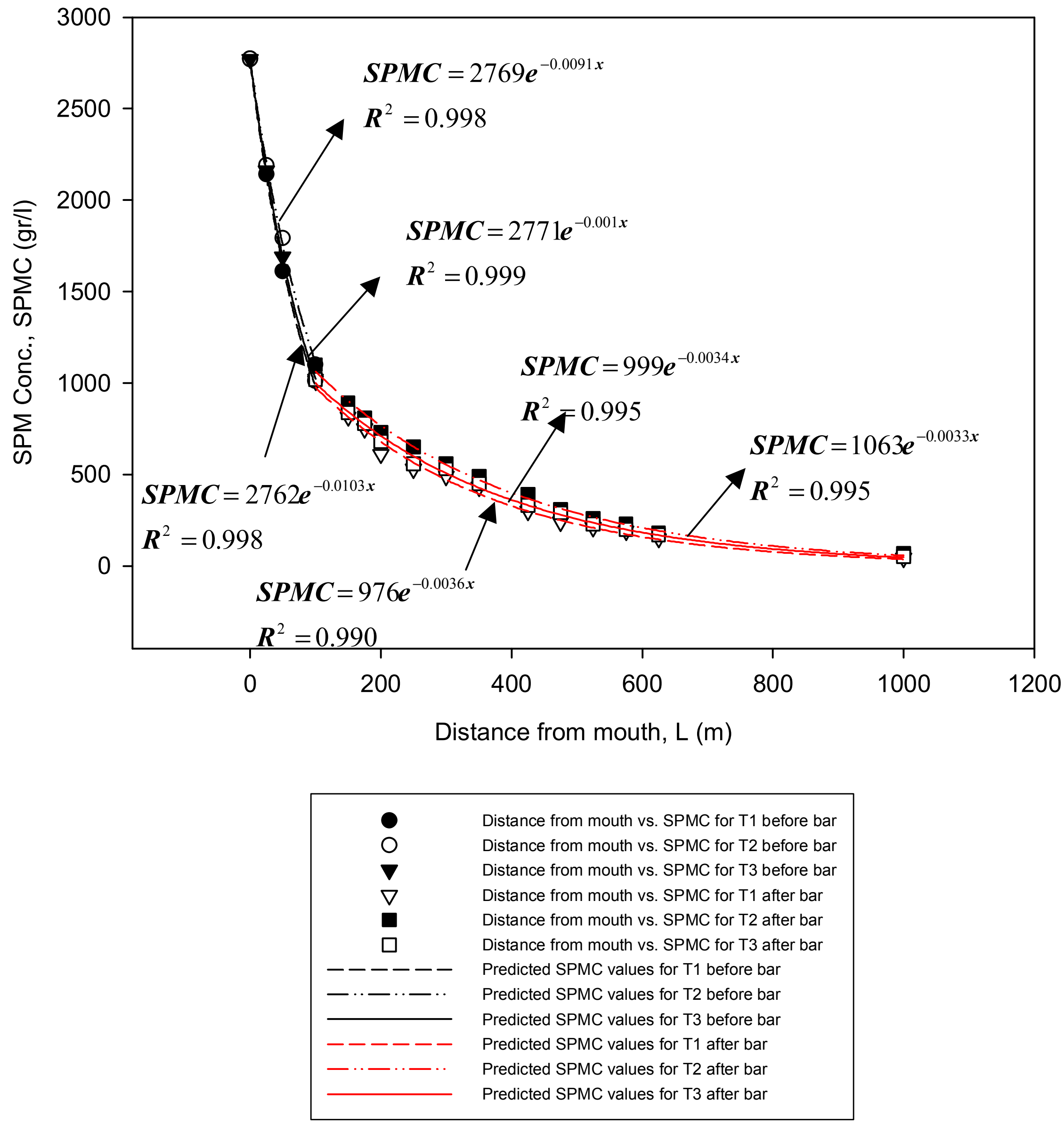

Figure B.3: SPM Concentrations at jet flow for 3 transects at Q = 31.4 m^3/s

Table B.4: Experiment #7 – SPMC values for Q = 8.5 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	280	280	280
2	25	120	170	130
3	50	55	92	62
3′	75	21	53	31
4	100	9	25	14
4′	125	6	20	11
5	150	5	15	9
6	175	4	14	7
7	200	3	11	5
7′	225	2	9	4
8	250	1	6	3
8′	275	1	3	2

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=8.5 m^3/s Transect 1 before bar</u>

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 279.863}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0335157}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99988394
Rsqr = 0.99976789
Adj Rsqr = 0.99969052

Standard Error of Estimate = 1.9531

	Coefficient	**Std. Error**	**t**	**P**
a	279.8629	1.9204	145.7332	<0.0001
b	0.0335	0.0005	70.1431	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	49290.5565	49290.5565	12921.9236	<0.0001
Residual	3	11.4435	3.8145		
Total	4	49302.0000	12325.5000		

PRESS = 42.1240

Durbin-Watson Statistic = 2.9872

Normality Test:
K-S Statistic = 0.2835
Significance Level = 0.7411

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	279.8629	0.1371	0.0702	0.3853	0.3227
2	121.0748	-1.0748	-0.5503	-0.7617	-0.6924
3	52.3796	2.6204	1.3417	1.6645	4.9162
4	22.6605	-1.6605	-0.8502	-0.9237	-0.8916
5	9.8034	-0.8034	-0.4114	-0.4225	-0.3557

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	2.1616	0.9668	1.7413
2	0.2656	0.4780	-0.6627
3	0.7469	0.3503	3.6098
4	0.0769	0.1528	-0.3786
5	0.0049	0.0521	-0.0834

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	279.8629	273.7514	285.9744	271.1461	288.5797
2	121.0748	116.7774	125.3721	113.5183	128.6312
3	52.3796	48.7009	56.0582	45.1570	59.6021
4	22.6605	20.2311	25.0900	15.9871	29.3340
5	9.8034	8.3847	11.2222	3.4280	16.1788

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=8.5 m³/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 282.832}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0221125}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99881523
Rsqr = 0.99763186
Adj Rsqr = 0.99684249

Standard Error of Estimate = 5.7797

	Coefficient	**Std. Error**	**t**	**P**
a	282.8316	5.5089	51.3404	<0.0001
b	0.0221	0.0008	26.3925	0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	42217.7852	42217.7852	1263.8195	<0.0001
Residual	3	100.2148	33.4049		
Total	4	42318.0000	10579.5000		

PRESS = 1130.5700

Durbin-Watson Statistic = 2.0778

Normality Test:
K-S Statistic = 0.3695
Significance Level = 0.4086

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 0.9995

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	282.8316	-2.8316	-0.4899	-1.6197	-3.7323
2	162.7215	7.2785	1.2593	1.5252	2.6276
3	93.6186	-1.6186	-0.2800	-0.3450	-0.2875
4	53.8616	-0.8616	-0.1491	-0.1741	-0.1429
5	30.9882	-5.9882	-1.0361	-1.1336	-1.2243

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	13.0242	0.9085	-11.7608
2	0.5429	0.3182	1.7952
3	0.0308	0.3413	-0.2069
4	0.0055	0.2672	-0.0863
5	0.1267	0.1647	-0.5437

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	282.8316	265.2998	300.3635	257.4212	308.2420
2	162.7215	152.3453	173.0978	141.6031	183.8399
3	93.6186	82.8729	104.3642	72.3162	114.9209
4	53.8616	44.3530	63.3701	33.1557	74.5674
5	30.9882	23.5230	38.4533	11.1375	50.8389

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=8.5 m^3/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 279.532}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0301619}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99993394
Rsqr = 0.99986789
Adj Rsqr = 0.99982385

Standard Error of Estimate = 1.4363

	Coefficient	Std. Error	t	P
a	279.5317	1.4034	199.1853	<0.0001
b	0.0302	0.0003	98.6013	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	46837.0113	46837.0113	22704.5589	<0.0001
Residual	3	6.1887	2.0629		
Total	4	46843.2000	11710.8000		

PRESS = 119.3529

Durbin-Watson Statistic = 1.9737

Normality Test:
K-S Statistic = 0.3431
Significance Level = 0.5036

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	279.5317	0.4683	0.3260	1.5320	2.6812
2	131.5079	-1.5079	-1.0499	-1.3851	-1.8837
3	61.8690	0.1310	0.0912	0.1139	0.0932
4	29.1068	1.8932	1.3182	1.4609	2.2206
5	13.6935	0.3065	0.2134	0.2219	0.1827

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	24.7377	0.9547	12.3102
2	0.7104	0.4255	-1.6210
3	0.0036	0.3586	0.0697
4	0.2437	0.1859	1.0611
5	0.0020	0.0754	0.0522

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	279.5317	275.0656	283.9979	273.1412	285.9223
2	131.5079	128.5265	134.4894	126.0507	136.9652
3	61.8690	59.1319	64.6060	56.5413	67.1966
4	29.1068	27.1360	31.0775	24.1291	34.0844
5	13.6935	12.4388	14.9482	8.9536	18.4334

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=8.5 m^3/s Transect 1 after bar</u>

```
[Variables]
x = col(6)
y = col(7)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 8.81745}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0118733}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99198880
Rsqr = 0.98404179
Adj Rsqr = 0.98138209

Standard Error of Estimate = 0.3750

	Coefficient	**Std. Error**	**t**	**P**
a	8.8175	0.3206	27.5058	<0.0001
b	0.0119	0.0008	15.3735	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	52.0312	52.0312	369.9820	<0.0001
Residual	6	0.8438	0.1406		
Total	7	52.8750	7.5536		

PRESS = 1.7435

Durbin-Watson Statistic = 1.8406

Normality Test:
K-S Statistic = 0.1693
Significance Level = 0.9602

Constant Variance Test: P = 0.4228

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	8.8175	0.1825	0.4868	0.9381	0.9270
2	6.5529	-0.5529	-1.4742	-1.7051	-2.1681
3	4.8699	0.1301	0.3470	0.3836	0.3545
4	3.6191	0.3809	1.0156	1.1306	1.1635
5	2.6896	0.3104	0.8276	0.9231	0.9098
6	1.9989	0.0011	0.0031	0.0034	0.0031
7	1.4855	-0.4855	-1.2946	-1.4038	-1.5638
8	1.1040	-0.1040	-0.2772	-0.2950	-0.2713

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	1.1940	0.7307	1.5271
2	0.4910	0.2525	-1.2600
3	0.0163	0.1817	0.1671
4	0.1530	0.1931	0.5693
5	0.1040	0.1963	0.4496
6	0.0000	0.1790	0.0014
7	0.1733	0.1496	-0.6559
8	0.0058	0.1171	-0.0988

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	8.8175	8.0331	9.6018	7.6103	10.0246
2	6.5529	6.0918	7.0139	5.5259	7.5798
3	4.8699	4.4787	5.2611	3.8724	5.8674
4	3.6191	3.2159	4.0224	2.6168	4.6215
5	2.6896	2.2831	3.0961	1.6860	3.6933
6	1.9989	1.6106	2.3871	1.0025	2.9952
7	1.4855	1.1306	1.8404	0.5016	2.4693
8	1.1040	0.7900	1.4179	0.1341	2.0738

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=8.5 m^3/s Transect 2 after bar

```
[Variables]
x = col(6)
y = col(8)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 25.1456}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00910166}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.98779015
Rsqr = 0.97572937
Adj Rsqr = 0.97168427

Standard Error of Estimate = 1.2182

	Coefficient	**Std. Error**	**t**	**P**
a	25.1456	0.9947	25.2799	<0.0001
b	0.0091	0.0007	13.2270	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	357.9707	357.9707	241.2124	<0.0001
Residual	6	8.9043	1.4840		
Total	7	366.8750	52.4107		

