CHAPTER-6 GRAIN SIZE ANALYSIS OF SEDIMENT OF RIVER GANGA AT VARANASI BEND AND ITS IMPACT ON EROSION AND SEDIMENTATION

6.1 INTRODUCTION

Grain Size is a fundamental property of sediment particles. It affects their entrainment, transport and deposition, and therefore provides important clues to the sediment provenance, transport history and depositional conditions (Pye, 2004).

Historically, river hydrology has focused on questions concerning the magnitude and role of sediment movement in rivers rather than their associated contaminant loads, as the major hydrological problems were those dealing with the control of soil erosion, e.g. River Meandering. However, awareness of the wider environmental significance of suspended sediments as contaminant vectors has led to an emerging interface between hydrology and geochemistry. There is a growing recognition that information on both the physical and chemical properties of the sediment, and more particularly its grain size characteristics are required to answer.

Information on the grain size of suspended sediment is of increasing interest to those concerned with sediment transport and associated problems (Walling & Moorehead, 1987). Available data demonstrate considerable variation in the particle size characteristics of sediment from different rivers and streams in response to variations in source material and other physiographic controls (cf. Walling & Moorehead, 1989). Therefore, the linkage may be established between the sediment properties and the corresponding processes in the drainage basin. So far, much research has been done on the sediment grain-size characteristics of gravel-bed rivers (e.g. Hey et al., 1982; Thorne et al., 1987; Leopold, 1992; Billi et al., 1992; Klingerman et al., 1998), but the research on the sediment properties of rivers with fine sediment is limited. Walling & Moorehead, (1987, 1989) have studied the spatial and temporal variations of grain-size characteristics of suspended sediment in some British rivers. They found that, at local scales, the relationship between suspended sediment and water discharge is complicated and can be generalized as different patterns. Xu (1996) found that, after reservoir construction, the temporal variation in suspended-sediment size in the downstream channel of the River Hanjiang, China, was complex. He has also found that the long-term variation of the grain-size distribution of suspended sediment in the Yellow River can be related to variations in precipitation and human activities (Xu, 2000a).

The availability of particle size data is more limited than discharge data, but does show considerable variability at the global scale, due to the effects of climate, river basin lithology and sediment delivery or transport processes (Walling and Moorehead 1989). However, it is suggested that particulates that are routinely suspended in the water column tend to range from 0.1 to 200 gm (Palmateer et al. 1993). Particulates above this size may be suspended during floods, but average stream flows of rivers and streams do not have the energy to re-suspend these larger particulates (Dickinson 1987). Grain size characteristics of the suspended particulate load transported by a river can be expected to vary temporally in response to variations in water discharge and other environmental variables. Traditionally it has been argued that Discharge exerts the dominant control, and therefore a positive relationship will exist between

Discharge and the magnitude of coarse fraction, or the median particle size in transport (Walling and Moorehead 1989).

Although much work has been done to the changing quantity of sediment load, little research has been focused on the variation in grain-size features of suspended sediment load. The sediment carrying capacity of stream flow is closely related to sediment grain size and the variation in grain size of the sediment load from the upper Yangtze River may result in variation in sedimentation in its middle and lower reaches (Xu, 2000b; Zhang & Wen, 2002; Fu et al., 2002; 2002a; Yang et al., 2005). The behavior of the sediments depends more on the fine fractions of the sediment than on the coarse fractions.

Size and density of the deposited sediment play an important role in determining the extent to which the flow velocity influences sediment transport. Jones and Lawton (1994) indicate that faecal pellets of deposit feeders can increase the sediment grain size from fine mud to fine sand, that is, from 16 µm to 250 µm.

Sediments are mainly derived from the weathering and denudation of preexisting rocks (McLennan, 1995). Grain size distribution, and mineralogical compositions are the three basic properties of sediments and sedimentary rocks. They are dominated by the characteristics of parent rocks (Gromet et al., 1984; Taylor and McLennan, 1985; McLennanet al., 1993; Condie et al., 2001 and Xu et al., 2007), and modified by various processes, such as weathering and erosion (Nesbitt and Young, 1982; McLennan, 1993; Fedoet al., 1996; Cole et al., 2009), mixing and sorting (Nesbitt and Young, 1996), and diagenesis (McLennan, 1989; Holser, 1997; Webb and Kamber, 2000; Nothdurftet al., 2004).

The tendency to braid may also decrease with increasing bank erodibility by affecting the width/depth ratio and secondary flow (Ferguson, 1987). However, the channel patterns in siltladen rivers on the Chinese Loess Plateau probably also depend on the sediment concentration (Xu, 2002): meandering dominates at low and high sediment concentrations, whereas braiding prevails at intermediate concentrations. Xu related this transitional behavior to the occurrence of hyper concentrated floods, though the physical mechanisms regulating this transition are not yet known. Previous work on stratification effects in highly concentrated sediment-laden flow by Winterwerp (2001) and Winterwerp (2006) revealed the existence of three flow regimes controlled by the sediment concentration: sub saturated low concentration flow, supersaturated flow, and sub saturated hyper concentrated flow.

