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Rauf Ramooz
AUTEUR DE LA THÈSE / AUTHOR OF THESIS

M.A.Sc. (Civil Engineering)
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Department of Civil Engineering
FACULTÉ, ÉCOLE, DÉPARTEMENT / FACULTY, SCHOOL, DEPARTMENT

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TITRE DE LA THÈSE / TITLE OF THESIS

Dr. Colin Rennie
DIRECTEUR (DIRECTRICE) DE LA THÈSE / THESIS SUPERVISOR

CO-DIRECTEUR (CO-DIRECTRICE) DE LA THÈSE / THESIS CO-SUPERVISOR

EXAMINATEURS (EXAMINATRICES) DE LA THÈSE / THESIS EXAMINERS

Dr. M. Fall

Dr. I. Nistor

Dr. P. Van Geel

Gary W. Slater
Le Doyen de la Faculté des études supérieures et postdoctorales / Dean of the Faculty of Graduate and Postdoctoral Studies

Laboratory ADCP Bedload Measurements: Comparison with Capture Rates and Dune Tracking

by

Rauf Ramooz

A thesis
submitted under the supervision of
Dr. Colin D Rennie

in partial fulfillment of the
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in
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Department of Civil Engineering
University of Ottawa
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ABSTRACT:

Moving bottom bias in acoustic Doppler current profiler (ADCP) bottom tracking has been used as an estimate of apparent bedload velocity (Rennie et al., 2002). However, it remains unknown if the apparent bedload velocity is an unbiased estimate of average bedload particle velocity. This paper presents a controlled laboratory calibration of ADCP bedload velocity, which was performed in the Main Test Channel at the St. Anthony Falls Laboratory as part of the National Centre for Earth-Surface Dynamics SedT project.

The length of the sediment-recirculating mobile bed test section was 20 m. Both sand-bed (d_{50} = 0.98 mm) and gravel-bed (d_{50} = 11.06 mm) bedload transport experiments were conducted, with five flow rates tested for each sediment. Bottom track data were collected with both 600 and 1200 kHz Rio Grande ADCPs, and over a range of bottom track pulse lengths (&R20 to &R40). Actual bedload transport rates were measured using 1) conventional samplers, 2) five automatic weigh pans spread across the channel at the end of the test section, 3) dune tracking by means of eight sonars, and 4) high speed digital videography. In this paper, measured apparent bedload velocity is compared to bedload transport rate from the weigh pans and dune tracking. In addition, the influence of bottom track pulse length and operating frequency on measured bedload velocity is assessed. The results show correlation between ADCP bottom tracking and measured bedload transport rates, with coefficient of determination (r^2) ranging from 0.59 to 0.93 with RMSE (root mean square error) ranging from 0.059 m/s to 0.106 m/s for sand bed. For the gravel bed, correlation was found between capture rates and dune tracking with r^2 0.52 to 0.97; however, the results were scattered. Initial experimental test results verified that moving bottom bias in acoustic Doppler current profiler (ADCP) bottom tracking can be used as an estimate of bedload velocity. A comparison was achieved successfully with measured flux of capture rates and dune tracking transport rates. The preliminary results were promising for sand bed experiments; however for gravel bed it appears that the flow depths were insufficient for the operation of ADCP.

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1- BEDLOAD MEASUREMENT TECHNIQUES AND POTENTIAL OF NONINVASIVE GAUGING BEDLOAD TRANSPORT TECHNIQUE

1.1: BEDLOAD:

Sedimentation can be represented as the processes of erosion, entrainment, transportation, deposition, and the compaction of sediment. Sediment is transported as suspended load or bedload. Bed material load can be transported as bedload or in suspension. Wash load is suspended passage of fine material through a river reach without deposition or entrainment from the river bed.

Bedload can be described as the sediment moving on or near the streambed and remains in contact with the bed for most of the time. It is a portion of the total sediment in transport that is carried by intermittent contact with the streambed by rolling, sliding, and saltating or bouncing.

Understanding of bedload is important for the reliable estimation of erosion and silting rates of engineering projects. Bedload measurements in rivers are also required to assess the sediment load for the design of hydraulic structures, such as bridges, pipelines and other hydraulic structures across a river, water management such as river training works, reservoir silting problems, and for the assessment of aquatic habitat, etc. It is also important for the better understanding of the problems of river morphology which depend on the pattern of sediment transfer along a river reach through local erosion and deposition. Fluvial phenomena, such as meandering of the river, development of bars and ripples, and dune migration all depend on the erosion and deposition of the bedload in the rivers. Therefore, understanding the bedload helps in assessing the above mentioned phenomena in the river which guides the better design of engineering projects.

A detailed review of the development of knowledge and research into bedload transport during the past century is presented by Gomez (1991). Detailed summary of sediment transport equations for predicting sediment transport, including bedload relations, is presented in a number of manuals and books like Sedimentation Engineering by ASCE (1977), Simsons and Senturk (1992), Reid and Dunne (1996), Chien and Wan (1999), etc. There appear to be as many approaches to predict bedload transport in the literature as there are varied stream conditions. However, the application of any sediment transport relation relies on the understanding of its assumptions/limitations and the availability of measured data to properly calibrate the model. Unfortunately, despite of lot of attention and development on this topic in past decades, reliable bedload measurement is still a challenge. Therefore, a reliable bedload measurement technique is essential for development of improved predictive models. Rennie (2002) developed a bedload measurement technique using the bottom tracking capability of an acoustic doppler current profiler (ADCP) for a reliable and easy means to measure bedload during flood and high flow rivers. This research is the extension of his work and emphasis will be to assess the reliability and the accuracy of bedload measurements using an ADCP. This introductory chapter provides a review of available bedload measurement techniques, and will conclude with a description of thesis objectives. A comprehensive review of bedload transport measuring techniques up to the 1960's was provided by Hubbell (1965). However a brief summary, including more recent techniques, is given in the following sections.

1.2: BEDLOAD TRANSPORT MEASUREMENT TECHNIQUES:

Sediment transport measurements in streams and rivers is not an easy task. It is difficult and dangerous to deploy heavy samplers in high flows. It is also expensive, time-consuming, and the accuracy of the measurements still likely to be poor.

There are different methods to measure bedload which vary from digging a pit in the river to acoustic methods which give temporally and spatially distributed bedload measurements. In the following sections we will describe some of the common techniques in use for the measurement of bedload in the field.

1.2.1: Conventional Physical Samplers and Traps

1.2.1.1: Direct measurements:

Bedload can be estimated by digging a hole in the streambed as shown in Figure 1.1 as follows:

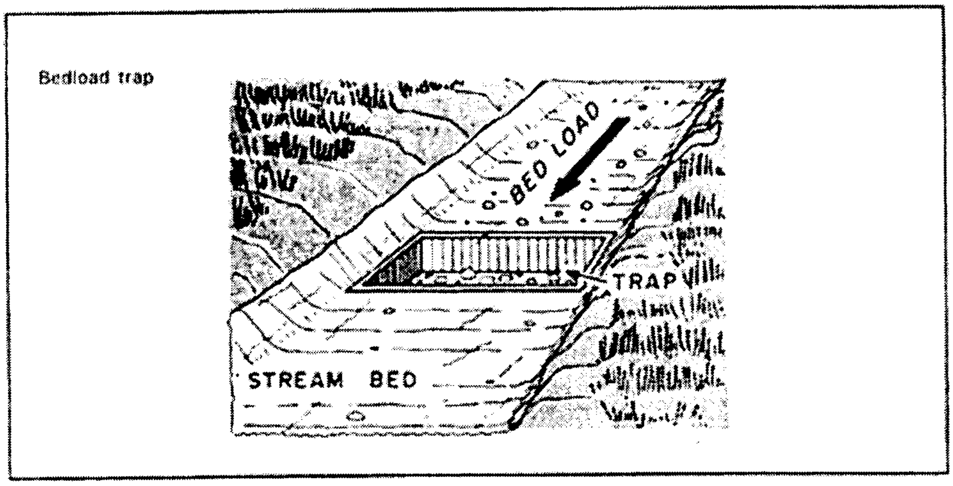


Figure 1.1: Direct Measurement of Bedload

http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/T0848E/t0848e-10.htm

After an event the sediment that dropped in the pit is removed and weighed.

The advantages of pit trap/ slot samplers are that they are relatively unobtrusive and minimum affect on the flow and provide more accurate estimates than other bedload samplers.

The shortcoming of this sampler is that it is not certain whether all the bedload has been trapped. Relatively fine bed material (sand) may saltate over the trap and very large events may fill the trap. Also for heavy loads it will be time consuming and laborious. Finally, the technique is not possible for high flows and deep waters.

1.2.1.2.: **Bedload Samplers**

Bedload measurements can also be obtained from bedload samplers by lowering that device to the streambed for a measured time then retrieving for weighing the sediment caught in the sampler. There are a number of samplers in use for the measurement of bedload discharge. These samplers are designed to sample sand, silt, gravel or rock debris carried by a stream on or immediately above its bed.

The simplest form is a wire basket with a stabilizing tail fin as illustrated in Figure 1.2 as below:

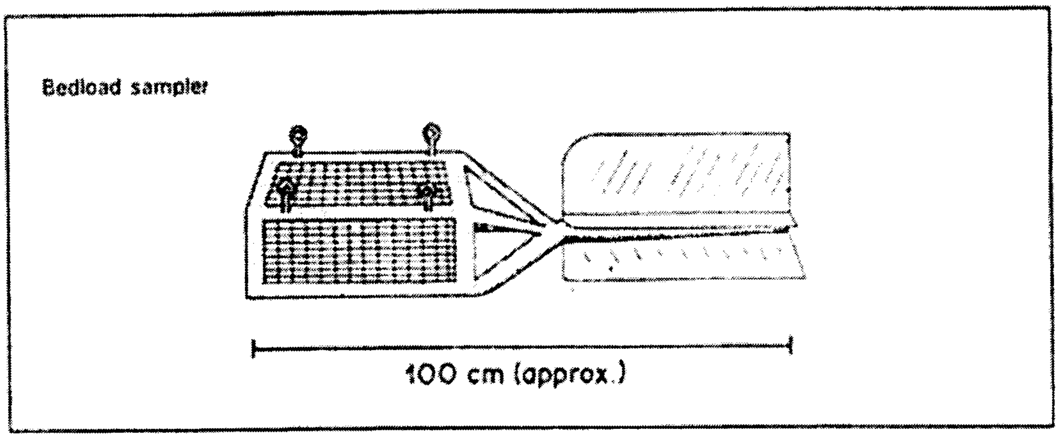


Figure 1.2: The simplest form of a bedlaod sampler.

http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/T0848E/t0848e-10.htm

In these types of samplers, sample (catch taken in one shot) taken is low. The reason is that they interfere with the flow and some material can be deflected round the sampler. This is more important when the bucket of the sampler is near to fill. In other words, back pressure reduces the flow into the sampler.

Similarly, some samplers have a diverging section behind the orifice and allow entry to the sampler at the surrounding stream velocity. These samplers are called pressure-difference samplers and an example is illustrated in Figure 1.3.

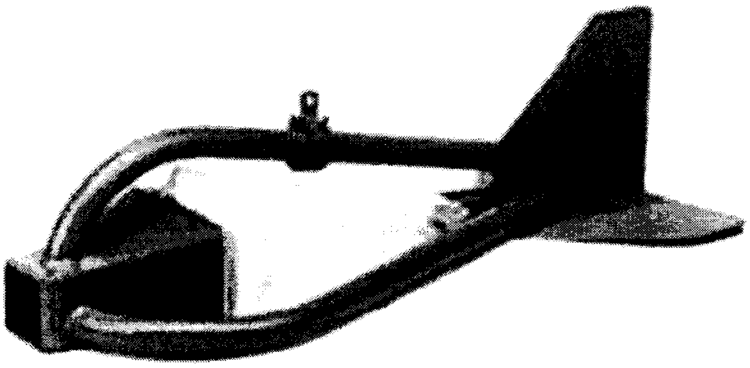


Figure 1.3: An example of pressure difference sampler
http://www.scientif.com/bedload.htm

There are two styles of samplers are in use in the field for bedload sampling. These are the Federal Interagency Sedimentation Project (FISP) design series which uses a 1.4 expansion ratio. The Helley Smith series has a 3.22 expansion ratio design. The commonly used bedload samplers are BL-Series (BLH-84, BL-84, BL-84C), Helly-Smith Pressure difference samplers and Toutle River Sampler (US-TR-2). The US ER1 is a smaller version of US-TR-2 and also known as the Elwha River Sampler.

There are various types of bedload sediment samplers and all have varying degrees of efficiency, since the devices themselves alter flow characteristics in different ways depending on bed conditions and flow intensity. These samplers need support and can be difficult and dangerous to deploy in deep flows and their exact position and orientation on the bed is unknown most of the time. These instruments are also limited to time-integrated single-point sampling. Thus spatial and temporal variation of the bedload can not be readily assessed. Accordingly, limited work has been carried out to-date to understand the spatial and temporal variation of bedload in rivers. Bedload measuring techniques require sophistication so that it should be flexible, non-intrusive, and able to access the spatial and temporal variations to get better bedload measurement.

1.2.2: Particle Image Velocimetry (PIV):

PIV is a technique in which the particle flow is photographed using a digital camera and a pulsed laser light sheet at two points of time, one right after the other. As the particles have moved in the time interval between the flashes so the distance and velocity of the particles can be calculated. PIV is technique provides instantaneous velocity vector measurements in a cross-section of a flow. In the case of bedload transport, the cross-section is in the vertical-streamwise plane near the bed. Plan-view video images can also record particle movements (e.g. Drake et al. 1988). Two velocity components can be measured using PIV but dual-camera stereoscopic approaches can record all three velocity components. For conventional 2-D measurements, the PIV method is only capable of recording the projection of the velocity vector into the plane of the light sheet in which the 3rd velocity component is always missing. For three-dimensional flows this may provide a substantial measurement error of the local velocity vector.

The most prominent work carried out in the field of bedload measurement using PIV techniques is by Chegini (2002), in which they used PIV to estimate simultaneous localized measurement of the near bed turbulent flow field together with the entrainment and transport of sediment grains. PIV is able to collect large numbers of simultaneous measurements of the near bed turbulent flow and individual grain movements over an area of bed and the spatial and temporal distribution of the near bed turbulent fluid forces and their impact on grain entrainment. The images collected from each camera were processed differently so that data on grain entrainment and transport and near bed flow velocities could be obtained. The PIV system was configured to measure the streamwise and lateral velocities in a plane, located above the sediment bed. Their preliminary results show that there is a range of flow velocities present over a water-worked sediment bed and that grains tend to be subjected to higher flow velocities before they are entrained.

Biron et al. (2005) utilized PIV techniques to study the impact of stream deflectors which were installed for fish habitat enhancement in the Nicollet River in 1993. They characterized the current flow dynamics and sediment transport around paired deflectors in this river. In their work, bedload sediment transport was investigated using particle tracers and sediment traps in 2004. Acoustic Doppler velocimeter (ADV) measurements, as well as particle image velocimetry (PIV) were used to look at the flow dynamics.

Arnott et al. (Ref 1) used PIV to measure the velocities of sand particles in sheet flow conditions. Because of the sheet flow conditions the amount of sediment entrained into the flow was high so PIV measurements could not be obtained. They were only able to obtain PIV measurements at approximately 7 cm from the bed, and they suggested that PIV is not a suitable method in the case of sheet flow.

1.2.3: Acoustic Doppler Backscatter:

Doppler sensors measure relative flow motion by transmitting high-frequency sound in a narrow beam and measuring the frequency shift (Doppler) of the returned sound as it is scattered from particles in the water. The Doppler frequency shift is directly proportional to the radial velocity of the flow relative to the sensor.

Acoustic Doppler backscatters are in use for sediment transport studies such as measurement of suspended sediment profiles, ripple bed/ bedforms morphology and turbulence. This technique has the capability of measuring relative velocity, using the Doppler shift of a backscattered sound "ping", at a distance away from the point of interest and thus does not disturb the signal of interest like other conventional methods of measuring sediment transport. Acoustic techniques have been gaining acceptance for the measurement of small-scale sediment processes over the last 20 years.

The concept of using acoustic diagnostics in the underwater environment is simple and explained by Thorne and Hanes (2002). They explained in detail the use of acoustic backscatter for the estimation of suspended sediment size and concentration, profiles of flow, and bedform morphology which leads to bedload estimation subject to known bedform celerity and the porosity of the sediment. The main aim of their study was to utilize the potential of acoustics to simultaneously and non-intrusively measure seabed morphology, the suspended sediment particle size and concentration profile, and the velocity profile.

Acoustic backscatter is in use for the study of suspended sediment size and concentration, however the accuracy and precision of the Doppler flow measurement is a complex function and requires the detailed knowledge of these parameters for the analysis of field data.

Commercially available Acoustic Doppler Current Profilers (ADCPs) are also acoustic Doppler backscatter instruments. ADCP is an electronic instrument developed and manufactured by RD Instruments that is used to measure water velocities (NORTEK and SonTek are the other main manufacturers). The instrument transmits acoustic signals into the water column. When the frequency of the transmitted signals is compared with the frequency of backscatter signals reflected off particles in the water, the velocity of the particles and, hence, the water, can be calculated. ADCPs employ either three or four acoustic beams, with a single velocity component obtained from each beam. Three beams are required to resolve three-dimensional velocities, and a fourth beam provides a redundant estimate of vertical velocity that may be used for error checking. The beams diverge from the instrument, usually with slant angles of 20°, thus each beam measures a different location in the water column. Accordingly, an assumption of homogenous velocity in horizontal planes is required. Deines

(1999) explained how to obtain backscatter level from an RD Instruments Workhorse or Broadband ADCP, and Alvarez and Jones (2002) used ADCP backscatter for suspended load measurements. ADCP from RD Instruments is shown in figure 1.6 below:

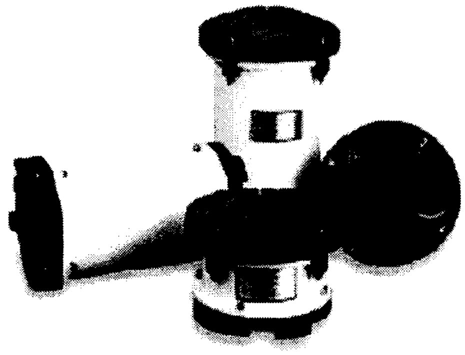


Figure 1.4: Workhorse ADCP, Technical Manual, RD Instruments

1.2.4: Bedforms from sonar

Sonars are in use for the estimation of bedform morphology which leads to the bedload estimation if bedform celerity and porosity are known (Simons 1965). At present there are three types of transducers in use for bedforms profiles (Hanes 2002) and these are single transducer, multi-transducer and a single transducer radialy rotates to provide a profile of the bed.

1.2.5: Acoustic Doppler Current Profiler (ADCP) Bottom Tracking:

As explained earlier ADCP is an electronic instrument that is used to measure water velocities. The instrument transmits acoustic signals into the water column. When the frequency of the transmitted signals is compared with the frequency of backscatter signals reflected off particles in the water, the velocity of the particles and, hence, the water, can be calculated.

This section will not describe details of ADCP like its operating techniques and theory nor the theoretical and practical (configuration) aspects of ADCP. The focus will be on the bottom tracking feature of ADCP, as this is utilized in this thesis.

Bottom tracking has been utilized for the measurement of bedload (Rennie et al. 2002) with the goal of developing a noninvasive technique for gauging bed-load transport. The following section will describe the principles of bottom tracking and the work carried out to date to utilize bottom tracking for measurement of bedload.

1.2.5.1: Principles of Bottom Tracking

An ADCP measures water velocity relative to itself, whether the ADCP is fixed in position or moving on a vessel. Correction for ADCP velocity for moving-vessel applications is required to derive actual absolute water velocities. Bottom tracking provides the required vessel velocity. Bottom tracking is a procedure/technique to measure speed-over-ground. The sonar emits acoustic pulses that are scattered by the bottom. Determining the Doppler shift in the returned echo provides a measure of the relative velocity between ADCP and the bottom. This information is used to provide motion data required by the ADCP for its water-velocity measurement.

An ADCP measures both water velocity and its own motion from bottom tracking in the same reference frame (defined by its four acoustic beams), thus several potential error sources affecting the motion-corrected ADCP velocities are eliminated automatically. If bottom tracking is not available, then other vessel velocimeters must be employed, such as a Differential Global Positioning System (DGPS). Correcting ADCP velocity by using data from these other devices requires very careful orientation and calibration to avoid systematic errors in the resulting velocity estimates.

Bottom tracking provides ADCP velocity, assuming that the river bed is stationary. However, in mobile river beds, e.g. during floods, bottom tracking is biased by particles moving on or near the river bed. The technique introduced by Rennie et al. (2002) was to extract bedload-induced bias in bottom track velocity, which serves as an estimate of the apparent velocity of bedload (v_a), by comparing bottom track velocity (v_{BT}) with DGPS velocity (v_{DGPS}).

$$v_a = v_{DGPS} - v_{BT} \qquad 1.1$$

Bottom-tracking requires long pulses to obtain vertical resolution as compared with water-profiling. These allow the sound beam to reflect off the bottom over the entire beam width all at once. A long pulse produces an accurate and stable estimate of velocity, more accurate than is typically obtained from water profiles. The downside of long transmit pulses is that a considerable part of the echo can come from water-mass echoes (Rennie and Millar, 2004). In the places with high concentrations of suspended sediment (i.e. in some rivers) the water-mass echoes can introduce significant *water bias* — this biases the bottom-track velocity toward the water velocity. Bottom-track velocity closely follows the pattern of flow velocity. Research shows that bottom-tracking may provide reliable estimates of bed velocity during periods of low suspended sand transport but it is biased by sand in suspension during periods of high transport (Kostaschuk et al. 2004). Caution should clearly be used in applying bottom-tracking to estimate bedload in sand-bed channels.

As discussed earlier, Rennie et al. (2002) were the first to use ADCP for bedload measurements. They used a SonTek 1500 kHz Acoustic Doppler Profiler (ADP). They estimated the apparent bedload velocity in the gravel bed of Fraser River, B.C. using ADCP bottom tracking and DGPS. Apparent bedload velocity (v_a) measurements were collected in stationary positions at 1 Hz (ensemble averaged at 0.2 Hz) for periods up to 90 minutes. They correlated mean observed apparent velocity with mean bedload transport rates measured using conventional samplers. They also co-related mean v_a with boundary shear stress which was assessed by a log-law fit to the mean velocity profile. They found large variations of v_a from individual 5 s ensemble averages and suggested that a minimum of 25 minutes of sampling was required to achieve stable estimates of the mean and coefficient of variation. Their view is that this variance was due to both real temporal variability of transport and measurement error, and they discussed mechanisms that caused this variability.

In 2003, Villard et al. tested the ADP for the estimation of bedload velocity in sand-bed rivers. Further, with some simple assumptions they converted the velocity of a mobile sand bed to an estimate of bedload. They compared their results with a Helley-Smith sampler and predictions from the V. Rijn (1984) bedload formula. The study shows that all three methods (Helly smith, V-Rijn and ADCP) produce consistent values. They found the best correlation ADCP and computed results. Their results shows that acoustic method has a potential for estimating bedload in sandbed channels and provides time saving and accurately.

Rennie and Millar (2004) extended the study by introducing a new technique to estimate temporal variability of bedload transport. In this paper they presented a method to estimate the probability density functions of bedload speed (f_V) and noise (f_N) from noisy stationary ADCP data. A semi-theoretical compound Poisson-gamma (cPg) distribution and an empirical gamma distribution for V were evaluated for bedload speed distributions. They tested these two distributions on ADCP bedload velocity time series measured in two different gravel-bed rivers (Fraser River and Norrish Creek) and found that both models fit well. Models generated using both the cPg and gamma distributions for V fit both data sets very well and the modeled convolution distribution did not differ significantly from the distribution of the original data. They found the gamma distribution fit slightly better than the cPg. They also showed the results of optimized bedload speed distributions (f_V) and found that distribution were highly left skewed which indicates that the bedload speed averaged within a beam area tended to be mostly near zero with a few high values, as was expected for partial bedload transport of gravel, where most of the particles remain at rest most of the time (Einstein 1937). They concluded that the acoustic noise is comparable to acoustic noise for ADCP water velocity measurements, which is an order of magnitude greater than typical bottom tracking noise.

Kostaschuk et al. (2004) used SonTek 1500 kHz ADP for the estimation of bedload from the Fraser River estuary, Canada in a sandbed. The purpose of the study was to utilize ADCP for the measurement of bedload and suspended load. In addition to that Kostaschuk et al. (2004) also utilized ADP for the measurement of velocity profiles over dunes in an estuary. They used ADP from a moving launch to measure three-dimensional velocity profiles, and used these profiles to discuss flow structure and to develop initial estimates of shear stress. They also concluded that the beam geometry of ADP results a large sampling diameter close to the bed that does not measure velocity in dune troughs accurately.

Rennie and Millar (2004) developed maps of the spatial distribution of two-dimensional bedload transport velocity vectors from ADP bedload velocity data for gravel and sand bed reaches of the Fraser River, British Columbia. They used block-averaged and interpolated bedload velocity vectors and found coherent patterns in the bedload velocity distribution. They also carried out Helley-smith bedload sampling in the sand-bed reach and confirmed the trends observed in the bedload velocity map. Further, by using a vector correlation coefficient, they found that the bedload velocity distribution was significantly correlated to the near-bed and depth-averaged water velocity distributions. The bedload velocity distribution was also compared with variations in depth and estimates of the spatial distribution of shear stress.

Rennie and Villard (2004) correlated and developed relations between ADP bedload transport velocity (v_a) and bedload transport rate (g_b) from conventional pressure difference samplers in both gravel bed and sand bed reaches of the Fraser River. Further, they concluded that the standard shear stress models provide poor correlation to the measured bedload transport rates. The results show that the sand bed data were over-predicted, and the gravel bed predictions correlated poorly with the measured transport rates. The main aim of the study was to highlight the potential of acoustic techniques for estimating bedload.

Gaeuman and Rennie (2006) compared the bed-velocity responses to bedload transport and flow changes measured with a 1500 kHz ADP in a sand-bed reach of the Fraser River (Rennie and Villard, 2004) to similar data collected with a 600 kHz ADCP in the lower Missouri River. The objective was to explore the adequacy of existing theory for describing differences in bed-velocity responses arising from differences in instrument frequency and reach characteristics. This study results show that the measure bedload transport rates using measurements obtained with an ADCP or similar instrument is possible. They suggested that significant obstacles must be overcome before calibrated ADCP bed-velocity measurements may be applied for routine monitoring of bedload. They also suggested that physical bedload transport samples can be difficult to obtain under some field conditions and therefore the accurate data is not available for ADCP calibration. Another source of error proposed by them related to the acoustic response of a given instrument which depends to some degree on site characteristics, including the sizes of sediment particles in transport.

Recently Gaueman and Jacobson (2006) published a paper in which they discussed the response of ADCP bed velocity measurements defined as the near-bed sediment velocity detected by the instrument's bottom-tracking feature, to changing sediment-transporting conditions in the lower Missouri River. They described that the ratio of bed velocity to mean bedload particle velocity depends on the concentration of the particles moving in the bedload layer, the bedload layer thickness, and the backscatter strength from a unit area of moving particles relative to the echo strength from a unit area of immobile bed. Their main focus was to evaluate the quality of bedload measurements using ADCP.

1.3: OBJECTIVES:

As discussed above, reliable bedload measurements are difficult to obtain by conventional methods because these methods are unable to assess the spatial and temporal variation of the bedload. Bedload measuring techniques require sophistication so that it should be flexible, non-intrusive, and able to assess the spatial and temporal variations to get better bedload measurement. The acoustic method permits continuous measurement of coarse particle apparent velocity during flood events, which is a direct reflection of the magnitude of bedload movement. ADCPs are now widely used for measuring fluid velocity in geophysical flows (e.g., Rennie et al. 2002, Kostaschuk et al. 2004, Rennie and Villard 2004, Gaeuman and Rennie 2006, Gaeuman and Jacobson 2006). The main aim of the studies was to evaluate the potential of bottom track capability of aDcp technique for estimating bedload. Despite of all these efforts, the method has not been calibrated in a controlled laboratory setting. Due to the lack of laboratory calibration, bedload velocity precision and bias remain unknown. Rennie et al. (2002) concluded that there remain two uncertainties that could lead to bias.

First, particularly in sandbed environments with a concentrated near-bed suspended layer, the precise location of reflection of a bottom track pulse and the corresponding location of measurement has not been determined. Assuming a velocity gradient from the bed, measurement near the top of the near-bed suspended layer would result in positive bias of the measured bedload velocity.

Second, other than the recent Gaueman and Jacobson (2006) paper, it has thus far been assumed that the measured velocity is a spatial average of surface particle velocities, including immobile particles. Particle velocities are actually weighted by backscatter intensity, with smaller isolated particles more likely to be de-emphasized due to Rayleigh scattering (refraction) instead of specular scattering (reflection). For a 1200 kHz aDcp, Rayleigh scattering should occur for particles < 0.04 mm, and specular scattering for particles > 2 mm. It is difficult to predict scattering from mid-size particles, thus weighting of sand and fine gravel velocities is uncertain.

In order to resolve these uncertainties, a research program was developed to calibrate ADCP bedload velocity measurement in a controlled laboratory setting.

1.3.1: Laboratory Calibration:

A laboratory experiment was carried out to assess the accuracy and bias of ADCP bedload velocity measurement. The study plan was to evaluate the precision and bias of bedload velocity measurement using a Rio Grande ADCP. Bedload velocity measured by ADCP will be compared to particle velocities estimated by videography, and bedload transport rates measured using an automated bedload pit trap. The goal was that the simultaneous measurements obtained should identify ADCP bedload velocity precision and bias, and sources of bias, in different fluvial environments and with different ADCP operating parameters. A secondary goal was to relate observed bedload to the simultaneous flow field, which may lead to new insights regarding patch-scale interactions between bed material transport and the turbulent flow field.

Development of a robust remote measurement technique for bedload will be a major advance in fluvial science. Measurements of the spatial distribution of bedload can be used for calibration and validation of morphodynamic river models to predict channel change. The development of a relatively simple technique to measure bedload transport non-invasively, using ADCPs currently being employed by government agencies, should lead to greater understanding of river morphological change.

1.3.1.1: SAFL Main Test Channel:

Based on Dr. Colin D. Rennie's proposal to the (US) National Center for Earth-Surface Dynamics (NCED), the experiments were carried out in the large flume at the Saint Anthony

Falls Laboratory (SAFL), University of Minnesota. This flume is for large-scale testing with a glass wall observation section, wave generator and sediment recirculation system. The flume is 85 m long x 2.75 m wide x 1.80 m deep and has a design discharge capacity of 8.5 m^3/s. The flume was substantially modified for the study, including upgrading of a bedload pit-trap with automatic weigh pans and sediment recirculation for the sediment measurements. The detail of the facility will be described in the next chapter.

1.3.1.2: Measurements:

The laboratory experiment to assess the accuracy and bias of bedload velocity measurement by using ADCP was a component of a major project titled "2006 Large-Scale Fluvial Ecology and Geomorphology Flume Study – A Major NCED Collaborative Research Project". Project phases were as follows:

– Phase I and II	– Bedload monitoring technologies
– Phase III, IV, V	– Eco-geomorphology processes

This project was a part of Phase I and II in which sediment transport monitoring technologies both conventional and surrogate technologies were tested for sampling the transport rate of sand and gravel. It was divided into two parts, 1st sand bed experiments and 2nd gravel bed experiments. Both 600 kHz and 1200 kHz four-beam ADCPs were used for bedload velocities and several single beam sonars were used to track bedforms/dunes. Two Acoustic Doppler Velocimeters (ADV) were deployed, one downstream (d/s) of ADCP to track near bed velocity of d/s ADCP's beam (beam 4), and the other was used to develop vertical velocity profiles to study the shear stress. Videography was used to track the particle velocities in the ADCP's beam 4 insonified area to compare with measured ADCP bedload velocities. The instrument package was deployed immediately upstream of the automatic bedload trap. Bedload samplers, specifically the 3" Helley-Smith, 3" BL84, Elwha, and Toutle River 2 (6"x12") were also used for bedload measurements. Details will be provided in the next chapter.

1.3.2: Thesis Objectives:

To achieve all the above explained goals was beyond the scope of this thesis. Therefore the goals for this thesis were to evaluate the precision and accuracy of ADCP measured bedload data which is a part of the main objective of the actual project described above and will lead to success of the main project. In addition, available data from the entire project will be catalogued in order to organize future research. The specific thesis objectives are explained below:

All objectives apply to both sand-bed and gravel-bed experiments.

1- Summarize the basic flow data, slope data for each flow, measurements taken for each flow and details of the experiments.

2- Assess influence of bottom track pulse length and operating frequency on measured bedload velocity.

3- Comparison of ADCP bedload velocity measurement with capture rates and dune tracking.

4- Shear stress profiles of sand and gravel bed experiments by using the measured vertical profile data by ADV and comparison with measured bedload.

Details of methodology and the analytical approach developed to achieve these objectives are described in chapter 2.

2- METHODOLOGY:

This chapter will cover in detail the study plan and the analytical methods to estimate the bedload by using the collected data. The study plan will include details of the experimental set-up and of the tasks planned for the study. In addition, it will also cover the experimental procedures used to collect the data using different instruments including ADCP, weigh pans, bedload samplers, ADV for near bed velocity, ADV for vertical profiles, videography and sonars for bed morphology. All of the instruments were used for the data collection for five different discharges for each of the sand-bed and gravel-bed environments.

2.1: STUDY PLAN

The study plan is divided into three parts, which covers data collection plan, experimental procedures and data collected using the instruments explained earlier.

2.1.1: Data Collection Plan:

2.1.1.1: Introduction:

This section will describe the plan of the Project in detail. Initially it will describe the SAFL main channel facility, overview of the project and the experimental setup in detail. The following map shows the location of the project situated in SAFL, UMN, Minneapolis, Minnesota.

Figure 2.1: Location of the Project (Taken by myself from the information about Mississippi River on the left bank near St Anthony Falls Laboratories, MN)

The lab is located on the Mississippi River, as shown in Figure 2.1, which is one of the largest rivers in the world. The main channel facility at the SAFL is over 85 m long, has an intake from the Mississippi River with a water discharge capacity of 8.5 m^3/s and is configured with a sediment (both gravel and sand) recirculation system and a automatic weigh pan system for measuring bedload transport rates.

As discussed earlier, in 2006, a multi-phase, large-scale, collaborative research project was carried out by utilizing the main channel facility at the SAFL, UMN, Minneapolis, USA through the National Center for Earth-surface Dynamics (NCED). The main channel facility was used as a "natural" mobile-bed stream with interacting stream-system processes. The channel was utilized with natural sediments (gravel and sand) with mobile bed conditions. The channel was run with five different steady discharges to evaluate transport under different shear stresses. The present study was part of Phase I and II (detail of phases has been described in chapter 1). The scope of this phase was testing the sediment transport monitoring technologies by using conventional and surrogate technologies for sampling the transport rate of sand and gravel. In addition to ADCP and weigh pans, conventional samplers (3" Helley-smith bedload sampler, 3" BL84 bedload sampler, Elwha sampler and Toutle River 2 sampler

(6"x12")) were also used to estimate bedload. In addition videography, ADV and sonars were also utilized for the study of river morphodynamics.

Main Channel in SAFL:

The SAFL main channel is one of the largest facilities for water resources experiments for rivers in the world. The following is the sketch of the channel.

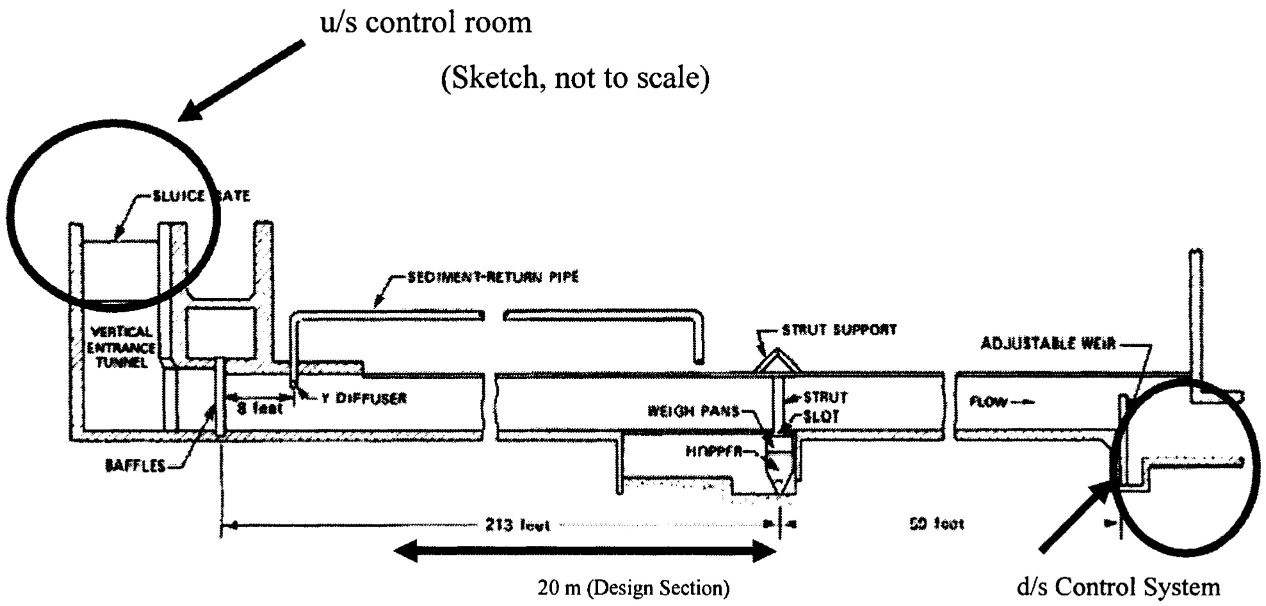


Figure 2.2: Sketch of main flume at St. Anthony Falls Laboratory

Adapted from Jeff Mar Presentation (Project Director for this Project at SAFL) and modified

This flume is for large-scale testing with a glass wall observation section, wave generator and sediment recirculation system. The hydraulic parameters have already been described in Chapter-1.

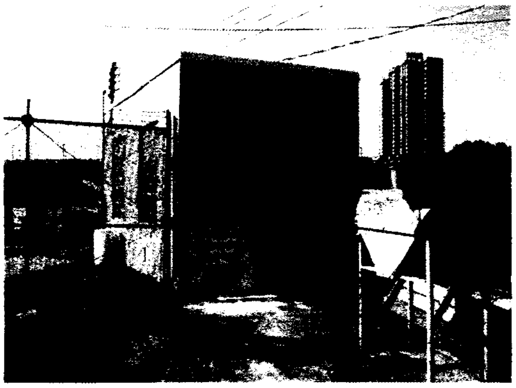


Figure 2.3 a


Figure 2.3 b


Figure 2.3 c


Figure 2.3 d


Figure 2.3 e

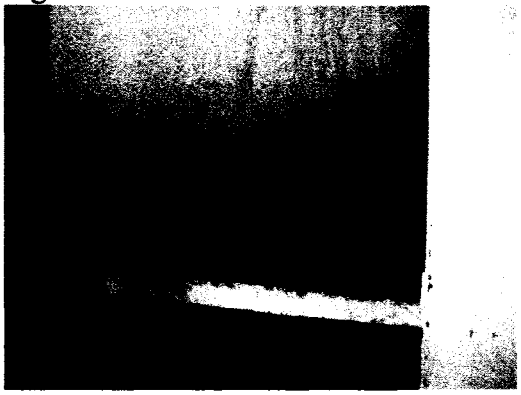


Figure 2.3 f

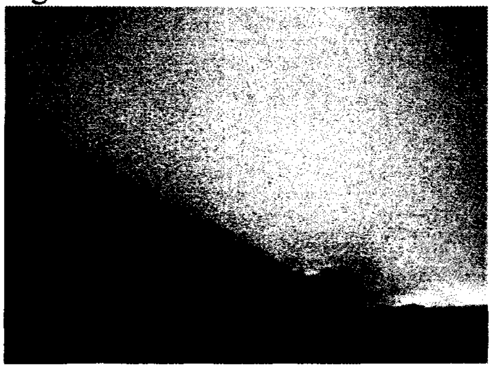


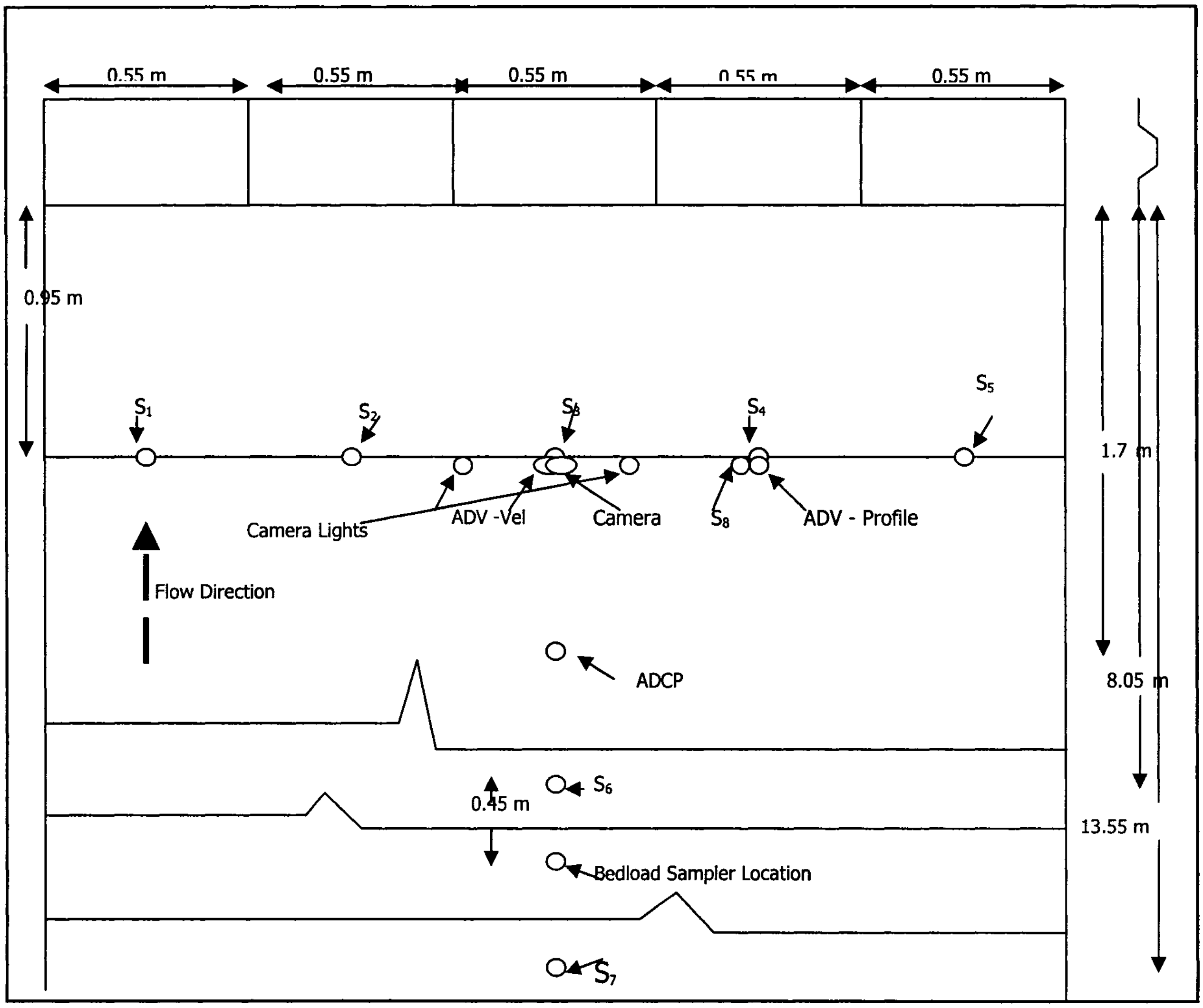
Figure 2.3 h

Figure 2.3: Photographs showing the main flume components:

Figure 2.3 shows the components of the main flume at SAFL. Figure 2.3 a shows the u/s gate operation room. 2.3 b shows the outside area of the channel u/s of the gated structure at Mississippi River and the u/s flume operation room. Figures 2.3 c and 2.3 d show the d/s gate inside the lab of the flume. Figure 2.3 e shows a general view of the flume looking u/s. Figure 2.3 f shows the volumetric tank outside of the tail of the flume. Figures 2.3 g and 2.3 h are the glass wall of the flume on right bank which starts just u/s of the place where the weigh pans were installed. Figure 2.3 g also shows the dunes pattern in sand bed experiments and figure 2.3 h shows the slope just u/s of the weigh pans, where the sand goes to the weigh pan drums. This slope was used to estimate the angle of repose.

2.1.1.2: Experimental Set-Up:

The instruments set-up for the experiments is explained in Figure 2.4.



S = Sonars, ADCP = Acoustic Doppler Current Profiler, ADV = Acoustic Doppler Velocimeter

Figure 2.4: Schematic diagram of the experimental set-up (Plan view)

The ADCP was mounted at a distance of 1.7 m from the u/s of weigh pans. The sampling area ADV is at a distance of 72 cm d/s of ADCP and 7.25 cm left looking d/s (from centerline of the channel). The video camera was mounted on the same mount as the sampling area ADV, and was directly d/s of the ADCP. The focus of the camera was 10 cm d/s of the center of ADCP beam 4 insonified area based on nominal sand bed elevation as described in Figure 2.5.

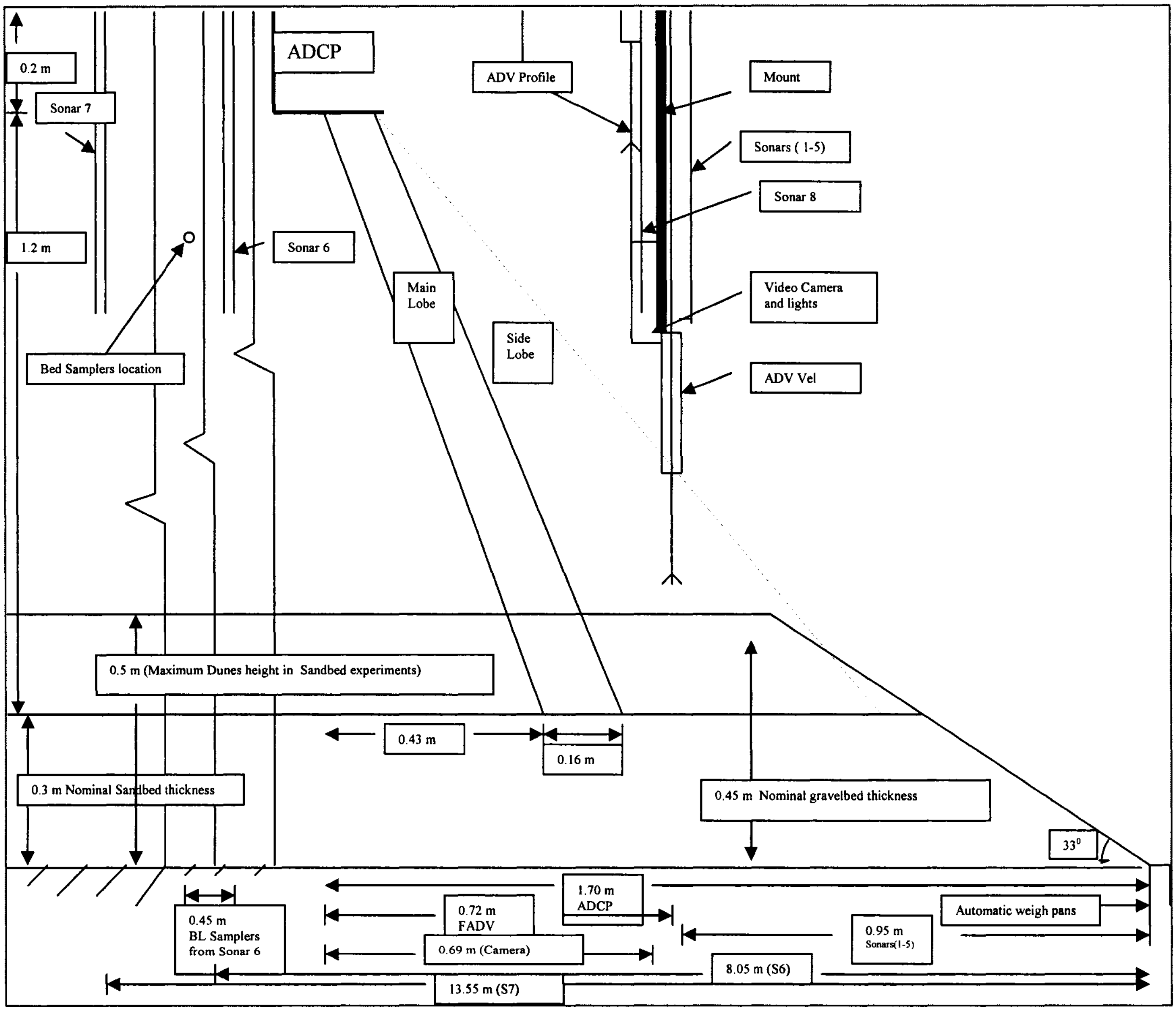
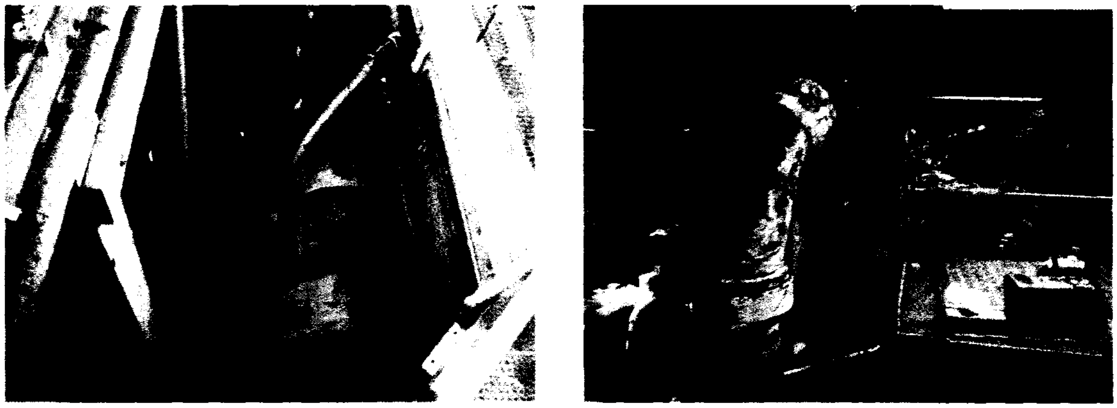


Figure 2.5: Schematic diagram of the experimental set-up (sectional view)

The field ADV (vertical profile ADV) was 72 cm d/s of ADCP and 69 cm to the right of the camera, looking d/s. A total of 8 sonars were placed to measure the dune heights, including five placed at the center of each weigh pan and at a distance of 95 cm u/s of the weigh pans. Sonars 6 and 7 were at a distance of 8.05 m and 13.55 m u/s of weigh pan 3, respectively. The bedload samplers were used at a distance of 8.5 m u/s of the weigh pans, and were not operated concurrently with other instruments during high flows when the wake from the samplers propagated downstream.

The design section was 20 meter long starting from u/s of weigh pans. The weigh pans were installed at a distance of 18 meter u/s of the d/s gate. Nominal sediment depths of 30 cm and 45 cm were used for the sand-bed and gravel-bed experiments respectively. A pump system was designed for the recirculation of the sand and gravel used in the experiments. The photos are shown in figure 2.6:



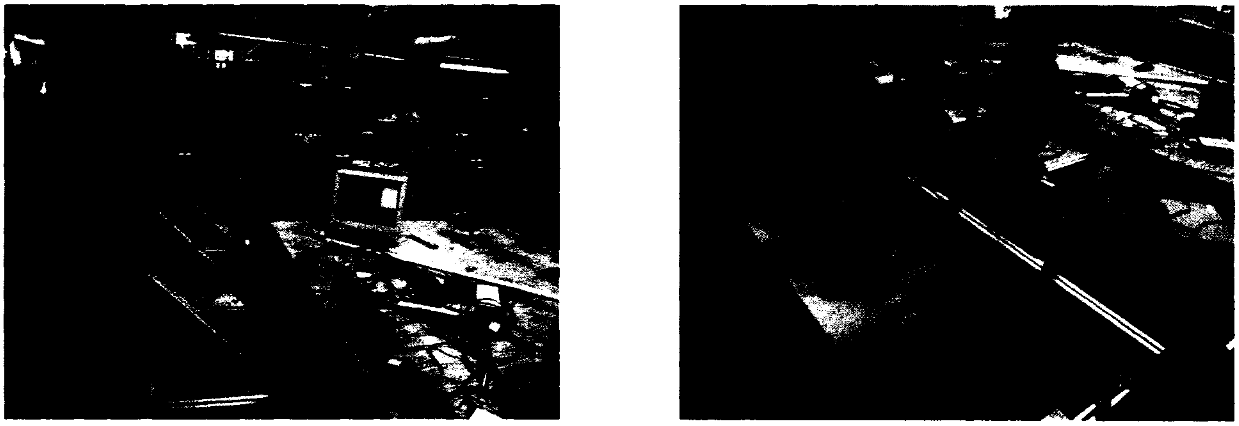
a) Re-circulation Pump

b) Return Pipe (Looking u/s)

c) Sediment discharge nozzle (looking u/s)

Figure 2.6: Photos of re-circulating pump system

Figure 2.6 shows the re-circulating pump system. The first photo shows the pump sucking the sand from the channel and lifting up through a pipe installed vertically and joined with an elbow as shown in the second photo. This pipe is then placed horizontally fixed with the roof and along the channel towards u/s. Finally it is placed in the channel as shown in the last photo to return the sediment into the channel. Figure 2.7 gives an overall vision of the experimental set-up near the d/s end of the design section as sketched in figure 2.4 and figure 2.5.



a) Mounts u/s of the bridge

b) Mounts d/s of the bridge

c) All instruments looking d/s

Figure 2.7: Overall experimental set-up.

Figure 2.7 shows the overall set-up arrangement. The whole set-up was arranged on one bridge. The first picture a) is the view of the setup across the channel u/s side of the wooden bridge and the 2nd is the view of mounts d/s side of the wooden bridge. The pictures are from left bank to the right bank. In the 1st picture, a), the first mount (close to left bank of flume) is for the camera no. 2, which was installed for profile view near the sediment bed in March,

2006. The second mount is for micro ADV and 1st camera. U/s side of the bridge in figure a) is the mount for ADCP, small black mount, which can be seen in the photo. The 3rd mount, close to right bank of flume (glass wall), was designed to install the 2nd ADV and sonar no.6. In the 2nd photo (b), another horizontal mount can be seen on which sonar No.1 to No. 5 are installed at a distance of 95 cm u/s of the weigh pans. Figure 2.7 (c) shows all of the instruments used for data collection.

2.1.2: Experimental Procedure:

This section will elaborate the experimental procedure used for the measurements of bedload using ADCP, ADV, field ADV, videography, bedload samplers, sonars and weigh pans.

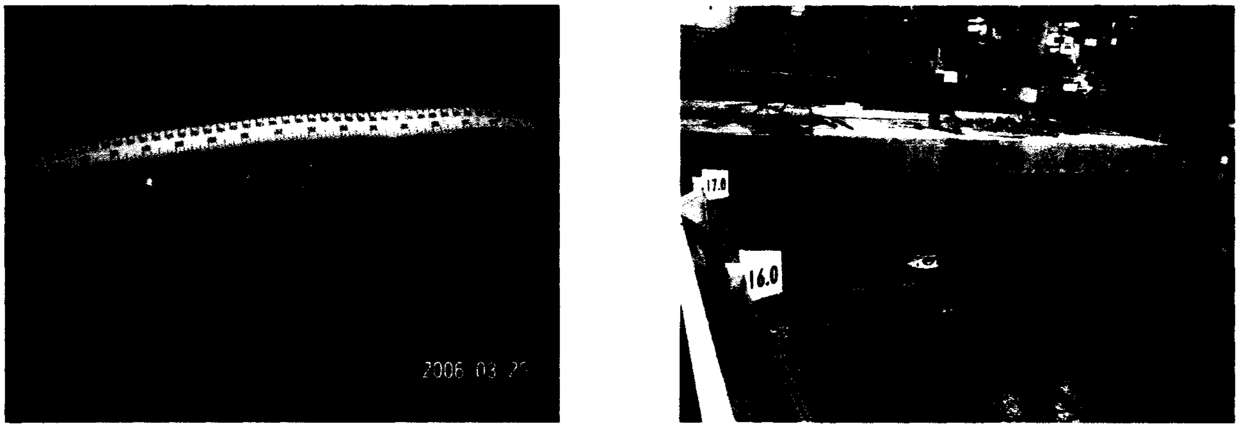
The main objective of the study was to test the reliability of bedload measurements using conventional and surrogate techniques including ADCP for their use in sand and gravel-bed streams. The focus was to collect calibration data, such that the accuracy and precision of various measurement techniques could be evaluated. Sand and gravel beds were used for the data collection with the five different steady discharges in each of sand and gravel beds.

The following is the description about the instruments used for the bedload measurements.

Acoustic Doppler Current Profiler (ADCP):

An ADCP is in use for measuring fluid velocity in geophysical flows. Rennie et al. (2002) studied the potential of the bottom tracking capability of a commercially available ADCP for the measurement of bedload velocity, with the goal of developing a noninvasive technique for gauging bedload transport. The details are described in Chapter 1.

In this research two ADCP's with 600 kHz and 1200 kHz frequency were utilized for the measurement of bed velocity by using the bottom track capability of the ADCP for both sand and gravel bed experiments and are shown in Figure 2.8.



a) 1200 and 600 kHz ADCP b) Installed 1200 kHz ADCP looking d/s

Figure 2.8: 1200 kHz and 600 kHz ADCP's and the installed 1200 ADCP in the SAFL flume

Acoustic Doppler Velocimeters (ADV):

An Acoustic Doppler Velocimeter (ADV) is a single-point current meter that accurately measures the three components of water velocity in both high and extremely low flow conditions. Velocities are measured in a sampling volume located a distance away from the probe head as shown in the figure below:

Figure 2.9: Sketch of ADV and the position of the sampling volume location:

The probe head is made up of a single transmitter located in the center of the probe head and three receivers mounted on arms. The transmitter generates a narrow beam of sound that is projected through the water. Reflections from particles or "scatterers" (such as suspended sediment, biological matter, or bubbles) in the water are sampled by the highly sensitive receivers, and the Doppler shift in frequency of the sound is used to measure velocity. The intersection of the receiver axes designates the location of the sampling volume.

In this project two ADV were used. The detail is described below:

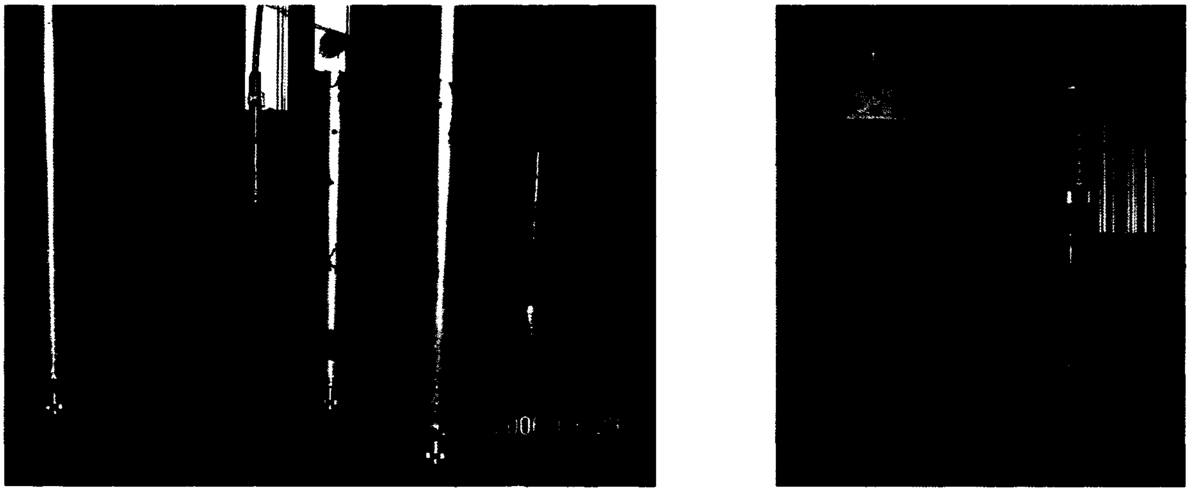
16-MHz MicroADV:

The Micro ADV is for use in the laboratory. The sampling for measuring low flows with this ADV is possible up to 50 Hz frequency and a sampling volume up to 0.1 cm^3 is possible. This system is suitable in applications such as the measurement of turbulence, orbital velocities in a wave field, and precise flow field studies. The sampling volume was 5 cm from the probe. In these experiments the 50 Hz sampling frequency and sampling volume distance from the probe tip of 5 cm were used for the data collection.

10-MHz ADV:

The 10-MHz ADV is suitable for a wide range of applications ranging from laboratory, to field, to full oceanographic applications. Sampling rates may be as high as 25 Hz and the sampling volume is located 5 or 10 cm from the probe. During the data collection 25 Hz sampling frequency and 5 cm sampling volume were used.

A 16 MHz Micro ADV was utilized 72 cm d/s of the ADCP (immediately d/s of the beam 4 insonified area) to provide a velocity profile of the flow and near bed velocity during the videography. This will be used in combination with videography data. In addition, another ADV (10-MHz ADV) was used in the experiments for the vertical profiles at a distance of 72 cm d/s from ADCP and 69 cm to the right when looking d/s. These data will be used to develop shear stress profiles. These profiles will be used to assess influence of bedform geometry on total shear stress, and isolate grain shear. The following figure shows the position of the d/s ADV, ADCP, the velocity profile ADV, and sonars.



