INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

GIS And Geostatistical Analysis of Tetrital Grains of Gadilam River Basin, Tamil Nadu India

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Abstract:
Most river sediments are polymodal and the peak heights shift from upstream (-0.04ϕ and 1.24ϕ) to downstream (0.29ϕ and 1.17ϕ), whereas the beach sediments show much reduced complexity (2.61ϕ). The river sediments are coarse sand (0.3ϕ - 1.24ϕ) poorly sorted (1.73ϕ - 2.82ϕ), coarse skewed (-0.3 to 0.78) and mesokurtic (2.9) in upstream and leptokurtic in downstream (5.15), whereas the textural parameters of beach sediments show medium grain (2.61ϕ) well sorting (1.4ϕ), near symmetrically skewness (-0.13) and platykurtic (2.87). The effectiveness of bivariant plots is confined from the clear segregation of river and beach samples in the respective zones. The mean and skewness establish a negative correlation with standard deviation (r=-0.55). The distribution of the samples in the NOP sector in the CM diagram proves the prevalence of high energy environment in the river and graded suspension in the beach sediments. Visher's log probability curves reveal the maximum traction population in the upstream, saltation in the downstream and excellent double saltation population in the beach. The linear discriminant values prepared from the statistical parameters have concurred with the respective environment in the present study. The sudden change in textural parameters, i.e. coarse grains in the river bed and medium grains in the beach are attributed to the possibilities of an additional source. The USGS Sedimentological Tool, Geostatistical analysis, CM pattern and Visher's diagram also supplement such probabilities.

Keywords: *Gadilam River, GIS & Geostatistics, Sedimentology*

1. Introduction
The Gadilam River Basin extends from 79°1′38″E to 79°41′46″E longitude and 11°30′14″N to 12°0′20″N latitude (Topo Index 58M/1-14), bound by the Pennaiyar Basin in the north and Vellar basin in the south (Fig-1). the total length of the river is 156.90 km and it has been divided into upstream, midstream and downstream, parts for geology, slope, relief, etc. Geologically the area is comprised of Precambrian, Cretaceous, Tertiary (Cuddalore sandstone), Quaternary formations and recent alluvium. The areal extend of the basin is 157396.052ha.
Researchers put forth the view that terrigenous beach sediments results from the deposition of sediments brought by rivers in addition to the contribution from waves, currents, etc. But the validity of river contribution has been questioned by other researchers, as beaches are the foci of interaction of various natural agents like waves, currents and tides in addition to the contribution of bio- and chemogenous materials and reworked sediments. Hence, arguments about the origin of beach sediments still continue. In India the depositional environments of various rivers like Krishna, the Mahanadhi, the Coleroon and the Vellar and others have been studied by many researchers. However, only few studies correlate the variations in riverine environment with that of beaches. An attempt has been made to study the variations in the depositional nature of the sediments in both the Gadilam River and related beach.

2. Methods of Study
Sediment samples were collected from up-stream to the beach at an interval of 9km. Total 33 samples at 19 locations along the river and 5 samples at either side of the beach where the river debouches into the sea were collected (Fig – 1). The host rock samples were also collected to compare the mineral assemblages. In order to understand the relation of the distribution of sediments with the drainage pattern and understand the deposition of samples along the course of the river, the drainage pattern is also provided (fig -2).
After coning and quartering, approximately 50gm of each sample was taken and washed, dried and sieved at 0.25ϕ interval using ASTM standard sieve sizes for 20 minutes in a Ro-Tap sieve shaker. The fractions left over in each sieve were separately weighed. The results were compared by graphic (Folk and Ward, 1957) and moment (Friedman, 1961) methods following a computer program

modified after Schleee and Webster (1967). The frequency curves, bivariant plots, CM diagram and Visher diagram were drawn to determine the grain size parameters and environment of deposition.

3. Results and Discussion

3.1. Frequency Curves

In general, the frequency curves show polymodal distribution (Fig.3). The upstream shows two dominant populations with the peak height of 1.75ϕ and 0.25ϕ (Fig.3a), whereas at station KDY the sands indicate one dominant population of 2.75ϕ with almost three more equi-populations. In the lower part of the upstream at station VPM I & II, there is another dominant population of 0.75ϕ and secondary population with the peak height of 1.25ϕ. The three station of upstream region show a shift in the dominant grain size by becoming progressively coarser as the finer particles have been winnowed away from there.

The VSR & CMR station in the midstream are seen with mainly bimodal distribution, having the dominant population of 1.75ϕ & 1.25ϕ (Fig.3b), rather finer than the earlier stations. It can be presumed that finer material is being added to the mainstream from the Seshanadhi tributary. At Station MLR, there is a polymodal distribution almost of three equi-populations, one with the peak height of -0.25ϕ, 1.25ϕ and the other of 2ϕ while the percentage of the previous +1.5ϕ is reduced from 15 to 7. The coarser ends of the populations have shown a multi supply with the addition of one more stream Malattar. The KPM station has brought a change in the frequency pattern by having polymodality of the population (Fig.3c) due to the supply of sediments from different streams draining through different of new material for a long distance or to the finer side where there is frequent debouching of the material. The beach sediments have shown the influence of good winnowing action (Fig.3d). This has led to the deposition of more medium size sands (2.75ϕ).

3.2. Mean

The different values obtained for textual statistical parameters through the graphic and moment methods are given in Table 1.

The mean grain size of the sediments ranges from -0.04ϕ to 1.24ϕ in the upstream section except KDY shows 2.17ϕ. KDY sediments shows the in-situ weathering and the sediments trapped within the boulders. The addition of tributaries and the fast flowing Gadilam River are expected to have removed the fine particles by repeated winnowing actions. The repetition of this process has led to the concentration of coarse sediments in these regions. The more coarseness observed (-0.04ϕ) in location VPM when compared with the adjacent locations GKP (0.64ϕ) and VPM2 (0.81ϕ) may be due to the mixing of coarse sediments derived from 3 minor tributaries debouching thereby.

In the midstream section, sediments are coarse grained with their mean values ranging from 0.37ϕ to 1.02ϕ. At location CMR, sediments show a mean value of 1.02ϕ in total contrast to the values of other midstream stations. This region, being the confluence of small streams and tributaries like the Seshanadhi, is characterised by the deposition of fine sediments brought by the rivers.

In the lower reaches of the Gadilam River, sediments are coarse –grained, the mean values ranging from 0.28ϕ to 1.17ϕ. In the mouth region, the sediments are medium –grained due to continuous winnowing action, by the washing and back washing of waves and tides. The beach sediments also show more or less a similar range of grain sizes varying from 1.78ϕ to 2.61ϕ.

3.3. Standard Deviation

In this area, the river samples vary from poorly sorted to moderately well sorted according to the Folk and Ward’s (1957) classification.

At location KDY, sediments are poorly sorted (2.52ϕ). Towards the onward course of the stream, the sediments show a progressive increase in sorting, i.e., moderately sorted to a value of 1.25ϕ to 1.73ϕ. This may be due to the gradual elimination of the fines from the uppermost part of upstream.

In the midstream, starting from location CMC, the samples are found to have gone back to poorly sorted nature (2.35ϕ) like that of location KDY. This may be attributed to the mixture of the finer materials brought by the Seshanadhi with the existing moderately sorted but coarser materials derived from midstream. The Chinna Marudhur sediments have similar sorting (2.34ϕ) like location AGK, with the slight decrease in sorting. Poor sorting (2.54ϕ) is seen al location MLR. It is considered to be the result of prolific addition of very fine sediments from the Malattar. This type of sorting continues upto location VSR. In the midstream one can observe the change in sorting characters for each addition of materials especially at locations CMC and MLR.