Systematic granulomatric studies of the various rivers of India have been carried out by many researchers (Rajamanickam and Gujar 1984, 1985, 1993; Chaudhri et al.1981; Rao et al.2005; Angusamy and Rajamanickam 2006, 2007; Suresh Gandhi et al. 2008; Ramanathan et al.2009; Anithamary et al. 2011). The complex coastal processes operated in the past and operating today have left their imprints in the sediments. In this regards, the Sedimentology of beach sediments plays a vital role in documenting the depositional history of a region (Angusamy and Rajamanickam 2007). Sedimentologists are particularly concerned with three aspects of particle size.

1. Techniques for measuring grain size and expressing it in terms of a scale
2. Methods for quantifying grain size data and presenting them in graphical or statistical form
3. The genetic significance of these data (Boggs 1995)

The study of above mentioned references and their process has been helpful for this chapter. In this chapter, the theoretical relationship between the grain size of River Ganga and the erosional and sedimenational pattern of River Ganga at Varanasi bend with the help of data collected from the all 14 cross-sections.

6.2 METHODOLOGY

For the grain size distribution analysis of sediments the samples were collected from the three locations at each cross-section i.e. at left bank, middle and right bank at Varanasi bend from M-1 to M-14 sections. The complete study possesses 14 cross-sections so the total number of samples was 42. This analysis is performed to determine the percentage of different grain size particle present within the collected samples. The mechanical or sieve analysis is performed to determine the distribution of the coarse and fine grain-sized particles. The distribution of different grain size affects the engineering properties of soil. Grain size analysis provides the grain size distribution and it is required to classify the soil samples. The grain size distribution analysis has been completed with following steps:-

(1) Collected samples were dried in furnace for 24 hrs. at 100 to 150^0 C to remove the complete moisture content of the sample.
(2) After the step (1) take out the sample from the furnace and make the powder by gentle hammering.
(3) Weigh the sample as of each 500 gm. for the sieve analysis.
(4) Write down the weight of each sieve as well as the bottom pan to be used in the analysis.
(5) Make sure that all the sieves are clean, and assemble them in the ascending order of sieve numbers (2000 μm sieve at top and 45 μm sieve at bottom). Place the pan below 45 μm sieve. Carefully pour the soil sample into the top sieve and place the cap over it.
(6) Place the sieve stack in the automatic sieve analyzer shaker and shake for 2 minutes.
(7) Remove the stack from the shaker and carefully weigh and record the weight of each sieve with its retained sample. In addition, remember to weigh and record the weight of the bottom pan with its retained fine soil.

6.3 EQUIPMENT USED

(1) Electronic Balance
(2) Set of sieves (45um, 75 µm, 150 µm, 250 µm, 500µm, 1000 µm and 2000 µm)
(3) Cleaning brush
(4) Automatic Sieve shaker
(5) Mixer (blender)
(6) Furnace

6.4 SIEVE ANALYSIS

(1) Obtain the mass of soil retained on each sieve by subtracting the weight of the empty sieve from the mass of the sieve + retained soil, and record this mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals the initial mass of the soil sample. A loss of more than two percent is unsatisfactory.

(2) Calculate the percentage retained on each sieve by dividing the weight retained on each sieve by the original sample mass.

(3) Calculate the percentage passing (or percent finer) by starting with 100 percent and subtracting the percentage retained on each sieve as a cumulative procedure.

6.5 DATA SHEET AND ITS GRAPHICAL REPRESENTATION

The complete measured Grain size distribution data for each cross-section i.e. M-1, M-2, M-3, M-4, M-5, M-6, M-7, M-8, M-9, M-10, M-11, M-12, M-13 and M-14 are listed in Table 6.1. The data is categorized in three parts i.e. left bank, middle and right bank of River Ganga at Varanasi bend. The graphical representation for each cross-section is shown in Figure 6.1. to Figure 6.14. for cross-section M-1 to M-14 respectively. The sieve size in µm is taken at X-axis for all cross-section and percentage passing is taken on Y-axis.

