CHAPTER 3: STUDY AREA AND DATA MEASUREMENT

3.1 INTRODUCTION

Measurement of the water discharge is a key parameter in open channel flow. For measurement of discharge various measurement techniques were developed (Bos 1976 and Herschy 2002). Many techniques to measure the discharge depend upon empirical coefficients and it is required to obtain a new accurate physical data to complement the existing one. The basic method to measure the flow in open channels at stream gauging stations has not changed for over 100 years. A current meter with rotating propeller with cups which is lowered into the river and may be stabilized by a heavy lead weight when depth or velocity is large. The velocity of flow at a point is proportional to the rate of rotation of the rotor during a measured period of time (Rantz, 1982). Multiple depth and velocity measurements are taken across the channel, and these sub-areas summed to calculate the total stream discharge. These discharge values are used to define a relation between the stage (depth) and rate of flow (discharge), referred to as a rating curve. Discharge data collected under ideal conditions, using a properly rated current meter and following accepted practices, are generally considered to be within 5 % of the true value (Sauer and Meyer, 1992).

Direct measurement of flow with a current meter or any other instrument that must be placed in the water could introduce high measurement errors, and safety hazards. Debris can snag equipment and cables, jeopardizing the safety of technicians suspended over the water on cableways. At times conditions are sufficiently hazardous that no current-meter measurement can be made. Flood discharge measurement can be hazardous to personnel as well as to the instruments. In order to avoid exposure to the hazardous environment too long, some non-contact methods (Spicer et al., 1997; Herschy 1999; Costaet al., 2000) that do not involve immersing equipment in the stream have been developed to measure flood discharge. Until recently, a key limitation to understanding flood flow has been the difficulty and expense associated with using conventional methods. Owing to rapid change of flow conditions allowing very little time for measurements, new techniques have been applied to measure velocity quickly (Klein et al., 1993; Schultz, 1996; Callede et al., 2000; Sulzer et al., 2002). However, a new method to determine flood discharge efficiently is still required. A fast method of flood discharge measurement that is efficient and requires only a small number of velocity samples is preferred. So new advanced technology or equipment must be used in such scenario which can be used for profiling and measurement of discharge in rivers during high flow conditions.

Acoustic Doppler Current Profiler (ADCP), which has been applied widely to geo-environmental sciences, uses the Doppler Effect to measure the motion of water flow (Kraus, 1994; King et al., 1996; Wegner et al., 2005; Lu et al., 2006; Chen et al., 2007). This effect refers to the compression of the transmitted sonar signal as a result of relative motion between ADCP and the scattering materials in the water column measured. The major merit of ADCP is that it is capable of continuously measuring a profile of water flow current through the water column, and thus provides a more reliable and efficient database at different scales (Chen et al., 2007). In the present study, ADCP was applied to measure the discharge distribution and to achieve the correlation between the different cross-section of a river and the velocity changes through the various cross-sections, especially the differences of distribution patterns of flow current velocity in the river knot associated middle-lower Ganga River channel. This would help with better river flood management in the coming decades. The measured river width of the study area is between 814 m and 297 m. During surveying, no large scale precipitation occurred. The data obtained from ADCP, contain mean flow velocity, maximum and minimum flow velocity, and flow direction. In addition, the river channel morphology, backscatter density and cross-sectioned area of the 14 cross-sections were also obtained through this ADCP survey.

The present research work is useful to make an understanding about the river behavior in terms of discharge, velocity, depth and bend angle (θ) in Varanasi region with certain defined boundary condition. The complete study area is an arc type shape which is clearly shown in the Figure 3.1. The length of the arc is about 7500 meter and average radius of curvature is about 4672 meter and the arc angle is about 91.71˚ for the main Varanasi region from Pantoon Bridge of Ramnagar to about 200 meters in downstream from the Rajghat Bridge.

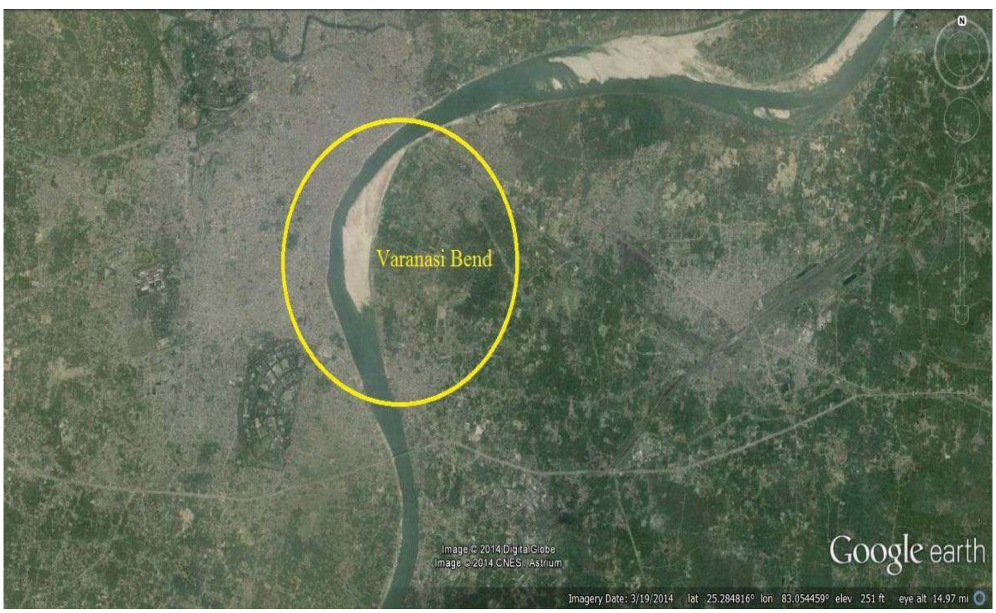

Figure 3.1. Study area

3.2 STUDY AREA

The study area “Varanasi” (25˚ 20' N and 83˚ 7' E) is located in the middle Ganges valley of North India, in the Eastern part of the state of Uttar Pradesh, the average length of the left crescent-shaped bank of the Ganges at Varanasi lies between 50 feet (15 m) and 70 feet (21 m) above the river. Varanasi is oldest city situated on the convex bank of holy river Ganga. It is called the longest river of India as having its total length 2525 Km from Gangotri to Ganga sagar. The "Varanasi Urban Agglomeration" an agglomeration of seven urban sub-units, covers an area of 112.26 km^2. Being located in the Indo-Gangetic Plains of North India, the land is very fertile because low level floods in the Ganges continually replenish the soil. Varanasi is often said to be located between two confluences: one of the Ganges and Varuna, and other of the Ganges and Assi, although the latter has always been a rivulet rather than a river. The distance between the two confluences is around 4.0 km, and religious Hindus regard a round trip between these two places, a Pancha-kroshi Yatra (8.3 km) journey ending with a visit to a Sakshi Vinayak Temple as a holy ritual.

