Department of Hydrology, Faculty of Geography,
Lomonosov Moscow State University, Moscow, Russia

A STUDY OF SEDIMENTATION IN RIVERS USING SEDIMENT TRAPS

Sergey R. Chalov
Ekaterina Belozerova
Nikolay Alexeevsky

Suspended sediment origin

- watershed-sourced sediment

(slope wash, gully erosion, volcanic eruptions)

$d_w < d_*$

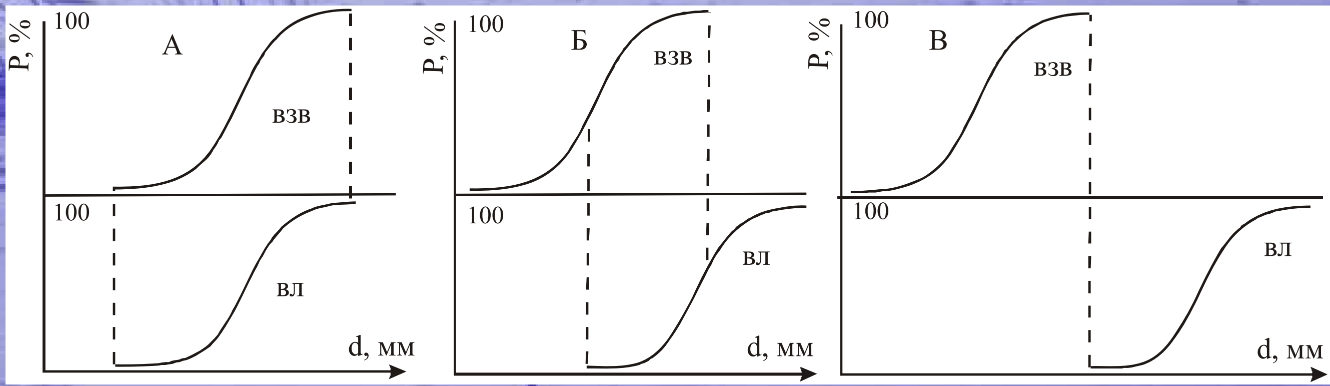
- channel-sourced sediment

$d_{ch} \geq d_*$

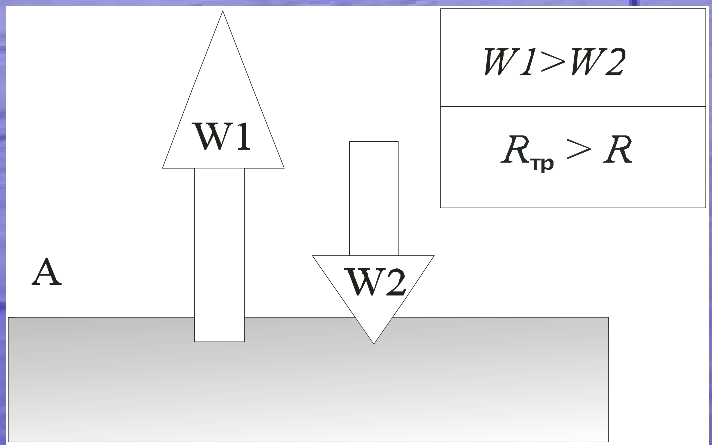
$d_* = 0{,}05$ мм

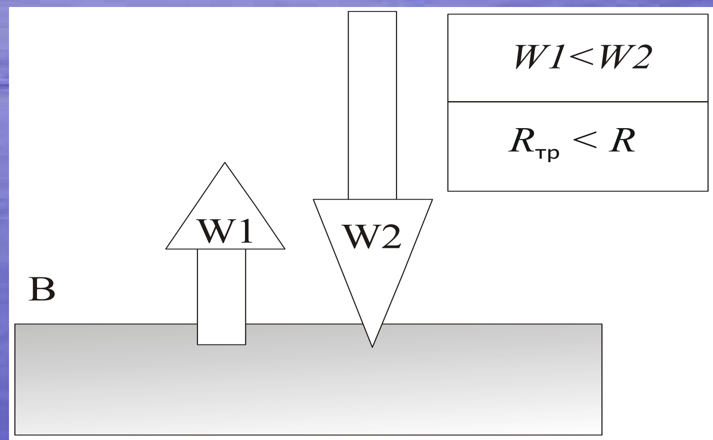
Channel-flow interaction

Comparison between bed load (вл) and suspended load (взв)



