Evaluation and Improvement of Bed Load Formulae Using Measured Ephemeral Stream Data

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Data Table – Figure 4. Bed slope measurement in river reach.

Slope Measurement	
Distance	**RL**
10	98.28
20	98.35
30	98.29
40	98.14
50	97.76
60	97.845
70	97.955
80	97.845
90	97.755
100	97.875
110	97.725
120	97.865
130	97.955
142	97.55

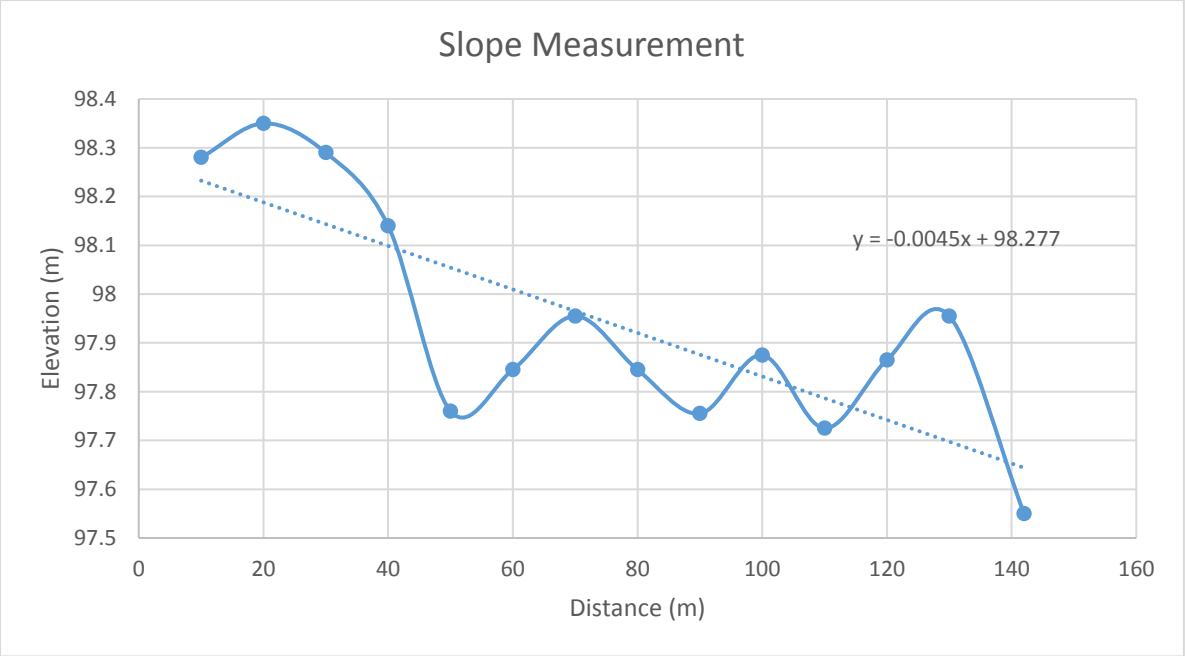

Figure 4. Bed slope measurement in river reach.

Data Table

Figure 6. Gradation curves for bedload samples collected at cross-section A

Sample ID	Weight Retained on Sieve (gm)									Total Weight (gm)
	20 (mm)	10 (mm)	4.75 (mm)	2.36 (mm)	1.18 (mm)	0.5 (mm)	0.3 (mm)	0.15 (mm)	0.075 (mm)	
R1S2	0	12	14	11	29.5	27	8.5	0	0	102
R2S2	0	0	35.5	28.5	38.5	22.5	4.5	0	0	129.5
R7S2	0	0	10	6	8	6	0	0	0	30
R8S2	28	58	46	22	36	22	4	2	0	218
R9S2	52	6	10	6	12	8	0	0	0	94