Table 6.1. Grain size analysis of complete samples from Varanasi bend of River Ganga at cross-section M-1to M-14

Profile Name	Range (µm)	Left Bank	Middle	Right Bank
M-1	< 45	16.69	6.55	8.57
	45-75	56.39	38.05	33.24
	75-90	65.01	57.16	42.26
	90-150	76.79	89.05	61.01
	150-250	78.75	92.54	64.11
	250-500	80.87	93.97	67.28
	500-1000	84.54	95.34	72.72
	1000-2000	90.24	96.86	81.95
	>2000	100	100	100
M-2	< 45	7.59	3.4	7.29
	45-75	25.73	19.94	28.3
	75-90	29.65	29.96	35.98
	90-150	35.01	46.69	52
	150-250	35.9	48.52	54.63
	250-500	44.96	56.8	77.43
	500-1000	62.56	66.61	85.91
	1000-2000	92.59	84.99	94.58
	>2000	100	100	100
M-3	< 45	17.9	3.23	5.38
	45-75	60.49	18.93	20.89
	75-90	69.73	28.44	26.56
	90-150	82.36	44.32	38.38
	150-250	84.45	46.02	40.32
	250-500	91.18	95.3	95.93
	500-1000	91.35	97	98.72
	1000-2000	93.21	97.69	99.19
	>2000	100	100	100
M-4	< 45	6.11	2.61	9.48
	45-75	20.65	15.3	36.79
	75-90	23.8	22.98	46.77
	90-150	28.11	35.82	67.59
	150-250	28.82	37.2	71.01

	250-500	42.41	48.65	82.73
	500-1000	60.78	67.99	91.87
	1000-2000	94.36	98.83	98.65
	>2000	100	100	100
M-5	< 45	8.18	4.49	3.16
	45-75	27.65	26.34	12.26
	75-90	31.55	39.57	15.58
	90-150	36.87	61.67	22.52
	150-250	37.75	64.04	23.66
	250-500	52.61	69.82	96.91
	500-1000	56.87	79.92	99.42
	1000-2000	60.79	97.4	99.77
	>2000	100	100	100
M-6	< 45	19.37	3.63	11.74
	45-75	65.46	21.27	45.55
	75-90	75.46	31.95	57.9
	90-150	89.13	49.8	83.67
	150-250	91.4	51.71	87.9
	250-500	96.47	58.98	97.82
	500-1000	98.37	67.62	99.22
	1000-2000	99.62	91.85	99.42
	>2000	100	100	100
M-7	< 45	17.17	5.54	8.83
	45-75	58.03	32.45	34.27
	75-90	66.9	48.75	43.57
	90-150	79.01	75.97	62.96
	150-250	81.02	78.89	66.14
	250-500	84.48	88.8	98.63
	500-1000	90.77	91.75	99.66
	1000-2000	98.83	96.82	99.93
	>2000	100	100	100
M-8	< 45	18.49	0.44	1.02
	45-75	62.49	2.58	3.96
	75-90	72.04	3.87	5.03
	90-150	85.09	6.03	7.27
	150-250	87.25	6.26	7.63
	250-500	91.66	97.93	97.25
	500-1000	95.38	98.84	98.98
	1000-2000	99.53	99.08	99.33
	>2000	100	100	100
M-9	< 45	1.62	1.08	2.69
	45-75	5.49	6.36	10.45

	75-90	6.33	9.55	13.28
	90-150	7.47	14.89	19.19
	150-250	7.66	15.46	20.16
	250-500	97.28	97.58	97.84
	500-1000	99.01	98.38	98.49
	1000-2000	99.36	99.48	98.87
	>2000	100	100	100
M-10	< 45	19.1	1.4	2.02
	45-75	64.55	8.22	7.83
	75-90	74.41	12.35	9.95
	90-150	87.89	19.25	14.38
	150-250	90.12	19.99	15.1
	250-500	94.21	95.27	97.44
	500-1000	97.54	96.4	98.65
	1000-2000	99.63	96.75	99.09
	>2000	100	100	100
M-11	< 45	8.32	1.56	2.89
	45-75	28.13	9.16	11.21
	75-90	32.43	13.76	14.25
	90-150	38.3	21.45	20.59
	150-250	39.27	22.27	21.63
	250-500	55.8	99.2	99.34
	500-1000	69.11	99.5	99.52
	1000-2000	95	99.62	99.54
	>2000	100	100	100
M-12	< 45	19.92	3.87	9.91
	45-75	67.32	22.68	38.47
	75-90	77.61	34.07	48.91
	90-150	91.66	53.1	70.68
	150-250	93.99	55.14	74.25
	250-500	97.61	68.56	81.12
	500-1000	99.66	81.27	88.55
	1000-2000	99.7	99.62	93
	>2000	100	100	100
M-13	< 45	13.12	5.11	10.33
	45-75	44.35	29.97	40.08
	75-90	51.13	45.03	50.95
	90-150	60.39	70.18	73.63
	150-250	61.92	72.88	77.35
	250-500	70.46	79.25	84.48
	500-1000	82.73	87.49	98.14
	1000-2000	99.77	99.57	99.33