Rarely has any river gathered in itself so much meaning and reverence as the Ganga has over three millennia in the Indian subcontinent. The land-water interface on the Ganga’s banks is fashioned out of the need to access the rising and falling water levels in the monsoon and dry seasons. The cultural landscape of this interface ghats (steps and landings) lined by temples and other public buildings, pavilions, kunds (tanks), streets and plazas are layered and kinetic, and responsive to the river’s flow. At Varanasi, where the Ganga reverses its flow northwards, the ghats describe a crescent sweep in a 7.5 km stretch.

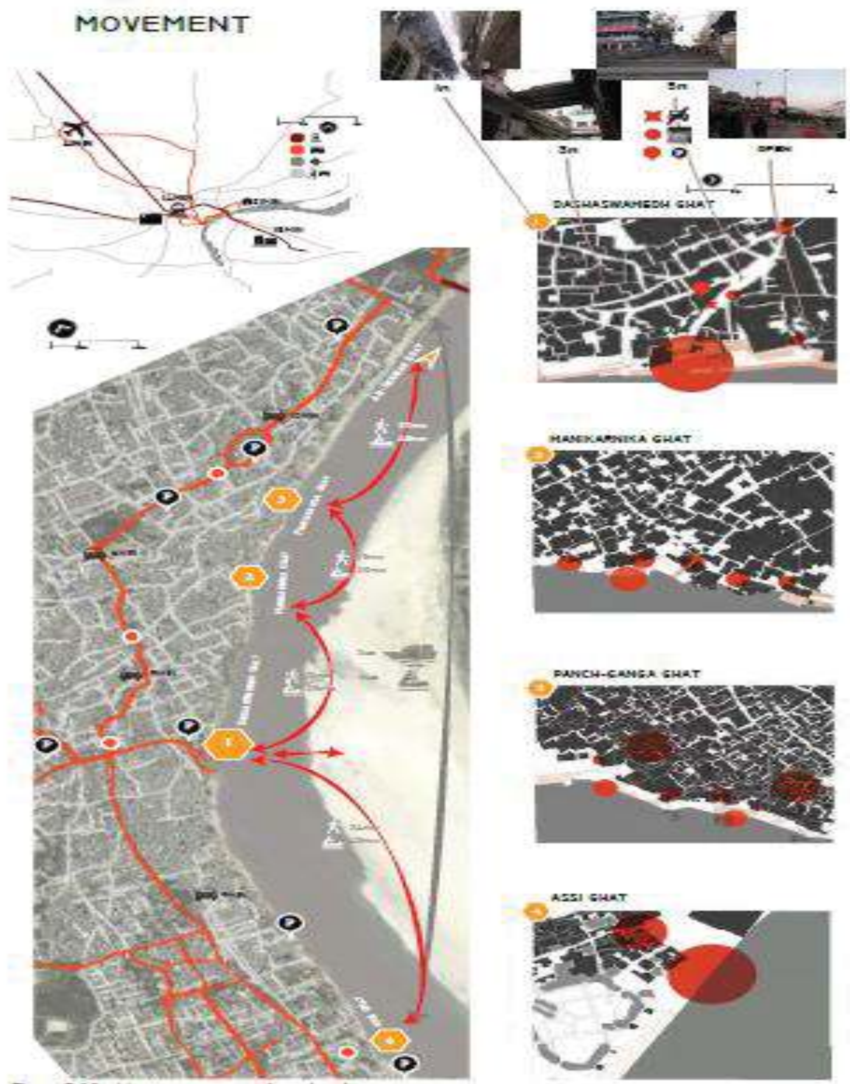

Figure 3.2. Movement pattern of Ganga along the different Ghats in study area

The climate of the city, as of Northern India on the whole, is of tropical nature with extremes of temperature, varying from a minimum of 3°C in winter to a maximum of 47°C in summer. The annual rainfall varies from 680 mm to 1500mm, with a large proportion occurring during the monsoon season, in the months of July to September.

3.3 DIVISION OF CROSS-SECTION

The complete arc length of river Ganga is about 7500 meters and the cross-section are divided with help of hand GPS with having length about 500 meters distance. The total numbers of cross-sections are 14 as shown in the figure below, as each cross-section latitude and longitude are listed in the Table and also the cross-section to cross-section distance and average radius of curvature is defined in the Table 3.1. It was tried to do the detail study over this bend situated in Varanasi for forecasting effect of velocity, depth and arc on the discharge. There data were obtained with the help of various analyses done over the data collected using different type of software like SPSS, Sigmaplot, Win-River-II, Ky plot, Easyfit, Origin, XLSTAT and many more which are not listed here.