In the lower reaches the sorting is found to vary from place to place due to continuous addition of finer materials in varying proportion that too, probably from season to season. However, one is able to see the moderately well sorted sediments in the downstream, where the active winnowing of tides must have removed the fines and allowed the medium sands to get segregated. In general, the sediments are found to be well sorted. The beach sediments are well sorted, suggesting that this might be due to the environment where efficient sorting takes place.

3.4. Skewness

The course skewed at upstream locations may be considered here due to a single source. As there is no major supply of sediments upto 3 stations, the skewness values are found to remain coarse skewed.

The midstreams up to Station from CMC to VSR show variations according to the nature of input sediments. Stations CMC, MLR and SMD are dominated by coarse skewed (0.3) sediments. Even though the mean size suggests addition of fine size through the tributary, skewness indicates that the coarse skewed nature is due to the insignificant addition of fines with the very coarse skewed sediments of location CMC and MLR. CMR is nearly symmetrically skewed (0.52). This change is proved by the presence of fine sediments dumped from the Malattar River.

In the lower reaches the stations KMP and PNT, one finds fast changes in the nature of sediments but for the last station PNT, where the sediments had so far remained 0.63 they have been brought to reach the level 0.39. This may be attributed to the degree of winnowing applied over the sediments brought by the rivers to the downstream by means of tides. It is presumed that much of the fines are being transported from this point probably to the offshore, leaving the sediments at station TVP to get more and coarser. All the skewness in the river bed remains to be dominantly of negatively skewed but for temporal change. The near symmetrical nature of the beach sediments results from better sorting of sediments.

3.5. Kurtosis

The upper part of upstream (Station KDY) is leptokurtic. This is due to sorting of the medium size fraction. Station IYR to VPM are found to be mesokurtic (2.31 to 3.78). This is due to implication of better sorted sediments. However, station VPM2 shows leptkurtic, suggesting the addition of materials which are not as well-sorted as the original main stream sediments. When these sediments reach the downstream, effective sorting, the admixture of various percentages of different modes retaining their respective characters, have helped to maintain the leptokurtic nature. The leptokurtic nature of sediments in the beach suggests these sediments have achieved good sorting in the high energy environment. According to Folk and Ward (1957), the unimodal sediments have kurtosis values greater than the small subsidiary sediments manifest a strong leptokutic nature with kurtosis values greater than unity. The present observation of average kurtosis of the each sediment of 2 to 3 supports this fact.

3.6. Scatter Plots

Folk and Ward (1957) have used the values of graphic mean, inclusive graphic standard deviation, inclusive graphic skewness and graphic kurtosis. Mason and Folk (1958) have successfully used the lot of skewness vs. normalized kurtosis for demarcating the fields of beach, dune, and river sands. Friedman (1961) has plotted the values of mean standard deviation and skewness to distinguish the beach, river and dune sands. Friedman (1967) has gone to include the standard deviation to describe the environment of deposition. Using first percentile and moment measures Friedman (1967) has constructed a scatter plot to separate the beach and river environments to reflect the shape of the distribution curves and sorting characteristics of fine and coarse tail distribution. Moila and Weiser (1968) have distinguished the beach and river environments and also the beach and dune environments by taking standard deviation vs. mean, etc. Friedman's (1967) mean vs. simple sorting, skewness, and kurtosis (Fig 4a) have clearly indicated the deposition of sediments of inland transportation of riverine environments. Examining the residual plot, it appears that the homogeneity of variance assumption is not violated since the residuals scatter randomly around the zero line and the degree of scatter appears constant across the range of predicted values. The histogram of the residuals is also consistent with the assumption of normality (Fig 4b).

The sands analysed here from the different environments especially the Gadilam River and beach sands have clearly shown a distinct separation. In some of the scatter plots the beach samples are found to have been segregated in the field of river itself, but many are found distinctly away from the river groups. So, one can observe a clear distinct separation between the Gadilam river sands and Gadilam beach sands through Box Plot (Fig 4c). However, the beach sediments do not fall in the environmental boundary meant for beach. The correlation of statistical parameter throws light on differences existing between beach sediments and the river bed sediments, Mean shows negative correlation ($r = -0.557$) to standard deviation and ($r = -0.72$) Skewness. The kurtosis and mean are found to show directly proportional relation and are positively correlated. ($r = 0.018$). One can reasonably ascribe the role of addition and deletion of fine grains, during the transit of the sediments in the river bed as well as in the beach, in controlling the textural statistical parameters samples in the bivariant plot has not shown any significant variation within the river sediments.

3.7. CM Pattern

A scatter plot of Median in microns (M) Vs First percentile in microns (C) was proposed by Passega (1957) and has been revised in 1964 by him. It is a diagram meant to illustrate the depositional environment with respect to size, range and energy level of transportation. The time gap in the mode of transportation has been described by him. It has been clearly proved by Nordstrom (1977) in identifying the ancient environments in their study area by utilizing the CM diagram.

The values of first percentile (C) and the Median (M) converted from phi values to microns have been plotted in the log normal sheet in the ordinate and abscissa respectively (Fig. 4d) It is constructed with 33 samples from two clear environments. But for one or two samples of river all the samples are found to spread in a narrow band in rolling segment. The broad limit of the median values range from 400 to 900 microns. The distribution of the sediments in the CM pattern mainly in the NO sector has indicated the active role of rolling in the transportation of the sediments right from the upstream to downstream. The first percentile ranges from 3000 to 4000, and the median values clearly placed the prevailing high energy environment in the transportation of the sediments.

The beach sediments are showing the distribution in the QR sector suggestion the main role of graded suspension in the formation of the sediments. A clear gap in the beach sediments of 400 to 500 micron is attributable to the absence of a particular size material, for graded suspension, and rolling in different periods, for sediments above 500 micron and for below 400 micron. Among the beach sediments, the samples display good sorting by forming a separate group. Beach sediments are segregated closer to the line C=M. The environments of beach sediments and river sediments differ not only in the nature of energy but also in nature of transportation of sediments. The river and beach sediments are transported by rolling and graded suspension respectively. Pasega (1957) have suggested the existence of graded suspension, for the probable role of paleo-sediments in the formation of respective sediments. Here, the beach sediments distribution can be ascribed to the derivation of earlier Holocene, Pleistocene sediments.

3.8. Visher Diagram

The log probability curves prepared according to Visher (1969) is shown in Fig 5a-d. This figure carries the representative curves for upstream, midstream, downstream and beach. The upstream and midstream deposits clearly indicate three sub-populations, whereas the downstream samples indicate a weak additional saltation population and the beach sediments the presence of two saltation populations. The coarse truncation for upstream sediments is found to vary from 0.25ϕ to 0.5ϕ and the fine truncation has shown a variation of 2.5ϕ to 3.5ϕ (Fig 5a). Each curve is found to vary in its behavior especially in the percentage of different sub-populations. Almost a complete absence of suspension population (less than 0.5 percent) as in the present case is attributed to the characteristic of the high energy riverine environment (Visher, 1972). The large extent of functions in fine truncation not only depict the poor sorting of the tail portion but also the existence of various proportion of mixing. The poor sorting in the tail portion is also attested by negative skewness and mesokurtic nature. Figure 5b & 5c displays the log probability curves of midstream and down stream sediments. One can easily observe the shift of fine truncation of the saltation population from 2.5ϕ to 3.0ϕ. The spread of the traction population to a wider stretch has clearly projected the admixture of rolling population to the earlier upstream sediments in which the spread of traction population percentage is limited. The higher amount of traction population compared to the upstream is evidently understood by the process of additional rolling. The variation of traction population from upstream to midstream to the tune of 32 percent to 70 percent indicates a distinct charge in the distribution of these populations.