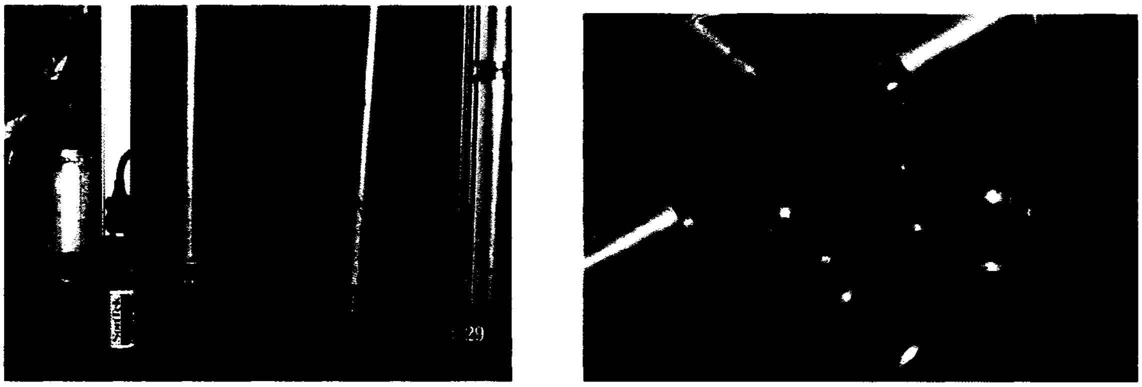
a) Profile ADV extreme left near glass wall
(Leaves attached with the instruments and main source of error for gravel bed experiments)

b) Micro ADV near left bank

Figure 2.10: Photos showing ADV used in the experiments:

Videography:

Initially, it was planned to use a PIV technique to trace the bed particles but because of the limitations of the project and unforeseen constraints, it was finally decided to use a water proof camera for particle tracing. A 100 frame-per-second digital video camera capable of resolving individual grains was used in the experiments to capture the bed particle transport for each ADCP run. The following photos show the water proof casings designed in the SAFL and the installed set-up of the video camera.



a) Installed video camera extreme left

b) Casing and parts of video camera

Figure 2.11: Video camera arrangements and set-up in the flume.

In figure 2.11, the first photo (from left) shows the installed camera in the flume, second shows the casing parts and cameras inside the casing.

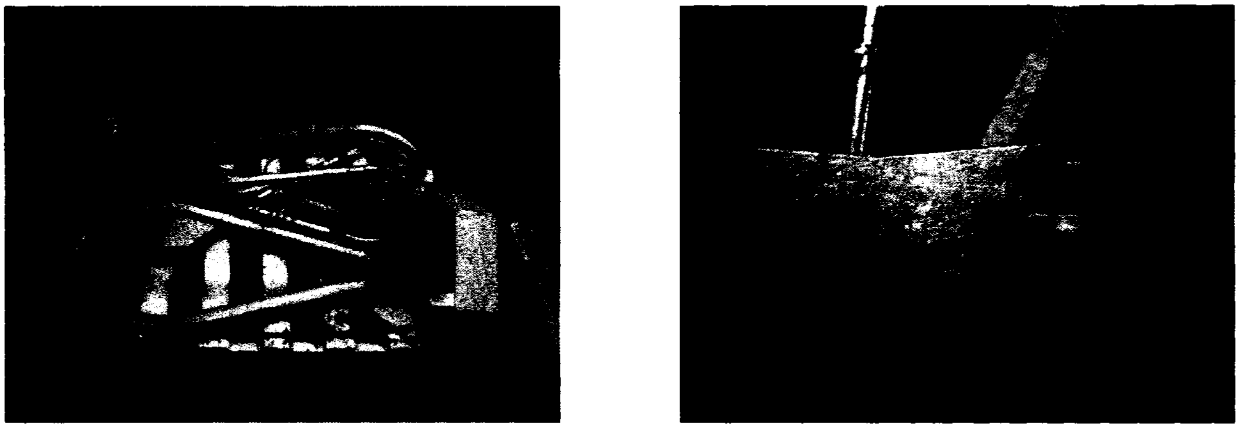
Bedload Samplers:

The following bedload samplers were used for the measurements during sand and gravel bed experiments:

- TR-2 Handheld, provided by John Pitlick, U. Colorado. (For gravel bed only)
- Elwha Handheld, provided by Kurt Spicer, USGS, CVO.
- BL-84:
- Helley-smith (3") (HS):

All cable-suspended samplers used bags with a 0.5 mm mesh size. All rod-deployed bedload samplers used 0.25-mm mesh bags. Each sample was measured, photographed, and marked for future use/identification.

Each sampler was tested at different discharges for sand and gravel bed experiments. Because deployment of the TR-2H bedload sampler caused an unacceptable level of disturbance for the downstream hydroacoustics work (ADCP, ADV's and videography), the data collection for these two projects (bedload sampler calibration and hydroacoustics work) proceeded in series in a given day. All bedload samplers were deployed at a section 8.5 meters upstream from the weigh pans. The duration of collection of a single bedload sample was a multiple of 15 seconds (i.e, 15, 30, 45... seconds) with a probable maximum duration of 180 seconds (but longer if transport rates were exceedingly low).



a) TR-2, Helly-smith and BL-84 b) Elwha Handheld for sand experiments

Figure 2:12: Bedload samplers used in the experiments:

Automatic Weigh Pans:

The weigh pans consist of 5 drums equally spaced and the capturing width is 0.55 m for each pan. Each pan has a funneled entrance into a cylindrical drum. There are 3 baffles in each drum at an angle of 120 degrees. When the drum reaches maximum load, the drum automatically rotates to dump the sediment into the auger below, which delivers the sediment to the recirculation line. The recirculation line consists of a pump and pipe system which return the sediment to the upstream end of the channel. The weigh pans were designed to capture the bedload only. The weigh pans were connected to load cells which recorded the total weight every 0.11 seconds. Data were recorded as ten point averages every 1.1 seconds. SAFL reported accuracy of the load cells to be 0.1 lb or 50 grams.

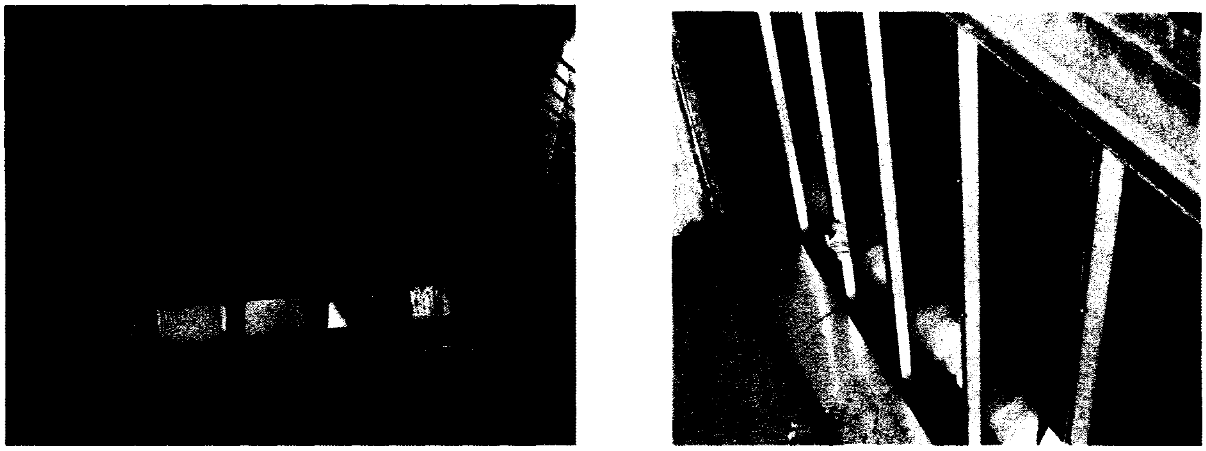


Figure 2.13: Photos of weigh pans looking u/s:

Sonars:

Eight sonars were installed in the design section of the channel. The main purpose was to monitor the sediment bed elevations at different locations of the design section. The sonars used in the study vary from 2.25, 1 or 0.5 Mhz and the diameters vary from 0.5, 0.75, 1.00 and 2.25 inches. The spread angle was estimated by using the diameter and frequency of the sonar.

Figure 2.14: Some of the installed sonars in the flume:

2.1.2.1: Sand bed Experiments:

For the sand bed experiments all of the samplers/ instruments explained earlier were used in the flume. The nominal sand bed depth was 30 cm along the width of the channel and at a length of 20 m, which was the design length of the section. The channel was pre-loaded with sediment consisting of nearly uniformly sized particles or grains. The sand was purchased as graded to 0.8 mm but random sampling (Table 2.1 and Figure 2.15) suggests that d_{50} and d_{90} were 1.05 mm and 1.55 mm respectively.

Table 2.1: St Anthony Falls Sand Experiment Grain Size Analysis
based on random sample from one bag of supplied sediment
Jan 3 2005

size, mm	% retained	size, mm	cum % finer
2.0000	0.1952	2.0000	99.8048
1.6510	5.2125	1.6510	94.5923
1.4000	11.2637	1.4000	83.3286
1.1680	11.5391	1.1680	71.7895
1.0000	30.2470	1.0000	41.5425
0.8330	17.0813	0.8330	24.4612
0.7010	17.0307	0.7010	7.4305
0.5890	5.2371	0.5890	2.1934
0.5000	1.5478	0.5000	0.6456
0.2500	0.6290	0.2500	0.0166
Pan	0.0166		

Transported sand was captured in the channel's weigh pans, weighed, and re-circulated. A total of five different discharges from 2.0 to 3.6 m^3/s were planned to be used for the experiments.

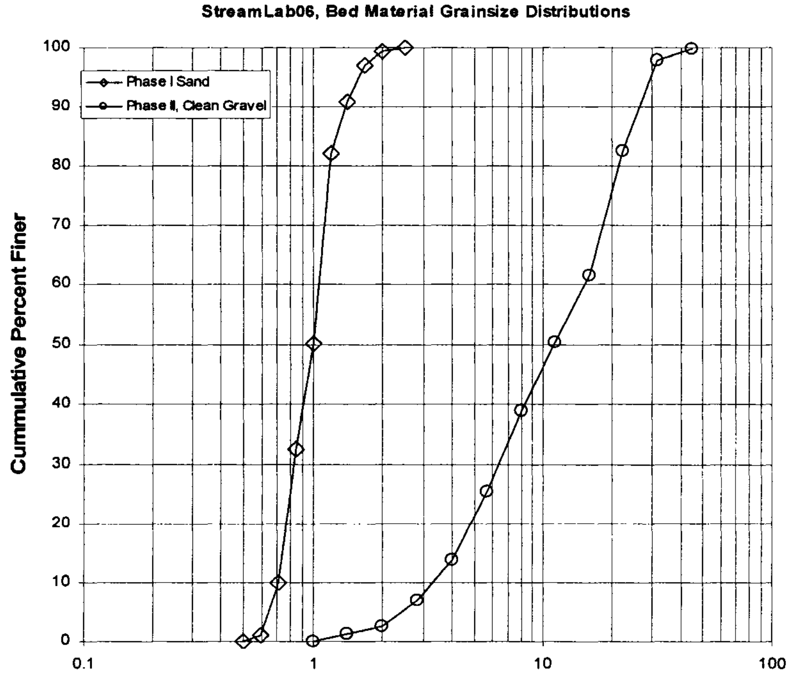


Figure 2.15: Grain size distribution – sand and gravel
Adapted from Jeff Mar Presentation (Project Director for this Project at SAFL)

2.1.2.1.1: Flow Rates:

As explained earlier a total of five discharges were used for the sand bed experiments ranging from 2.0 m^3/s to 3.6 m^3/s, however, more than five discharges were available for the experiments. The detail is given in the Table 2.2:

Table 2.2: Detail of hydro-morphological data for sandbed experiments

Sr. No.	Date	Discharge m^3/s	Water slope	Bed slope
1	04-Jan-06	0.25		
2	From Jan. 5th to Jan. 7th	Higher		
3	10-Jan-06	2.50		
4	17-Jan-06	1.58		
5	29-Jan-06	2.89		
6	From Jan.30th to Jan. 31st	3.00		
7	01-Feb-06	2.98	0.00188	NA
8	02-Feb-06	2.90		
9	From Feb 3rd to Feb 4th	3.60	0.001712	NA
10	From Feb. 6th to Feb. 7th	2.00	0.000211	NA
11	From Feb. 8th to Feb. 9th	2.50	0.000469	NA
12	14-Feb-06	3.20	0.002603	NA

2.1.2.1.2: Measurements Taken:

All of the instruments including ADCPs, were used for the bedload measurements. Both ADCPs were used in the measurements with different pulse lengths for each discharge. The Winriver configuration file for sandbed was modified for each run and is given as below as an example:

1200 ADCP configuration:

```
BE 9999
EX00111
&R20
```

600 ADCP configuration:

```
BE 9999
EX00111
&R20
BA 20
BX 16
```

In addition, the concurrent sampling area ADV (Mirco ADV) was used to measure the velocity near the insonified area of ADCP. This ADV was also used to measure near bed velocity during the videography. Two videos were taken for each ADCP bottom track pulse length.

The 10MHZ ADV (Field ADV) was used to measure the vertical profiles. The set-up arrangement has already been discussed in the earlier sections of this chapter. Sonars and weigh pans were measuring bed elevations and bedload respectively throughout the experiments. A 3" Helley-Smith, 3" BL84 and hand held Elwha sampler was used to capture bedload in sandbed experiments.

2.1.2.2: Gravelbed Experiments:

For the gravel bed experiments the same instruments were used. The nominal gravel bed used was 45 cm along the width of the channel and at a length of 20 m, which was the design length of the section. The sand was cleared from the channel, replaced with gravel, and several runs with varying discharges (up to a maximum of 5.5 m^3/s) were conducted. Again a total of five different discharges from 3.4 to 5.5 m^3/s were planned to use for the experiments. For gravel bed experiments Wolman pebble count through the sample area by random walking in the flume was carried out after each run. The results for d_{50} and d_{90} for each discharge are given in Table 2.3:

Table 2.3: Results of Wolman Pebble Counts – Average of five discharges.

Sr. No.	Discharge m3/s	d_{50} mm	d_{90} mm
1	3.90	10.00	20.00
2	4.00	10.00	17.67
3	4.30	12.33	20.33
4	4.90	12.66	22.66
5	5.50	10.33	20.33
	Average	11.06	20.20

The particle size distribution for 5.5 m^3/s discharge is depicted in Figure 2.16:

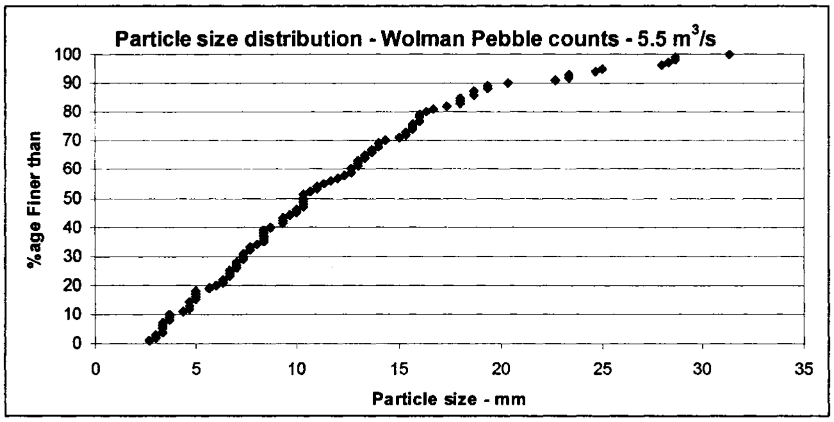


Figure 2.16: Particle size distribution –Gravelbed using Wolman pebble counts

2.1.2.2.1: Flow Rates:

As explained above a total of five discharges were used for the gravel bed experiments ranging from 3.4 to 5.5 m^3/sec, however more than five discharges were utilized for these gravelbed experiments. The detail is given in table 2.4.

Table 2.4: The detail of discharges available for gravelbed experiments

Sr. No.	Date	Discharge m^3/s	Average water slope	Average bed slope
1	3-Mar-06 (test run)	3.40		
2	From March 3rd to March 10th	3.90		
3	From March 12th to March 14th	5.50	0.0044	
4	From March 15th to March 22nd	4.00	0.0013	0.0131
5	From March 23rd to March 25th	4.30	0.002	0.00625
6	From March 27th to March 29th	4.90	0.00348	0.00515

2.1.2.1.2: Measurements Taken:

The same measurements were carried out as in sandbed experiments. In addition 600 kHz ADCP data for different bottom tracking pulse lengths were also collected, which was not collected during the sandbed experiments. The reason was that the 600 kHz ADCP could not measure bottom track data with &R20 and &R30 in the sandbed experiments.

The following configuration for 1200 kHz and 600 kHz ADCP's are used in the experiments.

1200 ADCP configuration:

BE 9999

EX00111

&R20

BA 05

BX 16

600 ADCP configuration:

BE 9999

EX00111

&R20

BA 05

BX 16

A Toutle River 2 bedload sampler was also used in gravel bed runs in addition to the previously used samplers in the sandbed experiments. In these experiments a 2nd profile view video camera was also used on the last day of runs on 29th of March, which was not installed during the sandbed experiments.

2.1.3: Data Collected:

2.1.3.1: ADCP:

The ADCPs were planned to measure the data with different pulse lengths ranging from &R10 to &R50 for both of ADCPs. &R command is used to set the "Bottom Illumination". This value determines the size of the bottom track transmit pulse in relation to the depth. &R is entered in percent. If bottom tracking in 10 m of water and had collecting data with &R20, the bottom track transmit pulse would be 20% of 10 m which is 2 m. If bottom tracking data with &R30, then the transmit pulse would be 3 m for a water depth of 10 m.

The length of data collection proposed was one hour, thus a total of 10 runs for each discharge were proposed. However after the time constraint and testing the instruments, it was decided to collect the data for &R20, &R30 and &R40 for 1200 kHz ADCP and &R40 for 600 kHz ADCP for an hour of each run. The actual data collected ranges from 30 min. to 2 hours because of project limitations and operation of the other instruments.

Initially it was decided to use both bottom track mode 5 (BM5) and bottom track mode 7 (BM7). All Rio Grande ADCPs include the standard bottom tracking modes. BM 5 gives good performance in systems of all frequencies. It is the default BM in *WinRiver* and in the Rio Grande firmware (Rio Grande 1200 kHz ADCP). RDI have also developed BM 7 as an additional option, which allows bottom tracking in water as shallow as 30 cm. However, initial tests with BM7 had poor data quality as compared with BM5 data; thus BM5 was used for the experiments.

Considering all sediment types, discharges, and pulse lengths, a total of 142 sets of data were collected for both ADCPs, including the pretest data sets. For sandbed experiments a total of

85 data files were developed, in which 36 were pretest files. Thus, a total of 49 files are available which include 10 files with 600 kHz ADCP and 39 files with 1200 kHz ADCP. For the 600 kHz ADCP, BM5 mode was used and pulse length was &R40. Two files with &R20 and &R30 were also tested but did not find data for 600 kHz ADCP. For 1200 kHz ADCP, 5 files were with BM7 and remaining data are with BM5. For 1200 kHz ADCP; 12, 13 and 23 files with the data of pulse lengths &R20, &R30 and &R40 respectively were collected. One file is also available for &R50 pulse length. The detail is explained in the "Summary of Collected Data" table Annexure I. A total of 40 runs for sandbed and 56 runs for gravelbed were analyzed after reviewing the collected data based on real time data available for weigh pans and sonars corresponding to ADCP's data.

2.1.3.2: Sampling area ADV (Micro ADV):

The sampling area ADV was used to estimate the sediment bed velocity d/s of the ADCP. ADV was installed to capture the near bed sediment velocity of beam 4 for ADCP. The instrument was tested on Jan 07th, 2006 and the data available is from 17th of January, 2006. The ADV data were collected simultaneously with ADCP data. Also for the videography, the ADV was lowered down to measure the near bed velocity for the comparison of video data with ADV data.

2.1.3.3: Videography:

One camera was ready for operation on February 03rd, 2006. After tests, it was proposed to collect two videos of about 2 min. each for each run of ADCP data. Thus a total of 8 videos were captured for each flow. In addition, a 2nd camera was installed on 28th of March to see the side view of the bed to capture the active bedlayer of the sediment. These data were also collected using this camera on 29th of March with a flow of 4.90 m^3/s for gravelbed experiments. A total of 86 videos were collected during the experiments including gravel and sandbed experiments. The detail is given in Annexure I.

2.1.3.4: **ADV Velocity Profiles:**

The field ADV (2nd ADV) was installed to measure the vertical profiles to estimate the bed shear stress. The data were collected from Feb 2nd 2006. Two to three vertical profiles were collected for each flow. The number of points in each vertical profile was 13 to 15 points depending on the bedforms along the length of the vertical water column. To elaborate the near bed layer for shear stress estimation, the nearbed data were collected with 1 cm increments, which increased to 2, 3, 4, 5, 10 and 20 cm near the water surface. A total of 9 and 12 profiles were measured for five discharges for both sand and gravel bed experiments respectively. Details of the data collected are described in Annexure I.

2.1.3.5: **Sonars:**

The sonars were also installed for continuous measurements of sediment bed elevations. Initially two sonars were installed in January. However, the other six sonars were installed in the beginning of February. The data collection for 7 sonars was started from Jan. 30th 2006, however, the actual data are available from February 02nd, 2006.

2.1.3.6: **Bedload Samplers:**

Three standard "manual" samplers as described in section 2.1.2 were used for sandbed and gravelbed experiments.

2.1.3.7: **Weigh Pan Data:**

The weigh pans were running throughout the day during the time of experiments and an automatic data collection was in progress. An engineer was deployed to monitor the data and also responsible for the flume operation processes. The data started from Jan. 29th, 2006. The details are depicted in Annexure I.

2.1.3.8: **Summary of Collected Data:**

Finally a worksheet was developed for all of the experiments corresponding to ADCP measured real time data except the data collected for bedload samplers, which was not available. The methodology for the data collection of these samplers has been described in this chapter earlier. The worksheet cover the available data files corresponding to ADCP data files along with hydraulic parameters of the channel during the experiments and are given in Annexure I.

2.2: ANALYTICAL METHODS:

In the earlier sections all of the instruments used in the sand and gravelbed experiments were described in detail. In this section the analytical approach will be described based on the thesis objectives. Therefore the analytical methods fro ADCP, weigh pans and sonars are described to estimate bedload from the measured data. The analytical approach for shear stress estimation from vertical profiles measured during the experiments is also described in the following sections.

2.2.1 ADCP

The ADCP was fixed to a bridge across the flume, thus the ADCP was assumed to be stationary. Therefore bottom track velocity was used directly as a measure of apparently bed velocity (see equation 1.1).

MATLAB codes to estimate the mean bed velocity from raw ADCP data were developed by Rennie (UoO), Muller (USGS) and Rainville (Environment Canada). The program reads the RDI PD0 binary format raw data as recorded by WinRiver and accounts for the special locations used by WinRiver to store GPS data. It was designed for PD0 files created by WinRiver. Data are stored in Matlab data structures to provide easy and efficient transfer of data between functions. No filtering of the data is provided, although some unit conversion is provided for consistency and convenience. (The listing is attached as Annexure II).

For the analysis of ADCP data from SAFL the codes were modified to process of ADCP raw data in case of stationary boat conditions. The program estimates mean bedload velocity in X and Y directions and North and East directions with standard deviation in X direction. It also calculates the mean and standard deviation for the downstream component in beam 3 and beam 4. Beam 3 and 4 insonified areas are u/s and d/s of the installed ADCP respectively.

After estimating the velocities, the influence of bottom pulse length and operating frequency on measured bedload velocity was carried out based on the results of the data generated by MATLAB CODE and is explained in Chapter 3.

2.2.2: Weigh Pans:

MATLAB codes were developed to calculate the mean and standard deviation of bedload transport rate for all of the five pans. A boxcar average method was used to estimate the average bedload of all of the five weigh pans. As discussed earlier the weigh pans are automatic and the sensors measure bedload every 1.1 sec. However the data were noisy due to the relatively low precision of the load cells (50 g). A detailed filter analysis was carried out to finalize the average time for the analysis and is described in Chapter 3.

A detailed analysis was carried out for the sensitivity analysis of the raw weigh pan data. Two runs were analyzed, one for gravel and the second for sand.

Analysis is for one bedload pan data run (gravel at 5.5 m^3/sec) with various averaging times and various deletions of points after a tip of the weigh pan. Deletion time can be understood by using Figure 2.17. It is the time taken by a drum of each pan to drop the sediment and is shown by almost straight vertical lines.

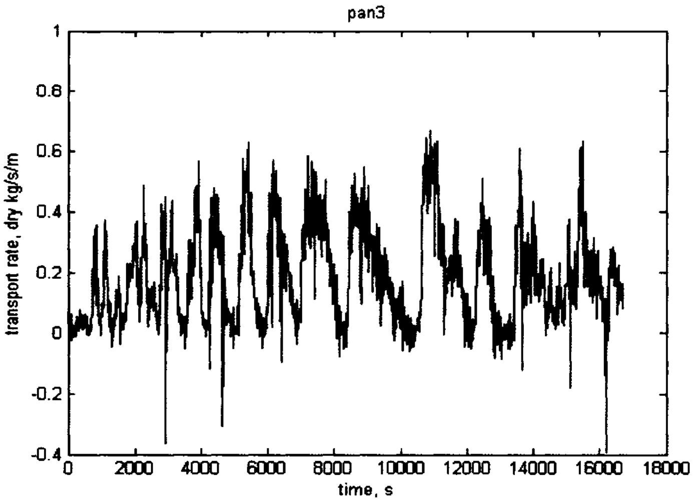


Figure 2.17: Weigh Pan 3 transport rate kg/s/m on February 03, 2006 (Sand bed)

These results are based on a boxcar average. The various analysis combinations were:

1-One (1) second average time with 0, 5, 6, 7, 10 and 15 points skip after a weigh pan tip.

2-Five (5) seconds average time with 0, 5, 6, 7, 10 and 15 points after a weigh pan tip.

3-Fifteen (15) second average time with 0, 5, 6, 7, 10 and 15 points after a weigh pan tip.

4-Thirty (30) second average time with 0, 5, 6, 7, 10 and 15 points after a weigh pan tip.

5-Sixty (60) second average time with 0, 5, 6, 7, 10 and 15 points after a weigh pan tip.

The following is the example from the detail results as shown in Annexure III.

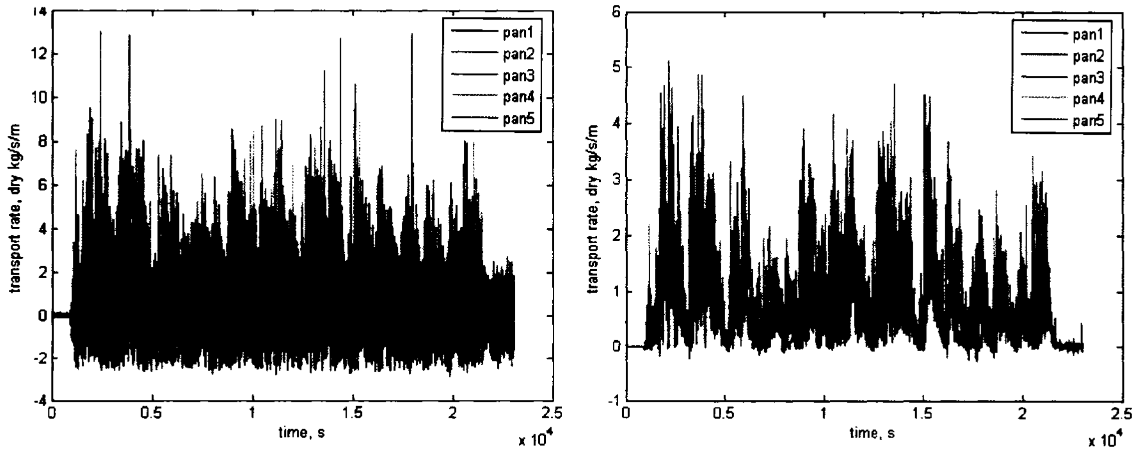


Figure 2.18: Gravel run results (a) Raw sediment flux (1 s averaging and 0 point skip) (b) Sediment flux 15 s averaging time and 6 point skip.

All of the results in the analysis are for one day gravel weigh pan data on March 12th 2006 with 5.5 m^3/s discharge. A total of 30 results were estimated by considering the average time of 1, 5, 15, 30 and 60 s and assuming the skip points (One skip point = 1.1 s) as 0, 5, 6, 7, 10 and 15. In addition one sand bed data analysis was also carried out similar to the gravel bed analysis. The detail is depicted in Annexure III including example bedlaod time series for various filtering options.

It was found that 15 s averaging with 6 points deleted (skip) time after a weigh pan tip gave the best results. The data are not over smoothed, but most negative values are removed.

2.2.3: Sonars:

The sonar data are available in EXCEL files with an example shown in Figure 2.19 below:

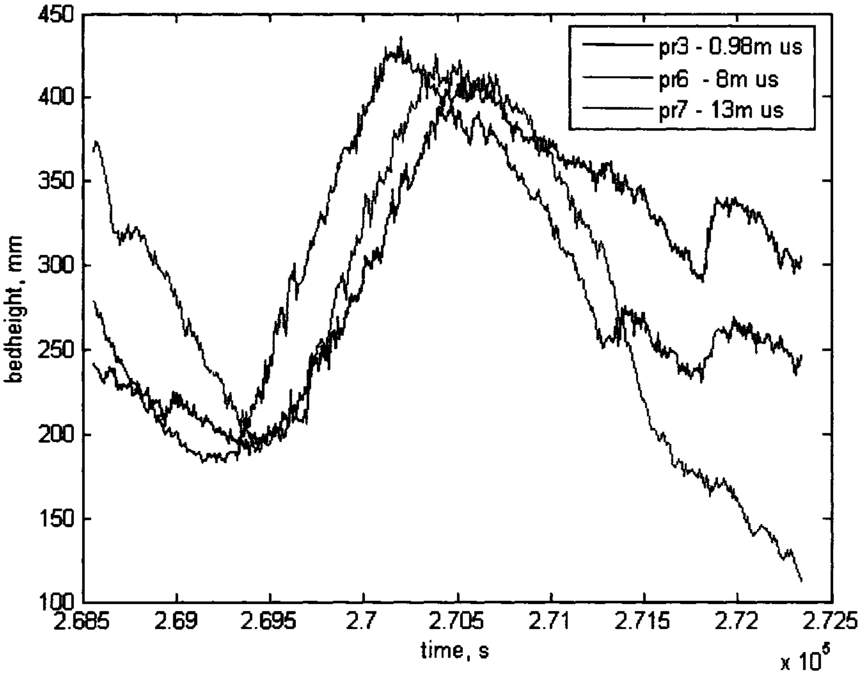


Figure 2.19: Bed height variations with time in sand bed experiments measured by sonars along center line of the flume.

For the comparison of the bedload measurements of ADCP with weigh pan and sonar data another code was developed to estimate the real time data comparison between all of these three instruments. The program estimates the celerity between beam 3 & 4 of ADCP and sonar 3 & 6 and 6 & 7. The following simple model was used to estimate the celerity.

$$C = \frac{L}{\Delta t} \tag{2.1}$$

C = Celerity of the dune.

L = Distance traveled by a crest from point one to the second point i.e. distance b/w sonars 1 and 2

Δt = Time of the dune travel b/w points 1 and 2

The travel time of dune travel between two sonars (Δt) is calculated from the cross-correlation function between the bed elevations measured by the two sonars. The time lag that gives the peak co-relation is equaled to Δt assuming that the peak bed elevation cross-correlation between two locations occurs at a time lag that corresponds to passage of the same phase of a dune. The graphical example is shown in Figure 2.20 below:

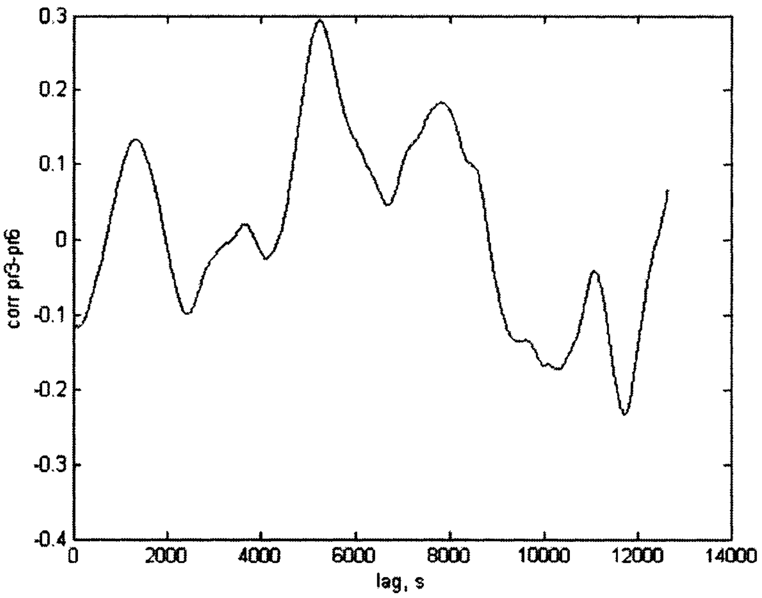


Figure 2.20: Correlation between centerline sonars 3 and 6 for the entire day data.

In this case, a lag of 1400 s was assumed to correspond to Δt for translation of a dune from sonar 6 to sonar 3. The average dune height for a run was manualy estimated using the available sonar data. The results are included in Annexure 4.

After generating these data, it is required to estimate the bedload from ADCP bedload velocity, sonar data and weigh pans data which is explained in the following section.

2.2.4: Bedload estimation for ADCP, weigh pans and sonars:

2.2.4.1: Weigh Pans:

As explained earlier in section 2.2.2 a boxcar average was used to estimate bedload transport rates from the trap weights. Sediment specific gravity (Ss) was measured to be 2.63 and 2.69 for sand and gravel respectively. The following formula used for the bedload estimation which converts from submerged to dry weights.

$$g_b = \left[\frac{\left(\frac{sed.wt}{TimeStep} \right)}{PanWidth} \right] * \left(\frac{Ss}{Ss-1} \right) \qquad 2.2$$

g_b = bedload transport (kg/m/s)

2.2.4.2: Sonars:

For the estimation of bedload using celerity of dunes by sonars, a technique developed by B.D. Simons (1964) was used. The method is based on the assumption that the dunes have triangular shapes. They developed the following model.

$$g_b = \rho_s \left[\frac{(1-\lambda)V_s h}{2} \right] \qquad 2.3$$

g_b = Bedload transport (kg/m/s)

λ = Porosity of sand bed (39% for sand and 43% for gravel)

V_s = Average velocity of the dunes in the direction of flow (from Equation 2.1)

h = Average height of the dunes

2.2.4.3: ADCP:

For the estimation of bedload from measured ADCP apparent bed velocity, equation 2.4 as given in the V. Rijn (1984) was used and reproduced below:

$$g_b = \rho_s (C_b u_b \delta_b) \qquad 2.4$$

g_b = bedload transport rate (kg/m/s)

u_b = average bedload velocity of ADCP (m/s)

C_b = bedload concentration by volume (ρ_s 10^3 C_b in ppm)

δ_b = thickness of bedload layer (m)

The bedload thickness was estimated visually for two different discharges because of the non availability of the video camera. For the bedload concentration the empirical equation from V. Rijn (1984) was utilized and is reproduced as equation 2.5 below:

$$C_b = 0.18 C_0 \frac{T}{D_*} \qquad 2.5$$

C_b = bedload concentration by volume

C_0 = maximum (bed) concentration = 0.65

T = Transport stage parameter

D_* = Dimentionless particle parameter

Finally, the bedload was estimated using equation 2.4.

The model of V. Rijn was chosen as it has been found to produce reasonable approximations of bedload for a range of river and estuary conditions (Soulsby, 1997). Moreover, the V. Rijn (1984) formula defines sediment transport as a function of mean velocity, while in many of the other formulas sediment transport is a function of water slope, which is much more difficult to measure accurately than the velocity. Therefore in V. Rijn model bed velocity of ADCP can be used to estimate bedload by using V. Rijn method.

All of the above methods explained in section 2.4 are used and the results are depicted in Annexure IV for both sand and gravel bed experiments in the tabular format. The tables include the data required for the analysis and the results are given in Chapter 3.

2.2.5: Shear Stress Profiles and comparison of bedload with grain shear:

An independent analysis for the observed velocity profiles for sand and gravel bed experiments was carried out. The fully rough turbulent equation was utilized to determine the shear velocity.

$$u = \frac{u*}{\kappa}\ln(y) + \frac{u*}{\kappa}\ln\left(\frac{30}{k_s}\right) \qquad 2.6$$

u = mean streamwise velocity at distance y from the wall
k = von Karman constant (equal to about 0.4)
u* = shear velocity (estimated from observed velocity profile as explain in Annexure V)
k_s = roughness (determined from observed velocity profiles explained in Annexure V)

Shear stress profiles of sand and gravel bed experiments by using the measured vertical profiles data by ADV and comparison with measured bedload including the shear stress partitioning method are depicted in Annexure V. The figures for all of the profiles are also shown at the end of this annexure. The results for shear velocity, shear stress and k_s of upper total boundary shear and lower quasi grain shear are explained in Chapter 3 and Annexure V.

3- RESULTS

This chapter will cover results of this study based on the analytical approach described in Chapter 2. The main objective is to compare the ADCP's laboratory bedload measurement with the capture rates and dune tracking. However in the following sections all the results will be presented step by step as explained in the Chapter 1 under the section of objectives.

As explained earlier, the measurements were taken at SAFL for the period from January 2006 to March 2006 under the NCED project. After completing the data collection phase, a detailed worksheet was developed to summarize the basic flow and slope data for each flow, measurements taken for each flow and details of the experiments including all instruments used during the experiments. The details about the instruments have been provided in Section 2.1.2 and the data collection is summarized in Annexure I. The results for each objective are described in the following sections.

3.1: INFLUENCE OF BOTTOM TRACK PULSE LENGTH AND OPERATING FREQUENCY ON MEASURED BEDLOAD VELOCITY

First bottom track pulse length sensitivity was studied. The following are the results of MATLAB CODES for bottom track (bedload) time series for one sand bed run.

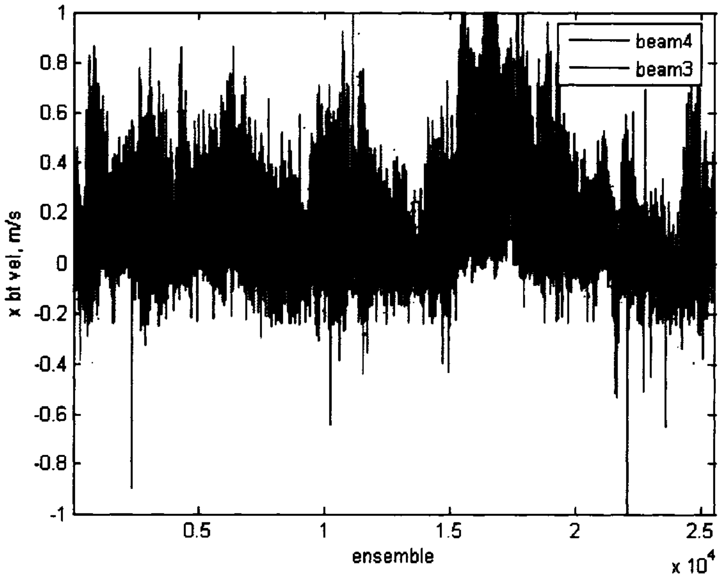


Figure 3.1: Time series of ADCP bottom track velocity in d/s direction in beams 3 and 4.

X bt vel, m/s (Bottom track bed velocity in X- direction in m/s)

The Figure 3.1 is the bedload variations with time for one run of sand bed on February 04, 2006 with a discharge of 3.6 m^3/s. An ensemble is a group of measurements (ADCP acoustic pulses, or "pings") which are averaged to make one measurement. In the analysis, single ping ensembles were utilized. The ping rate was 0.19 s and 0.40 s for 1200 kHz ADCP and 600 kHz ADCP, respectively, in sand bed experiments. For gravel bed runs, the pinging rate was 0.20 s and 0.40 s for 1200 kHz ADCP and 600 kHz ADCP.

The figure shows the variations of streamwise (x) apparent bed velocity in beams 3 and 4 of the ADCP. The peaks in bottom track velocity are due to passage of dunes, with highest velocity occurring on the dune stoss near the dune crest. The passage of dunes from the upstream (beam 3) to downstream (beam 4) is apparent.

An average apparent bed velocity from the time series for each run was used to plot the pulse length sensitivity analysis (Figure 3.2).

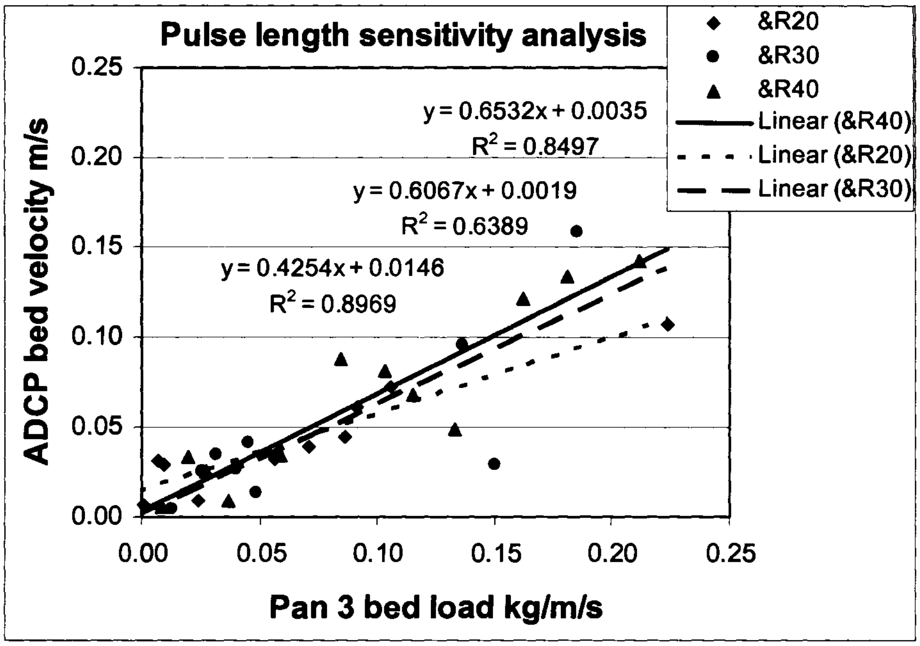


Figure 3.2: Sensitivity analysis for ADCP bottom track pulse length for 1200 kHz ADCP during sand bed runs

The Figure 3.2 shows the variation of different pulse lengths with respect to pan 3 capture rates for the 1200 kHz ADCP sand bed runs. Pulse length 20 showed better correlation ($r^2 = 0.90$) as compared with pulse length 30 ($r^2 = 0.64$) and pulse length 40 ($r^2 = 0.85$).

As discussed in the previous Chapters 2 ADCP's with 600 kHz and 1200 kHz were deployed for the analysis therefore a sensitivity analysis for frequency was also carried out and shown in Figure 3.3:

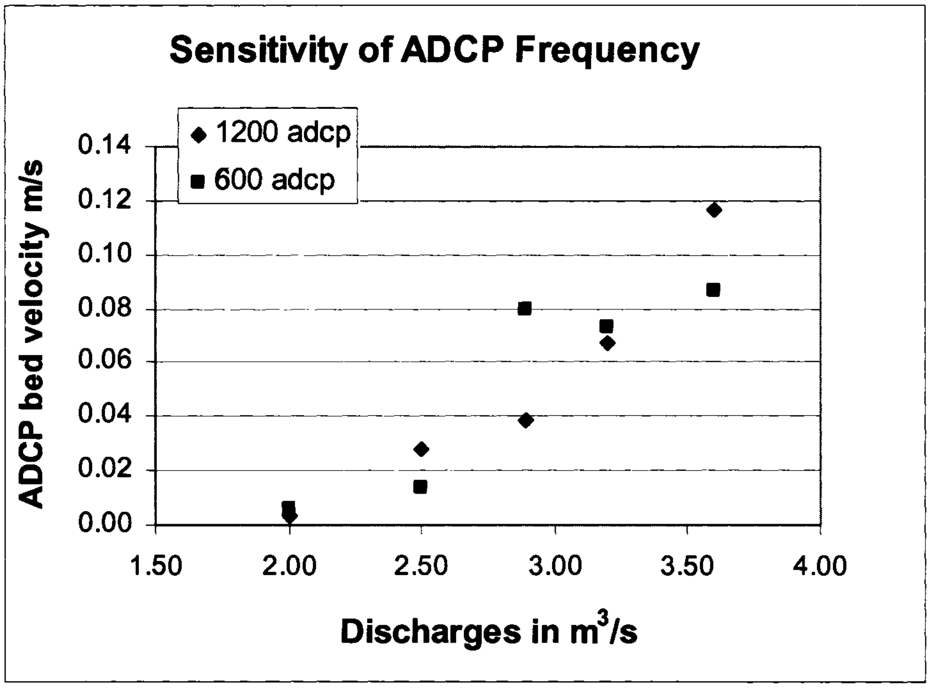


Figure 3.3: Sensitivity analysis for ADCP frequency during sand bed runs at &R40 pulse length

The results show the variation in bedload measurements with two different frequency ADCP's. Apparently, the 1200 kHz ADCP gave better bedload measurements than the 600 kHz ADCP, as the trend of increasing apparent bed velocity with increasing discharge is smoother for the 1200 kHz ADCP.

ADCP pulse length and frequency sensitivity analysis reveal that there is variation of bedload measurements when using different pulse lengths and frequency for bedload measurements

3.2: A COMPARISON OF BEDLOAD ADCP'S MEASUREMENT WITH CAPTURE RATES AND DUNE TRACKING

The bedload transport rates measured by ADCP beam 4 mean bedload, Pan 3 transport rate and dune tracking from sonars 3 and 6 are compared in this section. Beam 4 is the closest to the weigh pans. Pan 3 is the centre pan along ADCP and sonar 3 and 6 are also closer to the ADCP and Pan 3. Refer to Figures 2.4 and Figure 2.5 for instrument locations.

3.2.1: Sand bed

Figure 3.4 gives the comparison of ADCP bedload measurements with dune tracking and capture rates for the sand bed experiments.

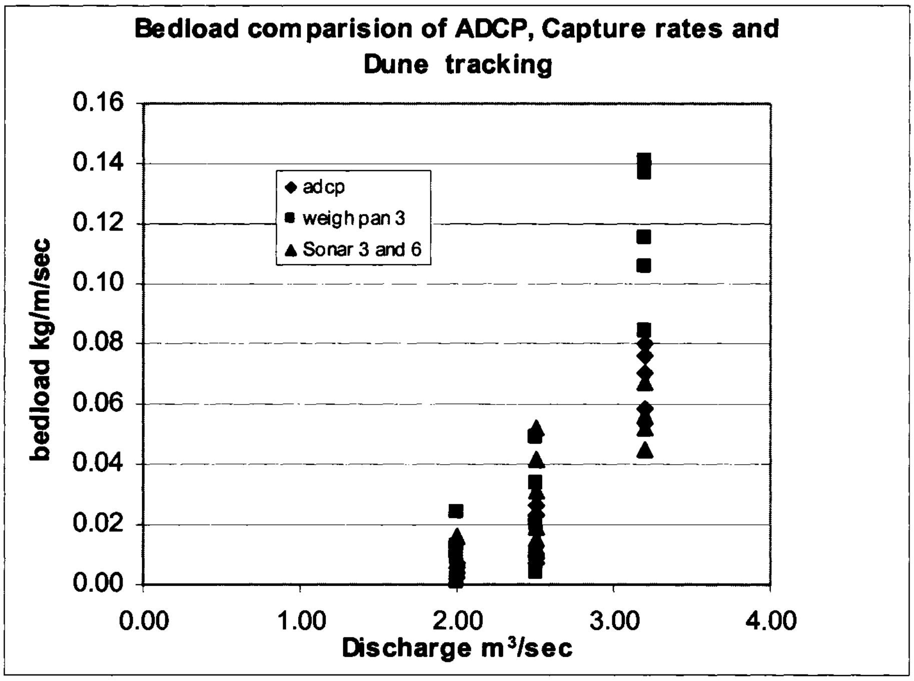


Figure 3.4: Sand bed bedload comparison of ADCP, capture rates and dune tracking

For ADCP, the model used to estimate bedload discharge is given in equation 2.4 of Chapter 2 and is reproduced here.

$$g_b = \rho_s (C_b u_b \delta_b)$$

In the above model "u_b" was the mean downstream bed velocity measured by beam 4 of ADCP which is closer to Pan 3. The bedload thickness "δ_b" was estimated visually for two different discharges of 3.20 m^3/s and 3.18 m^3/s on 9th and 14th of February, 2006 to be 1.3 cm and 1.2 cm respectively. The depth was measured visually because of the non availability of the video camera data. For the bedload concentration, empirical expression of V. Rijn (1984), equation 2.5, was used and will be reassess after video data analysis. Finally the bedload is estimated using equation 2.4. The details are given in Chapter 2.

Figure 3.4 shows that the trends for ADCP, capture rates and dune tracking are comparable though at high discharge the capture rates were greater than ADCP and dune tracking bedload measurements. It has been explained above that bedload concentration was estimated using V Rijn (1984). The bedload concentration (C_b) values were estimated to match ADCP (g_{bADCP}) and weigh Pan 3 capture rates ($g_{b\ pan3}$) assuming pan 3 results as a reference. The results show large variations between V Rijn bedload concentration and concentration estimated by the Pan 3 bedload transport rate. The results are shown in Figure 3.5 and Table 3.1:

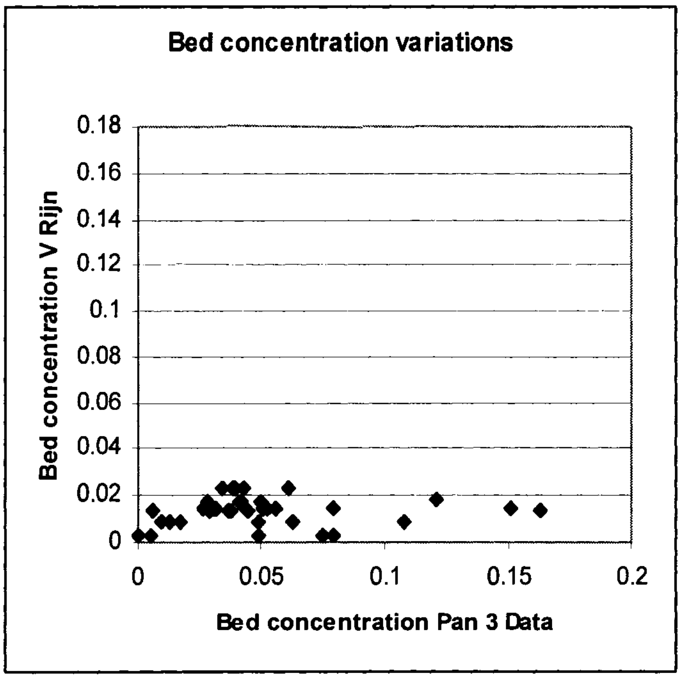


Figure 3.5: Bedload concentration comparison

Table 3.1: Optimization of bedload concentration:

Sr. No:	Date	Discharge m^3/s	Pulse Length	ADCP Frequency kHz	V Rijn Model C_b	Best fit C_b
1	29-Jan-06	2.89	40	1200	0.0182	0.120649
2	29-Jan-06	2.89	30	1200	0.01307	0.029022
3	29-Jan-06	2.89	20	1200	0.01307	-0.00273
4	29-Jan-06	2.89	20	1200	0.01307	0.006404
5	29-Jan-06	2.89	30	1200	0.01307	0.044766
6	30-Jan-06	3.00	40	1200	0.014525	0.031305
7	30-Jan-06	3.00	30	1200	0.014525	0.026551
8	30-Jan-06	3.00	20	1200	0.014525	0.043752
9	30-Jan-06	3.00	20	1200	0.014525	0.052751
10	31-Jan-06	3.00	40	1200	0.014525	0.079388
11	31-Jan-06	3.00	30	1200	0.014525	0.150449
12	31-Jan-06	3.00	20	1200	0.014525	0.056146
13	01-Feb-06	2.98	40	1200	0.014257	0.050496
14	01-Feb-06	2.98	30	1200	0.014257	0.032061
15	01-Feb-06	2.98	20	1200	0.014257	0.050914
16	02-Feb-06	2.90	40	1200	0.0132	0.037311
17	02-Feb-06	2.90	40	**600**	0.0132	0.038077
18	02-Feb-06	2.90	30	**600**	0.0132	0.162609
19	03-Feb-06	3.60	40	**600**	0.023421	0.039852
20	03-Feb-06	3.60	40	1200	0.023421	0.039127
21	04-Feb-06	3.60	40	1200	0.023421	0.03979
22	04-Feb-06	3.60	30	1200	0.023421	0.034473
23	04-Feb-06	3.60	20	1200	0.023421	0.061011
24	04-Feb-06	3.60	40	1200	0.023421	0.043411
25	06-Feb-06	2.00	20	1200	0.003293	0.075165
26	07-Feb-06	2.00	20	1200	0.003293	0.005161
27	07-Feb-06	2.00	30	1200	0.003293	0.079655
28	07-Feb-06	2.00	40	1200	0.003293	0.049497
29	07-Feb-06	2.00	40	**600**	0.003293	
30	08-Feb-06	2.50	40	**600**	0.008348	0.049235
31	08-Feb-06	2.50	30	**600**	0.008348	0.062996
32	08-Feb-06	2.50	20	**600**	0.008348	0.012894
33	09-Feb-06	2.50	20	1200	0.008348	0.009749
34	09-Feb-06	2.50	30	1200	0.008348	0.107537
35	09-Feb-06	2.50	40	1200	0.008348	0.017513
36	09-Feb-06	3.20	40	1200	0.017311	0.028113
37	14-Feb-06	3.20	30	1200	0.017311	0.041998
38	14-Feb-06	3.20	20	1200	0.017311	0.042543
39	14-Feb-06	3.20	40	1200	0.017311	0.050239
40	14-Feb-06	3.20	40	**600**	0.017311	0.041506

The above results show that the maximum C_b estimated by V Rijn method is 0.023, which is used for the bedload estimation using ADCP velocity. However C_b estimated by Pan 3 bedload, using ADCP V and observed active bed thickness gives a maximum value of C_b 0.17. Video data have been collected during the experiments but not processed due to the time constraints. It was beyond the scope of this thesis to analyze the video data. The analysis of video data will give some more clarification on this issue.

The following figures, Figure 3.6, 3.7 and 3.8, show the comparison of ADCP bedload data with capture rates of Pan 3, ADCP and dune tracking, and dune tracking and capture rates, respectively. It should be noted that g_{bADCP} data are based on C_b modeled with the empirical V. Rijn equation (equation 2.5 of this thesis), thus these have not been calibrated to the observed trap rates. All available data are presented in Figure 3.6. Data for individual pulse lengths and ADCP frequencies will be presented below.

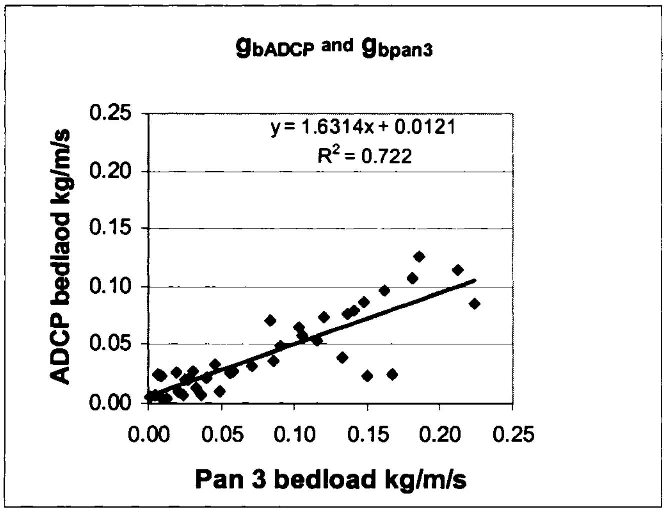


Figure 3.6: Comparison of ADCP and weigh pan 3 bedload results

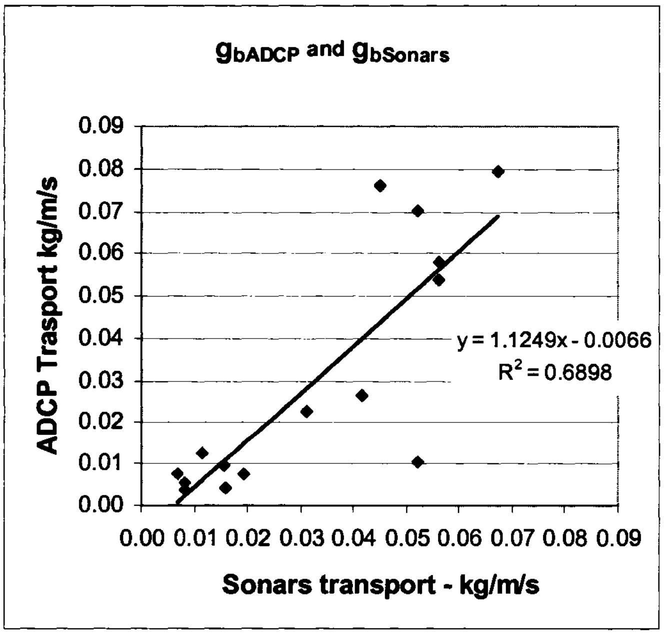


Figure 3.7 : Comparison of ADCP and dune tracking bedload results

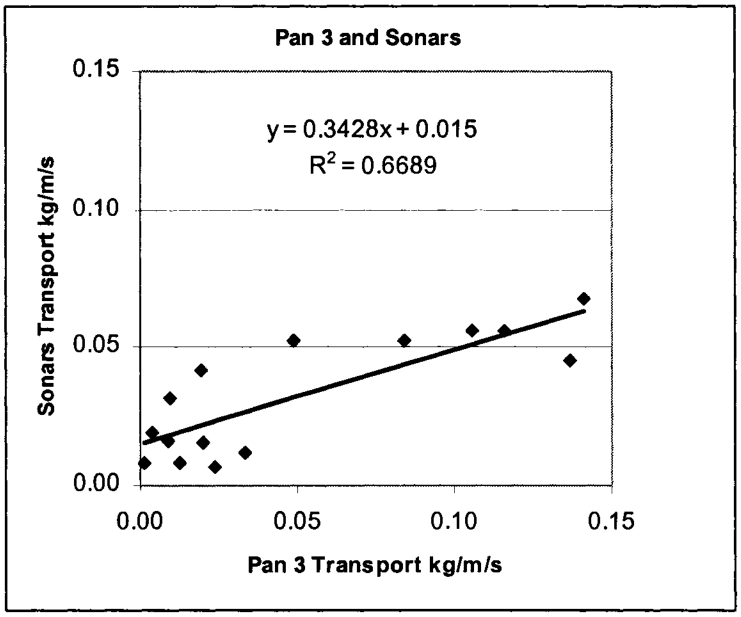


Figure 3.8 : Comparison of capture rates and dune tracking bedload results

The results reveal that there is acceptable correlation between ADCP, capture rates and sonar transport rates and the value of r^2 varies from 0.72 to 0.67 and the best r^2 is for ADCP and capture rates, which is 0.72. Root mean square error (RMSE) was also estimated for each run using the following equation:

$$\sqrt{\frac{(a_1 - c_1)^2 + (a_2 - c_2)^2 + \ldots + (a_n - c_n)^2}{n}}$$

a_i = Corresponding correct value (In our case g_{bpan3})
ci = Corresponding computed value (In our case g_{bADCP})

The mean-squared error is a commonly used measure of success for numeric prediction. This value is computed by taking the average of the squared differences between each computed value (c_i) and its corresponding correct value (a_i). The root mean-squared error is simply the square root of the mean-squared-error. The root mean-squared error gives the error value the same dimensionality as the actual and predicted values.

The results are 0.062, 0.018, 0.023 kg/m/s for the ADCP verses capture rates, ADCP verses sonars and capture rates verses sonars respectively. The results are described in Table 3.2.

The significance of regression line was also tested to improve the confidence level on the results. A significant prediction means a significant proportion of the variability in the predicted variable can be accounted for by the predictor variable. Table 3.2 shows the results of the statistical analysis carried out for ADCP, weigh pan 3 and sonars.