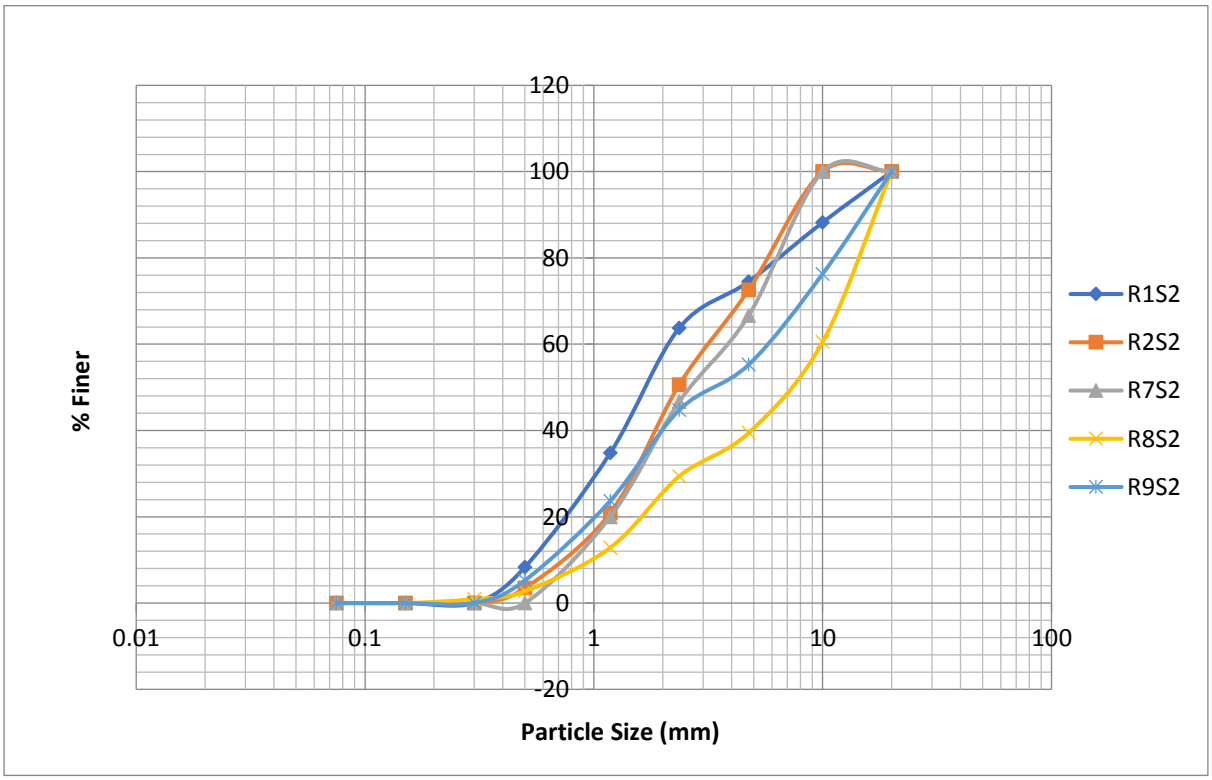

Figure 6. Gradation curves for bedload samples collected at cross-section A

Data Table

Figure 7. Bedload variation at cross-section A

River Section	Distance from left Bank (m)	Bedload Transport Rate (gm/m/sec)
		Run 2
A	0	0
	3	0.7218
	8	1.4162
	13	0.4703
	16	0