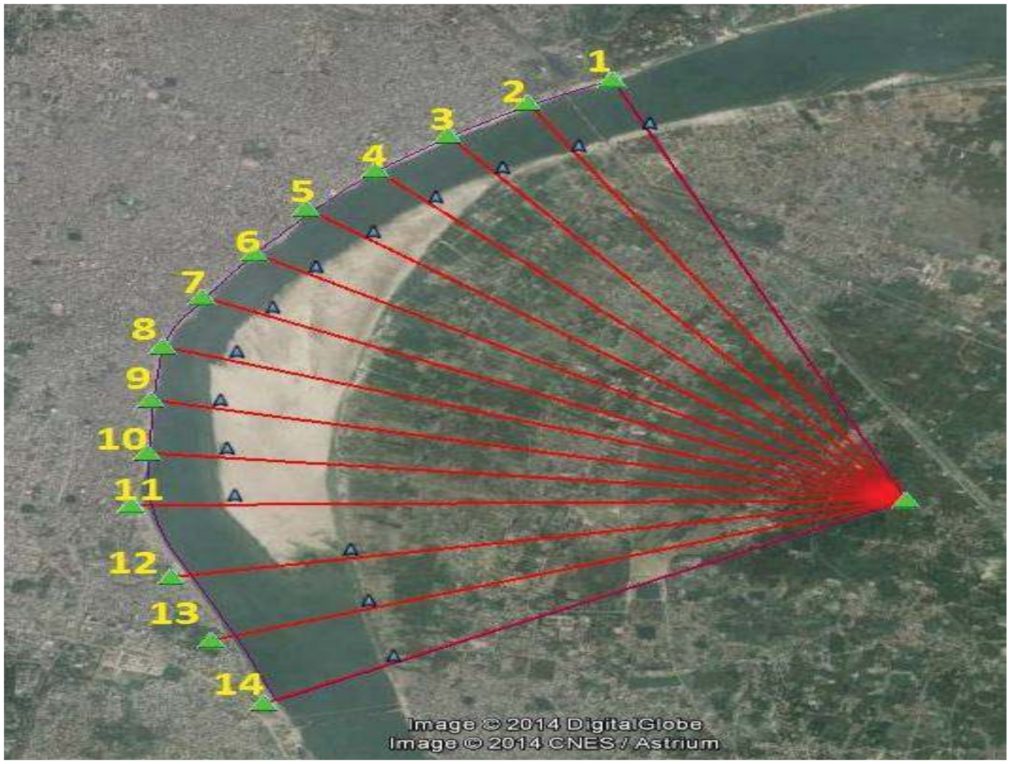

Figure 3.3. Showing all 14 cross-section on River Ganga

A river section has a length which is considered to be the distance the river travels over the ground and not the crow-fly distance between two points. It also has a width and a depth. Because a meandering river has alternating bends, it is like a wave and therefore has amplitude, a wavelength, and a radius of curvature. The amplitude is the distance along the ground that the river bend extends away from the overall downward path of the river. The wavelength is the distance along the ground between successive bends that are in the same direction. The radius of curvature is like the radius of a circle; for a bend in a river, it is the radius of the arc that the bend makes. The water that takes the longer route will need to go faster. This is the same principle that creates the lift in an airfoil, the upper surface is curved so the air must go faster, creating a pressure drop. The faster flow will cause more erosion on that side of the obstruction and eventually, a concave bank will be formed. The silt that is removed by the erosion will be transported downstream where it will settle out in an area where the flow has abated, eventually forming a bar. As this process continues, the concave banks become more eroded and the sediment is deposited along the sides of the river, generally at the convex curve of the next bend. The flow of the river is therefore fastest and hugs the bank at on the concave side and crosses over to the other bank at the infection point. Because the river's flow has streamlines that are not congruent with the shape of the banks, it is given a special name, thalweg, the line of fastest flow in a river.

Location of each cross-section has been marked by GPS for correct measurement of its coordinate so that in later studies it can be geo-referenced. In order to do this for proper understanding of bank, the direction of river flow is marked along concave and convex side of bank. In Fig., 3.3, where marking is done, shows cave like shape so it is called concave side of river and opposite of it is called convex bank or side. Details of each 14 cross-sections in study area are listed in table 3.1 with coordinates of each cross-section. Table 3.2 represents the distances corresponding to each coordinates.

Table 3.1. Location of each cross-section with coordinates

Sr.No.	N-Reading (Concave bank)	E-Reading (Concave Bank)	N-Reading (Convex Bank)	E-Reading (Convex Bank)
1	25° 19.530'	083°02.175'	25° 19.285'	083°02.302'
2	25° 19.410'	083°01.849'	25° 19.147'	083°02.042'
3	25° 19.243'	083°01.552'	25° 19.0203'	083°01.76'
4	25° 19.065'	083°01.284'	25° 18.878'	083°01.50'
5	25° 18.868'	083°01.021'	25° 18.7123'	083°01.2626'
6	25° 18.640'	083°00.828'	25° 18.532'	083°01.042'
7	25° 18.420'	083°00.631'	25° 18.336'	083°0.847'
8	25° 18.166'	083°00.486'	25° 18.0944'	083°0.750'
9	25° 17.896'	083°00.437'	25° 17.8415'	083°0.744'

10	25^o 17.627'	083^o00.424'	25^o 17.598'	083^o0.769'
11	25^o 17.361'	083^o00.662'	25^o 17.365'	083^o0.769'
12	25^o 17.024'	083^o00.572'	25^o 17.054'	083^o0.936'
13	25^o 16.696'	083^o00.731'	25^o 16.808	083^o01.164'
14	25^o 16.367'	083^o00.899'	25^o 16.546'	083^o01.313'

Table 3.2. Details of angles and average radius of curvature at each cross-section

Sr. No.	Distance Between Cross-Sections	Arc length (m)	Concave Bank to Centre (m)	Angle in radian=Arc/Average Radius	Angle in Degree=(180/л)*Angle (Radian)
1	M-1 to M-2	585	4372	0.125192987	7.176668031
2	M-2 to M-3	595	4438	0.127333038	7.299346117
3	M-3 to M-4	563	4490	0.120484874	6.906776241
4	M-4 to M-5	570	4569	0.12198291	6.992650902
5	M-5 to M-6	532	4678	0.113850716	6.526474175
6	M-6 to M-7	527	4728	0.112780691	6.465135132
7	M-7 to M-8	540	4845	0.115562757	6.624616644
8	M-8 to M-9	511	4921	0.109356609	6.268850194
9	M-9 to M-10	497	4870	0.106360537	6.097100874
10	M-10 to M-11	507	4823	0.108500589	6.21977896
11	M-11 to M-12	719	4903	0.153869671	8.820554383
12	M-12 to M-13	649	4706	0.138889314	7.961807781
13	M-13 to M-14	681	4589	0.145737477	8.354377656
14			4487		
		Avg. rad	**4672.78**		

3.4 INSTRUMENT USED

1. ADCP (Acoustic Doppler Current Profiler)
2. Total station
3. Auto Level

3.4.1 Instrument Description

3.4.1.1 Acoustic Doppler current profiler

The ADCP is an Instrument working on the principle of Doppler-effect, which is used to measure the velocity and corresponding depth in very short duration means only cross river from one end to another. It is also a very widely used instrument and comes into the measurement field; around 25 years ago primarily it used to study ocean current and estuaries by deploying it at a fixed location. In the end of 80's ADCP began to be used to flow measurement from moving vessel. The early instrument were used for measurement of very high water (3~4 m) depth, which limits their use to ocean and deep rivers but 1992, a more advanced acoustic Doppler instrument, known as broadband Doppler Current Profiler, was developed that could be used in shallow waters (as shallow as 1m) with a high degree of vertical resolution (0.10m) throughout 1990's this instrument was updated by various manufacturers as initially it was very heavy and long to carry [upto 1m long and 20 Kg weight] have been modified to 14 cm long and 7 Kg weight. Now the ADCP are designed or manufactured for rivers especially both as well as its hardware and software. ADCP are routinely used by USGS to measure velocity and flow rate at different locations on ocean, rivers and canals where ever needed over the various conventional methods due to its easiness of working and accurate measurement.