The Visher,s log probability curve for the beach sediments (Fig 5d) has clearly depicted the presence of two saltation populations. In other words, it is the typical pattern of beach environment of Visher (1969). Symmetrical distribution of both the saltation population has also been supplemented by the presence of symmetrical skewness rather a shift from positive to symmetrical accounts for the saltation population alone. The gradual change of sediments from the riverine environment to the beach environment is clearly evidenced.

3.9. Dendrogram

The commonly used Dendrogram by Nearest Neighbourhood Method, Squared Euclidean has applied to discriminate the analysis of Grain size Parameters of Gadilam River Basin reveals that the clear segregation Beach sediments from the riverine environment (Fig 6). Among the riverine sediments the location in-situ weathered sediments trapped in the boulders and cobbles at KDY shows a separate entity that is the top most location where the river originates.

3.10. USGS Sediment Classification Tool

The USGS Sediment Tool is the GIS application used to bring the Sediments classification into GIS platform. The tool has the facility to adopt both for Folks classification of sediments and also to Shepards classification of sediments. The USGS Sediment Tool has been applied to classify the Gadilam River Basin Sediments to decipher the environment using Folk Classification method (Fig 7a) and Shepard classification method (Fig 7b), Folk method reveals the characteristic Sandy Gravel or Gravelly sand in the Riverine Environment whereas Sand in the Beach environment. Shepard classification shows that the Up and Mid-stream sediments are of gravelly sand and Sand in the downstream and beach sediments. From the USGS Sediment Tool one can notice the different type of source for the Beach environment.

4. Conclusion

The frequency curves of the river sediments show a complete domination of coarser sediments, whereas the beach sediments show a medium size. Further, well sorted character of the sediments also supports that no coarser sediments from the river is deposited on the beach. Moreover by the presence of two dominant populations in the medium grain size of 1.5ϕ peak and 2.75ϕ dominant population in the river suggests that two dominant types of medium – grained populations are brought by the same river to the beach, it is rather difficult to get an uniformly sorted and symmetrically skewed products from the source. So it can be surmised that, the population other than river sediments of almost of equally skewed, are being added to the beach.

The texture of the sediments by means of bivariant plots, CM Patterns, Visher's sub populations frequency curves, various discriminant functions and USGS Sediment Tool have clearly attested to characteristic differences in the texture of the river sediments and the beach sediments. The aforesaid results evidence that the beach sediments are entirely different from those of the river sediments; they may have been derived from the offshore as well as the coastal relict deposits.