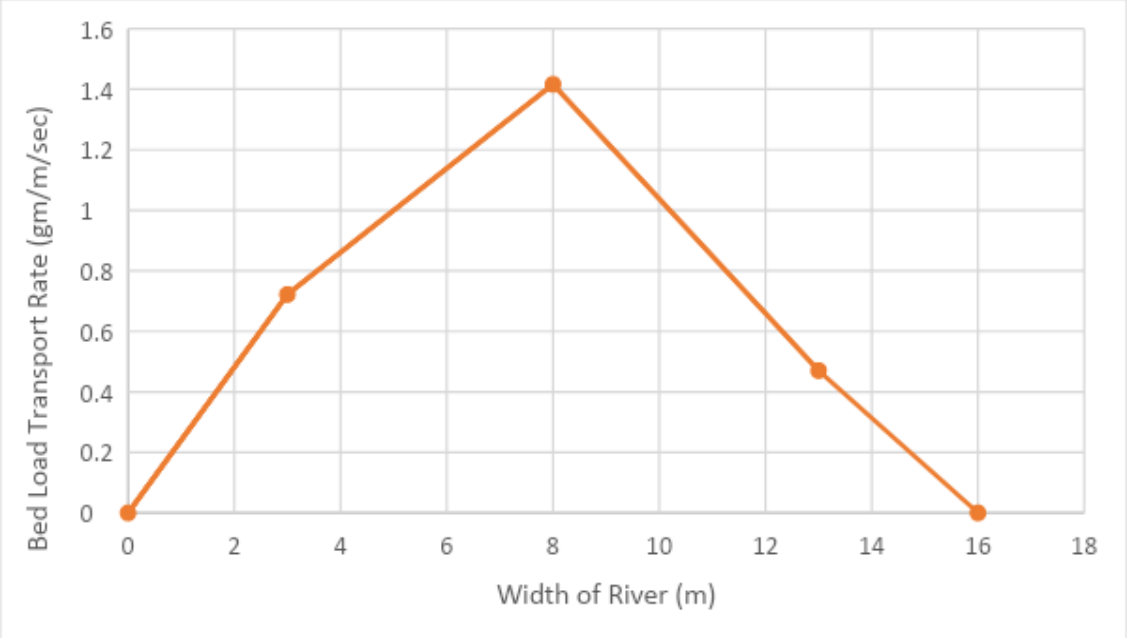

Figure 7. Bedload variation at cross-section A

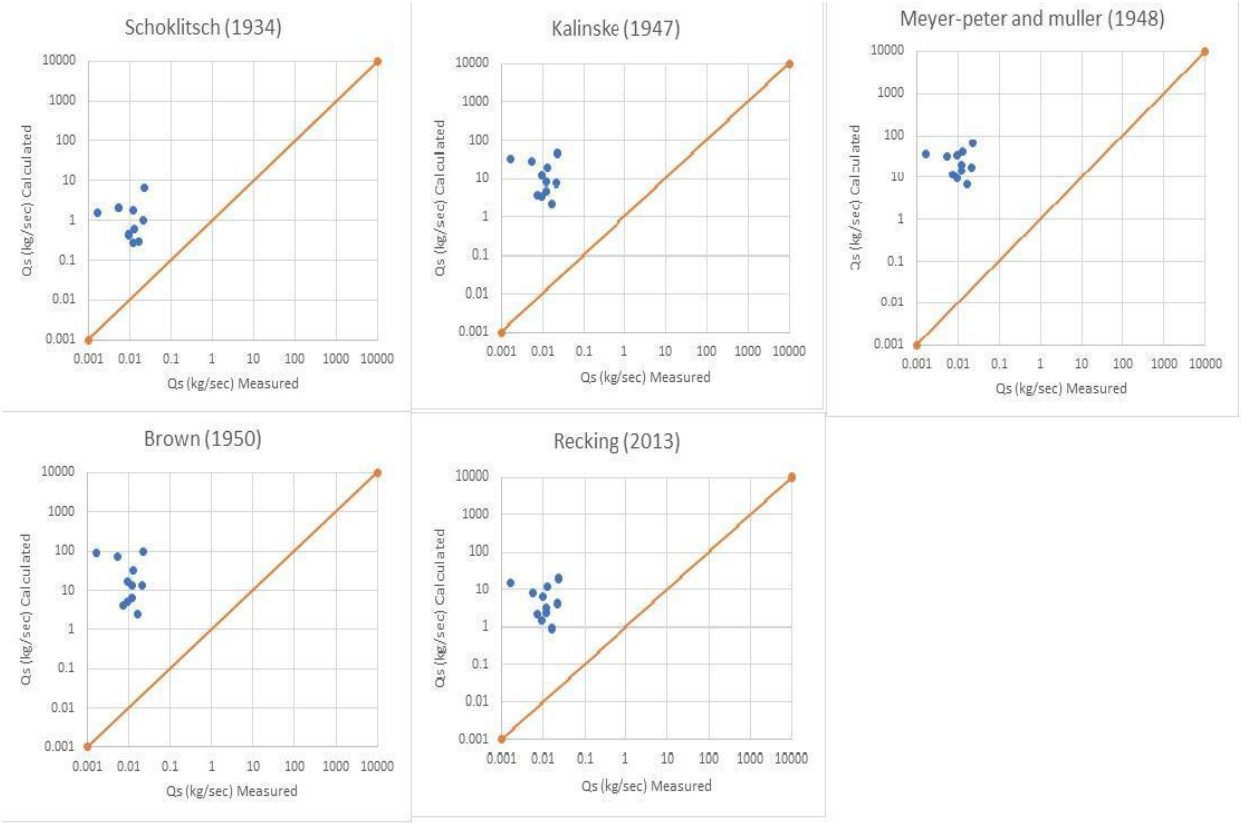

Figure 8. Comparison of computed and measured bedload rate for Kharera stream

Table 4. Statistical parameters for selected bedload equation

Bedload equations	Schoklitsch (1934)	Kalinske (1947)	Meyer-peter and muller (1948)	Brown (1950)	Recking (2013)
Average of variation coefficient	197.264	3028.280	4002.430	7276.078	1279.940
RMSE	2.424	20.843	31.338	48.051	8.951
Discrepancy Ratio	>2	>2	>2	>2	>2

Data Tables for Figure 8 and Table 4

Table: Calculation of bedload transport rate using Schoklitsch (1934) approach

Run No.	River Section	Width (m)	Discharge (m^3/sec)	Depth (m)	Hydraulic Radius (m)	Slope	d_{50} (m)	q_c	q	q_b	Qs (kg/sec) Calculated	Qs (kg/sec) Measured	Discrepancy Ratio
1	A	16	1.9746	0.3533	0.2472	0.0045	0.0025	0.0419	0.1234	0.0615	0.9843	0.0214	46.0608