Table 3.2: Statistical parameters comparison for ADCP, weigh pan and sonars (sandbed runs)

		Weigh pan and ADCP	Sonars and ADCP	Weigh pan and Sonars
1	N	38	15	15
2	Slope	0.4537	0.8827	0.3428
3	Intercept	-0.005	-0.0097	0.015
4	Residual SS	0.0134	0.0026	0.0021
5	residualDF	36	13	13
6	SE	0.0193	0.0141	0.0128
7	R	0.8403	0.8107	0.8179
8	Rsquare	0.7061	0.6572	0.6689
9	SEslope	0.0488	0.1768	0.0669
10	Lower confidence slope	0.3548	0.5008	0.1984
11	Upper confidence slope	0.5527	1.2645	0.4873
12	Lambda	1.5519	1.5519	1.5519
13	Slopef	0.4768	1.0553	0.3552
14	R2*Lamda/r2	5.3231	1.3091	8.832
15	Upper confidence slopef	0.6097	1.6716	0.5521
16	Lower confidence slopef	0.3528	0.6412	0.1734
17	Interceptf	-0.0069	-0.0153	0.0143
18	Upper confidence interceptf	-0.0179	-0.0353	0.0043
19	Lower confidence interceptf	0.0033	-0.0018	0.0236
20	Avg yinv	0.0823	0.0325	0.0511
21	Avg xinv	0.0323	0.019	0.0325
22	sum xsquare inv	0.0455	0.0076	0.0064
23	sum ysquare inv	0.1561	0.0064	0.0363
24	slope inv	1.5563	0.7446	1.9511
25	SEslope inv	0.1673	0.1491	0.3807
26	Lower confidence slopeinv	1.217	0.4225	1.1288
27	Upper confidence slopeinv	1.8957	1.0667	2.7735
28	Lower confidence slopeinvinv	0.8217	2.3671	0.8859
29	Upper confidence slopeinvinv	0.5275	0.9374	0.3606

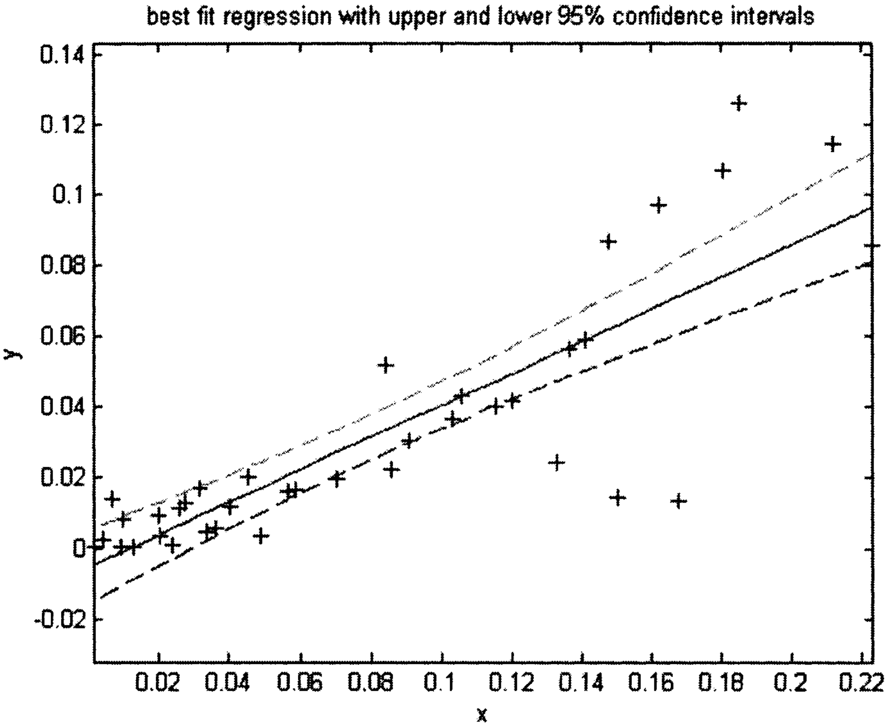


Figure 3.9: Best fit regression with upper and lower 95% confidence intervals (Weigh pan 3 {x-axis} and ADCP {y-axis})

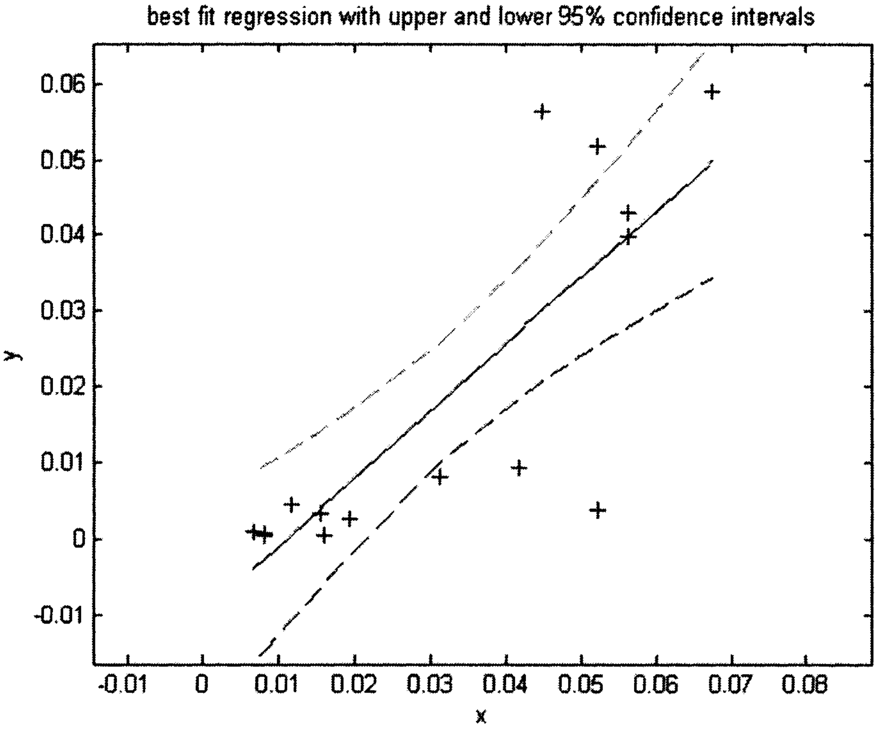


Figure 3.10: Best fit regression with upper and lower 95% confidence intervals (Sonars {x-axis} and ADCP {y-axis})

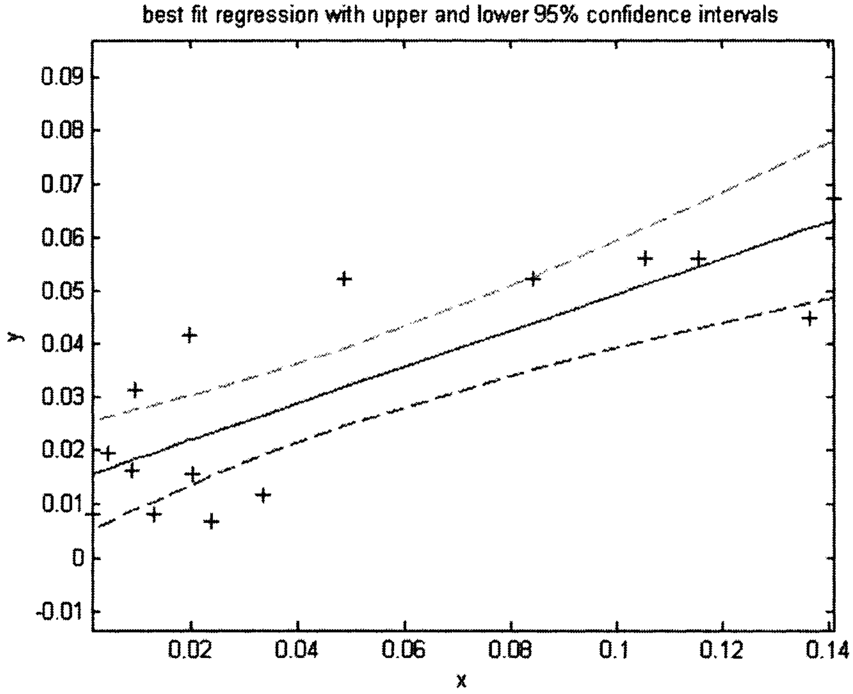


Figure 3.11: Best fit regression with upper and lower 95% confidence intervals (Weigh pan 3{x-axis} and sonars{y-axis})

Figures 3.9, 3.10 and 3.11 show the upper and lower 95% confidence intervals for ADCP, weigh pan3 and sonars. The details can be seen in Table 3.1.

In addition, Figures 3.12 shows the standard deviation error bars when ADCP bedload compared with the measured bedload of pan 3. As the bed elevations measured by sonars are based on point sampling, therefore error bars did not included in this thesis.

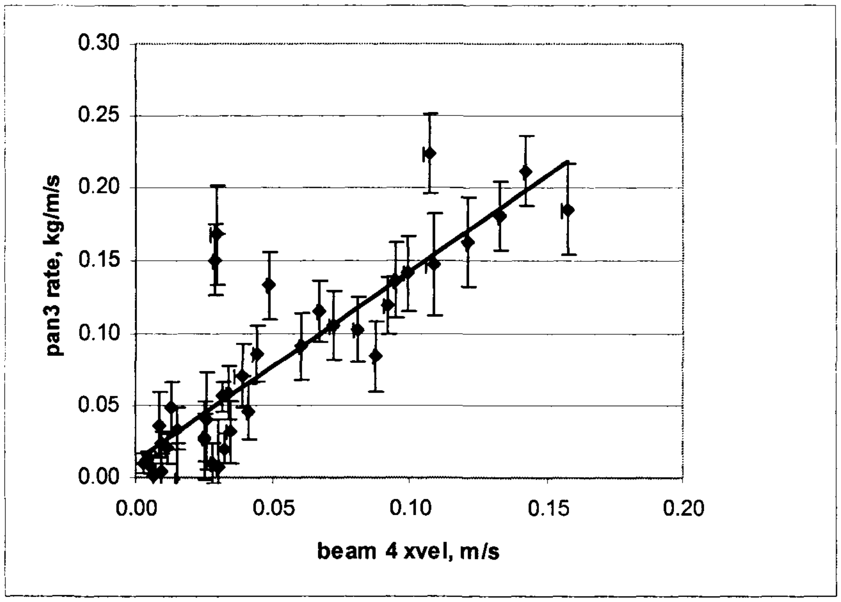


Figure 3.12: Beam 4 bed velocity and measured bedload transport rates of beam 4 with error bars.

Due to non availability of the side view video camera as proposed for the project the results still need to the verified. In addition, the raw video data still need to be processed and after analyzing that data, the above model can reanalyzed by incorporating the measured bedload concentration from video data instead of estimated bedload concentration by V. Rijn (1984).

As the volumetric bedload concentration still needs to be estimated using video data, therefore ADCP bedload velocity is calibrated with capture rates of pan 3 and dune tracking. The results are shown in the following sections and given in Table 3.3.

Pan 3 capture rates comparison with ADCP bedload velocity based on Pulse length and Frequency (Sandbed experiments):

The analysis is carried out with different bottom track pulse lengths &R20, 30 and 40 and different frequencies. The results are shown in Figures 3.13 to 3.16.

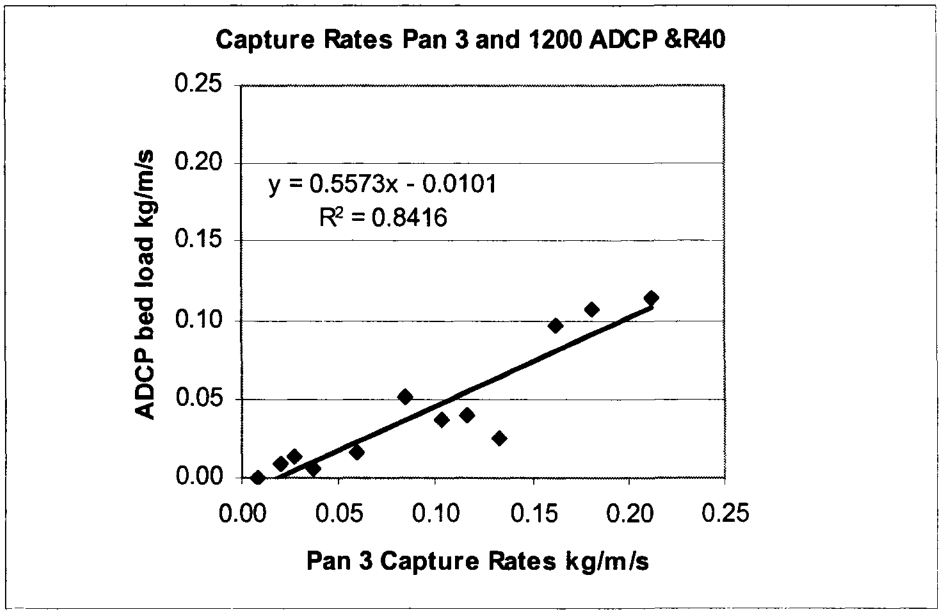


Figure 3.13 : Comparison of ADCP bedload and Capture Rates (1200 ADCP and &R40)

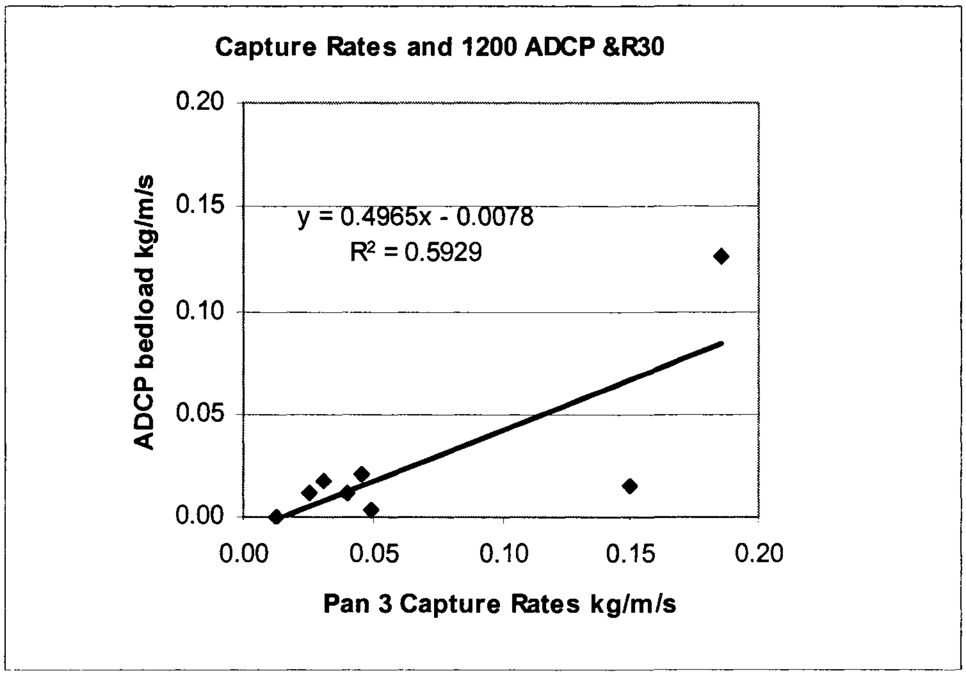


Figure 3.14: Comparison of ADCP bedload and Capture Rates (1200 kHz ADCP and &R30)

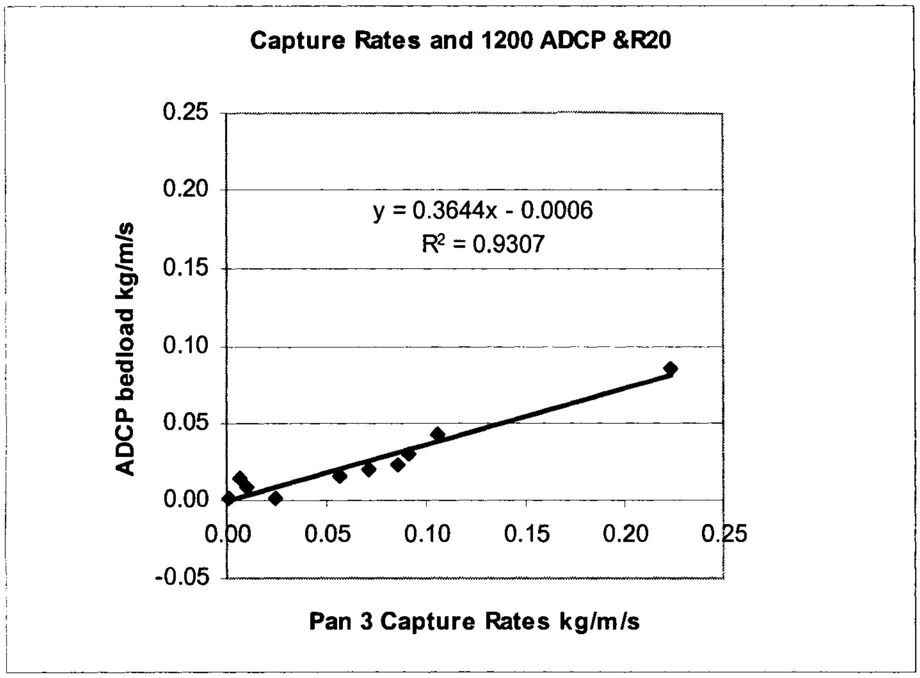


Figure 3.15: Comparison of ADCP bedload and Capture Rates (1200 kHz ADCP and &R20)

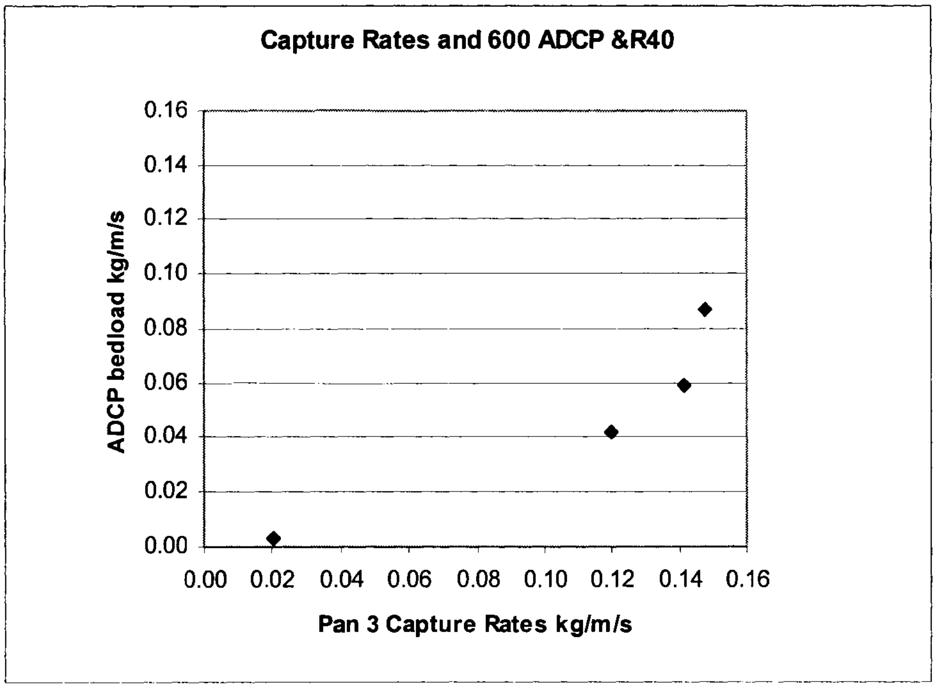


Figure 3.16: Comparison of ADCP bedload and capture rates (600 kHz ADCP, &R40)

The results reveal that there is acceptable correlation between ADCP bedload and capture rates, and the value of r^2 varies from 0.59 to 0.93 and the best r^2 is for 1200 kHz ADCP with pulse length 40. RMSE was also estimated for each run. The results are 0.062, 0.060 and 0.059 for pulse length 40, 30, 20 of 1200 kHz ADCP. Figure 3.15 shows the results for 600 kHz ADCP with bedload pulse length 40. Apparently 1200 ADCP with pulse length 20 is giving the best results.

Sonars comparison with ADCP bedload velocity based on pulse length and frequency (Sandbed):

The bedload transport rates estimated with dune tracking from sonars were compared to bedload from ADCP bed velocity. The analysis was carried out with different bottom track pulse lengths &R20, 30 and 40 and different frequencies. The results are shown in Figures 3.17 to 3.21.

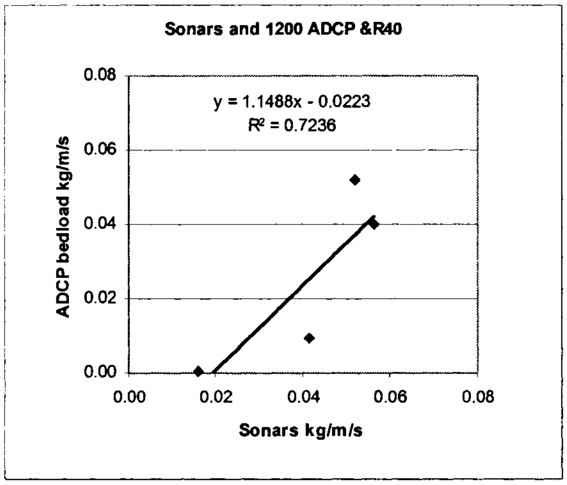


Figure 3.17: Comparison of ADCP bedload and Dune Tracking (1200 kHz ADCP, &R40)

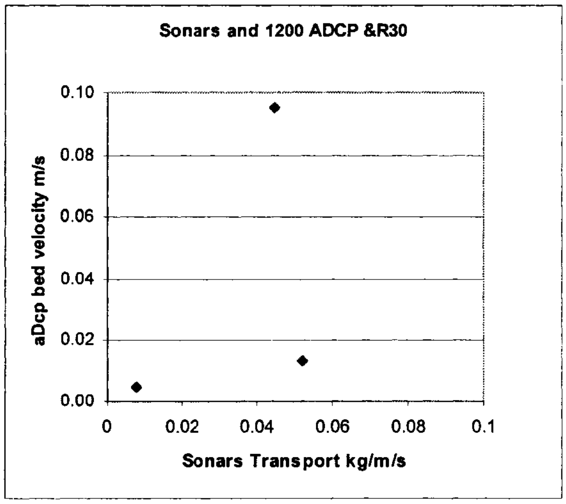


Figure 3.18: Comparison of ADCP bedload and Dune Tracking (1200 kHz ADCP, &R30)

Figure 3.18 shows that sonar is predicting low transport which can be seen when compare these results with capture rates as shown in Figure 3.19 below:

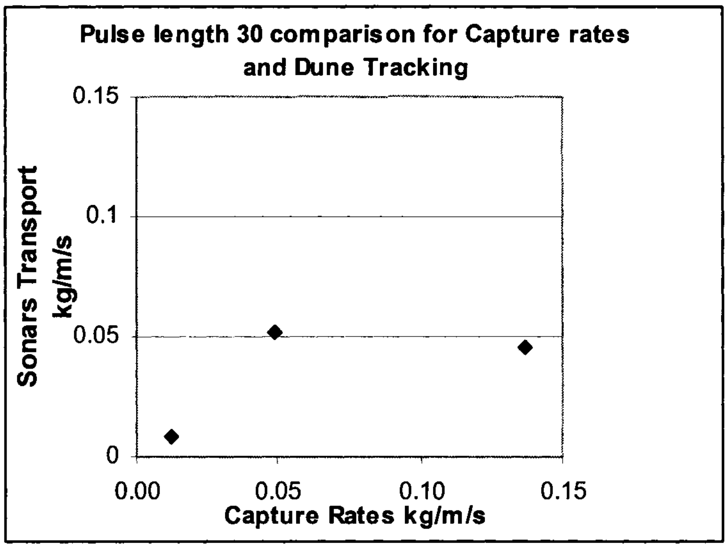


Figure 3.19: Pan 3 and sonars comparison for pulse length 30

As can be seen in Figure 3.19 that estimated bedload for sonars is extremely low as compare to pan 3 measured transport for point 3, when sonar transport is 0.04 kg/m/s as compared to 0.14 kg/m/s transport of pan 3 transport.

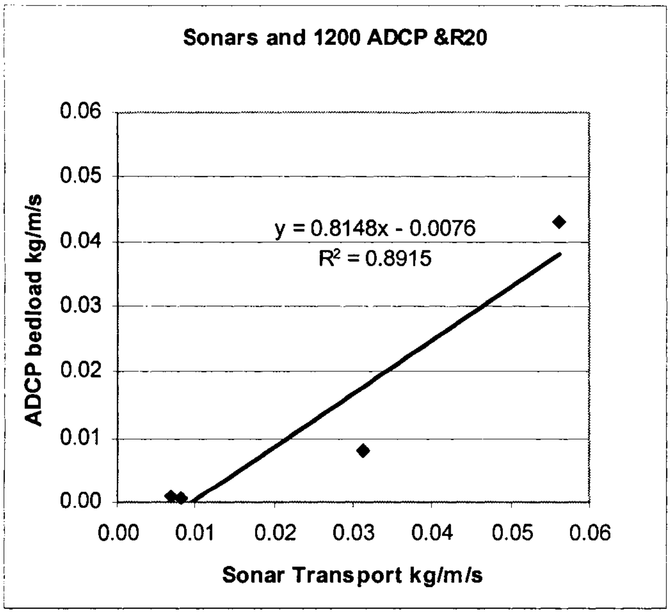


Figure 3.20: Comparison of ADCP bedload and Dune Tracking (1200 kHz ADCP, &R20)

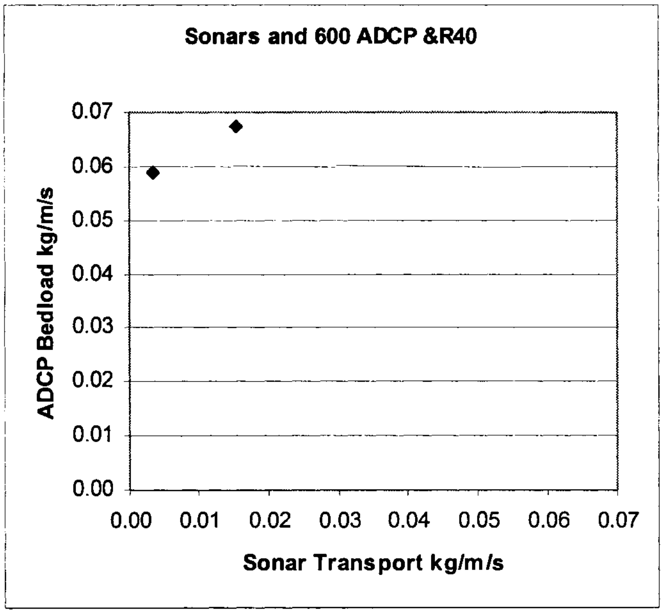


Figure 3.21: Comparison of ADCP bedload and dune tracking (600 kHz ADCP, &R40)

The results reveal that there is acceptable correlation between ADCP bedload and dune tracking, the value of r^2 varies from 0.82 to 0.92 and the best r^2 is for 1200 kHz ADCP at &R20. RMSE was also estimated for each run. The results are 0.020, 0.056 (0.029 with actual data) and 0.0141 kg/m/s for pulse length 40, 30 and 20 of 1200 kHz ADCP respectively. Pulse length 40 for 600 kHz ADCP did not analyzed as can be seen on Figure 3.18. Apparently 1200 kHz ADCP with pulse length 20 is giving the best results.

However the results of this analysis are based on two to four samples only which are insufficient for representative results. Also for the 600 kHz ADCP only two samples are available. The reason is that the sonars were implemented late in the project.

3.2.2: Gravelbed

Due to the non-availability of bedload volumetric concentration and active bedload layer thickness bedload transport was not estimated using equation 2.4 instead the calibration of ADCP bed velocity for gravel bed data was carried out with pan 3 capture rates and dune tracking verses bed velocity itself. For ADCP, beam 4 down stream mean bed velocity was used in the analysis. For capture rates and dune tracking the procedure to estimate bedload discharge is the same as sandbed experiments and is described in detail in chapter 2. Calibration curves are developed for ADCP bed velocity with capture rates and dune tracking transport (Figures 3.22, 3.23 and 3.24).

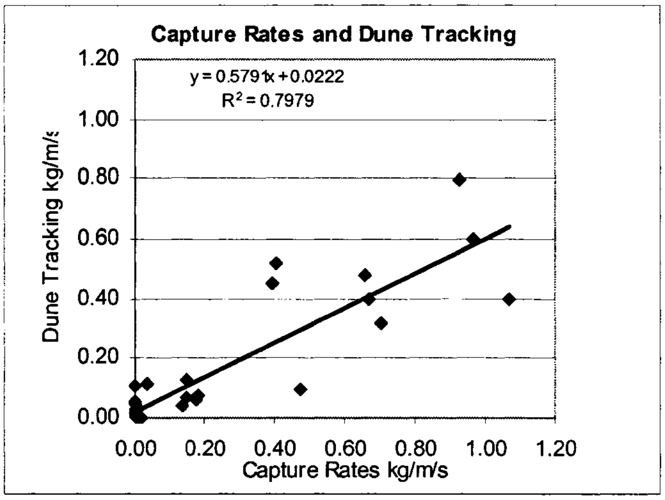


Figure 3.22: Calibration curve of capture rates and d une tracking

The above figure reveals that the good correlation between Pan 3 and sonars transport rate with r^2 of 0.80 and RMSE was 0.153 kg/m/s.

However when the transport of Pan 3 and sonars was compared with ADCP bed velocity the results are different and shown in Figure 3.23 and 3.24.

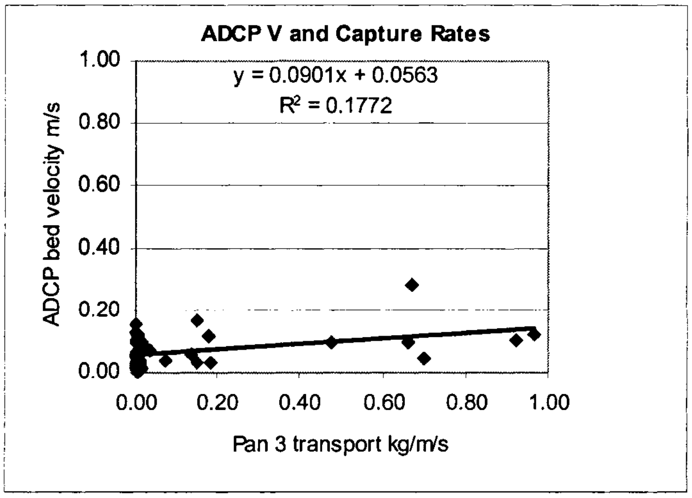


Figure 3.23: Calibration of ADCP bed velocity with capture rates

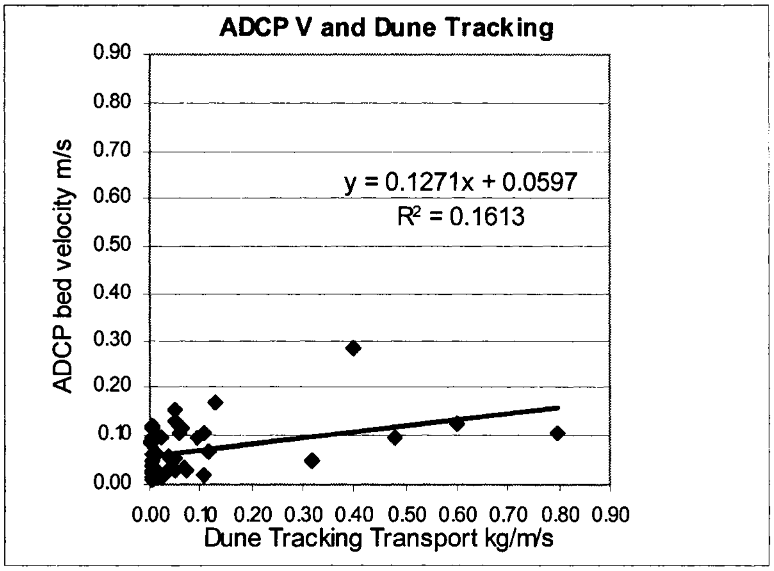


Figure 3.24: Calibration of ADCP bed velocity with dune tracking

The results show a correlation of only r^2 0.18 and 0.16 when compared ADCP bed velocity with pan 3 and sonars transport respectively. After reviewing the data it was found that pulse length &R40 gave irregular results. The results can be seen in Figure 3.25 as below:

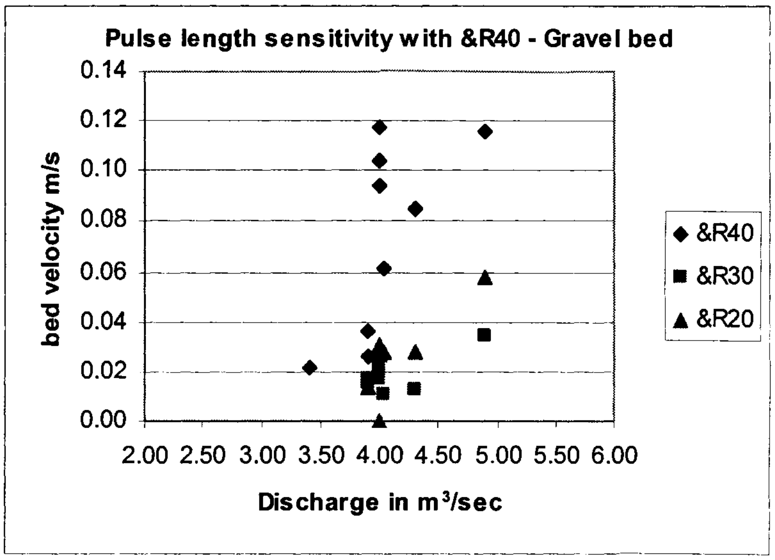


Figure 3.25: ADCP bed velocity with different discharges for gravel bed experiments

The results show that the &R40 data has variations and ranges of 0.02 m/s to 0.12 m/s bed velocity for 4 m^3/s discharge, which is not a representative bed velocity. One of the reasons is that during the 4 m^3/s discharge the flow was turbid and the velocity was biased by the scatterers (leaves etc). In addition, bed velocity with &R20 and 30 displayed a regular trend but the values were higher with &R20 than &R30. Keeping in view of these factors, another calibration curve was developed with out &R40 (Figures 3.26 and 3.27).

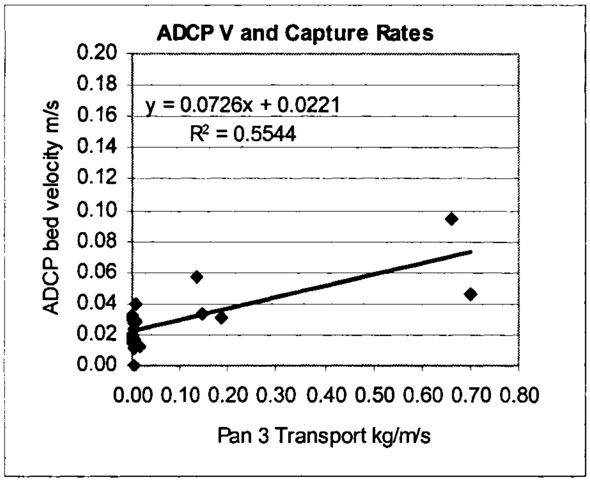


Figure 3.26: Calibration of ADCP bed velocity with capture rates (without &R40)

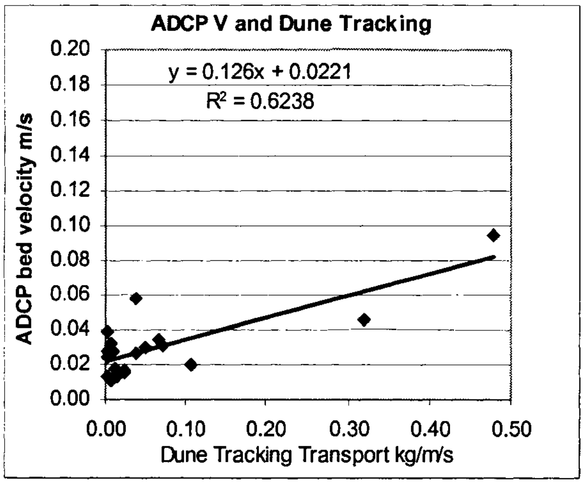


Figure 3.27: Calibration curve of ADCP data and dune tracking (without &R40)

The results show that there is a drastic improvement if we consider r^2 and it changes from 0.161 to 0.554 to 0.177 to 0.624.

After this analysis the results are also developed for different pulse lengths of ADCP with capture rates and dune tracking and are explained in the following sections:

Pan 3 capture rates comparison with ADCP bedload velocity based on pulse length and frequency (gravelbed experiments):

The analysis is carried out with different bottom track pulse lengths &R20, 30 and 40 and different frequencies. The detail is given in Table No: 3.4.

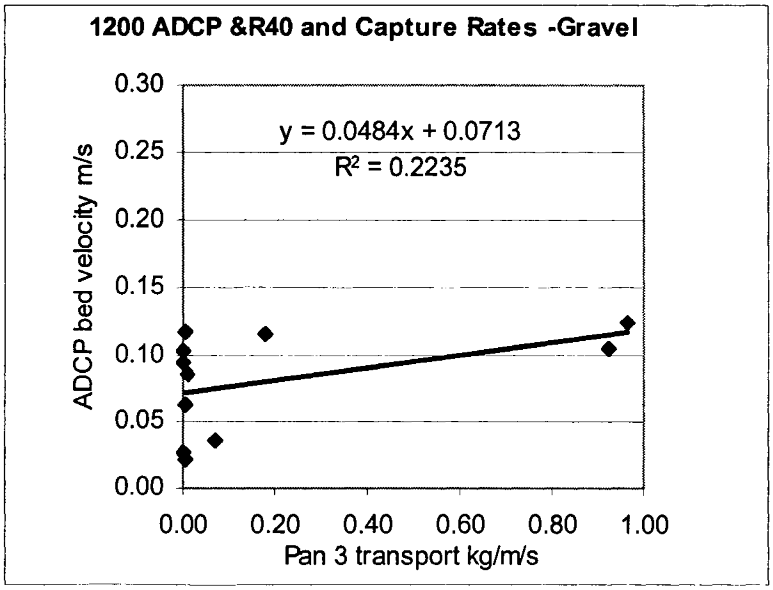


Figure 3.28: Calibration of ADCP bed velocity with Capture rates (1200 kHz ADCP &R40)

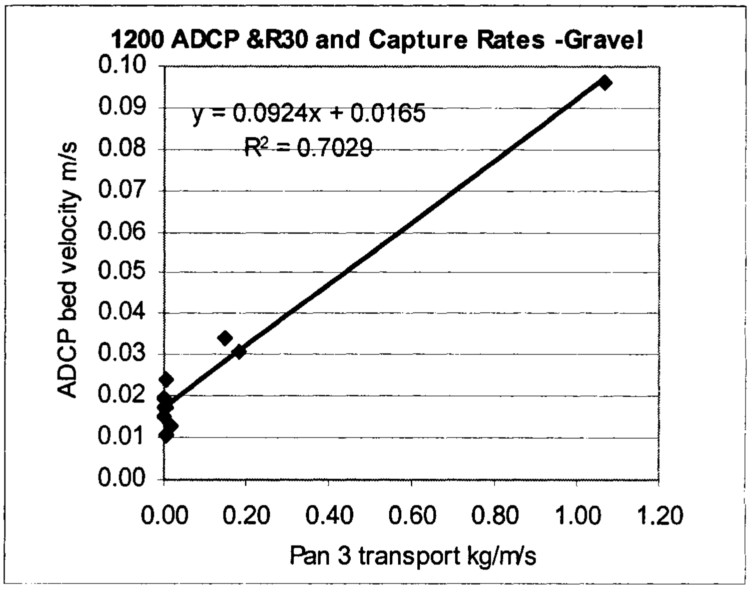


Figure 3.29: Calibration of ADCP bed velocity with Capture rates (1200 kHz ADCP, &R30)

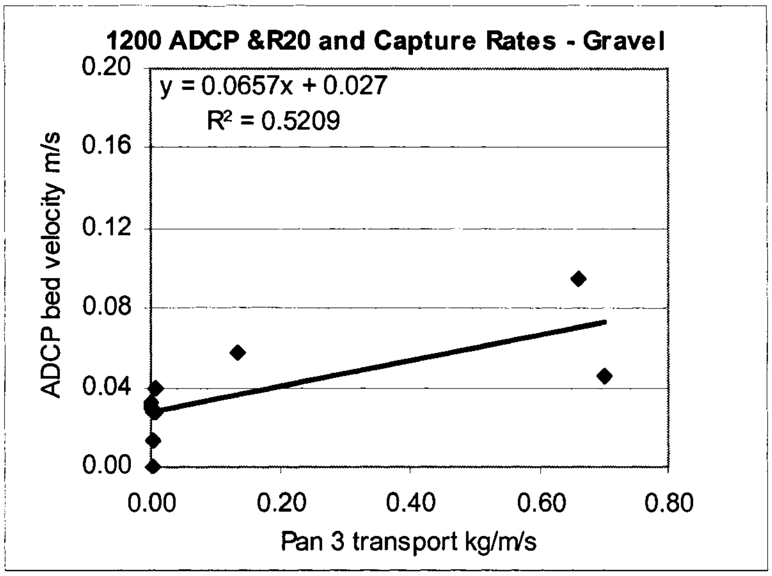


Figure 3.30: Calibration of ADCP bed velocity with capture rates (1200 kHz ADCP, &R20)

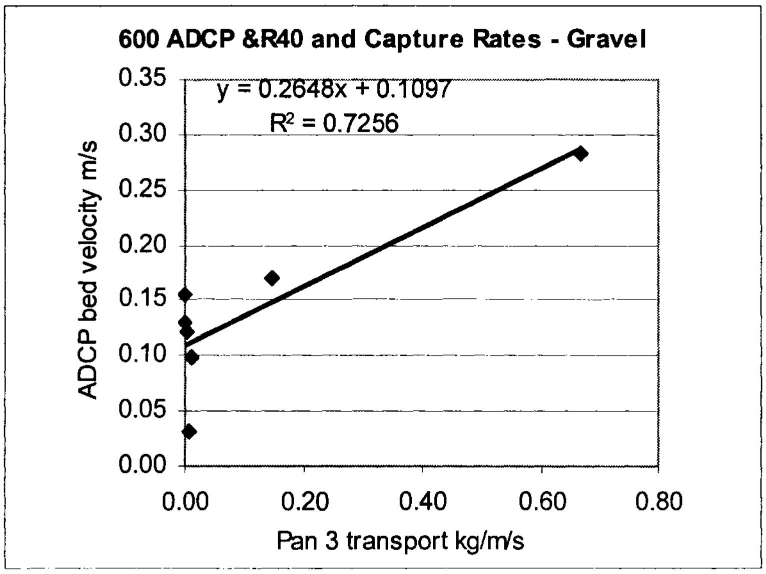


Figure 3.31: Calibration of ADCP bed velocity with capture rates (600 kHz ADCP, &R40)

The results reveal that there was acceptable correlation between ADCP and capture rates, and the value of r^2 varied from 0.5209 to 0.7256 (0.2235 for &R40 of 1200 kHz ADCP and the reason for this was explained in the previous section) and the best r^2 was for 600 kHz ADCP with pulse length 40.

Sonars comparison with ADCP bedload velocity based on pulse length and frequency (gravelbed):

The analysis is carried out with different bottom track pulse lengths &R20, 30 and 40 and different frequencies for gravel bed.

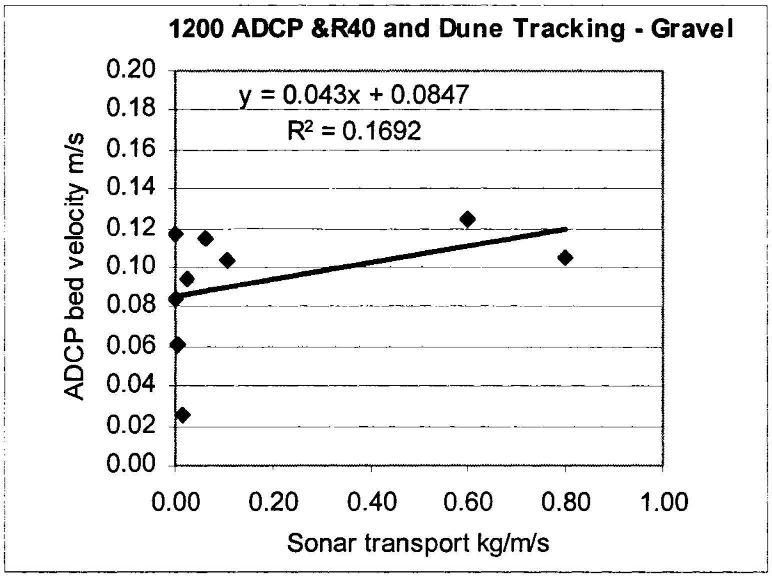


Figure 3.32: Calibration of ADCP bed velocity and dune tracking (1200 kHz ADCP, &R40)

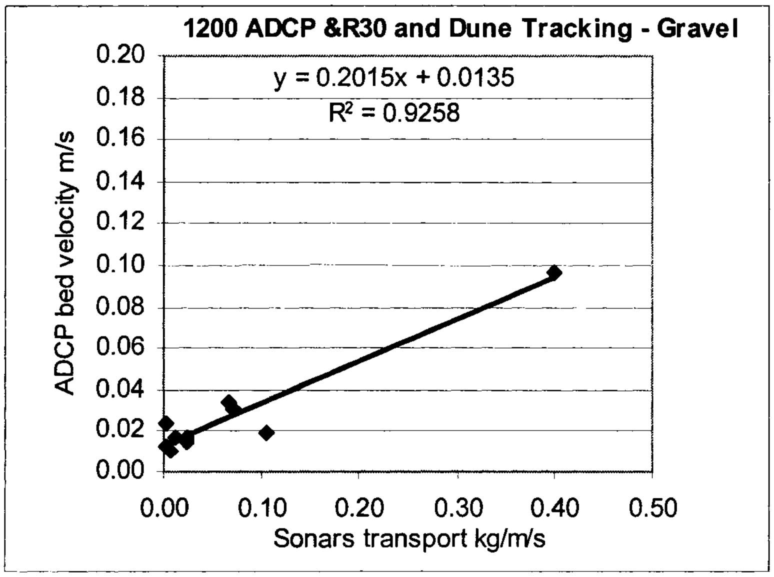


Figure 3.33: Calibration of ADCP bed velocity and dune tracking (1200 kHz ADCP, &R30)

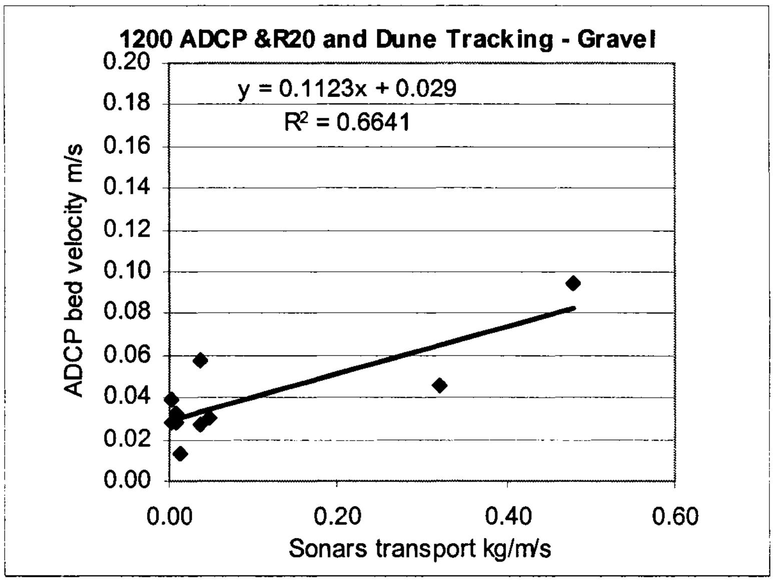


Figure 3.34: Calibration of ADCP bed velocity and dune tracking (1200 kHz ADCP, &R20)

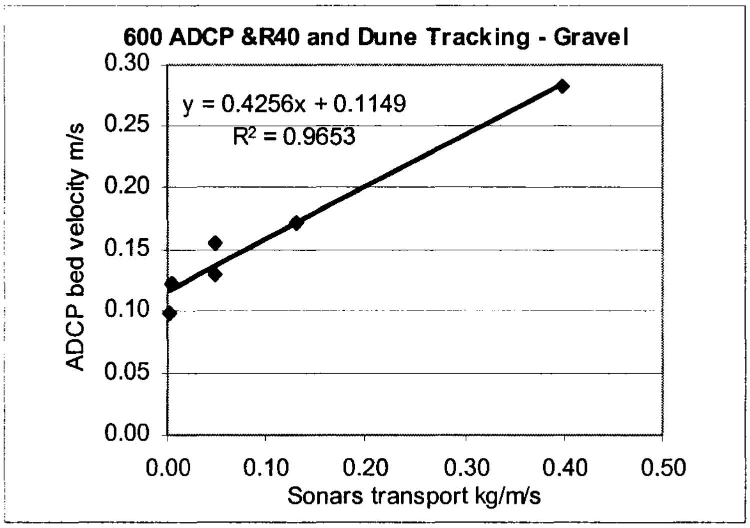


Figure 3.35: Calibration of ADCP bed velocity and dune tracking (600 kHz ADCP, &R40)

There was acceptable correlation between ADCP and capture rates, and the value of r^2 varied from 0.66 to 0.93 (0.17 for &R40) and the best r^2 is for 600 kHz ADCP with pulse length 40.

For the gravel bed, reasonable correlation was found between capture rates and dune tracking, but the results are scattered when these bedload measurement methods are compared with ADCP bed velocity. Apparently, it seems that the flow depths were not up to the minimum requirement for the ADCP or just close to the minimum requirements. In addition, it appears that the bedload followed a threshold behavior and ADCP bed velocity increases at low transport rate until a significant portion of bed is moving at which point the transport rate increased dramatically.

The final results for all of the above figures are described in Table 3.3 and 3.4.

TABLE 3.3: COMPARISION OF ADCP, CAPTURE RATES AND DUNE TRACKING

	Method	Regression Analysis	r^2	RMSE kg/m/s	n
Sandbed					
	g_A Vs g_C	1.631x + 0.012	0.72	0.062	39
	g_A Vs g_D	1.125x + 0.007	0.69	0.018	16
	g_c Vs g_D	0.343x + 0.015	0.67	0.023	15
Gravelbed					
	V_A Vs g_C	0.090x - 0.056	0.18		38
	V_A Vs g_D	0.127x + 0.060	0.19		34
	g_c Vs g_D	0.579x + 0.022	0.80	0.153	47
Without &R40	**V_A Vs g_C**	**0.072x + 0.022**	**0.55**		**20**
	V_A Vs g_D	**0.126x + 0.022**	**0.62**		**19**

g_A	ADCP bedload measured using Van Rijn model in kg/m/s
g_c	Measured Capture Rate for weigh Pan 3 in kg/m/s
g_D	Estimated Sonars bedload using B. D. Simons model in kg/m/s
V_A	Measured bed velocity of ADCP in m/s
RMSE	Root mean square error

TABLE 3.4: COMPARISON OF ADCP, CAPTURE RATES AND DUNE TRACKING

SENSITIVITY ANALYSIS FOR ADCP PULSE LENGTHS AND FREQUENCY

ADCP	&R	Method	Regression Analysis	r^2	RMSE	n
Capture Rates and ADCP Bedload comparison (SANDBED)						
1200	40	q_A Vs g_C	0.056x - 0.010	0.84	0.062	12
	30	q_A Vs g_C	0.496x - 0.008	0.59	0.046	9
	20	q_A Vs g_C	0.384x - 0.001	0.93	0.043	11
600	40	q_A Vs g_C			0.032	4
Dune Tracking and ADCP Bedload comparison (SANDBED)						
1200	40	q_A Vs g_D	1.149x - 0.022	0.72	0.020	4
	30	q_A Vs g_D			0.029	3
	20	q_A Vs g_D	0.815x - 0.008	0.89	0.014	4
600	40	q_A Vs g_D			0.023	2
Capture Rates and ADCP Bed Velocity Calibration (GRAVELBED)						
1200	40	V_A Vs g_C				11
	30	V_A Vs g_C	0.092x + 0.017	0.70		9
	20	V_A Vs g_C	0.066x + 0.072	0.52		11
600	40	V_A Vs g_C	0.265x + 0.11	0.73		7
Dune Tracking and ADCP Bed Velocity Calibration (GRAVELBED)						
1200	40	V_A Vs g_D				9
	30	V_A Vs g_D	0.202x + 0.014	0.93		10
	20	V_A Vs g_D	0.112x + 0.029	0.66		10
600	40	V_A Vs g_D	0.426x + 0.115	0.97		6

g_A	ADCP bedload measured using Van Rijn model in kg/m/s
g_c	Measured Capture Rate for weigh Pan 3 in kg/m/s
g_D	Estimated Sonars bedload using B. D. Simons model in kg/m/s
V_A	Measured bed velocity of ADCP in m/s
RMSE	Root mean square error

3.3: SHEAR STRESS PROFILES OF SAND AND GRAVEL BED EXPERIMENTS BY USING THE MEASURED VERTICAL PROFILES DATA BY ADV AND COMPARISON WITH MEASURED BEDLOAD.

As explained in Chapter 2, ADV data were collected for vertical profiles for both sandbed and gravelbed. The ADV was installed to measure the vertical profiles to estimate the grain shear stress since Feb 2nd 2006. Two to three vertical profiles were collected for each flow. For sand bed runs a total of 9 profiles were measured for five discharges. The profiles were collected on the stoss side of a dune near the dune crest. For gravelbed runs 12 profiles for five different discharges were collected.

The fully rough turbulent equation (Keulegan equation) was utilized to determine the shear velocity. Both u* and k_s were determined from the profile. The details are described in annexure V.

The velocity profiles were measured in front of pan 2. Therefore a comparison is carried out for grain shear and pan 2 bedload data. Tables 3.5 and 3.6 give the detail of the results for sandbed and gravelbed vertical profiles respectively. The detail analysis is described in Annexure V.

TABLE 3.5: VERTICAL PROFILE RESULTS: SANDBED

		(Upper Total Boundary Shear)			Lower (quasi grain shear)		
Date	Discharge	u*	τ	k_s	u*	τ	k_s
	m^3/sec	m/s	N/m^2	m	m/s	N/m^2	m
01/10/2006	2.4	0.110	12.049	0.363	0.080	6.314	0.15700
02/02/2006	2.9	0.066	4.403	0.047	0.045	1.997	0.00400
02/04/2006	3.6	0.126	15.801	0.205	0.114	13.003	0.25800
02/07/2006	2.0	0.040	1.601	0.032			
02/07/2006	2.0	0.059	3.469	0.261	0.014	0.192	0.00002
02/09/2006	2.5	0.067	4.540	0.191	0.075	5.572	0.20437
02/09/2006	2.5	0.062	3.856	0.142	0.158	24.609	0.82100
02/14/2006	3.2	0.146	19.876	0.501	0.123	15.069	0.72100
02/14/2006	3.2	0.065	4.204	0.041	0.063	3.994	0.05400

For January 10, 2006 the bedload data for comparison was not available and for February 07, 2006, Ist profile, it can be seen on the Figure above for this profile, that bed was aggrading too quickly to capture the lower profile (velocity going down, not up, so probably bed is getting closer). Second profile, 2.5 m^3/s on February 09, 2006, is not correct because of error in the measurements. Therefore these two profiles were not considered in the analysis.

TABLE 3.6: VERTICAL PROFILE RESULTS: GRAVELBED

		(Upper Total Boundry Shear)			Lower (quasi grain shear)		
Date	Discharge	u*	τ	k_s	U*	τ	k_s
	m^3/sec	m/s	N/m^2	M	m/s	N/m^2	m
03/10/2006	3.9	0.085	7.154	0.035	0.101	10.119	0.0740
03/12/2006	5.5	0.141	19.899	0.055	0.092	8.531	0.2530
03/16/2006	4.0	0.100	9.972	0.118	0.079	6.172	0.0360
03/16/2006	4.0	0.099	9.776	0.119	0.066	4.300	0.0160
03/21/2006	4.0	0.102	10.335	0.108	0.067	4.474	0.0190
03/21/2006	4.0	0.089	7.900	0.058	0.049	2.432	0.0040
03/25/2006	4.3	0.101	10.177	0.053	0.086	7.441	0.0280
03/25/2006	4.3	0.089	7.878	0.023	0.093	8.698	0.0330
03/28/2006	4.9	0.131	17.029	0.089	0.051	2.63	0.0040

The results of comparison of grain shear and measured capture rates are shown in Figure 3.36 and 3.37 for sand and gravel bed respectively as below:

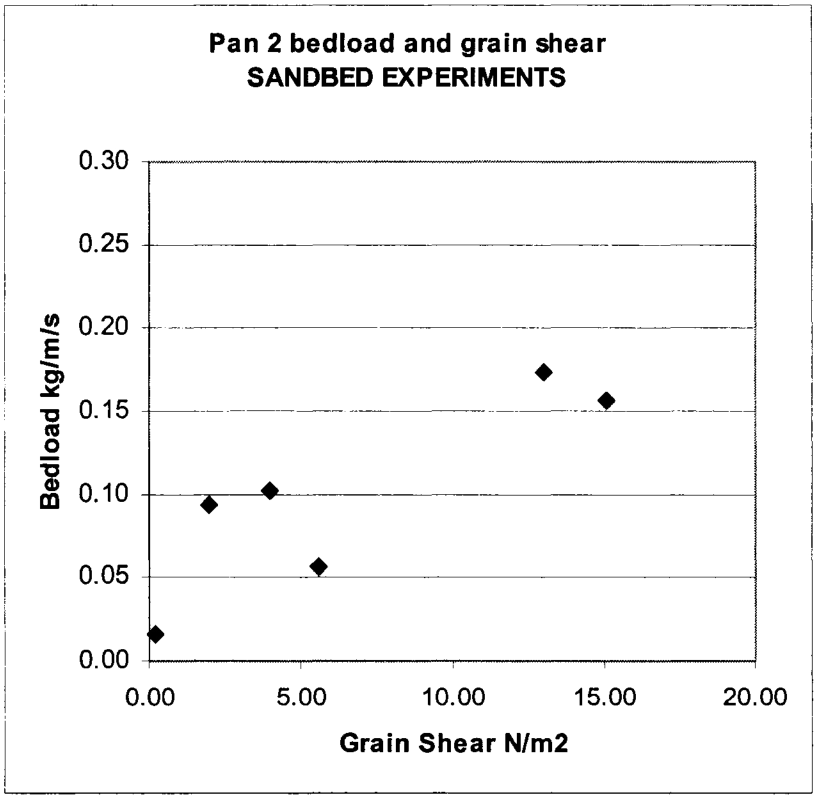


Figure 3.36: Influence of grain shear on transport rate. (sandbed)

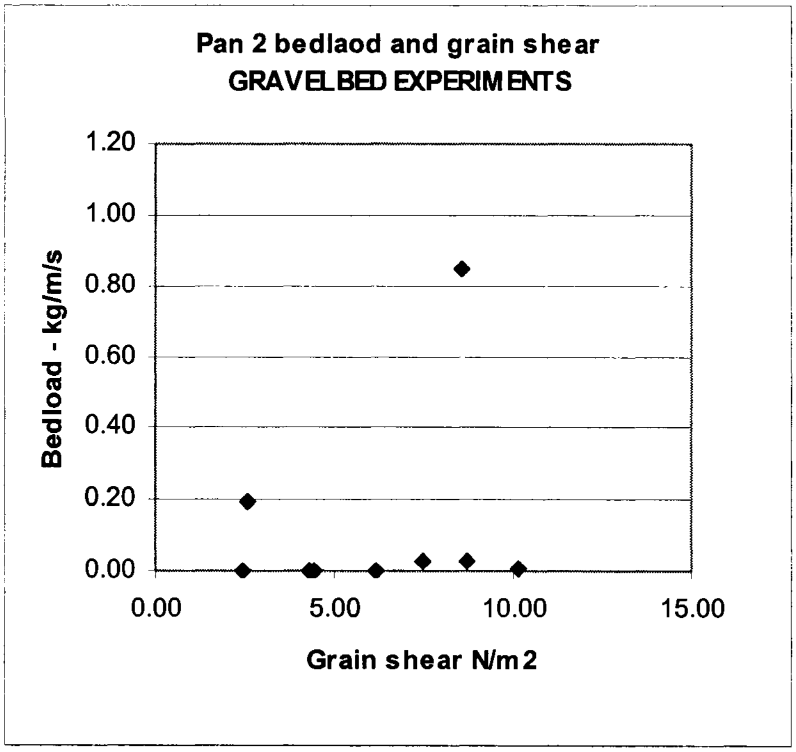


Figure 3.37: Influence of grain shear on transport rate. (gravelbed)

The two points which gives higher rate of transport are with 4.9 m^3/s and 5.5 m^3/s discharge. All of the other results are with almost no sediment transport even with high grain shear. Apparently it seems that the bed was not equilibrium for those flows. Also for gravel bed profiles except two profiles for 3.9 m^3/s and 5.5 m^3/s all of the files were recorded with too much turbid water due to leaves in the water and most of the time leaves stuck on the tip of the probe and gave erratic results.

4- DISCUSSIONS AND CONCLUSIONS

4.1: DISCUSSIONS

The hypothesis of this thesis was to study a controlled laboratory calibration of ADCP bedload velocity, which was performed in the main test channel at the SAFL as part of the NCED Sediment project. This was based on the research carried out by Rennie et al. (2002) in which he developed a new technique to measure non-invasive bedload and proposed that moving bottom bias in acoustic Doppler current profiler (ADCP) bottom tracking can be used as an estimate of apparent bedload velocity. However, it remains unknown if the apparent bedload velocity is an unbiased estimate of average bedload particle velocity.

To achieve this objective, the author performed experimental research at SAFL, UMN, USA from January 2006 to March 2006, to assess the accuracy and bias of ADCP bedload velocity measurement. The study plan was to evaluate the precision and bias of bedload velocity measurement using a Rio Grande ADCP. The bedload velocity measured by ADCP was compared to bedload transport rates measured using an automated bedload pit trap and dune tracking by sonars. The goal was that the simultaneous measurements obtained should identify ADCP bedload velocity precision and bias, and sources of bias, in different fluvial environments and with different ADCP operating parameters. In addition, available data from the entire project measured by weigh pans, sonars, videography, and ADV were catalogued in order to organize future research (Annexure I). For the first time in this research, the influence of bottom track pulse length and operating frequency on measured bedload velocity of ADCP was also assessed.

The study plan was divided into three parts, which covers experimental set-up and data collection plan, experimental procedures, and data collected by using the instruments explained above. Sand and gravel beds were used for the data collection with the five different steady discharges in each of sand and gravel beds. Nominal sediment depths of 30 cm and 45 cm were used for the sand-bed and gravel-bed experiments respectively. As suggested by Rennie et al. (2002) that a minimum of 25 minutes of sampling was required to achieve stable estimates of the mean and coefficient of variation, therefore, one hour continuous ADCP time series data were collected for each run in this study.

MATLAB codes were modified for this study by Rennie to estimate the mean bed velocity from raw ADCP data which were developed by Rennie (UoO), Muller (USGS) and Rainville (Environment Canada). In addition, two more MATLAB codes were developed for weigh pan and sonars data processing. The detail is given in Chapter 2 and the codes are depicted in Annexure II and the results of the processed data are given in Annexure IV.

All of the data collected and processed were analyzed to achieve the goal. First bottom track pulse length sensitivity and frequency sensitivity were studied before analyzing the ADCP bed velocity data. The results showed the variation of the bedload velocity measurement by ADCP and pulse length 20 is showing best correlation ($r^2 = 0.90$) as compared with pulse length 30 ($r^2 = 0.64$) and pulse length 40 ($r^2 = 0.85$). The frequency analysis results also show the variation in bedload measurements with two different frequency ADCP's. Apparently, 1200 kHz ADCP is giving better results when compared with 600 kHz ADCP bedload measurements as the variations were smoother as compared with 600 kHz ADCP. ADCP pulse length and frequency sensitivity analysis revealed that there is variation of bedload measurements when using different pulse lengths and frequency for bedload measurements and suggested that calibration of individual instrument settings is required if ADCPs are to be used to measure bedload velocity.

For bedload comparison ADCP beam 4 mean bedload, pan 3 transport rate and sonar 3 and 6 transport rates were used. Beam 4 was closer to the weigh pans. Pan 3 was the center pan immediately d/s of the ADCP and sonars 3 and 6 were also closer to the ADCP and Pan 3. The results were presented in Chapter 3.

For sand bed experiments, bedload estimation from ADCP, "u_b", mean bed velocity measured by beam 4 of ADCP was used. The active bedload thickness measured was 1.3 cm and 1.2 cm for 3.2 m^3/s and 3.18 m^3/s discharges during experiments. The depth was measured visually because of the non availability of the video camera data. The measured mobile bed thickness is on higher then $2D_{50}$, an approach by Einstein (1950) and Bagnold (1973). However V.Rijn

(1984) suggested about 8 particle diameter when observed visually for plane bed conditions. V. Rijn also explained that William (1970) suggested 10 particles diameter and Francis, 1973, suggested 2 to 4 D as active bed thickness, but argued that the experiment carried out by Francis with low flow depths and does not represent the natural conditions. Our visual observation for mobile bed thickness is close to V. Rijn (1984) and William (1970) experiments.

For the bedload concentration V. Rijn bedload transport formula was used because the video data still need to be analyzed. The results (Chapter 3) show that ADCP bed velocity is giving relatively low values of bedload as compared with the Pan 3 measured transport rates when estimated using V. Rijn (1984) concentration. So an attempt is carried out to optimize bedload concentration (C_b) values that make g_{bADCP} match to weigh pan 3 capture rates $g_{b\ pan3}$ assuming pan 3 results as a reference. The results show large variations between V. Rijn bedload concentration and concentration estimated by the pan 3 bedload transport rate and shows that the concentration measured by V. Rijn is giving the results on the lower side. The video data has been collected during this experimental research and still awaited from NCED. The video data can be analyzed for the bedload concentration using Leclair (2005), in which she processed the data to determine sediment concentration near the bed using Photoshop. These results can be verified by comparing with the measured near bed volumetric concentration using the video data collected during this study.