5. References

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ANNXURE

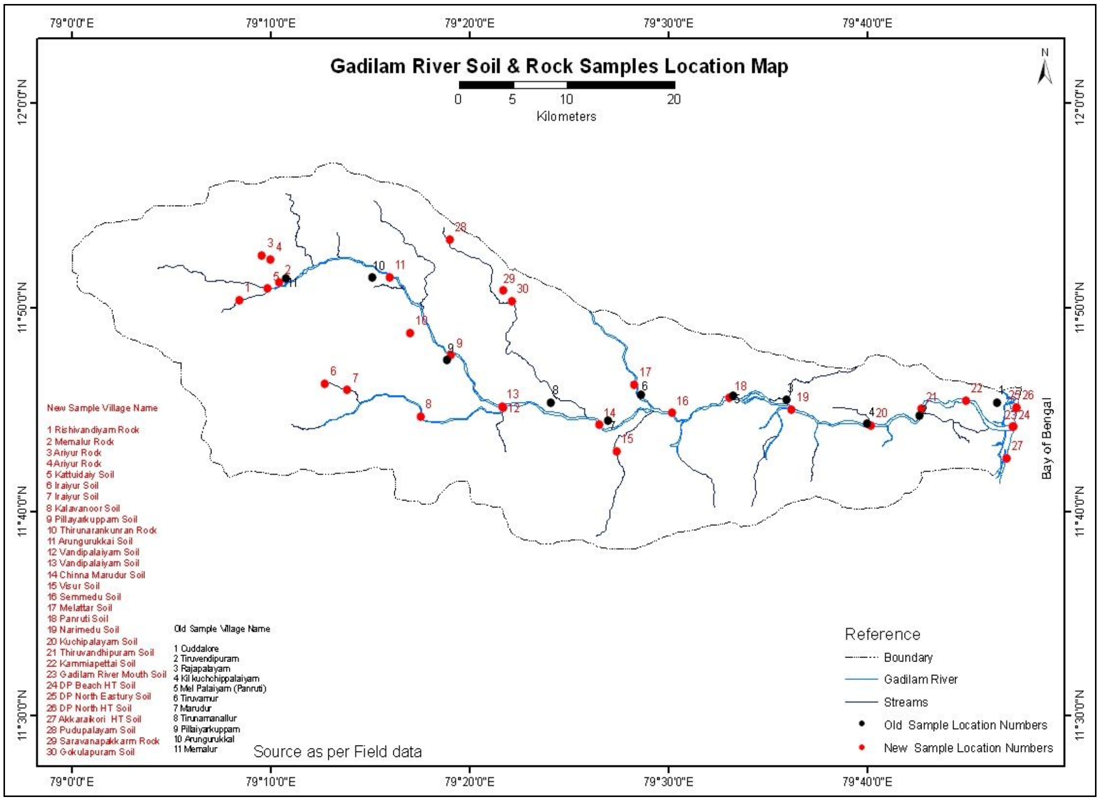


Figure 1: Gadilam River Basin Sample Location Map

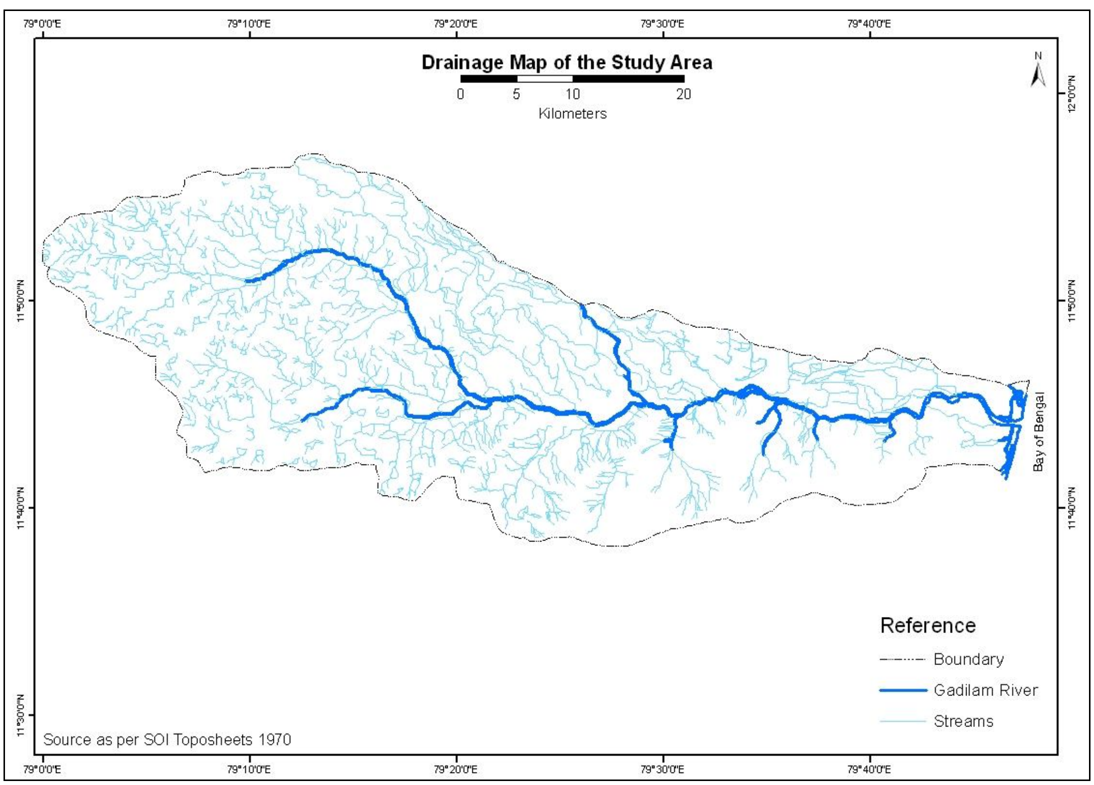


Figure 2: Gadilam River Basin Drainage Map

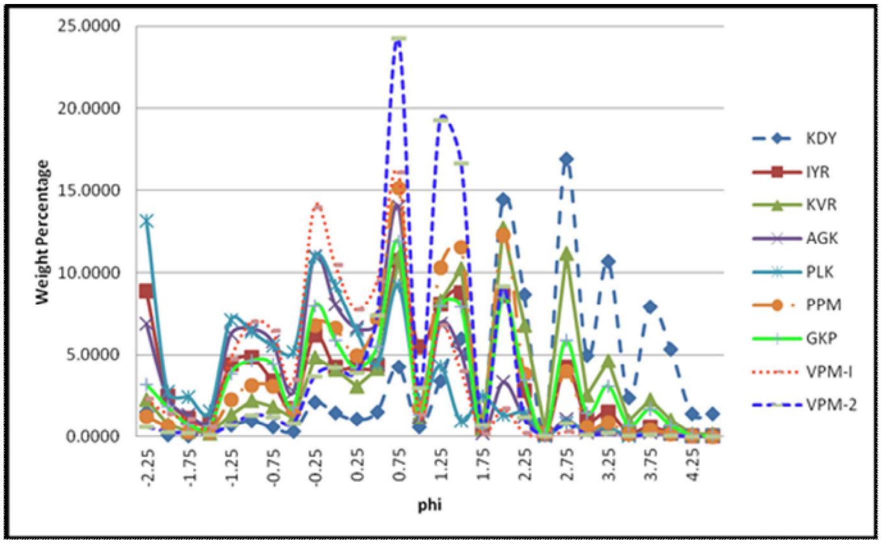


Figure 3a: Gadilam River Basin up Stream frequency curves

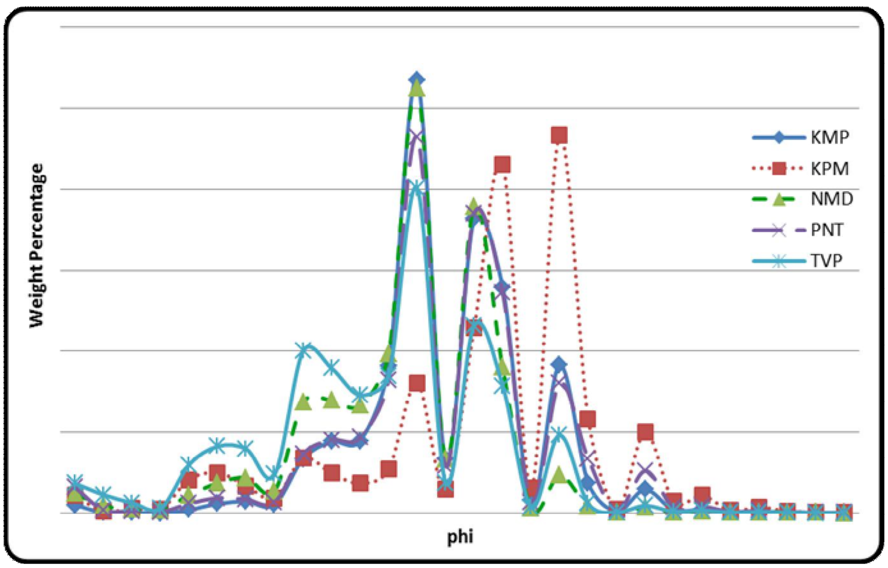


Figure 3b: Gadilam River Basin Mid Stream frequency curves