2	A	16	1.6346	0.3367	0.2426	0.0045	0.0039	0.0797	0.1022	0.0169	0.2710	0.0118	22.8727
3	B	16	2.9932	0.3933	0.3221	0.0045	0.0014	0.0164	0.1871	0.1288	2.0610	0.0055	375.4088
4	B	16	2.6603	0.3933	0.3008	0.0045	0.0084	0.2524	0.1663	-	-	0.0074	-
5	C	16	2.8601	0.4867	0.4059	0.0045	0.0057	0.1427	0.1788	0.0272	0.4359	0.0096	45.4205
6	C	16	2.3439	0.5167	0.4352	0.0045	0.0044	0.0946	0.1465	0.0392	0.6272	0.0127	49.3943
7	A	16	10.0556	0.7333	0.5448	0.0045	0.0032	0.0591	0.6285	0.4297	6.8756	0.0227	302.5527
8	A	16	1.6921	0.2500	0.1762	0.0045	0.0039	0.0812	0.1058	0.0186	0.2968	0.0161	18.4134
9	A	16	1.2371	0.2500	0.1762	0.0045	0.0024	0.0397	0.0773	0.0284	0.4542	0.0093	48.6326
10	B	16	3.3755	0.3067	0.2716	0.0045	0.0031	0.0563	0.2110	0.1167	1.8675	0.0120	155.8055
11	C	16	2.2726	0.4000	0.3505	0.0045	0.0014	0.0170	0.1420	0.0943	1.5095	0.0017	908.0815