For sandbed experiments, the comparison of ADCP bedload with weigh pan and sonars data revealed that there is acceptable correlation between ADCP, capture rates and sonar transport rates and the value of r^2 varies from 0.72 to 0.67 and the best r^2 is for ADCP and capture rates, which is 0.72. RMSE was also estimated for each run. The results are 0.062, 0.018 and 0.023 for the ADCP verses capture rates, ADCP verses sonars and capture rates verses sonars respectively.

The results are comparable with Rennie and Villard (2004) and Villard and Chruch(2004), which ranges between 0.36 to 0.76 and 0.42 to 0.75 respectively. Rennie and Gaeuman (2006) correlated bottom track bed velocity $_{va}$ with physical samplers and found a low correlation of 0.33. Based of this comparison, the results of this study are prominent when compared with the previous studies. In addition to that significance of regression was also tested and explained in Chapter 3. The upper and lower confidence level ranges 0.55 - 0.35, 1.265 - 0.50 and 0.49 – 0.20 for pan3 verses ADCP, sonars verses ADCP and pan3 verses sonars respectively.

The results for different pulse lengths and frequencies of ADCP's revealed that there is acceptable correlation between ADCP bedload and capture rates, and the value of r^2 varies from 0.59 to 0.93 and the best r^2 is for 1200 kHz ADCP with pulse length 20. RMSE was also estimated for each run. The results are 0.062, 0.060, 0.059 and 0.106 for pulse length 40, 30 20 of 1200 kHz ADCP and pulse length 40 for 600 kHz ADCP respectively. Apparently 1200 kHz ADCP with pulse length 20 is giving the best results. In addition to that, the results of ADCP bedload velocity comparison with dune tracking (Table 3.3) show that pulse length 20 of 1200 kHz ADCP is the best option. An overall result shows that pulse length 20 with 1200 kHz ADCP is giving most unbiased results when compared to other pulse lengths and also giving consistent results when ADCP velocity is compared with both pan 3 and sonars data.

For the gravel bed, as the bedload concentration still need to be studied after video data analysis, the analysis for gravel bed experiments was carried out to calibrate the measured ADCP bed velocity to pan 3 measured transport rates and sonars bedlaods. A reasonable correlation was found between capture rates and dune tracking but the results are scattered when these bedload measurement methods are compared with ADCP bed velocity(Table 3.2 and 3.3). Also RMSE values show much higher side when compared RMSE for sand bed experiments. Apparently, it seems that the flow depths were not up to the minimum requirement for the ADCP or just close to the minimum requirements. In addition, it appears that the bedload followed a threshold behavior and ADCP bed velocity increases at low transport rate until a significant portion of bed is moving at which point the transport rate increased dramatically. But most of the flows the results show the threshold values and seems that for the calibration of ADCP bedload, deep flows and high velocity is required and needs to be investigated.

4.2: CONCLUSIONS:

Here again it is not worthless to say that bedload is difficult to measure and to predict. Estimates of bedload vary using available formulas and are typically in error by an order of magnitude or more (Gomez and Church, 1989 and Habersack and Laronne, 2002).

Bedload measurements are also brought with errors. Sampling errors with Helly-smith samplers collected in the Frazer River have been estimated at 35% of the mean (Kostaschuk and Ilersich, 1995) and Rennie and Villard (2004) found that 50% of the bedload standard deviation could be attributed to sampling error. Finally Gaeuman and Jacobson (2006) speculated that Helly-smith sampling was less reliable (i.e. more variable due to sampling error) than ADCP bedload velocity sampling.

Based on the above findings and the results of present study after comparison with the previous studies as discussed in section 4.1, it can be concluded that these experimental test results verified that moving bottom bias in ADCP bottom tracking can be used as an estimate of bedload velocity. A comparison was achieved successfully with measured bedload of capture rates and dune tracking transport rates. The results verify that bedload velocity measured by ADCP can be utilized for the measuring bedload transport so far as sand bed experiments are considered. These results need to calibrate after analyzing the videography data for bed concentration. For gravel bed apparently, it was found that the flow depths are not up to the minimum requirement for the ADCP.

The development of a relatively simple technique to measure bedload transport non-invasively, using ADCPs and measurements of the spatial distribution of bedload can be used for calibration and validation of morphodynamic river models to predict channel change and should lead to greater understanding of river morphological change.

These are the initial results. The video data analysis for the bed volumetric concentration will refine the results and hopefully will lead to develop a robust remote measurement technique for bedload and will be a major advance in fluvial science.

Based on the results of this study the conclusions can be divided as below:

- The influence of bottom track pulse length was assessed and found that the results are reasonable for different pulse lengths and operating frequency when compared with capture rates. However, the results of pulse length 20 with 1200 kHz ADCP were found most unbiased as compared to the pulse length 30 and 40.
- The influence of operating frequency was also assessed and found that 1200 kHz ADCP showed better results as compared with 600 kHz ADCP under experimental conditions. This suggested that calibration of individual instrument settings is required if ADCPs are to be used to measure bedload velocity.
- A comparison is made for ADCP bedload velocity with capture rates and dune tracking and found good correlation for sandbed experiments.
- The results are biased in gravelbed suggesting that higher velocities and deeper waters are required for the calibration of ADCP bedload measurements in the gravelbed environment.

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ANNEXURE I

Sheet 1 of 4

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR ADCP DATA

No of Runs	Date	Discharge m^3/sec	Mode	&R	ADCP File Name	ADCP Type
1	4-Jan-06	0.25 m/sec	BM5	20	NCED_Pretest_060104_000r, 96cm w depth, WM12	1200
2	4-Jan-06	0.25 m/sec	BM5	20	NCED_Pretest_060104_001r, 96cm w depth, WM12	1200
3	4-Jan-06	0.25 m/sec	BM5	20	NCED_Pretest_060104_002r, 96cm w depth, WM12	1200
4	4-Jan-06	0.25 m/sec	BM7	20	NCED_Pretest_060104_003r, 96cm w depth, WM11	1200
5	4-Jan-06	0.25 m/sec	BM7	20	NCED_Pretest_060104_004r, 96cm w depth, WM11	1200
6	4-Jan-06	0.25 m/sec	BM7	20	NCED_Pretest_060104_005r, 96cm w depth, WM11, Beam coord	1200
7	4-Jan-06	0.25 m/sec	BM7	20	NCED_Pretest_060104_005r, 96cm w depth, WM11, EX00001	1200
8	5-Jan-06		BM7		NCED_Pretest_060104_007r, WM11	1200
9	5-Jan-06		BM5		NCED_Pretest_060105_000r, WM11	1200
10	5-Jan-06		BM5		NCED_Pretest_060105_001, WM11, Beam Coordi	1200
11	5-Jan-06	Higher	BM5	30	NCED_Pretest_060105_002, WM11	1200
12	5-Jan-06	Flows	BM5	10	NCED_Pretest_060105_003, WM1	1200
13	5-Jan-06	"	BM5		NCED_Pretest_060105_004, WM1	1200
14	5-Jan-06	"	BM5		NCED_Pretest_060105_005, WM1, BF=10	1200
15	5-Jan-06	"	BM5		NCED_Pretest_060105_006, WM1, BF=10	1200
16	5-Jan-06	"	BM5	30	NCED_Pretest_060105_007, WM1, BF=10	1200
17	5-Jan-06	"	BM7	30	NCED_Pretest_060105_008, WM1, BF=10	1200
18	5-Jan-06	"	BM7	30	NCED_Pretest_060105_009, WM1, BF=10, changed config file	1200
19	5-Jan-06	"	BM7	30	NCED_Pretest_060105_010, WM1, BF=10, BE9999	1200
20	5-Jan-06	"	BM7	30	NCED_Pretest_060105_011, WM1, BF=10,BC200	1200
21	5-Jan-06	"	BM7	30	NCED_Pretest_060105_012, WM1, BF=10,BC200, BA20	1200
22	5-Jan-06	"			NCED_Pretest_060105_013 , **NO DATA**	1200
23	5-Jan-06	"	BM5	30	NCED_Pretest_060105_014, WM1, BF=10, BC200, BA20	1200
24	5-Jan-06	"	BM5	30	NCED_Pretest_060105_015, WM1, BF=10, BC200, BA20, BE9999	1200
25	5-Jan-06	"	BM5	30	NCED_Pretest_060105_016, WM1, BE9999	1200
26	5-Jan-06	"	BM5	30	NCED_Pretest_060105_017, WM1, BE9999, EX00001	1200
27	5-Jan-06	**NOT SURE WHAT DATA WE**			NCED_Pretest_060105_018r	
28	6-Jan-06	**NOT SURE WHAT DATA WE**			NCED_Pretest_060110_000r	
29	7-Jan-06		BM5		NCED_Pretest_060107_000r, WM11	1200
30	7-Jan-06				NCED_Pretest_060107_001r,WM1, over 1 m/sec WM11 did not worke	1200
31	7-Jan-06				NCED_Pretest_060107_002r, **NOT SURE THE DETAILS OF THIS FIL**	1200
32	7-Jan-06			20	NCED_Pretest_060107_003r	1200
33	7-Jan-06			30	NCED_Pretest_060107_004r	1200
34	7-Jan-06			20	NCED_Pretest_060107_005r	1200
35	7-Jan-06				NCED_Pretest_060107_006r, **NOT SURE THE DETAILS OF THIS FIL**	1200
36	10-Jan-06	2.5	BM5		NCED_pretest-060110-wm1-bm5-beamcoordinates000r (test)	600
37	10-Jan-06					
38	10-Jan-06					
39	10-Jan-06					
40	10-Jan-06					
41	10-Jan-06					
42	17-Jan-06	1.58	BM7		NCED_Pretest_060107_006r, BE9999, EX00111, Less than black line	1200
43	17-Jan-06	1.58	BM7	30	NCED_Pretest_060117_000r	1200
44	17-Jan-06	1.58	BM7	40	NCED_Pretest_060117_006r, **NOT SURE**	1200
45	17-Jan-06	1.58	BM7	40	NCED_Pretest_060117_007r	1200
46	17-Jan-06	1.58	BM5	40	NCED_Pretest_060117_008r	1200
47	29-Jan-06	2.89	BM5	40	NCED_Pretest_060129_000r, WM1, From this date onward WM1	1200
48	29-Jan-06	2.89	BM5	30	NCED_Pretest_060129_001r	1200
49	29-Jan-06	2.89	BM5	20	NCED_Pretest_060129_002r	1200
50	29-Jan-06	2.89	BM5	20	NCED_Pretest_060129_003r	1200

Sheet 2 of 4

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR ADCP DATA

No of Runs	Date	Discharge m^3/sec	Mode	&R	ADCP File Name	ADCP Type
51	29-Jan-06	2.89	BM5	30	NCED_Pretest_060129_004r	1200
52	30-Jan-06	3	BM5	40	NCED_Pretest_060130_000r	1200
53	30-Jan-06	3	BM5	30	NCED_Pretest_060130_001r	1200
54	30-Jan-06	3	BM5	20	NCED_Pretest_060130_002r	1200
55	30-Jan-06	3	BM5	20	NCED_Pretest_060130_003r,	1200
56	30-Jan-06	3	BM5	50	NCED_Pretest_060130_004r	1200
57	30-Jan-06	3	BM5	15	NCED_Pretest_060130_005r	1200
58	30-Jan-06	3			**NCED_Pretest_060130_006r, NOT SURE of this data**	1200
59	31-Jan-06	3	BM5	40	NCED_Pretest_060131_000r	1200
60	31-Jan-06	3	BM5	30	NCED_Pretest_060131_001r	1200
61	31-Jan-06	3	BM5	20	NCED_Pretest_060131_002r	1200
FEBRUARY						
1	1-Feb-06	2.98	BM5	40	NCED_Pretest_060201_000r	1200
2	1-Feb-06	2.98	BM5	30	NCED_Pretest_060201_001r	1200
3	1-Feb-06	2.98	BM5	20	NCED_Pretest_060201_001r	1200
4	2-Feb-06	2.90	BM5	40	NCED_Pretest_060202_000r	1200
5	2-Feb-06	2.90	BM5	40	NCED_2point9-_060202_000r	**600**
6	2-Feb-06	2.90	BM5	30	NCED_2point9dis_060202_001r	**600**
7	3-Feb-06	3.60	BM5	40	NCED_3point6dis_060203_600adcp_000r	**600**
8	3-Feb-06	3.60	BM5	40	NCED_3point6_060203_1200adcp000r	1200
9	4-Feb-06	3.60	BM5	40	NCED_3point6_060204_1200adcp000r	1200
10	4-Feb-06	3.60	BM5	30	NCED_3point6_060204_1200adcp001r	1200
11	4-Feb-06	3.60	BM5	20	NCED_3point6_060204_1200adcp002r	1200
12	4-Feb-06	3.60	BM5	40	NCED_3point6_060204_1200adcp003r	1200
13	6-Feb-06	2.00	BM5	20	NCED_2point0_060206_1200adcp000r	1200
14	7-Feb-06	2.00	BM5	20	NCED_2point0_060207_1200adcp000r	1200
15	7-Feb-06	2.00	BM5	30	NCED_2point0_060207_1200adcp001r	1200
16	7-Feb-06	2.00	BM5	40	NCED_2point0_060207_1200adcp002r	1200
17	7-Feb-06	2.00	BM5	40	NCED_3point6dis_060207_600adcp_000r	**600**
18	8-Feb-06	2.50	BM5	40	NCED_2point5dis_060208_600adcp_000r	**600**
19	8-Feb-06	2.50	BM5	30	NCED_2point5dis_060208_600adcp_001r	**600**
20	8-Feb-06	2.50	BM5	20	NCED_2point5dis_060208_600adcp_002r	**600**
21	8-Feb-06	2.50	**BM7**	30	NCED_2point5_060208_1200adcp000r	1200
22	8-Feb-06	2.50	**BM7**	40	NCED_2point5_060208_1200adcp001r	1200
23	9-Feb-06	2.50	BM5	20	NCED_2point5_060209_1200adcp000r	1200
24	9-Feb-06	2.50	BM5	30	NCED_2point5_060209_1200adcp001r	1200
25	9-Feb-06	2.50	BM5	40	NCED_2point5_060209_1200adcp002r	1200
26	9-Feb-06	3.20	BM5	40	NCED_3point2_060209_1200adcp000r	1200
27	14-Feb-06	3.20	BM5	30	NCED_3point2_060214_1200adcp000r	1200
28	14-Feb-06	3.20	BM5	20	NCED_3point2_060214_1200adcp001r	1200
29	14-Feb-06	3.20	BM5	40	NCED_3point2_060214_1200adcp002r	1200
30	14-Feb-06	3.20	BM5	40	NCED_3point2dis_060214_600adcp_000r	**600**

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR ADCP DATA

No of Runs	Date	Discharge m^3/sec	Mode	&R	ADCP File Name	ADCP Type
GRAVEL EXPERIMENTS						
1	3-Mar-06	3.40	BM5	40	NCED_3point4dis_060303_1200adcp_000r	1200
2	3-Mar-06	3.40	BM5	40	NCED_3point4dis_060303_600adcp_000r	**600**
3	3-Mar-06	3.90	BM5	40	NCED_3point9dis_060303_1200adcp_000r	1200
4	9-Mar-06	3.90	BM5	30	NCED_3point9dis_060309_1200adcp_000r	1200
5	9-Mar-06	3.90	BM5	40	NCED_3point9dis_060309_1200adcp_001r	1200
6	9-Mar-06	3.90	BM5	20	NCED_3point9dis_060309_1200adcp_002r	1200
7	9-Mar-06	3.90	BM5	20	NCED_3point9dis_060309_600adcp_000r	**600**
8	10-Mar-06	3.90	BM5	30	NCED_3point9dis_060310_1200adcp_000r	1200
9	10-Mar-06	3.90	BM5	40	NCED_3point9dis_060310_1200adcp_001r	1200
10	12-Mar-06	5.50	BM5	20	NCED_5point5dis_060312_1200adcp_000r	1200
11	12-Mar-06	5.50	BM5	30	NCED_5point5dis_060312_1200adcp_001r	1200
12	12-Mar-06	5.50	BM5	40	NCED_5point5dis_060312_1200adcp_002r	1200
13	14-Mar-06	5.50	BM5	30	NCED_5point5dis_060314_1200adcp_000r	1200
14	14-Mar-06	5.50	BM5		NCED_5point5dis_060314_1200adcp_001r	1200
15	14-Mar-06	5.50	BM5	40	NCED_5point5dis_060314_1200adcp_002r	1200
16	14-Mar-06	5.50	BM5	40	NCED_5point5dis_060314_1200adcp_003r	1200
17	14-Mar-06	5.50	BM5	20	NCED_5point5dis_060314_1200adcp_003r (same file name?)	1200
18	14-Mar-06	5.50	BM5	40	NCED_5point5dis_060314_1200adcp_004r	1200
19	14-Mar-06	5.50	BM5	40	NCED_5point5dis_060314_600adcp_000r	**600**
20	15-Mar-06	4.00	BM5	20	NCED_4point0dis_060315_1200adcp_000r (Only 10 min. data)	1200
21	15-Mar-06	4.00	BM5	20	NCED_4point0dis_060315_1200adcp_001r	1200
22	15-Mar-06	4.00	BM5	30	NCED_4point0dis_060315_1200adcp_002r	1200
23	15-Mar-06	4.00	BM5	40	NCED_4point0dis_060315_1200adcp_003r	1200
24	16-Mar-06	4.00	BM5	40	NCED_4point0dis_060316_1200adcp_000r	1200
25	16-Mar-06	4.00	BM5	30	NCED_4point0dis_060316_1200adcp_001r	1200
26	16-Mar-06	4.00	BM5	20	NCED_4point0dis_060316_1200adcp_002r	1200
27	16-Mar-06	4.00	BM5	40	NCED_4point0dis_060316_600adcp_000r	**600**
28	16-Mar-06	4.00	BM5	40	NCED_4point0dis_060316_600adcp_001r, with BA20	**600**
29	16-Mar-06	4.00	BM5	40 ?	NCED_4point0dis_060316_600adcp_002r, with BA10	**600**
30	16-Mar-06	4.00	BM5	20	NCED_4point0dis_060316_600adcp_003r, with BA15	**600**
31	16-Mar-06	4.00	BM5	20	NCED_4point0dis_060316_600adcp_004r	**600**
32	17-Mar-06	4.00	BM5	20	NCED_4point0dis_060317_600adcp_000r, V = 0.062 m/sec	**600**
33	17-Mar-06	4.00	BM5	20	NCED_4point0dis_060317_1200adcp_000r, V = 0.027 m/sec	1200
34	17-Mar-06	4.00	BM5	20	NCED_4point0dis_060317_1200adcp_001r, V = 0.032 m/sec	1200
35	17-Mar-06	4.00	BM5	30	NCED_4point0dis_060317_1200adcp_002r, V = 0.0259 m/sec	1200
36	17-Mar-06	4.00	BM5	40	NCED_4point0dis_060317_1200adcp_003r, V = 0.11 m/sec	1200
37	21-Mar-06	4.04	BM5	40	NCED_4point0dis_060321_1200adcp_000r, V = 0.06 m/sec	1200
38	21-Mar-06	4.04	BM5	30	NCED_4point0dis_060321_1200adcp_001r, V = 0.013 m/sec	1200
39	21-Mar-06	4.04	BM5	20	NCED_4point0dis_060321_1200adcp_002r, V = 0.02 m/sec	1200
40	21-Mar-06	4.04	BM5	40	NCED_4point0dis_060321_600adcp_000r, V = 0.12 m/sec	**600**
41	21-Mar-06	4.04	BM5	30	NCED_4point0dis_060321_600adcp_001r, V = 0.06 m/sec	**600**
42	22-Mar-06	4.04	BM5	20	NCED_4point0dis_060322_600adcp_000r, V = 0.24 m/sec	**600**
43	22-Mar-06	4.04	BM5	20	NCED_4point0dis_060322_600adcp_001r, V = 0.083 m/sec	**600**
44	25-Mar-06	4.30	BM5	40	NCED_4point3dis_060325_600adcp_000r, V = 0.09 m/sec	**600**
45	25-Mar-06	4.30	BM5	30	NCED_4point3dis_060325_600adcp_001r, V = 0.04 m/sec	**600**
46	25-Mar-06	4.30	BM5	20	NCED_4point3dis_060325_600adcp_002r, V = 0.052 m/sec	**600**
47	25-Mar-06	4.30	BM5	40	NCED_4point3dis_060325_1200adcp_000r, V = 0.084 m/sec	1200
48	25-Mar-06	4.30	BM5	30	NCED_4point3dis_060325_1200adcp_001r, V = 0.011 m/sec	1200
49	25-Mar-06	4.30	BM5	20	NCED_4point3dis_060325_1200adcp_002r, V = 0.023 m/sec	1200
50	28-Mar-06	4.90	BM5	40	NCED_4point9dis_060328_1200adcp_000r, V = 0.113 m/sec	1200

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR ADCP DATA

No of Runs	Date	Discharge m^3/sec	Mode	&R	ADCP File Name	ADCP Type
51	28-Mar-06	4.90	BM5	30	NCED_4point9dis_060328_1200adcp_001r, V = 0.034 m/sec	1200
52	28-Mar-06	4.90	BM5	30	NCED_4point9dis_060328_1200adcp_002r, V = 0.032 m/sec	1200
53	28-Mar-06	4.90	BM5	20	NCED_4point9dis_060328_1200adcp_003r, V = 0.052 m/ sec	1200
54	29-Mar-06	4.90	BM5	20	NCED_4point9dis_060329_600adcp_001r, V = 0.064 m/ sec	**600**
55	29-Mar-06	4.90	BM5	30 ?	NCED_4point9dis_060329_600adcp_001r, V = 0.095 m/ sec	**600**
56	29-Mar-06	4.90	BM5	40	NCED_4point9dis_060329_600adcp_002r, V = 0.168 m/ sec	**600**

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR SONARS AND WEIGH PAN DATA

No of Runs	Date	Discharge m^3/sec	SONARS File Names	WEIGH PANS File Names
1	4-Jan-06	0.25 m/sec	NO	NO
2	4-Jan-06	0.25 m/sec	NO	NO
3	4-Jan-06	0.25 m/sec	NO	NO
4	4-Jan-06	0.25 m/sec	NO	NO
5	4-Jan-06	0.25 m/sec	NO	NO
6	4-Jan-06	0.25 m/sec	NO	NO
7	4-Jan-06	0.25 m/sec	NO	NO
8	5-Jan-06		NO	NO
9	5-Jan-06		NO	NO
10	5-Jan-06		NO	NO
11	5-Jan-06	Higher	NO	NO
12	5-Jan-06	Flows	NO	NO
13	5-Jan-06	"	NO	NO
14	5-Jan-06	"	NO	NO
15	5-Jan-06	"	NO	NO
16	5-Jan-06	"	NO	NO
17	5-Jan-06	"	NO	NO
18	5-Jan-06	"	NO	NO
19	5-Jan-06	"	NO	NO
20	5-Jan-06	"	NO	NO
21	5-Jan-06	"	NO	NO
22	5-Jan-06	"	NO	NO
23	5-Jan-06	"	NO	NO
24	5-Jan-06	"	NO	NO
25	5-Jan-06	"	NO	NO
26	5-Jan-06	"	NO	NO
27	5-Jan-06	**NOT SURE W**	NO	NO
28	6-Jan-06	**NOT SURE W**	NO	NO
29	7-Jan-06		NO	NO
30	7-Jan-06		NO	NO
31	7-Jan-06		NO	NO
32	7-Jan-06		NO	NO
33	7-Jan-06		NO	NO
34	7-Jan-06		NO	NO
35	7-Jan-06		NO	NO
36	10-Jan-06	2.5	NO	NO
37	10-Jan-06		NO	NO
38	10-Jan-06		NO	NO
39	10-Jan-06		NO	NO
40	10-Jan-06		NO	NO
41	10-Jan-06		NO	NO
42	17-Jan-06	1.58	NO	runa01(sed_flux)
43	17-Jan-06	1.58	NO	
44	17-Jan-06	1.58	NO	
45	17-Jan-06	1.58	NO	
46	17-Jan-06	1.58	NO	
47	29-Jan-06	2.89	NO	01-26-06(sed_flux) (from 26th to 29th of January)
48	29-Jan-06	2.89	NO	
49	29-Jan-06	2.89	NO	
50	29-Jan-06	2.89	NO	

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR SONARS AND WEIGH PAN DATA

No of Runs	Date	Discharge m^3/sec	SONARS File Names	WEIGH PANS File Names
51	29-Jan-06	2.89	NO	
52	30-Jan-06	3	1/30/2006	2900lps_20060130_sedflux_sand(sed_flux)
53	30-Jan-06	3		
54	30-Jan-06	3		
55	30-Jan-06	3		
56	30-Jan-06	3		
57	30-Jan-06	3		
58	30-Jan-06	3		
59	31-Jan-06	3	1-31-06c (one sample per set)	2900lps_20060130_sedflux_sand(sed_flux)
60	31-Jan-06	3	1-31-06 d (started at about 6:00 pm till next day)	
61	31-Jan-06	3		
FEBRUARY				
1	1-Feb-06	2.98	2-1-06 a, 2-1-06 b and 2-1-06 c (total of three files)	2900lps_20060130_sedflux_sand(sed_flux)
2	1-Feb-06	2.98		
3	1-Feb-06	2.98		
4	2-Feb-06	2.90	2-2-06 a	2900lps_20060130_sedflux_sand(sed_flux)
5	2-Feb-06	2.90		
6	2-Feb-06	2.90		
7	3-Feb-06	3.60	test1-060203 and test1-060203 c (not sure)	3600lps_20060206_sedflux_sand(sed_flux)
8	3-Feb-06	3.60		
9	4-Feb-06	3.60	test-060204 (Not sure)	3600lps_20060206_sedflux_sand(sed_flux)
10	4-Feb-06	3.60		
11	4-Feb-06	3.60		
12	4-Feb-06	3.60		
13	6-Feb-06	2.00	2-6-06	2000lps_20060206_sedflux_sand
14	7-Feb-06	2.00	2-7-06	2000lps_20060206_sedflux_sand
15	7-Feb-06	2.00		
16	7-Feb-06	2.00		
17	7-Feb-06	2.00		
18	8-Feb-06	2.50	2-8-06	2500lps_20060208_sedflux_sand(sed_flux)
19	8-Feb-06	2.50		
20	8-Feb-06	2.50		
21	8-Feb-06	2.50		
22	8-Feb-06	2.50		
23	9-Feb-06	2.50	2-9-06	2500lps_20060208_sedflux_sand(sed_flux)
24	9-Feb-06	2.50		
25	9-Feb-06	2.50		
26	9-Feb-06	3.20		
27	14-Feb-06	3.20	3200lps_20060214_sonar1-7_sand	3200lps_20060213_sedflux_sand(sed_flux)
28	14-Feb-06	3.20		
29	14-Feb-06	3.20		
30	14-Feb-06	3.20		

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY
FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR SONARS AND WEIGH PAN DATA

No of Runs	Date	Discharge m^3/sec	SONARS File Names	WEIGH PANS File Names
GRAVEL EXPERIMENTS				
1	3-Mar-06	3.40		3400lps_20060303_sedflux_gravel
2	3-Mar-06	3.40	Did not find data	
3	3-Mar-06	3.90		3900lps_20060303_sedflux_gravel
4	9-Mar-06	3.90	3900lps_20060309_sonar1-7_gravel	3900lps_20060309_sedflux_gravel
5	9-Mar-06	3.90		
6	9-Mar-06	3.90		
7	9-Mar-06	3.90		
8	10-Mar-06	3.90	3900lps_20060310_sonar1-7_gravel	3900lps_20060310_sedflux_gravel
9	10-Mar-06	3.90		
10	12-Mar-06	5.50	5500lps_20060312_sonar1-7_gravel	5500lps_20060312_sedflux_gravel
11	12-Mar-06	5.50		
12	12-Mar-06	5.50		
13	14-Mar-06	5.50	5500lps_20060314_sonar1-7_gravel	5500lps_20060314_sedflux_gravel
14	14-Mar-06	5.50		
15	14-Mar-06	5.50		
16	14-Mar-06	5.50		
17	14-Mar-06	5.50		
18	14-Mar-06	5.50		
19	14-Mar-06	5.50		
20	15-Mar-06	4.00	4000lps_20060315_sonar1-7_gravel	4000lps_20060315_sedflux_gravel
21	15-Mar-06	4.00		
22	15-Mar-06	4.00		
23	15-Mar-06	4.00		
24	16-Mar-06	4.00	4000lps_20060316_sonar1-7_gravel	4000lps_20060316_sedflux_gravel
25	16-Mar-06	4.00		4000lps_20060316_sedflux_gravel_2
26	16-Mar-06	4.00		Two files for this day. One upto approxi. 3pm and
27	16-Mar-06	4.00		2nd upto 9 pm
28	16-Mar-06	4.00		
29	16-Mar-06	4.00		
30	16-Mar-06	4.00		
31	16-Mar-06	4.00		
32	17-Mar-06	4.00	4000lps_20060317_sonar1-7_gravel	4000lps_20060317_sedflux_gravel
33	17-Mar-06	4.00		
34	17-Mar-06	4.00		
35	17-Mar-06	4.00		
36	17-Mar-06	4.00		
37	21-Mar-06	4.04	4000lps_20060321_sonar1-7_gravel	4000lps_20060321_sedflux_gravel
38	21-Mar-06	4.04		
39	21-Mar-06	4.04		
40	21-Mar-06	4.04		
41	21-Mar-06	4.04		
42	22-Mar-06	4.04	4000lps_20060322_sonar1-7_gravel	4000lps_20060322_sedflux_gravel
43	22-Mar-06	4.04		
44	25-Mar-06	4.30	4300lps_20060325_sonar1-7_gravel	4300lps_20060325_sedflux_gravel
45	25-Mar-06	4.30		
46	25-Mar-06	4.30		
47	25-Mar-06	4.30		
48	25-Mar-06	4.30		

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY
FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR SONARS AND WEIGH PAN DATA

No of Runs	Date	Discharge m^3/sec	SONARS File Names	WEIGH PANS File Names
49	25-Mar-06	4.30		
50	28-Mar-06	4.90	4900lps_20060328_sonar1-7_gravel	4900lps_20060328_sedflux_gravel
51	28-Mar-06	4.90		
52	28-Mar-06	4.90		
53	28-Mar-06	4.90		
54	29-Mar-06	4.90	4900lps_20060329_sonar1-7_gravel	4900lps_20060329_sedflux_gravel
55	29-Mar-06	4.90		
56	29-Mar-06	4.90		

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY
FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR FIELD ADV DATA

No of Runs	Date	Discharge m^3/sec	FIELD ADV File Names
1	4-Jan-06	0.25 m/sec	NO
2	4-Jan-06	0.25 m/sec	NO
3	4-Jan-06	0.25 m/sec	NO
4	4-Jan-06	0.25 m/sec	NO
5	4-Jan-06	0.25 m/sec	NO
6	4-Jan-06	0.25 m/sec	NO
7	4-Jan-06	0.25 m/sec	NO
8	5-Jan-06		NO
9	5-Jan-06		NO
10	5-Jan-06		NO
11	5-Jan-06	Higher	NO
12	5-Jan-06	Flows	NO
13	5-Jan-06	"	NO
14	5-Jan-06	"	NO
15	5-Jan-06	"	NO
16	5-Jan-06	"	NO
17	5-Jan-06	"	NO
18	5-Jan-06	"	NO
19	5-Jan-06	"	NO
20	5-Jan-06	"	NO
21	5-Jan-06	"	NO
22	5-Jan-06	"	NO
23	5-Jan-06	"	NO
24	5-Jan-06	"	NO
25	5-Jan-06	"	NO
26	5-Jan-06	"	NO
27	5-Jan-06	**NOT SURE**	NO
28	6-Jan-06	**NOT SURE**	NO
29	7-Jan-06		NO
30	7-Jan-06		NO
31	7-Jan-06		NO
32	7-Jan-06		NO
33	7-Jan-06		NO
34	7-Jan-06		NO
35	7-Jan-06		NO
36	10-Jan-06	2.5	NO
37	10-Jan-06		NO
38	10-Jan-06		10cmbelowbed0001.ADV (with Dave Gueaman, Micro ADV)
39	10-Jan-06		10cmbelowbed0002.ADV (with Dave Gueaman, Micro ADV)
40	10-Jan-06		shear velocity measurement0001.ADV with Micro ADV
41	10-Jan-06		shear velocity measurement20001.ADV with Micro ADV
42	17-Jan-06	1.58	NO
43	17-Jan-06	1.58	NO
44	17-Jan-06	1.58	NO
45	17-Jan-06	1.58	NO
46	17-Jan-06	1.58	NO
47	29-Jan-06	2.89	NO
48	29-Jan-06	2.89	NO
49	29-Jan-06	2.89	NO
50	29-Jan-06	2.89	NO

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR FIELD ADV DATA

No of Runs	Date	Discharge m^3/sec	FIELD ADV File Names
51	29-Jan-06	2.89	NO
52	30-Jan-06	3	NO
53	30-Jan-06	3	NO
54	30-Jan-06	3	NO
55	30-Jan-06	3	NO
56	30-Jan-06	3	NO
57	30-Jan-06	3	NO
58	30-Jan-06	3	NO
59	31-Jan-06	3	NO
60	31-Jan-06	3	NO
61	31-Jan-06	3	**NO**
			NO
FEBRUARY			
1	1-Feb-06	2.98	NO
2	1-Feb-06	2.98	NO
3	1-Feb-06	2.98	NO
4	2-Feb-06	2.90	Crest_2.ADV
5	2-Feb-06	2.90	NO
6	2-Feb-06	2.90	NO
7	3-Feb-06	3.60	NO
8	3-Feb-06	3.60	NO
9	4-Feb-06	3.60	NO
10	4-Feb-06	3.60	NO
11	4-Feb-06	3.60	NO
12	4-Feb-06	3.60	0204-S1.ADV
13	6-Feb-06	2.00	NO
14	7-Feb-06	2.00	NO
15	7-Feb-06	2.00	NO
16	7-Feb-06	2.00	0207SS01.ADV
17	7-Feb-06	2.00	0207SS03.ADV
18	8-Feb-06	2.50	NO
19	8-Feb-06	2.50	NO
20	8-Feb-06	2.50	NO
21	8-Feb-06	2.50	NO
22	8-Feb-06	2.50	NO
23	9-Feb-06	2.50	0209SS01.ADV
24	9-Feb-06	2.50	0209SS02.ADV
25	9-Feb-06	2.50	NO
26	9-Feb-06	3.20	NO
27	14-Feb-06	3.20	NO
28	14-Feb-06	3.20	0214ss10001.ADV
29	14-Feb-06	3.20	0114ss20001.ADV
30	14-Feb-06	3.20	0214SS30003.ADV

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR FIELD ADV DATA

No of Runs	Date	Discharge m^3/sec	FIELD ADV File Names
GRAVEL EXPERIMENTS			
1	3-Mar-06	3.40	
2	3-Mar-06	3.40	
3	3-Mar-06	3.90	
4	9-Mar-06	3.90	
5	9-Mar-06	3.90	
6	9-Mar-06	3.90	
7	9-Mar-06	3.90	
8	10-Mar-06	3.90	060310SS0002.ADV
9	10-Mar-06	3.90	
10	12-Mar-06	5.50	Two Profiles, one uncomplete, other one burst missing
11	12-Mar-06	5.50	0603twelthSS0006.ADV
12	12-Mar-06	5.50	
13	14-Mar-06	5.50	060314SS0001.ADV with Micro ADV
14	14-Mar-06	5.50	
15	14-Mar-06	5.50	060314001.ADV (not sure and need to be checked)
16	14-Mar-06	5.50	060314SS0002 to 0603140007.ADV (6 files one profile)
17	14-Mar-06	5.50	
18	14-Mar-06	5.50	
19	14-Mar-06	5.50	
20	15-Mar-06	4.00	
21	15-Mar-06	4.00	
22	15-Mar-06	4.00	
23	15-Mar-06	4.00	
24	16-Mar-06	4.00	060316SS0001.ADV
25	16-Mar-06	4.00	060316SS0002.ADV, did not complete b/s of leaves on prob
26	16-Mar-06	4.00	060316SS0003.ADV
27	16-Mar-06	4.00	
28	16-Mar-06	4.00	
29	16-Mar-06	4.00	
30	16-Mar-06	4.00	
31	16-Mar-06	4.00	
32	17-Mar-06	4.00	
33	17-Mar-06	4.00	
34	17-Mar-06	4.00	
35	17-Mar-06	4.00	
36	17-Mar-06	4.00	
37	21-Mar-06	4.04	
38	21-Mar-06	4.04	060316SS0001.ADV and 060316SS0002.ADV (2 files one profile)
39	21-Mar-06	4.04	
40	21-Mar-06	4.04	
41	21-Mar-06	4.04	060316SS0003.ADV and 060316SS0004.ADV (2 files one profile)
42	22-Mar-06	4.04	
43	22-Mar-06	4.04	
44	25-Mar-06	4.30	060325SS0002 to 060325SS0004.ADV (3 files one profile)
45	25-Mar-06	4.30	
46	25-Mar-06	4.30	
47	25-Mar-06	4.30	060325SS0005 to 060325SS0007.ADV (3 files one profile)
48	25-Mar-06	4.30	

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR FIELD ADV DATA

No of Runs	Date	Discharge m^3/sec	FIELD ADV File Names
49	25-Mar-06	4.30	
50	28-Mar-06	4.90	060328SS0006 to 060328SS0009.ADV (4 files one profile)
51	28-Mar-06	4.90	060328SS0001 to 060328SS0005 are not completed profile data
52	28-Mar-06	4.90	
53	28-Mar-06	4.90	
54	29-Mar-06	4.90	
55	29-Mar-06	4.90	060329SS0001 to 060329SS0005.ADV (5 files one profile)
56	29-Mar-06	4.90	

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR MICRO ADV DATA

No of Runs	Date	Discharge m^3/sec	ADV File Names
1	4-Jan-06	0.25 m/sec	NO
2	4-Jan-06	0.25 m/sec	NO
3	4-Jan-06	0.25 m/sec	NO
4	4-Jan-06	0.25 m/sec	NO
5	4-Jan-06	0.25 m/sec	NO
6	4-Jan-06	0.25 m/sec	NO
7	4-Jan-06	0.25 m/sec	NO
8	5-Jan-06		NO
9	5-Jan-06		NO
10	5-Jan-06		NO
11	5-Jan-06	Higher	NO
12	5-Jan-06	Flows	NO
13	5-Jan-06	"	NO
14	5-Jan-06	"	NO
15	5-Jan-06	"	NO
16	5-Jan-06	"	NO
17	5-Jan-06	"	NO
18	5-Jan-06	"	NO
19	5-Jan-06	"	NO
20	5-Jan-06	"	NO
21	5-Jan-06	"	NO
22	5-Jan-06	"	NO
23	5-Jan-06	"	NO
24	5-Jan-06	"	NO
25	5-Jan-06	"	NO
26	5-Jan-06	"	NO
27	5-Jan-06	**NOT SURE**	NO
28	6-Jan-06	**NOT SURE**	NO
29	7-Jan-06		NO
30	7-Jan-06		default0001.ADV to 0007 (test data)
31	7-Jan-06		NO
32	7-Jan-06		default0009.ADV to 00016 (test data)
33	7-Jan-06		NO
34	7-Jan-06		NO
35	7-Jan-06		NO
36	10-Jan-06	2.5	NO
37	10-Jan-06		NO
38	10-Jan-06		NO
39	10-Jan-06		NO
40	10-Jan-06		NO
41	10-Jan-06		NO
42	17-Jan-06	1.58	Near bed0001.ADV
43	17-Jan-06	1.58	Near bed0002.ADV
44	17-Jan-06	1.58	Near bed0003.ADV
45	17-Jan-06	1.58	Near bed0004.ADV
46	17-Jan-06	1.58	Near bed0005.ADV
47	29-Jan-06	2.89	Near bed0001.ADV
48	29-Jan-06	2.89	Near bed0002.ADV
49	29-Jan-06	2.89	Near bed0003.ADV
50	29-Jan-06	2.89	Near bed0005.ADV

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR MICRO ADV DATA

No of Runs	Date	Discharge m^3/sec	ADV File Names
51	29-Jan-06	2.89	Near bed0006.ADV
52	30-Jan-06	3	Near bed0001.ADV
53	30-Jan-06	3	Near bed0002.ADV
54	30-Jan-06	3	Near bed0003.ADV, 0004, 0005
55	30-Jan-06	3	Near bed0006.ADV
56	30-Jan-06	3	Near bed0007.ADV and 0008
57	30-Jan-06	3	Near bed0009.ADV
58	30-Jan-06	3	NO
59	31-Jan-06	3	Near bed0001.ADV
60	31-Jan-06	3	Near bed0002.ADV, 0003 and 0004
61	31-Jan-06	3	Near bed0005.ADV, 0006
FEBRUARY			**Three other files of ADV 0007. 0008 and 0009, for camera test**
1	1-Feb-06	2.98	Near bed0001.ADV
2	1-Feb-06	2.98	Near bed0002.ADV, 0003, 0004, 0005 and 0006
3	1-Feb-06	2.98	Near bed0007.ADV
4	2-Feb-06	2.90	Nearbed0001.ADV
5	2-Feb-06	2.90	060202-0001.ADV
6	2-Feb-06	2.90	060202-0001.ADV
7	3-Feb-06	3.60	060203-600khz-0001.ADV
8	3-Feb-06	3.60	060302-1200khz-0001.ADV
9	4-Feb-06	3.60	060204-1200khz-0001.ADV
10	4-Feb-06	3.60	060204-1200khz-0002.ADV and 0003.ADV
11	4-Feb-06	3.60	060204-1200khz-0004.ADV, 0005.ADV, 0006-ADV and 0007.ADV
12	4-Feb-06	3.60	060204-1200khz-0008-ADV and 0009.ADV
13	6-Feb-06	2.00	060206-1200khz-0001.ADV
14	7-Feb-06	2.00	060207-1200khz-0001.ADV and 0002.ADV
15	7-Feb-06	2.00	060207-1200khz-0003.ADV and 0004.ADV
16	7-Feb-06	2.00	060207-1200khz-0005.ADV and 0006.ADV
17	7-Feb-06	2.00	060207-600khz-0001.ADV and 0002.ADV
18	8-Feb-06	2.50	060208-600khz-0001.ADV and 0002.ADV
19	8-Feb-06	2.50	060208-600khz-0003.ADV
20	8-Feb-06	2.50	060208-600khz-0004.ADV and 0005.ADV
21	8-Feb-06	2.50	060208-1200khz-0001.ADV and 0002.ADV
22	8-Feb-06	2.50	060208-1200khz-0003.ADV and 0004.ADV
23	9-Feb-06	2.50	060209-1200khz-0001.ADV, 0002.ADV and 0003.ADV
24	9-Feb-06	2.50	060209-1200khz-0004 and 0005.ADV
25	9-Feb-06	2.50	060209-1200khz-0006 and 0007.ADV
26	9-Feb-06	3.20	060209-1200khz-0008 and 0009.ADV
27	14-Feb-06	3.20	060214-1200khz-0001 and 0002.ADV
28	14-Feb-06	3.20	060214-1200khz-0003 and 0004.ADV
29	14-Feb-06	3.20	060214-1200khz-0005 and 0006.ADV
30	14-Feb-06	3.20	060214-600khz-0001 and 0002.ADV

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR MICRO ADV DATA

No of Runs	Date	Discharge m^3/sec	ADV File Names
GRAVEL EXPERIMENTS			
1	3-Mar-06	3.40	060303-1200khz-0001.ADV
2	3-Mar-06	3.40	060303-600khz-0001.ADV
3	3-Mar-06	3.90	060303-1200khz-0002.ADV
4	9-Mar-06	3.90	060309-1200khz-0001.ADV
5	9-Mar-06	3.90	060309-1200khz-0002.ADV, Sample Volume 5.40 cm
6	9-Mar-06	3.90	060309-1200khz-0003.ADV, Sample Volume 5.32 cm
7	9-Mar-06	3.90	060309-600khz-0001.ADV, Sample Volume 7.49 cm
8	10-Mar-06	3.90	060310-1200khz-0001.ADV, Sample Volume 7.69 cm
9	10-Mar-06	3.90	060310-1200khz-0002.ADV, Sample Volume 8.60 cm
10	12-Mar-06	5.50	060312-1200khz-0001.ADV
11	12-Mar-06	5.50	060312-1200khz-0002.ADV
12	12-Mar-06	5.50	060312-1200khz-0003.ADV
13	14-Mar-06	5.50	060314-1200khz-0001.ADV
14	14-Mar-06	5.50	
15	14-Mar-06	5.50	060314SS-0002.ADV, Sampling Volume (SV) = 2.5 cm
16	14-Mar-06	5.50	
17	14-Mar-06	5.50	060314SS-0003.ADV, Sampling Volume (SV) = 2.31 cm
18	14-Mar-06	5.50	060314SS-0004.ADV
19	14-Mar-06	5.50	060314-600adcp-0001.ADV and 060314-600adcp0002.ADV
20	15-Mar-06	4.00	
21	15-Mar-06	4.00	060315-1200adcp000.ADV (Vibrating alot)
22	15-Mar-06	4.00	060315-1200adcp0002.ADV, on scale it is 45 cm
23	15-Mar-06	4.00	060315-1200adcp0003.ADV, on scale it is 45 cm
24	16-Mar-06	4.00	060316-1200adcp0001.ADV and 060316-1200adcp0002.ADV
25	16-Mar-06	4.00	060316-1200adcp0003.ADV and 060316-1200adcp0004.ADV
26	16-Mar-06	4.00	060316-1200adcp0005.ADV
27	16-Mar-06	4.00	060316-600adcp0001.ADV and 060316-600adcp.0002.ADV
28	16-Mar-06	4.00	060316-600adcp.0002.ADV
29	16-Mar-06	4.00	060316-600adcp.0002.ADV
30	16-Mar-06	4.00	060316-600adcp.0002.ADV
31	16-Mar-06	4.00	060316-600adcp.0002.ADV
32	17-Mar-06	4.00	060317-600adcp.0001.ADV, at 40 cm on Scale, S.V.=7.35 cm
33	17-Mar-06	4.00	060317-1200adcp.0001.ADV, at 40 cm on Scale, S.V. = 7.86 cm
34	17-Mar-06	4.00	ADV was not with us today
35	17-Mar-06	4.00	ADV was not with us today
36	17-Mar-06	4.00	ADV was not with us today
37	21-Mar-06	4.04	060321-1200adcp.0001.ADV, at 45 cm on Scale, S.V. = 11.23 cm
38	21-Mar-06	4.04	060321-1200adcp.0002.ADV, at 45 cm on Scale, S.V. = 11.97 cm
39	21-Mar-06	4.04	060321-1200adcp.0003.ADV, at 45 cm on Scale
40	21-Mar-06	4.04	060321-600adcp.0001.ADV, at 45 cm on Scale
41	21-Mar-06	4.04	060321-600adcp.0002.ADV, at 45 cm on Scale
42	22-Mar-06	4.04	060322-600adcp.0001.ADV, at 45 cm on Scale
43	22-Mar-06	4.04	060322-600adcp.0002.ADV, at 45 cm on Scale
44	25-Mar-06	4.30	060325-600adcp.0001.ADV, at 45 cm on Scale, SV=9.28 cm
45	25-Mar-06	4.30	060325-600adcp.0004.ADV, at 39 cm on Scale, SV=4.4 cm
46	25-Mar-06	4.30	060325-600adcp.0005.ADV, at 39 cm on Scale, SV=4.09 cm
47	25-Mar-06	4.30	060325-1200adcp.0001.ADV and 060325-1200adcp0002.ADV, at 39 cm on Scale
48	25-Mar-06	4.30	060325-1200adcp.0003.ADV at 40 cm on Scale, SV = 3.31 cm

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR MICRO ADV DATA

No of Runs	Date	Discharge m^3/sec	ADV File Names
49	25-Mar-06	4.30	060325-1200adcp.0005.ADV at 40 cm on Scale, SV = 3.31 cm
50	28-Mar-06	4.90	060328-1200adcp.0001.ADV at 50 cm on Scale, SV = 5.37 cm (May be the date is 060325)
51	28-Mar-06	4.90	060328-1200adcp.0002.ADV at 50 cm on Scale, SV = 7.37 cm
52	28-Mar-06	4.90	060328-1200adcp.0001.ADV at 50 cm on Scale, SV = 9.91 cm
53	28-Mar-06	4.90	060328-1200adcp.0003.ADV at 50 cm on Scale, SV = 12.50 cm
54	29-Mar-06	4.90	060329-600adcp.0001.ADV at 50 cm on Scale, SV = 9.77 cm
55	29-Mar-06	4.90	060329-600adcp.0002.ADV at 50 cm on Scale
56	29-Mar-06	4.90	060329-600adcp.0005.ADV at 50 cm on Scale

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR VIDEO DATA

No of Runs	Date	Discharge m^3/sec	VIDEO File Names
1	4-Jan-06	0.25 m/sec	NO
2	4-Jan-06	0.25 m/sec	NO
3	4-Jan-06	0.25 m/sec	NO
4	4-Jan-06	0.25 m/sec	NO
5	4-Jan-06	0.25 m/sec	NO
6	4-Jan-06	0.25 m/sec	NO
7	4-Jan-06	0.25 m/sec	NO
8	5-Jan-06		NO
9	5-Jan-06		NO
10	5-Jan-06		NO
11	5-Jan-06	Higher	NO
12	5-Jan-06	Flows	NO
13	5-Jan-06	"	NO
14	5-Jan-06	"	NO
15	5-Jan-06	"	NO
16	5-Jan-06	"	NO
17	5-Jan-06	"	NO
18	5-Jan-06	"	NO
19	5-Jan-06	"	NO
20	5-Jan-06	"	NO
21	5-Jan-06	"	NO
22	5-Jan-06	"	NO
23	5-Jan-06	"	NO
24	5-Jan-06	"	NO
25	5-Jan-06	"	NO
26	5-Jan-06	"	NO
27	5-Jan-06	**NOT SURE**	NO
28	6-Jan-06	**NOT SURE**	NO
29	7-Jan-06		NO
30	7-Jan-06		NO
31	7-Jan-06		NO
32	7-Jan-06		NO
33	7-Jan-06		NO
34	7-Jan-06		NO
35	7-Jan-06		NO
36	10-Jan-06	2.5	NO
37	10-Jan-06		NO
38	10-Jan-06		NO

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR VIDEO DATA

No of Runs	Date	Discharge m^3/sec	VIDEO File Names
39	10-Jan-06		NO
40	10-Jan-06		NO
41	10-Jan-06		NO
42	17-Jan-06	1.58	NO
43	17-Jan-06	1.58	NO
44	17-Jan-06	1.58	NO
45	17-Jan-06	1.58	NO
46	17-Jan-06	1.58	NO
47	29-Jan-06	2.89	NO
48	29-Jan-06	2.89	NO
49	29-Jan-06	2.89	NO
50	29-Jan-06	2.89	NO
51	29-Jan-06	2.89	NO
52	30-Jan-06	3	NO
53	30-Jan-06	3	NO
54	30-Jan-06	3	NO
55	30-Jan-06	3	NO
56	30-Jan-06	3	NO
57	30-Jan-06	3	NO
58	30-Jan-06	3	NO
59	31-Jan-06	3	NO
60	31-Jan-06	3	NO
61	31-Jan-06	3	NO
			4 Tests
FEBRUARY			
1	1-Feb-06	2.98	NO
2	1-Feb-06	2.98	NO
3	1-Feb-06	2.98	NO
4	2-Feb-06	2.90	NO
5	2-Feb-06	2.90	NO
6	2-Feb-06	2.90	NO
7	3-Feb-06	3.60	02-03-06run1
8	3-Feb-06	3.60	3-2-06run2, 02-03-run2 and 02-03-06runa
9	4-Feb-06	3.60	NO
10	4-Feb-06	3.60	NO
11	4-Feb-06	3.60	02-04-06-rund.vif and 02-04-06-runf.vif
12	4-Feb-06	3.60	02-04-06-runi.vif and 02-04-06-runk.vif
13	6-Feb-06	2.00	NO

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR VIDEO DATA

No of Runs	Date	Discharge m^3/sec	VIDEO File Names
14	7-Feb-06	2.00	02-07-06run1&R20-1200adcp.vif
15	7-Feb-06	2.00	02-07-06run2&R30-1200adcp.vif
16	7-Feb-06	2.00	02-07-06run3&R40-1200adcp.vif
17	7-Feb-06	2.00	02-07-06run4&R40-600adcp.vif
18	8-Feb-06	2.50	02-08-06run1&R40-600adcp.vif
19	8-Feb-06	2.50	NO
20	8-Feb-06	2.50	02-08-06run2&R20-600adcp.vif
21	8-Feb-06	2.50	02-08-06run3&R30-1200adcp.vif
22	8-Feb-06	2.50	02-08-06run4&R40-1200adcp.vif
23	9-Feb-06	2.50	02-09-06run1&R20-1200adcp.vif
24	9-Feb-06	2.50	02-09-06run2&R30-1200adcp.vif
25	9-Feb-06	2.50	02-09-06run3&R40-1200adcp.vif
26	9-Feb-06	3.20	02-09-06run4&R40-1200adcp.vif
27	14-Feb-06	3.20	02-14-06run1&R30-1200adcp.vif
28	14-Feb-06	3.20	02-14-06run2&R20-1200adcp.vif
29	14-Feb-06	3.20	02-14-06run3&R40-1200adcp.vif
30	14-Feb-06	3.20	02-14-06run4&R40-600adcp.vif

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR VIDEO DATA

No of Runs	Date	Discharge m^3/sec	VIDEO File Names
GRAVEL EXPERIMENTS			
1	3-Mar-06	3.40	
2	3-Mar-06	3.40	
3	3-Mar-06	3.90	
4	9-Mar-06	3.90	
5	9-Mar-06	3.90	
6	9-Mar-06	3.90	Took 10 frames only to view suface particle distribution
7	9-Mar-06	3.90	frames3point9-06-03-09
8	10-Mar-06	3.90	060310-1200adcp-640-480 (~9.5 cm view)
9	10-Mar-06	3.90	060310-1200adcp-240-1040 (~20 cm view)
10	12-Mar-06	5.50	
11	12-Mar-06	5.50	
12	12-Mar-06	5.50	
13	14-Mar-06	5.50	03-14-06run1&R40-1200adcp-5point5-107fps.vif
14	14-Mar-06	5.50	03-14-06run2&R40-1200adcp-5point5-30fps.vif
15	14-Mar-06	5.50	03-14-06run3&R40-1200adcp-5point5-30fps.vif
16	14-Mar-06	5.50	03-14-06run4&R40-1200adcp-5point5-107fps.vif
17	14-Mar-06	5.50	
18	14-Mar-06	5.50	03-14-06run5&R40-600adcp-5point5-107fps.vif
19	14-Mar-06	5.50	03-14-06run5&R40-600adcp-5point5-107fps.vif
20	15-Mar-06	4.00	
21	15-Mar-06	4.00	
22	15-Mar-06	4.00	
23	15-Mar-06	4.00	
24	16-Mar-06	4.00	03-16-06run1&R40-1200adcp-4point0-30fps.vif
25	16-Mar-06	4.00	03-16-06run2&R40-1200adcp-4point0-107fps.vif
26	16-Mar-06	4.00	03-16-06run3&R40-1200adcp-4point0-107fps.vif
27	16-Mar-06	4.00	03-16-06run4&R40-1200adcp-4point0-30fps.vif
28	16-Mar-06	4.00	03-16-06run5&20-1200adcp-4point0-30fps.vif
29	16-Mar-06	4.00	03-16-06run6&R20-1200adcp-4point0-107fps.vif
30	16-Mar-06	4.00	03-16-06run7&R40-600adcp-4point0-107fps.vif
31	16-Mar-06	4.00	03-16-06run8&R40-600adcp-4point0-30fps.vif
32	17-Mar-06	4.00	
33	17-Mar-06	4.00	03-17-06run1&R30-1200adcp-4point0-30fps.vif
34	17-Mar-06	4.00	03-17-06run2&R30-1200adcp-4point0-107fps.vif
35	17-Mar-06	4.00	
36	17-Mar-06	4.00	

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

FOR VIDEO DATA

No of Runs	Date	Discharge m^3/sec	VIDEO File Names
37	21-Mar-06	4.04	
38	21-Mar-06	4.04	
39	21-Mar-06	4.04	03-21-06run1&R20-1200adcp-4point0-30fps.vif
40	21-Mar-06	4.04	03-21-06run2&R20-1200adcp-4point0-107fps.vif
41	21-Mar-06	4.04	
42	22-Mar-06	4.04	
43	22-Mar-06	4.04	
44	25-Mar-06	4.30	03-25-06run1&R40-600adcp-4point3-30fps.vif AND run2 with 107fps
45	25-Mar-06	4.30	03-25-06run3&R30-600adcp-4point3-107fps.vif and run 4 with 107 frames
46	25-Mar-06	4.30	03-25-06run5&R30-600adcp-4point3-30fps.vif and run 6 with 107 frames
47	25-Mar-06	4.30	03-25-06run7&R40-1200adcp-4point3-107fps.vif and run 8 with 30 frames
48	25-Mar-06	4.30	03-25-06run9&R30-1200adcp-4point3-30fps.vif and run 10 with 107 frames
49	25-Mar-06	4.30	03-25-06run11R20-1200adcp-4point3-107fps.vif and run 12 with 30 frames and run 14 again 107 frame. Run 13 has no data
50	28-Mar-06	4.90	03-28-06run1&R40-1200adcp-4point9-30fps.vif AND run2 with 107fps
51	28-Mar-06	4.90	
52	28-Mar-06	4.90	03-28-06run3&R30-1200adcp-4point9-107fps.vif AND run4 with 30fps
53	28-Mar-06	4.90	03-28-06run5&R20-1200adcp-4point9-30fps.vif AND run6 with 107fps
54	29-Mar-06	4.90	03-29-06run1&R30-600adcp-4point9-30fps.vif AND run2 with 107fps
55	29-Mar-06	4.90	03-29-06run3&R30-600adcp-4point9-107fps.vif and run 4 and run 4a, 4b and 4c with 30 frames. 4d is for &R40 with 15 frames
56	29-Mar-06	4.90	03-29-06run5&R40-600adcp-4point9-15fps.vif and run 6 with 60 frames

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY
FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

COMMENTS ON DATA

No of Runs	Date	Discharge m^3/sec	COMMENTS
1	4-Jan-06	0.25 m/sec	
2	4-Jan-06	0.25 m/sec	
3	4-Jan-06	0.25 m/sec	
4	4-Jan-06	0.25 m/sec	
5	4-Jan-06	0.25 m/sec	
6	4-Jan-06	0.25 m/sec	
7	4-Jan-06	0.25 m/sec	
8	5-Jan-06		
9	5-Jan-06		
10	5-Jan-06		
11	5-Jan-06	Higher	
12	5-Jan-06	Flows	
13	5-Jan-06	"	
14	5-Jan-06	"	
15	5-Jan-06	"	
16	5-Jan-06	"	
17	5-Jan-06	"	
18	5-Jan-06	"	
19	5-Jan-06	"	
20	5-Jan-06	"	
21	5-Jan-06	"	
22	5-Jan-06	"	
23	5-Jan-06	"	
24	5-Jan-06	"	
25	5-Jan-06	"	
26	5-Jan-06	"	
27	5-Jan-06	**NOT SURE WHAT DATA WE RECORDED WITH THIS FILE**	
28	6-Jan-06	**NOT SURE WHAT DATA WE RECORDED WITH THIS FILE**	
29	7-Jan-06		
30	7-Jan-06		
31	7-Jan-06		
32	7-Jan-06		
33	7-Jan-06		
34	7-Jan-06		
35	7-Jan-06		
36	10-Jan-06	2.5	
37	10-Jan-06		
38	10-Jan-06		

**EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY
FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st**

COMMENTS ON DATA

No of Runs	Date	Discharge m^3/sec	COMMENTS
39	10-Jan-06		
40	10-Jan-06		
41	10-Jan-06		
42	17-Jan-06	1.58	
43	17-Jan-06	1.58	
44	17-Jan-06	1.58	
45	17-Jan-06	1.58	
46	17-Jan-06	1.58	
47	29-Jan-06	2.89	
48	29-Jan-06	2.89	
49	29-Jan-06	2.89	
50	29-Jan-06	2.89	
51	29-Jan-06	2.89	
52	30-Jan-06	3	
53	30-Jan-06	3	
54	30-Jan-06	3	
55	30-Jan-06	3	
56	30-Jan-06	3	
57	30-Jan-06	3	
58	30-Jan-06	3	
59	31-Jan-06	3	
60	31-Jan-06	3	
61	31-Jan-06	3	
FEBRUARY			
1	1-Feb-06	2.98	
2	1-Feb-06	2.98	0006.ADV was only beam test data
3	1-Feb-06	2.98	
4	2-Feb-06	2.90	2 mins. Of camera time
5	2-Feb-06	2.90	
6	2-Feb-06	2.90	No data and also &R20 did not work out
7	3-Feb-06	3.60	
8	3-Feb-06	3.60	
9	4-Feb-06	3.60	
10	4-Feb-06	3.60	
11	4-Feb-06	3.60	
12	4-Feb-06	3.60	
13	6-Feb-06	2.00	

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

COMMENTS ON DATA

No of Runs	Date	Discharge m^3/sec	COMMENTS
14	7-Feb-06	2.00	
15	7-Feb-06	2.00	0004.ADV is after the video
16	7-Feb-06	2.00	
17	7-Feb-06	2.00	Wrong File Name, Actually it is 2.0 m3/sec.
18	8-Feb-06	2.50	
19	8-Feb-06	2.50	
20	8-Feb-06	2.50	
21	8-Feb-06	2.50	
22	8-Feb-06	2.50	
23	9-Feb-06	2.50	
24	9-Feb-06	2.50	
25	9-Feb-06	2.50	
26	9-Feb-06	3.20	
27	14-Feb-06	3.20	
28	14-Feb-06	3.20	
29	14-Feb-06	3.20	
30	14-Feb-06	3.20	Dave and Sara calculated the densities for Sand and Gravel

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

COMMENTS ON DATA

No of Runs	Date	Discharge m^3/sec	COMMENTS
GRAVEL EXPERIMENTS			Sand 2.63 g/ml with 7 samples
			Gravel 2.69 g/ml with 5 samples
1	3-Mar-06	3.40	Nominal Gravel bed is 60 cm
2	3-Mar-06	3.40	600 ADCP did not worked with 3.9 discharge
3	3-Mar-06	3.90	Sara and Dave estimated the density of sand as 2.63 g/ml (7 samples) and gravel 2.69 g/ml (5 samples)
4	9-Mar-06	3.90	Today Nominal depth changed from 60 cm to 45 cm
5	9-Mar-06	3.90	
6	9-Mar-06	3.90	
7	9-Mar-06	3.90	With 600 it is not working,however took some data
8	10-Mar-06	3.90	Video is not correct
9	10-Mar-06	3.90	
10	12-Mar-06	5.50	The water depth is 7 cm below black line, also not able to move down tha ADV
11	12-Mar-06	5.50	
12	12-Mar-06	5.50	
13	14-Mar-06	5.50	ADCP did not worked but took ADV data to see the effects of Bedload Samplers on the data
14	14-Mar-06	5.50	ADCP test only
15	14-Mar-06	5.50	In this set of data adcp was not working but we collected the Videos during this set of data
16	14-Mar-06	5.50	
17	14-Mar-06	5.50	
18	14-Mar-06	5.50	
19	14-Mar-06	5.50	
20	15-Mar-06	4.00	
21	15-Mar-06	4.00	
22	15-Mar-06	4.00	
23	15-Mar-06	4.00	
24	16-Mar-06	4.00	
25	16-Mar-06	4.00	The Micro ADV file with 0004.ADV did not worked, I forgot to start the data
26	16-Mar-06	4.00	
27	16-Mar-06	4.00	For Ist Micro ADV, the co-relation was bad and <30 so raised the ADV and start data again
28	16-Mar-06	4.00	
29	16-Mar-06	4.00	
30	16-Mar-06	4.00	
31	16-Mar-06	4.00	
32	17-Mar-06	4.00	
33	17-Mar-06	4.00	
34	17-Mar-06	4.00	After crossing the dune, it was decided to take another set of readings
35	17-Mar-06	4.00	
36	17-Mar-06	4.00	

EXPERIMENTS DETAILS OF MAIN CHANNEL AT ST ANTHONY FALLS LABORATORY FOR SEDIMENT TRANSPORT BETWEEN Jan 02 to March 31st

COMMENTS ON DATA

No of Runs	Date	Discharge m^3/sec	COMMENTS
37	21-Mar-06	4.04	Channel Started at 2:00 PM and this set of data started at 3:00 PM
38	21-Mar-06	4.04	
39	21-Mar-06	4.04	The leafs in water are less than 16th and 17th.
40	21-Mar-06	4.04	Also the light of Video was not fixed properly on 16th and 17th and the result was bad video
41	21-Mar-06	4.04	
42	22-Mar-06	4.04	USGC Team was on lunch so took this data. They returned and I stopped the data. Only 14 min. of data
43	22-Mar-06	4.04	During this work USGC were working with ELWA and other samplers. More than an hour data
44	25-Mar-06	4.30	Two Videos with new ADV file 060325-600adcp0002.ADV and 0003.ADV
45	25-Mar-06	4.30	Frames are missing in these videos. Error in recording and some frames were missing
46	25-Mar-06	4.30	Two Videos with new ADV file 060325-600adcp0006. Also in recording 107 frames , not recording 107 frames
47	25-Mar-06	4.30	Two Videos. 30 Frames is working properly but 107 frames is giving less frames during recording
48	25-Mar-06	4.30	Two videos worked fine this time with 060325-1200adcp0004.ADV and SV = 2.28
49	25-Mar-06	4.30	4 Videos. Run 11 has not good data with 107 frms, run12 good data with 30 frms, run13 no data and run 14 good 107 frms
50	28-Mar-06	4.90	2 videos with 060328-1200adcp0001.ADV or 060325?? Ben and Dave were working to fix the camera no. 2
51	28-Mar-06	4.90	Computer halted and reboot the computer and start the data collection again
52	28-Mar-06	4.90	
53	28-Mar-06	4.90	Two Videos with 060328-1200adcp0004.ADV
54	29-Mar-06	4.90	Two Videos of 30 fps and one with 107 fps. For 107 fps the name is &R30 instead of &R20
55	29-Mar-06	4.90	six videos, run3 with 107 fps, run 4 and 4a with 30 fps (the difference is only on time scale on 4) but frames missed with 30fps
56	29-Mar-06	4.90	Three Videos. One with run 4d 15fps, run5 15fps and run6 60 fps.