	>2000	100	100	100
M-14	< 45	18.35	5.24	8.67
	45-75	62.02	30.72	33.66
	75-90	71.5	46.15	42.79
	90-150	84.45	71.93	61.84
	150-250	86.6	74.7	64.97
	250-500	91.69	79.75	82.1
	500-1000	95.63	86.86	90.2
	1000-2000	98.92	98.83	99.06
	>2000	100	100	100

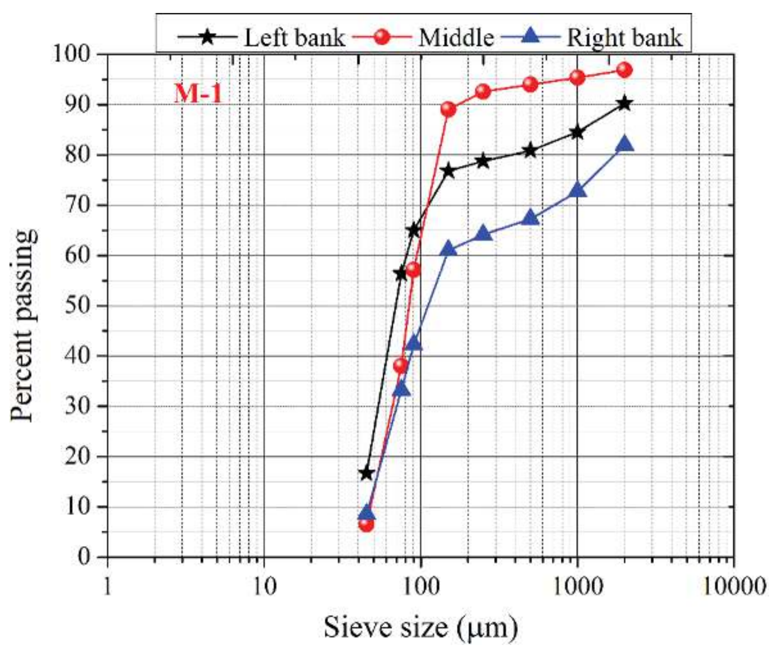

Figure 6.1. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-1 cross-section

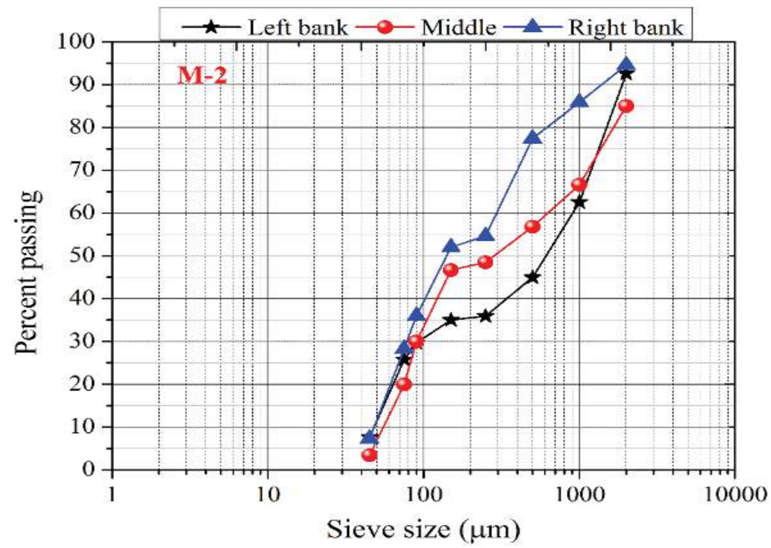

Figure 6.2. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-2 cross-section