Table: Calculation of bedload transport rate using Kalinske (1947) approach

Run No.	River Section	Width (m)	Depth (m)	Hydraulic Radius (m)	Slope	d_{50} (m)	T_o	[(G-1)g(d^3)]^0.5	$T_o/(\gamma s-\gamma)d$	q_{bv}	Qs (kg/sec) Calculated	Qs (kg/sec) Measured	Discrepancy Ratio
1	A	16	0.3533	0.2472	0.0045	0.0025	10.9111	0.0005	0.2655	0.0002	7.9265	0.0214	370.9296
2	A	16	0.3367	0.2426	0.0045	0.0039	10.7103	0.0010	0.1697	0.0001	4.9277	0.0118	415.8618
3	B	16	0.3933	0.3221	0.0045	0.0014	14.2172	0.0002	0.6466	0.0007	28.7145	0.0055	5230.3783
4	B	16	0.3933	0.3008	0.0045	0.0084	13.2767	0.0031	0.0976	0.0001	3.9101	0.0074	526.5721
5	C	16	0.4867	0.4059	0.0045	0.0057	17.9181	0.0018	0.1926	0.0003	12.1027	0.0096	1261.1652
6	C	16	0.5167	0.4352	0.0045	0.0044	19.2131	0.0012	0.2717	0.0004	18.9549	0.0127	1492.8815
7	A	16	0.7333	0.5448	0.0045	0.0032	24.0501	0.0007	0.4655	0.0011	45.4793	0.0227	2001.2631
8	A	16	0.2500	0.1762	0.0045	0.0039	7.7772	0.0010	0.1218	0.0001	2.1876	0.0161	135.7074
9	A	16	0.2500	0.1762	0.0045	0.0024	7.7772	0.0005	0.1961	0.0001	3.5238	0.0093	377.3057
10	B	16	0.3067	0.2716	0.0045	0.0031	11.9903	0.0007	0.2396	0.0002	8.2388	0.0120	687.3683
11	C	16	0.4000	0.3505	0.0045	0.0014	15.4728	0.0002	0.6862	0.0008	34.5950	0.0017	20811.6475

Table: Calculation of bedload transport rate using Meyer-Peter and Muller (1948) approach

Run No.	River Section	Width (m)	Discharge (m^3/sec)	Depth (m)	Hydraulic Radius (m)	Slope	d50 (m)	T_o	θ	Φ	q_{sv}	Qs (kg/sec) Calculated	Qs (kg/sec) Measured	Discrepancy Ratio
1	A	16.0000	1.9746	0.353333	0.247164	0.0045	0.002539	10.91105	0.265501	0.817093	0.000421	17.8313	0.021369204	834.4411
2	A	16.0000	1.6346	0.336667	0.2426153	0.0045	0.003899	10.71025	0.169719	0.343918	0.000337	14.2815	0.0118493	1205.2610
3	B	16.0000	2.9932	0.393333	0.3220558	0.0045	0.001358	14.21715	0.646649	3.714804	0.000748	31.7223	0.005489939	5778.2601
4	B	16.0000	2.6603	0.393333	0.3007529	0.0045	0.008406	13.27674	0.097576	0.090992	0.000282	11.9630	0.007425634	1611.0405
5	C	16.0000	2.8601	0.486667	0.4058918	0.0045	0.005747	17.91809	0.192634	0.444614	0.000779	33.0396	0.009596457	3442.8975
6	C	16.0000	2.3439	0.516667	0.435227	0.0045	0.004368	19.21309	0.271714	0.852189	0.00099	41.9736	0.01269685	3305.8274
7	A	16.0000	10.0556	0.733333	0.5447976	0.0045	0.003192	24.05009	0.465506	2.165923	0.001571	66.6258	0.022725284	2931.7928
8	A	16.0000	1.6921	0.25	0.1761746	0.0045	0.003946	7.777228	0.121763	0.163538	0.000163	6.9151	0.01611986	428.9784
9	A	16.0000	1.2371	0.25	0.1761746	0.0045	0.00245	7.777228	0.196139	0.460764	0.000225	9.5297	0.009339458	1020.3750
10	B	16.0000	3.3755	0.306667	0.2716116	0.0045	0.003092	11.99029	0.239556	0.675965	0.000468	19.8277	0.011986002	1654.2380
11	C	16.0000	2.2726	0.4	0.3504995	0.0045	0.001393	15.4728	0.686195	4.088274	0.000855	36.2606	0.001662292	21813.6148