ANNEXURE II

```
%CRennie modified this July 19 2006 so that constants are stored only once (in Cfg, Hdr, ↙
and Inst).
%this doesn't actually save time, because it still reads every line, but
%memory use should be less, because smaller Cfg, Hdr, and Inst structures
%are created.
%A new data structure BtCfg has been created to store Bottom track config
%info, which appears to not be constant during a transect, even though it should be.
%I also modified the Gps.gsaSat structure so that it wasn't a huge array.


% VTGAssessment
% TO SORT NAVIGATION DATA VELOCITY REFERENCES AND COMPUTE STATISTICS ON PERFORMANCE.
%
% Result of a combination of MatLab scripts from:
%
% David S. Mueller (dmueller@usgs.gov)
% U.S. Geological Survey
% Office of Surface Water
%
% DR. COLIN RENNIE (crennie@genie.uottawa.ca)
% Dept. of Civil Engineering
% University of Ottawa
%
% Francois Rainville (francois.rainville@ec.gc.ca)
% Water Survey of Canada
% Environment Canada
%
%
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% RAW ADCP RDI FILES INGEST SEGMENT:
% The program reads the RDI PD0 format raw data as recorded by WinRiver.
% It accounts for the special locations used by WinRiver to store GPS data.
% It should read standard PD0 formatted files but was written specifically
% for PD0 files created by WinRiver.
%
% Data are stored in Matlab data structures to provide easy and efficient
% transfer of data between functions. For numeric data the arrays are
% preallocated with "nan" (not a number) so that no value is assumed for bad
% or missing data. Data coded with -32768 are not stored and default to "nan".
% No filtering of the data is provided, although some units conversion is
% provided for consistency and convience.
%
% All data structures begin with an % upper case letter.
% All variable names begin with a lower case letter.
% If a specific dimension is associated with a variable its name will
% include an underscore "_" followed by the dimension.
% The dimension abrevations used are as follows:
%   cm      - centimeters
%   deg     - degrees
%   degc    - degrees Celsius
%   dm      - decimeters
```

```
%   m       - meters
%   mm      - millimeters
%   mmps    - millimeters per second
%   mps     - meters per second
%   msc     - minutes seconds hundreths of a second
%   pascal  - pascals
%   ppt     - parts per thousand
%   sec     - seconds
%
% Data that vary with depth are stored so that the bin (depth) varies by
% row and the ensemble varies by column. Most other data are stored so that
% the ensemble varies by row. Data associated with various beams are stored
% with a 3rd dimension reflecting the beam number.
%

% Get and display file information
clear all
fullName = input('File Name?: ' , 's');
MagVar = input( 'Magnetic variation value from WinRiver, in degrees?: ' );
FileInfo=dir(fullName);

% Open File
fid=fopen(fullName,'r','l');

%% Read Selected Parameters
% Selected portions of the raw data file are read to determine the number
% of ensembles, the number of bins, and the number of beams. These
% variables are used to preallocate the arrays in the data structures used
% to store the data in Matlab. Although preallocation is not required it
% does improve the performance of Matlab.

% Set the position in the file and read the number of bytes per ensemble.
fseek(fid,2,'bof');
bytesPerEns=fread(fid,1, 'uint16');

% Set position in the file and read the number of data types in the file.
fseek(fid,1,'cof');
nTypes=fread(fid,1, 'uint8');
offset=fread(fid,1, 'uint16');

% Set position in the file and read the number of beams and number of bins.
fseek(fid,offset+8,'bof');
nBeams=fread(fid,1, 'uint8');
nBins=fread(fid,1, 'uint8');

% Compute the number of ensembles
nEnsembles=ceil(FileInfo.bytes/(bytesPerEns+2));

%% Define Data Storage Structure.
% A data storage structure is used to provide an easy and efficient method
% for passing large amounts of data between functions. The arrays within
% the structure are preallocated for efficiency.
```

```
% Clear variables to be used.
clear Hdr Inst Cfg Sensor Gps Wt Bt Nmea BtCfg;

% Data structure for the Binary Header Data
Hdr=struct( 'bytesPerEns' , zeros(1,1), ...
            'dataOffsets' , zeros(1,nTypes), ...
            'nDataTypes' , zeros(1,1));

% Data structure for variables related to the instrument
Inst=struct('beamAng' , zeros(1,1), ...
            'beams' , zeros(1,1), ...
            'dataType' , repmat(blanks(4),1,1), ...
            'firmVer' , zeros(1,1), ...
            'freq', zeros(1,1), ...
            'pat', repmat(blanks(7),1,1), ...
            'resRDI' , zeros(1), ...
            'sensorCfg' , nan(1,1), ...
            'xducer' , repmat(blanks(12),1,1));

% Data structure for bottom track direct commands and other configuration information
BtCfg=struct( 'ba', nan(nEnsembles,1), ...
            'bc' , nan(nEnsembles,1), ...
            'be_mmps' , nan(nEnsembles,1), ...
            'bg' , nan(nEnsembles,1), ...
            'bm' , nan(nEnsembles,1), ...
            'bp' , nan(nEnsembles,1), ...
            'bx_dm' , nan(nEnsembles,1));


        % Data structure for direct commands and other configuration information
Cfg=struct( 'codeReps' , nan(1,1), ...
            'coordSys' , repmat(blanks(5),1,1), ...
            'cpuSerNo' , nan(1,8), ...
            'cq' , nan(1,1), ...
            'cx' , nan(1,1), ...
            'distBin1_cm' , nan(1,1), ...
            'ea_deg' , nan(1,1), ...
            'eb_deg' , nan(1,1), ...
            'ec' , repmat(blanks(8),1,1), ...
            'ex' , repmat(blanks(8),1,1), ...
            'ez' , repmat(blanks(8),1,1), ...
            'headSrc' , repmat(blanks(11),1,1), ...
            'lag_cm' , nan(1,1), ...
            'mapBins' , repmat(blanks(3),1,1), ...
            'nBeams' , nan(1,1), ...
            'pitchSrc' , repmat(blanks(11),1,1), ...
            'refLayEndCell' , nan(1,1), ...
            'refLayStrCell' , nan(1,1), ...
            'rollSrc' , repmat(blanks(11),1,1), ...
            'salSrc' , repmat(blanks(9),1,1), ...
            'wm' , nan(1,1), ...
```

```
            'sosSrc' , repmat(blanks(11),1,1), ...
            'tempSrc' , repmat(blanks(11),1,1), ...
            'tp_sec' , nan(1,1), ...
            'use3beam' , repmat(blanks(3),1,1), ...
            'usePR' , repmat(blanks(3),1,1), ...
            'wa' , nan(1,1), ...
            'wb' , nan(1,1), ...
            'wc' , nan(1,1), ...
            'we_mmps' , nan(1,1), ...
            'wf_cm' , nan(1,1), ...
            'wg_per' , nan(1,1), ...
            'wj' , nan(1,1), ...
            'wn' , nan(1,1), ...
            'wp' , nan(1,1), ...
            'ws_cm' , nan(1,1), ...
            'xdcrDepSrs' , repmat(blanks(9),1,1), ...
            'xmitPulse_cm' , nan(1,1));

% Data structure for data obtained from the various internal and external sensors.
Sensor=struct(   'ambientTemp' , nan(nEnsembles,1), ...
                 'attitudeTemp' , nan(nEnsembles,1), ...
                 'attitude', nan(nEnsembles,1), ...
                 'bitTest', nan(nEnsembles,1), ...
                 'contamSensor' , nan(nEnsembles,1), ...
                 'date' , nan(nEnsembles,4), ...
                 'dateNotY2k' , nan(nEnsembles,3), ...
                 'dateY2k', nan(nEnsembles,4), ...
                 'errorStatusWord' , repmat(blanks(8),[nEnsembles,1,4]), ...
                 'headingStdDev' , nan(nEnsembles,1), ...
                 'heading_deg' , nan(nEnsembles,1), ...
                 'mpt_msc', nan(nEnsembles,3), ...
                 'num' , nan(nEnsembles,1), ...
                 'numFact', nan(nEnsembles,1), ...
                 'orient' , repmat(blanks(4),nEnsembles,1), ...
                 'pitchStdDev' , nan(nEnsembles,1), ...
                 'pitch_deg' , nan(nEnsembles,1), ...
                 'pressureNeg' , nan(nEnsembles,1), ...
                 'pressurePos' , nan(nEnsembles,1), ...
                 'pressureVar_pascal' , nan(nEnsembles,1), ...
                 'pressure_pascal' , nan(nEnsembles,1), ...
                 'rollStdDev_deg' , nan(nEnsembles,1), ...
                 'roll_deg', nan(nEnsembles,1), ...
                 'salinity_ppt' , nan(nEnsembles,1), ...
                 'sos_mps', nan(nEnsembles,1), ...
                 'temperature_degc' , nan(nEnsembles,1), ...
                 'time' , nan(nEnsembles,4), ...
                 'timeY2k', nan(nEnsembles,4), ...
                 'xdcrDepth_dm' , nan(nEnsembles,1), ...
                 'xmitCurrent' , nan(nEnsembles,1), ...
                 'xmitVoltage' , nan(nEnsembles,1));

% Data structure for the water track data. Data are stored in 3-dimensional
```

```
% arrays with the 1st dimension (rows) being the bin number, the second
% dimension (column) being the ensemble index, and the 3rd dimension being
% the beam number.
Wt=struct(  'corr', nan(nBins,nEnsembles,nBeams), ...
            'pergd', nan(nBins,nEnsembles,nBeams), ...
            'rssi', nan(nBins,nEnsembles,nBeams), ...
            'vel_mps', nan(nBins,nEnsembles,nBeams));

% Data structure for the bottom track data. Data are stored in 2-dimensional
% arrays with the 1st dimension (rows) being the beam number and the 2nd
% dimension being the ensemble index.
Bt=struct(  'corr', nan(nBeams,nEnsembles), ...
            'depth_m', nan(nBeams,nEnsembles), ...
            'evalAmp', nan(nBeams,nEnsembles), ...
            'extDepth_cm', nan(nEnsembles,1), ...
            'pergd', nan(nBeams,nEnsembles), ...
            'rssi', nan(nBeams,nEnsembles), ...
            'vel_mps', nan(nBeams,nEnsembles));

% Data structure for GPS data: Some variables now defined (eg. vtgTrue).
% Some variables were not initialy pre-defined in DM structure, such as:
% ggaUTC, ggaLat, ggaLon, vtgTrue, vtgMagN and vtgSpd.
Gps=struct( 'alt_m', nan(nEnsembles,1), ...
            'ggaDiff', nan(nEnsembles,1), ...
            'ggaHdop', nan(nEnsembles,1), ...
            'ggaNStats', nan(nEnsembles,1), ...
            'ggaVelE_mps', nan(nEnsembles,1), ...
            'ggaVelN_mps', nan(nEnsembles,1), ...
            'gsaPdop', nan(nEnsembles,1), ...
            'gsaSat', nan(nEnsembles,6), ...
            'gsaVdop', nan(nEnsembles,1), ...
            'lat_deg', nan(nEnsembles,1), ...
            'long_deg', nan(nEnsembles,1), ...
            'vtgVelE_mps', nan(nEnsembles,1), ...
            'vtgVelN_mps', nan(nEnsembles,1), ...
            'posX', nan(nEnsembles,1), ...      %these 2 have been added in to get Gps ↙
position
            'posY', nan(nEnsembles,1));
% Should we not declare the following variables?
%            'ggaUTC', nan(nEnsembles,1),...
%            'ggaLat', nan(nEnsembles,1),...
%            'ggaLon', nan(nEnsembles,1),...
%            'vtgTrue', nan(nEnsembles,1),...
%            'vtgMagN', nan(nEnsembles,1),...
%            'vtgSpd', nan(nEnsembles,1),...

% Data structure for raw NMEA data strings. The strings are stored
% in a character array with rows being the ensemble index and columns
% the characters in the respective string.
Nmea=struct('gga', repmat(blanks(97),nEnsembles,1), ...
            'gsa', repmat(blanks(60),nEnsembles,1), ...
            'vtg', repmat(blanks(50),nEnsembles,1));
```

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Read Raw Data
% Data in the PD0 format are organized by leader_id. The leader_id is read
% and the appropriate statements executed to read the data defined by the
% leader_id. All data are read and stored, even data that should not change
% between ensembles. The data are read until the end of file character is
% encountered.
fseek(fid,0, 'bof');
iEns=0;
disp('Reading file')

while ~feof(fid)

%   Read leader_id
    leader_id=dec2hex(fread(fid,1, 'uint16'),4);

%   Select appropriate code to read data based on leader_id
    switch leader_id

%%      Read Binary Header Data
        case '7F7F'
            fileloc=ftell(fid)-2;
            idataTypes=0;
            iEns=iEns+1;
            Hdr.bytesPerEns(1)=fread(fid,1, 'uint16');
            fseek(fid,1, 'cof');
            Hdr.nDataTypes(1)=fread(fid,1,'uint8' );
            Hdr.dataOffsets(1,1:Hdr.nDataTypes(1))=fread(fid,Hdr.nDataTypes(1),  'uint16');
            if (idataTypes+1)<=Hdr.nDataTypes(1)
                fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
            else
                fseek(fid,fileloc+bytesPerEns-2);
            end

%%      Read Binary Fixed Leader Data
        case '0000'
            idataTypes=idataTypes+1;
            Inst.firmVer(1)=fread(fid,1, 'uint8');
            Inst.firmVer(1)=Inst.firmVer(1)+fread(fid,1, 'uint8')/100;
            bitls=fread(fid,1, 'uint8');
            bitls=dec2base(bitls,2,8);

            switch base2dec(bitls(6:8),2)
                case 0;     Inst.freq(1)=75;
                case 1;     Inst.freq(1)=150;
                case 2;     Inst.freq(1)=300;
                case 3;     Inst.freq(1)=600;
                case 4;     Inst.freq(1)=1200;
                case 5;     Inst.freq(1)=2400;
                otherwise;  Inst.freq(1)=NaN;
```

```
    end;

    switch base2dec(bitls(5),2)
        case 0;      Inst.pat(1,:)= 'Concave';
        case 1;      Inst.pat(1,:)= 'Convex ';
        otherwise    Inst.pat(1,:)= 'n/a    ';
    end;

    Inst.sensorCfg(1)=base2dec(bitls(3:4),2)+1;

    switch base2dec(bitls(2),2)
        case 0;      Inst.xducer(1,:)= 'Not Attached';
        case 1;      Inst.xducer(1,:)= 'Attached    ';
        otherwise;   Inst.xducer(1,:)= 'n/a         ';
    end;

    switch base2dec(bitls(1),2)
        case 0;      Sensor.orient(1,:)= 'Down';
        case 1;      Sensor.orient(1,:)= 'Up  ';
        otherwise;   Sensor.orient(1,:)= 'n/a ';
    end;

    bitms=fread(fid,1, 'uint8');
    bitms=dec2base(bitms,2,8);

    switch base2dec(bitms(7:8),2)
        case 0;      Inst.beamAng(1)=15;
        case 1;      Inst.beamAng(1)=20;
        case 2;      Inst.beamAng(1)=30;
        case 3;      Inst.beamAng(1)=NaN;
        otherwise;   Inst.beamAng(1)=NaN;
    end;

    switch base2dec(bitms(1:4),2)
        case 4
            Inst.beams(1)=4;
        case 5
            Inst.beams(1)=5;
            Inst.demod(1)=1;
        case 15
            Inst.beams(1)=5;
            Inst.demod(1)=2;
        otherwise
            Inst.beams(1)=NaN;
            Inst.demod(1)=NaN;
    end;

    switch fread(fid,1, 'uint8')
        case 0;      Inst.dataType(1,:)= 'Real';
        otherwise;   Inst.dataType(1,:)= 'Simulated';
    end;
```

```
        fseek(fid,1, 'cof');
        Cfg.nBeams(1)=fread(fid,1, 'uint8');
        Cfg.wn(1)=fread(fid,1, 'uint8');
        Cfg.wp(1)=fread(fid,1, 'uint16');
        Cfg.ws_cm(1)=fread(fid,1, 'uint16');
        Cfg.wf_cm(1)=fread(fid,1, 'uint16');
        Cfg.wm(1)=fread(fid,1, 'uint8');
        Cfg.wc(1)=fread(fid,1, 'uint8');
        Cfg.codeReps(1)=fread(fid,1, 'uint8');
        Cfg.wg_per(1)=fread(fid,1, 'uint8');
        Cfg.we_mmps(1)=fread(fid,1, 'uint16');
        Cfg.tp_sec(1,:)=sum(fread(fid,3, 'uint8').*[60 1 0.01]');
        Cfg.ex(1,:)=dec2base(fread(fid,1, 'uint8'),2,8);

        switch base2dec(Cfg.ex(1,4:5),2)
            case 0;      Cfg.coordSys(1,:)= 'Beam ';
            case 1;      Cfg.coordSys(1,:)= 'Inst ';
            case 2;      Cfg.coordSys(1,:)= 'Ship ';
            case 3;      Cfg.coordSys(1,:)= 'Earth';
            otherwise;   Cfg.coordSys(1,:)= 'n/a  ';
        end;

        switch base2dec(Cfg.ex(1,6),2)
            case 0;      Cfg.usePR(1,:)= 'No ';
            case 1;      Cfg.usePR(1,:)= 'Yes';
            otherwise;   Cfg.usePR(1,:)= 'n/a';
        end;

        switch base2dec(Cfg.ex(1,7),2)
            case 0;      Cfg.use3beam(1,:)= 'No ';
            case 1;      Cfg.use3beam(1,:)= 'Yes';
            otherwise;   Cfg.use3beam(1,:)= 'n/a';
        end;

        switch base2dec(Cfg.ex(1,8),2)
            case 0;      Cfg.mapBins(1,:)= 'No ';
            case 1;      Cfg.mapBins(1,:)= 'Yes';
            otherwise;   Cfg.mapBins(1,:)= 'n/a';
        end;

        Cfg.ea_deg(1)=fread(fid,1, 'int16')*0.01;
        Cfg.eb_deg(1)=fread(fid,1, 'uint16')*0.01;
        Cfg.ez(1,:)=dec2base(fread(fid,1, 'uint8'),2,8);

        switch base2dec(Cfg.ez(1,1:2),2)
            case 0;      Cfg.sosSrc(1,:)= 'Manual EC   ';
            case 1;      Cfg.sosSrc(1,:)= 'Calculated  ';
            case 3;      Cfg.sosSrc(1,:)= 'SVSS Sensor';
            otherwise;   Cfg.sosSrc(1,:)= 'n/a        ';
        end

        switch base2dec(Cfg.ez(1,3),2)
```

```
        case 0;     Cfg.xdcrDepSrc(1,:)= 'Manual ED';
        case 1;     Cfg.xdcrDepSrc(1,:)= 'Sensor   ';
        otherwise;  Cfg.xdcrDepSrc(1,:)= 'n/a      ';
    end

    switch base2dec(Cfg.ez(1,4),2)
        case 0;     Cfg.headSrc(1,:)= 'Manual EH  ';
        case 1;     Cfg.headSrc(1,:)= 'Int. Sensor';
        otherwise;  Cfg.headSrc(1,:)= 'n/a        ';
    end

    switch base2dec(Cfg.ez(1,5),2)
        case 0;     Cfg.pitchSrc(1,:)= 'Manual EP  ';
        case 1;     Cfg.pitchSrc(1,:)= 'Int. Sensor';
        otherwise;  Cfg.pitchSrc(1,:)= 'n/a        ';
    end

    switch base2dec(Cfg.ez(1,6),2)
        case 0;     Cfg.rollSrc(1,:)= 'Manual ER  ';
        case 1;     Cfg.rollSrc(1,:)= 'Int. Sensor';
        otherwise;  Cfg.rollSrc(1,:)= 'n/a        ';
    end

    switch base2dec(Cfg.ez(1,7),2)
        case 0;     Cfg.salSrc(1,:)= 'Manual ES';
        case 1;     Cfg.salSrc(1,:)= 'n/a      ';
        otherwise;  Cfg.salSrc(1,:)= 'n/a      ';
    end

    switch base2dec(Cfg.ez(1,8),2)
        case 0;     Cfg.tempSrc(1,:)= 'Manual ET  ';
        case 1;     Cfg.tempSrc(1,:)= 'Int. Sensor';
        otherwise;  Cfg.tempSrc(1,:)= 'n/a        ';
    end

    Cfg.ec(1,:)=dec2base(fread(fid,1, 'uint8'),2,8);
    Cfg.distBin1_cm(1)=fread(fid,1, 'uint16');
    Cfg.xmitPulse_cm(1)=fread(fid,1, 'uint16');
    Cfg.refLayStrCell(1)=fread(fid,1, 'uint8');
    Cfg.refLayEndCell(1)=fread(fid,1, 'uint8');
    Cfg.wa(1)=fread(fid,1, 'uint8');
    Cfg.cx(1)=fread(fid,1, 'uint8');
    Cfg.lag_cm(1)=fread(fid,1, 'uint16');
    Cfg.cpuSerNo(1,:)=fread(fid,8,'uint8' );
    Cfg.wb(1)=fread(fid,1, 'uint8');
    Cfg.cq(1)=fread(fid,1, 'uint8');
    if (idataTypes+1)<=Hdr.nDataTypes(1)
       fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
    else
       fseek(fid,fileloc+bytesPerEns-2, 'bof');
    end
```

```
%%      Read Variable Leader Data
        case '0080'
            idataTypes=idataTypes+1;
            Sensor.num(iEns)=fread(fid,1, 'uint16');
            Sensor.dateNotY2k(iEns,:)=fread(fid,3,'uint8' );
            Sensor.time(iEns,:)=fread(fid,4, 'uint8');
            Sensor.numFact(iEns)=fread(fid,1, 'uint8');
            Sensor.numTot(iEns)=Sensor.num(iEns)+Sensor.numFact(iEns)*65535;
            Sensor.bitTest(iEns)=fread(fid,1, 'uint16');
            Sensor.sos_mps(iEns)=fread(fid,1, 'uint16');
            Sensor.xdcrDepth_dm(iEns)=fread(fid,1,'uint16' );
            Sensor.heading_deg(iEns)=fread(fid,1, 'uint16')/100;
            Sensor.pitch_deg(iEns)=fread(fid,1, 'int16')/100;
            Sensor.roll_deg(iEns)=fread(fid,1, 'int16')/100;
            Sensor.salinity_ppt(iEns)=fread(fid,1,'uint16' );
            Sensor.temperature_degc(iEns)=fread(fid,1, 'uint16');
            Sensor.mpt_msc(iEns,:)=fread(fid,3, 'uint8');
            Sensor.headingStdDev_deg(iEns)=fread(fid,1, 'uint8');
            Sensor.pitchStdDev_deg(iEns)=fread(fid,1, 'uint8')/10;
            Sensor.rollStdDev_deg(iEns)=fread(fid,1, 'uint8')/10;
            Sensor.xmitCurrent(iEns)=fread(fid,1, 'uint8');
            Sensor.xmitVoltage(iEns)=fread(fid,1, 'uint8');
            Sensor.ambientTemp(iEns)=fread(fid,1, 'uint8');
            Sensor.pressurePos(iEns)=fread(fid,1, 'uint8');
            Sensor.pressureNeg(iEns)=fread(fid,1, 'uint8');
            Sensor.attitudeTemp(iEns)=fread(fid,1,'uint8' );
            Sensor.atttitude(iEns)=fread(fid,1, 'uint8');
            Sensor.contamSensor(iEns)=fread(fid,1,'uint8' );
            Sensor.errorStatusWord(iEns,:,1)=dec2base(fread(fid,1, 'uint8'),2,8);
            Sensor.errorStatusWord(iEns,:,2)=dec2base(fread(fid,1, 'uint8'),2,8);
            Sensor.errorStatusWord(iEns,:,3)=dec2base(fread(fid,1, 'uint8'),2,8);
            Sensor.errorStatusWord(iEns,:,4)=dec2base(fread(fid,1, 'uint8'),2,8);
            fseek(fid,2, 'cof');
            Sensor.pressure_pascal(iEns)=fread(fid,1, 'uint32');
            Sensor.pressureVar_pascal(iEns)=fread(fid,1, 'uint32');
            fseek(fid,1, 'cof');
            Sensor.dateY2k(iEns,:)=fread(fid,4, 'uint8');
            Sensor.timeY2k(iEns,:)=fread(fid,4, 'uint8');
            Sensor.date(iEns,:)=Sensor.dateNotY2k(iEns);
            Sensor.date(iEns,1)=Sensor.dateY2k(iEns,1)*100+Sensor.dateY2k(iEns,2);
            if (idataTypes+1)<=Hdr.nDataTypes(1)
                fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
            else
                fseek(fid,fileloc+bytesPerEns-2, 'bof');
            end

%%      Read Velocity Data
        case '0100'
            idataTypes=idataTypes+1;
            for iBin=1:Cfg.wn
                for iBeam=1:Inst.beams
                    dummy=fread(fid,1, 'int16');
```

```
                if dummy~=-32768
                    Wt.vel_mps(iBin,iEns,iBeam)=dummy/1000;
                end;
            end;
        end;
        if (idataTypes+1)<=Hdr.nDataTypes(1)
            fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
        else
            fseek(fid,fileloc+bytesPerEns-2, 'bof');
        end
%%      Read Correlation Magnitude
        case '0200'
        idataTypes=idataTypes+1;
        for iBin=1:Cfg.wn
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'uint8');
                if dummy~=-32768
                    Wt.corr(iBin,iEns,iBeam)=dummy;
                end;
            end;
        end;
        if (idataTypes+1)<=Hdr.nDataTypes(1)
            fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
        else
            fseek(fid,fileloc+bytesPerEns-2, 'bof');
        end

%%      Read Echo Intensity
        case '0300'
        idataTypes=idataTypes+1;
        for iBin=1:Cfg.wn
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'uint8');
                if dummy~=-32768
                    Wt.rssi(iBin,iEns,iBeam)=dummy;
                end;
            end;
        end;
        if (idataTypes+1)<=Hdr.nDataTypes(1)
            fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
        else
            fseek(fid,fileloc+bytesPerEns-2, 'bof');
        end

%%      Read Percent-Good Data
        case '0400'
        idataTypes=idataTypes+1;
        for iBin=1:Cfg.wn
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'uint8');
                if dummy~=-32768
                    Wt.pergd(iBin,iEns,iBeam)=dummy;
```

```
                end;
            end;
        end;
        if (idataTypes+1)<=Hdr.nDataTypes(1)
            fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
        else
            fseek(fid,fileloc+bytesPerEns-2, 'bof');
        end

%%      Read Bottom Track Data
        case '0600'
            idataTypes=idataTypes+1;
            BtCfg.bp(iEns)=fread(fid,1, 'uint16');
            long1=fread(fid,1, 'uint16');
            BtCfg.bc(iEns)=fread(fid,1, 'uint8');
            BtCfg.ba(iEns)=fread(fid,1, 'uint8');
            BtCfg.bg(iEns)=fread(fid,1, 'uint8');
            BtCfg.bm(iEns)=fread(fid,1, 'uint8');
            BtCfg.be_mmps(iEns)=fread(fid,1, 'uint16');
            Gps.lat_deg(iEns,1)=(fread(fid,1, 'int32')/2^31)*180;
            for iBeam=1:Inst.beams
                    dummy=fread(fid,1, 'uint16');
                    if dummy~=-32768
                        Bt.depth_m(iBeam,iEns)=dummy/100;
                    end;
            end;
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'int16');
                if dummy~=-32768
                    Bt.vel_mps(iBeam,iEns)=dummy/1000;
                end;
            end;
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'uint8');
                if dummy~=-32768
                    Bt.corr(iBeam,iEns)=dummy;
                end;
            end;
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'uint8');
                if dummy~=-32768
                    Bt.evalAmp(iBeam,iEns)=dummy;
                end;
            end;
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'uint8');
                if dummy~=-32768
                    Bt.pergd(iBeam,iEns)=dummy;
                end
            end;
            dummy=fread(fid,1, 'uint16');
            if dummy~=-32768
```

```
    Gps.alt_m(iEns)=(dummy-32768)/10;
end
long2=fread(fid,1, 'uint16');
Gps.long_deg(iEns,1)=((long1+long2*2^16)/2^31)*180;
if Gps.long_deg(iEns,1) > 180
    Gps.long_deg(iEns,1)=Gps.long_deg(iEns,1)-360;
end;
Bt.extDepth_cm(iEns)=fread(fid,1, 'int16');
dummy=fread(fid,1, 'int16');
if dummy~=-32768
        Gps.ggaVelE_mps(iEns)=dummy*-1/1000;
end
dummy=fread(fid,1, 'int16');
if dummy~=-32768
        Gps.ggaVelN_mps(iEns)=dummy*-1/1000;
end
dummy=fread(fid,1, 'int16');
if dummy~=-32768
        Gps.vtgVelE_mps(iEns)=dummy*-1/1000;
end
dummy=fread(fid,1, 'int16');
if dummy~=-32768
        Gps.vtgVelN_mps(iEns)=dummy*-1/1000;
end
dummy=fread(fid,1, 'uint8');
if dummy~=0
    Gps.gsaVdop(iEns)=dummy;
end
 dummy=fread(fid,1, 'uint8');
if dummy~=0
    Gps.gsaPdop(iEns)=dummy;
end
 dummy=fread(fid,1, 'uint8');
if dummy~=0
    Gps.ggaNStats(iEns)=dummy;
end
fseek(fid,1, 'cof');
Gps.gsaSat(iEns,5)=fread(fid,1, 'uint8');
Gps.gsaSat(iEns,6)=fread(fid,1, 'uint8');
Gps.ggaDiff(iEns)=fread(fid,1,'uint8' );
 dummy=fread(fid,1, 'uint8');
if dummy~=0
    Gps.ggaHdop(iEns)=dummy/10;
end
Gps.gsaSat(iEns,1)=fread(fid,1, 'uint8');
Gps.gsaSat(iEns,2)=fread(fid,1, 'uint8');
Gps.gsaSat(iEns,3)=fread(fid,1, 'uint8');
Gps.gsaSat(iEns,4)=fread(fid,1, 'uint8');
BtCfg.bx_dm(iEns)=fread(fid,1,'uint16' );
Bt.rssi(1,iEns)=fread(fid,1, 'uint8');
Bt.rssi(2,iEns)=fread(fid,1, 'uint8');
Bt.rssi(3,iEns)=fread(fid,1, 'uint8');
```

```
            Bt.rssi(4,iEns)=fread(fid,1, 'uint8');
            Cfg.wj(iEns)=fread(fid,1, 'uint8');
            for iBeam=1:Inst.beams
                dummy=fread(fid,1, 'uint8');
                if dummy~=-32768
                    Bt.depth_m(iBeam,iEns)=Bt.depth_m(iBeam,iEns)+  ...
                    (dummy*2^16)/100;
                end

            end;
            if (idataTypes+1)<=Hdr.nDataTypes(1)
                fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
            else
                fseek(fid,fileloc+bytesPerEns-2, 'bof');
            end

%%      Read DBT NMEA String
        case '2100'
            idataTypes=idataTypes+1;
            marker=ftell(fid);
            fseek(fid,(Hdr.dataOffsets(iEns,idataTypes)+fileloc+2),'bof'  );
            Nmea.dbt(iEns,:)=char(fread(fid,38, 'char'));
            dummy=zeros(1,38);
            endstr=find(Nmea.dbt(iEns,:)==char(13));
            dummy(1,1:endstr)=Nmea.dbt(iEns,1:endstr);
            Nmea.dbt(iEns,:)=dummy(1,:);
            if (idataTypes+1)<=Hdr.nDataTypes(iEns)
                fseek(fid,(Hdr.dataOffsets(iEns,idataTypes+1)+fileloc), 'bof');
            else
                fseek(fid,fileloc+bytesPerEns-2, 'bof');
            end

%%      Read GGA NMEA String
        case '2101'
            idataTypes=idataTypes+1;
            marker=ftell(fid);
            fseek(fid,(Hdr.dataOffsets(1,idataTypes)+fileloc+2), 'bof');
            dummy1=char(fread(fid,97, 'char'));
            dummy=zeros(1,97);
            endstr=find(dummy1==char(42))+2;
            dummy(1,1:endstr)=dummy1(1:endstr);
            Nmea.gga(iEns,:)=dummy(1,:);
            idx=find(Nmea.gga(iEns,:)== ',');
            if numel(idx)~=0
                if idx(1)+1<idx(2)-1
                    Gps.ggaUTC(iEns,1)=str2num(Nmea.gga(iEns,idx(1)+1:idx(2)-1));
                else
                    Gps.ggaUTC(iEns,1)=NaN;
                end
                if idx(2)+1<idx(3)-1
                    Gps.ggaLat(iEns,1)=str2num(Nmea.gga(iEns,idx(2)+1:idx(3)-1));
                else
```

```
                Gps.ggaLat(iEns,1)=NaN;
            end
            if idx(4)+1<idx(5)-1
                Gps.ggaLon(iEns,1)=str2num(Nmea.gga(iEns,idx(4)+1:idx(5)-1));
            else
                Gps.ggaLon(iEns,1)=NaN;
            end
        else
                Gps.ggaUTC(iEns,1)=NaN;
                Gps.ggaLat(iEns,1)=NaN;
                Gps.ggaLon(iEns,1)=NaN;
        end
        if (idataTypes+1)<=Hdr.nDataTypes(1)
            fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
        else
            fseek(fid,fileloc+bytesPerEns-2, 'bof');
        end

%%      Read VTG NMEA String
        case '2102'
            idataTypes=idataTypes+1;
            marker=ftell(fid);
            fseek(fid,(Hdr.dataOffsets(1,idataTypes)+fileloc+2), 'bof');
            dummy2=char(fread(fid,50, 'char'))';
            dummy=zeros(1,50);
            endstr=find(dummy2==char(42))+2;
            dummy(1,1:endstr)=dummy2(1:endstr);
            Nmea.vtg(iEns,:)=dummy(1,:);
            idx=find(Nmea.vtg(iEns,:)== ',');
            if numel(idx)~=0
                if idx(1)+1<idx(2)-1
                   Gps.vtgTrue(iEns,1)=str2num(Nmea.vtg(iEns,idx(1)+1:idx(2)-1));
                else
                   Gps.vtgTrue(iEns,1)=NaN;
                end
                if idx(3)+1<idx(4)-1
                    Gps.vtgMagN(iEns,1)=str2num(Nmea.vtg(iEns,idx(3)+1:idx(4)-1));
                else
                    Gps.vtgMagN(iEns,1)=NaN;
                end
                if idx(7)+1<idx(8)-1
                    Gps.vtgSpd(iEns,1)=str2num(Nmea.vtg(iEns,idx(7)+1:idx(8)-1));
                else
                    Gps.vtgSpd(iEns,1)=NaN;
                end
            else
                Gps.vtgTrue(iEns,1)=NaN;
                Gps.vtgMagN(iEns,1)=NaN;
                Gps.vtgSpd(iEns,1)=NaN;
            end
            if (idataTypes+1)<=Hdr.nDataTypes(1)
                fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
```

```
            else
                fseek(fid,fileloc+bytesPerEns-2, 'bof');
            end

%%      Read GSA NMEA String
        case '2103'
            idataTypes=idataTypes+1;
            marker=ftell(fid);
            fseek(fid,(Hdr.dataOffsets(1,idataTypes)+fileloc+2), 'bof');
            dummy3=char(fread(fid,60, 'char'))';
            dummy=zeros(1,60);
            endstr=find(dummy3==char(42))+2;
            dummy(1,1:endstr)=dummy3(1:endstr);
            Nmea.gsa(iEns,:)=dummy(1,:);
            if (idataTypes+1)<=Hdr.nDataTypes(1)
                fseek(fid,(Hdr.dataOffsets(1,idataTypes+1)+fileloc), 'bof');
            else
                fseek(fid,fileloc+bytesPerEns-2, 'bof');
            end
        otherwise
            disp(ftell(fid))
    end;
    if idataTypes==Hdr.nDataTypes(1)
        Inst.resRDI=fread(fid,1, 'uint16');
        checksum=fread(fid,1, 'uint16');
    end;
end;

%% Conversion of BTM to uniform units and cartesian system.
% Assumes Bt.vel_mps'(:,1) is beam1, (:,2) is beam2, (:,3) is beam3, (:,4)is beam4
%beam 3 is the upstream beam (positive for downstream transport)
%beam 4 is downstream beam (negative for downstream transport)
BTbeamvel = Bt.vel_mps'; %this will give velocity of bed wrt to instrument (negative of ↙
winriver output)

figure(1), clf
plot(Sensor.num, BTbeamvel(:,4))
legend('beam4 - d/s beam, neg for d/s transport' )
xlabel('ensemble')
ylabel('beam vel, m/s' )

figure(2), clf
plot(Sensor.num, BTbeamvel(:,3))
legend('beam3 - u/s beam, pos for d/s transport' )
xlabel('ensemble')
ylabel('beam vel, m/s' )

figure(3), clf
plot(Sensor.num, BTbeamvel(:,1), '+',Sensor.num, BTbeamvel(:,2), 'd',Sensor.num, BTbeamvel ↙
(:,3),'o',Sensor.num, BTbeamvel(:,4), 'x')
axis([Sensor.num(1) Sensor.num(end) -0.2 0.2])
legend('beam1','beam2','beam3','beam4')
```

```
xlabel('ensemble')
ylabel('beam vel, m/s')

vx=(BTbeamvel(:,3)-BTbeamvel(:,4))./(2*sin(Inst.beamAng(1)*pi/180));
vy=(BTbeamvel(:,1)-BTbeamvel(:,2))./(2*sin(Inst.beamAng(1)*pi/180));
vz1=(-BTbeamvel(:,3)-BTbeamvel(:,4))./(2*cos(Inst.beamAng(1)*pi/180));
vz2=(-BTbeamvel(:,1)-BTbeamvel(:,2))./(2*cos(Inst.beamAng(1)*pi/180));
vzcombine=[vz1'; vz2'];
vz=nanmean(vzcombine);
verror=2*(vz1-vz2); %Note: Winriver appears to apply the 2x factor

figure(4), clf
plot(Sensor.num, vx)
xlabel('ensemble')
ylabel('x bt vel, m/s')
title([fullName 'BT vel in x (downstream) direction' ])

%now, let's assume the vertical velocity is zero in beam 4, and estimate
%the x component of velocity in beam 4 (the downstream beam)
v4x=-BTbeamvel(:,4)./sin(Inst.beamAng(1)*pi/180);
figure(5), clf
plot(Sensor.num, v4x)
xlabel('ensemble')
ylabel('beam4 x bt vel, m/s')
title([fullName 'BT vel in x (downstream) direction in beam 4' ])
%this shows lovely periodicity.  It should probably be filtered to clean it
%up, but I'm hoping it can be related to the the transport throught the
%trap.  Similarly, hopefully we can correlate the beam4 vx to the beam3 vx
%and get the lag time between the beams, which would be the time of
%translation of the dunes between the beam 3 and beam 4!!!
v3x=BTbeamvel(:,3)./sin(Inst.beamAng(1)*pi/180);
figure(7), clf
plot(Sensor.num, v4x, Sensor.num, v3x,  'r')
xlabel('ensemble')
ylabel('x bt vel, m/s')
title([fullName ' BT vel in x (downstream) direction in beams 3 and 4' ])
legend('beam4','beam3')
axis([Sensor.num(1) Sensor.num(end) -1 1])
%Excellent! yes, I think this will work to find lag time between beams.

figure(8), clf
plot(Sensor.num, BTbeamvel(:,3), 'o',Sensor.num, -BTbeamvel(:,4), 'x')
axis([Sensor.num(1) Sensor.num(end) -0.2 0.2])
legend('beam3','beam4')
xlabel('ensemble')
ylabel('beam vel, m/s')
title([fullName ' BT beam vel (downstream) in beams 3 and 4' ])

figure(9), clf
plot(vx,vy,'+')
xlabel('x vel, m/s')
ylabel('y vel, m/s')
```

```
title([fullName ' BT'])
axis equal

rotationangle=-(360-Sensor.heading_deg+90).*pi./180;

vE=vx.*cos(rotationangle)+vy.*sin(rotationangle);
vN=vy.*cos(rotationangle)-vx.*sin(rotationangle);

meanvx=nanmean(vx)
stdvx=nanstd(vx)
meanvy=nanmean(vy)
meanvE=nanmean(vE)
meanvN=nanmean(vN)
meanv4x=nanmean(v4x) %the mean ADCP bedspeed in beam 4 in m/s
stdv4x=nanstd(v4x) %the standard deviation of bedspeed in beam 4 in m/s
meanv3x=nanmean(v3x) %the mean ADCP bedspeed in beam 4 in m/s
stdv3x=nanstd(v3x) %the standard deviation of bedspeed in beam 4 in m/s

savename=[fullName(1:(end-4)) '_ADCPdata' ]

dummy = ['save ' savename ]
eval(dummy)

%find beam 3 and beam 4 depth
beam3depth=Bt.depth_m(3,:);
beam4depth=Bt.depth_m(4,:);
for k=1:length(beam3depth)
    if beam3depth(k)==0
        beam3depth(k)=NaN;
    end
    if beam4depth(k)==0
        beam4depth(k)=NaN;
    end
end
ADCPheight=1.42; %elevation of ADCP above flume floor
sedimentdepthbeam3=ADCPheight-beam3depth;
sedimentdepthbeam4=ADCPheight-beam4depth;
averagesedimentdepthbeam3=nanmean(sedimentdepthbeam3)
averagesedimentdepthbeam4=nanmean(sedimentdepthbeam4)
figure(10)
plot(Sensor.num,sedimentdepthbeam3, '+',Sensor.num,sedimentdepthbeam4, 'o')
xlabel('ensemble')
ylabel('sediment depth, m')
legend('beam3','beam4')
```

```
%This code will process sonar data to look for periodicity in dune transport
%The sonar data are issued as a csv file. This file must be
%clipped by eliminating the first 20 rows, the first 3 columns, and the
%last 8 columns.  The data can then be saved and read into matlab as a text
%file (.txt).


filename=input('input the preprocessed sonar data file name, without .txt extension ' ,↙
's')
dummy=['load(''' filename '.txt'')']
eval(dummy)
dummy=['sonardata=' filename ';']
eval(dummy)

%load('lps5500_20060314_sedflux_gravel_inputtomatlab.txt')
%data=lps5500_20060314_sedflux_gravel_inputtomatlab;

%the columns in data correspond to
%ContinuousSec  Probe_1 Probe_2 Probe_3 Probe_4 Probe_5 Probe_6 Probe_7
sonartime=sonardata(:,1);
probe1=sonardata(:,2);
probe2=sonardata(:,3);
probe3=sonardata(:,4);
probe4=sonardata(:,5);
probe5=sonardata(:,6);
probe6=sonardata(:,7);
probe7=sonardata(:,8);

%convert to bed height above flume floor.  probe data z (mm) down from steel
%rail tube, which is 1.9 m above flume floor.
datum=1900;%height in mm of steel rail above flume floor
bedheight1=datum-probe1;
bedheight2=datum-probe2;
bedheight3=datum-probe3;
bedheight4=datum-probe4;
bedheight5=datum-probe5;
bedheight6=datum-probe6;
bedheight7=datum-probe7;

whos bedheight1
for k=1:(length(sonartime)-1)
    sonartimestep(k)=sonartime(k+1)-sonartime(k);
end

%figure(25)
%plot(sonartimestep,'+')
%ylabel('timestep')


%for lps3600_20060206_sedflux_sand second day begins on matlab index 14311 therefore ↙
datachange (bad timestep) is 14310
%this number needs to be modified for each file
```

```
%do this automatically by finding large time steps and eliminating them
%(this will also eliminate data when collection was paused)
k=1;
while k<length(sonartimestep)
    if sonartimestep(k)>100
        sonardatechange=k;
        sonartimestep=[sonartimestep(1:sonardatechange-1) sonartimestep(sonardatechange+1: ↙
end)];
        bedheight1=[bedheight1(1:sonardatechange-1); bedheight1(sonardatechange+1:end)];
        bedheight2=[bedheight2(1:sonardatechange-1); bedheight2(sonardatechange+1:end)];
        bedheight3=[bedheight3(1:sonardatechange-1); bedheight3(sonardatechange+1:end)];
        bedheight4=[bedheight4(1:sonardatechange-1); bedheight4(sonardatechange+1:end)];
        bedheight5=[bedheight5(1:sonardatechange-1); bedheight5(sonardatechange+1:end)];
        bedheight6=[bedheight6(1:sonardatechange-1); bedheight6(sonardatechange+1:end)];
        bedheight7=[bedheight7(1:sonardatechange-1); bedheight7(sonardatechange+1:end)];
        sonartime=[sonartime(1:sonardatechange-1); sonartime(sonardatechange+1:end)];
    else
    k=k+1;
    end
end


%figure(26)
%plot(sonartimestep,'+')
%ylabel('timestep')

badheight=1000;
badlow=-300;

for k=1:length(sonartimestep)
    if bedheight1(k)>badheight | bedheight1(k)<badlow
        bedheight1(k)=NaN; %get rid of bad data.  The bed was never more than 1 m from ↙
flume floor, and should never be below flume floor
    end
    if bedheight2(k)>badheight | bedheight2(k)<badlow
        bedheight2(k)=NaN; %get rid of bad data.  The bed was never more than 1 m from ↙
flume floor, and should never be below flume floor
    end
    if bedheight3(k)>badheight | bedheight3(k)<badlow
        bedheight3(k)=NaN; %get rid of bad data.  The bed was never more than 1 m from ↙
flume floor, and should never be below flume floor
    end
    if bedheight4(k)>badheight | bedheight4(k)<badlow
        bedheight4(k)=NaN; %get rid of bad data.  The bed was never more than 1 m from ↙
flume floor, and should never be below flume floor
    end
    if bedheight5(k)>badheight | bedheight5(k)<badlow
        bedheight5(k)=NaN; %get rid of bad data.  The bed was never more than 1 m from ↙
flume floor, and should never be below flume floor
    end
    if bedheight6(k)>badheight | bedheight6(k)<badlow
        bedheight6(k)=NaN; %get rid of bad data.  The bed was never more than 1 m from ↙
```

```
flume floor, and should never be below flume floor
    end
    if bedheight7(k)>badheight | bedheight7(k)<badlow
        bedheight7(k)=NaN; %get rid of bad data.  The bed was never more than 1 m from ↙
flume floor, and should never be below flume floor
    end
end
bedheight1interp=interpolateNaN(bedheight1); %fill in gaps for bad data
bedheight2interp=interpolateNaN(bedheight2); %fill in gaps for bad data
bedheight3interp=interpolateNaN(bedheight3); %fill in gaps for bad data
bedheight4interp=interpolateNaN(bedheight4); %fill in gaps for bad data
bedheight5interp=interpolateNaN(bedheight5); %fill in gaps for bad data
bedheight6interp=interpolateNaN(bedheight6); %fill in gaps for bad data
bedheight7interp=interpolateNaN(bedheight7); %fill in gaps for bad data


figure(27),clf
plot(sonartime,bedheight1,sonartime,bedheight2,sonartime,bedheight3,sonartime,bedheight4, ↙
sonartime,bedheight5)
xlabel('time, s')
ylabel('bedheight, mm')
legend('pr1','pr2','pr3','pr4','pr5')
title([filename ' bed height across section (pr5 on channel right d/s)' ])

figure(28),clf
plot(sonartime,bedheight3,sonartime,bedheight6,sonartime,bedheight7)
xlabel('time, s')
ylabel('bedheight, mm')
legend('pr3 - 0.98m us','pr6  - 8m us','pr7 - 13m us')
title([filename ' bed height along centreline' ])

figure(29),clf
plot(sonartime,bedheight3,sonartime,bedheight6)
xlabel('time, s')
ylabel('bedheight, mm')
legend('pr3 - 0.98m us','pr6  - 8m us')
title([filename ' bed height along centreline, 7 m apart' ])


savename=[filename '_sonardata' ]

dummy = ['save ' savename ]
eval(dummy)


[b,a]=butter(2,0.01);
filtpan3 = filtfilt(b,a,bedheight3);

figure(20),clf
plot(sonartime,bedheight3,'r-',sonartime,filtpan3,'k-')
xlabel('time, s')
ylabel('bedheight, mm')
```

```
legend('pr3','filtpr3')
title([filename ' bed height in middle ' ])
```

```
%This code will calculate 15 s averages of the SAFL main channel weigh pan
%data.  The weigh pan data is issued as a csv file. This file must be
%clipped by eliminating the first 10 rows, the first five columns, and the
%last four columns.  The data can then be saved and read into matlab as a text
%file (.txt).

%%for first bedload pan file I processed date change is index 19747 , which gives huge ↙
time change


panwidth=0.55; % in m

sandorgravel=input( 'input 1 for sand, 2 for gravel ' );
if sandorgravel==1
    Ss=2.63; %measured Ss for sand
else
    Ss=2.69; %measured Ss for gravel
end

filename=input( 'input the preprocessed bedload pan data file name, without .txt extension ↙
', 's' )
dummy=['load(''' filename '.txt'')']
eval(dummy)
dummy=['data=' filename ';']
eval(dummy)

%load('bedloadinput.txt')
%data=bedloadinput;
%load('lps5500_20060314_sedflux_gravel_inputtomatlab.txt')
%data=lps5500_20060314_sedflux_gravel_inputtomatlab;

%the columns in data correspond to
%Date    ClockTime    RunTime     RunSeconds  ContinuousTime  ContSeconds Weight 1    Weight ↙
2    Weight 3     Weight 4     Weight 5     Flux 1   Flux 2   Flux 3   Flux 4   Flux 5
time=data(:,1);
weight1=data(:,2);
weight2=data(:,3);
weight3=data(:,4);
weight4=data(:,5);
weight5=data(:,6);
for k=1:(length(time)-1)
    timestep(k)=time(k+1)-time(k);
    increment1(k)=weight1(k+1)-weight1(k);
    increment2(k)=weight2(k+1)-weight2(k);
    increment3(k)=weight3(k+1)-weight3(k);
    increment4(k)=weight4(k+1)-weight4(k);
    increment5(k)=weight5(k+1)-weight5(k);
end
time=time(2:end)';
%figure(10)
%plot(timestep,'+')
%ylabel('timestep')
```

```
%figure(11),clf
%plot(data(2:end,1),increment1)
%xlabel('time, s')
%ylabel('increment')
%title('pan1')


%for lps3600_20060206_sedflux_sand second day begins on matlab index 14311 therefore ↙
datachange (bad timestep) is 14310
%this number needs to be modified for each file
%do this automatically by finding large time steps and eliminating them
%(this will also eliminate data when collection was paused)
k=1;
while k<length(timestep)
    if timestep(k)>10
        datechange=k;
        timestep=[timestep(1:datechange-1) timestep(datechange+1:end)];
        increment1=[increment1(1:datechange-1) increment1(datechange+1:end)];
        increment2=[increment2(1:datechange-1) increment2(datechange+1:end)];
        increment3=[increment3(1:datechange-1) increment3(datechange+1:end)];
        increment4=[increment4(1:datechange-1) increment4(datechange+1:end)];
        increment5=[increment5(1:datechange-1) increment5(datechange+1:end)];
        time=[time(1:datechange-1) time(datechange+1:end)];
    else
    k=k+1;
    end
end


%figure(13)
%plot(timestep,'+')
%ylabel('timestep')
%figure(14)
%plot(increment3,'+')
numbertoskip=6;
for k=1:(length(timestep)-numbertoskip)
    if increment1(k)<-1
        increment1(k:k+numbertoskip)=NaN; %get rid of bad data when weigh pan is tripping, ↙
it takes about 5 seconds for pan to trip
    end
    if increment2(k)<-1
        increment2(k:k+numbertoskip)=NaN;
    end
    if increment3(k)<-1
        increment3(k:k+numbertoskip)=NaN;
    end
    if increment4(k)<-1
        increment4(k:k+numbertoskip)=NaN;
    end
    if increment5(k)<-1
        increment5(k:k+numbertoskip)=NaN;
```

```
    end
end
increment1=interpolateNaN(increment1); %fill in gaps when weigh pan is tripping
increment2=interpolateNaN(increment2);
increment3=interpolateNaN(increment3);
increment4=interpolateNaN(increment4);
increment5=interpolateNaN(increment5);

rate1=increment1./timestep.*(Ss./(Ss-1))./panwidth;
rate2=increment2./timestep.*(Ss./(Ss-1))./panwidth;
rate3=increment3./timestep.*(Ss./(Ss-1))./panwidth;
rate4=increment4./timestep.*(Ss./(Ss-1))./panwidth;
rate5=increment5./timestep.*(Ss./(Ss-1))./panwidth;

figure(15),clf
plot(time,rate1)
xlabel('time, s')
ylabel('transport rate, dry kg/s/m' )

meanrate1=mean(rate1)
stdrate1=std(rate1)
meanrate2=mean(rate2)
stdrate2=std(rate2)
meanrate3=mean(rate3)
stdrate3=std(rate3)
meanrate4=mean(rate4)
stdrate4=std(rate4)
meanrate5=mean(rate5)
stdrate5=std(rate5)

%there are many negatives.  perhaps I should average over ten seconds
%(about 10 measurements)
%actually, I'll do 15 seconds, because bedload samplers in increments of 15 s
%this is not a running average, rather it is a window (boxcar) average
%note that pan data not exactly 1 Hz, therefore not exactly 15 s

%determine the number of points that will give 15 s
requiretime=15;
meantimestep=nanmean(timestep)
s=1;
k=1;
numtoavg=round(requiretime/meantimestep)-1%actually the number will be one greater than ↙
this
while k<length(rate1)-numtoavg
    rate1avg(s)=mean(rate1(k:k+numtoavg));
    rate2avg(s)=mean(rate2(k:k+numtoavg));
    rate3avg(s)=mean(rate3(k:k+numtoavg));
    rate4avg(s)=mean(rate4(k:k+numtoavg));
    rate5avg(s)=mean(rate5(k:k+numtoavg));
    timeplot(s)=mean(time(k:k+numtoavg));
    k=k+numtoavg+1;
    s=s+1;
```

```
end
figure(16),clf
plot(timeplot,rate1avg)
xlabel('time, s')
ylabel('transport rate, dry kg/s/m')
title('pan1')
figure(17),clf
plot(timeplot,rate2avg)
xlabel('time, s')
ylabel('transport rate, dry kg/s/m')
title('pan2')
figure(18),clf
plot(timeplot,rate3avg)
xlabel('time, s')
ylabel('transport rate, dry kg/s/m')
title('pan3')
figure(19),clf
plot(timeplot,rate4avg)
xlabel('time, s')
ylabel('transport rate, dry kg/s/m')
title('pan4')
figure(20),clf
plot(timeplot,rate5avg)
xlabel('time, s')
ylabel('transport rate, dry kg/s/m')
title('pan5')

%still some negatives, but I don't have time right now to figure out where
%this noise is coming from.

figure(21), clf
plot(data(:,1),weight1)

figure(22),clf
plot(time,rate1)
xlabel('time, s')
ylabel('transport rate, sub kg/s')
title('pan1')

figure(23),clf
plot(time,increment1)
xlabel('time, s')
ylabel('increment')
title('pan1 increment after filter')

figure(24),clf
plot(timeplot,rate1avg,timeplot,rate2avg,timeplot,rate3avg,timeplot,rate4avg,timeplot, ↙
rate5avg)
xlabel('time, s')
ylabel('transport rate, dry kg/s/m')
legend('pan1','pan2','pan3','pan4','pan5')
title([filename 'all five traps'])
```

```
savename=[filename '_pandata']

dummy = ['save ' savename ' timeplot rate1avg rate2avg rate3avg rate4avg rate5avg' ]
eval(dummy)
```

```
%first, ADCPbedspeedfrombinary_3 must be run for the ADCP file
%second, analyzebedloadtrap_nocvjustdata must be run for the pan data
%these two files save the trap and ADCP processing

%panfirsttime must be input. The time in seconds from the beginning of the pan data
%to the time when ADCP run began.  This can be found by matching the time
%time stamp of the ADCP start to the time stamp of the bedload data in the
%bedload .csv file

%load NCED_5point5dis_060314_600adcp_000r_ADCPdata
%load lps5500_20060314_sedflux_gravel_inputtomatlab_pandata
%panfirsttime=27068.5;

%load NCED_3point6_060204_1200adcp003r_ADCPdata
%load lps3600_20060206_sedflux_sand_pandata
%panfirsttime=7289.8

load NCED_3point4_060303_1200adcp000r_ADCPdata
load lps3400_20060303_sedflux_gravel_pandata
%load lps3600_20060204_sonar1_7_sand_sonardata
panfirsttime=76896.0;


%%This is the version that allows you to be queried for file names and ADCP start time
%ADCPfile=input('enter name of processed ADCP .mat file (without .mat extension)','s')
%dummy=['load ' ADCPfile];
%eval(dummy)
%panfile=input('enter name of processed bedload pan .mat file (without .mat ↙
extension)','s')
%dummy=['load ' panfile];
%eval(dummy)
%ADCPbeginningtime_hr_min_sec_100thsec=Sensor.time(1,:)
%panfirsttime=input('enter the bedload pan time in seconds for the beginning of ADCP run ↙
(lookup pan .csv file)');

for k=1:length(Sensor.time)
    ADCPtimesec(k)=Sensor.time(k,4)*0.01+Sensor.time(k,3)+Sensor.time(k,2)*60+Sensor.time ↙
(k,1)*3600-(Sensor.time(1,4)*0.01+Sensor.time(1,3)+Sensor.time(1,2)*60+Sensor.time(1,1) ↙
*3600);
end


%figure(30)
%plot(ADCPtimesec)
%xlabel('ADCP time,s')

%convert ADCP time to pan time in sec
ADCPtimepan=ADCPtimesec+panfirsttime;

panendtime=ADCPtimepan(end);
%panendtime=13674.3 for NCED_3point6_060204_1200adcp003r_ADCPdata
%panendtime=28870; for NCED_5point5dis_060314_600adcp_000r_ADCPdata
```

```
%find the matlab index in pandata that corresponds to ADCP time
k=1;
while timeplot(k)<panfirsttime
    k=k+1;
end
panfirstindex=k-1;
while timeplot(k)<panendtime
    k=k+1;
end
panendindex=k-1;


figure(31),clf
plot(timeplot(panfirstindex:panendindex),rate3avg(panfirstindex:panendindex),ADCPtimepan,  ↙
v4x,ADCPtimepan, v3x)
xlabel( 'time, s' )
ylabel( 'transport rate, dry kg/s/m or beamxvel, m/s' )
%title('pan3')
legend( 'pan3' , 'beam4vx' , 'beam3vx' )