Interaction between bed deposits (W) and suspended load (R)





$$W_2 - W_1 = \Delta W$$

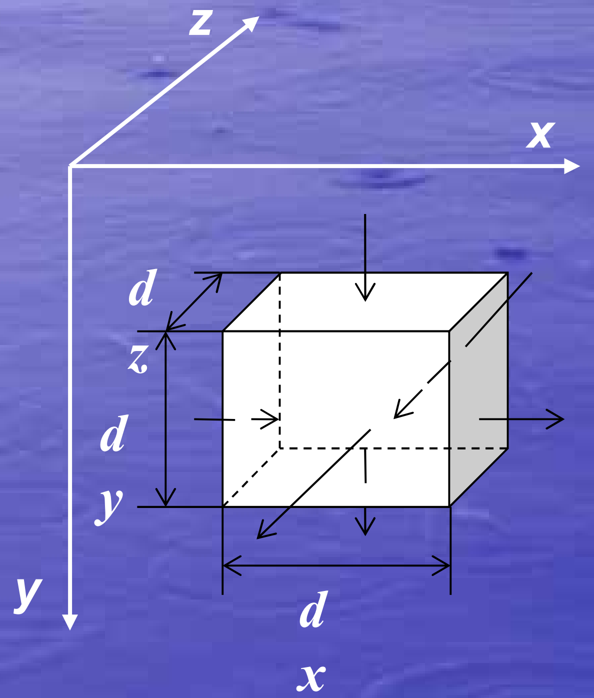
W_1 – sediment input (m^3), W_2 – sediment output from the channel reach (m^3), ΔW – sediment budget (m^3),

Suspended sediment concentration

$$\frac{\partial s}{\partial t} = \frac{A}{\rho}\left(\frac{\partial^2 s}{\partial x^2} + \frac{\partial^2 s}{\partial y^2} + \frac{\partial^2 s}{\partial z^2}\right) - \left(v\frac{\partial s}{\partial x} + u\frac{\partial s}{sy} + w\frac{\partial s}{\partial z}\right) - \omega\frac{\partial s}{\partial y}$$

- Turbulent advection – longitudinal changes of water body parameters
- Dispersion – transverse changing of parameters
- Convection – vertical changing of parameters

+ gravity



Methods

1. Sediment installation on the river bottom

Small trap:
2 sm diameter and 20 sm height.

Large trap:
height 30–50 sm, diameter 4,4 sm

2. Comparison with published data

Kozerski HP, Leuschner K. New plate sediment trap: design and first experiences. Verh Intern Verein Limnol 2000;

Kozerski HP. Determination of areal sedimentation rates in rivers by using plate sediment trap measurements and flow velocity—settling flux relationship. Water Res 2002;36:2983–90.

Wilson A.J., Walling D.E., Leeks G.J.L. In-channel storage of fine sediment in rivers of southwest England // Sediment transfer through fluvial system. IAHS Publ. 288. 2004. P.291-299