Table: Calculation of bedload transport rate using Brown (1950) approach

Run No.	River Section	Average D50 (m)	R (m)	τ_*	q_*	F_1	q_{bv}	Qs (kg/sec) Calculated	Qs (kg/sec) Measured	Discrepancy Ratio
1	A	0.0025	0.247164	0.265501	0.748619	0.806961	0.000311	13.183346	0.0213692	616.9320
2	A	0.0039	0.242615	0.169719	0.195546	0.812432	0.000156	6.59710506	0.0118493	556.7506
3	B	0.0014	0.322056	0.646649	10.81599	0.789286	0.001719	72.9003106	0.0054899	13278.8932
4	B	0.0084	0.300753	0.097576	0.037161	0.816603	9.41E-05	3.98963276	0.0074256	537.2784
5	C	0.0057	0.405892	0.192634	0.285928	0.815119	0.000408	17.3192893	0.0095965	1804.7588
6	C	0.0044	0.435227	0.271714	0.802412	0.813386	0.000758	32.1465604	0.0126969	2531.8531
7	A	0.0032	0.544798	0.465506	4.034936	0.810307	0.002372	100.574016	0.0227253	4425.6439
8	A	0.0039	0.176175	0.121763	0.072211	0.812541	5.85E-05	2.48100461	0.0161199	153.9098
9	A	0.0024	0.176175	0.196139	0.301825	0.806327	0.000119	5.03348616	0.0093395	538.9484
10	B	0.0031	0.271612	0.239556	0.549893	0.809908	0.000308	13.0635962	0.011986	1089.9044
11	C	0.0014	0.3505	0.686195	12.92417	0.790355	0.002137	90.5982285	0.0016623	54501.9869

Table: Calculation of bedload transport rate using Recking (2013) approach

Run No.	River Section	Average D50 (m)	Average D84 (m)	D84/D50	Tm*	R (m)	T84*	Φ	q_{bv}	Qs (kg/sec) Calculated	Qs (kg/sec) Measured	Discrepancy Ratio
1	A	0.0025	0.0064	2.512629101	0.027188	0.247163971	0.105667	0.050591	0.000104	4.397239507	0.021369204	205.7746
2	A	0.0039	0.0109	2.79301187	0.023935	0.242615288	0.060765	0.012443	5.69E-05	2.411944969	0.0118493	203.5517
3	B	0.0014	0.0069	5.057377278	0.011705	0.322055774	0.127863	0.081838	0.000187	7.948273151	0.005489939	1447.7890
4	B	0.0084	0.0154	1.827083101	0.039911	0.300752894	0.053405	0.007034	5.39E-05	2.28380999	0.007425634	307.5576
5	C	0.0057	0.0146	2.532282506	0.026934	0.405891762	0.076071	0.021999	0.000155	6.587591806	0.009596457	686.4608
6	C	0.0044	0.0097	2.210546989	0.031725	0.435226966	0.122917	0.073831	0.000282	11.9516163	0.01269685	941.3056
7	A	0.0032	0.0106	3.316505013	0.01946	0.544797587	0.140361	0.103295	0.000453	19.19112653	0.022725284	844.4835
8	A	0.0039	0.0118	3.0001672	0.021958	0.176174602	0.040585	0.004279	2.22E-05	0.940255094	0.01611986	58.3290
9	A	0.0024	0.0080	3.266947884	0.019816	0.176174602	0.060038	0.01222	3.52E-05	1.492371883	0.009339458	159.7921
10	B	0.0031	0.0109	3.522533427	0.018097	0.2716116	0.068007	0.016801	7.68E-05	3.258100919	0.011986002	271.8255
11	C	0.0014	0.0045	3.254297109	0.019909	0.350499502	0.210858	0.285805	0.000351	14.88161807	0.001662292	8952.4681