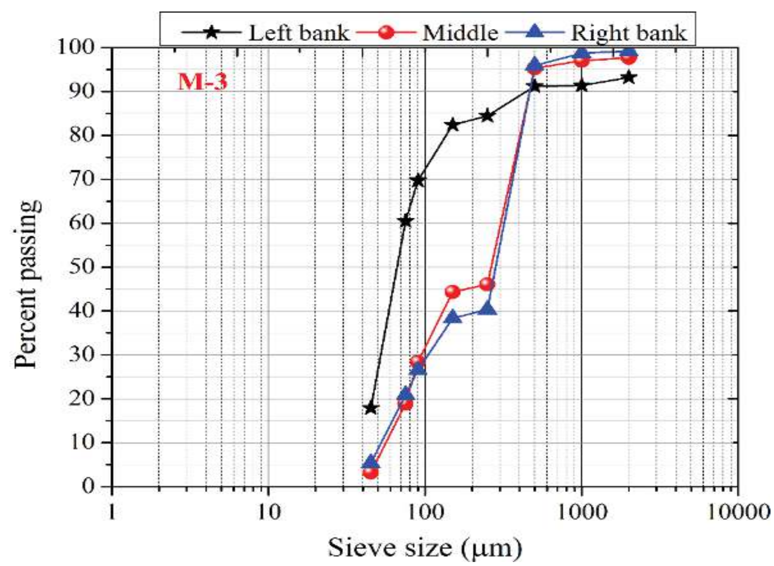

Figure 6.3. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-3 cross-section

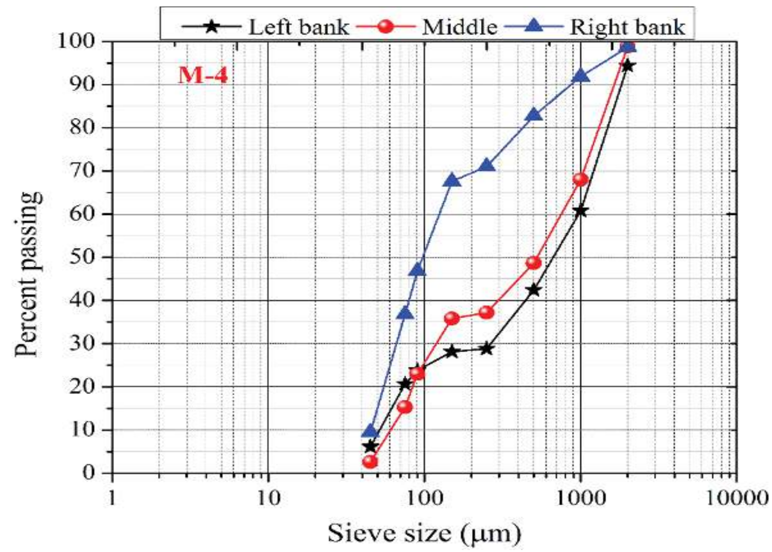

Figure 6.4. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-4 cross-section

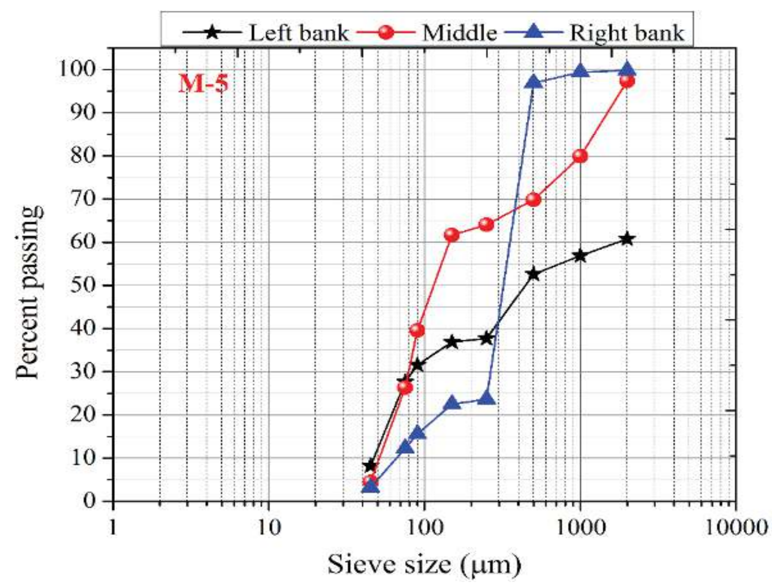

Figure 6.5. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-5 cross-section

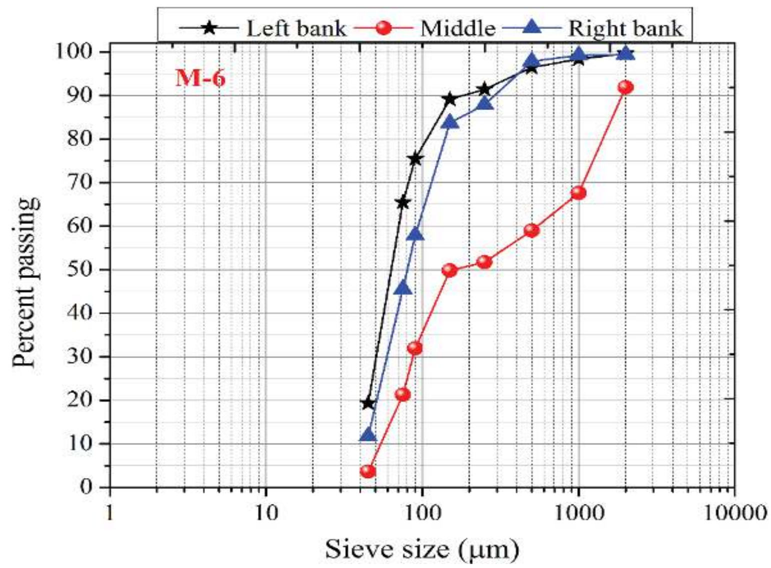