PRESS = 13.2219

Durbin-Watson Statistic = 1.2135

Normality Test:
K-S Statistic = 0.1579
Significance Level = 0.9793

Constant Variance Test: P = 0.1388

Power of performed test with alpha = 0.0500: 0.9999

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	25.1456	-0.1456	-0.1195	-0.2070	-0.1897
2	20.0282	-0.0282	-0.0232	-0.0269	-0.0246
3	15.9523	-0.9523	-0.7817	-0.8543	-0.8321
4	12.7058	1.2942	1.0624	1.1636	1.2071
5	10.1200	0.8800	0.7223	0.8009	0.7736
6	8.0605	0.9395	0.7712	0.8599	0.8384
7	6.4201	-0.4201	-0.3448	-0.3831	-0.3541
8	5.1135	-2.1135	-1.7349	-1.9071	-2.7743

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0429	0.6667	-0.2682
2	0.0001	0.2598	-0.0146
3	0.0710	0.1628	-0.3669
4	0.1351	0.1664	0.5393
5	0.0735	0.1865	0.3704
6	0.0899	0.1957	0.4135
7	0.0172	0.1897	-0.1713
8	0.3789	0.1724	-1.2663

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	25.1456	22.7117	27.5795	21.2973	28.9939
2	20.0282	18.5088	21.5477	16.6824	23.3740
3	15.9523	14.7496	17.1549	12.7379	19.1666
4	12.7058	11.4899	13.9217	9.4865	15.9251
5	10.1200	8.8327	11.4074	6.8731	13.3670
6	8.0605	6.7419	9.3791	4.8010	11.3200
7	6.4201	5.1218	7.7184	3.1688	9.6714
8	5.1135	3.8758	6.3513	1.8859	8.3412