Data Table – Figure 9 / Table 5

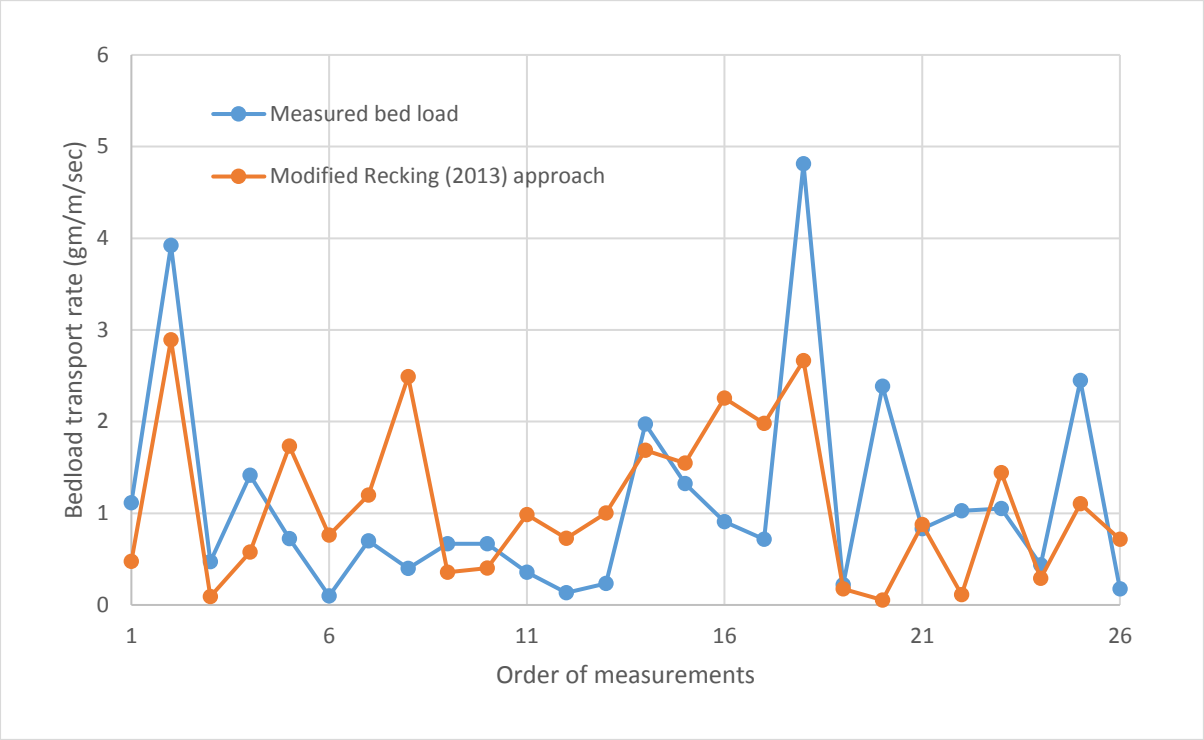

Figure 9. Comparison of modified Recking (2013) approach and measured bedload rate

Table 5. Statistical parameters for modified Recking (2013) approach

Bedload Model	Average of variation coefficient	RMSE	Discrepancy Ratio
Modified Recking (2013) approach	1.921	1.353	Ranges from 0.022 to 7.751

Data Table for Figure 9. Comparison of modified Recking (2013) approach and measured bedload rate and Table 5. Statistical parameters for modified Recking (2013) approach

Order of measurements	Measured bed load (gm/m/sec)	Modified Recking (2013) approach (gm/m/sec)	Discrepancy Ratio
1	1.115485564	0.476012476	0.4267
2	3.920603675	2.893285598	0.7380
3	0.470253718	0.090964823	0.1934
4	1.416229221	0.575441859	0.4063
5	0.721784777	1.733856384	2.4022
6	0.098425197	0.762924088	7.7513
7	0.699912511	1.196352343	1.7093
8	0.399168854	2.491262167	6.2411
9	0.667104112	0.35554129	0.5330
10	0.667104112	0.402525687	0.6034
11	0.355424322	0.986335742	2.7751
12	0.131233596	0.725024208	5.5247
13	0.235126859	1.002688279	4.2645
14	1.973972003	1.687409889	0.8548
15	1.323272091	1.547902068	1.1698
16	0.907699038	2.256930723	2.4864
17	0.71631671	1.97952341	2.7635
18	4.811898513	2.665345314	0.5539
19	0.21872266	0.175577579	0.8027
20	2.38407699	0.053383454	0.0224
21	0.831146107	0.878324675	1.0568
22	1.0279965	0.112868718	0.1098
23	1.049868766	1.442863445	1.3743
24	0.437445319	0.29037922	0.6638
25	2.449693788	1.102449741	0.4500
26	0.174978128	0.714721918	4.0846