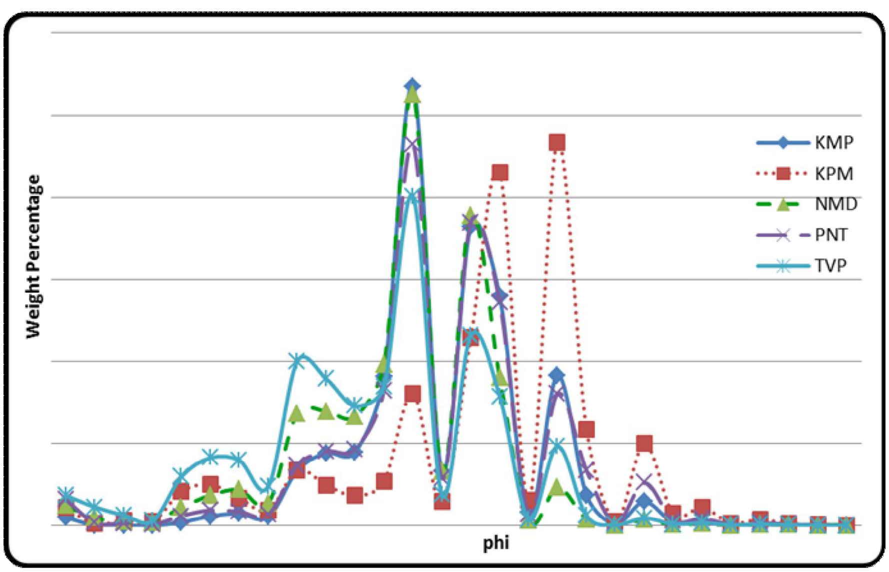


Figure 3c: Gadilam River Basin Down Stream frequency curves

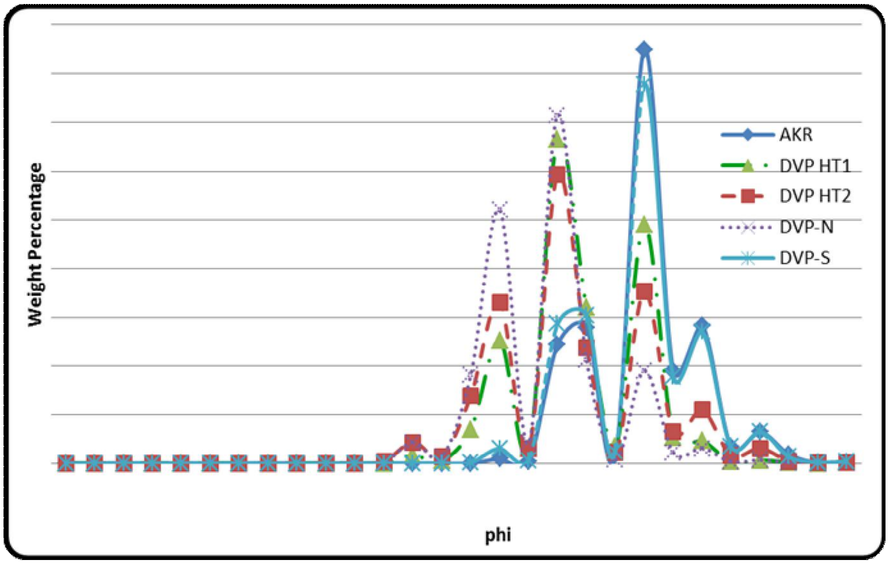


Figure 3d: Gadilam River Basin Beach Grain size frequency curves

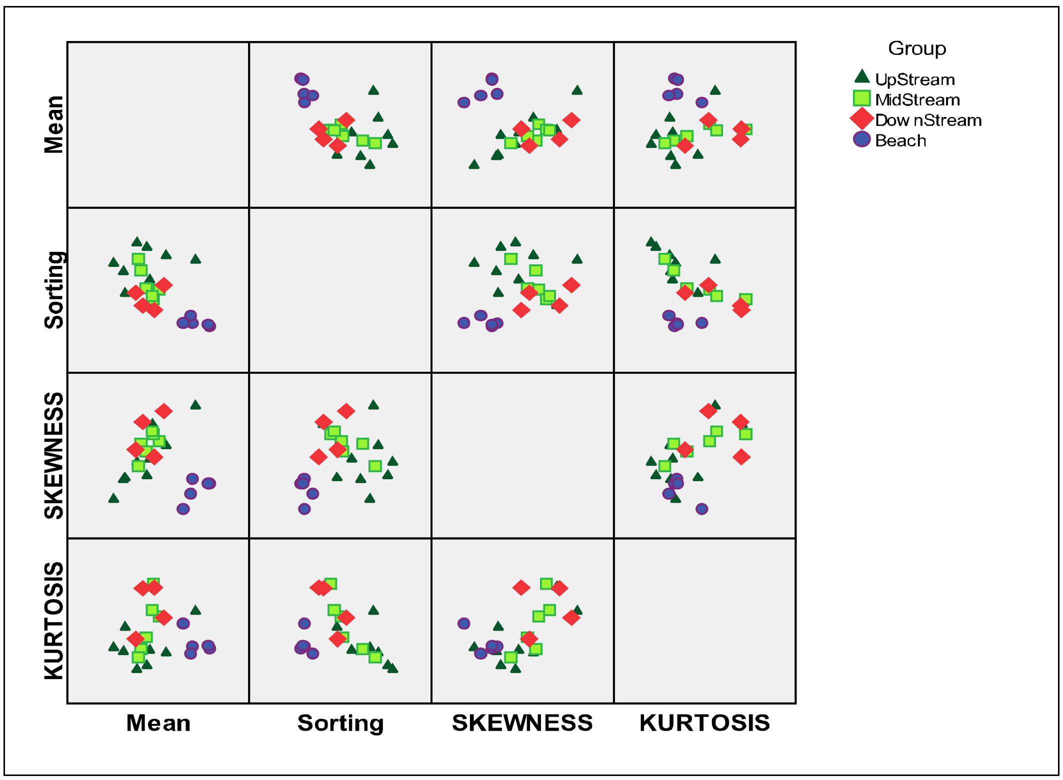


Figure 4a: Scattor Plot of Gadilam River Basin Grain size parameters

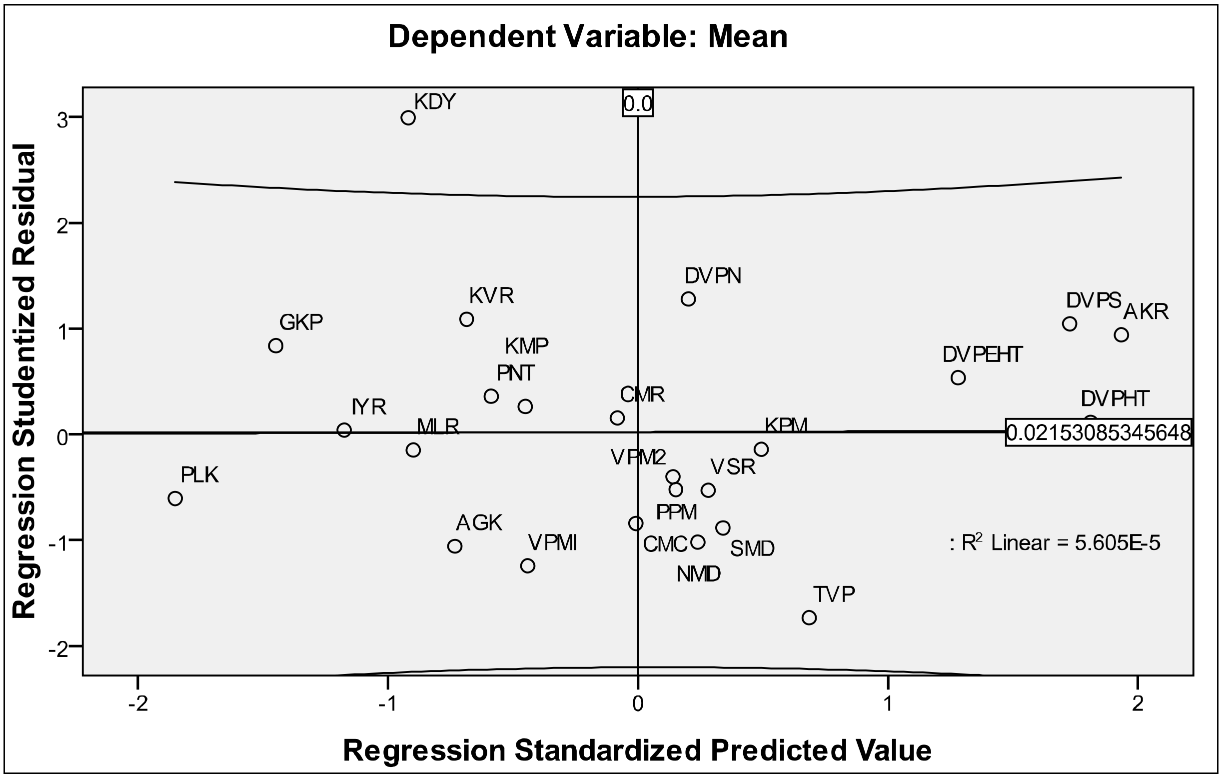


Figure 4b: Regression Standardised Plot of Gadilam River Basin Grain size parameters