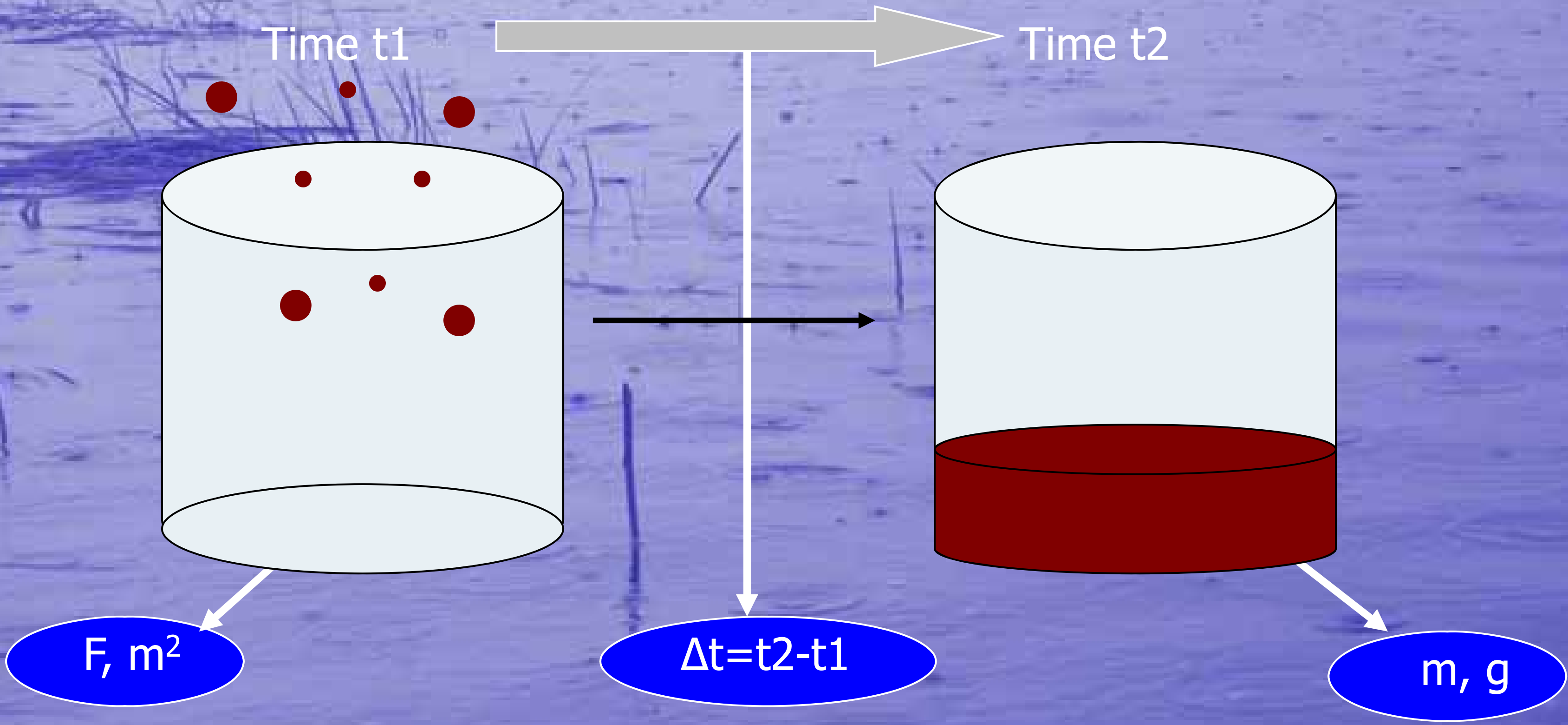
Walling D.E., Amos C.M. 1999. Fine sediment in a chalk stream system // Hydrological processes. Vol. 13. P. 323-340

Parameters of sediment traps for rivers

Type	Height, m	Diameter, m	Bottom area F, m^2	Volume, m^3	Total trap weight, kg	Location, m
Large	0,4	0,075	0,004	0,001	5	1 - on the bed level 2 - above bottom 3 – above bottom
Small	0,25	0,04	0,002	0,001	2	1 - on the bed level