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=8.5 m^3/s Transect 3 after bar

```
[Variables]
x = col(6)
y = col(9)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 14.213}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0101026}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99768578
Rsqr = 0.99537691
Adj Rsqr = 0.99460640

Standard Error of Estimate = 0.3077

	Coefficient	**Std. Error**	**t**	**P**
a	14.2130	0.2558	55.5721	<0.0001
b	0.0101	0.0003	30.0043	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	122.3069	122.3069	1291.8339	<0.0001
Residual	6	0.5681	0.0947		
Total	7	122.8750	17.5536		

PRESS = 1.2265

Durbin-Watson Statistic = 1.1304

Normality Test:
K-S Statistic = 0.2784
Significance Level = 0.4935

Constant Variance Test: P = 0.8393

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	14.2130	-0.2130	-0.6923	-1.2451	-1.3199
2	11.0407	-0.0407	-0.1324	-0.1535	-0.1404
3	8.5765	0.4235	1.3764	1.5092	1.7491
4	6.6623	0.3377	1.0976	1.2092	1.2693
5	5.1753	-0.1753	-0.5696	-0.6334	-0.5986
6	4.0202	-0.0202	-0.0656	-0.0729	-0.0666
7	3.1229	-0.1229	-0.3994	-0.4398	-0.4081
8	2.4259	-0.4259	-1.3841	-1.5020	-1.7357

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	1.7327	0.6909	-1.9733
2	0.0041	0.2566	-0.0825
3	0.2304	0.1683	0.7867
4	0.1562	0.1760	0.5867
5	0.0474	0.1912	-0.2911
6	0.0006	0.1909	-0.0323
7	0.0206	0.1753	-0.1881
8	0.2003	0.1508	-0.7315

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	14.2130	13.5872	14.8388	13.2340	15.1920
2	11.0407	10.6593	11.4221	10.1967	11.8847
3	8.5765	8.2677	8.8853	7.7627	9.3903
4	6.6623	6.3464	6.9782	5.8458	7.4788
5	5.1753	4.8460	5.5045	4.3535	5.9970
6	4.0202	3.6913	4.3491	3.1986	4.8418
7	3.1229	2.8077	3.4381	2.3067	3.9391
8	2.4259	2.1335	2.7183	1.6182	3.2336

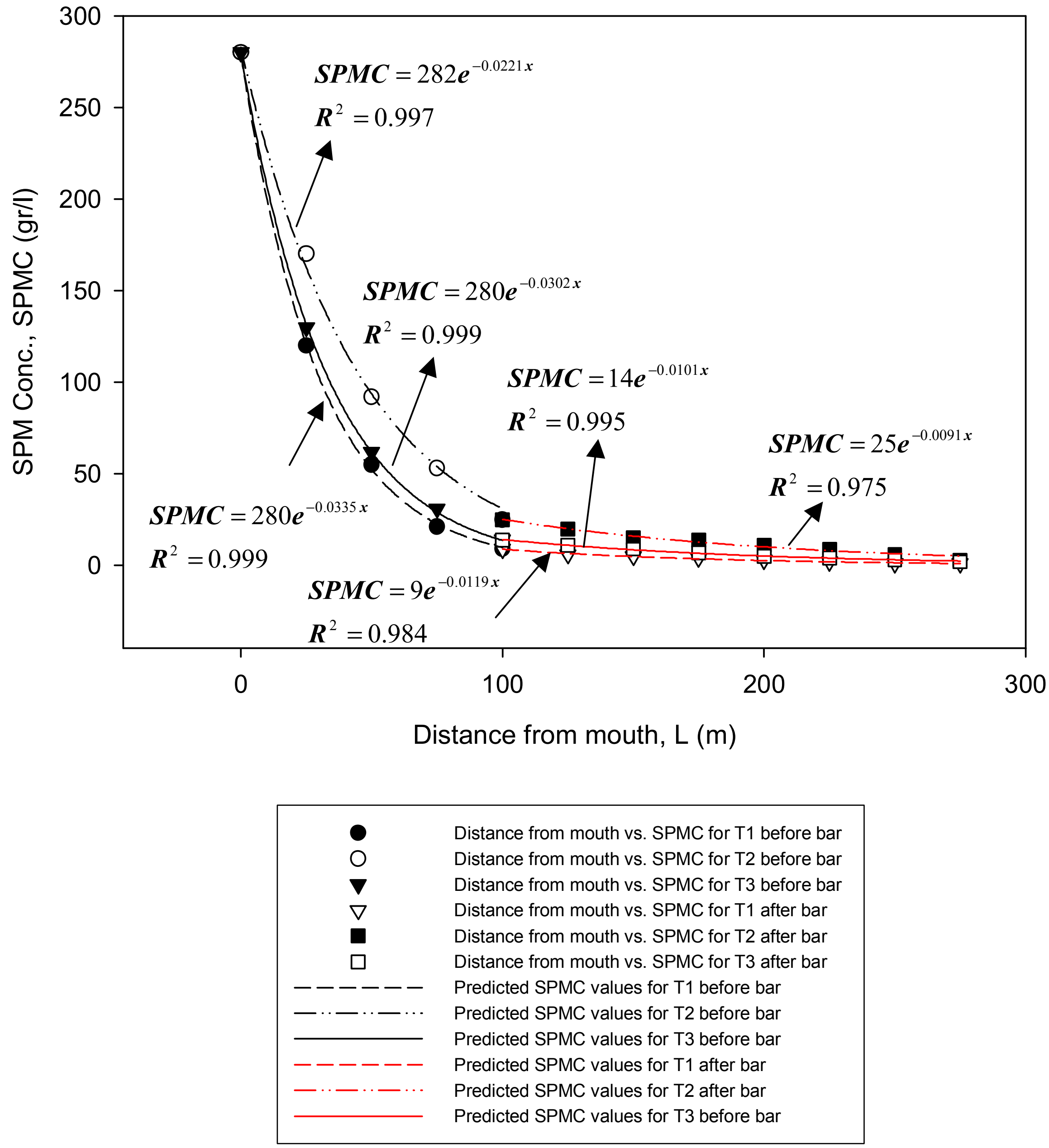

Figure B.4: SPM Concentrations at jet flow for 3 transects at Q = 8.5 m^3/s

Table B.5: Experiment #9 – SPMC values for $Q = 5.5\ m^3/s$

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	29	29	29
1′	10	21	23	24
2	25	15	18	18
2′	35	11	14	12
3	50	9	12	10
3′	60	6	10	8
3″	70	6	7	7
3‴	80	6	6	6
3⁗	90	5	6	6
4	100	1	2	2

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=5.5 m^3/s Transect 1 before bar

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 27.9032}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0237337}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.98944305
Rsqr = 0.97899756
Adj Rsqr = 0.97637225

Standard Error of Estimate = 1.3112

	Coefficient	**Std. Error**	**t**	**P**
a	27.9032	1.0708	26.0572	<0.0001
b	0.0237	0.0015	15.3486	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	641.1455	641.1455	372.9080	<0.0001
Residual	8	13.7545	1.7193		
Total	9	654.9000	72.7667		

PRESS = 27.3786

Durbin-Watson Statistic = 1.7205

Normality Test:
K-S Statistic = 0.1525
Significance Level = 0.9602

Constant Variance Test: P = 0.1371
Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	27.9032	1.0968	0.8365	1.4494	1.5789
2	22.0080	-1.0080	-0.7687	-0.9067	-0.8954
3	15.4159	-0.4159	-0.3172	-0.3468	-0.3268
4	12.1589	-1.1589	-0.8838	-0.9664	-0.9619
5	8.5169	0.4831	0.3684	0.4029	0.3807
6	6.7175	-0.7175	-0.5472	-0.5943	-0.5686
7	5.2983	0.7017	0.5352	0.5750	0.5493
8	4.1789	1.8211	1.3889	1.4742	1.6158
9	3.2960	1.7040	1.2996	1.3631	1.4552
10	2.5996	-1.5996	-1.2199	-1.2662	-1.3246

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	2.1036	0.6670	2.2344
2	0.1608	0.2811	-0.5599
3	0.0117	0.1634	-0.1445
4	0.0914	0.1636	-0.4255
5	0.0159	0.1637	0.1685
6	0.0317	0.1522	-0.2409
7	0.0255	0.1337	0.2159
8	0.1376	0.1124	0.5749
9	0.0931	0.0911	0.4607
10	0.0619	0.0717	-0.3682

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	27.9032	25.4338	30.3726	23.9993	31.8071
2	22.0080	20.4047	23.6112	18.5855	25.4304
3	15.4159	14.1935	16.6383	12.1544	18.6773
4	12.1589	10.9357	13.3820	8.8972	15.4206
5	8.5169	7.2934	9.7404	5.2551	11.7788
6	6.7175	5.5381	7.8969	3.4719	9.9631
7	5.2983	4.1924	6.4041	2.0787	8.5178
8	4.1789	3.1652	5.1925	0.9898	7.3679
9	3.2960	2.3834	4.2086	0.1376	6.4544
10	2.5996	1.7899	3.4094	-0.5306	5.7299

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=5.5 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 28.7234}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0193092}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99310901
Rsqr = 0.98626551
Adj Rsqr = 0.98454870

Standard Error of Estimate = 1.0532

	Coefficient	**Std. Error**	**t**	**P**
a	28.7234	0.8273	34.7191	<0.0001
b	0.0193	0.0010	19.9718	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	637.2261	637.2261	574.4753	<0.0001
Residual	8	8.8739	1.1092		
Total	9	646.1000	71.7889		

PRESS = 12.2214

Durbin-Watson Statistic = 2.0703

Normality Test:
K-S Statistic = 0.1465
Significance Level = 0.9721

Constant Variance Test: P = 0.2746
Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	28.7234	0.2766	0.2627	0.4244	0.4016
2	23.6797	-0.6797	-0.6454	-0.7645	-0.7427
3	17.7251	0.2749	0.2610	0.2830	0.2661
4	14.6127	-0.6127	-0.5817	-0.6277	-0.6022
5	10.9381	1.0619	1.0083	1.0938	1.1094
6	9.0174	0.9826	0.9330	1.0128	1.0146
7	7.4340	-0.4340	-0.4121	-0.4459	-0.4223
8	6.1286	-0.1286	-0.1221	-0.1313	-0.1229
9	5.0525	0.9475	0.8996	0.9589	0.9535
10	4.1653	-2.1653	-2.0559	-2.1715	-3.1702

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.1451	0.6170	0.5097
2	0.1178	0.2873	-0.4715
3	0.0070	0.1492	0.1114
4	0.0324	0.1411	-0.2441
5	0.1057	0.1502	0.4664
6	0.0915	0.1514	0.4286
7	0.0170	0.1458	-0.1745
8	0.0013	0.1345	-0.0485
9	0.0626	0.1198	0.3518
10	0.2726	0.1036	-1.0780

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	28.7234	26.8156	30.6311	25.6350	31.8117
2	23.6797	22.3780	24.9814	20.9242	26.4353
3	17.7251	16.7869	18.6633	15.1215	20.3287
4	14.6127	13.7004	15.5249	12.0183	17.2070
5	10.9381	9.9969	11.8793	8.3334	13.5428
6	9.0174	8.0723	9.9625	6.4113	11.6235
7	7.4340	6.5067	8.3613	4.8343	10.0337
8	6.1286	5.2379	7.0194	3.5418	8.7155
9	5.0525	4.2118	5.8932	2.4824	7.6226
10	4.1653	3.3834	4.9472	1.6139	6.7167

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=5.5 m³/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 29.1393}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.021191}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99259821
Rsqr = 0.98525120
Adj Rsqr = 0.98340760

Standard Error of Estimate = 1.1243

	Coefficient	Std. Error	t	P
a	29.1393	0.8985	32.4303	<0.0001
b	0.0212	0.0011	18.9337	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	675.4882	675.4882	534.4170	<0.0001
Residual	8	10.1118	1.2640		
Total	9	685.6000	76.1778		

PRESS = 13.4308

Durbin-Watson Statistic = 2.2334
Normality Test:

K-S Statistic = 0.2358
Significance Level = 0.5734

Constant Variance Test: P = 0.2746
Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	29.1393	-0.1393	-0.1239	-0.2062	-0.1934
2	23.5748	0.4252	0.3782	0.4472	0.4236
3	17.1554	0.8446	0.7512	0.8168	0.7981
4	13.8794	-1.8794	-1.6716	-1.8133	-2.2101
5	10.1000	-0.1000	-0.0890	-0.0969	-0.0907
6	8.1713	-0.1713	-0.1524	-0.1655	-0.1551
7	6.6109	0.3891	0.3461	0.3735	0.3525
8	5.3485	0.6515	0.5795	0.6197	0.5941
9	4.3271	1.6729	1.4880	1.5749	1.7735
10	3.5008	-1.5008	-1.3349	-1.3987	-1.5053

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0376	0.6387	-0.2572
2	0.0398	0.2847	0.2672
3	0.0608	0.1542	0.3407
4	0.2904	0.1501	-0.9289
5	0.0009	0.1565	-0.0391
6	0.0025	0.1526	-0.0658
7	0.0115	0.1414	0.1430
8	0.0275	0.1254	0.2249
9	0.1490	0.1073	0.6148
10	0.0957	0.0891	-0.4709

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	29.1393	27.0674	31.2113	25.8205	32.4582
2	23.5748	22.1915	24.9581	20.6363	26.5133
3	17.1554	16.1375	18.1733	14.3702	19.9407
4	13.8794	12.8749	14.8839	11.0990	16.6597
5	10.1000	9.0744	11.1257	7.3120	12.8881
6	8.1713	7.1585	9.1841	5.3879	10.9547
7	6.6109	5.6361	7.5857	3.8411	9.3807
8	5.3485	4.4305	6.2664	2.5982	8.0987
9	4.3271	3.4780	5.1762	1.5990	7.0552
10	3.5008	2.7267	4.2748	0.7951	6.2064

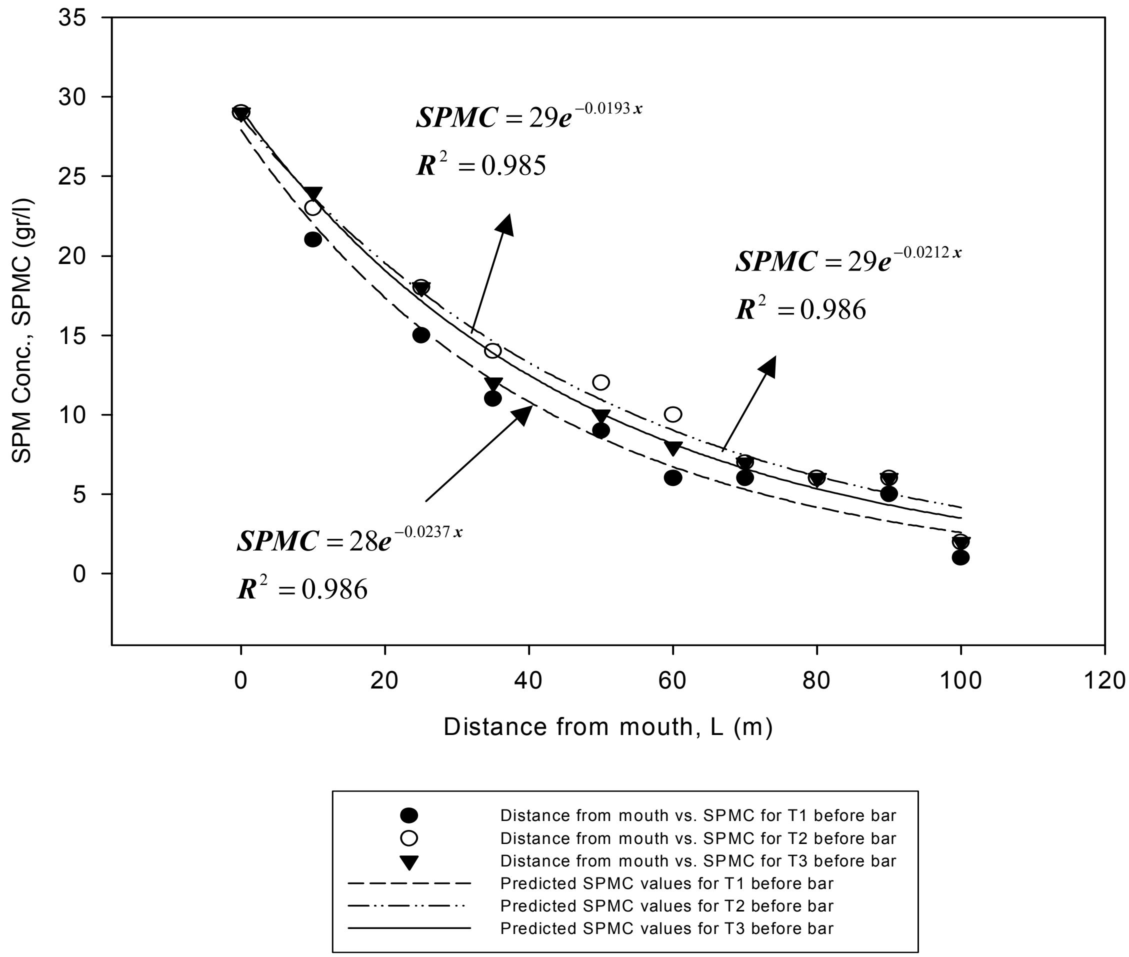

Figure B.5: SPM Concentrations at jet flow for 3 transects at Q = 5.5 m^3/s

Table B.6: Experiment #10 – SPMC values for Q = 3.8 m^3/s

Station No.	Distance, L (m)	SPM Conc. at Transect 1 (gr/l)	SPM Conc. at Transect 2 (gr/l)	SPM Conc. at Transect 3 (gr/l)
1	0	20	20	20
1′	10	12	15	14
2	25	9	11	10
2′	35	7	9	8
3	50	5	4	4
3′	60	3	3	3
3″	70	1	2	1

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=3.8 m^3/s Transect 1 before bar

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 19.0571}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0313906}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.98471859
Rsqr = 0.96967071
Adj Rsqr = 0.96360485

Standard Error of Estimate = 1.2187

	Coefficient	**Std. Error**	**t**	**P**
a	19.0571	1.0645	17.9018	<0.0001
b	0.0314	0.0032	9.6713	0.0002

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	237.4308	237.4308	159.8571	<0.0001
Residual	5	7.4263	1.4853		
Total	6	244.8571	40.8095		

PRESS = 27.0910

Durbin-Watson Statistic = 2.1274

Normality Test:
K-S Statistic = 0.2508
Significance Level = 0.7043

Constant Variance Test: P = 0.7810

Power of performed test with alpha = 0.0500: 0.9982