%average ADCP over 15 seconds to match pan data averaging
%note: this is not moving average, it is a sliding boxcar average
%determine the number of pings that will give 15 s
for m=2:length(ADCPtimesec)
    ADCPtimestep(m)=ADCPtimesec(m)-ADCPtimesec(m-1);
end
meanADCPtimestep=nanmean(ADCPtimestep)
requireADCPtime=15;
s=1;
k=1;
numtoavg=round(requireADCPtime/meanADCPtimestep)-1%actually the number will be one greater  ↙
than this
while k<length(v3x)-numtoavg
    v3xavg(s)=nanmean(v3x(k:k+numtoavg));
    v4xavg(s)=nanmean(v4x(k:k+numtoavg));
    vxavg(s)=nanmean(vx(k:k+numtoavg));
    vyavg(s)=nanmean(vy(k:k+numtoavg));
    vz1avg(s)=nanmean(vz1(k:k+numtoavg));
    vz2avg(s)=nanmean(vz2(k:k+numtoavg));
    vzcombineavg(s)=nanmean(vzcombine(k:k+numtoavg));
    vzerroravg(s)=nanmean(vzcombine(k:k+numtoavg));
    ADCPtimeplot(s)=nanmean(ADCPtimepan(k:k+numtoavg));
    k=k+numtoavg+1;
    s=s+1;
end

figure(32),clf
plot(timeplot(panfirstindex:panendindex),rate3avg(panfirstindex:panendindex),ADCPtimeplot,  ↙
v4xavg,ADCPtimeplot, v3xavg)
xlabel( 'time, s' )
```

```
ylabel( 'transport rate, dry kg/s/m or beamxvel, m/s' )
title([fullName '  15s averages of pan, beam3x, and beam4x' ])
legend( 'pan3', 'beam4vx', 'beam3vx' )

figure(33),clf
plot(timeplot(panfirstindex:panendindex),rate1avg(panfirstindex:panendindex),timeplot  ↙
(panfirstindex:panendindex),rate2avg(panfirstindex:panendindex),timeplot(panfirstindex:  ↙
panendindex),rate3avg(panfirstindex:panendindex),timeplot(panfirstindex:panendindex),  ↙
rate4avg(panfirstindex:panendindex),timeplot(panfirstindex:panendindex),rate5avg  ↙
(panfirstindex:panendindex))
xlabel( 'time, s' )
ylabel( 'transport rate, dry kg/s/m' )
title([fullName '  15s averages of pan data during ADCP' ])
legend( 'pan1', 'pan2', 'pan3', 'pan4', 'pan5' )


%now incorporate sonar data

%find the matlab index in sonar data that corresponds to ADCP time
%

%find time lag between beam3 and beam4 that maximizes correlation - this
%should be the average time for dune to translate from beam3 to beam4
for k=1:length(ADCPtimeplot)/2
   tau(k)=ADCPtimeplot(k)-ADCPtimeplot(1);
end
for lag=1:length(tau)
    v4xavgshift=v4xavg(lag:end);
    v3xtemp=v3xavg(1:length(v4xavgshift));
    corrtemp=corrcoef(v3xtemp,v4xavgshift);
    corrtau(lag)=corrtemp(1,2);
end
figure(35),clf
plot(tau,corrtau)
ylabel( 'corr v3x-v4x' )
xlabel( 'lag, s' )
title([filename ' correlation between ADCP v3x and v4x' ])

lagbetweenbeams=input( 'enter the time lag (s) from peak correlation between beams 3 and 4  ↙
')
%this gives dune celerity according to ADCP bedspeed.
%(distance between beams depends on depth, but is about 1 m)
%meanbedheight=mean(bedheight3)*0.001;%bed elevation
%ADCPelevation=1.43;%elevation of ADCP transducers above flume floor
%verticalrange=ADCPelevation-meanbedheight;
beammeanverticalrangefromADCP=meanignoringNaNandzeroswithdim(Bt.depth_m);
meanverticalrangefromADCP=mean(beammeanverticalrangefromADCP)
ADCPradius=0.0685;
distancebetweenbeams=2*meanverticalrangefromADCP*tan(Inst.beamAng(1)*pi/180)+2*ADCPradius
celerityADCP=distancebetweenbeams/lagbetweenbeams
```

```
%regression
%function [output] = regression(y,x)
%function regression(y,x)
%y=gbvrkin;
%x=gbm;
avgy=mean(y)
avgx=mean(x)
n=length(y)
sumxy=(sum(x.*y)-sum(x)*sum(y)/n)
sumxsquare=(sum(x.^2)-(sum(x))^2/n)
sumysquare=(sum(y.^2)-(sum(y))^2/n)
slope=sumxy/sumxsquare
intercept=avgy-slope*avgx
yhat=intercept+slope*x;
totalSS=sum(y.^2)-(sum(y))^2/n;
regressionSS=sum((yhat-avgy).^2);
residualSS=totalSS-regressionSS
residualDF=n-2
%regressionMS=regressionSS;
regressionMS=regressionSS/(n-2); %I think this is correct (see Zar p.327) - not that it ↙
matters, as I never use it again
residualMS=residualSS/(n-2);
SE=sqrt(residualMS)
R=sumxy/sqrt(sumxsquare*sumysquare)
rsquare=regressionSS/totalSS
residuals=y-yhat;
stdevresiduals=sum((residuals-mean(residuals)).^2)/(n-2); %Montgomery and Peck 1991 p68
%stdevresiduals=sqrt(sum((y-yhat).^2)/(n-2));%I don't know where I got this
standardresiduals=residuals/stdevresiduals;
%figure
%plot(x,standardresiduals,'+')
%title('standardized residuals versus x','FontSize',12)
%ylabel('residuals','FontSize',12)
%xlabel('x','FontSize',12)
%figure
%plot(yhat,standardresiduals,'+')
%title('standardized residuals versus fitted yhat','FontSize',12)
%ylabel('residuals','FontSize',12)
%xlabel('yhat','FontSize',12)
SEslope=sqrt(residualMS/sumxsquare) %from Zar p330, and Montgomery and Peck 1991 p.25
%SEslope=stdevresiduals/(sum((x-avgx).^2)^0.5;%I don't know where this is from either
SEintercept=sqrt(residualMS*(1/n+avgx^2/sumxsquare)); %Montgomery and Peck 1991 p.25
testslope=0;
t=(slope-testslope)/SEslope; %test against tcrit with nu=n-2
resDF=n-2;
[tcrit]=input([ 'Enter the critical t0.05(2) value with nu= '  num2str(resDF)  ', (Zar table ↙
B.3) '] );
LowerConfSlope=slope-tcrit*SEslope
UpperConfSlope=slope+tcrit*SEslope
%confidence intervals
syi=sqrt(residualMS*(1/n+(x-avgx).^2/sumxsquare));
lowerconfidence=yhat-tcrit.*syi;
```

```
upperconfidence=yhat+tcrit.*syi;
confidenceplot=[x y yhat lowerconfidence upperconfidence];
confidenceplot=sortrows(confidenceplot,1);
figure
plot(confidenceplot(:,1),confidenceplot(:,2), '+',confidenceplot(:,1),confidenceplot(:, ↙
3),'-',confidenceplot(:,1),confidenceplot(:,4), '--',confidenceplot(:,1),confidenceplot(:, ↙
5),'--')
title('best fit regression with upper and lower 95% confidence intervals' )
xlabel('x')
ylabel('y')
axis equal

%now do functional analysis
%this will be for lambda=1 (ie the principal axis, assuming errors in x and y are equal
lambda=1.5519
slopef=(slope^2/R^2-lambda+sqrt((slope^2/R^2-lambda)^2+4*lambda*slope^2))/(2*slope)
R2TimeLamdaDivBr2=rsquare*lambda/slope^2
%upper and lower conf intervals
%use 95% conf intervals therefore one-tailed students t with n-2 degrees freedom
[tcritf]=input(['Enter the critical t0.05(1) value with nu= ' num2str(resDF) ', (Zar table↙
B.3) '] );
upperconfslopef=lambda^0.5*tan(atan(slopef*lambda^-0.5)+0.5*asin(2*tcritf*(lambda* ↙
(slope^2/R^2-slope^2)/((n-2)*((slope^2/R^2-1)^2+4*slope^2)))^0.5))
lowerconfslopef=lambda^0.5*tan(atan(slopef*lambda^-0.5)-0.5*asin(2*tcritf*(lambda* ↙
(slope^2/R^2-slope^2)/((n-2)*((slope^2/R^2-1)^2+4*slope^2)))^0.5))
interceptf=avgy-slopef*avgx
upperconfinterceptf=avgy-upperconfslopef*avgx
lowerconfinterceptf=avgy-lowerconfslopef*avgx
%compare regression to functional analysis
yfunctional=slopef*x+interceptf;
confidenceplot2=[x y yhat lowerconfidence upperconfidence yfunctional];
confidenceplot2=sortrows(confidenceplot2,1);

figure
plot(confidenceplot2(:,1),confidenceplot2(:,2), '+',confidenceplot2(:,1),confidenceplot2(:, ↙
3),'-',confidenceplot2(:,1),confidenceplot2(:,4), '--',confidenceplot2(:,1),confidenceplot2 ↙
(:,5),'--',confidenceplot2(:,1),confidenceplot2(:,6), '-')
title('best fit regression with upper and lower 95% confidence intervals and principal ↙
axis')
xlabel('x')
ylabel('y')
axis equal
legend('data','reg','lowreg','upreg','pa')

%do regression of x upon y, find confidence limits on slope, and convert
%back to y upon x
avgyinv=mean(x)
avgxinv=mean(y)
sumxsquareinv=sumysquare
sumysquareinv=sumxsquare
slopeinv=sumxy/sumxsquareinv
interceptinv=avgyinv-slopeinv*avgxinv;
```