3.4.1.1.1 Working principle of ADCP

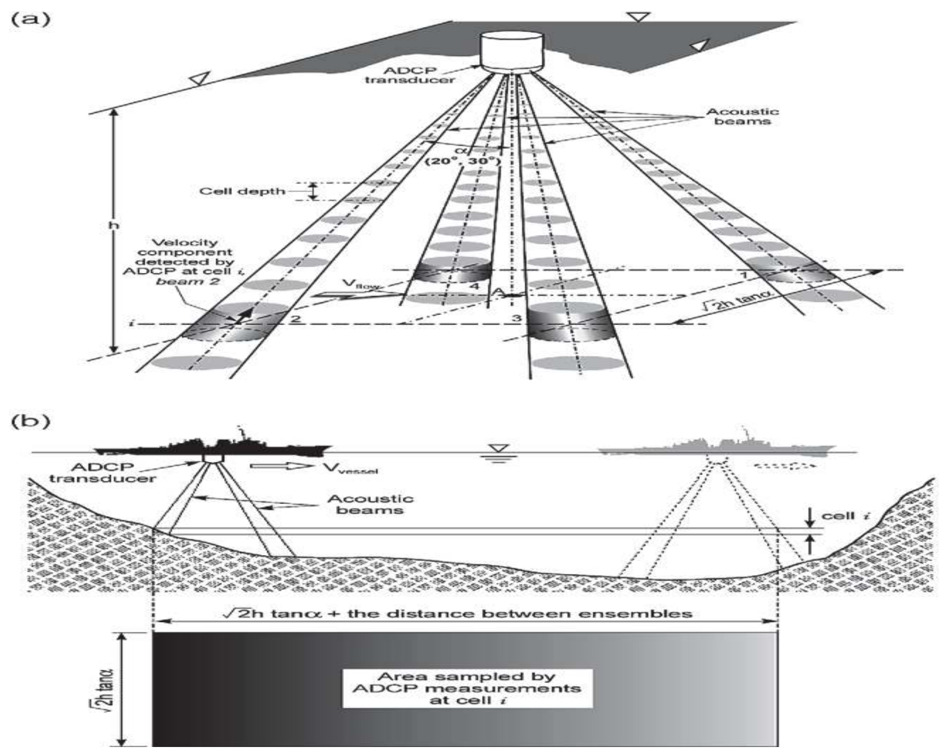

Figure 3.4. Showing the working methodology of ADCP

For measurement the installation of ADCP on the moving vessel is required become the acoustic Doppler profiler is fitted on the vessel that is moving across the river perpendicular to the current. The water velocities is measured with help of acoustic pulses, emitted by the acoustic Doppler profiler, these pulses has constant frequency between 75 to 3000 kHz. The beams are 3 to 4 in numbers and inclined at an specific horizontal angle from each other (120˚ for three beam instruments and 90˚ for four beam instruments), the beam are inclined at known angle from vertical, usually 20˚ to 30˚. The instrument produces echoes in the whole water column along each beam. The resultant difference in frequency (shift) between received echoes and transmitted pulses, known as the Doppler effect, which can be used to calculate the relative velocity between the instrument and suspended material in the water that reflects the pulses back to the instrument with the help of Doppler effect. The acoustic Doppler Profiler uses to calculate the water velocity component along each beam. On the other hand system software computes the water velocity using trigonometric relations on three dimensions. The velocities that are being calculated at present intervals are called bins along the acoustic path. The setup parameter of the instrument can be used to optimize the system for geometric characteristic of the river cross-section being measured, the setup parameter generally includes the depth cell size, the number of depth cell size, number of pings and velocity references command. The water velocity measurement includes both the boat velocity and the water velocity. The Doppler shift of separate acoustic pulses reflected from the river bottom can be used to measure the boat velocity. The technique generally referred to as bottom tracking and was primarily used with sonar to detect the speed of moving vessel for calculating the boat velocity, the analysis of bottom track echoes is used for calculating river depth. There is another method called real time differential global positioning systems (DGPS) is also used to calculate the boat velocity. A series of acoustic pulses know as pings are transmitted when an acoustic Doppler profiler was used to measure discharge. Pings for calculating the boat velocity are known as bottom-tracking pings were as pings for calculating water velocity are known as water pings. At the time of transmission the water pings and the bottom tracking pings are interleaved. These interleaved pings are also referred to as an ensemble. It (ensembles) is similar to one vertical in a traditional velocity area measurement. For the river discharge measurement generally includes use of single ping data to help in providing quality assurance to the data and for the use of proper DGPS. In the method of traditional discharge calculation, velocity is calculated at single point in the vertical, when the depth is less than 0.8 meter and similarly 2, 3 or 5 points in the vertical when the depth is higher than 0.8 meter. For the calculation of 10 meter deep in water an acoustic Doppler profiler could make as many as 34 velocity measurement separated at 0.25 meter in the vertical (Yorke et al.2002)

Power function is used to estimate the area at the top and bottom of the profile (blanking/draft distance and side-lobe interference area), but because of these limitations, depth across the edge of the river cannot be measured. This unmeasured area can be measured by ratio interpolation method (Fulford and Sauer, 1986), from which can be further used to estimate the velocity in a cross-section (Simpson 2001).

3.4.1.2 Total station

A Total Station is a modern surveying instrument that integrates an electronic theodolite with an electronic distance meter. The development of Total Stations has markedly increased productivity in the surveying profession in the following ways First of all, improved accuracy: while coordinate measurements by the theodolite are done in the traditional way trigonometry and triangulation the angles are measured by means of electro-optical scanning to a high degree of accuracy up to 0.5 arc-seconds. What's more, a drawback of traditional theodolites is they require a line of sight between two points; now GPS technology can be used by a Total Station to include unseen points in the survey. Other increases in productivity are due to efficiency and functionality. One advantage is that many Total Stations, such as the Leica Viva TS15 used by Jurovich Surveying, are robotic. This means they can be operated at a distance, hence requiring only one surveyor in the field, rather than the traditional two. For example, the robotic controller can stream the Total Station's view to a surveyor at a remote point, who can make measurements and change the target area without returning to the Total Station. The photograph of total station is given below.

Figure 3.5. Showing the Autolevel

3.4.1.3 Auto level

Auto level surveys are commonly used to complete cross-sectional and longitudinal surveys. This method requires a minimum of two field personnel. It is recommended that a base map be generated. Before starting the field work, it requires to make a conceptual map with cross-sections details. The extents of the cross-sections, the extents of longitudinal survey and any other physical measurements that helpful for subsequent analyses may also require. This initial plan will aid in ensuring that to have collected sufficient data while in the field. The plan will also assist in determining the amount of time that will be required in the field.