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	19.0571	0.9429	0.7737	1.5892	2.0205
2	13.9229	-1.9229	-1.5778	-1.8548	-2.9703
3	8.6944	0.3056	0.2508	0.2862	0.2581
4	6.3520	0.6480	0.5317	0.6099	0.5670
5	3.9666	1.0334	0.8479	0.9501	0.9387
6	2.8979	0.1021	0.0837	0.0915	0.0819
7	2.1172	-1.1172	-0.9167	-0.9784	-0.9732

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	4.0651	0.7630	3.6253
2	0.6570	0.2764	-1.8357
3	0.0124	0.2324	0.1420
4	0.0588	0.2400	0.3187
5	0.1153	0.2035	0.4745
6	0.0008	0.1627	0.0361
7	0.0666	0.1221	-0.3629

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	19.0571	16.3206	21.7936	14.8974	23.2168
2	13.9229	12.2759	15.5699	10.3835	17.4622
3	8.6944	7.1842	10.2045	5.2166	12.1721
4	6.3520	4.8171	7.8869	2.8634	9.8406
5	3.9666	2.5534	5.3797	0.5298	7.4034
6	2.8979	1.6344	4.1615	-0.4801	6.2760
7	2.1172	1.0225	3.2119	-1.2013	5.4358

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=3.8 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 20.2847}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0281426}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99013999
Rsqr = 0.98037720
Adj Rsqr = 0.97645264

Standard Error of Estimate = 1.0310

	Coefficient	**Std. Error**	**t**	**P**
a	20.2847	0.8860	22.8947	<0.0001
b	0.0281	0.0023	12.2541	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	265.5422	265.5422	249.8056	<0.0001
Residual	5	5.3150	1.0630		
Total	6	270.8571	45.1429		

PRESS = 9.5712

Durbin-Watson Statistic = 1.4308

Normality Test:
K-S Statistic = 0.3340
Significance Level = 0.3427

Constant Variance Test: P = 0.2965

Power of performed test with alpha = 0.0500: 0.9996

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	20.2847	-0.2847	-0.2762	-0.5400	-0.4977
2	15.3090	-0.3090	-0.2997	-0.3525	-0.3193
3	10.0372	0.9628	0.9338	1.0532	1.0679
4	7.5752	1.4248	1.3820	1.5737	1.9814
5	4.9666	-0.9666	-0.9375	-1.0569	-1.0727
6	3.7483	-0.7483	-0.7258	-0.8026	-0.7691
7	2.8289	-0.8289	-0.8040	-0.8701	-0.8449

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.4117	0.7385	-0.8364
2	0.0238	0.2771	-0.1977
3	0.1510	0.2140	0.5572
4	0.3676	0.2289	1.0795
5	0.1512	0.2131	-0.5582
6	0.0718	0.1822	-0.3631
7	0.0649	0.1463	-0.3498

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	20.2847	18.0072	22.5623	16.7903	23.7792
2	15.3090	13.9139	16.7041	12.3139	18.3041
3	10.0372	8.8113	11.2632	7.1171	12.9573
4	7.5752	6.3072	8.8431	4.6372	10.5132
5	4.9666	3.7432	6.1900	2.0476	7.8856
6	3.7483	2.6170	4.8797	0.8667	6.6300
7	2.8289	1.8151	3.8427	-0.0087	5.6665

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=3.8 m^3/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 19.9403}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0305068}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99208595
Rsqr = 0.98423452
Adj Rsqr = 0.98108143

Standard Error of Estimate = 0.9256

	Coefficient	**Std. Error**	**t**	**P**
a	19.9403	0.8052	24.7654	<0.0001
b	0.0305	0.0023	13.3509	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	267.4306	267.4306	312.1487	<0.0001
Residual	5	4.2837	0.8567		
Total	6	271.7143	45.2857		

PRESS = 6.7212

Durbin-Watson Statistic = 1.4673

Normality Test:
K-S Statistic = 0.1859
Significance Level = 0.9482

Constant Variance Test: P = 0.2965

Power of performed test with alpha = 0.0500: 0.9998

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	19.9403	0.0597	0.0645	0.1308	0.1172
2	14.6974	-0.6974	-0.7535	-0.8858	-0.8628
3	9.3005	0.6995	0.7557	0.8597	0.8330
4	6.8552	1.1448	1.2368	1.4162	1.6369
5	4.3380	-0.3380	-0.3651	-0.4098	-0.3729
6	3.1974	-0.1974	-0.2133	-0.2338	-0.2102
7	2.3567	-1.3567	-1.4658	-1.5698	-1.9717

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0266	0.7567	0.2068
2	0.1498	0.2764	-0.5332
3	0.1088	0.2274	0.4519
4	0.3120	0.2373	0.9131
5	0.0218	0.2062	-0.1901
6	0.0055	0.1678	-0.0944
7	0.1812	0.1282	-0.7561

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	19.9403	17.8705	22.0100	16.7867	23.0938
2	14.6974	13.4466	15.9482	12.0094	17.3855
3	9.3005	8.1659	10.4351	6.6645	11.9365
4	6.8552	5.6961	8.0142	4.2085	9.5018
5	4.3380	3.2574	5.4185	1.7248	6.9511
6	3.1974	2.2227	4.1721	0.6261	5.7686
7	2.3567	1.5048	3.2087	-0.1706	4.8840

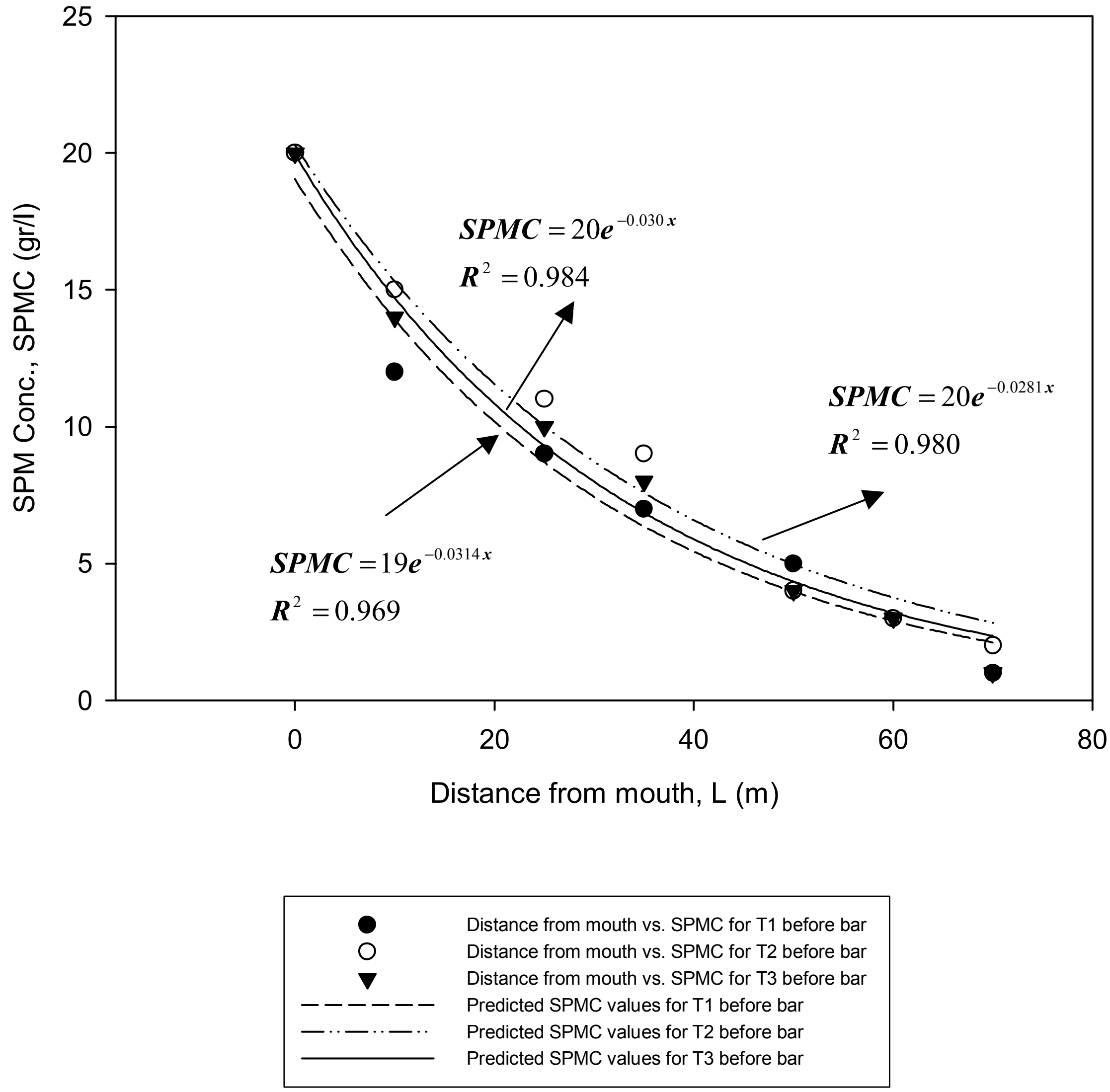

Figure B.6: SPM Concentrations at jet flow for 3 transects at Q = 3.8 m^3/s

Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=46.8 m^3/s Transect 1 before bar

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 4690.28}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00794135}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.98978736
Rsqr = 0.97967903
Adj Rsqr = 0.96951854

Standard Error of Estimate = 189.8909

	Coefficient	Std. Error	t	P
a	4690.2791	164.5212	28.5087	0.0012
b	0.0079	0.0009	8.8934	0.0124

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	3476782.8940	3476782.8940	96.4205	0.0102
Residual	2	72117.1060	36058.5530		
Total	3	3548900.0000	1182966.6667		

PRESS = 365678.6909

Durbin-Watson Statistic = 2.7613

Normality Test:
K-S Statistic = 0.3929
Significance Level = 0.4583

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.7505

The power of the performed test (0.7505) is below the desired power of 0.8000.
You should interpret the negative findings cautiously.

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	4690.2791	119.7209	0.6305	1.2626	1.9818
2	3845.7104	-225.7104	-1.1886	-1.4095	-12.2589
3	3153.2214	56.7786	0.2990	0.3637	0.2661
4	2119.8749	60.1251	0.3166	0.5252	0.4000

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	2.3994	0.7506	3.4384
2	0.4035	0.2889	-7.8133
3	0.0317	0.3240	0.1842
4	0.2415	0.6365	0.5293

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	4690.2791	3982.4014	5398.1569	3609.2442	5771.3141
2	3845.7104	3406.5772	4284.8437	2918.1418	4773.2790
3	3153.2214	2688.1857	3618.2571	2213.1131	4093.3297
4	2119.8749	1468.0284	2771.7215	1074.6719	3165.0780

Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=46.8 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 4756.07}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00556037}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99099291
Rsqr = 0.98206694
Adj Rsqr = 0.97310041

Standard Error of Estimate = 140.8610

	Coefficient	**Std. Error**	**t**	**P**
a	4756.0666	118.5132	40.1311	0.0006
b	0.0056	0.0006	9.8630	0.0101

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2173191.3813	2173191.3813	109.5259	0.0090
Residual	2	39683.6187	19841.8093		
Total	3	2212875.0000	737625.0000		

PRESS = 206481.3041

Durbin-Watson Statistic = 2.5579

Normality Test:
K-S Statistic = 0.2887
Significance Level = 0.8253

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.7701

The power of the performed test (0.7701) is below the desired power of 0.8000. You should interpret the negative findings cautiously.

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	4756.0666	53.9334	0.3829	0.7084	0.5788
2	4138.8240	11.1760	0.0793	0.0943	0.0668
3	3601.6871	-161.6871	-1.1478	-1.3686	-3.8397
4	2727.4955	102.5045	0.7277	1.3359	2.8776

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.6080	0.7079	0.9009
2	0.0018	0.2923	0.0430
3	0.3948	0.2965	-2.4930
4	2.1145	0.7033	4.4299

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	4756.0666	4246.1455	5265.9878	3964.0139	5548.1193
2	4138.8240	3811.1262	4466.5217	3449.8293	4827.8187
3	3601.6871	3271.6471	3931.7272	2911.5753	4291.7989
4	2727.4955	2219.2398	3235.7512	1936.5140	3518.4770

Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=46.8 m^3/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 4763.67}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00640569}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99064005
Rsqr = 0.98136772
Adj Rsqr = 0.97205157

Standard Error of Estimate = 161.3093

	Coefficient	**Std. Error**	**t**	**P**
a	4763.6701	137.1938	34.7222	0.0008
b	0.0064	0.0007	9.4304	0.0111

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	2741033.6328	2741033.6328	105.3406	0.0094
Residual	2	52041.3672	26020.6836		
Total	3	2793075.0000	931025.0000		

PRESS = 141948.5167

Durbin-Watson Statistic = 3.3723

Normality Test:
K-S Statistic = 0.1375
Significance Level = 1.0000

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 0.7642

The power of the performed test (0.7642) is below the desired power of 0.8000. You should interpret the negative findings cautiously.

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	4763.6701	46.3299	0.2872	0.5461	0.4186
2	4058.7549	-158.7549	-0.9842	-1.1685	-1.4666
3	3458.1511	151.8489	0.9414	1.1298	1.3281
4	2510.4193	-40.4193	-0.2506	-0.4432	-0.3300

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.3898	0.7234	0.6769
2	0.2796	0.2906	-0.9386
3	0.2810	0.3057	0.8813
4	0.2090	0.6804	-0.4815

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	4763.6701	4173.3728	5353.9674	3852.5350	5674.8052
2	4058.7549	3684.6302	4432.8795	3270.2845	4847.2252
3	3458.1511	3074.3874	3841.9148	2665.0617	4251.2405
4	2510.4193	1937.9354	3082.9031	1610.7227	3410.1159

<u>Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=46.8 m³/s Transect 1 after bar</u>