- Field-based sediment trapping

Sediment trapping: obtained data

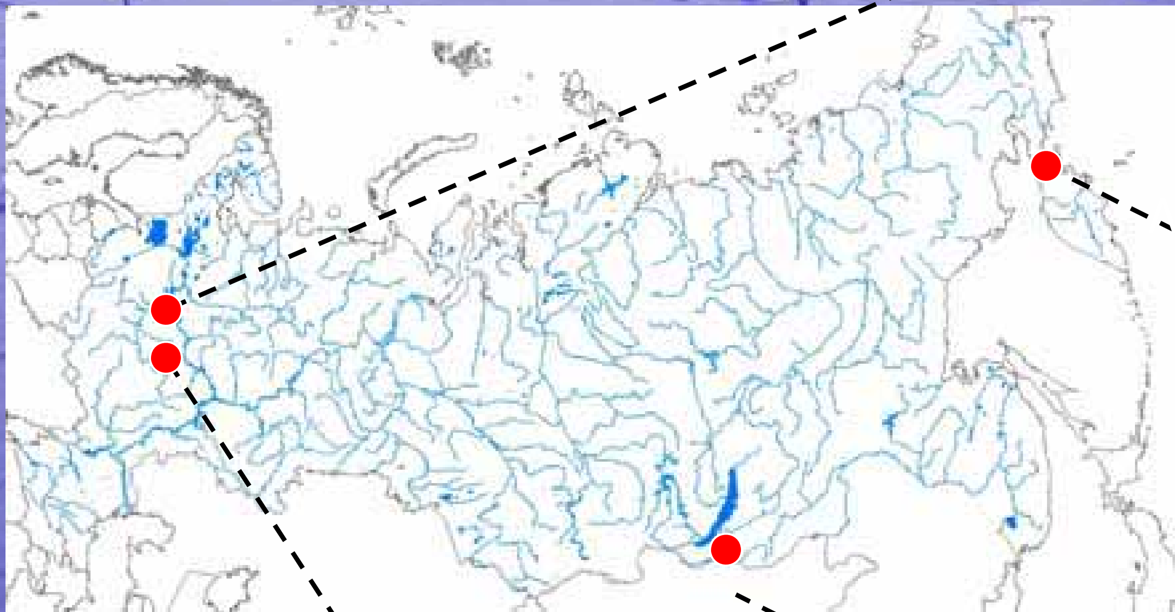


1. $TR = m/(Ft)$ - «trapping rate»' TR (gm^{-2} s^{-1} or $gm^{-2}d^{-1}$)
2. Sedimentation rate for stream reach with bottom area F1=F*n: $SED = TR*F1$
3. Dimensionless relative settling coefficient : $C = TR/(vs)$

"Input" data: S – suspended sediment concentration, V – stream velocity, h – depth

Obtained data

25 field experiments in the different rivers



- Protva river(
- Koryak platue river

Oka river

Selenga river

Variation of trapping rate's for different rivers recorded by the sediment trap at different times (data bank fragment)

River	Distance from the bank, m	Depth h, m	Height above channel bed l, m	Relative depth $=l/h$	Stream velocity v, m/s	Reinolds number $Re \cdot 10^{-3}$	SSC, g/m^3	Weight of material in each trap m, g	Average trapping rate C_{cp}, g·sm^{-2}·s^{-1}	Relative trapping rate $10^7 C_{cp}/(vs)$
Protva	1,5	0,8	0,55	0,69	0,1	79	7,1	3,1	0,02	2,82
								2,91		
								2,75		
	0,4	1	0,75	0,75	0,35	346	5,3	2,92	0,016	0,86
								1,32		
								2,99		
	1,5	0,5	0,25	0,50	0,15	74	4,4	2,61	0,022	3,33
								4,06		
								3,08		
	2,5	0,8	0,55	0,69	0,36	285	4,5	2,64	0,016	0,99
								1,66		
								2,61		
Koryak plateu rivers	1,5	0,35	0,10	0,29	0,15	52	1,44	0,005	0,00004	0,000048
	2,5	0,4	0,15	0,38	0,42	166	15	0,31	0,0017	0,0002
	2,5							0,06		
	2,0	0,3	0,05	0,17	0,49	145	4,3	0,17	0,004	0,0018
	2,5	0,4	0,15	0,38	0,45	178	8,0	0,11	0,0018	0,0005