It is strongly encouraged that a reconnaissance visit to the project site is made prior to the starting of any field work. This initial visit will allow becoming familiar with the site, identifying any access issues (such as locked gates, private property, etc.). It will also provide us an opportunity to assess the amount of vegetation onsite which may present difficulties during survey work. The initial assessment of the site will better allow estimating how much time will be required to complete the desired field work. Once conceptual field work plan has been developed and initial site reconnaissance is complete, it is time to start collecting data. As previously mentioned, the first step in conducting field work is to have a base map developed for site.

3.5 DATA COLLECTION TECHNIQUES

After the measurement process through the ADCP was completed (means, crossing of river completed with ADCP) the Data recorded in the instrument hardware which have to extract from it with the help of the supporting software of ADCP named as Win-River –II , an advanced software to extract the data in various format like JPEG, note pad etc. For extracting the data from the instrument first of all open the software in the computer and follow some easy steps which is also shown with the help of screen shots taken of every step

- *Open the measurement in software (Figure 3.4.a.)*
- *Reprocess the Transect (Figure 3.4 b.)*
- *Select the window to capture the image of required data (Figure 3.4 c.)*
- *Save it to desired location (Figure 3.4 d.)*

Figure 3.5 a. to 3.5 d. shows the real time processing of raw data.

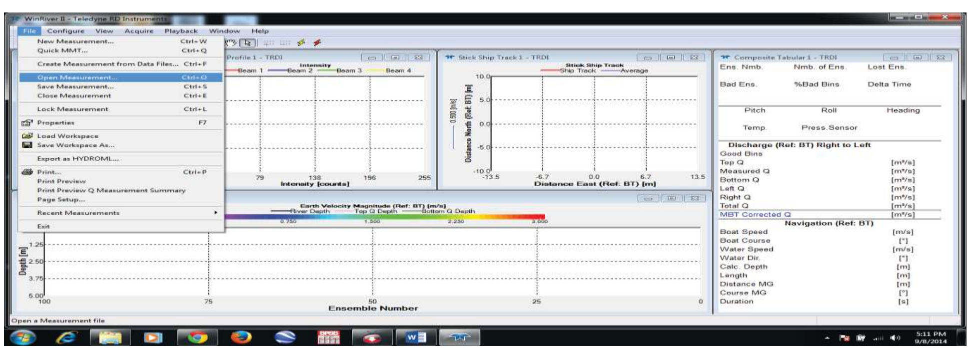

Figure 3.6 a. Screen shot for starting the measurement in software

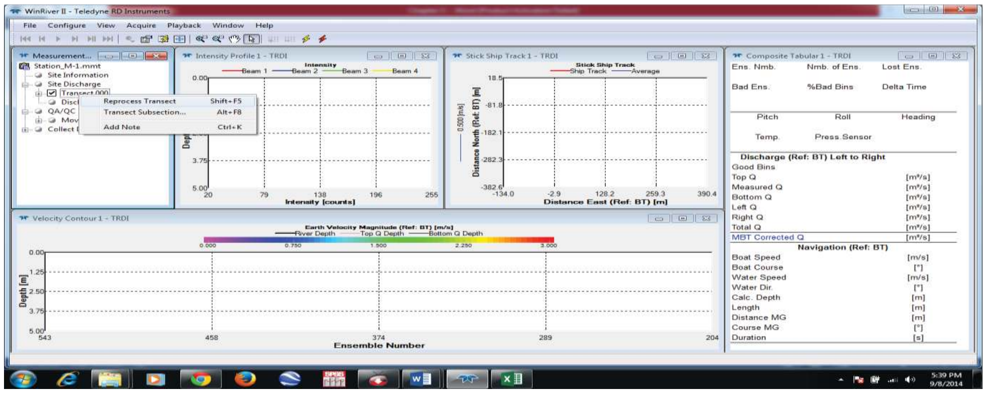

Figure 3.6 b. Screen shot for reprocessing the transect

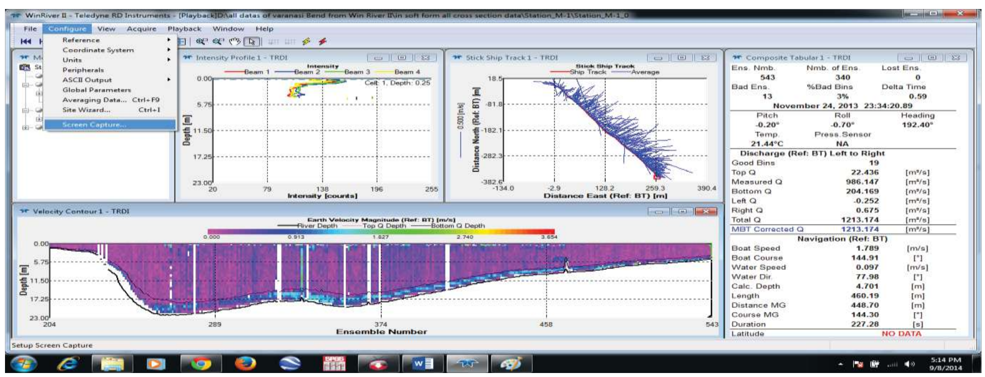

Figure 3.6 c. Screen shot for capture the image of required data

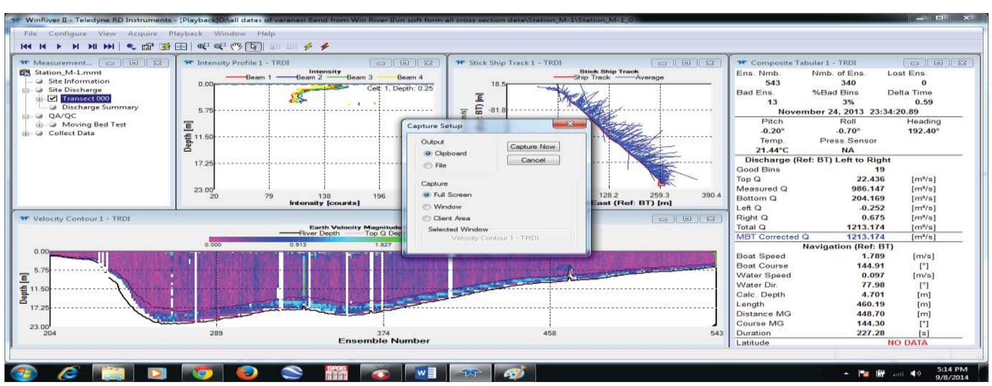

Figure 3.6 d. Screen shot for saving the data to desired location

3.6 Complete Data Collection

To know the hydraulic properties of natural rivers, depth pattern with respect to distance from concave side in the river cross-section should be studied in detail. The measurement task is not straightforward because there is not an instrument that can measure the depth pattern covering the entire cross-section. Particularly, the depths in regions near the free surface and in the bottom boundary layer are difficult to measure, and yet the depth properties in these regions play the most significant role in characterizing the hydraulic properties. Figures 3.6 to 3.192 show the variation of depth with the distance from concave side of river in study cross-section. It can be easily observed from Fig. 1 that at the edge of cross-section depth is supposed to be zero but it is not like due to using of boat which occupies its space (in length) so this is the disadvantage of using ADCP. Table 3.3. briefs the description of cross-section variation.