```
[Variables]
x = col(7)
y = col(8)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 2243.91}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00243065}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99692514
Rsqr = 0.99385973
Adj Rsqr = 0.99330152

Standard Error of Estimate = 49.9109

	Coefficient	**Std. Error**	**t**	**P**
a	2243.9124	31.4502	71.3481	<0.0001
b	0.0024	0.0001	32.9305	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	4435274.8747	4435274.8747	1780.4517	<0.0001
Residual	11	27402.0483	2491.0953		
Total	12	4462676.9231	371889.7436		

PRESS = 41561.4707

Durbin-Watson Statistic = 1.3303

Normality Test:
K-S Statistic = 0.1724
Significance Level = 0.7956

Constant Variance Test: P = 0.4136

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	2243.9124	-63.9124	-1.2805	-1.6491	-1.8123
2	1987.1237	12.8763	0.2580	0.2918	0.2793
3	1869.9690	-39.9690	-0.8008	-0.8771	-0.8671
4	1759.7214	30.2786	0.6067	0.6511	0.6331
5	1558.3425	91.6575	1.8364	1.9350	2.2716
6	1380.0090	49.9910	1.0016	1.0531	1.0589
7	1222.0836	-22.0836	-0.4425	-0.4677	-0.4504
8	1018.4259	31.5741	0.6326	0.6765	0.6588
9	901.8794	28.1206	0.5634	0.6065	0.5882
10	798.6702	-58.6702	-1.1755	-1.2710	-1.3120
11	707.2720	-57.2720	-1.1475	-1.2432	-1.2786
12	626.3332	-16.3332	-0.3272	-0.3545	-0.3399
13	251.7376	-21.7376	-0.4355	-0.4551	-0.4380

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.8955	0.3971	-1.4707
2	0.0119	0.2182	0.1475
3	0.0767	0.1663	-0.3873
4	0.0322	0.1319	0.2468
5	0.2064	0.0993	0.7542
6	0.0585	0.0954	0.3439
7	0.0128	0.1049	-0.1542
8	0.0328	0.1255	0.2495
9	0.0292	0.1370	0.2343
10	0.1366	0.1447	-0.5396
11	0.1344	0.1481	-0.5331
12	0.0109	0.1476	-0.1415
13	0.0095	0.0840	-0.1326

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	2243.9124	2174.6909	2313.1339	2114.0690	2373.7558
2	1987.1237	1935.8080	2038.4394	1865.8760	2108.3714
3	1869.9690	1825.1669	1914.7711	1751.3312	1988.6068
4	1759.7214	1719.8196	1799.6232	1642.8460	1876.5968
5	1558.3425	1523.7270	1592.9580	1443.1647	1673.5203
6	1380.0090	1346.0758	1413.9422	1265.0344	1494.9836
7	1222.0836	1186.5015	1257.6658	1106.6116	1337.5557
8	1018.4259	979.5164	1057.3354	901.8856	1134.9663
9	901.8794	861.2208	942.5379	784.7435	1019.0153
10	798.6702	756.8875	840.4528	681.1393	916.2010
11	707.2720	664.9943	749.5497	589.5643	824.9797
12	626.3332	584.1262	668.5403	508.6509	744.0156
13	251.7376	219.9001	283.5750	137.3639	366.1112

Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=46.8 m^3/s Transect 2 after bar

```
[Variables]
x = col(7)
y = col(9)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 2737.54}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00185304}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99639761
Rsqr = 0.99280820
Adj Rsqr = 0.99215440

Standard Error of Estimate = 57.9581

	Coefficient	**Std. Error**	**t**	**P**
a	2737.5421	34.3294	79.7434	<0.0001
b	0.0019	0.0001	32.4415	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	5100926.3180	5100926.3180	1518.5188	<0.0001
Residual	11	36950.6051	3359.1459		
Total	12	5137876.9231	428156.4103		

PRESS = 59266.4889

Durbin-Watson Statistic = 2.1858

Normality Test:
K-S Statistic = 0.1634
Significance Level = 0.8455

Constant Variance Test: P = 0.9639

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	2737.5421	92.4579	1.5953	1.9799	2.3531
2	2495.2985	-35.2985	-0.6090	-0.6860	-0.6685
3	2382.3379	17.6621	0.3047	0.3339	0.3200
4	2274.4910	-104.4910	-1.8029	-1.9381	-2.2772
5	2073.2225	-23.2225	-0.4007	-0.4220	-0.4057
6	1889.7642	20.2358	0.3491	0.3656	0.3508
7	1722.5400	27.4600	0.4738	0.4974	0.4797
8	1499.0354	-19.0354	-0.3284	-0.3487	-0.3344
9	1366.3865	-16.3865	-0.2827	-0.3029	-0.2900
10	1245.4758	44.5242	0.7682	0.8302	0.8176
11	1135.2643	24.7357	0.4268	0.4646	0.4474
12	1034.8054	-74.8054	-1.2907	-1.4128	-1.4889
13	516.5013	73.4987	1.2681	1.3748	1.4404

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	1.0593	0.3508	1.7299
2	0.0632	0.2117	-0.3464
3	0.0112	0.1669	0.1432
4	0.2924	0.1347	-0.8984
5	0.0097	0.0986	-0.1341
6	0.0065	0.0881	0.1091
7	0.0127	0.0928	0.1535
8	0.0077	0.1130	-0.1194
9	0.0068	0.1289	-0.1116
10	0.0578	0.1437	0.3350
11	0.0200	0.1561	0.1924
12	0.1977	0.1654	-0.6627
13	0.1657	0.1492	0.6031

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	2737.5421	2661.9836	2813.1006	2589.2791	2885.8051
2	2495.2985	2436.6066	2553.9904	2354.8793	2635.7178
3	2382.3379	2330.2204	2434.4554	2244.5371	2520.1387
4	2274.4910	2227.6735	2321.3084	2138.6060	2410.3759
5	2073.2225	2033.1732	2113.2718	1939.5185	2206.9266
6	1889.7642	1851.8907	1927.6377	1756.6957	2022.8327
7	1722.5400	1683.6712	1761.4089	1589.1848	1855.8953
8	1499.0354	1456.1458	1541.9249	1364.4533	1633.6175
9	1366.3865	1320.5833	1412.1898	1230.8478	1501.9253
10	1245.4758	1197.1138	1293.8378	1109.0510	1381.9005
11	1135.2643	1084.8645	1185.6641	998.1039	1272.4247
12	1034.8054	982.9304	1086.6804	897.0961	1172.5147
13	516.5013	467.2356	565.7671	379.7536	653.2491

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=46.8 m^3/s Transect 3 after bar</u>

```
[Variables]
x = col(7)
y = col(10)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0®)
[Parameters]
a = yatxnear0(y,x)  ''Auto {{previous: 2451.29}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  ''Auto {{previous: 0.00204149}}
[Equation]
f = a*exp(-b*x)
fit f to y
''fit f to y with weight reciprocal_y
''fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99710474
Rsqr = 0.99421785
Adj Rsqr = 0.99369220

Standard Error of Estimate = 49.1725

	Coefficient	**Std. Error**	**t**	**P**
a	2451.2881	29.7511	82.3932	<0.0001
b	0.0020	0.0001	35.1786	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	4573295.0555	4573295.0555	1891.4076	<0.0001
Residuals	11	26597.2522	2417.9320		
Total	12	4599892.3077	383324.3590		

PRESS = 36577.8188

Durbin-Watson Statistic = 2.1268

Normality Test:
K-S Statistic = 0.1763
Significance Level = 0.7729

Constant Variance Test: P = 0.4579

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	2451.2881	18.7119	0.3805	0.4779	0.4605
2	2213.4204	-73.4204	-1.4931	-1.6844	-1.8644
3	2103.2877	-3.2877	-0.0669	-0.0733	-0.0699
4	1998.6349	1.3651	0.0278	0.0298	0.0284
5	1804.6917	65.3083	1.3281	1.3988	1.4709
6	1629.5683	-19.5683	-0.3980	-0.4172	-0.4010
7	1471.4385	18.5615	0.3775	0.3971	0.3814
8	1262.5437	97.4563	1.9819	2.1096	2.6067
9	1140.0292	-40.0292	-0.8141	-0.8739	-0.8637
10	1029.4032	-59.4032	-1.2081	-1.3064	-1.3552
11	929.5122	-19.5122	-0.3968	-0.4315	-0.4150
12	839.3143	20.6857	0.4207	0.4591	0.4420
13	390.3429	-20.3429	-0.4137	-0.4421	-0.4253

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0660	0.3661	0.3499
2	0.3868	0.2142	-0.9735
3	0.0005	0.1670	-0.0313
4	0.0001	0.1338	0.0112
5	0.1069	0.0985	0.4861
6	0.0086	0.0901	-0.1262
7	0.0084	0.0966	0.1247
8	0.2960	0.1174	0.9507
9	0.0582	0.1322	-0.3371
10	0.1446	0.1449	-0.5579
11	0.0170	0.1544	-0.1773
12	0.0201	0.1604	0.1932
13	0.0139	0.1244	-0.1604

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	2451.2881	2385.8064	2516.7698	2324.7926	2577.7837
2	2213.4204	2163.3264	2263.5145	2094.1615	2332.6793
3	2103.2877	2059.0635	2147.5119	1986.3730	2220.2024
4	1998.6349	1959.0442	2038.2256	1883.3930	2113.8768
5	1804.6917	1770.7294	1838.6539	1691.2601	1918.1232
6	1629.5683	1597.0800	1662.0566	1516.5693	1742.5672
7	1471.4385	1437.8083	1505.0686	1358.1060	1584.7710
8	1262.5437	1225.4622	1299.6253	1148.1396	1376.9479
9	1140.0292	1100.6790	1179.3794	1024.8697	1255.1887
10	1029.4032	988.2046	1070.6019	913.5991	1145.2074
11	929.5122	886.9812	972.0432	813.2273	1045.7970
12	839.3143	795.9690	882.6596	722.7292	955.8994
13	390.3429	352.1635	428.5222	275.5782	505.1076

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=12.5 m^3/s Transect 1 before bar</u>

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 830.498}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0147285}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99960342
Rsqr = 0.99920701
Adj Rsqr = 0.99894268

Standard Error of Estimate = 8.2857

	Coefficient	**Std. Error**	**t**	**P**
a	830.4983	7.5827	109.5260	<0.0001
b	0.0147	0.0003	52.9531	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	259514.0437	259514.0437	3780.1323	<0.0001
Residual	3	205.9563	68.6521		
Total	4	259720.0000	64930.0000		

PRESS = 417.8109

Durbin-Watson Statistic = 2.0706

Normality Test:
K-S Statistic = 0.1710
Significance Level = 0.9958

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	830.4983	-0.4983	-0.0601	-0.1492	-0.1223
2	574.6802	5.3198	0.6420	0.7496	0.6789
3	397.6617	-7.6617	-0.9247	-1.0941	-1.1524
4	275.1701	-5.1701	-0.6240	-0.7563	-0.6864
5	190.4096	9.5904	1.1575	1.3749	1.8458

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0574	0.8375	-0.2776
2	0.1020	0.2663	0.4090
3	0.2394	0.2857	-0.7289
4	0.1341	0.3192	-0.4700
5	0.3884	0.2913	1.1832

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	830.4983	806.3670	854.6296	794.7544	866.2421
2	574.6802	561.0732	588.2872	545.0078	604.3526
3	397.6617	383.5668	411.7566	367.7624	427.5610
4	275.1701	260.2720	290.0683	244.8839	305.4564
5	190.4096	176.1790	204.6402	160.4461	220.3731

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=12.5 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 830.889}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0120947}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99864951
Rsqr = 0.99730084
Adj Rsqr = 0.99640112

Standard Error of Estimate = 14.0024

	Coefficient	**Std. Error**	**t**	**P**
a	830.8893	12.5586	66.1609	<0.0001
b	0.0121	0.0004	29.7290	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	217331.7992	217331.7992	1108.4571	<0.0001
Residual	3	588.2008	196.0669		
Total	4	217920.0000	54480.0000		