```
yhatinv=interceptinv+slopeinv*y;
totalSSinv=sum(x.^2)-(sum(x))^2/n;
regressionSSinv=sum((yhatinv-avgyinv).^2);
residualSSinv=totalSSinv-regressionSSinv;
regressionMSinv=regressionSSinv/(n-2); %I think this is correct (see Zar p.327) - not that ↙
it matters, as I never use it again
residualMSinv=residualSSinv/(n-2);
SEinv=sqrt(residualMSinv);
rsquareinv=regressionSSinv/totalSSinv;
SEslopeinv=sqrt(residualMSinv/sumxsquareinv) %from Zar p330, and Montgomery and Peck 1991 ↙
p.25
LowerConfSlopeinv=slopeinv-tcrit*SEslopeinv
UpperConfSlopeinv=slopeinv+tcrit*SEslopeinv
%convert back to y upon x
LowerConfSlopeinvinv=1/LowerConfSlopeinv
UpperConfSlopeinvinv=1/UpperConfSlopeinv
```

ANNEXURE III

WEIGH PAN DATA SENSITIVITY ANALYSIS

These are the results of one day gravel weight pan data on March 12th 2006 with 5.5 m^3/sec discharge. Total of 30 results were analyzed by considering the average time of 1, 5, 15, 30 and 60 sec. and assuming the skip points (One skip point = 1.1 sec) as 0, 5, 6, 7, 10 and 15.

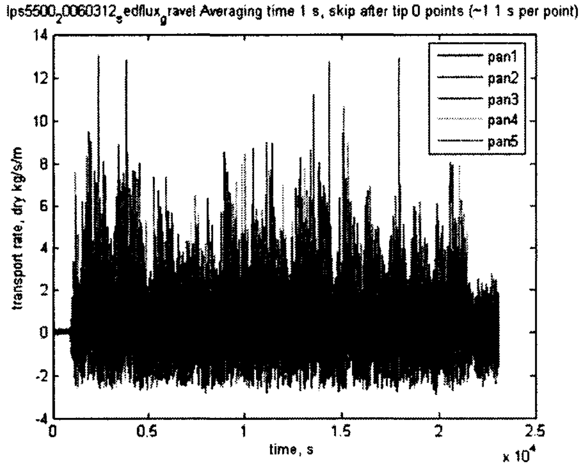
In addition to that the skip time (Time to trip the weigh pan) as 7 sec was also analyzed based on a sand bed data of Feb 2006 based on the results of gravelbed data. In this way only 5 results were analyzed.

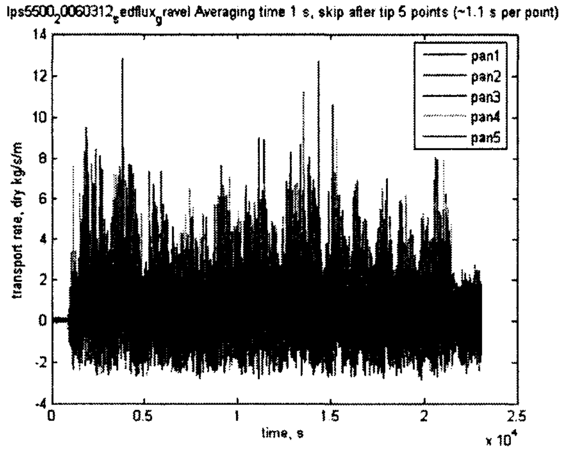
The results show that in one second average time it is hard to analyze the variations in the data. For five second, some variations can be seen but still there is large number of negative points. For 15 second average data looks better to analyze and less number of negative points. For 30 second and 60 second average data, the negative points are almost eliminated but with 60 sec average real time variations while comparing with other instruments may be eliminated. Therefore it is decided to analyze the 15 second average data.

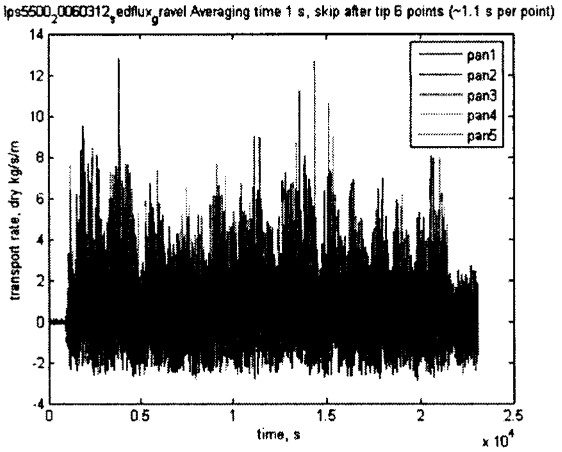
Now for the trip time of weigh pan, if we consider 7second trip time, which we have estimated for sand bed run, it looks that the better option to use the data for analysis is 15 second average time and skip time 6.

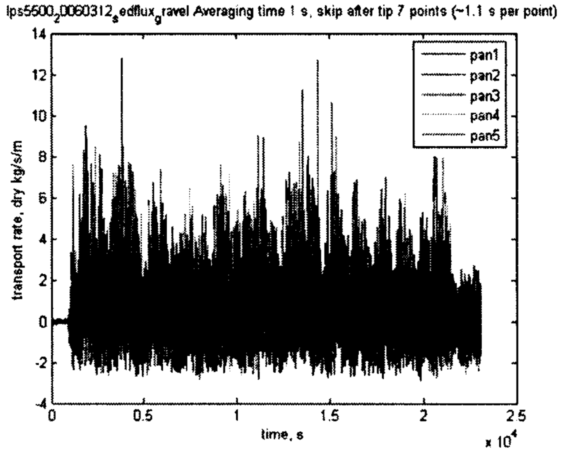
One bedload pan data run (gravel at 5.5 cumecs) with various averaging times and various deletions of points after a tip is shown in the follwing figures. Apparently 15 s averaging with 6 points deleted after a tip gives the best results. The data are not oversmoothed, but most negative values are removed. These results are based on a boxcar average.

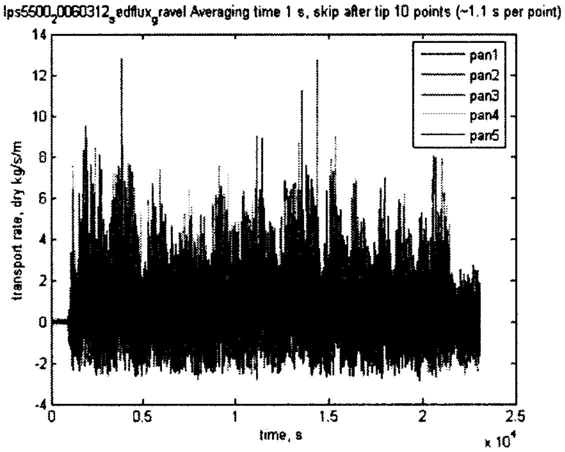
One (1) Second Average Time with 0, 5, 6, 7, 10 and 15 points skip

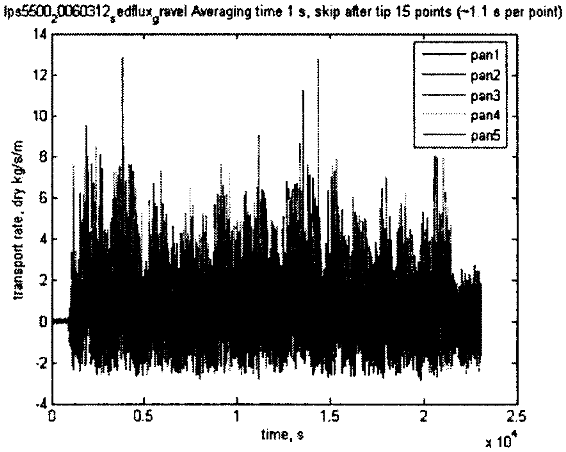




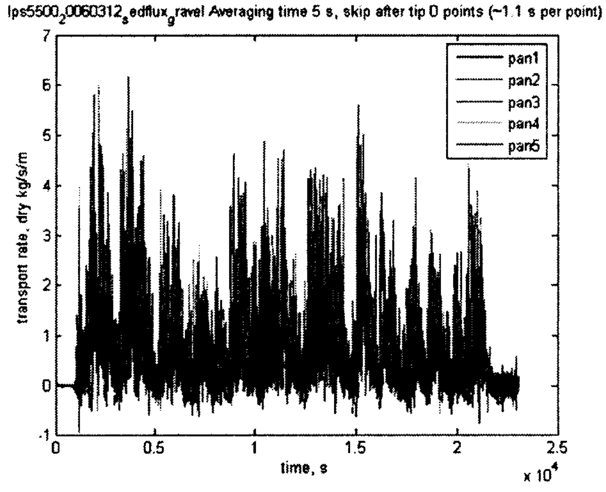


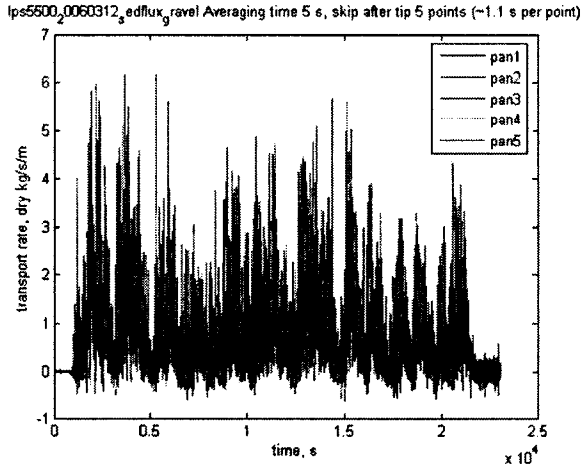


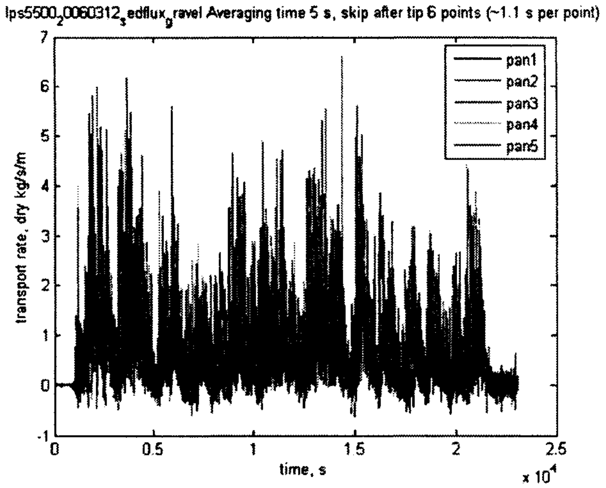


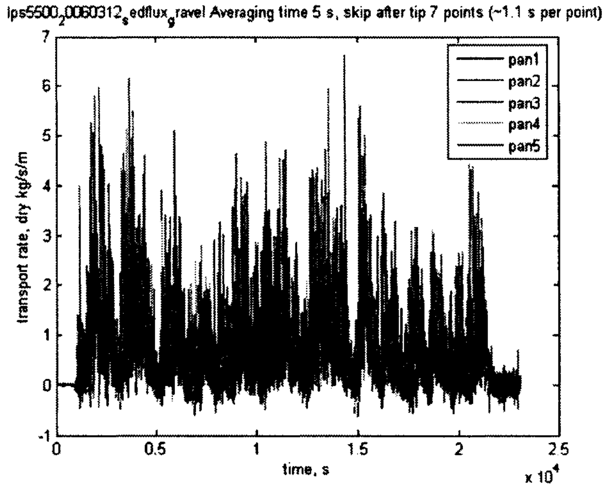


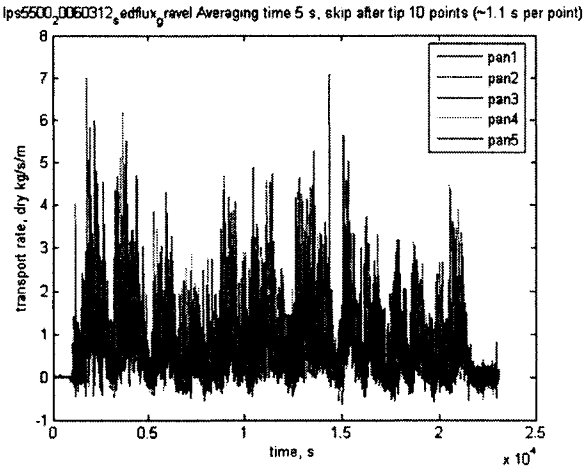
Five (5) Seconds Average Time with 0, 5, 6, 7, 10 and 15 points skip.

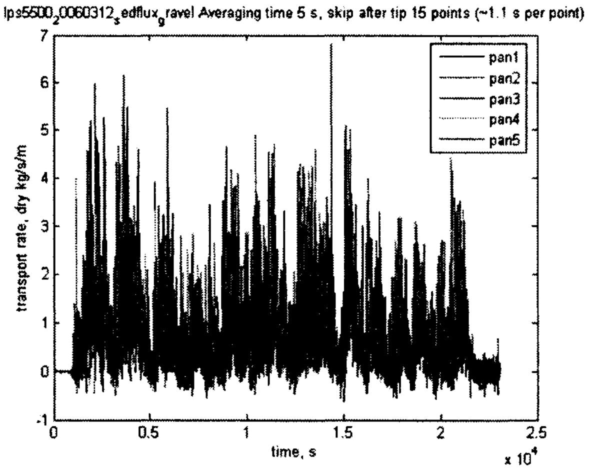




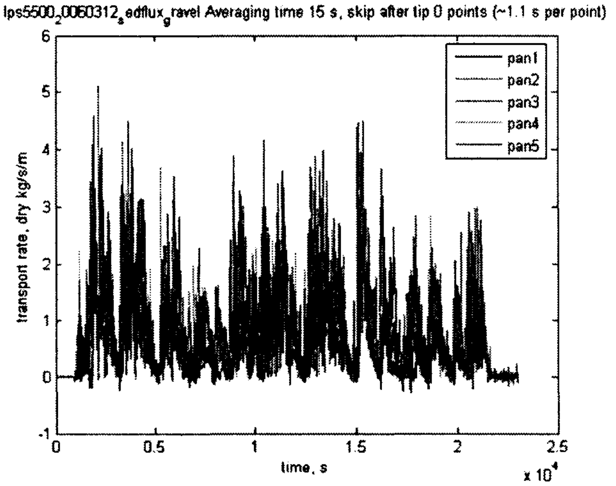

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 5 s, skip after tip 6 points (~1.1 s per point)

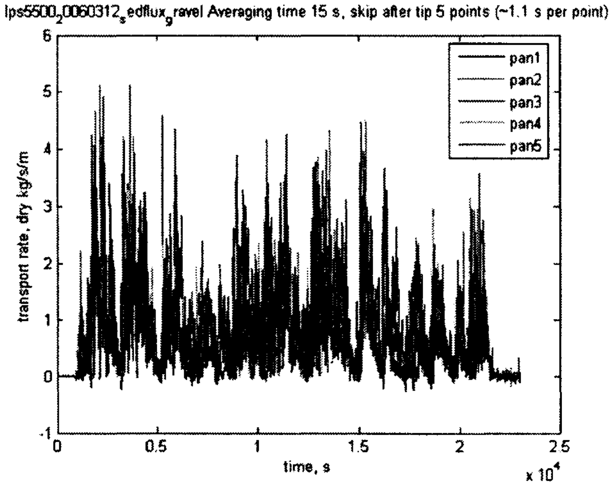

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 5 s, skip after tip 7 points (~1.1 s per point)

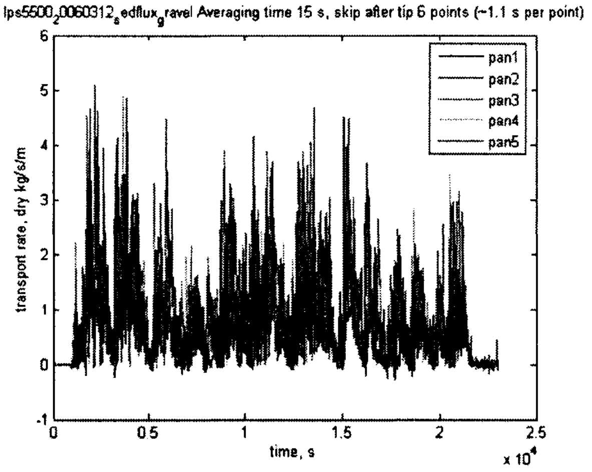

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 5 s, skip after tip 10 points (~1.1 s per point)

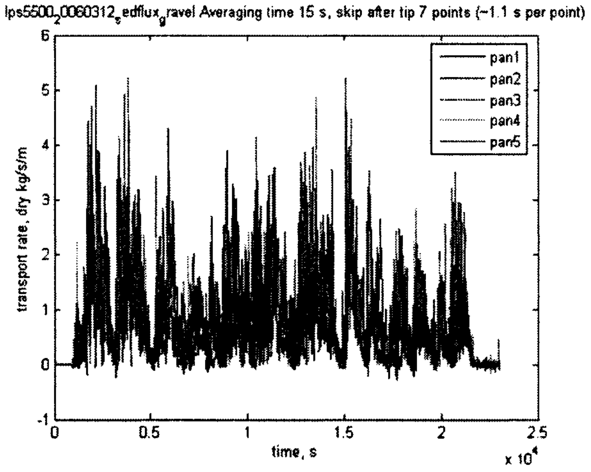

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 5 s, skip after tip 15 points (~1.1 s per point)

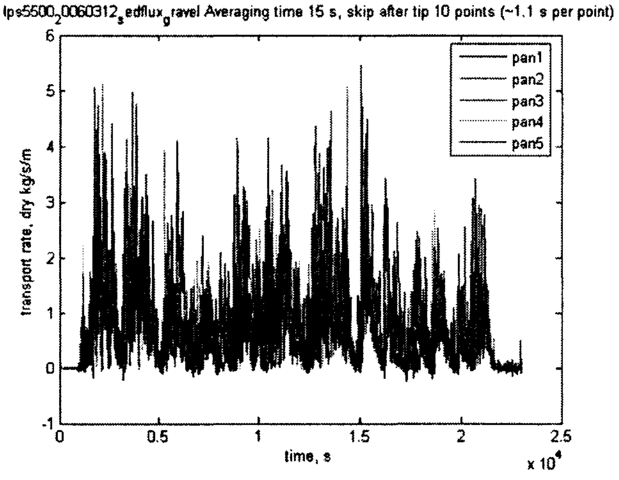
Fifteen (15) Second Average Time with 0, 5, 6, 7, 10 and 15 points skip

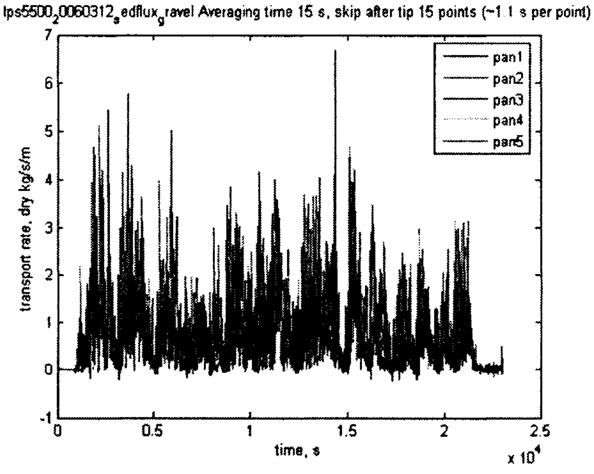

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 15 s, skip after tip 0 points (~1.1 s per point)


lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 15 s, skip after tip 5 points (~1.1 s per point)

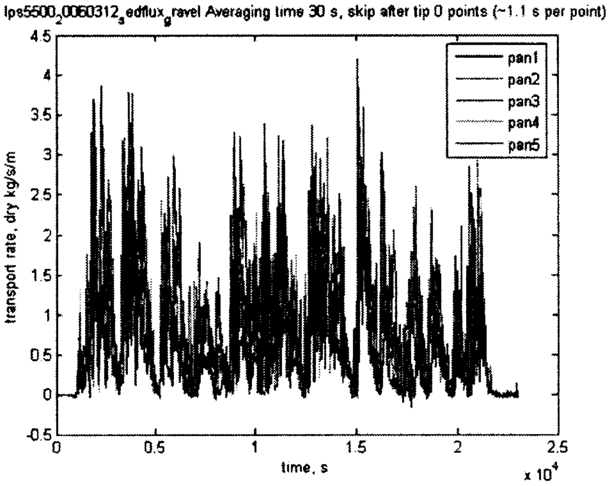

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 15 s, skip after tip 6 points (~1.1 s per point)

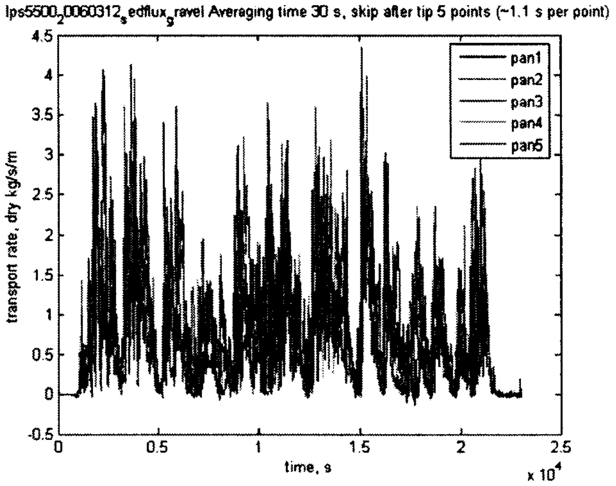

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 15 s, skip after tip 7 points (~1.1 s per point)

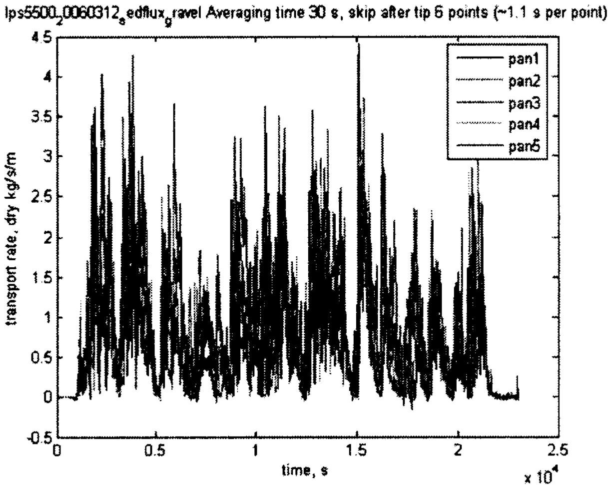

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 15 s, skip after tip 10 points (~1.1 s per point)

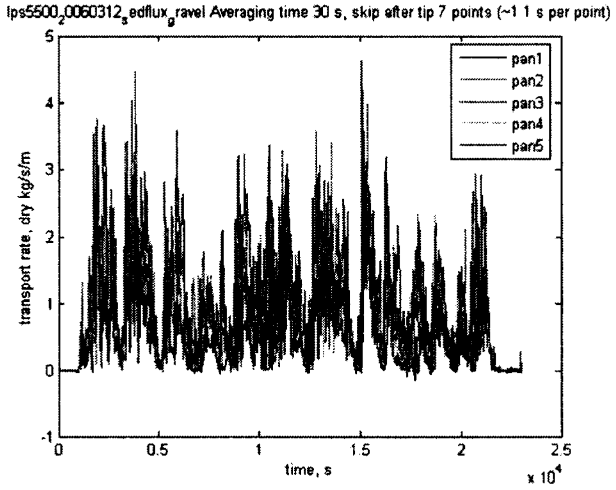

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 15 s, skip after tip 15 points (~1.1 s per point)

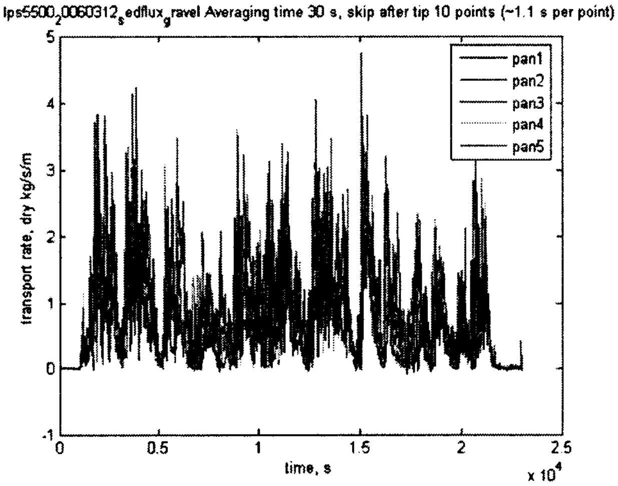
Thirty (30) Second Average Time with 0, 5, 6, 7, 10 and 15 points skip:

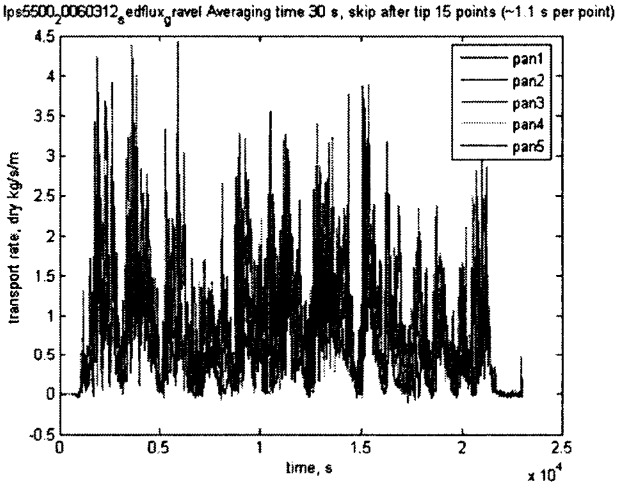

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 30 s, skip after tip 0 points (~1.1 s per point)


lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 30 s, skip after tip 5 points (~1.1 s per point)

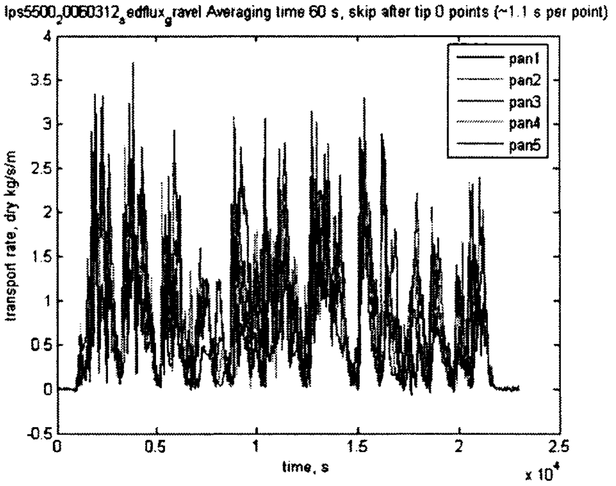

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 30 s, skip after tip 6 points (~1.1 s per point)

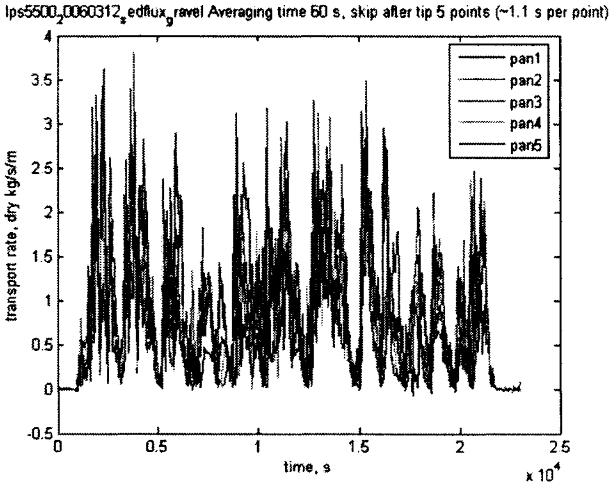

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 30 s, skip after tip 7 points (~1.1 s per point)

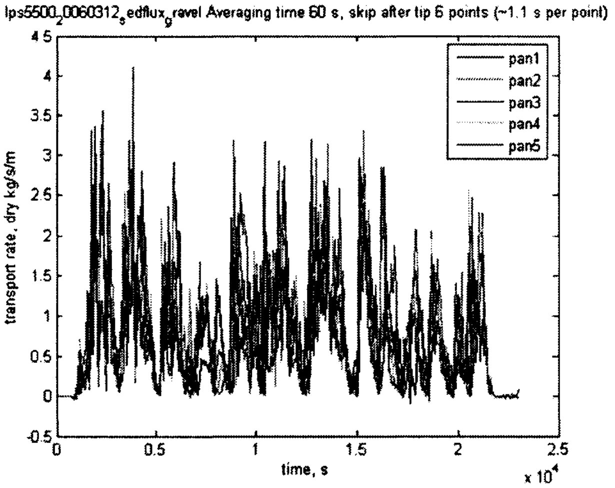

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 30 s, skip after tip 10 points (~1.1 s per point)

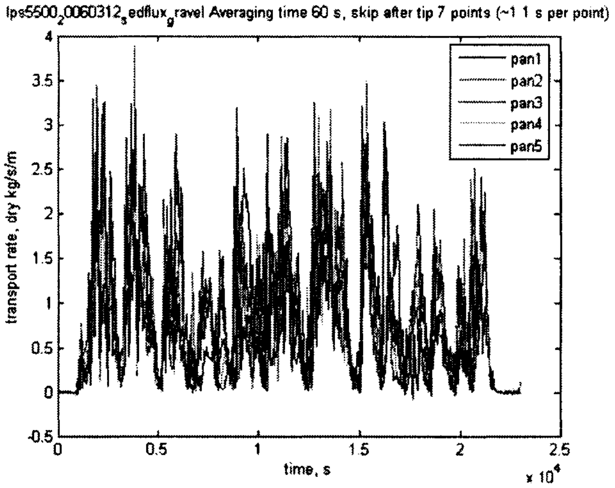

lps5500$_2$0060312$_s$edflux$_g$ravel Averaging time 30 s, skip after tip 15 points (~1.1 s per point)

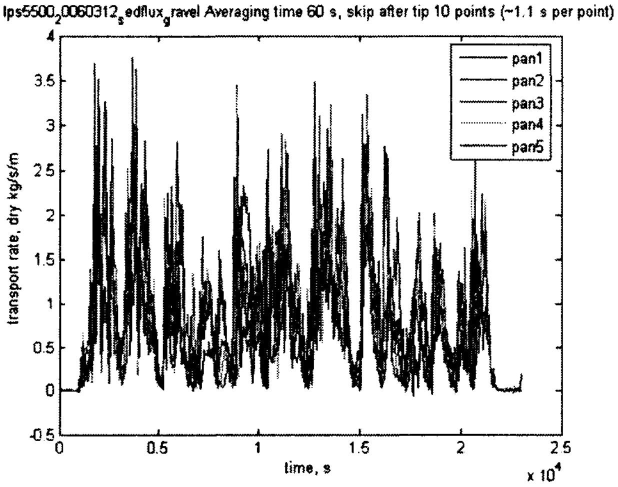
Sixty (60) Second Average Time with 0, 5, 6, 7, 10 and 15 points skip:

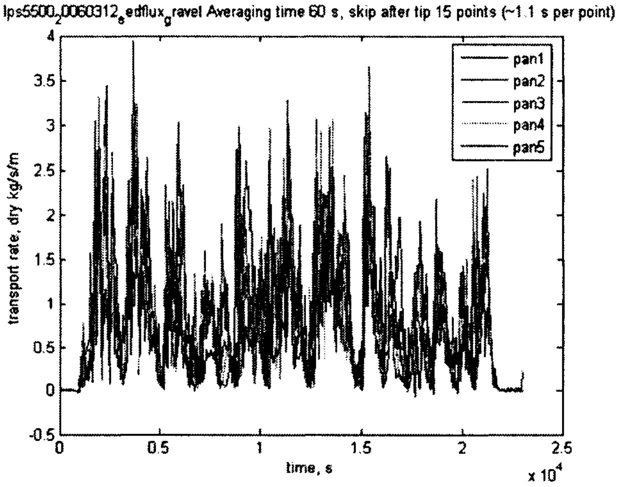












The above results are incorporated in the following table:

RESULTS OF WEIGH PAN DATA ON 12TH OF MARCH, 2006 WITH 5.5 CUMECS DISCHARGE
IN GRAVEL BED AT SAFL, NCED, UMN

Counts				weight pan 1	weight pan 2	weight pan 3	weight pan 4	weight pan 5
1	Average Time 1 second and Pan Trip point 0					(One trip Point = 1.1 seconds)		
			Mean	0.6544	1.0031	0.8431	0.7450	0.5666
	Mean Time Step	1.0842	St. Devi	1.2832	1.4202	1.2445	1.1493	1.0577
	Number To Average	0	Avg. Mean	0.6545	1.0032	0.8431	0.7451	0.5667
	Numberof samples	21264	Avg. St. Devi.	1.2833	1.4202	1.2445	1.1493	1.0577
2	Average Time 1 second and Pan Trip point 5							
			Mean	0.6749	1.0203	0.8658	0.7571	0.5883
	Mean Time Step	1.0842	St. Devi	1.2488	1.3786	1.2381	1.1279	1.0510
	Number To Average	0	Avg. Mean	0.6749	1.0204	0.8659	0.7571	0.5884
	Numberof samples	21264	Avg. St. Devi.	1.2488	1.3786	1.2381	1.1279	1.0509
3	Average Time 1 second and Pan Trip point 6							
			Mean	0.6808	1.0112	0.8587	0.755	0.59
	Mean Time Step	1.0842	St. Devi	1.2481	1.3683	1.2247	1.127	1.0532
	Number To Average	0	Avg. Mean	0.6808	1.0112	0.8588	0.7551	0.5901
	Numberof samples	21264	Avg. St. Devi.	1.2481	1.3683	1.2247	1.127	1.0531
4	Average Time 1 second and Pan Trip point 7							
			Mean	0.6898	1.016	0.8583	0.7494	0.5881
	Mean Time Step	1.0842	St. Devi	1.2427	1.3641	1.2171	1.1152	1.0509
	Number To Average	0	Avg. Mean	0.6899	1.0161	0.8584	0.7495	0.5882
	Numberof samples	21264	Avg. St. Devi.	1.2428	1.3641	1.2171	1.1152	1.0508
5	Average Time 1 second and Pan Trip point 10							
			Mean	0.7056	1.0087	0.8579	0.7533	0.5903
	Mean Time Step	1.0842	St. Devi	1.2341	1.3506	1.2073	1.1107	1.0456
	Number To Average	0	Avg. Mean	7056	1.0088	0.858	0.7533	0.5903
	Numberof samples	21264	Avg. St. Devi.	1.2341	1.3505	1.2073	1.1107	1.0456

6 Average Time 1 second and Pan Trip point 15

		Mean	0.7084	1.0024	0.8548	0.7385	0.5887
Mean Time Step	1.0842	St. Devi	1.2122	1.3186	1.1836	1.0896	1.0289
Number To Average	0	Avg. Mean	0.7084	1.0024	0.8549	0.7385	0.5888
Numberof samples	21264	Avg. St. Devi.	1.2122	1.3186	1.1836	1.0896	1.0289

7 Average Time 5 second and Pan Trip point 0

		Mean	0.6544	1.0031	0.8431	0.745	0.5666
Mean Time Step	1.0842	St. Devi	1.2832	1.4202	1.2445	1.1493	1.0577
Number To Average	4	Avg. Mean	0.6546	1.0034	0.8433	0.7452	0.5669
Numberof samples	4252	Avg. St. Devi.	0.7582	1.0504	0.9176	0.7926	0.6316

8 Average Time 5 second and Pan Trip point 5

		Mean	0.6749	1.0203	0.8658	0.7571	0.5883
Mean Time Step	1.0842	St. Devi	1.2488	1.3786	1.2381	1.1279	1.051
Number To Average	4	Avg. Mean	0.6751	1.0206	0.886	0.7573	0.5885
Numberof samples	4252	Avg. St. Devi.	0.773	1.0687	0.9497	0.8034	0.6506

9 Average Time 5 second and Pan Trip point 6

		Mean	0.6808	1.0112	0.8587	0.755	0.59
Mean Time Step	1.0842	St. Devi	1.2481	1.3683	1.2247	1.127	1.0532
Number To Average	4	Avg. Mean	0.681	1.0114	0.8589	0.7552	0.5902
Numberof samples	4252	Avg. St. Devi.	0.7804	1.0609	0.9358	0.8069	0.6587

10 Average Time 5 second and Pan Trip point 7

		Mean	0.6898	1.016	0.8583	0.7494	0.5881
Mean Time Step	1.0842	St. Devi	1.2427	1.3641	1.2171	1.1152	1.0509
Number To Average	4	Avg. Mean	0.69	1.0163	0.8585	0.7496	0.5883
Numberof samples	4252	Avg. St. Devi.	0.7812	1.0614	0.9307	0.7959	0.6592

11 Average Time 5 second and Pan Trip point 10

		Mean	0.7056	1.0087	0.8579	0.7533	0.5903
Mean Time Step	1.0842	St. Devi	1.2341	1.3506	1.2073	1.1107	1.0456
Number To Average	4	Avg. Mean	0.7058	1.009	0.8582	0.7535	0.5905
Numberof samples	4252	Avg. St. Devi.	0.787	1.0596	0.9309	0.8006	0.6651

12 Average Time 5 second and Pan Trip point 15

		Mean	0.7084	1.0024	0.8548	0.7385	0.5887
Mean Time Step	1.0842	St. Devi	1.2122	1.3186	1.1836	1.0896	1.0289
Number To Average	4	Avg. Mean	0.7086	1.0026	0.855	0.7387	0.5889
Numberof samples	4252	Avg. St. Devi.	0.7857	1.0468	0.9206	0.7939	0.6608

13 Average Time 15 second and Pan Trip point 0

		Mean	0.6544	1.0031	0.8431	0.745	0.5666
Mean Time Step	1.0842	St. Devi	1.2832	1.4202	1.2445	1.1493	1.0577
Number To Average	13	Avg. Mean	0.6549	1.0038	0.8436	0.7455	0.5671
Numberof samples	1518	Avg. St. Devi.	0.6896	0.9728	0.8495	0.725	0.5689

14 Average Time 15 second and Pan Trip point 5

		Mean	0.6749	1.0203	0.8658	0.7571	0.5883
Mean Time Step	1.0842	St. Devi	1.2488	1.3786	1.2381	1.1279	1.051
Number To Average	13	Avg. Mean	0.6753	1.021	0.8664	0.7576	0.5887
Numberof samples	1518	Avg. St. Devi.	0.7087	0.9956	0.8886	0.7411	0.5928

15 Average Time 15 second and Pan Trip point 6

		Mean	0.6808	1.0112	0.8587	0.755	0.59
Mean Time Step	1.0842	St. Devi	1.2481	1.3683	1.2247	1.127	1.0532
Number To Average	13	Avg. Mean	0.6812	1.0118	0.8593	0.7555	0.5905
Numberof samples	1518	Avg. St. Devi.	0.7151	0.9894	0.8735	0.7434	0.5998

16 Average Time 15 second and Pan Trip point 7

		Mean	0.6898	1.016	0.8583	0.7494	0.5881
Mean Time Step	1.0842	St. Devi	1.2427	1.3641	1.2171	1.1152	1.0509
Number To Average	13	Avg. Mean	0.6903	1.0167	0.8589	0.7499	0.5885
Numberof samples	1518	Avg. St. Devi.	0.7197	0.9928	0.8735	0.7312	0.5986

17 Average Time 15 second and Pan Trip point 10

		Mean	0.7056	1.0087	0.8579	0.7533	0.5903
Mean Time Step	1.0842	St. Devi	1.2341	1.3506	1.2073	1.1107	1.0456
Number To Average	13	Avg. Mean	0.706	1.0093	0.8585	0.7538	0.5907
Numberof samples	1518	Avg. St. Devi.	0.73	0.9927	0.8724	0.7379	0.6062

18 Average Time 15 second and Pan Trip point 15

		Mean	0.7084	1.0024	0.8548	0.7385	0.5887
Mean Time Step	1.0842	St. Devi	1.2122	1.3186	1.1836	1.0896	1.0289
Number To Average	13	Avg. Mean	0.7088	1.003	0.8554	0.739	0.5891
Numberof samples	1518	Avg. St. Devi.	0.7301	0.9818	0.8688	0.7359	0.6086

19 Average Time 30 second and Pan Trip point 0

		Mean	0.6544	1.0031	0.8431	0.745	0.5666
Mean Time Step	1.0842	St. Devi	1.2832	1.4202	1.2445	1.1493	1.0577
Number To Average	27	Avg. Mean	0.6549	1.0038	0.8436	0.7455	0.5671
Numberof samples	759	Avg. St. Devi.	0.6546	0.925	0.8029	0.6831	0.5431

20 Average Time 30 second and Pan Trip point 5

		Mean	0.6749	1.0203	0.8658	0.7571	0.5883
Mean Time Step	1.0842	St. Devi	1.2488	1.3786	1.2381	1.1279	1.051
Number To Average	27	Avg. Mean	0.6753	1.021	0.8664	0.7576	0.5887
Numberof samples	759	Avg. St. Devi.	0.6688	0.9419	0.838	0.6965	0.5649

21 Average Time 30 second and Pan Trip point 6

		Mean	0.6808	1.0112	0.8587	0.755	0.59
Mean Time Step	1.0842	St. Devi	1.2481	1.3683	1.2247	1.127	1.0532
Number To Average	27	Avg. Mean	0.6812	1.0118	0.8593	0.7555	0.5905
Numberof samples	759	Avg. St. Devi.	0.6702	0.9386	0.8241	0.6988	0.567

22 Average Time 30 second and Pan Trip point 7

		Mean	0.6898	1.016	0.8383	0.7494	0.5881
Mean Time Step	1.0842	St. Devi	1.2427	1.3641	1.2171	1.1152	1.0509
Number To Average	27	Avg. Mean	0.6903	1.0167	0.8589	0.7499	0.5885
Numberof samples	759	Avg. St. Devi.	0.6766	0.9381	0.8255	0.6887	0.5671

23 Average Time 30 second and Pan Trip point 10

		Mean	0.7056	1.0087	0.8579	0.7533	0.5903
Mean Time Step	1.0842	St. Devi	1.2341	1.3506	1.2073	1.1107	1.0456
Number To Average	27	Avg. Mean	0.706	1.0093	0.8585	0.7538	0.5907
Numberof samples	759	Avg. St. Devi.	0.6814	0.9356	0.8212	0.6938	0.5642

24 Average Time 30 second and Pan Trip point 15

		Mean	0.7084	1.0024	0.8548	0.7385	0.5887
Mean Time Step	1.0842	St. Devi	1.2122	1.3186	1.1836	1.0896	1.0289
Number To Average	27	Avg. Mean	0.7088	1.003	0.8554	0.739	0.5891
Numberof samples	759	Avg. St. Devi.	0.6794	0.9239	0.8215	0.6898	0.5677

25 Average Time 60 second and Pan Trip point 0

		Mean	0.6544	1.0031	0.8431	0.745	0.5666
Mean Time Step	1.0842	St. Devi	1.2832	1.4202	1.2445	1.1493	1.0577
Number To Average	54	Avg. Mean	0.6555	1.0048	0.8445	0.7463	0.5676
Numberof samples	386	Avg. St. Devi.	0.6157	0.8735	0.7581	0.6449	0.5076

26 Average Time 60 second and Pan Trip point 5

		Mean	0.6749	1.0203	0.8658	0.7571	0.5883
Mean Time Step	1.0842	St. Devi	1.2488	1.3786	1.2381	1.1279	1.051
Number To Average	54	Avg. Mean	0.676	1.022	0.8672	0.7584	0.5893
Numberof samples	386	Avg. St. Devi.	0.627	0.8895	0.7883	0.6562	0.5288

27 Average Time 60 second and Pan Trip point 6

		Mean	0.6808	1.0112	0.8587	0.755	0.59
Mean Time Step	1.0842	St. Devi	1.2481	1.3683	1.2247	1.127	1.0532
Number To Average	54	Avg. Mean	0.6819	1.0128	0.8601	0.7563	0.591
Numberof samples	386	Avg. St. Devi.	0.6252	0.8838	0.7768	0.6589	0.5315

28 Average Time 60 second and Pan Trip point 7

		Mean	0.6898	1.016	0.8583	0.7494	0.5881
Mean Time Step	1.0842	St. Devi	1.2427	1.3641	1.2171	1.1152	1.0509
Number To Average	54	Avg. Mean	0.691	1.0177	0.8597	0.7507	0.5891
Numberof samples	386	Avg. St. Devi.	0.6339	0.8849	0.7763	0.6468	0.5288

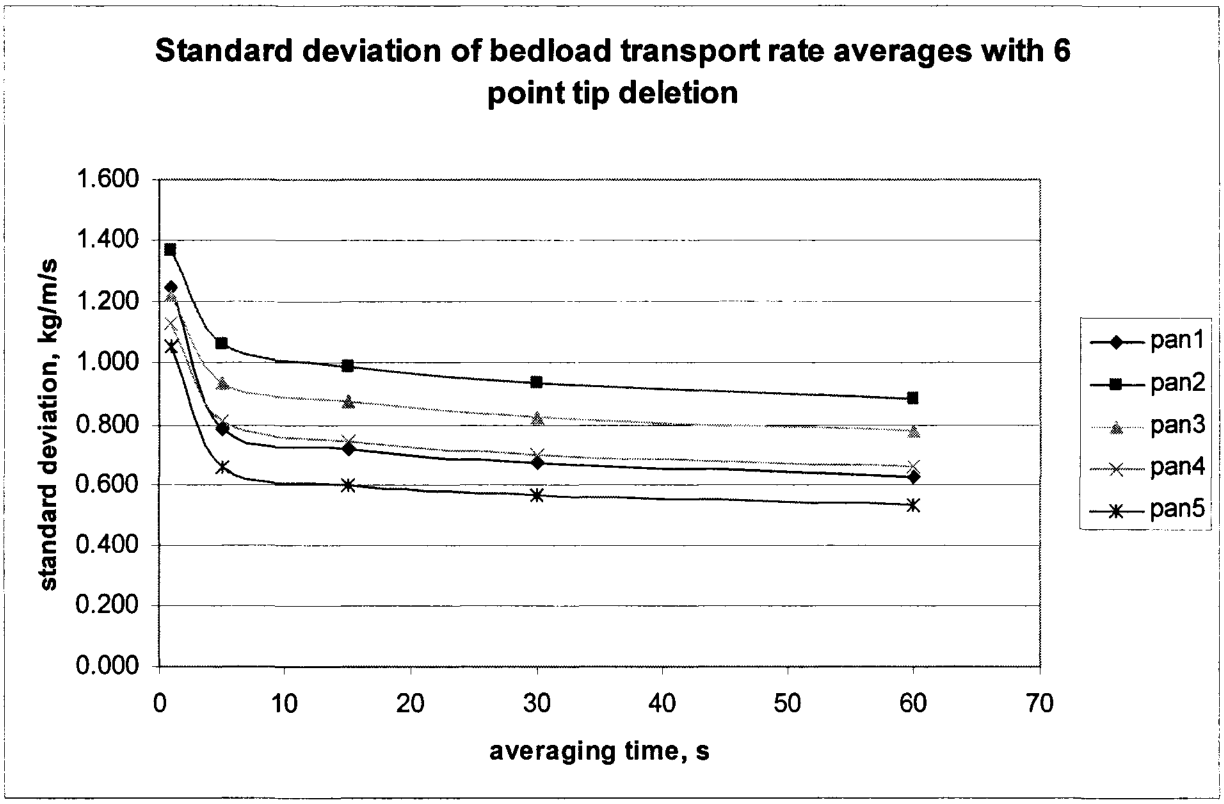
29 Average Time 60 second and Pan Trip point 10

		Mean	0.7056	1.0087	0.8579	0.7533	0.5903
Mean Time Step	1.0842	St. Devi	1.2341	1.3506	1.2073	1.1107	1.0456
Number To Average	54	Avg. Mean	0.7068	1.0104	0.8594	0.7545	0.5913
Numberof samples	386	Avg. St. Devi.	0.6355	0.8798	0.7737	0.6498	0.5259

30 Average Time 60 second and Pan Trip point 15

		Mean	0.7084	1.0024	0.8548	0.7385	0.5887
Mean Time Step	1.0842	St. Devi	1.2122	1.3186	1.1836	1.0896	1.0289
Number To Average	54	Avg. Mean	0.7096	1.004	0.8562	0.7397	0.5897
Numberof samples	386	Avg. St. Devi.	0.6267	0.8655	0.7696	0.6416	0.5152

Based on the above table a curve was developed between standard deviation and average time with 6 point tip deletion (7 sec) for all of the five weigh pans and shown below:



The variation of measured bedload is due to both true variability and measurement error. The average time should be selected in a way to reduce the measurement error and does not cause undue smoothing of the true variability. Based on the above curve and the number of negative values still present with shorter averaging intervals, the 15 sec. averaging time is the better option.

Thus all of the analysis of weigh pan data in this project is based on 15 sec average time and pan trip time of 6 data points.

ANNEXURE IV

ADCP, weigh pans and Sonars matching time - SAND

No of Runs	Date	Discharg m^3/sec	Water Slope	Bed Slope	Flow Depth From Flume Floor meters (m)	Nominal sediment depth (m)	Nominal water depth (m)	ACOUSTIC DO		
								Mode	&R	ADCP Type
1	29-Jan-06	2.89			1.55	0.45	1.1	BM5	40	1200
2	29-Jan-06	2.89			1.7	0.45	1.25	BM5	30	1200
3	29-Jan-06	2.89			1.7	0.45	1.25	BM5	20	1200
4	29-Jan-06	2.89			1.7	0.45	1.25	BM5	20	1200
5	29-Jan-06	2.89			1.7	0.45	1.25	BM5	30	1200
6	30-Jan-06	3.00			1.7	0.45	1.25	BM5	40	1200
7	30-Jan-06	3.00			1.7	0.45	1.25	BM5	30	1200
8	30-Jan-06	3.00			1.7	0.45	1.25	BM5	20	1200
9	30-Jan-06	3.00			1.7	0.45	1.25	BM5	20	1200
10	31-Jan-06	3.00			1.7	0.45	1.25	BM5	40	1200
11	31-Jan-06	3.00			1.7	0.45	1.25	BM5	30	1200
12	31-Jan-06	3.00			1.7	0.45	1.25	BM5	20	1200
13	1-Feb-06	2.98			1.7	0.45	1.25	BM5	40	1200
14	1-Feb-06	2.98	0.00188	■	1.7	0.45	1.25	BM5	30	1200
15	1-Feb-06	2.98			1.7	0.45	1.25	BM5	20	1200
16	2-Feb-06	2.90			1.7	0.45	1.25	BM5	40	1200
17	2-Feb-06	2.90			1.7	0.45	1.25	BM5	40	**600**
18	2-Feb-06	2.90			1.7	0.45	1.25	BM5	30	**600**
19	3-Feb-06	3.60			1.7	0.45	1.25	BM5	40	**600**
20	3-Feb-06	3.60			1.7	0.45	1.25	BM5	40	1200
21	4-Feb-06	3.60			1.7	0.45	1.25	BM5	40	1200
22	4-Feb-06	3.60	0.00171	■	1.7	0.45	1.25	BM5	30	1200
23	4-Feb-06	3.60			1.7	0.45	1.25	BM5	20	1200
24	4-Feb-06	3.60			1.7	0.45	1.25	BM5	40	1200
25	6-Feb-06	2.00			1.7	0.45	1.25	BM5	20	1200
26	7-Feb-06	2.00			1.7	0.45	1.25	BM5	20	1200
27	7-Feb-06	2.00	0.00021	■	1.7	0.45	1.25	BM5	30	1200
28	7-Feb-06	2.00			1.7	0.45	1.25	BM5	40	1200
29	7-Feb-06	2.00			1.7	0.45	1.25	BM5	40	**600**
30	8-Feb-06	2.50			1.7	0.45	1.25	BM5	40	**600**
31	8-Feb-06	2.50			1.7	0.45	1.25	BM5	30	**600**
32	8-Feb-06	2.50			1.7	0.45	1.25	BM5	20	**600**
33	9-Feb-06	2.50			1.7	0.45	1.25	BM5	20	1200
34	9-Feb-06	2.50	0.00047	■	1.7	0.45	1.25	BM5	30	1200
35	9-Feb-06	2.50			1.7	0.45	1.25	BM5	40	1200
36	9-Feb-06	3.20			1.7	0.45	1.25	BM5	40	1200
37	14-Feb-06	3.20	0.0026	■	1.7	0.45	1.25	BM5	30	1200
38	14-Feb-06	3.20			1.7	0.45	1.25	BM5	20	1200
39	14-Feb-06	3.20			1.7	0.45	1.25	BM5	40	1200
40	14-Feb-06	3.20			1.7	0.45	1.25	BM5	40	**600**

Note: The water depth of 1.7 m is the design water depth of flume (Top Black line).
The days I am not sure about the actual depth, I assumed as 1.7 m
The Water Slopes I got from NCED/SAFL but did not find the Bed Slope
Data of Pit Trap and Sonars in this worksheet is with respect of ADCP data

E:\Rauf\For Peter Wilcock\Hydro-Morphological Data-Final

PPLER CURRENT PROFILER

ADCP	ADCP		Continueous weigh pans			Continueous sonars		
Start	End		Start	End				
11:57:51	12:33:05		243928.9	246042.9		no data	no data	
12:36:44	13:07:48		246262.1	248125.7		no data	no data	
13:33:27	14:17:04		249664.7	252281.8		no data	no data	
14:32:15	15:09:34		253193.3	255432.2		no data	no data	
15:13:10	15:46:53		255647.7	257671.1		no data	no data	
12:14:53	13:02:32		2988.1	5848.1		no data	no data	
13:11:04	13:53:21		6359.4	8896.7		6357.00	8897.40	
13:56:34	14:43:49		9090.1	11925.0		9092.00	11927.00	
14:44:00	15:33:08		11935.6	14884.1		11932.80	14887.20	
9:29:55	10:30:30		79492.8	83127.0		79487.10	83127.50	
10:35:20	11:36:05		83417.2	87062.8		83407.10	87067.10	
11:57:56	13:02:35		88374.1	92253.1		88367.20	92267.20	
10:44:15	11:50:32		170337.1	174305.2		Not good data to compare		
11:52:31	13:07:18	13:02:24	174422.7	178605.8		Not good data to compare		
13:47:59	16:42:50	16:36:15	181334.4	191405.3		Not good data to compare		
14:03:43	15:06:04		268598.3	272339.4		268562.40	272341.40	
16:47:45	**18:04:48**		**278440.9**	**283064.3**		**278431.20**	**283071.30**	
18:10:17	**18:34:37**		**283392.4**	**284853.3**		**283391.20**	**284861.00**	
17:16:13	**18:01:50**		**11985.7**	**14722.8**		Not good data to compare		
17:30:46	18:30:48		12859.5	16461.4		Not good data to compare		
11:18:02	13:02:54		76896.0	83188.3		76892.40	83193.80	
13:04:58	14:20:05		83312.2	87819.2		83303.50	87233.10	**ends early**
14:23:43	15:57:05		88038.0	93640.3		No data	No data	
15:57:56	17:44:20		93690.8	100074.4		No data	No data	
15:43:37	17:14:00		1942.0	7365.0		1942.10	7371.90	
10:05:31	11:20:40		68057.4	72566.2		68079.00	72572.00	
11:22:36	14:21:35		72683.0	83422.2	**wt pans**	72682.60	83422.80	
14:24:09	16:07:38		83575.6	89785.3	**ends at**	83572.00	89792.20	
17:54:52	**19:11:37**		**96220.1**	**97445.3**	**0.76**	**96212.10**	**97432.30**	
11:32:01	**12:34:22**		**4058.6**	**7799.6**		**4052.40**	**7802.70**	
12:37:51	**13:09:50**		**8008.7**	**9927.5**		**8002.20**	**9932.30**	
13:12:00	**13:55:40**		**10057.6**	**12677.4**		**10052.10**	**12682.10**	
10:06:35	10:52:41		85372.6	88136.9		85372.70	88142.90	
10:55:44	11:36:48		88319.6	90781.0		88312.10	90782.40	
11:44:04	12:44:11		91216.6	94820.7		91212.10	94822.00	
14:51:37	16:01:40		102460.0	106660.1		102458.30	106668.30	
11:21:13	12:21:21		70761.9	74370.2		70753.50	74373.10	
12:27:05	13:27:17		74713.7	78325.5		74713.80	78333.80	
13:29:36	14:42:24		78464.9	82832.8		78463.50	82833.40	
15:35:14	**16:37:51**		**86003.0**	**89759.9**		**85993.50**	**89763.60**	

Run Time Sec.	Distance MG m	Appearent Bedload Velocity (DMG/Run Time) m/sec	meanvx mean Velocity X-Dir.	stdvx Standerd Deviation X-Dir	meanvy mean Velocity Y-Dir	meanv4x Mean Bed Velocity Beam 4 X-direction	stdv4x Standerd Deviation Beam 4 X-direction	meanv3x Mean Bed Velocity Beam 3 X-direction
2113.51	37.61	0.01780	0.01730	0.03460	0.00320	0.00880	0.03800	0.02620
1863.7	58.28	0.03127	0.03150	0.04780	-0.00270	0.02590	0.05930	0.03710
2617.03	42.63	0.01629	0.01500	0.06670	0.00490	0.01500	0.08900	0.01490
2239.93	44.12	0.01970	0.01820	0.12180	-0.00460	0.03060	0.10300	0.00600
2023.03	71.08	0.03514	0.03680	0.04750	-0.00030	0.02620	0.07090	0.04760
2859.85	60.52	0.02116	0.02140	0.03860	0.00078	0.02560	0.05530	0.01750
2536.8	326.14	0.12856	0.05920	0.07670	-0.01830	0.03470	0.09960	0.08440
2834.71	112.43	0.03966	0.07940	0.10280	0.00960	0.06090	0.13530	0.08560
2948	107.44	0.03645	0.03170	0.23120	0.00860	0.03920	0.37910	0.02930
3634.41	189.99	0.05228	0.05500	0.05920	0.00630	0.04900	0.08470	0.06110
3645.68	198.41	0.05442	0.05670	0.07240	-0.01170	0.02920	0.09500	0.08480
3878.94	152.71	0.03937	0.03930	0.12570	0.00310	0.04480	0.24790	0.03440
3977.51	106.03	0.02666	0.02660	0.03750	-0.00073	0.03400	0.05640	0.01940
4487.05	182.89	0.04076	0.04040	0.04850	-0.00460	0.04160	0.06740	0.03930
10490.73	272.54	0.02598	0.02580	0.08860	0.00009	0.03240	0.14110	0.01990
3741.03	305.1	0.08156	0.09060	0.08790	0.01060	0.08090	0.13780	0.09940
4623.6	364.05	0.07874	0.07950	0.09540	0.00210	0.09210	0.14010	0.06860
1460.8	38.35	0.02625	0.02190	0.11600	0.01780	0.03020	0.15300	0.01680
2737	237.48	0.08677	0.08700	0.14030	-0.01640	0.10840	0.19500	0.07800
3602.31	359.97	0.09993	0.09770	0.08600	0.00640	0.12110	0.12250	0.07630
6292.78	732.41	0.11639	0.12170	0.12330	-0.00640	0.13290	0.17990	0.11100
4507.3	698.06	0.15487	0.13920	0.16750	-0.00490	0.15730	0.25680	0.12250
5601.52	492.72	0.08796	0.09610	0.22930	0.00370	0.10700	0.37460	0.07670
6383.92	935.39	0.14652	0.13120	0.10820	-0.00180	0.14270	0.17060	0.12530
5422.84	20.29	0.00374	0.00380	0.06150	0.00280	0.00930	0.08240	-0.00240
4509.09	16.51	0.00366	0.00330	0.04070	-0.00020	0.00680	0.06690	-0.00023
10739.07	61.38	0.00572	0.00550	0.03190	-0.00072	0.00470	0.04450	0.00630
6208.9	29.62	0.00477	0.00360	0.01910	-0.00320	0.00520	0.02910	0.00200
4604.8	27.65	0.00600	0.00570	0.03520	-0.00340	0.00300	0.03540	0.00840
3740.4	48.03	0.01284	0.0135	0.0497	0.0008903	0.012	0.0687	0.015
1919.6	44.16	0.02300	0.02340	0.11520	-0.00290	0.01560	0.15180	0.03230
2620	38.89	0.01484	0.01600	0.10920	-0.00640	0.00930	0.15810	0.02340
2766.18	37.55	0.01357	0.01570	0.06570	0.00240	0.02850	0.10630	0.00052
2464.24	49.5	0.02009	0.02010	0.03880	-0.00150	0.01330	0.05100	0.02680
3607.39	99.44	0.02757	0.02800	0.04110	-0.00130	0.03290	0.05700	0.02310
4202.32	306.6	0.07296	0.07420	0.06920	0.00520	0.08760	0.09490	0.06020
3607.7	282.31	0.07825	0.08090	0.09620	0.00500	0.09520	0.13110	0.06700
3611.49	275.16	0.07619	0.06960	0.14840	-0.00520	0.07260	0.23430	0.06920
4368	253.5	0.05804	0.06010	0.07070	0.00130	0.06730	0.11250	0.05310
3757.6	**264.59**	0.07041	0.07310	0.09020	-0.00120	0.09950	0.13350	0.04750

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stdv3x	Avg	Avg	Weigh Pan data analysis						
Standerd Deviation Beam 3 X-direction	Sediment Depth Beam 3	Sediment Depth Beam 4	PAN NO:1 Meanrate	Stdrate	PAN NO:2 Meanrate	Stdrate	PAN NO:3 Meanrate	Stdrate	PAN NO:4 Meanrate
0.05740	0.25970	0.10010	0.00800	0.26420	0.02170	0.26230	0.03630	0.27350	0.04440
0.06800	0.21220	0.11110	0.00680	0.25860	0.01420	0.30000	0.02570	0.29720	0.02110
0.10300	0.18650	0.14890	0.00430	0.30900	0.00810	0.32310	-0.00140	0.33400	0.00260
0.20590	0.20490	0.18170	0.00220	0.37430	0.00940	0.38590	0.00670	0.40750	0.03160
0.07310	0.27070	0.17770	0.01410	0.37830	0.05930	0.39670	0.04010	0.39500	0.01360
0.05580	0.32020	0.24720	0.02220	0.21950	0.03890	0.23800	0.02740	0.22900	0.01360
0.12140	0.43040	0.32410	0.02280	0.29350	0.02440	0.27240	0.03150	0.27810	0.05400
0.15240	0.35520	0.38800	0.03040	0.28960	0.07580	0.29960	0.09110	0.31310	0.05230
0.11700	0.29050	0.34750	0.08060	0.30990	0.11690	0.35570	0.07070	0.30750	0.80650
0.09360	0.33280	0.34030	0.07810	0.32340	0.11460	0.33140	0.13300	0.35320	0.11270
0.12820	0.34300	0.30670	0.10730	0.33250	0.11560	0.34510	0.15020	0.37940	0.12950
0.26610	0.28550	0.28200	0.09060	0.30680	0.10620	0.29630	0.08600	0.31830	0.05830
0.04840	0.23140	0.19080	0.06820	0.25220	0.06170	0.27940	0.05870	0.30500	0.04060
0.06830	0.25580	0.18180	0.0389	0.2602	0.0543	0.3203	0.0456	0.3292	0.037
0.09320	0.18110	0.17990	0.03950	0.26750	0.05700	0.27850	0.05640	0.28980	0.04400
0.13590	0.44750	0.38490	0.05750	0.33360	0.09400	0.32710	0.10320	0.35330	0.13990
0.12930	0.45440	0.38160	0.1547	0.3163	0.1468	0.3619	0.1199	0.3403	0.1061
0.16610	0.37440	0.36820	0.09510	0.32940	0.14200	0.29320	0.16790	0.33500	0.17330
0.18800	0.28120	0.25250	0.05650	0.34570	0.10270	0.44500	0.14770	0.46740	0.17840
0.10770	0.31360	0.03370	0.06450	1.30710	0.15210	0.45330	0.16200	0.47070	0.18180
0.14950	0.37870	0.29590	0.13550	0.44140	0.17390	0.47310	0.18080	0.49230	0.18290
0.24820	0.39300	0.32290	0.15750	0.48290	0.20550	0.51780	0.18540	0.54420	0.16630
0.35140	0.33340	0.28130	0.14780	0.44660	0.20360	0.49720	0.22320	0.53950	0.21030
0.17240	0.41660	0.34760	0.17220	0.48220	0.20530	0.49830	0.21180	0.49660	0.21900
0.09060	0.35720	0.25900	0.03170	0.13960	0.03740	0.13730	0.02390	0.14730	0.01110
0.04700	0.27410	0.32000	0.02170	0.12490	0.01560	0.14170	0.00120	0.14230	0.00460
0.04550	0.35570	0.28060	0.00830	0.13550	0.01380	0.13010	0.01280	0.14150	0.01050
0.02460	0.35080	0.31540	0.01240	0.12860	0.01330	0.12830	0.00880	0.12000	0.00210
0.06060	0.38180	0.26980	0.02500	0.14220	0.01540	0.12000	0.00920	0.12110	0.01330
0.0726	0.37810	0.26670	0.0104	0.1608	0.0228	0.1683	0.0202	0.166	0.0269
0.16970	0.35000	0.30030	0.01820	0.17050	0.01610	0.18360	0.03360	0.16470	0.02880
0.15000	0.31880	0.33300	0.04300	0.18980	0.03930	0.19380	0.00410	0.17070	0.01210
0.07990	0.25010	0.31380	0.0483	0.1925	0.0567	0.202	0.0095	0.1906	0.0207
0.06030	0.32750	0.22960	0.04530	0.19120	0.06220	0.22080	0.04890	0.21990	0.05490
0.05710	0.33370	0.26670	0.00690	0.19170	0.01040	0.16780	0.01970	0.16110	0.01780
0.08560	0.33300	0.30880	0.10470	0.37810	0.12010	0.36820	0.08420	0.40080	0.07440
0.12400	0.35830	0.33410	0.10850	0.37970	0.15580	0.39370	0.13670	0.39560	0.11130
0.15600	0.37850	0.30230	0.1123	0.3718	0.1019	0.3512	0.1056	0.3607	0.1065
0.84000	0.37340	0.32570	0.12560	0.31140	0.11630	0.32140	0.11560	0.35860	0.10420
0.11840	0.36530	0.32970	0.15600	0.39060	0.16360	0.41680	0.14120	0.40120	0.14920

Stdrate	PAN NO:5 Meanrate	Stdrate	Mean Timestep	Num to Averag	ADCP Starrt Time	Corrospor Wt.Pan Time	Mean ADCP Timestep	numto avg	Continueous
0.26540	0.01640	0.25610	1.16410	12	11:57:51	243928.9	0.26930	55	no data
0.28860	0.02330	0.28510	1.16620	12	12:36:44	246262	0.2139	69	no data
0.32640	0.01610	0.31420	1.16830	12	13:33:27	249665	0.2016	73	no data
0.42940	0.00330	0.36830	1.16490	12	14:32:15	253193	0.2012	74	no data
0.36400	-0.00180	0.35910	1.16960	12	15:13:10	255648	0.2135	69	no data
0.21490	0.00780	0.22740	1.18570	12	12:14:53	2988.1	0.2717	54	no data
0.27100	0.07180	0.27530	1.18620	12	13:11:04	6359.4	0.2125	70	6357.00
0.29330	0.01300	0.32510	1.18620	12	13:56:34	9090.1	0.2033	73	9092.00
0.32180	0.08450	0.31470	1.18600	12	14:44:00	11935	0.2039	73	11932.80
0.32960	0.11250	0.32000	1.18610	12	9:29:55	87022.5	0.2725	54	79487.10
0.37430	0.09910	0.36460	1.18580	12	10:35:20	90948	0.2147	69	83407.10
0.28500	0.04820	0.30870	1.18520	12	11:57:56	95904	0.2051	72	88367.20
0.23910	0.02870	0.22170	1.18590	12	10:44:15	170337	0.2732	54	Not good da
0.2204	0.044	0.2131	1.1864	12	11:52:31	174423	0.2151	69	Not good da
0.24710	0.03370	0.26320	1.18690	12	13:47:59	181334	0.2035	73	Not good da
0.35840	0.15890	0.38700	1.18770	12	14:03:43	268598	0.2298	64	268562.40
0.3071	0.0966	0.3068	1.4231	10	16:47:45	278441	0.4	37	**278431.20**
0.34550	0.15120	0.32140	1.44930	9	18:10:17	283392	0.3999	37	**283391.20**
0.41690	0.19020	0.43930	1.17420	12	16:59:18	10971.3	0.3995	37	Not good da
0.41150	0.20000	0.43260	1.17400	12	17:16:13	11985.7	0.3999	37	Not good da
0.44810	0.16160	0.44910	1.17660	12	11:18:02	76896.0	0.24680	60	76892.40
0.47250	0.14240	0.47720	1.17660	12	13:04:58	83312.2	0.2468	60	83303.50
0.45820	0.19350	0.47290	1.18050	12	14:23:43	88038	0.2092	71	No data
0.46270	0.19130	0.48380	1.17520	12	15:57:50	93685	0.1941	76	No data
0.11680	0.00550	0.14280	1.08550	13	15:43:37	1942.0	0.19760	75	1942.10
0.13090	0.00570	0.14900	1.08100	13	10:05:31	68057.4	0.19740	75	68079.00
0.14040	0.01130	0.14450	1.08160	13	11:22:36	72683	0.2008	74	72682.60
0.12880	0.00130	0.15090	1.08070	13	14:24:09	83575.6	0.2731	54	83572.00
0.14090	0.01740	0.14840	1.08140	13	17:54:52	96220.1	0.4	37	**96212.10**
0.1769	0.0301	0.1861	1.0818	13	11:32:01	4058.6	0.4	37	**4052.40**
0.18530	0.02860	0.18480	1.08530	13	12:37:51	8008.7	0.3999	37	**8002.20**
0.18450	0.02600	0.18370	1.08480	13	13:12:00	10057.6	0.3999	37	**10052.10**
0.1986	0.0349	0.2261	1.0811	13	10:06:35	85372	0.2039	73	85372.70
0.19320	0.05010	0.21260	1.08100	13	10:55:44	88319.6	0.2098	70	88312.10
0.16190	0.01650	0.17460	1.08070	13	11:44:04	91216.6	0.2098	70	91212.10
0.37060	0.06480	0.38660	1.08140	13	14:51:37	102460	0.265	56	102458.30
0.38320	0.09970	0.39080	1.08320	13	11:21:13	70761.9	0.1997	74	70753.50
0.3885	0.1001	0.4256	1.0801	13	12:27:05	74713.7	0.1997	74	74713.80
0.34330	0.11430	0.33450	1.08010	13	13:29:36	78464.9	0.1997	74	78463.50
0.40570	0.14360	0.41250	.1.0825	13	15:35:14	86003	0.1997	74	**85993.50**

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sonars		Pan Ist Time	Mean Ht. Sonar 1 for ADCP Time	Mean Ht. Sonar 2 for ADCP Time	Mean Ht. Sonar 3 for ADCP Time	Mean Ht. Sonar 4 for ADCP Time	Mean Ht. Sonar 5 for ADCP Time	Mean Ht. Sonar 6 for ADCP Time
no data		243928.9						
no data		246262.1						
no data		249664.7						
no data		253193.3						
no data		255647.7						
no data		2988.1		no data				
8897.40		6359.4	not agood data					
11927.00		9090.1	not agood data					
14887.20		11935.6	not agood data					
83127.50		79492.8						
87067.10		83417.2						
92267.20		88374.1						
ta to compare		170337.1		Data Started at 6:00 PM and ended at 9:00 PM				
ta to compare		174422.7						
ta to compare		181334.4						
272341.40		268598.3						
283071.30		**278440.9**						
284861.00		**283392.4**						
ta to compare		**11985.7**					NOT ENOUGH DATA	
ta to compare		12859.5					NOT ENOUGH DATA	
83193.80		76896.0	-	737.96690	726.12230	-	-	-
87233.10	**ends early**	83312.2					NOT ENOUGH DATA	
No data		88038.0					NOT ENOUGH DATA	
No data		93690.8					NOT ENOUGH DATA	
7371.90		1942.0	327.60090	370.60090	300.96730	346.09040	363.92150	330.89100
72572.00		68057.4	290.41780	263.00640	287.48070	252.65780	256.45820	343.71420
83422.80		72683.0	330.1451	297.2841	271.5364	262.9908	225.4021	329.5831
89792.20		83575.6	315.0672	289.2117	230.5474	248.1114	256.8064	325.1416
97432.30		**96220.1**						dir
7802.70		**4058.6**	227.746	207.9543	241.7561	252.6796	232.5426	320.6208
9932.30		**8008.7**	231.4316	270.2249	246.2409	185.9606	173.8228	350.3642
12682.10		**10057.6**	200.4198	181.5224	275.2369	244.8403	135.7198	333.8175
88142.90		85372.6	337.1559	309.9688	310.8369	276.3373	286.719	337.6753
90782.40		88319.6	264.7643	181.1281	216.0329	218.9855	210.4177	350.8233
94822.00		91216.6	345.1988	259.0028	194.2656	229.5672	196.064	309.0466
106668.30		102460.0	300.5045	275.8711	258.4277	223.8564	216.2227	360.9055
74373.10		70761.9	320.8821	329.227	301.392	272.0388	237.83	328.8331
78333.80		74713.7	341.3154	337.6538	273.3904	215.2992	159.7734	241.319
82833.40		78464.9	319.2294	315.0399	280.1875	244.8501	204.6211	257.9283
89763.60		**86003.0**	382.9554	350.832	309.8948	314.884	338.1226	225.7069

	Results of MATLAB Comibed File								
Mean Ht. Sonar 7 for ADCP Time	Lag B/V Beams 3 & 4 sec	Mean Vertical Range fror ADCP	Distance B/W Beams	Celerity ADCP	Lag Time B/W Sonars 3 & 6	Celerity Sonar Dune Prob 3 & 6	Dune Height Manually mm	Lag Time B/W Sonars 6 & 7	Celerity Sonar Dune Prob 6 & 7
	no	1.2465	1.044	0.001					
	75	1.2328	1.034	0.013					
	1257	1.2558	1.051	0.001					
	745	1.2455	1.044	0.001					
	980	1.1711	0.990	0.001					
	883	1.1343	0.963	0.001					
	925	1.0539	0.904	0.001					
	925	1.0332	0.889	0.001	Assumed Lag as 925 b/s blank screen				
	760	1.0932	0.933	0.001					
	720	1.0776	0.921	0.001					
	850	1.0937	0.933	0.001					
	1153	1.1311	0.960	0.001					
	735	1.2091	1.017	0.001					
	660	1.2067	1.015	0.002					
	800	1.2286	1.301	0.001					
	340	0.9951	0.861	0.003		No Data			
	440	1.0015	0.866	0.002		No Data			
	440	1.0413	0.895	0.002					
)F SONAR	137	1.1038	0.941	0.007					
)F SONAR	835	1.1465	0.972	0.001					
-	306	1.08110	0.924	0.003	No data on the scerrn				
)F SONAR	305	1.0811	0.924	0.003	GOOD ADCP data				
)F SONAR	300	1.0482	0.900	0.003					
)F SONAR	300	1.1081	0.944	0.003					
281.57260	300	1.10090	0.938	0.003	3350	0.0021	4.0000	NO DATA	
284.29690	185	1.12170	0.954	0.005	2860	0.0025	3.0000	620	0.0081
292.1342	150	1.0975	0.936	0.006	2860	0.0025	3.0000	620	0.0081
272.5299	800	1.0869	0.928	0.001	2860	0.0025	5.0000	620	0.0081
	930	1.0978	0.936	0.001			2.0000		
322.0972	1460	1.1161	0.949	0.001	2900	0.0024	6.0000	1810	0.0028
373.3228	90	1.0887	0.930	0.010	2900	0.0024	6.0000	1810	0.0028
332.7449	91	1.0881	0.929	0.010	2900	0.0024	8.0000	1810	0.0028
292.6022	120	1.1473	0.972	0.008	1100	0.0065	8.0000	2300	0.0022
250.5715	1	1.1165	0.950	0.950	1100	0.0065	8.0000	2300	0.0022
352.1215	1	1.1165	0.950	0.950	1100	0.0065	6.0000	2300	0.0022
336.6685	210	1.0927	0.932	0.004	1100	0.0065		2300	0.0022
296.8711	440	1.0782	0.922	0.002	5250	0.0014	30.0000	4650	0.0011
360.2374	440	1.0782	0.922	0.002	5250	0.0014	25.0000	4650	0.0011
388.064	440	1.0782	0.922	0.002	5250	0.0014	34.0000	4650	0.0011
400.0868	440	1.0782	0.922	0.002	5250	0.0014	30.0000	4650	0.0011

Comments
assumed 1000

From 13:02 to 13:09 approximately 7 min. data is missing in sonars
In this set of adcp data the figure with combined code was empty so I assumed 800 is the lag time
From 16:36 to 16:44 approximately 7 min. data is missing again in sonars for the above data

No data on the screen

No data on the screen

No data on the screen of ADCP fig. so assumed a300 lag time
No data on the screen of ADCP fig. so assumed a300 lag time

Not agood corelation b/w adcp beams and in -ve
Good data

Not agood corelation b/w adcp beams and in -ve
Not agood corelation b/w adcp beams and in -ve

ADCP, weigh pans and Sonars matching time - GRAVEL

Sr. No:	Date	Disch (m3/s)	Water Slope	Bed Slope	Flow Depth From Flume Floor meters (m)	Nominal sediment depth (m)	Nominal water depth (m)	Mean water depth (m)	Avg WSEL Wall Tapes (m)	Avg BSEL Avg of Last Measure (m)	Avg. Water Slope
1	3-Mar	3.40			1.7	0.62	1.08	Not measured			
2	3-Mar	3.40			1.7	0.62	1.08	for 3.4 and	Not Collecte	Not Collecte	Not Collect
3	3-Mar	3.90									
4	9-Mar	3.90			1.7	0.45	1.25	discharges	Test Runs	Test Runs	Test Runs
5	9-Mar	3.90									
6	9-Mar	3.90									
7	9-Mar	3.90									
8	10-Mar	3.90									
9	10-Mar	3.90			1.7	0.45	1.25				
10	12-Mar	5.50			1.6	0.45	1.15				
11	12-Mar	5.50			1.6	0.45	1.15	1.195	0.261	Not Collecte	0.0044
12	12-Mar	5.50									
13	14-Mar	5.50									
14	14-Mar	5.50									
15	14-Mar	5.50									
16	14-Mar	5.50									
17	14-Mar	5.50									
18	14-Mar	5.50			1.6	0.45	1.15				
19	14-Mar	5.50	0.00435		1.6	0.45	1.15				
20	15-Mar	4.00	0.00115		1.7	0.45	1.25				
21	15-Mar	4.00									
22	15-Mar	4.00									
23	15-Mar	4.00									
24	16-Mar	4.00	0.0013		1.7	0.45	1.25				
25	16-Mar	4.00			1.7	0.45	1.25				
26	16-Mar	4.00									
27	16-Mar	4.00									
28	16-Mar	4.00									
29	16-Mar	4.00									
30	16-Mar	4.00									
31	16-Mar	4.00									
32	17-Mar	4.00	0.001	0.0144	1.7	0.45	1.25	1.172	0.232	1.369	0.0012
33	17-Mar	4.00									
34	17-Mar	4.00									
35	17-Mar	4.00									
36	17-Mar	4.00									
37	21-Mar	4.04	0.0013	0.0121	1.7	0.45	1.25				
38	21-Mar	4.04									
39	21-Mar	4.04									
40	21-Mar	4.04									
41	21-Mar	4.04									
42	22-Mar	4.04	0.0018	0.01277	1.7	0.45	1.25				
43	22-Mar	4.04									
44	25-Mar	4.30	0.002	0.00625	1.7	0.45	1.25	1.173	0.224	1.363	0.0023
45	25-Mar	4.30						Measured on 24th of March			
46	25-Mar	4.30									
47	25-Mar	4.30									
48	25-Mar	4.30									
49	25-Mar	4.30									
50	28-Mar	4.90	0.00315	0.0059	1.7	0.45	1.25	1.164	0.218	1.378	0.0034
51	28-Mar	4.90						Measured on 27th of March			
52	28-Mar	4.90									
53	28-Mar	4.90									
54	29-Mar	4.90									
55	29-Mar	4.90									
56	29-Mar	4.90	0.0038	0.00515	1.7	0.45	1.25				

SAFL staff measured water surface elevations using two methods.
First by using Point Gauge (Three point gauges) and second by using Wall Markings (Five Wall markings from d/s of the Design s
They found errors in using point gauge and then decided to move to Wall Marking method to measure water surface elevation by
The data in this worksheet utilize the Wall Markings Approach if available (from March 12/13 (not sure) To March 29)

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ACOUSTIC DOPPLER CURRENT PROFILER

Avg. Bed Slope	Mode	&R	ADCP Type	ADCP Start	ADCP End		Continueous weigh pans Start	Continueous weigh pans End	Continueous sonar data	
	BM5	40	1200	11:25:52	12:20:24		1773.70	5045.4	No Data	No Data
Not Collecte	BM5	40	**600**	13:11:23	13:22:52		8104.90	**8794.3**	**No Data**	**No Data**
	BM5	40	1200	14:46:41	16:08:23		3361.70	8263.4	No Data	No Data
Test Runs	BM5	30	1200	12:01:55	12:33:35		9684.50	11584.8	9683.2	11592.4
	BM5	40	1200	12:47:40	14:11:43		12430.10	17473.3	12423	17473.3
	BM5	20	1200	14:16:12	16:23:16		17742.10	25366	17733.2	25372.9
	BM5	20	**600**	16:55:28	17:14:57		**27297.60**	**28467.3**	**27292.8**	**28473.1**
	BM5	30	1200	11:29:24	13:47:17		11189.30	19462.8	11183	19463.2
	BM5	40	1200	13:52:54	14:51:51	no good da	19799.30	23336.4	19793.3	23272.8
	BM5	20	1200	11:57:12	12:58:11		4504.20	8163.7	4503.9	8163.8
Not Collecte	BM5	30	1200	13:18:01	14:22:55		9354.10	13247.8	9353.8	13253.3
	BM5	40	1200	14:25:07	16:05:25		13379.90	19397.6	13373.6	19403.5
	BM5	30	1200	12:20:30	12:44:24	no good da	8956.70	10387.6	8953.8	10393.4
	BM5	20	1200	13:37:52	13:40:31		13587.00	13746.1	13583.4	13752.9
	BM5	40	1200	13:43:15	14:10:44		13909.80	15554.9	13903	15563.7
	BM5	20	1200	16:05:23	16:28:15		22417.00	23785.6	22413.7	23793.1
	BM5	40	1200	16:30:25	17:02:06		23915.30	25811.1	23914.2	25813.5
	BM5	**40**	**600**	**17:23:06**	**17:53:13**		**27068.50**	**28870.4**	**27063.6**	**28873.6**
	BM5	**40**	**600**	**17:20:29**	**17:21:28**	**w pan sta**	**26911.50**	**26970**	**26903.6**	**26973.6**
	BM5	20	1200	14:01:13	14:14:35	14:02:28	0.00	726.6	163.5	735.5
	BM5	20	1200	14:15:09	15:18:54		760.00	4585.3	755.5	4586.1
	BM5	30	1200	15:22:11	16:38:44		4782.40	9375.5	4776	9376
	BM5	40	1200	16:40:38	16:58:20		9490.10	10551.6	9485.8	10555.5
	BM5	40	1200	15:00:16	16:29:18		608.60	5951.3	603.1	5952.9
	BM5	30	1200	16:31:27	17:42:28		6079.80	10341.2	6072.9	10343.2
	BM5	20	1200	17:46:29	19:03:37		10582.20	15210	10573.4	15213.5
	BM5	40	**600**	19:16:59	20:07:36		16012.30	**19049.7**	**16003.8**	**19053**
	BM5	40	**600**	20:09:48	20:10:40	no data	19181.60	**19233.5**	**19173.5**	**19233.6**
	BM5	40	**600**	20:11:22	20:20:57		19275.60	**19850.5**	**19273.7**	**19853.5**
	BM5	20	**600**	20:22:23	20:32:12		19935.80	**20525.4**	**19933.5**	**20533.6**
	BM5	20	**600**	20:43:09	21:13:49		21182.00	**23022**	**21173.7**	**23023.6**
0.0144	BM5	20	**600**	10:01:22	10:37:51		7199.10	**9469**	**7195**	**9475.1**
	BM5	20	1200	11:20:06	11:51:26		12004.20	13884.4	11995.7	13885.8
	BM5	20	1200	17:20:03	17:50:13		33601.30	35411.8	33595	35415
	BM5	30	1200	17:51:52	18:22:46		35510.10	37363.9	35505.7	37365.5
	BM5	40	1200	18:23:27	18:35:34		37404.90	38132.3	37395.5	38135
	BM5	40	1200	15:04:54	15:35:38		10555.40	12398.8	10546.9	12406.6
	BM5	30	1200	15:37:14	16:17:28		12495.00	14909.5	12486.8	14916.4
	BM5	20	1200	16:18:24	17:05:48		14964.60	17809.6	14956.3	17816.1
	BM5	40	**600**	17:34:35	17:57:20		19536.50	**20901.7**	**19526.2**	**20906.5**
	BM5	30	**600**	17:59:28	18:19:34		21029.10	**22235.5**	**21026.4**	**21826.2**
	BM5	20	**600**	16:46:43	17:01:04		31770.10	**32631.2**	**31769**	**32639**
	BM5	20	**600**	17:03:02	18:09:35		32748.90	**36742.6**	**32748.5**	**36748.9**
0.0047	BM5	40	1200	15:47:15	16:47:20		28602.30	32207.8	28600.6	32211
	BM5	30	1200	16:48:25	17:51:10		32272.80	36037.5	32270.6	36040.7
	BM5	20	1200	17:52:46	18:53:37		36133.90	39784.4	36130.3	39790.2
	BM5	40	**600**	12:01:38	13:24:39		15064.60	**20045.90**	**15060.7**	**20050.5**
	BM5	30	**600**	13:25:28	14:28:35		20094.60	**23882.00**	**20090.2**	**23890.5**
	BM5	20	**600**	14:30:23	15:32:24		23990.10	**27711.20**	**23980.3**	**27721**
0.0049	BM5	40	1200	16:25:57	17:48:09		27807.30	32739.20	27803.7	32743.3
	BM5	30	1200	17:49:42	18:41:56		32832.40	35966.20	32823.6	35973.7
	BM5	30	1200	18:49:23	19:27:22		36413.90	38693.00	36413.8	38693.1
	BM5	20	1200	19:28:36	20:35:41		38766.60	42791.90	38763.7	42793.7
	BM5	20	**600**	11:14:40	12:15:26		3918.40	**7564.5**	**3913.4**	**7573.1**
	BM5	30	**600**	12:18:16	14:01:51		7734.50	**13950.3**	**7733.5**	**13953.6**
	BM5	40	**600**	14:03:09	15:18:05		14027.20	**18523.4**	**14023.7**	**18533**

ection at 0, 4, 8, 12 and 16 meters)
eye visualization

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Sec.	Run Time	Distance MG m	Appearent Bedload Velocity DMG/Run Time m/sec	meanvx mean Velocity X-Dir.	stdvx Standerd Deviation X-Dir	meanvy mean Velocity Y-Dir	meanv4x Mean Bed Velocity Beam 4 X-direction	stdv4x Standerd Deviation Beam 4 X-direction	meanv3x Mean Bed Velocity Beam 3 X-direction
	3271.65	85.18	0.0260	0.0213	0.0399	0.0016	0.0196	0.0533	0.0221
	688.8	38.26	0.0555	0.0314	0.0981	0.0027	0.0282	0.1239	0.0368
	4901.77	210.79	0.0430	0.0362	0.2042	-0.0003	0.0352	0.2880	0.0382
7.6	1900.14	60.25	0.0317	0.0175	0.0579	0.0024	0.0177	0.0883	0.0114
	5042.13	145.84	0.0289	0.0260	0.0544	0.0005	0.0242	0.0725	0.0232
8.90	7624.22	265.92	0.0349	0.0134	0.0761	-0.0005	0.0066	0.1086	0.0196
	1169.6	0	0.0000	NaN	NaN	NaN	NaN	NaN	NaN
	8272.73	464.09	0.0561	0.0152	0.0690	-0.0010	0.0132	0.1074	0.0148
finished early	3537.41	0	0.0000	NaN	NaN	NaN	NaN	NaN	NaN
	3659.33	180.93	0.0494	0.0948	0.1371	-0.0010	0.0827	0.1909	0.0968
	3894.62	392.05	0.1007	0.0963	0.2105	0.0005988	0.1112	0.3363	0.0818
	6017.86	686.31	0.1140	0.1247	0.1933	-0.0057	0.1238	0.2632	0.1254
	1434.26	0	0.0000	NaN	NaN	NaN	NaN	NaN	NaN
	158.65	0	0.0000	NaN	NaN	NaN	NaN	NaN	NaN
	1648.82	0	0.0000	NaN	NaN	NaN	NaN	NaN	NaN
	1372.15	55.4	0.0404	0.0458	0.3449	-0.0070	0.0253	0.4597	0.0663
	1900.9	227.72	0.1198	0.1050	0.3528	-0.0066	0.1038	0.5140	0.1062