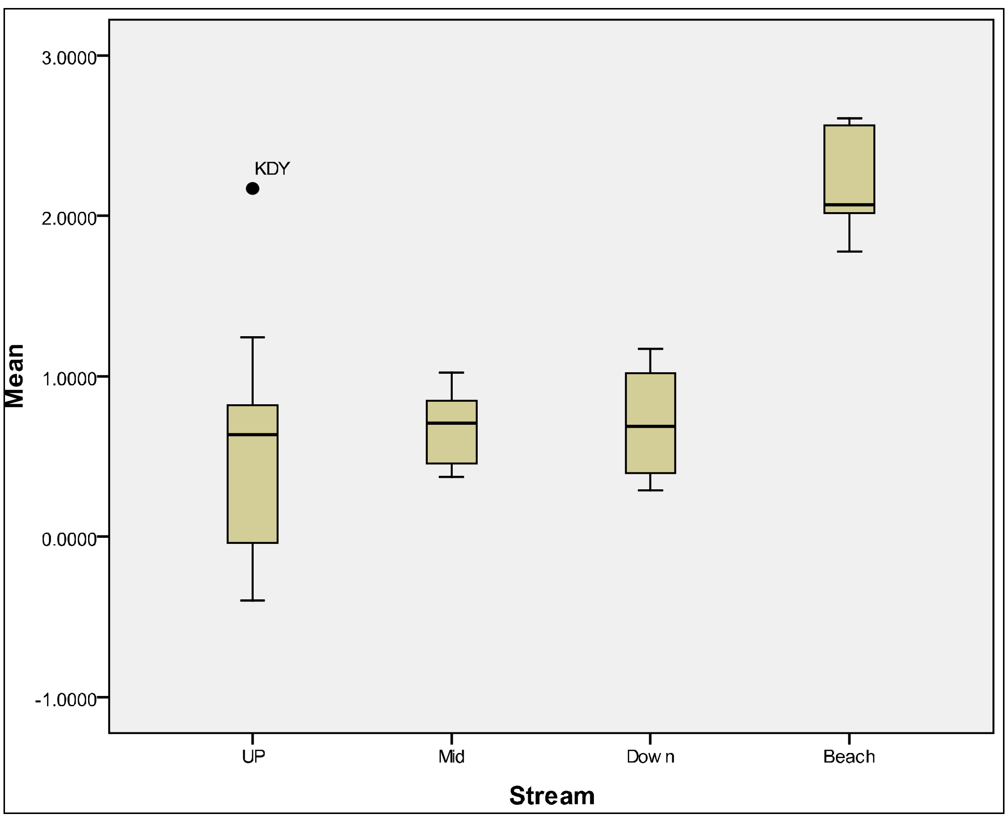


Figure 4c: Box Plot of Gadilam River Basin Grain size parameters

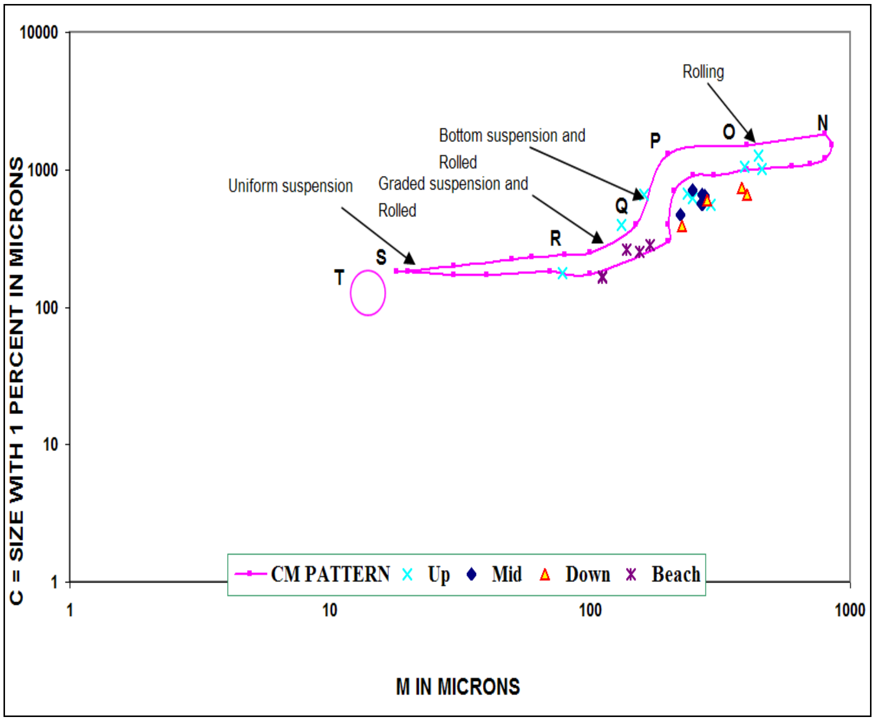
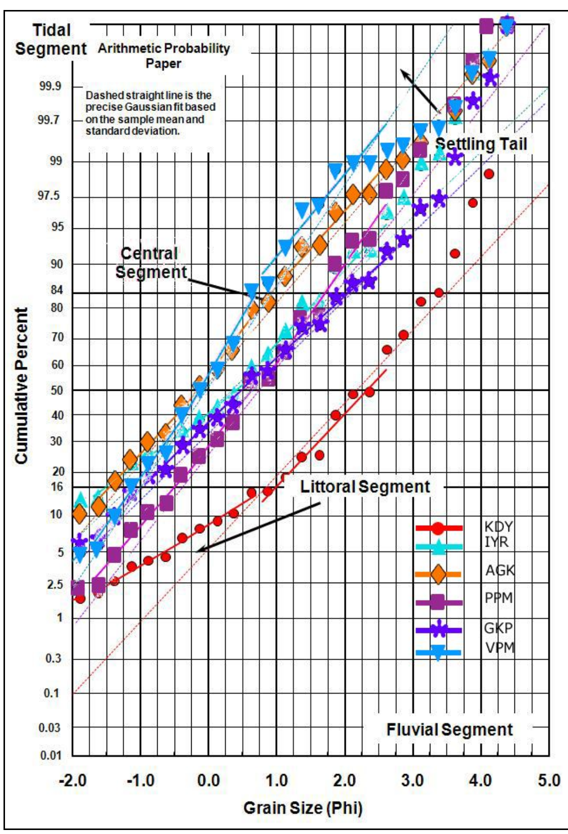


Figure 4d: CM Patterm Pattern after Passega (1957)

Visher Diagram



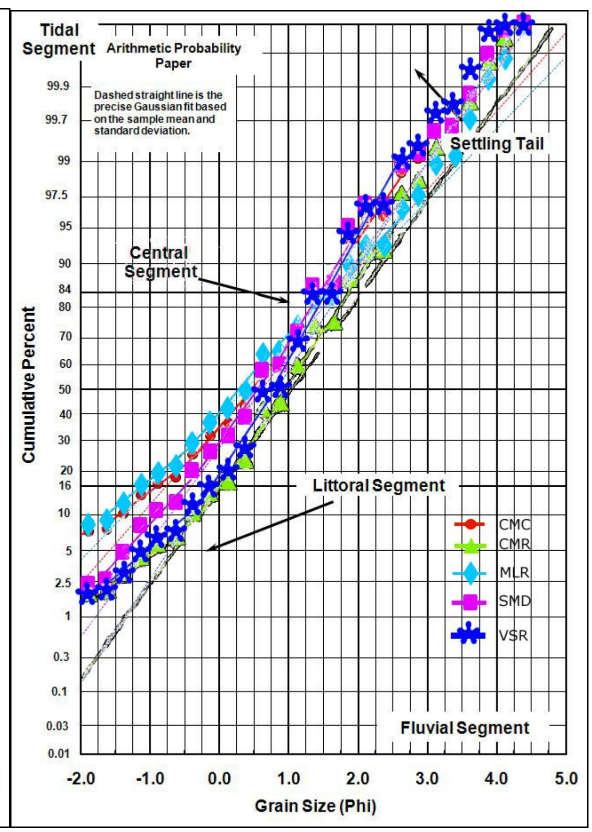


Figure 5a: Visher Diagram after Visher (1969) Up stream; Figure 5b: Visher Diagram Mid Stream