Figure 6.6. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-6 cross-section

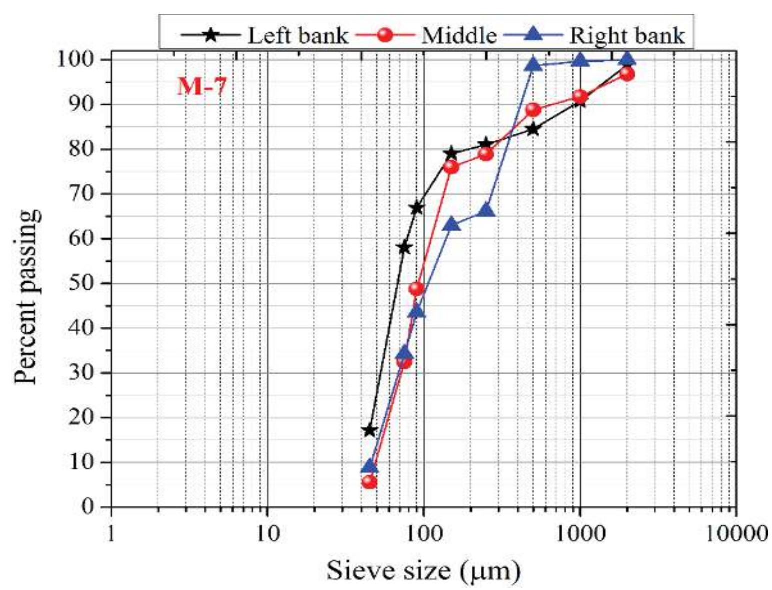

Figure 6.7. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-7 cross-section

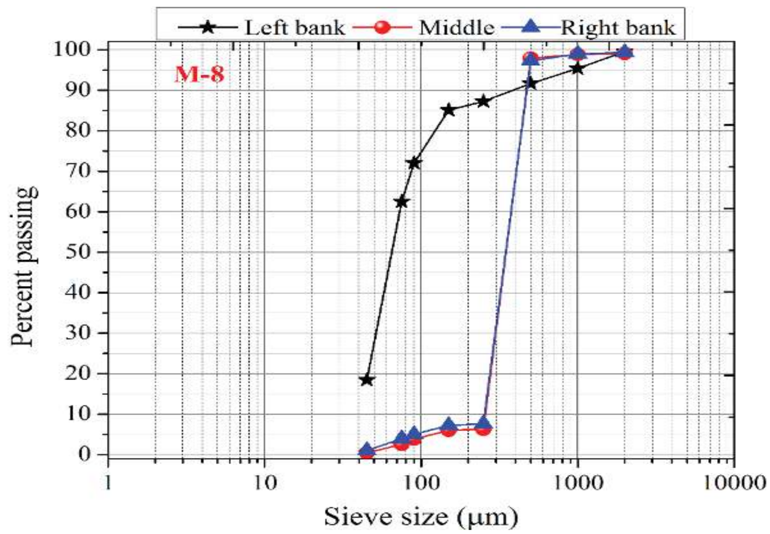

Figure 6.8. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-8 cross-section

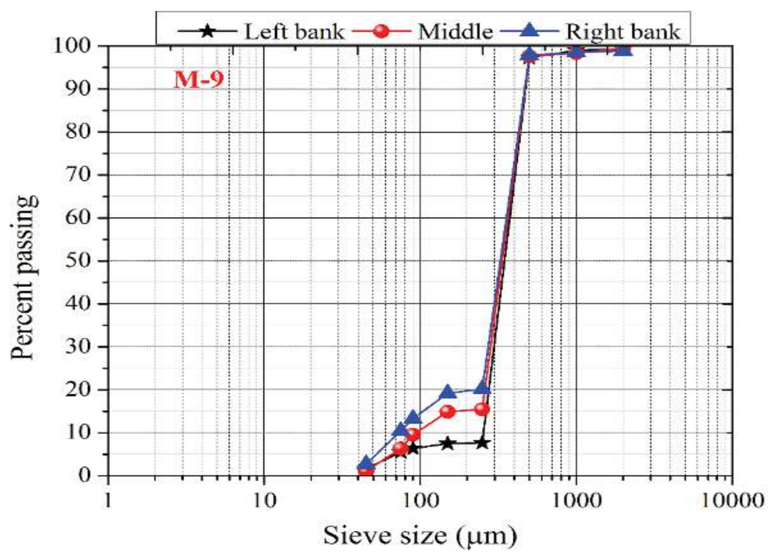

Figure 6.9. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-9 cross-section

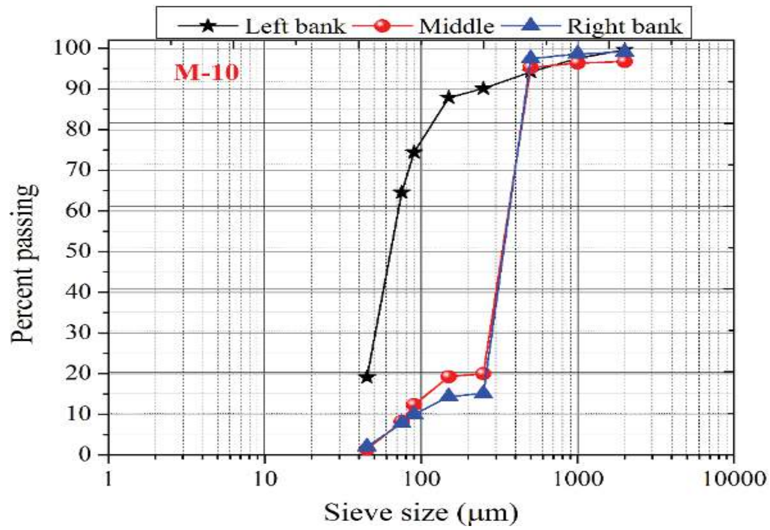