	1807.2	505.42	0.2797	0.2829	0.2039	0.0173	0.3363	0.2881	0.2287
	58.4	10.52	0.1801	Seems to be on 9th of March, but ignored because data is less than 1 min.					
not good sona	802.03	1.1	0.0014	0.0004	0.0850	0.0024	-0.0015	0.1257	0.0023
	3825.56	86.28	0.0226	0.0272	0.0806	-0.0027	0.0366	0.1288	0.0178
	4593.29	92.59	0.0202	0.0172	0.0653	-0.0026	0.0326	0.1204	0.0032
	1062.1	98.72	0.0929	0.0940	0.0616	0.0019	0.1196	0.0939	0.0685
	5341.57	528.19	0.0989	0.1035	0.0605	0.0011	0.1621	0.1002	0.0450
	4261.38	83.56	0.0196	0.0198	0.0636	-0.0015	0.0246	0.1023	0.0154
	4628.3	121.1	0.0262	0.0303	0.0899	0.0009	0.0234	0.1171	0.0372
	3036.8	378.39	0.1246	0.1302	0.1376	-0.0023	0.1537	0.1961	0.1092
	51.2	0	0.0000	NaN	NaN	NaN	NaN	NaN	NaN
	575.2	108.69	0.1890	0.1551	0.1607	-0.0207	0.1878	0.2302	0.1190
	589.2	61.53	0.1044	0.1045	0.1927	0.0066	0.1585	0.3092	0.0498
	1840	98.6	0.0536	0.0533	0.1849	0.0089	0.0591	0.2902	0.0487
	2188.8	135.52	0.0619	0.0677	0.1922	0.0016	0.0886	0.2789	0.047
	1880.32	50.66	0.0269	0.0326	0.0910	-0.0049	0.0448	0.1410	0.0204
	1810.01	58.59	0.0324	0.0392	0.0998	-0.0022	0.0402	0.1352	0.0383
	1854.4	48.1	0.0259	0.0242	0.0815	0.0043	0.0401	0.1117	0.0106
	726.92	85.74	0.1179	0.1170	0.0677	0.0016	0.1477	0.0971	0.0873
	1844.01	112.27	0.0609	0.0615	0.0535	-0.0032	0.0552	0.0748	0.0678
	2414.51	30.34	0.0126	0.0106	0.0729	-0.0046	0.0039	0.1075	0.0163
	2843.87	67.09	0.0236	0.0282	0.0806	-0.0067	0.0218	0.1023	0.0346
	1999.2	237.21	0.1187	0.1225	0.1257	-0.0006	0.1671	0.1849	0.0792
finished earl	1206	72.34	0.0600	0.0452	0.1701	-0.0312	0.0608	0.2200	0.0278
	860.4	64.7	0.0752	0.0916	0.2115	-0.0134	0.1471	0.3287	0.0391
	3992.4	329.84	0.0826	0.1011	0.1992	-0.0374	0.1378	0.3010	0.0650
	4981.6	458.94	0.0921	0.0846	0.0606	-0.0014	0.0801	0.0875	0.0890
	3786.8	150.63	0.0398	0.0129	0.0723	-0.0025	0.0136	0.0929	0.0114
	3720.8	195.13	0.0524	0.0281	0.0791	0.0003	0.0182	0.0998	0.0380
	3604.85	301.78	0.0837	0.0985	0.1139	0.0027	0.1154	0.1582	0.0818
	3764.91	42.72	0.0113	0.0487	0.1658	-0.0044	0.0380	0.1723	0.0585
	3651.67	84.72	0.0232	0.0569	0.1657	-0.0100	0.0442	0.1859	0.0684
	4932.37	558.68	0.1133	0.1152	0.0738	0.0028	0.1261	0.1077	0.1043
	3133.9	107.85	0.0344	0.0340	0.0796	0.0002	0.0432	0.1154	0.0265
	2279.34	71.92	0.0316	0.0309	0.0781	-0.0009	0.0440	0.1133	0.0207
	4024.28	210.81	0.0524	0.0577	0.1016	-0.0025	0.0597	0.1434	0.0558
	3646.4	233.66	0.0641	0.0688	0.1686	-0.0020	0.0772	0.2378	0.0614
	6215.2	588.3	0.0947	0.0963	0.1762	-0.0106	0.1114	0.2515	0.0824
	4495.6	753.49	0.1676	0.1705	0.1381	-0.0031	0.2072	0.2025	0.1346

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stdv3x	Avg	Avg		Weigh Pan data analysis					
Standerd Deviation Beam 3 *X-direction*	Sediment Depth Beam 3	Sediment Depth Beam 4	Beam 3 & 4 Time Series	PAN NO:1 Meanrate	Stdrate	PAN NO:2 Meanrate	Stdrate	PAN NO:3 Meanrate	Stdrate
0.0602	0.4795	0.4413		0.0023	0.4095	0.0074	0.3372	0.0042	0.3490
0.1721	0.5093	0.4973		0.0025	0.4385	0.0027	0.4030	0.0078	0.3534
0.2133	0.6359	0.5390		0.0267	0.4893	0.0745	0.5008	0.0720	0.5187
0.0956	0.4426	0.4209		0.0060	0.5318	0.0006	0.4981	0.0010	0.6002
0.0756	0.4535	0.4401		0.0036	0.4968	0.0025	0.4449	0.0020	0.4948
0.1110	0.4735	0.4308		0.0024	0.4915	0.0071	0.3969	0.0051	0.4149
NaN	NaN	NaN		0.0029	0.4477	0.0019	0.3590	0.0033	0.3852
0.0931	0.4658	0.4200		0.0040	0.4729	0.0037	0.4358	0.0019	0.4395
NaN	0.4324	0.4300		0.0021	0.5089	0.0031	0.4070	0.0023	0.4271
0.1960	0.4416	0.3912		0.5376	1.1871	0.8492	1.2351	0.6598	1.0341
0.2677	0.4732	0.4407		0.8059	1.2801	1.1921	1.3920	1.0694	1.2751
0.2286	0.4549	0.4018		0.7070	1.2262	1.1335	1.3634	0.9644	1.2258
NaN	0.5204	0.4892		0.5692	1.2225	0.9051	1.4349	0.4074	2.4892
NaN	0.4675	0.4433		1.5230	0.9398	0.7330	0.8966	0.3968	0.7574
NaN	0.5320	0.4550		0.4498	0.9998	0.8302	1.0787	0.7432	1.0066
0.5069	0.5011	0.4286		0.6964	1.1135	0.7514	1.2716	0.7010	1.0988
0.4704	0.4405	0.4103		0.8865	1.1032	1.2412	1.1993	0.9236	1.0536
0.2731	0.4381	0.3809		0.5637	1.0387	0.7960	1.1838	0.6680	1.0735
				0.4973	0.6527	0.8819	0.6344	0.5942	0.8370
0.1120	0.4000	0.4000		-0.0009475	0.6018	0.0046	0.5087	0.0028	0.4435
0.0972	0.4000	0.4000		0.0008428	0.5823	0.0032	0.4885	0.0040	0.4494
0.0522	0.3629	0.3601		0.00089501	0.5663	0.0018	0.4636	0.0040	0.4365
0.0768	0.4001	0.3984		0.00059045	0.6076	0.0006333	0.4582	0.0022	0.4273
0.0658	0.4000	0.3780		0.00035843	0.4293	0.0016	0.3947	0.0015	0.4255
0.0762	0.3963	0.3583		-0.0008622	0.4206	0.0027	0.3721	0.0014	0.3854
0.1361	0.4293	0.3788		0.00060903	0.3906	0.0021	0.3505	0.0017	0.3863
0.1953	0.3894	0.3592		0.00050257	0.4018	0.0011	0.3443	0.0015	0.3665
NaN	NaN	NaN		0.0052	0.3266	0.0048	0.2721	-0.0025	0.2485
0.2311	0.3682	0.3450		0.00074181	0.3957	0.0022	0.3241	0.000211	0.3455
0.2254	0.4084	0.3596		-0.00066	0.3974	-0.00031144	0.3271	0.00022459	0.3344
0.2284	0.4082	0.3603		0.00062579	0.3934	0.0014	0.3350	0.00078449	0.3495
0.263	0.4063	0.3524		0.00011828	0.4055	0.0012	0.3790	0.0015	0.4599
0.1138	0.4224	0.3927		-4.693E-05	0.3995	0.00096721	0.3751	0.0012	0.4465
0.1491	0.4800	0.4002		0.0014	0.3698	0.0024	0.3447	0.0078	0.4008
0.1171	0.4402	0.3678		0.00075349	0.3701	0.0024	0.3356	0.0057	0.4046
0.0884	0.4797	0.3998		-0.0005903	0.4166	-0.0049	0.3651	0.0056	0.3755
0.0803	0.4773	0.4000		0.0011	0.5413	0.00049726	0.4839	0.006	0.4595
0.0983	0.4399	0.3605		-0.000413	0.5402	0.00010246	0.4805	0.0043	0.4625
0.1242	0.4788	0.3998		-9.711E-06	0.5602	0.0006706	0.4876	0.0040	0.4897
0.1690	0.4098	0.3777		0.0017	0.5906	0.0027	0.4936	0.0042	0.4735
0.2596	0.4040	0.3932		0.00049782	0.5630	0.00053632	0.5012	0.0036	0.4622
0.2599	0.4036	0.3689		-0.0019	0.6594	0.0031	0.5263	0.0036	0.4573
0.2636	0.4024	0.3681		0.00048262	0.6139	0.0022	0.4889	0.0039	0.4333
0.0827	0.5173	0.4353		0.0125	0.5048	0.0261	0.3757	0.0102	0.3937
0.1115	0.4800	0.4002		0.0148	0.4734	0.0260	0.3914	0.0149	0.3866
0.1231	0.5194	0.4400		0.0172	0.4657	0.0232	0.4103	0.0088	0.3558
0.1619	0.4822	0.3917		0.0107	0.5368	0.0170	0.4844	0.0122	0.4843
0.2827	0.4737	0.4000		0.0058	0.4892	0.0062	0.3842	0.0057	0.4348
0.2721	0.4854	0.4000		0.0046	0.4683	0.0057	0.3527	0.0013	0.3917
0.0942	0.5360	0.4714		0.1716	0.9036	0.1940	0.5811	0.1792	0.5719
0.1101	0.5062	0.4388		0.1424	0.6727	0.1589	0.5659	0.1485	0.5745
0.1070	0.4776	0.4103		0.1825	0.6449	0.1913	0.5543	0.1856	0.5409
0.1426	0.5245	0.4614		0.1498	0.6697	0.1591	0.5375	0.1371	0.5457
0.2353	0.4896	0.4285		0.1681	0.4543	0.2270	0.5529	0.0362	1.8428
0.2438	0.5161	0.4611		0.2458	0.5305	0.3740	1.3021	0.4754	5.2259
0.1831	0.4865	0.4137		0.1321	0.4692	0.1605	0.5174	0.1488	0.5655

PAN NO:4 Meanrate	Stdrate	PAN NO:5 Meanrate	Stdrate	Mean Timestep	Num to Average	ADCP Starrt Time	Corrospond Wt.Pan Time	Mean ADCP Timestep	Num to Average	Mean Ht. Sonar 1 for ADCP Time
0.0023	0.4691	0.0020	0.6126	1.0766	13	11:25:52	1773.70	0.1933	77	
0.0018	0.4334	0.0031	0.5379	1.0755	13	13:11:23	8104.90	0.1933	77	
0.0765	0.5574	0.0368	0.5731	1.0813	13	14:46:41	3361.70	0.1901	78	
0.0016	0.5088	0.0005	0.6234	1.0791	13	12:01:55	9684.50	0.1902	78	390.4346
0.0035	0.5650	0.0018	0.5896	1.0795	13	12:47:40	12430.10	0.1902	78	382.6619
0.0070	0.4523	0.0021	0.5328	1.0826	13	14:16:12	17742.10	0.1902	78	381.7655
0.0068	0.4283	-0.0048	0.6136	1.0811	13	16:55:28	27297.60	0.3999	37	341.4364
0.0055	0.4853	0.0032	0.7855	1.0812	13	11:29:24	11189.30	0.1903	78	384.6316
0.0050	0.5374	0.0013	0.7679	1.0810	13	13:52:54	19799.30	0.1902	78	Not enough d
0.6812	1.0165	0.4901	0.9388	1.0833	13	11:57:12	4504.20	0.1876	79	339.6172
0.9905	1.1791	0.7566	1.8220	1.0816	13	13:18:01	9354.10	0.1881	79	355.6944
0.7443	1.6666	0.5852	1.0713	1.0872	13	14:25:07	13379.90	0.1966	75	347.1381
0.5332	1.0425	0.3839	1.0273	1.084	13	12:20:30	8956.70	0.1825	81	295.5319
0.4819	0.7847	0.2843	0.8006	1.0823	13	13:37:52	13587.00	0.19	78	228.6882
0.8022	1.0160	0.6186	0.9043	1.0837	13	13:43:15	13909.80	0.1903	78	352.4169
0.5474	1.0736	0.4651	0.9478	1.0819	13	16:05:23	22417.00	0.1942	76	385.2471
0.8372	2.2953	0.5866	0.9625	1.0815	13	16:30:25	23915.30	0.2281	65	357.6874
0.6454	1.0989	0.5272	1.0836	1.0816	13	17:23:06	27068.50	0.3999	37	318.8385
0.6839	0.7451	0.6868	0.8707	1.0833	13	17:20:29	26911.50			
0.0065	0.5598	0.0018	0.7444	1.0826	13	14:01:13	-0.20	Error b/s wt. pan started later than a		
0.0069	0.5240	0.0044	0.6613	1.0840	13	14:15:09	760.00	0.2037	73	342.1655
0.0075	0.4972	0.0018	0.6011	1.0840	13	15:22:11	4782.40	0.201	74	336.7766
0.0033	0.4706	0.0007592	0.5316	1.0843	13	16:40:38	9490.10	0.2156	69	340.6785
0.0029	0.4846	0.0015	0.7687	1.0778	13	15:00:16	608.60	0.2149	69	338.4707
0.0052	0.4541	0.000166	0.7051	1.0852	13	16:31:27	6079.80	0.2018	73	339.9449
0.0038	0.4939	0.0014	0.7423	1.0810	13	17:46:29	10582.20	0.2037	73	340.8948
0.0039	0.4544	0.0001239	0.7073	1.0813	13	19:16:59	16012.30	0.3999	37	342.1984
0.0282	0.4276	0.0195	0.6474	1.0813	13	20:09:48	19181.60	0.3969	37	341.9
0.0051	0.4553	0.0006182	0.7128	1.0806	13	20:11:22	19275.60	0.3997	37	342.1672
0.0019	0.4225	-0.000145	0.6848	1.0959	13	20:22:23	19935.80	0.3997	37	342.435
0.0025	0.4207	0.0004076	0.6538	1.0811	13	20:43:09	20588.40	0.3999	37	340.7204
0.0047	0.4624	0.0028	0.5571	1.0880	13	10:01:22	7199.10	0.3999	37	332.5286
0.00094907	0.4233	0.0013	0.4926	1.0931	13	11:20:06	12004.20	0.2052	72	339.2397
0.0251	0.4361	0.0144	0.5184	1.0809	13	17:20:03	33601.30	0.2056	72	338.0973
0.0249	0.4367	0.0105	0.6064	1.0809	13	17:51:52	35510.10	0.2013	73	339.7419
0.0231	0.4103	0.0153	0.5768	1.0808	13	18:23:27	37404.90	0.2173	68	340.1189
0.0064	0.5211	0.0064	0.6682	1.0837	13	15:04:54	10555.40	0.2141	69	334.6839
0.0032	0.4889	0.0064	0.5821	1.0808	13	15:37:14	12495.00	0.1987	74	333.3728
0.0060	0.5312	0.0055	0.5426	1.0834	13	16:18:24	14964.60	0.2037	73	335.1829
0.0047	0.5854	0.0253	0.9626	1.0809	13	17:24:35	18935.10	0.3999	37	336.3224
0.0050	0.5590	0.0039	0.9018	1.0810	13	17:59:28	21029.10	0.3999	37	Sonar data co
0.0018	0.4657	0.0016	0.5746	1.0804	13	16:46:43	31770.10	0.3998	37	336.6195
0.0022	0.4754	3.737E-05	0.5665	1.0805	13	17:03:02	32748.90	0.4000	37	339.9775
0.0157	0.4232	0.0096	0.5117	1.0821	13	15:47:15	28602.30	0.2140	69	356.7499
0.0257	0.4101	0.0086	0.5189	1.0821	13	16:48:25	32272.80	0.1987	74	366.0721
0.0177	0.3807	0.0112	0.4810	1.0820	13	17:52:46	36133.90	0.2013	73	364.7456
0.0179	0.5218	0.0145	0.6686	1.0822	13	12:01:38	15064.60	0.4000	37	343.8517
0.0169	0.4740	0.0085	0.5739	1.0824	13	13:25:28	20094.60	0.4000	37	342.6074
0.0226	0.4601	0.0079	0.6830	1.0827	13	14:30:23	23990.10	0.4000	37	347.7003
0.1942	0.9022	0.1833	0.6820	1.0830	13	16:25:57	27807.30	0.2159	68	359.3115
0.1762	0.6319	0.1345	0.7454	1.0829	13	17:49:42	32832.40	0.2032	73	370.1051
0.1908	0.5908	0.1766	0.6790	1.0827	13	18:49:23	36413.90	0.2026	73	354.4651
0.1451	0.5896	0.0878	0.7390	1.0827	13	19:28:36	38766.60	0.2082	71	357.7691
0.1950	0.5736	0.1354	0.6920	1.0855	13	11:14:40	3918.40	0.4000	37	359.3249
0.2477	0.6272	0.2081	0.6540	1.0959	13	12:18:16	7734.50	0.4000	37	389.6450
0.1777	0.619	0.1505	0.7359	1.0842	13	14:03:09	14027.20	0.4000	37	342.0616

						Results of MATLAB Comibed File	
Mean Ht.	Mean Ht.	Mean Ht.	Mean Ht.	Mean Ht.	Mean Ht.	Lag B/W	Mean
Sonar 2 for ADCP Time	Sonar 3 for ADCP Time	Sonar 4 for ADCP Time	Sonar 5 for ADCP Time	Sonar 6 for ADCP Time	Sonar 7 for ADCP Time	Beams 3 & 4 sec	Vertical Range from ADCP
						800	0.95090
						800	0.91780
						800	0.82290
393.6487	400.6906	394.2613	425.4487	547.2974	564.0141	3000	0.98270
395.8257	398.5006	389.0158	424.7972	554.801	666.0223	3000	0.97120
396.0149	395.9148	384.0238	424.456	567.8313	757.0393	5000	0.96890
389.9246	384.4322	368.872	424.2136	570.8398	751.0627	3000	NaN
389.5282	373.6309	342.8177	416.209	577.7185	695.1919	5000	0.97830
ata of sonars						3000	0.98260
289.049	293.8531	314.4183	332.3651	454.109	478.9011	2000	0.99680
353.6977	354.0018	369.9145	395.6168	459.9303	464.3221	2500	0.95860
288.5288	292.1945	314.6167	341.975	438.6733	460.7243	3500	0.98590
314.8021	324.825	335.1917	336.0257	490.4618	494.7569	1000	0.91280
253.8824	317.0941	398.9765	433.0176	498.6588	383.3941	1000	0.96110
330.5536	310.6867	313.7892	334.0386	404.4157	425.5548	1000	0.91830
334.5109	319.1696	335.0094	338.8899	430.4435	463.9812	612	0.95020
313.5267	300.8911	315.5262	340.5754	429.489	480.2346	67	0.98950
298.0912	301.3027	339.4599	363.167	426.7363	500.1088	30	1.00660
dcp data							
335.1144	329.4025	316.2589	339.4727	407.116	465.9282	365	1.01270
327.8859	320.984	301.5214	333.4701	408.3672	610.8834	255	1.04960
327.428	315.1178	288.8607	330.3402	408.385	599.2421	121	1.01990
315.6901	304.6317	282.1718	328.9925	478.6847	531.0491	200	1.02040
316.5774	303.5981	279.2265	328.7921	524.407	510.7214	270	1.03900
318.5866	307.1422	278.7203	327.8621	526.3504	498.5394	290	1.00870
315.8508	308.559	273.739	327.5728	524.2961	492.4554	93	1.04630
316.2667	307.0167	274.95	327.3667	514.7333	497.4	Not enough data to estimate celerity	
316.631	309.2603	274.0379	326.9259	521.9241	497.1638	400	1.06200
316.5167	308.895	274.015	326.25	524.1617	496.245	92	1.03390
315.5801	304.8371	270.1237	321.5903	516.0054	508.4656	78	1.03440
310.4786	284.4073	259.34	305.9964	438.1077	522.8782	655	1.03970
310.5291	285.8032	265.3899	306.4159	442.6386	517.8476	30	1.00630
312.4038	295.9231	335.6736	396.1808	456.8725	528.6093	515	0.97990
311.8355	298.171	311.9495	382.3145	465.1882	529.1548	60	1.01620
311.9405	297.177	299.2162	372.4527	472.5351	531.1716	105	0.98020
312.578	301.1177	271.2124	318.5376	469.2371	565.05	670	0.99070
311.6239	296.6996	258.8819	311.6436	478.9868	560.0383	270	1.02480
312.1199	289.2217	259.1713	306.3441	469.5339	561.1727	525	0.99010
312.5159	292.0761	264.9567	300.3443	472.6846	558.3219	410	1.02930
llection closed before the completion of the data of adcp						104	1.02610
310.0678	293.5299	282.9517	297.5897	482.3264	556.4966	93	1.02760
308.574	292.9272	273.925	299.145	490.079	548.3727	1130	1.02760
394.0551	331.3623	332.0773	366.4548	503.1620	543.2346	440	0.93410
392.3594	330.6594	342.3666	364.2411	499.5650	535.2714	300	0.97000
395.9500	329.0959	335.3926	370.1571	496.9194	528.1219	395	0.93310
420.1591	318.1202	328.7709	372.2495	523.8693	548.0531	198	0.97660
416.1747	317.1813	330.3603	370.2095	513.6187	543.2232	122	0.97180
408.7781	318.7615	323.2024	369.5508	504.4914	541.7476	275	0.97200
338.9421	350.8966	382.0505	421.7342	519.4042	509.9682	210	0.91050
347.2219	353.5578	364.4457	397.1102	504.9860	508.3070	75	0.94010
323.2480	329.1983	344.0917	374.4432	505.0485	510.3004	198	0.96940
327.1656	339.5720	352.2302	376.4418	483.8448	509.9124	194	0.91980
329.2732	331.6071	330.0743	354.8475	525.3383	501.8298	183	0.95680
353.5328	356.6799	356.9960	389.7058	494.7301	494.8368	200	0.92840
307.6867	315.1953	320.4576	357.1182	488.2064	458.7762	230	0.96650

E:\Rauf\For Peter Wilcock\Hydro-Morphological Data-Final

Distance	Celerity	Lag Time	Celerity	Dune	Lag Time	Celerity
B/W Beams	ADCP	B/W Sonars 3 & 6	Sonar Dune Prob 3 & 6	Height Manually mm	B/W Sonars 6 & 7	Sonar Dune Prob 6 & 7
0.82920	0.00100					
0.80510	0.00100					
0.73600	0.00092					
0.85240	0.00028	12000	0.00059	25	6750	0.00074
0.84400	0.00028	12000	0.00059	30	6750	0.00074
0.84230	0.00017	12000	0.00059	30	6750	0.00074
NaN	NaN	12000	0.00059	35	6750	0.00074
0.84920	0.00017	8310	0.00085	35	6750	0.00074
0.85220	0.00028	Not enough data of sonars, it er		40		
0.86260	0.00043	1358	0.00520	120	1025	0.00490
0.83480	0.00033	1358	0.00520	100	1025	0.00490
0.85470	0.00024	1358	0.00520	150	1025	0.00490
0.80140	0.00080	1358	0.00520	130	1550	0.00320
0.83660	0.00084	1358	0.00520	114	1550	0.00320
0.80540	0.00081	1358	0.00520	90	1550	0.00320
0.82870	0.00140	1358	0.00520	80	1550	0.00320
0.85730	0.01280	1358	0.00520	200	1550	0.00320
0.86980	0.02900	1358	0.00520	100	1550	0.00320
				16		
0.87420	0.00240	2200	0.00320	15	8350	0.00060
0.90100	0.00350	2200	0.00320	10	8350	0.00060
0.87940	0.00730	2200	0.00320	10	8350	0.00060
0.87980	0.00440	770	0.00920	15	7240	0.00069
0.89330	0.00330	770	0.00920	15	7240	0.00069
0.87130	0.00300	770	0.00920	7	7240	0.00069
0.89860	0.00970	770	0.00920	7	7240	0.00069
y of adcp beams		770	0.00920	0	7240	0.00069
0.91010	0.00230	770	0.00920	7	7240	0.00069
0.88960	0.00970	770	0.00920	8	7240	0.00069
0.89000	0.01140	770	0.00920	7	7240	0.00069
0.89380	0.00140	11400	0.00062	15	3000	0.00170
0.86950	0.02900	11400	0.00062	15	3000	0.00170
0.85030	0.00170	11400	0.00062	5	3000	0.00170
0.87670	0.01460	11400	0.00062	5	3000	0.00170
0.85050	0.00810	11400	0.00062	5	3000	0.00170
0.85820	0.00130	9000	0.00079	10	3375	0.00150
0.88300	0.00330	9000	0.00079	10	3375	0.00150
0.85870	0.00160	9000	0.00079	14	3375	0.00150
0.88630	0.00220	9000	0.00079	8	3375	0.00150
0.88390	0.00830	Sonar data collection closed be		8		
0.88500	0.00950	8650	0.00082	15	6850	0.00073
0.88510	0.00078	8650	0.00082	15	6850	0.00073
0.81700	0.00190	15000	0.00047	5	2730	0.00180
0.84310	0.00280	15000	0.00047	7	2730	0.00180
0.81630	0.00210	15000	0.00047	7	2730	0.00180
0.84790	0.00430	15000	0.00047	7	2730	0.00180
0.84440	0.00690	15000	0.00047	10	2730	0.00180
0.84460	0.00310	15000	0.00047	20	2730	0.00180
0.97780	0.00380	6340	0.00110	75	2600	0.00190
0.82130	0.01100	9340	0.00110	80	2600	0.00190
0.84270	0.00430	6340	0.00110	85	2600	0.00190
0.80650	0.00420	6340	0.00110	45	2600	0.00190
0.83350	0.00460	3575	0.00200	75	2580	0.00190
0.81280	0.00410	3575	0.00200	60	2580	0.00190
0.84050	0.00370	3575	0.00200	85	2580	0.00190

Comments
No data on the graph for lag so assumed as 800
No data on the graph for lag so assumed as 800
No data on the graph for lag so assumed as 3000
No data on the graph for lag so assumed as 3000
No data on the graph for lag so assumed as 5000
No data on the graph for lag so assumed as 3000
No data on the graph for lag so assumed as 5000
No data on the graph for lag so assumed as 3000
No data on the graph for lag so assumed as 2000
No data on the graph for lag so assumed as 2500
No data on the graph for lag so assumed as 3500
No data on the graph for lag so assumed as 1000
No data on the graph for lag so assumed as 1000
No data on the graph for lag so assumed as 1000
First good data in Gravel with adding some commands
Positive transport movement in d/s for 4 m3/sec discharge
No data on graph for beam 3 and 4 so assumed 400
Bed Slope 0.0047 on 26th of March in the morning for 4.3 disch
Only 5 hours of run (from 10 am to 3pm)

ANNEXURE V

BED SHEAR STRESS:

The total bed shear stress may be divided into grains and bed forms shear stress. Einstein (1950) determined that the grain shear stress could be determined by separating total bed shear stress into a grain component and a form component which are additive.

The total bed shear may be divided into grain and form shear

$$\tau_o = \tau_g + \tau_f = \gamma R S = \gamma (R_g + R_f) S = \gamma R (S_g + S_f)$$

In fact the friction factor may be partitioned into a grain and form friction factor (Einstein and Barbarossa 1952):

$$f = f_g + f_f$$

Grain roughness

For fully rough turbulent uniform flow, the log-law can be written as:

$$u = \frac{u^*}{\kappa} \ln(y) + \frac{u^*}{\kappa} \ln\left(\frac{30}{k_s}\right)$$

where u is the mean streamwise velocity at distance y from the wall, κ is the von Karman constant, which is equal to about 0.4.

$u^* = \sqrt{\frac{\tau_o}{\rho}}$ is the shear velocity

k_s is the roughness (the equivalent sand grain roughness, in which the roughness is equal to the diameter of roughness elements on the wall).

With this equation, a plot of u versus ln(y) will have a slope of $\frac{u^*}{\kappa}$ and an intercept of

$$\frac{u^*}{\kappa} \ln\left(\frac{30}{k_s}\right)$$

The value of k_s includes both grain and form roughness, because both forms of roughness influence flow resistance and thus the shape of the velocity profile.

SHEAR STRESS PROFILES OF SAND AND GRAVEL BED EXPERIMENTS BY USING THE MEASURED VERTICAL PROFILES DATA BY ADV AND COMPARISON WITH MEASURED BED LOAD.

As explained in Chapter 2, ADV data were collected for vertical profiles for both sandbed and gravelbed. The ADV was installed to measure the vertical profiles to estimate the grain shear stress since Feb 2nd 2006. Two to three vertical profiles were collected for each flow. For sand bed runs a total of 9 profiles were measured for five discharges. The profiles were collected on the stoss side of a dune near the dune crest. For gravelbed runs 12 profiles for five different discharges were collected.

The fully rough turbulent equation (Keulegan equation) was utilized to determine the shear velocity. Both u* and k_s were determined from the profile. The details are described in annexure V.

The velocity profiles were measured in front of pan 2. Therefore a comparison is carried out for grain shear and pan 2 bedload data. Tables 3.4 and 3.5 give the detail of the results for sandbed and gravelbed vertical profiles respectively. The detail analysis is described in the following sections.

TABLE : VERTICAL PROFILE RESULTS: SANDBED

		(Upper Total Boundary Shear)			Lower (quasi grain shear)		
Date	Discharge	u^*	τ	k_s	u^*	τ	k_s
	m^3/sec	m/s	N/m^2	m	m/s	N/m^2	m
01/10/2006	2.4	0.110	12.049	0.363	0.080	6.314	0.15700
02/02/2006	2.9	0.066	4.403	0.047	0.045	1.997	0.00400
02/04/2006	3.6	0.126	15.801	0.205	0.114	13.003	0.25800
02/07/2006	2.0	0.040	1.601	0.032			
02/07/2006	2.0	0.059	3.469	0.261	0.014	0.192	0.00002
02/09/2006	2.5	0.067	4.540	0.191	0.075	5.572	0.20437
02/09/2006	2.5	0.062	3.856	0.142	0.158	24.609	0.82100
02/14/2006	3.2	0.146	19.876	0.501	0.123	15.069	0.72100
02/14/2006	3.2	0.065	4.204	0.041	0.063	3.994	0.05400

For January 10, 2006 the bedload data for comparison was not available and for February 07, 2006, Ist profile, it can be seen on the Figure above for this profile, that bed was aggrading too quickly to capture the lower profile (velocity going down, not up, so probably bed is getting closer). For second profile with 2.5 m3/s on February 09, 2006 is not correct because of error in the measurements. Therefore these two profiles were not considered in the analysis.

TABLE 3.5: VERTICAL PROFILE RESULTS: GRAVELBED

		(Upper Total Boundry Shear)			Lower (quasi grain shear)		
Date	Discharge	u*	τ	k_s	U*	τ	k_s
	m^3/sec	m/s	N/m^2	M	m/s	N/m^2	m
03/10/2006	3.9	0.085	7.154	0.035	0.101	10.119	0.0740
03/12/2006	5.5	0.141	19.899	0.055	0.092	8.531	0.2530
03/16/2006	4.0	0.100	9.972	0.118	0.079	6.172	0.0360
03/16/2006	4.0	0.099	9.776	0.119	0.066	4.300	0.0160
03/21/2006	4.0	0.102	10.335	0.108	0.067	4.474	0.0190
03/21/2006	4.0	0.089	7.900	0.058	0.049	2.432	0.0040
03/25/2006	4.3	0.101	10.177	0.053	0.086	7.441	0.0280
03/25/2006	4.3	0.089	7.878	0.023	0.093	8.698	0.0330
03/28/2006	4.9	0.131	17.029	0.089	0.051	2.63	0.0040

The results of comparison of grain shear and measured capture rates are shown in the following figures for sand and gravel bed respectively as below:

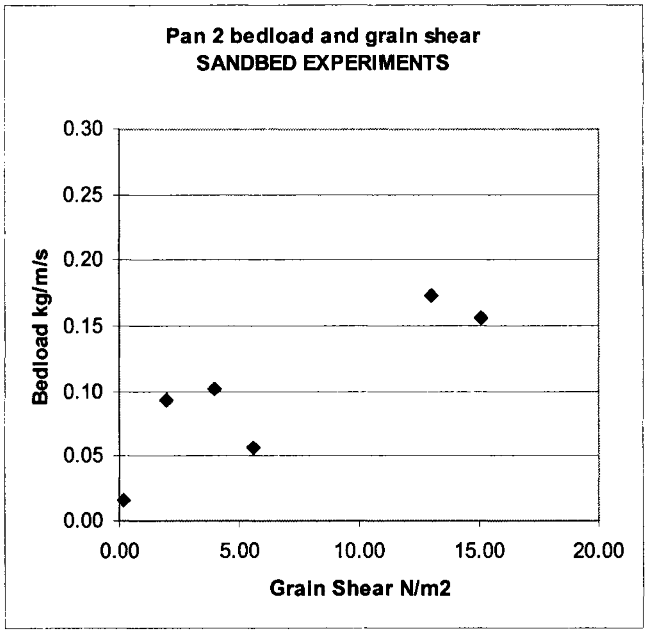


Figure : Influence of grain shear on Transport rate. (sandbed)

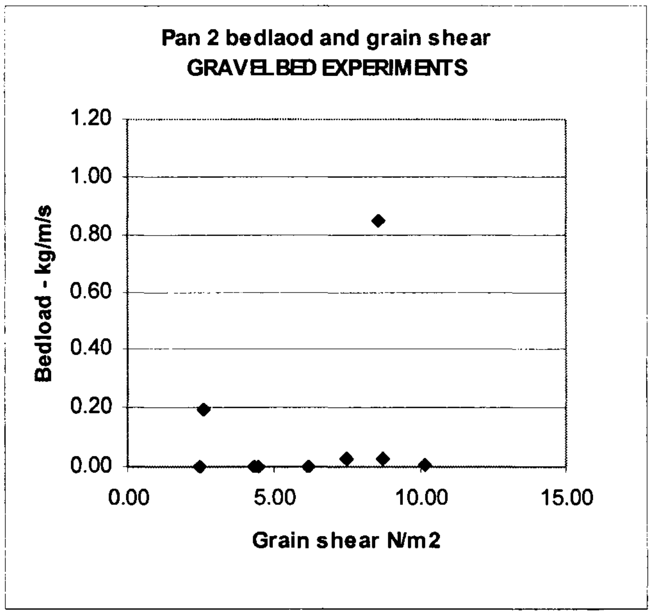


Figure : Influence of grain shear on Transport rate. (gravelbed)

The two points which gives higher rate of transport are with 4.9 m^3/s and 5.5 m^3/s discharge. All of the other results are with almost no sediment transport even with high grain shear. Apparently it seems that the bed was not equilibrium for those flows. Also for gravel bed profiles except two profiles for 3.9 m3/s and 5.5 m3/s all of the files were recorded with too much turbid water due to leaves in the water and most of the time leaves stuck on the tip of the prob and gave erratic results.

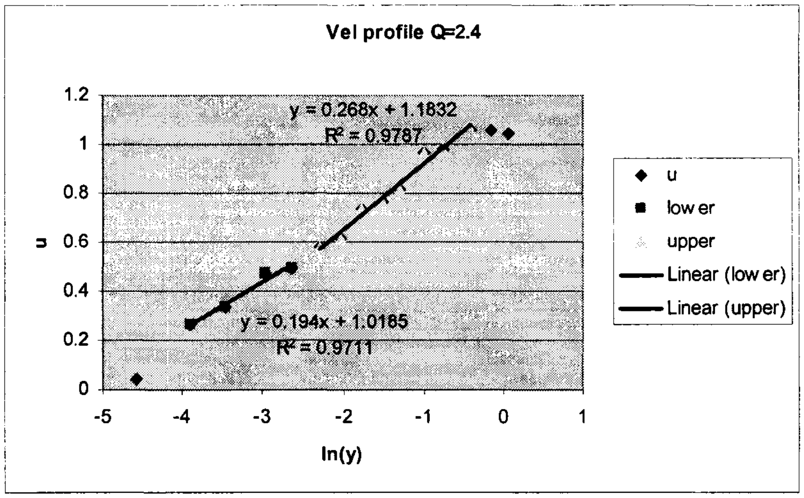
The details are given in the following pages:

SANDBED PROFILES:

Jan 10th 2006 with Dave

Q =	**2.4**	**Y =**	**1.12**	**U =**	**0.78119**
				Sampling Volume =	1.05 cm

Scale No.	y	ln(y)	u
51.9	0.0105	-4.55638	0.0406
52.9	0.0205	-3.88733	0.264
54	0.0315	-3.45777	0.338
56	0.0515	-2.96617	0.469
58	0.0715	-2.63806	0.491
61	0.1015	-2.2877	0.581
64	0.1315	-2.02875	0.612
68	0.1715	-1.76317	0.736
73	0.2215	-1.50733	0.764
78	0.2715	-1.30379	0.811
88	0.3715	-0.99021	0.963
98	0.4715	-0.75184	0.982
118	0.6715	-0.39824	1.06
138	0.8715	-0.13754	1.06
157.4	1.0655	0.063444	1.04



kappa	0.41	
density	998	kg/m3

lower (quasi grain shear)

slope	0.194	
intercept	1.0185	
u*	0.080	m/s
tau	6.314	N/m2
ks	0.157	m

upper (total boundary shear)

slope	0.268	
intercept	1.1832	
u*	0.110	m/s
tau	12.049	N/m2
ks	0.363	m

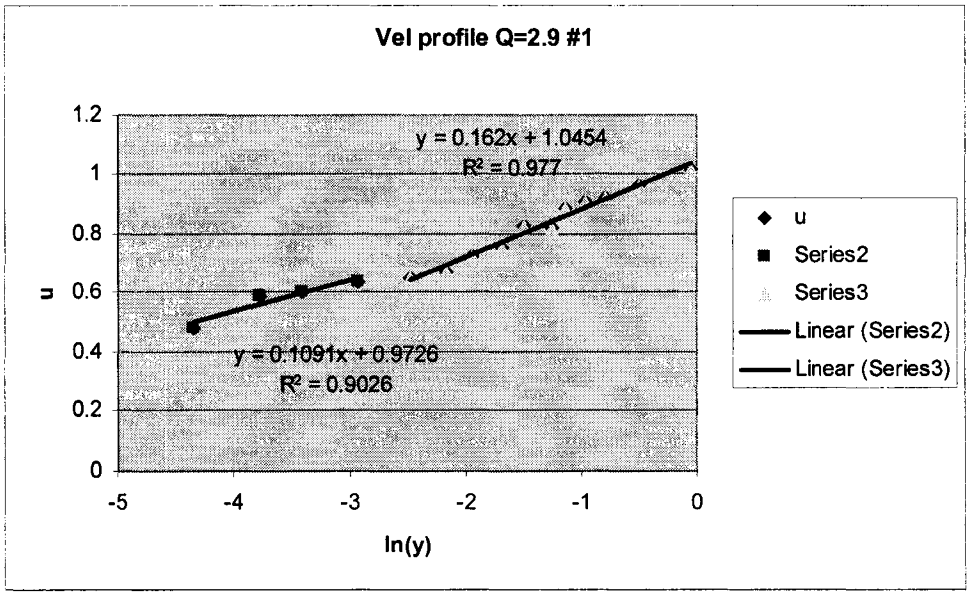
NOTE last two points are in velocity defect (i.e. above log layer)

Feb 02nd Colin Rennie and Rauf

Q = 2.9 m^3/sec Y = 135 cm **U = 0.783** m/sec.

Page 92 of our data note book **Sampling Volume =** 1.3 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
41	0.013	-4.34281	0.48039	48.039
42	0.023	-3.77226	0.58867	58.867
43	0.033	-3.41125	0.60589	60.589
45	0.053	-2.93746	0.63715	63.715
48	0.083	-2.48891	0.65355	65.355
51	0.113	-2.18037	0.67046	67.046
54	0.143	-1.94491	0.72863	72.863
58	0.183	-1.69827	0.74925	74.925
62	0.223	-1.50058	0.82537	82.537
68	0.283	-1.26231	0.82042	82.042
72	0.323	-1.1301	0.88753	88.753
78	0.383	-0.95972	0.90961	90.961
85	0.453	-0.79186	0.92061	92.061
100	0.603	-0.50584	0.9627	96.270
135	0.953	-0.04814	1.02024	102.024



lower (quasi grain shear)

slope	0.1091	
intercept	0.9726	
u*	0.045	m/s
tau	1.997	N/m2
ks	0.004	m

upper (total boundary shear)

slope	0.162	
intercept	1.0454	
u*	0.066	m/s
tau	4.403	N/m2
ks	0.047	m

extremely low errors

Feb 4th Colin Rennie and Rauf

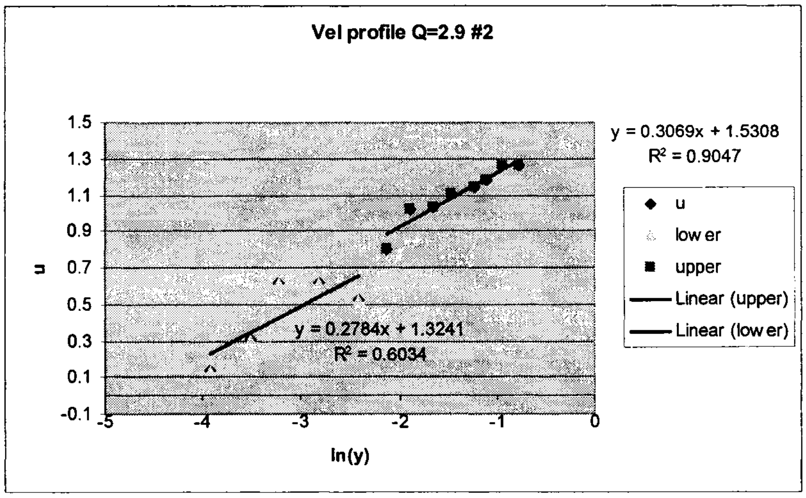
Q = 3.6 m^3/sec **Y = 144.7 cm** **U = 0.907** m/sec.

Density of Water = 1000 kg/m^3

Page 108 of our data note book **Sampling Volume =** 2.00 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
32	0.020	-3.91202	0.1429	14.29
33	0.030	-3.50656	0.30523	30.523
34	0.040	-3.21888	0.61965	61.965
36	0.060	-2.81341	0.61606	61.606
39	0.090	-2.40795	0.52224	52.224
42	0.120	-2.12026	0.79722	79.722
45	0.150	-1.89712	1.02518	102.518
49	0.190	-1.66073	1.03208	103.208
53	0.230	-1.46968	1.10796	110.796
59	0.290	-1.23787	1.14462	114.462
63	0.330	-1.10866	1.17956	117.956
69	0.390	-0.94161	1.26104	126.104
76	0.460	-0.77653	1.25816	125.816
91	0.610	-0.4943	0	
126	0.960	-0.04082	0	

NOTE: **Two bursts are missing**



lower (quasi grain shear)

slope	0.2784	
intercept	1.3241	
u*	0.114	m/s
tau	13.003	N/m2
ks	0.258	m

upper (total boundary shear)

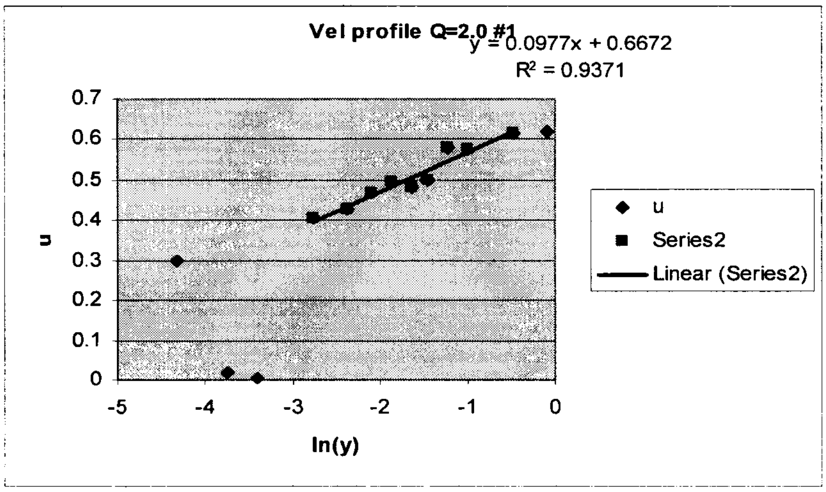
slope	0.3069	
intercept	1.5308	
u*	0.126	m/s
tau	15.801	N/m2
ks	0.205	m

Feb 7th Ben and Rauf (Ist Profile)

Q = 2.0 m^3/sec. Y = 146.04 cm **U = 0.499** m/sec.

Page 111 of our data note book **Sampling Volume =** 1.34 cm

	y	ln(y)	u	
30	0.013	-4.3125	0.2972	29.72
31	0.023	-3.75502	0.01903	1.903
32	0.033	-3.3992	0.00614	0.614
35	0.063	-2.75829	0.40458	40.458
38	0.093	-2.37086	0.42911	42.911
41	0.123	-2.09232	0.46694	46.694
44	0.153	-1.87471	0.49618	49.618
48	0.193	-1.64299	0.48179	48.179
52	0.233	-1.455	0.50031	50.031
58	0.293	-1.22622	0.57899	57.899
65	0.363	-1.01225	0.57453	57.453
90	0.613	-0.48874	0.61514	61.514
120	0.913	-0.09058	0.62167	62.167



upper (total boundary shear)

slope	0.0977	
intercept	0.6672	
u*	0.040	m/s
tau	1.601	N/m2
ks	0.032	m

NOTE: it appears that bed was agrading too quickly
to capture the lower profile (vel going down, not up, so probably bed is getting closer

Feb 7th Ben and Rauf (2nd Profile)

Q = 2.0 m^3/sec. Y = 143.26 cm **U = 0.509** m/sec.

Sampling Volume = 1.56 cm

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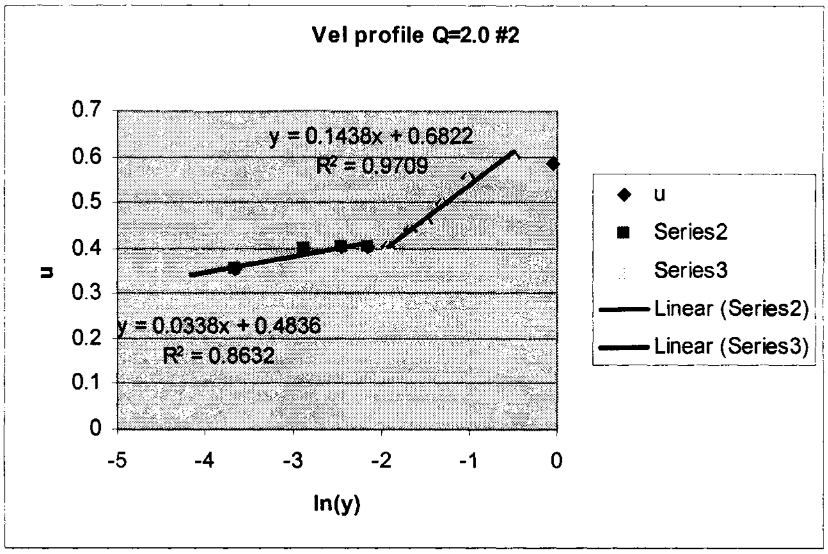
Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
33	0.016	-4.16048	0.36444	36.444
34	0.026	-3.66516	0.35354	35.354
35	0.036	-3.33541	0.31601	31.601
37	0.056	-2.88957	0.39776	39.776
40	0.086	-2.45807	0.40179	40.179
43	0.116	-2.15762	0.40336	40.336
46	0.146	-1.92689	0.40277	40.277
50	0.186	-1.68416	0.43767	43.767
54	0.226	-1.48899	0.45683	45.683
58	0.266	-1.32576	0.49816	49.816
67	0.356	-1.03395	0.55491	55.491
92	0.606	-0.50154	0.59759	59.759
127	0.956	-0.04542	0.58306	58.306



lower (quasi grain shear)

slope	0.0338	
intercept	0.4836	
u*	0.014	m/s
tau	0.192	N/m2
ks	0.00002	m

upper (total boundary shear)

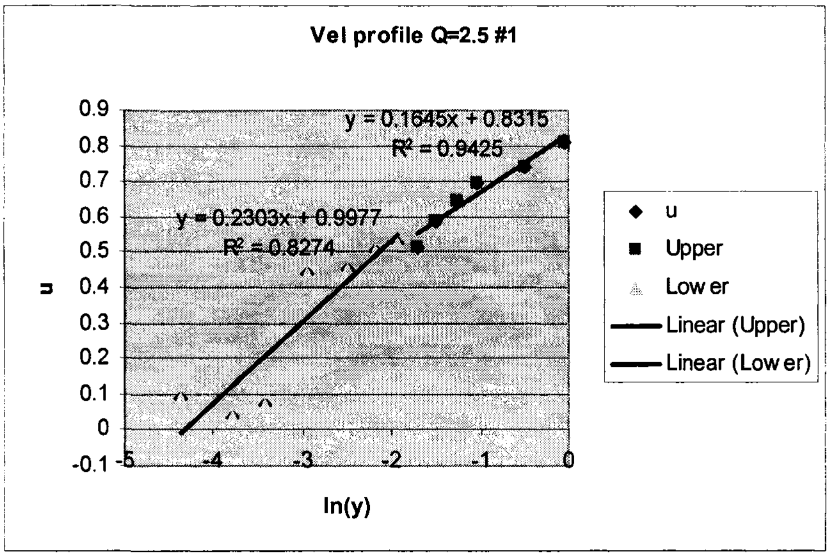
slope	0.1438	
intercept	0.6822	
u*	0.059	m/s
tau	3.469	N/m2
ks	0.261	m

Feb 9th Ben and Rauf (Ist Profile)

Q = 2.5 m^3/sec. Y = 143.96 cm **U = 0.633** m/sec.

Page 119 of our data note book **Sampling Volume =** 1.26 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
32	0.013	-4.37406	0.08605	8.605
33	0.023	-3.78981	0.03581	3.581
34	0.033	-3.42344	0.06978	6.978
36	0.053	-2.94504	0.43785	43.785
39	0.083	-2.49375	0.45379	45.379
42	0.113	-2.18391	0.50357	50.357
45	0.143	-1.94771	0.52362	52.362
49	0.183	-1.70046	0.51541	51.541
53	0.223	-1.50238	0.58737	58.737
59	0.283	-1.26372	0.64538	64.538
66	0.353	-1.04242	0.69435	69.435
91	0.603	-0.5065	0.73829	73.829
126	0.953	-0.04856	0.81098	81.098



lower (quasi grain shear)

slope	0.1823	
intercept	0.9095	
u*	0.075	m/s
tau	5.575	N/m2
ks	0.20437	m

upper (total boundary shear)

slope	0.1645	
intercept	0.8315	
u*	0.067	m/s
tau	4.540	N/m2
ks	0.191	m

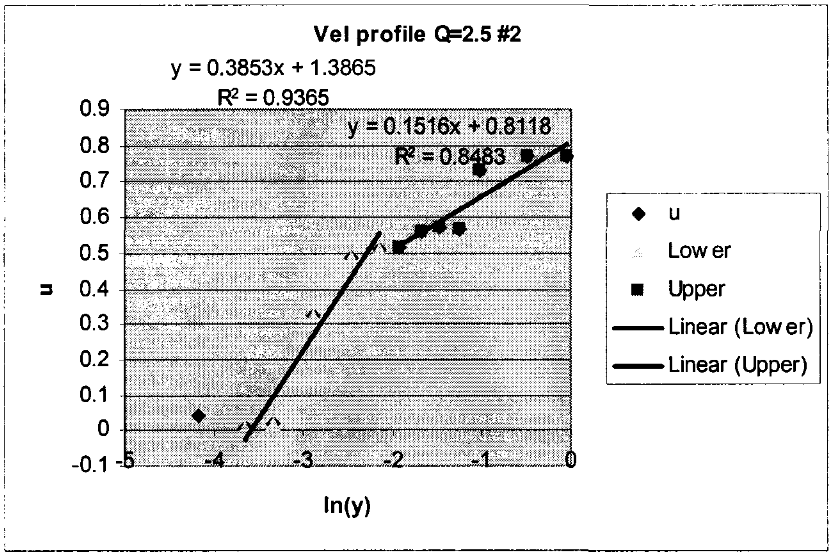
NOTE: it appears that bed was aggrading too quickly
to capture the lower profile (vel going down, not up, so probably bed is getting closer

Feb 9th Ben and Rauf (Ist Profile)
Q = 2.5 m^3/sec. Y = 152.26 cm **U = 0.599** m/sec.

Sampling Volume = 1.56 cm

Page 119 of our data note book

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
24	0.016	-4.16048	0.03987	3.987
25	0.026	-3.66516	0.0071	0.710
26	0.036	-3.33541	0.01636	1.636
28	0.056	-2.88957	0.32283	32.283
31	0.086	-2.45807	0.48864	48.864
34	0.116	-2.15762	0.50905	50.905
37	0.146	-1.92689	0.51603	51.603
41	0.186	-1.68416	0.5603	56.030
45	0.226	-1.48899	0.57072	57.072
51	0.286	-1.25316	0.5683	56.830
58	0.356	-1.03395	0.7291	72.910
83	0.606	-0.50154	0.76732	76.732
118	0.956	-0.04542	0.76817	76.817



lower (quasi grain shear)

slope	0.3853	
intercept	1.3865	
u*	0.158	m/s
tau	24.906	N/m2
ks	0.821	m

upper (total boundary shear)

slope	0.1516	
intercept	0.8118	
u*	0.062	m/s
tau	3.856	N/m2
ks	0.142	m

Feb 14th David and Rauf (Ist Profile)

Q = 3.2 m^3/sec. Y = 157.7 cm **U = 0.740** m/sec.

Sampling Volume = 1.00 cm

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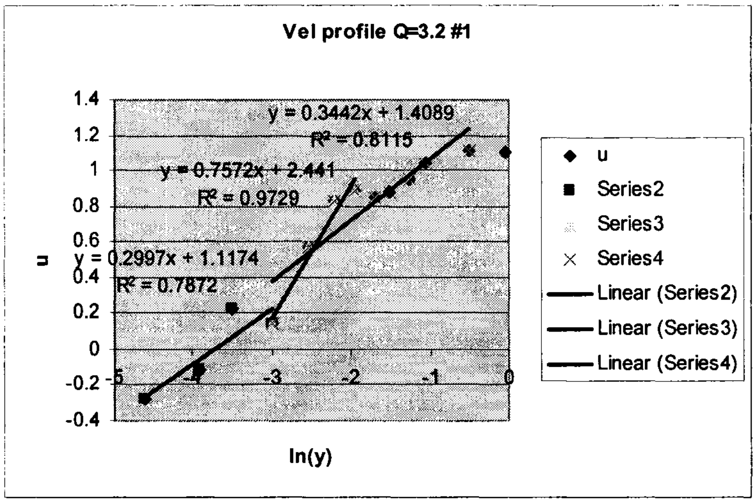
Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
18	0.010	-4.60517	-0.28125	-28.125
19	0.020	-3.91202	-0.10894	-10.894
20	0.030	-3.50656	0.22031	22.031
22	0.050	-2.99573	0.13748	13.748
25	0.080	-2.52573	0.57044	57.044
28	0.110	-2.20727	0.8234	82.340
31	0.140	-1.96611	0.89219	89.219
35	0.180	-1.7148	0.84297	84.297
39	0.220	-1.51413	0.88129	88.129
45	0.280	-1.27297	0.9536	95.360
52	0.350	-1.04982	1.04136	104.136
77	0.600	-0.51083	1.11375	111.375
112	0.950	-0.05129	1.10615	110.615



lower (quasi grain shear)

slope	0.2997		
intercept	1.1174		
u*	0.123	m/s	
tau	15.069	N/m2	
ks	0.721	m	

upper (total boundary shear)

slope	0.7572		
intercept	2.441		
u*	0.310	m/s	
tau	96.188	N/m2	This seems very large
ks	1.194	m	

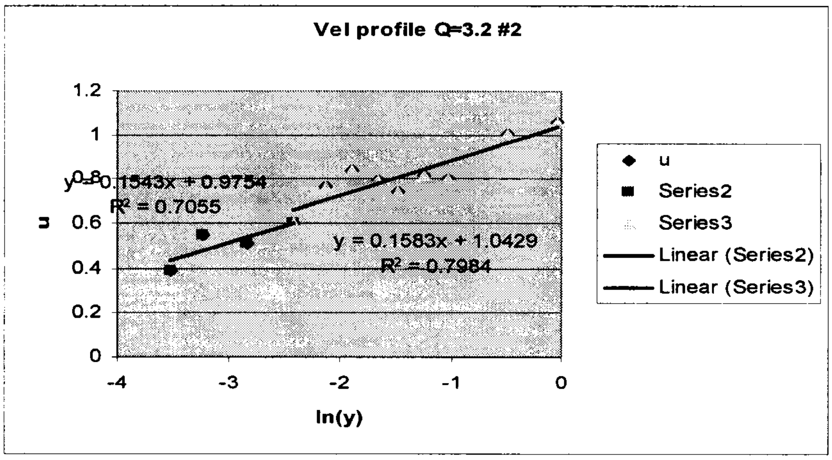
upper (total boundary shear) 2nd possibility

slope	0.3442		
intercept	1.4089		
u*	0.141	m/s	
tau	19.876	N/m2	
ks	0.501	m	

Feb 14th David and Rauf (2nd Profile)

Q = 3.2 m^3/sec. Y = 141.66 cm **U = 0.824** m/sec.
Page 126 of our data note book **Sampling Volume =** 2.96 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
36	0.030	-3.51998	0.39298	39.298
37	0.040	-3.22893	0.54485	54.485
39	0.060	-2.8201	0.51131	51.131
42	0.090	-2.4124	0.60364	60.364
45	0.120	-2.1236	0.76271	76.271
48	0.150	-1.89979	0.84152	84.152
52	0.190	-1.66284	0.79253	79.253
56	0.230	-1.47142	0.74291	74.291
62	0.290	-1.23925	0.8173	81.730
69	0.360	-1.02276	0.80551	80.551
94	0.610	-0.49495	1.00798	100.798
129	0.960	-0.04124	1.05436	105.436



lower (quasi grain shear)

slope	0.1543	
intercept	0.9754	
u*	0.063	m/s
tau	3.994	N/m2
ks	0.054	m

upper (total boundary shear)

slope	0.1583	
intercept	1.0429	
u*	0.065	m/s
tau	4.204	N/m2
ks	0.041	m

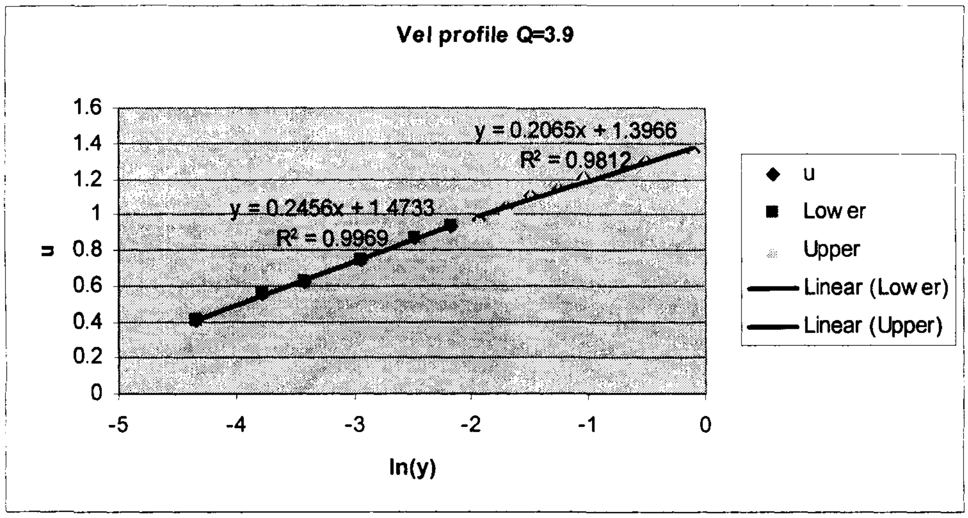
GRAVELBED VERTICAL PROFILES:

March 10th 2006

Q = [redacted] Y = 1.335 m U = 1.064994

Sampling Volume = [redacted] cm

Scale No.	y	ln(y)	u	
42.5	0.013	-4.34281	[redacted]	41.067
43.5	0.023	-3.77226	[redacted]	55.665
44.5	0.033	-3.41125	[redacted]	61.581
46.5	0.053	-2.93746	[redacted]	74.745
49.5	0.083	-2.48891	[redacted]	87.198
52.5	0.113	-2.18037	[redacted]	93.788
55.5	0.143	-1.94491	[redacted]	96.865
59.5	0.183	-1.69827	[redacted]	104.182
63.5	0.223	-1.50058	[redacted]	110.689
69.5	0.283	-1.26231	[redacted]	113.83
76.5	0.353	-1.04129	[redacted]	120.462
101.5	0.603	-0.50584	[redacted]	129.77
131.5	0.903	-0.10203	[redacted]	135.461



kappa [redacted]

density kg/m3

lower (quasi grain shear)

slope	[redacted]	
intercept		
u*	0.101	m/s
tau	10.119	N/m2
ks	0.074	m

upper (total boundary shear)

slope	[redacted]	
intercept		
u*	0.085	m/s
tau	7.154	N/m2
ks	0.035	m

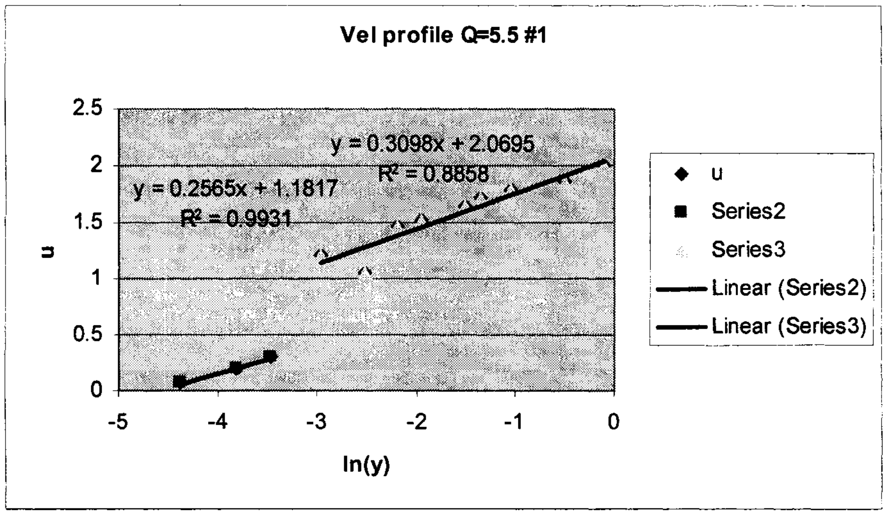
March 12th, 2006

Q = 5.5 m^3/sec Y = 1.2496 m U = 1.605 m/sec.

Sampling Volume = 1.26 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.013	-4.37406	[redacted]	[redacted]
[redacted]	0.022	-3.80317	[redacted]	[redacted]
[redacted]	0.031	-3.46414	[redacted]	[redacted]
[redacted]	0.052	-2.96423	[redacted]	[redacted]
[redacted]	0.081	-2.51207	[redacted]	[redacted]
[redacted]	0.111	-2.19732	[redacted]	[redacted]
[redacted]	0.141	-1.95829	[redacted]	[redacted]
[redacted]	0.221	-1.50914	[redacted]	[redacted]
[redacted]	0.261	-1.34285	[redacted]	[redacted]
[redacted]	0.351	-1.04668	[redacted]	[redacted]
[redacted]	0.601	-0.50899	[redacted]	[redacted]
[redacted]	0.901	-0.10414	[redacted]	[redacted]

assumed



lower (quasi grain shear)

slope	[redacted]	
intercept	[redacted]	
u*	0.092	m/s
tau	8.531	N/m2
ks	0.253	m

upper (total boundary shear)

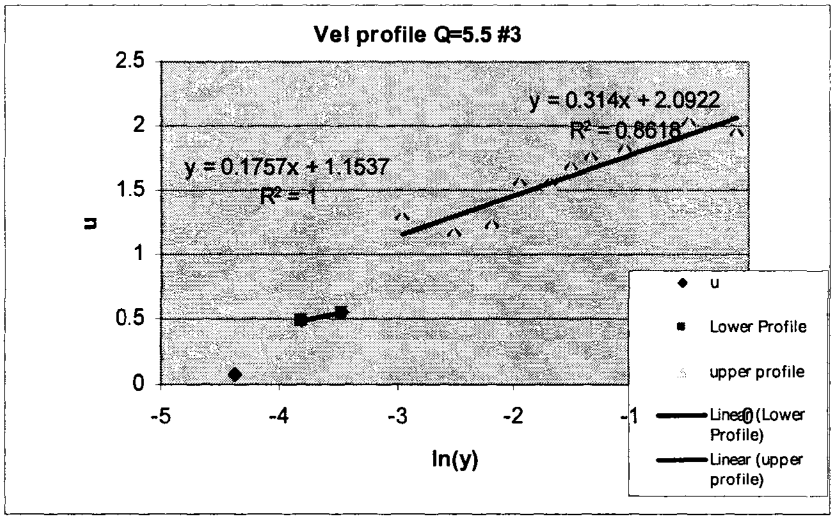
slope	[redacted]	
intercept	[redacted]	
u*	0.141	m/s
tau	19.899	N/m2
ks	0.055	m

March 14th, 2006

Q = 5.5 m^3/sec Y = 1.2496 m U = 1.605 m/sec.

Sampling Volume = 1.26 cm

	y	ln(y)	u		
[redacted]	0.013	-4.37406	[redacted]		1.26
[redacted]	0.022	-3.80317	[redacted]	edited	2.23
[redacted]	0.031	-3.46414	[redacted]		3.13
[redacted]	0.052	-2.96423	[redacted]		5.16
[redacted]	0.081	-2.51207	[redacted]		8.11
[redacted]	0.111	-2.19732	[redacted]	edited	11.11
[redacted]	0.141	-1.95829	[redacted]		14.11
[redacted]	0.181	-1.70871	[redacted]		18.11
[redacted]	0.221	-1.50914	[redacted]		22.11
[redacted]	0.261	-1.34285	[redacted]		26.11
[redacted]	0.351	-1.04668	[redacted]		35.11
[redacted]	0.601	-0.50899	[redacted]		60.11
[redacted]	0.901	-0.10414	[redacted]		90.11



lower (quasi grain shear)

slope	0.1757	
intercept	1.1537	
u*	0.072	m/s
tau	5.179	N/m2
ks	0.042	m

upper (total boundary shear)

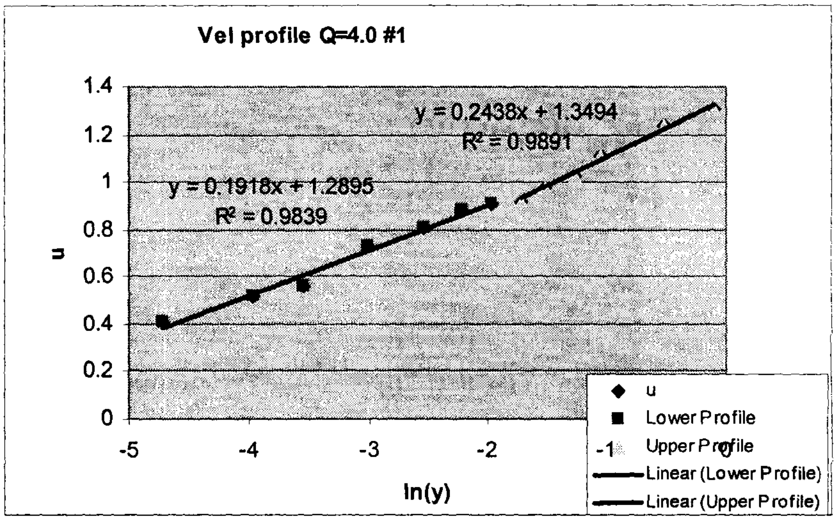
slope	0.314	
intercept	2.0922	
u*	0.129	m/s
tau	16.541	N/m2
ks	0.038	m

March 16th, 2006

Q =	4.0	m^3/sec.	Y =	1.376	m	U =	1.060	m/s

Sampling Volume = 0.9 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.009	-4.71053	[redacted]	[redacted]
[redacted]	0.019	-3.96332	[redacted]	[redacted]
[redacted]	0.029	-3.54046	[redacted]	[redacted]
[redacted]	0.049	-3.01593	[redacted]	[redacted]
[redacted]	0.079	-2.53831	[redacted]	[redacted]
[redacted]	0.109	-2.21641	[redacted]	[redacted]
[redacted]	0.139	-1.97328	[redacted]	[redacted]
[redacted]	0.179	-1.72037	[redacted]	[redacted]
[redacted]	0.219	-1.51868	[redacted]	[redacted]
[redacted]	0.279	-1.27654	[redacted]	[redacted]
[redacted]	0.349	-1.05268	[redacted]	[redacted]
[redacted]	0.599	-0.51249	[redacted]	[redacted]
[redacted]	0.899	-0.10647	[redacted]	[redacted]



lower (quasi grain shear)

slope	[redacted]	
intercept	[redacted]	
u*	0.079	m/s
tau	6.172	N/m2
ks	0.036	m

upper (total boundary shear)

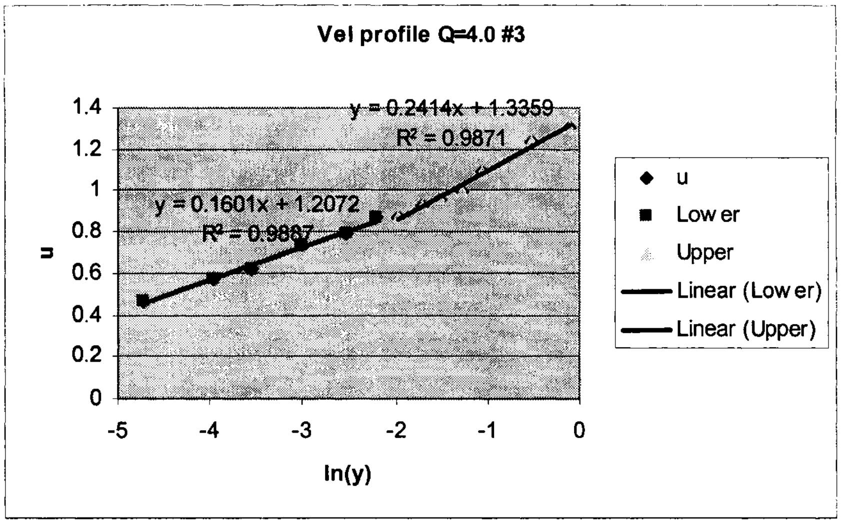
slope	[redacted]	
intercept	[redacted]	
u*	0.100	m/s
tau	9.972	N/m2
ks	0.118	m

March 16th, 2006 3rd profile

Q = 4.0 m^3/sec. Y = 1.376 m U = 1.060 m/sec.

Sampling Volume = 0.9 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.009	-4.71053	[redacted]	[redacted]
[redacted]	0.019	-3.96332	[redacted]	[redacted]
[redacted]	0.029	-3.54046	[redacted]	[redacted]
[redacted]	0.049	-3.01593	[redacted]	[redacted]
[redacted]	0.079	-2.53831	[redacted]	[redacted]
[redacted]	0.109	-2.21641	[redacted]	[redacted]
[redacted]	0.139	-1.97328	[redacted]	[redacted]
[redacted]	0.179	-1.72037	[redacted]	[redacted]
[redacted]	0.219	-1.51868	[redacted]	[redacted]
[redacted]	0.279	-1.27654	[redacted]	[redacted]
[redacted]	0.349	-1.05268	[redacted]	[redacted]
[redacted]	0.599	-0.51249	[redacted]	[redacted]
[redacted]	0.899	-0.10647	[redacted]	[redacted]



lower (quasi grain shear)

slope	[redacted]	
intercept	[redacted]	
u*	0.066	m/s
tau	4.300	N/m2
ks	0.016	m

upper (total boundary shear)

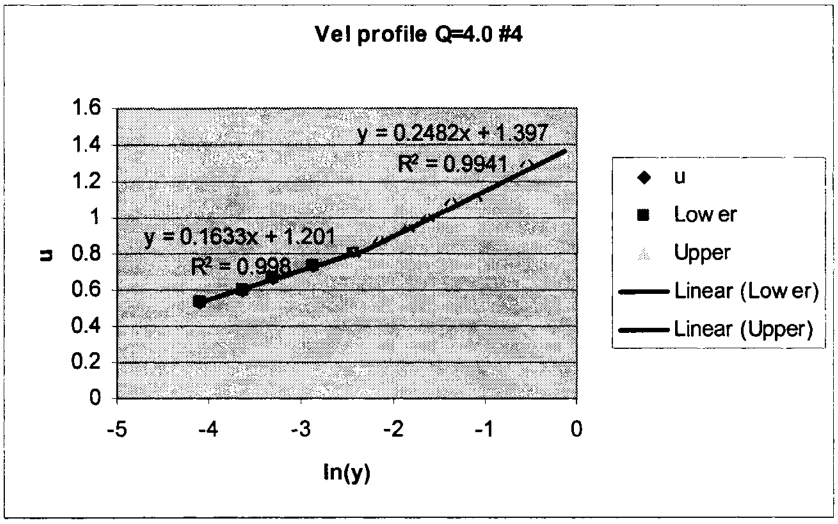
slope	[redacted]	
intercept	[redacted]	
u*	0.099	m/s
tau	9.776	N/m2
ks	0.119	m

March 21st, 2006 Ist profile

Q =	4.0	m^3/sec.	Y =	1.3637	m	U =	1.069	m/sec.

Sampling Volume = 1.67 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.017	-4.09235	[redacted]	[redacted]
[redacted]	0.027	-3.62309	[redacted]	[redacted]
[redacted]	0.037	-3.30498	[redacted]	[redacted]
[redacted]	0.057	-2.86998	[redacted]	[redacted]
[redacted]	0.057	-2.86998	[redacted]	[redacted]
[redacted]	0.087	-2.4453	[redacted]	[redacted]
[redacted]	0.087	-2.4453	[redacted]	[redacted]
[redacted]	0.117	-2.14815	[redacted]	[redacted]
[redacted]	0.157	-1.85342	[redacted]	[redacted]
[redacted]	0.197	-1.62608	[redacted]	[redacted]
[redacted]	0.257	-1.35985	[redacted]	[redacted]
[redacted]	0.327	-1.11871	[redacted]	[redacted]
[redacted]	0.577	-0.55043	[redacted]	[redacted]
[redacted]	0.877	-0.13159	[redacted]	[redacted]



lower (quasi grain shear)

slope	[redacted]	
intercept	[redacted]	
u*	0.067	m/s
tau	4.474	N/m2
ks	0.019	m

upper (total boundary shear)

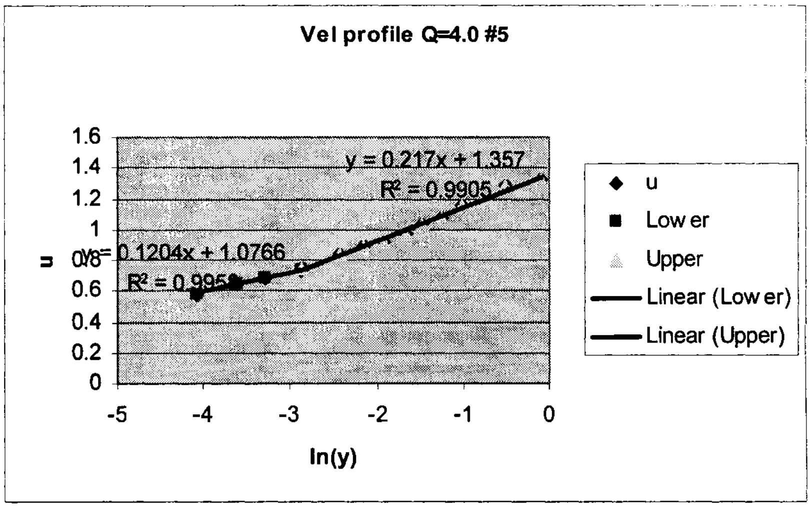
slope	[redacted]	
intercept	[redacted]	
u*	0.102	m/s
tau	10.335	N/m2
ks	0.108	m

March 21st, 2006 2nd profile

Q = 4.0 m^3/sec. Y = 1.364 m U = 1.069 m/sec.

Sampling Volume = 1.70 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.017	-4.07454	[redacted]	[redacted]
[redacted]	0.027	-3.61192	[redacted]	[redacted]
[redacted]	0.037	-3.29684	[redacted]	[redacted]
[redacted]	0.057	-2.8647	[redacted]	[redacted]
[redacted]	0.057	-2.8647	[redacted]	[redacted]
[redacted]	0.087	-2.44185	[redacted]	[redacted]
[redacted]	0.117	-2.14558	[redacted]	[redacted]
[redacted]	0.147	-1.91732	[redacted]	[redacted]
[redacted]	0.187	-1.67665	[redacted]	[redacted]
[redacted]	0.227	-1.48281	[redacted]	[redacted]
[redacted]	0.287	-1.24827	[redacted]	[redacted]
[redacted]	0.357	-1.03002	[redacted]	[redacted]
[redacted]	0.607	-0.49923	[redacted]	[redacted]
[redacted]	0.907	-0.09761	[redacted]	[redacted]



lower (quasi grain shear)

slope	[redacted]	
intercept	[redacted]	
u*	0.049	m/s
tau	2.432	N/m2
ks	0.004	M

upper (total boundary shear)

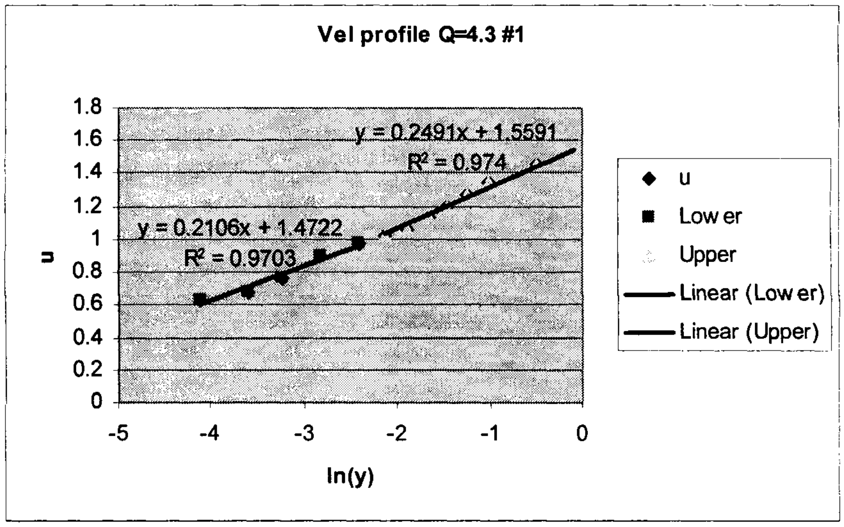
slope	[redacted]	
intercept	[redacted]	
u*	0.089	m/s
tau	7.900	N/m2
ks	0.058	M

March 25st, 2006 Ist profile

Q = 4.3 m^3/sec. Y = 1.2932 m U = 1.212 m/sec.

Sampling Volume = 1.62 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.016	-4.12274	[redacted]	[redacted]
[redacted]	0.027	-3.60454	[redacted]	[redacted]
[redacted]	0.040	-3.23145	[redacted]	[redacted]
[redacted]	0.060	-2.82178	[redacted]	[redacted]
[redacted]	0.090	-2.41352	[redacted]	[redacted]
[redacted]	0.120	-2.12444	[redacted]	[redacted]
[redacted]	0.150	-1.90046	[redacted]	[redacted]
[redacted]	0.190	-1.66337	[redacted]	[redacted]
[redacted]	0.230	-1.47185	[redacted]	[redacted]
[redacted]	0.290	-1.2396	[redacted]	[redacted]
[redacted]	0.360	-1.02304	[redacted]	[redacted]
[redacted]	0.610	-0.49512	[redacted]	[redacted]
[redacted]	0.910	-0.09486	[redacted]	[redacted]



lower (quasi grain shear)		
slope	[redacted]	
intercept	[redacted]	
u*	0.086	m/s
tau	7.441	N/m2
ks	0.028	m

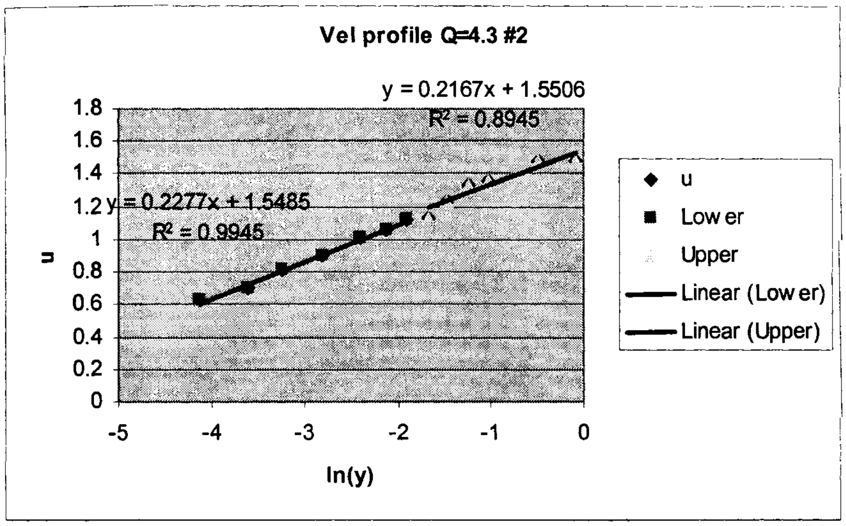
upper (total boundary shear)		
slope	[redacted]	
intercept	[redacted]	
u*	0.102	m/s
tau	10.410	N/m2
ks	0.057	m

March 25st, 2006 2nd profile

Q =	4.3	m^3/sec.	Y =	1.2932	m	U = 1.212	m/sec.

Sampling Volume = 1.62 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.016	-4.12274	[redacted]	[redacted]
[redacted]	0.027	-3.60454	[redacted]	[redacted]
[redacted]	0.040	-3.23145	[redacted]	[redacted]
[redacted]	0.060	-2.82178	[redacted]	[redacted]
[redacted]	0.090	-2.41352	[redacted]	[redacted]
[redacted]	0.120	-2.12444	[redacted]	[redacted]
[redacted]	0.150	-1.90046	[redacted]	[redacted]
[redacted]	0.190	-1.66337	[redacted]	[redacted]
[redacted]	0.230	-1.47185	[redacted]	[redacted]
[redacted]	0.290	-1.2396	[redacted]	[redacted]
[redacted]	0.360	-1.02304	[redacted]	[redacted]
[redacted]	0.610	-0.49512	[redacted]	[redacted]
[redacted]	0.910	-0.09486	[redacted]	[redacted]



lower (quasi grain shear)

slope	[redacted]	
intercept	[redacted]	
u*	0.093	m/s
tau	8.698	N/m2
ks	0.033	m

upper (total boundary shear)

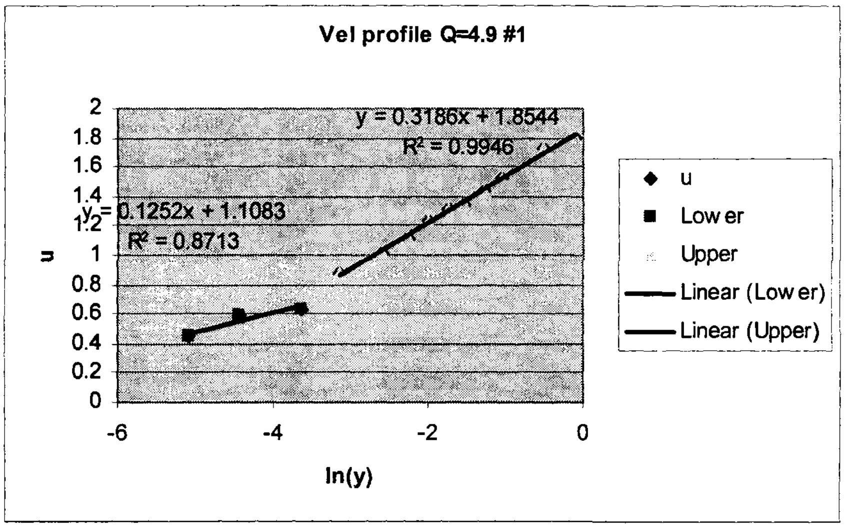
slope	[redacted]	
intercept	[redacted]	
u*	0.089	m/s
tau	7.878	N/m2
ks	0.023	m

March 28th, 2006 Ist profile

Q = 4.9 m^3/sec. Y = 1.3023 m U = 1.372 m/sec.

Sampling Volume = 1.53 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.006	-5.08321	[redacted]	[redacted]
[redacted]	0.012	-4.43122	[redacted]	[redacted]
[redacted]	0.027	-3.62309	[redacted]	[redacted]
[redacted]	0.044	-3.1327	[redacted]	[redacted]
[redacted]	0.074	-2.60911	[redacted]	[redacted]
[redacted]	0.104	-2.26722	[redacted]	[redacted]
[redacted]	0.134	-2.01291	[redacted]	[redacted]
[redacted]	0.174	-1.751	[redacted]	[redacted]
[redacted]	0.214	-1.54365	[redacted]	[redacted]
[redacted]	0.274	-1.29609	[redacted]	[redacted]
[redacted]	0.344	-1.06828	[redacted]	[redacted]
[redacted]	0.594	-0.52155	[redacted]	[redacted]
[redacted]	0.894	-0.1125	[redacted]	[redacted]



lower (quasi grain shear)

slope	[redacted]	
intercept	[redacted]	
u*	0.051	m/s
tau	2.630	N/m2
ks	0.004	m

upper (total boundary shear)

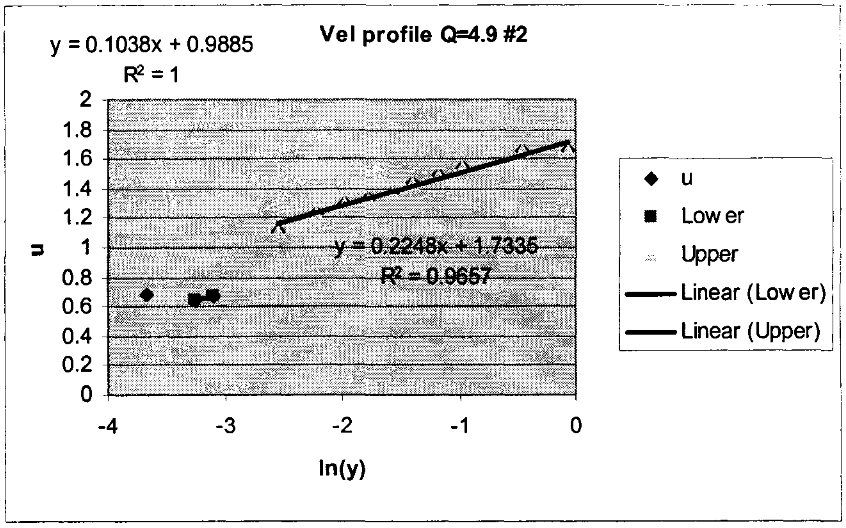
slope	[redacted]	
intercept	[redacted]	
u*	0.131	m/s
tau	17.029	N/m2
ks	0.089	m

March 29th, 2006 Ist profile

Q = 4.9 m^3/sec. Y = 1.2823 m U = 1.393 m/sec.

Sampling Volume = 1.50 cm

Scale No.	y	ln(y)	u (m/sec)	u (cm/s)
[redacted]	0.026	-3.65351	[redacted]	[redacted]
[redacted]	0.039	-3.2545	[redacted]	[redacted]
[redacted]	0.046	-3.08566	[redacted]	[redacted]
[redacted]	0.078	-2.5549	[redacted]	[redacted]
[redacted]	0.108	-2.22841	[redacted]	[redacted]
[redacted]	0.138	-1.98268	[redacted]	[redacted]
[redacted]	0.168	-1.78558	[redacted]	[redacted]
[redacted]	0.208	-1.57166	[redacted]	[redacted]
[redacted]	0.248	-1.39554	[redacted]	[redacted]
[redacted]	0.308	-1.17863	[redacted]	[redacted]
[redacted]	0.378	-0.97366	[redacted]	[redacted]
[redacted]	0.628	-0.46569	[redacted]	[redacted]
[redacted]	0.928	-0.07505	[redacted]	[redacted]



lower (quasi grain shear)		
slope	[redacted]	
intercept	[redacted]	
u*	0.043	m/s
tau	1.808	N/m2
ks	0.00219	M

upper (total boundary shear)		
slope	[redacted]	
intercept	[redacted]	
u*	0.092	m/s
tau	8.418	N/m2
ks	0.013	M

There is error in measuring the Ist two point on the graph in Lower Profile, so ignored during analysis

These profiles could be used to assess influence of bedform geometry on total shear stress, and isolate grain shear.