Table 3.3. Description of cross-section at Varanasi bend

Sr.No.	Section	Maximum Depth (m)	Location of Max. Depth from concave bank (m)	Width of cross-section (m)	Location of nearby Ghat Corresponding to Section
1	M-1	21.9	60.25	460	Near Rajghat
2	M-2	17.1	65.07	434	Near Guru Ravidas Temple
3	M-3	20.3	46.29	357	Near TeliyanaGhat
4	M-4	22.7	54.59	378	Near HanumangarhiGhat
5	M-5	21.1	91.01	386	In centre of Ramghat and JatarGhat
6	M-6	17.9	59.22	297	Near ManikarnikaGhat

7	M-7	15.5	33.33	281	Near DashaswamedhGhat
8	M-8	12.3	43.56	312	Near MansarowarGhat
9	M-9	9.7	22.98	307	HarishchandraGhat
10	M-10	13.1	14.61	392	Near Shrinishad Raj Ghat
11	M-11	6.1	169.27	422	In front of AssiGhat
12	M-12	5.3	57.41	559	In front of RavidasGhat
13	M-13	6.9	200.50	814	In between Pantoon Bridge and RavidasGhat
14	M-14	9.7	50.84	694	Near Pantoon Bridge

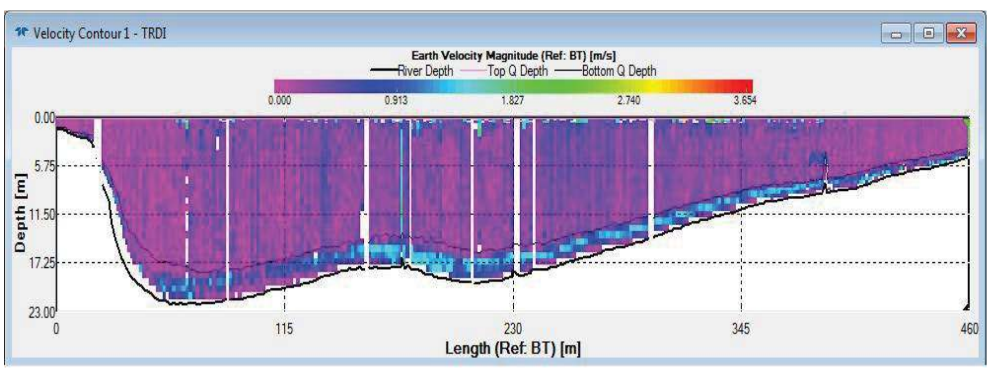

Figure 3.7. Distance from concave side vs. depth curve at Profile M-1

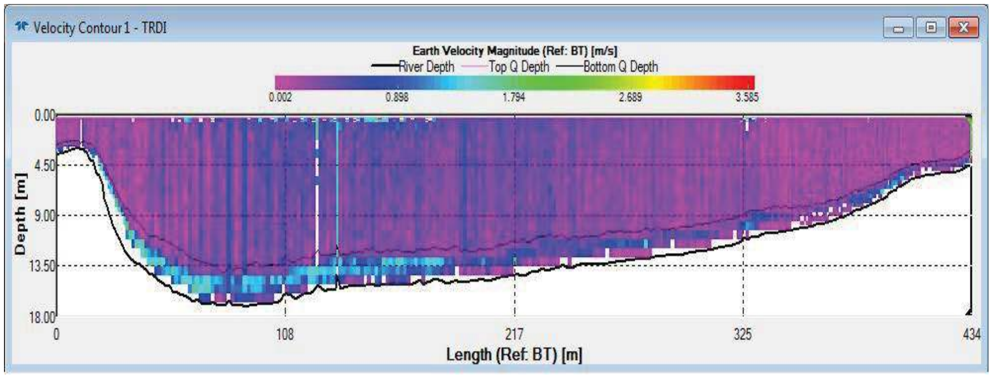

Figure 3.8. Distance from concave side vs. depth curve at Profile M-2

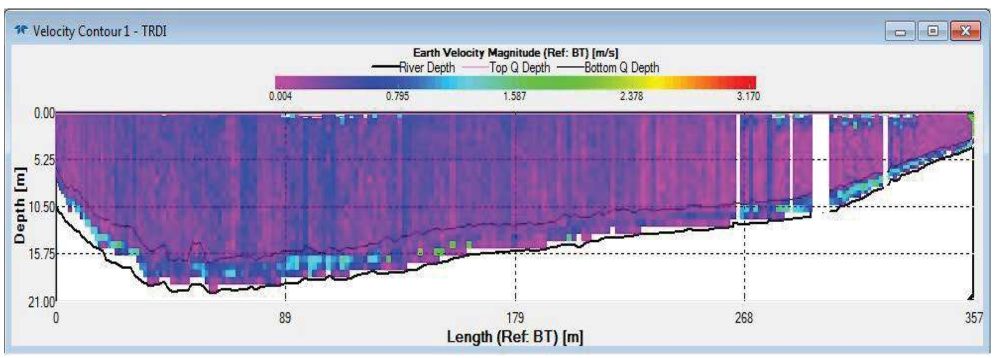

Figure 3.9. Distance from concave side vs. depth curve at Profile M-3

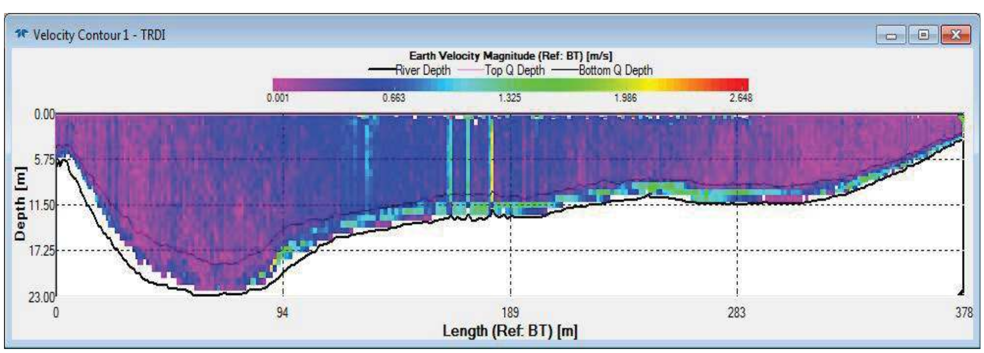

Figure 3.10. Distance from concave side vs. depth curve at Profile M-4

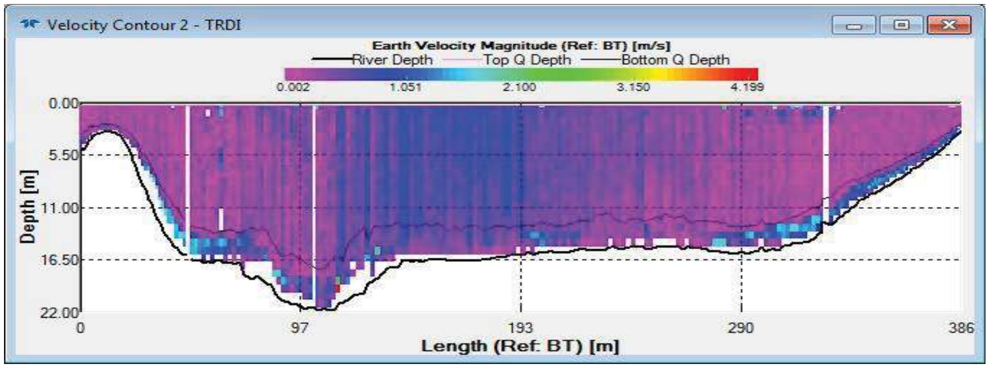

Figure 3.11. Distance from concave side vs. depth curve at Profile M-5

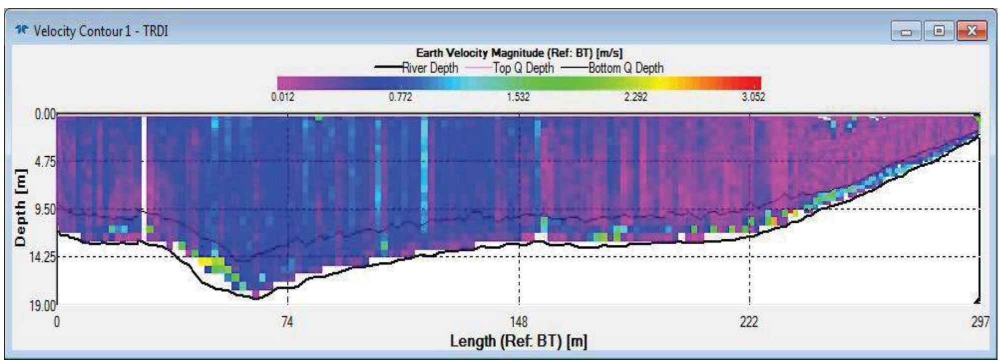

Figure 3.12. Distance from concave side vs. depth curve at Profile M-6

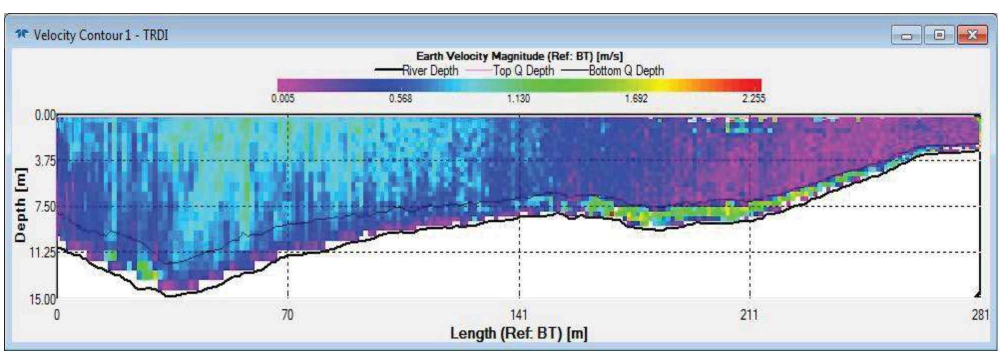

Figure 3.13. Distance from concave side vs. depth curve at Profile M-7