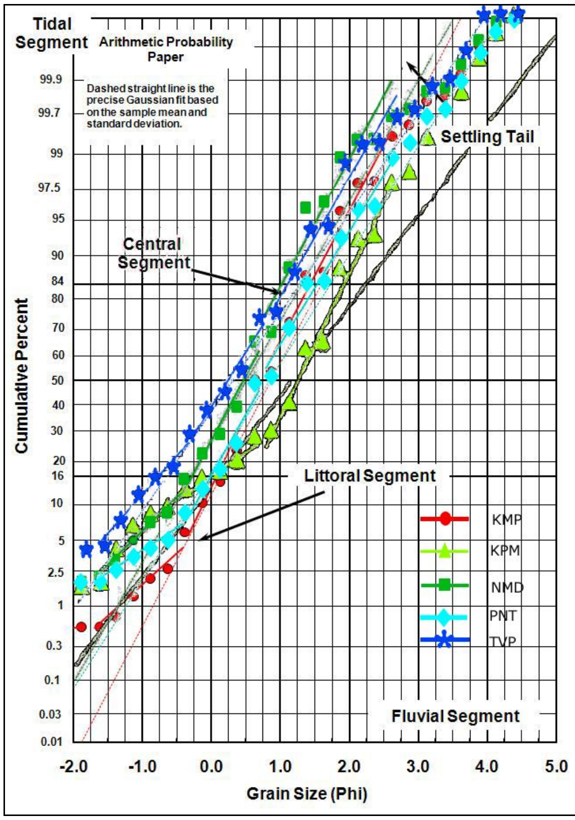


Figure 5c: Visher Diagram Down Stream

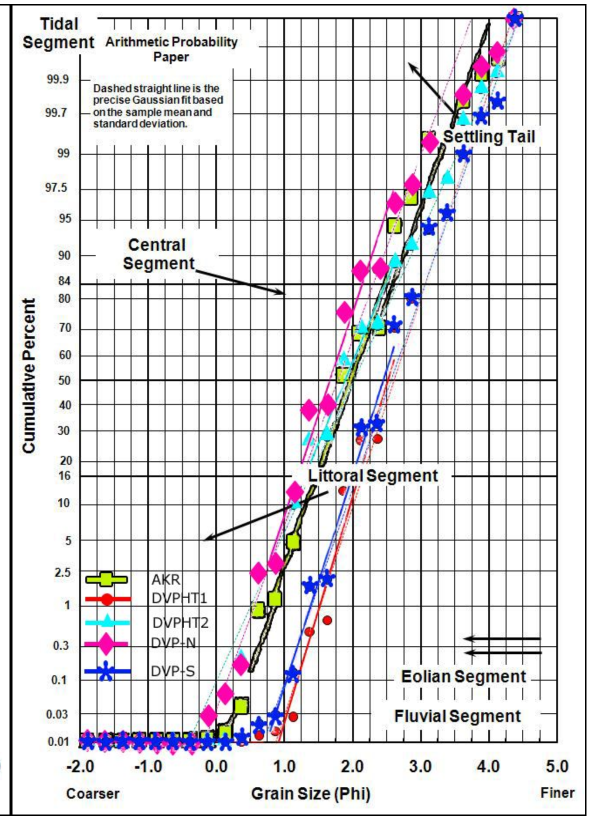


Figure 5d: Visher Diagram Beach

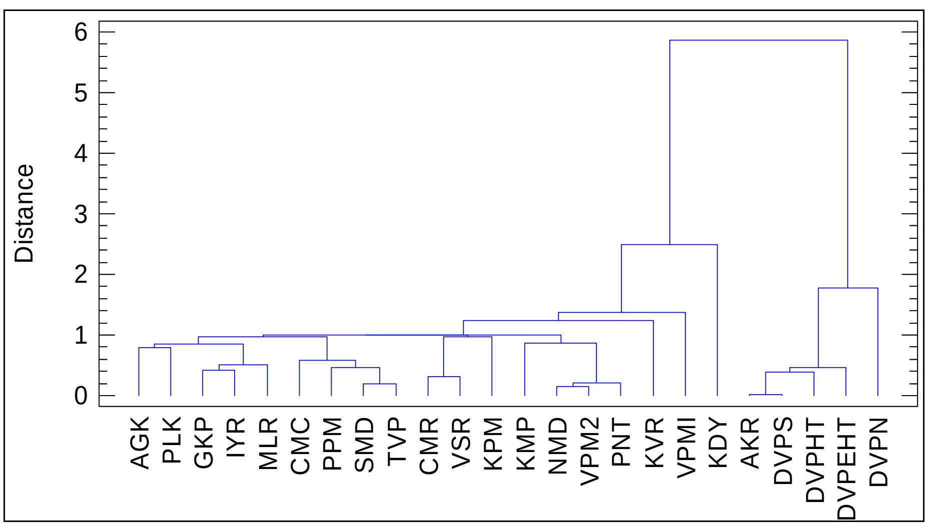


Figure 6: Gadilam River Basin Grain size Parameters Dendrogram by Nearest Neighbour hood Method

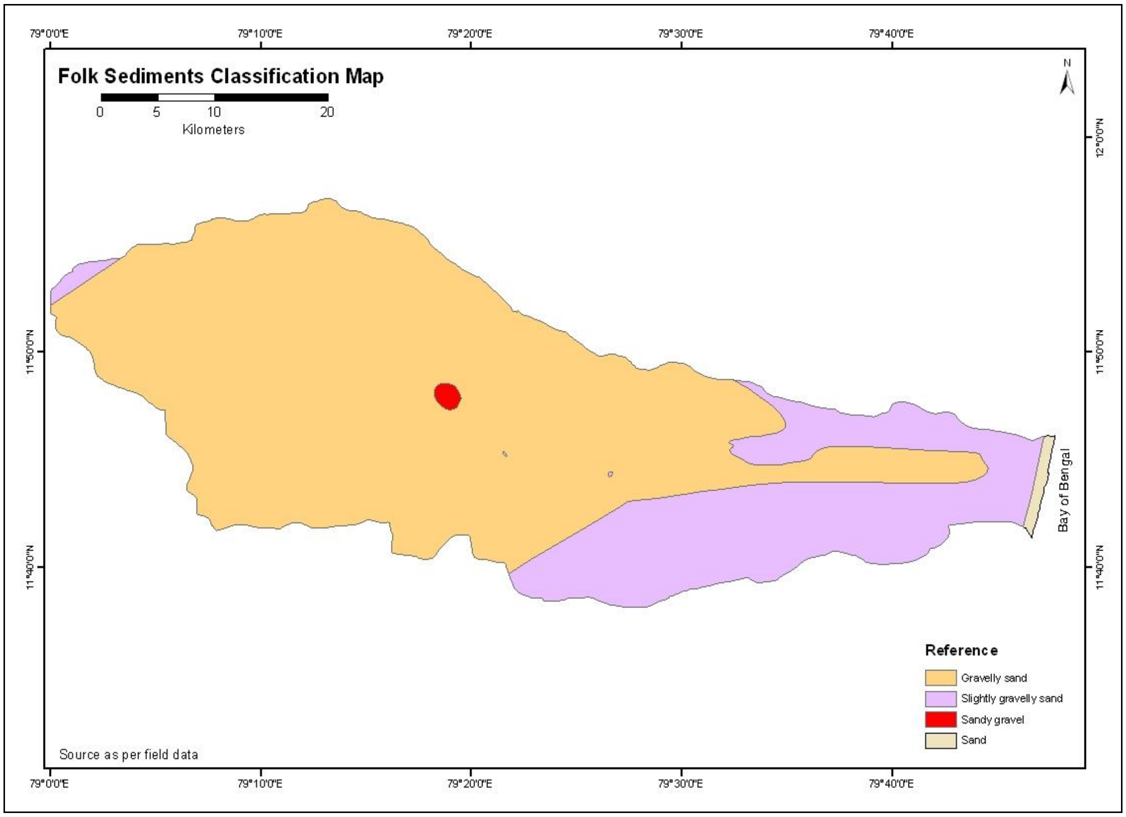


Figure 7a: Gadilam River Basin – Folk Sediments Classification using USGS Sediment Tool