PRESS = 1336.1850

Durbin-Watson Statistic = 2.1092

Normality Test:
K-S Statistic = 0.1681
Significance Level = 0.9967

Constant Variance Test: P = 0.0160

Power of performed test with alpha = 0.0500: 0.9993

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	830.8893	-0.8893	-0.0635	-0.1436	-0.1177
2	614.0816	-4.0816	-0.2915	-0.3391	-0.2823
3	453.8465	6.1535	0.4395	0.5117	0.4374
4	335.4223	14.5777	1.0411	1.2696	1.5240
5	247.8990	-17.8990	-1.2783	-1.5787	-3.1334

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.0424	0.8044	-0.2386
2	0.0203	0.2611	-0.1678
3	0.0466	0.2625	0.2610
4	0.3927	0.3276	1.0638
5	0.6546	0.3444	-2.2710

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	830.8893	790.9223	870.8562	771.0302	890.7483
2	614.0816	591.3129	636.8502	564.0400	664.1231
3	453.8465	431.0140	476.6790	403.7759	503.9171
4	335.4223	309.9166	360.9279	284.0775	386.7670
5	247.8990	221.7484	274.0496	196.2309	299.5672

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=12.5 m^3/s Transect 3 before bar</u>

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 831.761}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0134593}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99983625
Rsqr = 0.99967253
Adj Rsqr = 0.99956338

Standard Error of Estimate = 5.1217

	Coefficient	**Std. Error**	**t**	**P**
a	831.7609	4.6438	179.1107	<0.0001
b	0.0135	0.0002	84.0150	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	240241.3033	240241.3033	9158.2505	<0.0001
Residual	3	78.6967	26.2322		
Total	4	240320.0000	60080.0000		

PRESS = 245.2640

Durbin-Watson Statistic = 2.6534

Normality Test:
K-S Statistic = 0.2543
Significance Level = 0.8484

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	831.7609	-1.7609	-0.3438	-0.8151	-0.7543
2	594.1085	5.8915	1.1503	1.3398	1.7263
3	424.3586	-4.3586	-0.8510	-0.9991	-0.9987
4	303.1100	-3.1100	-0.6072	-0.7385	-0.6666
5	216.5047	3.4953	0.6824	0.8254	0.7666

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	1.5351	0.8221	-1.6215
2	0.3202	0.2629	1.0310
3	0.1888	0.2745	-0.6143
4	0.1307	0.3240	-0.4615
5	0.1577	0.3165	0.5216

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	831.7609	816.9822	846.5397	809.7590	853.7629
2	594.1085	585.7507	602.4662	575.7910	612.4259
3	424.3586	415.8187	432.8985	405.9573	442.7599
4	303.1100	293.8319	312.3880	284.3547	321.8652
5	216.5047	207.3352	225.6743	197.8029	235.2066

<u>Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=12.5 m^3/s Transect 1 after bar</u>

```
[Variables]
x = col(6)
y = col(7)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 208.673}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00505669}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99492441
Rsqr = 0.98987459
Adj Rsqr = 0.98919956

Standard Error of Estimate = 6.4672

	Coefficient	**Std. Error**	**t**	**P**
a	208.6727	4.2254	49.3850	<0.0001
b	0.0051	0.0002	28.9675	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	61332.7460	61332.7460	1466.4214	<0.0001
Residual	15	627.3716	41.8248		
Total	16	61960.1176	3872.5074		

PRESS = 943.6727

Durbin-Watson Statistic = 2.0451

Normality Test:
K-S Statistic = 0.1670
Significance Level = 0.6895

Constant Variance Test: P = <0.0001

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	208.6727	-8.6727	-1.3410	-1.7714	-1.9244
2	183.8922	6.1078	0.9444	1.0950	1.1028
3	162.0544	7.9456	1.2286	1.3438	1.3843
4	142.8100	7.1900	1.1118	1.1845	1.2020
5	125.8509	-15.8509	-2.4510	-2.5842	-3.3517
6	97.7354	2.2646	0.3502	0.3683	0.3575
7	75.9009	7.0991	1.0977	1.1574	1.1717
8	66.8875	-0.8875	-0.1372	-0.1447	-0.1399
9	58.9444	2.0556	0.3178	0.3348	0.3247
10	45.7760	-6.7760	-1.0477	-1.0986	-1.1068
11	40.3400	-5.3400	-0.8257	-0.8629	-0.8551
12	35.5495	-1.5495	-0.2396	-0.2495	-0.2415
13	31.3279	-0.3279	-0.0507	-0.0526	-0.0508
14	27.6076	1.3924	0.2153	0.2225	0.2153
15	24.3291	1.6709	0.2584	0.2660	0.2576
16	21.4400	2.5600	0.3958	0.4061	0.3946
17	18.8939	0.1061	0.0164	0.0168	0.0162

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	1.1686	0.4269	-1.6608
2	0.2063	0.2560	0.6470
3	0.1773	0.1642	0.6134
4	0.0949	0.1191	0.4420
5	0.3728	0.1004	-1.1199
6	0.0072	0.0962	0.1166
7	0.0748	0.1005	0.3917
8	0.0012	0.1007	-0.0468
9	0.0062	0.0989	0.1076
10	0.0599	0.0904	-0.3488
11	0.0343	0.0843	-0.2595
12	0.0026	0.0776	-0.0701
13	0.0001	0.0706	-0.0140
14	0.0017	0.0635	0.0561
15	0.0021	0.0566	0.0631
16	0.0043	0.0501	0.0906
17	0.0000	0.0439	0.0035

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	208.6727	199.6664	217.6789	192.2067	225.1386
2	183.8922	176.9171	190.8673	168.4434	199.3410
3	162.0544	156.4696	167.6393	147.1815	176.9274
4	142.8100	138.0526	147.5674	128.2276	157.3924
5	125.8509	121.4826	130.2193	111.3908	140.3110
6	97.7354	93.4595	102.0113	83.3029	112.1678
7	75.9009	71.5307	80.2712	61.4402	90.3617
8	66.8875	62.5139	71.2610	52.4258	81.3492
9	58.9444	54.6095	63.2793	44.4943	73.3945
10	45.7760	41.6324	49.9196	31.3822	60.1698
11	40.3400	36.3373	44.3427	25.9861	54.6939
12	35.5495	31.7091	39.3899	21.2400	49.8590
13	31.3279	27.6653	34.9905	17.0651	45.5907
14	27.6076	24.1331	31.0821	13.3919	41.8233
15	24.3291	21.0485	27.6097	10.1596	38.4987
16	21.4400	18.3554	24.5246	7.3145	35.5654
17	18.8939	16.0044	21.7834	4.8098	32.9780

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=12.5 m^3/s Transect 2 after bar

```
[Variables]
x = col(6)
y = col(7)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 235.363}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0042856}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99403816
Rsqr = 0.98811186
Adj Rsqr = 0.98731932

Standard Error of Estimate = 7.6546

	Coefficient	**Std. Error**	**t**	**P**
a	235.3626	4.7902	49.1346	<0.0001
b	0.0043	0.0002	28.3294	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	73052.0402	73052.0402	1246.7622	<0.0001
Residual	15	878.9010	58.5934		
Total	16	73930.9412	4620.6838		

PRESS = 1102.5979

Durbin-Watson Statistic = 1.2909

Normality Test:
K-S Statistic = 0.1923
Significance Level = 0.5103

Constant Variance Test: Passed (P = 0.6732)

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	235.3626	-5.3626	-0.7006	-0.8982	-0.8920
2	211.4497	-1.4497	-0.1894	-0.2187	-0.2116
3	189.9664	0.0336	0.0044	0.0048	0.0046
4	170.6658	-0.6658	-0.0870	-0.0927	-0.0896
5	153.3262	6.6738	0.8719	0.9173	0.9122
6	123.7530	16.2470	2.1225	2.2191	2.6158
7	99.8838	10.1162	1.3216	1.3849	1.4327
8	89.7356	-16.7356	-2.1863	-2.2941	-2.7508
9	80.6185	-10.6185	-1.3872	-1.4566	-1.5187
10	65.0690	0.9310	0.1216	0.1276	0.1233
11	58.4580	1.5420	0.2014	0.2110	0.2042
12	52.5187	2.4813	0.3242	0.3389	0.3287
13	47.1828	-0.1828	-0.0239	-0.0249	-0.0241
14	42.3890	-1.3890	-0.1815	-0.1887	-0.1825
15	38.0823	0.9177	0.1199	0.1243	0.1202
16	34.2131	-4.2131	-0.5504	-0.5691	-0.5558
17	30.7371	-3.7371	-0.4882	-0.5033	-0.4904

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.2596	0.3916	-0.7157
2	0.0080	0.2503	-0.1223
3	0.0000	0.1665	0.0021
4	0.0006	0.1200	-0.0331
5	0.0450	0.0967	0.2984
6	0.2292	0.0852	0.7981
7	0.0942	0.0894	0.4489
8	0.2658	0.0917	-0.8743
9	0.1088	0.0930	-0.4864
10	0.0008	0.0915	0.0391
11	0.0022	0.0888	0.0638
12	0.0053	0.0851	0.1003
13	0.0000	0.0806	-0.0071
14	0.0015	0.0756	-0.0522
15	0.0006	0.0702	0.0330
16	0.0112	0.0646	-0.1461
17	0.0080	0.0591	-0.1229

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	235.3626	225.1526	245.5725	216.1158	254.6093
2	211.4497	203.2875	219.6119	193.2065	229.6930
3	189.9664	183.3088	196.6240	172.3449	207.5879
4	170.6658	165.0148	176.3168	153.3994	187.9322
5	153.3262	148.2538	158.3985	136.2404	170.4119
6	123.7530	118.9918	128.5142	106.7570	140.7490
7	99.8838	95.0054	104.7623	82.8546	116.9130
8	89.7356	84.7937	94.6775	72.6882	106.7831
9	80.6185	75.6422	85.5948	63.5610	97.6760
10	65.0690	60.1332	70.0048	48.0233	82.1147
11	58.4580	53.5949	63.3211	41.4332	75.4828
12	52.5187	47.7580	57.2793	35.5228	69.5145
13	47.1828	42.5495	51.8160	30.2222	64.1434
14	42.3890	37.9032	46.8748	25.4681	59.3099
15	38.0823	33.7596	42.4049	21.2039	54.9607
16	34.2131	30.0651	38.3612	17.3786	51.0476
17	30.7371	26.7716	34.7025	13.9466	47.5275