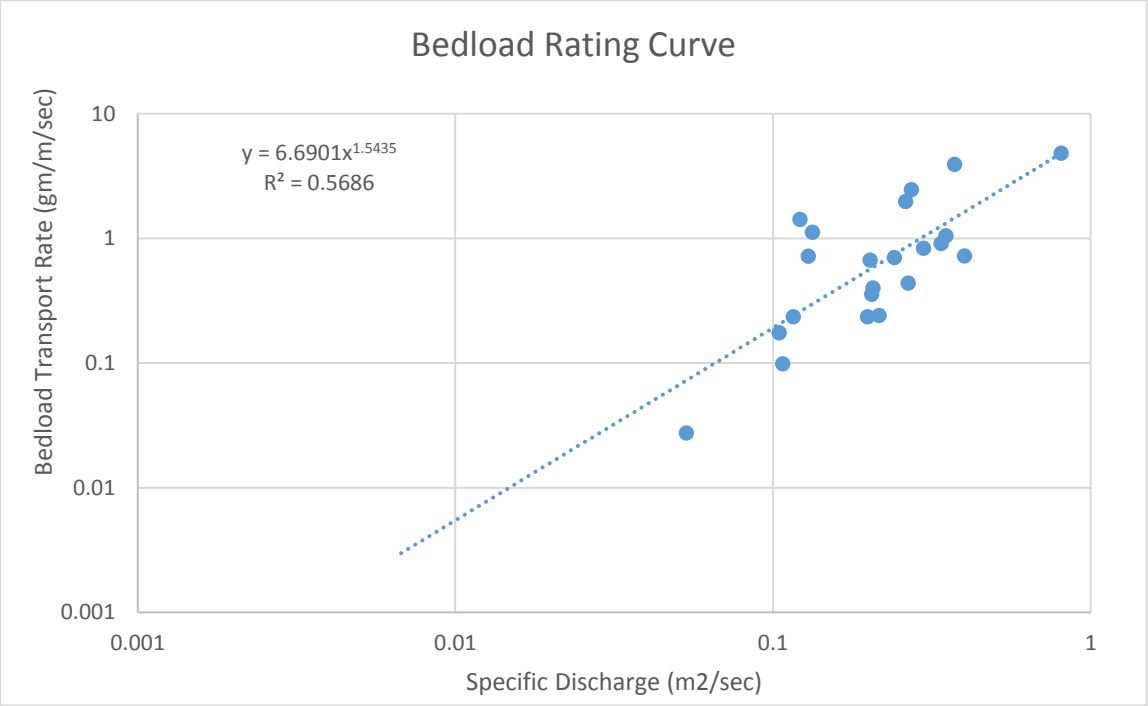

Figure 10. Bedload rating curve of the Kharera river.

Data Table :Figure 10. Bedload rating curve of the Kharera river.

River Section	Distance From Right Bank (m)	Sample ID	Average velocity (m/s)	Depth (m)	Specific Discharge (m2/sec)	Bed Load Transport Rate (gm/m/sec)
A	3	R1S1	0.266805	0.2	0.053361	0.02734033
A	8	R1S2	0.475262	0.28	0.1330733	1.11548556
A	13	R1S3	0.642933	0.58	0.3729013	3.92060367
A	8	R2S2	0.434477	0.28	0.1216535	1.41622922
A	13	R2S3	0.74263	0.54	0.4010202	0.72178478
B	3	R3S1	0.357438	0.3	0.1072315	0.0984252
B	8	R3S2	0.602148	0.4	0.2408593	0.69991251
B	13	R3S3	0.429945	0.48	0.2063736	0.39916885
B	8	R4S2	0.561363	0.36	0.2020908	0.66710411
B	13	R4S3	0.393692	0.52	0.2047197	0.35542432
C	3	R5S1	0.275868	0.42	0.1158647	0.23512686
C	8	R5S2	0.38916	0.51	0.1984716	0.23512686
C	13	R5S3	0.493388	0.53	0.2614958	1.973972
C	8	R6S2	0.615743	0.55	0.3386588	0.90769904
C	13	R6S3	0.235083	0.55	0.1292958	0.71631671
A	13	R7S3	1.155012	0.7	0.8085082	4.81189851
A	13	R8S3	0.66106	0.45	0.297477	0.83114611
A	13	R9S3	0.778883	0.45	0.3504975	1.04986877
B	8	R10S2	0.760757	0.35	0.2662648	0.43744532
B	13	R10S3	0.63387	0.43	0.2725641	2.44969379
C	3	R11S1	0.348375	0.3	0.1045125	0.17497813
C	13	R11S3	0.479793	0.45	0.215907	0.24059493