Discussion: driving forces

gravitational vertical sediment fluxes

+

downstream movement of sediment particles

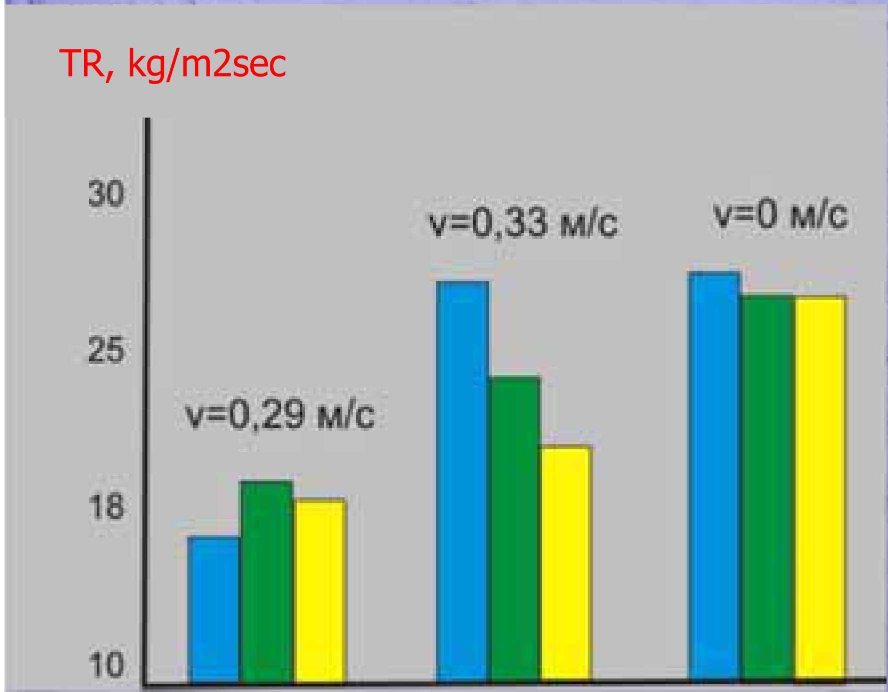
+

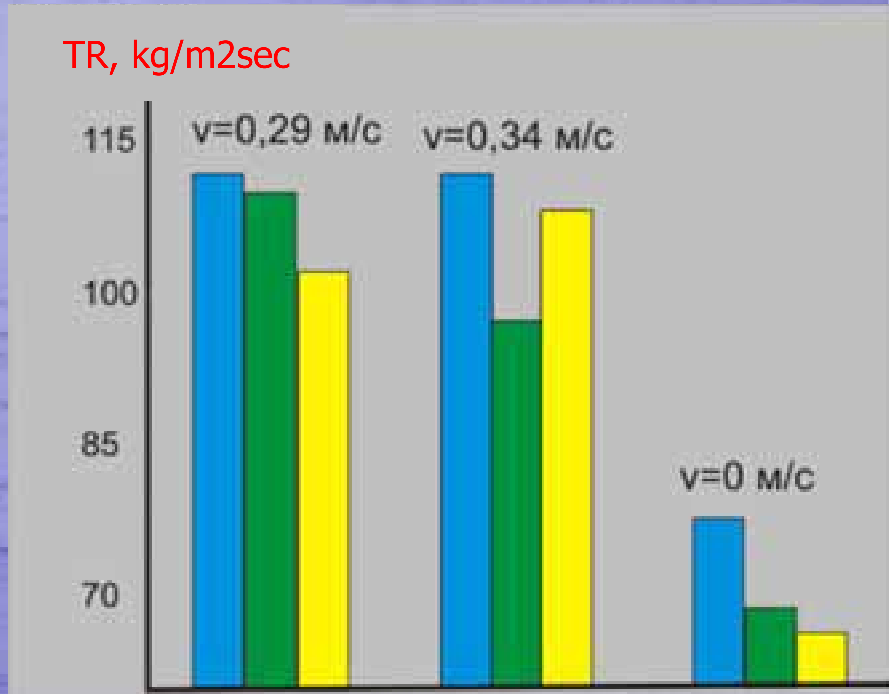
development of turbulent vortexes

Quantitative parameters

V + h_{κ}/h + SSC + Re

Sedimentation at different flow velocities (river Protva)