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=12.5 m^3/s Transect 3 after bar

```
[Variables]
x = col(6)
y = col(9)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 215.276}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00438872}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99815938
Rsqr = 0.99632215
Adj Rsqr = 0.99607696

Standard Error of Estimate = 3.8749

	Coefficient	**Std. Error**	**t**	**P**
a	215.2755	2.4392	88.2578	<0.0001
b	0.0044	0.0001	51.0828	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	61012.3072	61012.3072	4063.4742	<0.0001
Residual	15	225.2222	15.0148		
Total	16	61237.5294	3827.3456		

PRESS = 313.9134

Durbin-Watson Statistic = 1.4805

Normality Test:
K-S Statistic = 0.1242
Significance Level = 0.9413

Constant Variance Test: P = 0.0484

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	215.2755	4.7245	1.2192	1.5691	1.6581
2	192.9056	-2.9056	-0.7498	-0.8665	-0.8589
3	172.8601	-2.8601	-0.7381	-0.8083	-0.7985
4	154.8976	-4.8976	-1.2639	-1.3472	-1.3882
5	138.8017	1.1983	0.3092	0.3254	0.3155
6	111.4538	8.5462	2.2055	2.3075	2.7758
7	89.4942	0.5058	0.1305	0.1369	0.1323
8	80.1946	-5.1946	-1.3406	-1.4076	-1.4597
9	71.8613	-3.8613	-0.9965	-1.0469	-1.0505
10	57.7026	2.2974	0.5929	0.6221	0.6089
11	51.7065	3.2935	0.8500	0.8902	0.8837
12	46.3335	4.6665	1.2043	1.2585	1.2856
13	41.5188	-1.5188	-0.3920	-0.4085	-0.3969
14	37.2045	-1.2045	-0.3108	-0.3230	-0.3132
15	33.3384	-0.3384	-0.0873	-0.0905	-0.0874
16	29.8741	-0.8741	-0.2256	-0.2330	-0.2255
17	26.7698	-1.7698	-0.4567	-0.4703	-0.4578

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.8080	0.3962	1.3433
2	0.1259	0.2512	-0.4974
3	0.0651	0.1662	-0.3565
4	0.1234	0.1197	-0.5120
5	0.0057	0.0970	0.1034
6	0.2520	0.0865	0.8540
7	0.0009	0.0909	0.0418
8	0.1016	0.0930	-0.4674
9	0.0568	0.0939	-0.3382
10	0.0195	0.0915	0.1933
11	0.0384	0.0884	0.2752
12	0.0729	0.0843	0.3900
13	0.0072	0.0794	-0.1165
14	0.0042	0.0740	-0.0885
15	0.0003	0.0683	-0.0237
16	0.0018	0.0626	-0.0583
17	0.0067	0.0569	-0.1124

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	215.2755	210.0766	220.4745	205.5163	225.0348
2	192.9056	188.7665	197.0446	183.6673	202.1438
3	172.8601	169.4929	176.2273	163.9409	181.7793
4	154.8976	152.0397	157.7556	146.1580	163.6373
5	138.8017	136.2299	141.3735	130.1514	147.4520
6	111.4538	109.0252	113.8824	102.8450	120.0626
7	89.4942	87.0044	91.9840	80.8680	98.1205
8	80.1946	77.6759	82.7133	71.5599	88.8292
9	71.8613	69.3300	74.3926	63.2230	80.4996
10	57.7026	55.2038	60.2013	49.0737	66.3314
11	51.7065	49.2509	54.1621	43.0901	60.3230
12	46.3335	43.9361	48.7309	37.7334	54.9336
13	41.5188	39.1919	43.8458	32.9381	50.0995
14	37.2045	34.9577	39.4513	28.6452	45.7638
15	33.3384	31.1792	35.4977	24.8017	41.8752
16	29.8741	27.8078	31.9405	21.3604	38.3878
17	26.7698	24.7998	28.7399	18.2790	35.2607

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=10.3 m^3/s Transect 1 before bar

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 509.507}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0168192}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99696335
Rsqr = 0.99393592
Adj Rsqr = 0.99191456

Standard Error of Estimate = 14.8924

	Coefficient	Std. Error	t	P
a	509.5073	13.8170	36.8754	<0.0001
b	0.0168	0.0009	18.4437	0.0003

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	109054.6495	109054.6495	491.7167	0.0002
Residual	3	665.3505	221.7835		
Total	4	109720.0000	27430.0000		

PRESS = 1386.8395

Durbin-Watson Statistic = 3.2321

Normality Test:
K-S Statistic = 0.3069
Significance Level = 0.6470

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 0.9957

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	509.5073	0.4927	0.0331	0.0887	0.0725
2	334.6091	5.3909	0.3620	0.4253	0.3582
3	219.7481	-19.7481	-1.3261	-1.5892	-3.2632
4	144.3153	15.6847	1.0532	1.2664	1.5158
5	94.7763	0.2237	0.0150	0.0174	0.0142

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0243	0.8608	0.1803
2	0.0344	0.2754	0.2208
3	0.5510	0.3038	-2.1555
4	0.3576	0.3084	1.0122
5	0.0001	0.2516	0.0082

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	509.5073	465.5356	553.4791	444.8566	574.1580
2	334.6091	309.7363	359.4819	281.0848	388.1335
3	219.7481	193.6266	245.8696	165.6322	273.8640
4	144.3153	117.9956	170.6351	90.1034	198.5272
5	94.7763	71.0031	118.5495	41.7540	147.7986

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=10.3 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 506.964}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0146631}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99828299
Rsqr = 0.99656894
Adj Rsqr = 0.99542525

Standard Error of Estimate = 10.4717

	Coefficient	**Std. Error**	**t**	**P**
a	506.9638	9.5787	52.9260	<0.0001
b	0.0147	0.0006	25.5548	0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	95551.0296	95551.0296	871.3644	<0.0001
Residual	3	328.9704	109.6568		
Total	4	95880.0000	23970.0000		

PRESS = 997.0861

Durbin-Watson Statistic = 2.5740

Normality Test:
K-S Statistic = 0.2395
Significance Level = 0.8942

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 0.9988

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	506.9638	3.0362	0.2899	0.7175	0.6437
2	351.3776	-1.3776	-0.1316	-0.1536	-0.1259
3	243.5404	-13.5404	-1.2930	-1.5293	-2.6600
4	168.7983	11.2017	1.0697	1.2967	1.5971
5	116.9944	3.0056	0.2870	0.3412	0.2842

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	1.3192	0.8367	1.4572
2	0.0043	0.2661	-0.0758
3	0.4665	0.2851	-1.6799
4	0.3948	0.3195	1.0944
5	0.0241	0.2926	0.1828

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	506.9638	476.4801	537.4475	461.7992	552.1285
2	351.3776	334.1876	368.5675	313.8797	388.8754
3	243.5404	225.7451	261.3357	205.7613	281.3196
4	168.7983	149.9610	187.6356	130.5173	207.0793
5	116.9944	98.9689	135.0199	79.1063	154.8826

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=10.3 m^3/s Transect 3 before bar

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 509.397}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0154729}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99827525
Rsqr = 0.99655347
Adj Rsqr = 0.99540462

Standard Error of Estimate = 10.8293

	Coefficient	**Std. Error**	**t**	**P**
a	509.3972	9.9612	51.1382	<0.0001
b	0.0155	0.0006	25.0757	0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	101728.1780	101728.1780	867.4402	<0.0001
Residual	3	351.8220	117.2740		
Total	4	102080.0000	25520.0000		

PRESS = 729.8240

Durbin-Watson Statistic = 3.1119

Normality Test:
K-S Statistic = 0.3256
Significance Level = 0.5716

Constant Variance Test: P = 0.0500

Power of performed test with alpha = 0.0500: 0.9988

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	509.3972	0.6028	0.0557	0.1419	0.1162
2	345.9885	4.0115	0.3704	0.4333	0.3654
3	234.9994	-14.9994	-1.3851	-1.6464	-4.3282
4	159.6143	10.3857	0.9590	1.1594	1.2742
5	108.4119	1.5881	0.1466	0.1724	0.1415

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0553	0.8461	0.2725
2	0.0345	0.2690	0.2217
3	0.5596	0.2923	-2.7813
4	0.3102	0.3158	0.8656
5	0.0057	0.2768	0.0876

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	509.3972	477.6964	541.0981	462.5712	556.2233
2	345.9885	328.1131	363.8639	307.1649	384.8121
3	234.9994	216.3683	253.6305	195.8222	274.1767
4	159.6143	140.2478	178.9808	120.0821	199.1466
5	108.4119	90.2784	126.5454	69.4688	147.3550

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=10.3 m^3/s Transect 1 after bar

```
[Variables]
x = col(6)
y = col(7)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 94.8426}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00543055}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99722270
Rsqr = 0.99445310
Adj Rsqr = 0.99394884

Standard Error of Estimate = 2.1885

	Coefficient	**Std. Error**	**t**	**P**
a	94.8426	1.4911	63.6047	<0.0001
b	0.0054	0.0002	34.5612	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	9445.6216	9445.6216	1972.0910	<0.0001
Residual	11	52.6861	4.7896		
Total	12	9498.3077	791.5256		

PRESS = 68.9237

Durbin-Watson Statistic = 2.0172

Normality Test:
K-S Statistic = 0.1392
Significance Level = 0.9474

Constant Variance Test: P = 0.8775

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	94.8426	0.1574	0.0719	0.0983	0.0937
2	82.8022	1.1978	0.5473	0.6370	0.6189
3	72.2904	-2.2904	-1.0465	-1.1439	-1.1620
4	63.1130	-2.1130	-0.9655	-1.0305	-1.0337
5	55.1008	2.8992	1.3247	1.4050	1.4789
6	41.9986	3.0014	1.3714	1.4614	1.5523
7	32.0119	-2.0119	-0.9193	-0.9843	-0.9828
8	27.9480	0.0520	0.0238	0.0254	0.0243
9	24.4000	-3.4000	-1.5535	-1.6593	-1.8272
10	18.5980	0.4020	0.1837	0.1946	0.1859
11	16.2370	1.7630	0.8056	0.8492	0.8376
12	14.1757	1.8243	0.8336	0.8740	0.8639
13	12.3760	-1.3760	-0.6288	-0.6558	-0.6378

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	0.0042	0.4642	0.0872
2	0.0719	0.2618	0.3685
3	0.1274	0.1630	-0.5128
4	0.0738	0.1221	-0.3855
5	0.1232	0.1110	0.5225
6	0.1448	0.1194	0.5716
7	0.0709	0.1277	-0.3760
8	0.0000	0.1271	0.0093
9	0.1938	0.1234	-0.6855
10	0.0023	0.1092	0.0651
11	0.0401	0.1001	0.2793
12	0.0380	0.0904	0.2724
13	0.0189	0.0807	-0.1889

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	94.8426	91.5607	98.1246	89.0139	100.6713
2	82.8022	80.3377	85.2667	77.3915	88.2130
3	72.2904	70.3455	74.2353	67.0956	77.4851
4	63.1130	61.4298	64.7963	58.0105	68.2156
5	55.1008	53.4960	56.7055	50.0236	60.1780
6	41.9986	40.3342	43.6630	36.9022	47.0950
7	32.0119	30.2908	33.7331	26.8968	37.1271
8	27.9480	26.2308	29.6652	22.8341	33.0618
9	24.4000	22.7079	26.0920	19.2945	29.5054
10	18.5980	17.0063	20.1897	13.5249	23.6711
11	16.2370	14.7132	17.7607	11.1848	21.2891
12	14.1757	12.7273	15.6240	9.1457	19.2056
13	12.3760	11.0080	13.7441	7.3686	17.3835