Figure 6.10. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-10 cross-section

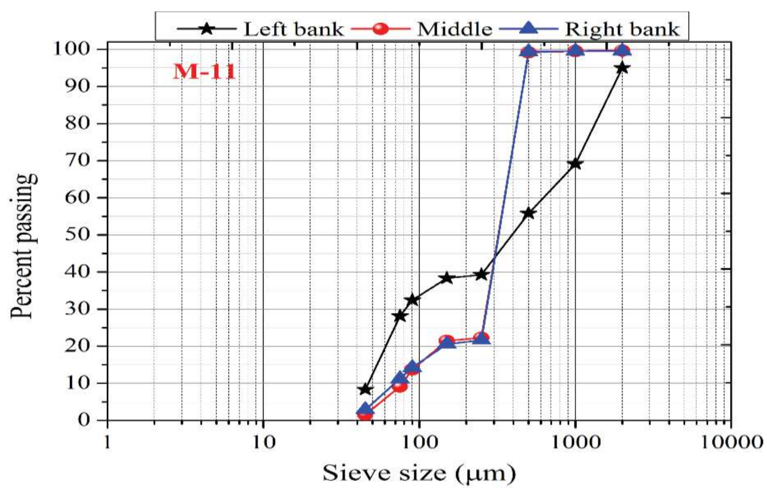

Figure 6.11. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-11 cross-section

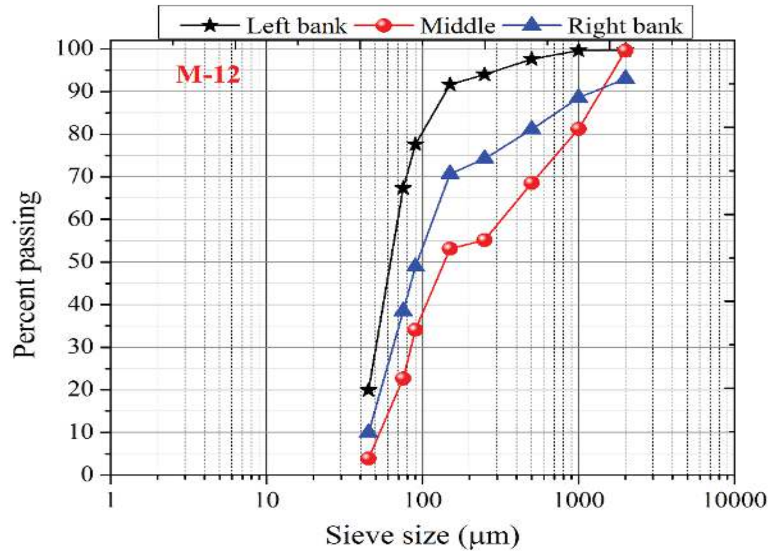

Figure 6.12. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-12 cross-section

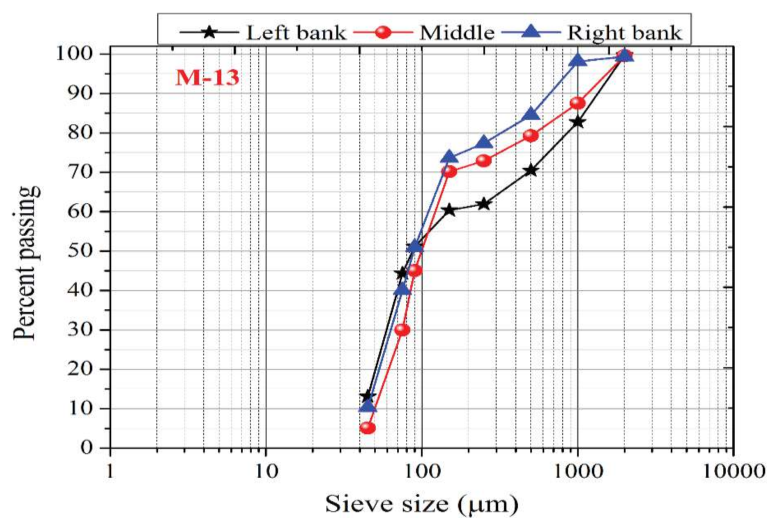

Figure 6.13. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-13 cross-section