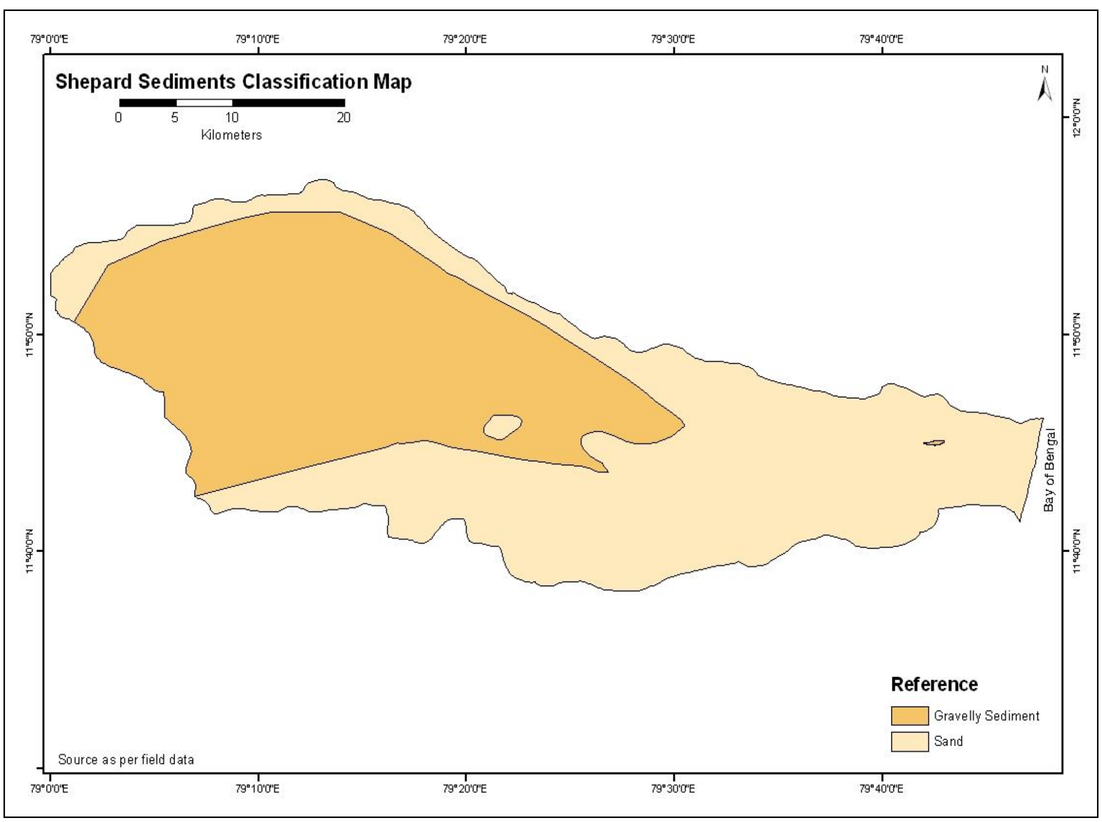


Figure 7b: Gadilam River Basin – Shepard Sediments Classification using USGS Sediment Tool

Location ID	Location Name	Arithmetic				Geometric									Mode
		MEAN	SORTING	SKEWNESS	KURTOSIS	Mean Ø	MEAN	Texture Group	Sorting Ø	Sorting	SKEWNESS	Skewing	KURTOSIS	KURTOSIS	
AGK	Arungurukkai	1506.72	1328.48	1.61	4.81	-0.09	1067.08	Very Coarse Sand	2.32	Poorly Sorted	-0.07	Symmetrical	2.94	Mesokurtic	Polymodal
AKR	Akkaraikori HT	174.84	56.13	0.83	4.99	2.61	165.57	Fine Sand	1.38	Well Sorted	-0.13	Symmetrical	3.05	Mesokurtic	Trimodal
CMC	Chinna Marudur Canal	1101.39	1216.93	2.34	7.84	0.46	731.24	Coarse Sand	2.35	Poorly Sorted	0.49	Coarse Skewed	3.03	Leptokurtic	Polymodal
CMR	Chinna Marudur	660.31	707.79	4.25	24.98	1.02	494.07	Medium Sand	2.01	Moderately Sorted	0.53	Symmetrical	4.15	Leptokurtic	Polymodal
DVP-HT1	DP South HT1	256.84	94.44	1.11	5.34	2.07	239.96	Medium Sand	1.43	Moderately Well Sorted	-0.06	Fine Skewed	3.12	Platykurtic	Polymodal
DVP-HT2	DP North HT2	274.93	119.67	0.91	4.15	2.02	248.90	Fine Sand	1.56	Moderately Well Sorted	-0.29	Symmetrical	2.87	Platykurtic	Trimodal
DVP-N	DP North Eastury	313.62	108.55	0.82	4.96	1.78	293.72	Medium Sand	1.43	Well Sorted	-0.53	Symmetrical	3.91	Mesokurtic	Trimodal
DVP-S	DP South Eastury	181.60	62.93	0.94	4.81	2.56	170.66	Fine Sand	1.41	Moderately Well Sorted	-0.13	Symmetrical	3.15	Mesokurtic	Trimodal
GKP	Gokulapuram	1052.99	1134.51	2.11	7.43	0.64	645.36	Coarse Sand	2.74	Poorly Sorted	-0.01	Symmetrical	2.47	Mesokurtic	Polymodal
IYR	Iraiyur	1362.11	1497.40	1.60	4.36	0.33	797.38	Coarse Sand	2.82	Poorly Sorted	0.20	Coarse Skewed	2.32	Mesokurtic	Polymodal
KDY	Kattuidaiyur	404.99	736.90	4.84	29.19	2.17	223.71	Fine Sand	2.52	Poorly Sorted	1.07	Coarse Skewed	4.33	Leptokurtic	Polymodal
KMP	Kammiampettai	637.53	457.38	5.68	52.21	0.87	551.40	Coarse Sand	1.66	Moderately Well Sorted	0.28	Fine Skewed	5.15	Leptokurtic	Trimodal
KPM	Kuchipalayam	631.25	741.26	3.61	18.96	1.17	445.94	Medium Sand	2.09	Poorly Sorted	0.99	Very Coarse Skewed	4.12	Leptokurtic	Polymodal
KVR	Kalavanoor	707.72	933.14	3.23	14.47	1.24	424.62	Medium Sand	2.59	Poorly Sorted	0.45	Coarse Skewed	2.90	Mesokurtic	Polymodal
MLR	Malattar	1208.30	1287.83	2.03	6.39	0.37	774.51	Coarse Sand	2.55	Poorly Sorted	0.13	Coarse Skewed	2.75	Leptokurtic	Polymodal
NMD	Narimedu	850.25	703.66	3.87	21.63	0.51	705.59	Coarse Sand	1.74	Moderately Sorted	0.82	Coarse Skewed	5.13	Mesokurtic	Trimodal
PLK	Pillayarkuppam	1894.07	1566.98	1.11	2.96	-0.40	1318.06	Very Coarse Sand	2.46	Poorly Sorted	-0.38	Symmetrical	3.08	Mesokurtic	Polymodal
PNT	Panruti	704.63	701.98	4.65	28.36	0.85	558.98	Coarse Sand	1.85	Moderately Sorted	0.63	Symmetrical	5.29	Leptokurtic	Trimodal
PPM	Pudupalayam	833.68	808.69	2.90	13.87	0.73	603.14	Coarse Sand	2.18	Poorly Sorted	0.24	Symmetrical	3.00	Mesokurtic	Polymodal
SMD	Semmedu	868.20	806.85	3.03	14.51	0.61	656.55	Coarse Sand	2.03	Moderately Sorted	0.37	Coarse Skewed	3.44	Mesokurtic	Polymodal
TVP	Thiruvandhipuram	1054.31	899.08	2.63	11.14	0.29	821.56	Coarse Sand	1.96	Moderately Sorted	0.39	Coarse Skewed	3.38	Mesokurtic	Polymodal
VPM-I	Vandipalaiyam1	1291.18	969.79	2.10	8.13	-0.04	1029.13	Very Coarse Sand	1.95	Moderately Sorted	-0.05	Coarse Skewed	3.78	Mesokurtic	Polymodal
VPM-2	Vandipalaiyam2	685.71	578.31	4.51	30.13	0.82	570.16	Coarse Sand	1.73	Moderately Well Sorted	0.78	Coarse Skewed	5.18	Leptokurtic	Polymodal
VSR	Visur	737.2949	715.7487	3.8691	21.3164	0.8066	574.3074	Coarse Sand	1.90	Moderately Sorted	0.68	Symmetrical	4.37	Leptokurtic	Polymodal

Table 1: Textual parameters through graphic and moment methods