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=10.3 m^3/s Transect 2 after bar

```
[Variables]
x = col(6)
y = col(8)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 121.491}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00513172}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99731883
Rsqr = 0.99464484
Adj Rsqr = 0.99415801

Standard Error of Estimate = 2.7045

	Coefficient	**Std. Error**	**t**	**P**
a	121.4914	1.8170	66.8628	<0.0001
b	0.0051	0.0001	35.9817	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	14944.3092	14944.3092	2043.0933	<0.0001
Residual	11	80.4601	7.3146		
Total	12	15024.7692	1252.0641		

PRESS = 114.0955

Durbin-Watson Statistic = 2.7055
Normality Test:

K-S Statistic = 0.1492
Significance Level = 0.9120

Constant Variance Test: P = 0.1370

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	121.4914	-1.4914	-0.5514	-0.7445	-0.7284
2	106.8633	3.1367	1.1598	1.3489	1.4078
3	93.9965	-2.9965	-1.1079	-1.2117	-1.2411
4	82.6789	2.3211	0.8582	0.9156	0.9083
5	72.7240	2.2760	0.8416	0.8911	0.8820
6	56.2657	-4.2657	-1.5772	-1.6763	-1.8522
7	43.5321	-2.5321	-0.9362	-1.0009	-1.0010
8	38.2906	1.7094	0.6320	0.6761	0.6585
9	33.6803	-0.6803	-0.2515	-0.2688	-0.2571
10	26.0580	3.9420	1.4575	1.5481	1.6690
11	22.9205	-1.9205	-0.7101	-0.7509	-0.7351
12	20.1608	-0.1608	-0.0595	-0.0626	-0.0597
13	17.7334	1.2666	0.4683	0.4904	0.4728

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.2280	0.4514	-0.6607
2	0.3209	0.2607	0.8361
3	0.1440	0.1639	-0.5496
4	0.0579	0.1214	0.3376
5	0.0481	0.1081	0.3070
6	0.1820	0.1147	-0.6666
7	0.0715	0.1250	-0.3783
8	0.0330	0.1261	0.2502
9	0.0051	0.1243	-0.0969
10	0.1535	0.1136	0.5974
11	0.0333	0.1058	-0.2528
12	0.0002	0.0971	-0.0196
13	0.0116	0.0880	0.1469

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	121.4914	117.4921	125.4906	114.3200	128.6627
2	106.8633	103.8237	109.9028	100.1795	113.5471
3	93.9965	91.5862	96.4067	87.5744	100.4186
4	82.6789	80.6051	84.7527	76.3753	88.9824
5	72.7240	70.7672	74.6807	66.4580	78.9900
6	56.2657	54.2499	58.2815	49.9810	62.5504
7	43.5321	41.4278	45.6364	37.2185	49.8458
8	38.2906	36.1765	40.4048	31.9737	44.6076
9	33.6803	31.5813	35.7793	27.3684	39.9922
10	26.0580	24.0521	28.0640	19.7765	32.3396
11	22.9205	20.9848	24.8563	16.6610	29.1800
12	20.1608	18.3061	22.0155	13.9259	26.3957
13	17.7334	15.9673	19.4994	11.5242	23.9425

Nonlinear Regression Analysis for SPMC values with SigmaPlot 8.0 for Q=10.3 m^3/s Transect 3 after bar

```
[Variables]
x = col(6)
y = col(9)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 106.39}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.00523923}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99620663
Rsqr = 0.99242766
Adj Rsqr = 0.99173926

Standard Error of Estimate = 2.8200

	Coefficient	**Std. Error**	**t**	**P**
a	106.3902	1.9044	55.8648	<0.0001
b	0.0052	0.0002	30.1693	<0.0001

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	11464.2189	11464.2189	1441.6544	<0.0001
Residual	11	87.4734	7.9521		
Total	12	11551.6923	962.6410		

PRESS = 142.2481

Durbin-Watson Statistic = 1.6165

Normality Test:
K-S Statistic = 0.2076
Significance Level = 0.5773

Constant Variance Test: P = 0.5907

Power of performed test with alpha = 0.0500: 1.0000

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	106.3902	3.6098	1.2801	1.7357	1.9421
2	93.3291	-1.3291	-0.4713	-0.5483	-0.5301
3	81.8715	-3.8715	-1.3729	-1.5012	-1.6052
4	71.8206	1.1794	0.4183	0.4463	0.4294
5	63.0035	-1.0035	-0.3558	-0.3770	-0.3618
6	48.4837	1.5163	0.5377	0.5720	0.5537
7	37.3102	-4.3102	-1.5285	-1.6349	-1.7917
8	32.7298	-1.7298	-0.6134	-0.6563	-0.6384
9	28.7117	1.2883	0.4569	0.4881	0.4705
10	22.0948	3.9052	1.3848	1.4696	1.5630
11	19.3823	2.6177	0.9283	0.9805	0.9786
12	17.0029	1.9971	0.7082	0.7443	0.7282
13	14.9155	-1.9155	-0.6793	-0.7102	-0.6933

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	1.2631	0.4561	1.7784
2	0.0531	0.2611	-0.3152
3	0.2204	0.1636	-0.7099
4	0.0138	0.1216	0.1598
5	0.0087	0.1091	-0.1266
6	0.0216	0.1164	0.2010
7	0.1927	0.1260	-0.6803
8	0.0312	0.1265	-0.2430
9	0.0169	0.1240	0.1771
10	0.1362	0.1120	0.5550
11	0.0556	0.1037	0.3328
12	0.0289	0.0946	0.2354
13	0.0235	0.0853	-0.2117

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	106.3902	102.1986	110.5818	98.9007	113.8797
2	93.3291	90.1574	96.5009	86.3590	100.2993
3	81.8715	79.3611	84.3820	75.1764	88.5667
4	71.8206	69.6562	73.9849	65.2473	78.3938
5	63.0035	60.9536	65.0534	56.4670	69.5399
6	48.4837	46.3662	50.6012	41.9258	55.0417
7	37.3102	35.1071	39.5133	30.7241	43.8963
8	32.7298	30.5220	34.9376	26.1421	39.3174
9	28.7117	26.5258	30.8977	22.1313	35.2921
10	22.0948	20.0178	24.1718	15.5499	28.6398
11	19.3823	17.3839	21.3807	12.8619	25.9028
12	17.0029	15.0938	18.9120	10.5092	23.4965
13	14.9155	13.1030	16.7280	8.4496	21.3814

<u>Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=6.9 m³/s Transect 1 before bar</u>

```
[Variables]
x = col(2)
y = col(3)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 151.114}}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0360692}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99837042
Rsqr = 0.99674350
Adj Rsqr = 0.99565800

Standard Error of Estimate = 4.0597

	Coefficient	**Std. Error**	**t**	**P**
a	151.1139	4.0065	37.7172	<0.0001
b	0.0361	0.0020	17.7218	0.0004

Analysis of Variance:

	DF	**SS**	**MS**	**F**	**P**
Regression	1	15133.7559	15133.7559	918.2345	<0.0001
Residual	3	49.4441	16.4814		
Total	4	15183.2000	3795.8000		

PRESS = 1964.7508

Durbin-Watson Statistic = 2.0442

Normality Test:
K-S Statistic = 0.4282
Significance Level = 0.2394

Constant Variance Test: P = 0.0500
Power of performed test with alpha = 0.0500: 0.9989

Regression Diagnostics:

Row	**Predicted**	**Residual**	**Std. Res.**	**Stud. Res.**	**Stud. Del. Res.**
1	151.1139	-1.1139	-0.2744	-1.6998	-7.2304
2	61.3321	4.6679	1.1498	1.6577	4.6683
3	24.8927	-2.8927	-0.7125	-0.8763	-0.8295
4	10.1031	-4.1031	-1.0107	-1.0833	-1.1336
5	4.1005	-1.1005	-0.2711	-0.2765	-0.2287

Influence Diagnostics:

Row	**Cook'sDist**	**Leverage**	**DFFITS**
1	54.0102	0.9739	-44.2084
2	1.4817	0.5189	4.8479
3	0.1968	0.3389	-0.5939
4	0.0873	0.1295	-0.4373
5	0.0015	0.0387	-0.0459

95% Confidence:

Row	**Predicted**	**Regr. 5%**	**Regr. 95%**	**Pop. 5%**	**Pop. 95%**
1	151.1139	138.3634	163.8643	132.9619	169.2658
2	61.3321	52.0256	70.6386	45.4094	77.2548
3	24.8927	17.3713	32.4140	9.9430	39.8423
4	10.1031	5.4531	14.7531	-3.6280	23.8342
5	4.1005	1.5577	6.6433	-9.0671	17.2682

Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=6.9 m^3/s Transect 2 before bar

```
[Variables]
x = col(2)
y = col(4)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 150.23 }}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0293665}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99879731
Rsqr = 0.99759606
Adj Rsqr = 0.99679475

Standard Error of Estimate = 3.3080

	Coefficient	Std. Error	t	P
a	150.2296	3.2265	46.5619	<0.0001
b	0.0294	0.0013	23.1861	0.0002

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	13623.1718	13623.1718	1244.9515	<0.0001
Residual	3	32.8282	10.9427		
Total	4	13656.0000	3414.0000		

PRESS = 83.0854

Durbin-Watson Statistic = 2.9797

Normality Test:
K-S Statistic = 0.2956
Significance Level = 0.6928

Constant Variance Test: P = 0.0500
Power of performed test with alpha = 0.0500: 0.9995

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	150.2296	-0.2296	-0.0694	-0.3146	-0.2612
2	72.0963	-0.0963	-0.0291	-0.0380	-0.0311
3	34.5996	3.4004	1.0279	1.2842	1.5626
4	16.6046	-4.6046	-1.3920	-1.5505	-2.8405
5	7.9687	0.0313	0.0095	0.0099	0.0081

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	0.9672	0.9513	-1.1548
2	0.0005	0.4134	-0.0261
3	0.4624	0.3593	1.1701
4	0.2894	0.1941	-1.3938
5	0.0000	0.0820	0.0024

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	150.2296	139.9617	160.4976	135.5239	164.9354
2	72.0963	65.3275	78.8652	59.5806	84.6121
3	34.5996	28.2895	40.9096	22.3259	46.8733
4	16.6046	11.9671	21.2420	5.1010	28.1082
5	7.9687	4.9550	10.9824	-2.9816	18.9190

<u>Nonlinear Regression Analysis for SPMC values with SIGMAPLOT 8.0 for Q=6.9 m^3/s Transect 3 before bar</u>

```
[Variables]
x = col(2)
y = col(5)
reciprocal_y = 1/abs(y)
reciprocal_ysquare = 1/y^2
'Automatic Initial Parameter Estimate Functions
xnear0(q) = max(abs(q))-abs(q)
yatxnear0(q,r) = xatymax(q,xnear0(r))
[Parameters]
a = yatxnear0(y,x)  "Auto {{previous: 150.629 }}
b = if(x50(x,y)-min(x)=0, 1,  -ln(.5)/(x50(x,y)-min(x)))  "Auto {{previous: 0.0325619}}
[Equation]
f = a*exp(-b*x)
fit f to y
"fit f to y with weight reciprocal_y
"fit f to y with weight reciprocal_ysquare
[Constraints]
b>0
[Options]
tolerance = 0.0001
stepsize = 100
iterations=100
```

R = 0.99945819
Rsqr = 0.99891668
Adj Rsqr = 0.99855558

Standard Error of Estimate = 2.2723

	Coefficient	Std. Error	t	P
a	150.6286	2.2307	67.5261	<0.0001
b	0.0326	0.0010	32.7864	<0.0001

Analysis of Variance:

	DF	SS	MS	F	P
Regression	1	14283.3098	14283.3098	2766.2682	<0.0001
Residual	3	15.4902	5.1634		
Total	4	14298.8000	3574.7000		

PRESS = 331.9356

Durbin-Watson Statistic = 2.1724

Normality Test:
K-S Statistic = 0.2595
Significance Level = 0.8307

Constant Variance Test: P = 0.0500
Power of performed test with alpha = 0.0500: 0.9999

Regression Diagnostics:

Row	Predicted	Residual	Std. Res.	Stud. Res.	Stud. Del. Res.
1	150.6286	-0.6286	-0.2766	-1.4517	-2.1733
2	66.7376	2.2624	0.9956	1.3584	1.7878
3	29.5688	-0.5688	-0.2503	-0.3113	-0.2584
4	13.1008	-3.1008	-1.3646	-1.4907	-2.3901
5	5.8044	0.1956	0.0861	0.0887	0.0725

Influence Diagnostics:

Row	Cook'sDist	Leverage	DFFITS
1	27.9669	0.9637	-11.1960
2	0.7949	0.4628	1.6595
3	0.0265	0.3535	-0.1911
4	0.2147	0.1620	-1.0508
5	0.0002	0.0580	0.0180

95% Confidence:

Row	Predicted	Regr. 5%	Regr. 95%	Pop. 5%	Pop. 95%
1	150.6286	143.5296	157.7276	140.4950	160.7622
2	66.7376	61.8180	71.6572	57.9914	75.4839
3	29.5688	25.2694	33.8683	21.1558	37.9819
4	13.1008	10.1904	16.0112	5.3056	20.8960
5	5.8044	4.0624	7.5465	-1.6339	13.2428

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