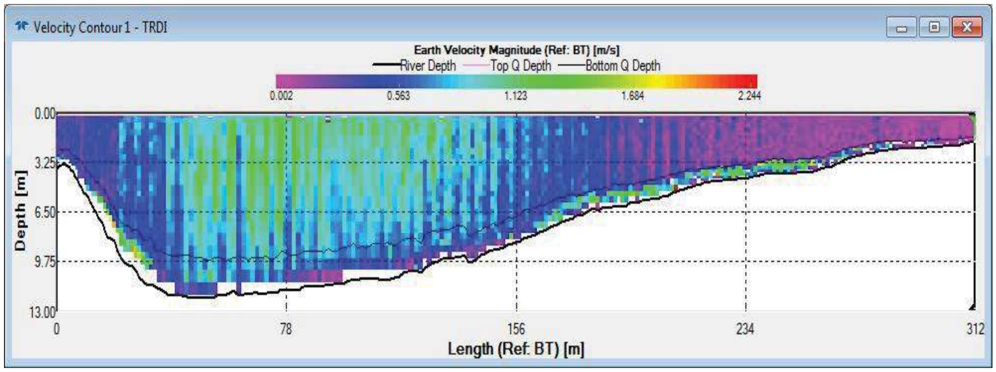

Figure 3.14. Distance from concave side vs. depth curve at Profile M-8

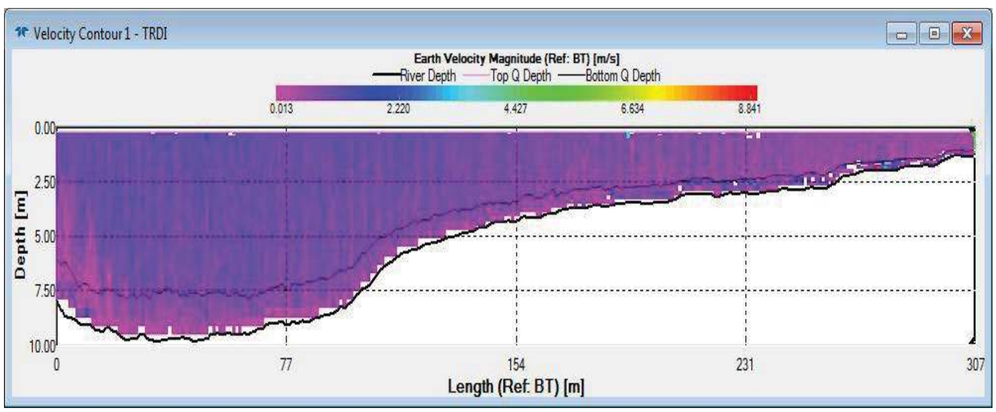

Figure 3.15. Distance from concave side vs. depth curve at Profile M-9

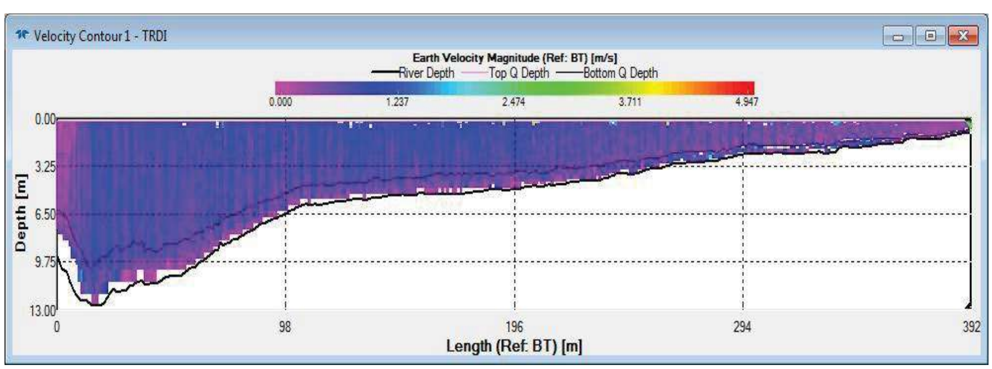

Figure 3.16. Distance from concave side vs. depth curve at Profile M-10

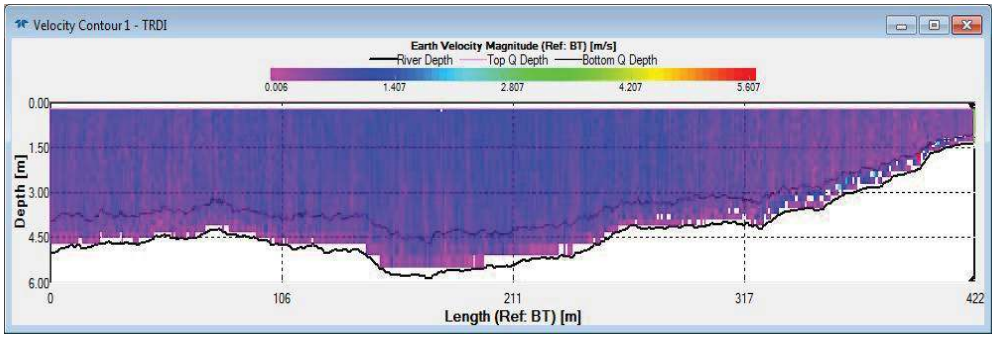

Figure 3.17. Distance from concave side vs. depth curve at Profile M-11

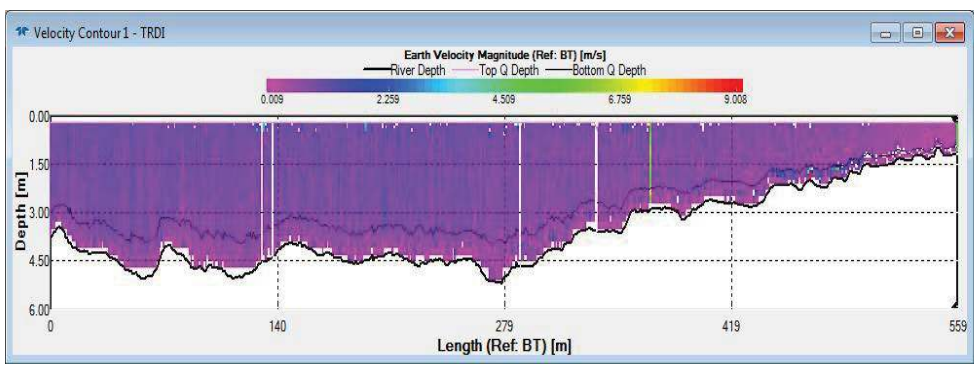

Figure 3.18. Distance from concave side vs. depth curve at Profile M-12

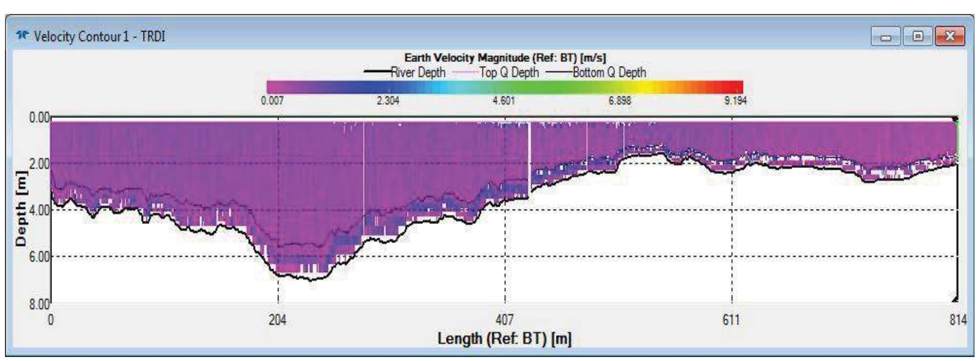

Figure 3.19. Distance from concave side vs. depth curve at Profile M-13

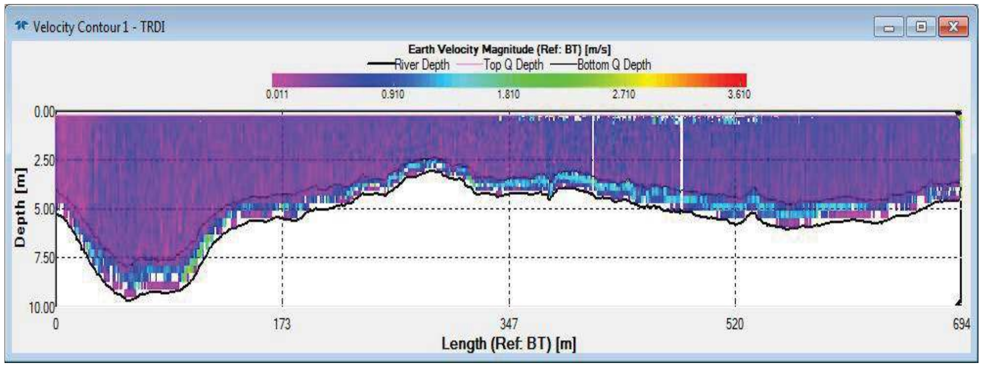

Figure 3.20. Distance from concave side vs. depth curve at Profile M-14