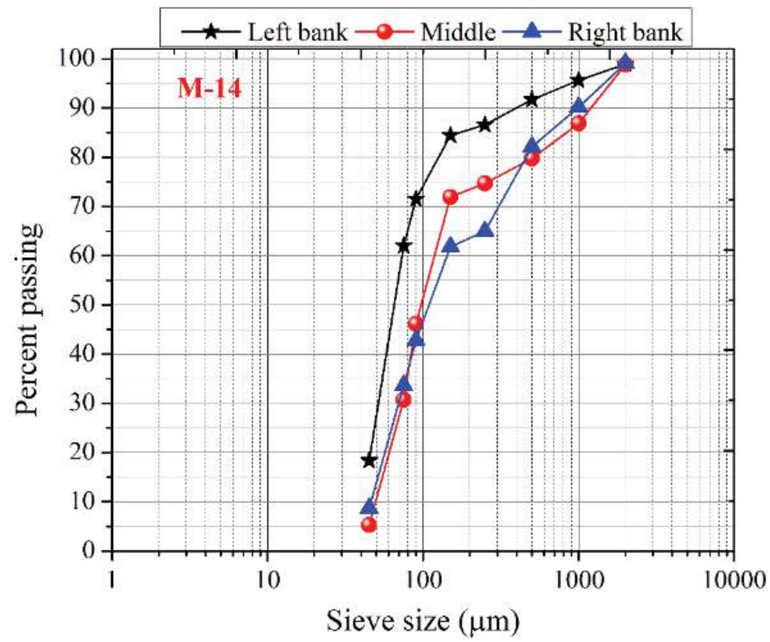

Figure 6.14. Grain size distribution at left bank (Black line), middle (red line) and Right bank (Blue line) of the River Ganga at M-14 cross-section

6.6 RESULTS AND DISCUSSIONS

- The grain size distribution data are given in the Table 6.1. and the pattern of distribution were defined in Figure 6.1. to 6.14., corresponding to cross-section M-1 to M-14. Grain Size analysis of sediments of River Ganga at Varanasi bend, reveals that size of the grain increases on left bank at section, M-3, M-6, M-7, M-8, M-10, M-12, and M-14 (Table 6.1. and Figures 6.3., 6.6., 6.7., 6.8., 6.10., 6.12. and 6.14.). The grain size of sediments at M-1 and M-5 (Figure 6.1. and 6.5.) are large whereas the size of sediments at section M-2, M-4, M-9, M-11, and M-13 (Figure 6.2., 6.4., 6.9., 6.11. and 6.13.) increases at right bank which is the sedimentation site of the grains. The increase of grain size of sediments at M-3, M-6, M-7, M-

8, M-10, M-12, and M-14 is responsible for the erosion of the left bank along the Ghat side of River Ganga. The erosion at these sections can be easily verify by the depth profile obtained at this section by ADCP thus it indicates that with increase of grain size the rate of erosion of sediments increases.

- The sand sample analysis shows that the sample contains of sand, silt and clay grade particles. It is well known that soil contain high proportion of silt and fine sand are usually most erodible. Soil erodibility is mainly depends upon the particle size distribution and here texture, permeability and fibrous organic matter content. The ability of soil to absorb water or surface runoff is characterize by it permeability. The potential for erosion is reduced, if the soil tends to absorb water as this decreases the volume of water available to cause sheet or rill and gully erosion. The grain size also related to sedimentation at the bank of the river. Sedimentation is the deposition of soil particle healed in suspension during flow of river. The sedimentation occurs at right bank of river due to reduction in the velocity flow and discharge of the river as shown by the table 6.1 and figure 6.1 to 6.14 at M-1 to M-14 cross-section. Initially the larger particles steeled out. As the flow velocity reduces further, the smaller particles settle, living only the clay finest particle, being the smallest, as the last to be deposited. Slope is also an important factor for the erosion at Varanasi bend along the Ghat side (left bank). The length and the inclination are critical factors with longer and steeper slope producing greater soil erosion. The shape of a slope also affect the potential of soil erosion, concave slopes will has inclination at the bank are generally less erodible then convex slope.