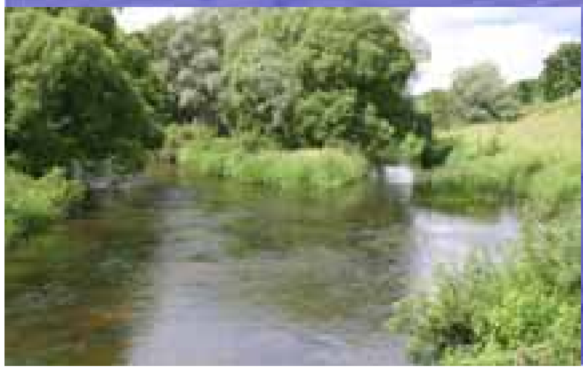




- high cylinder

- middle cylinder

- low cylinder

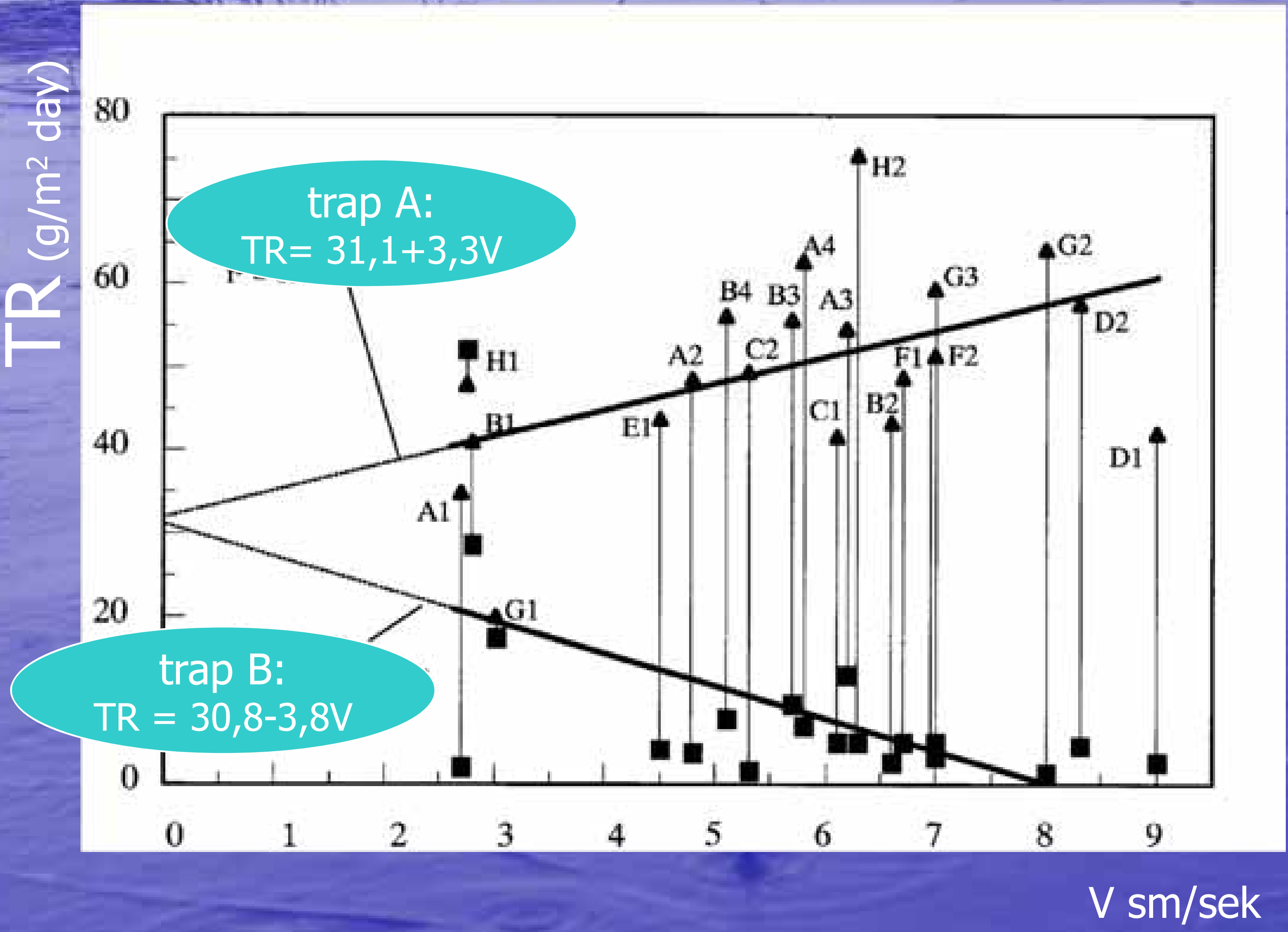


Protva

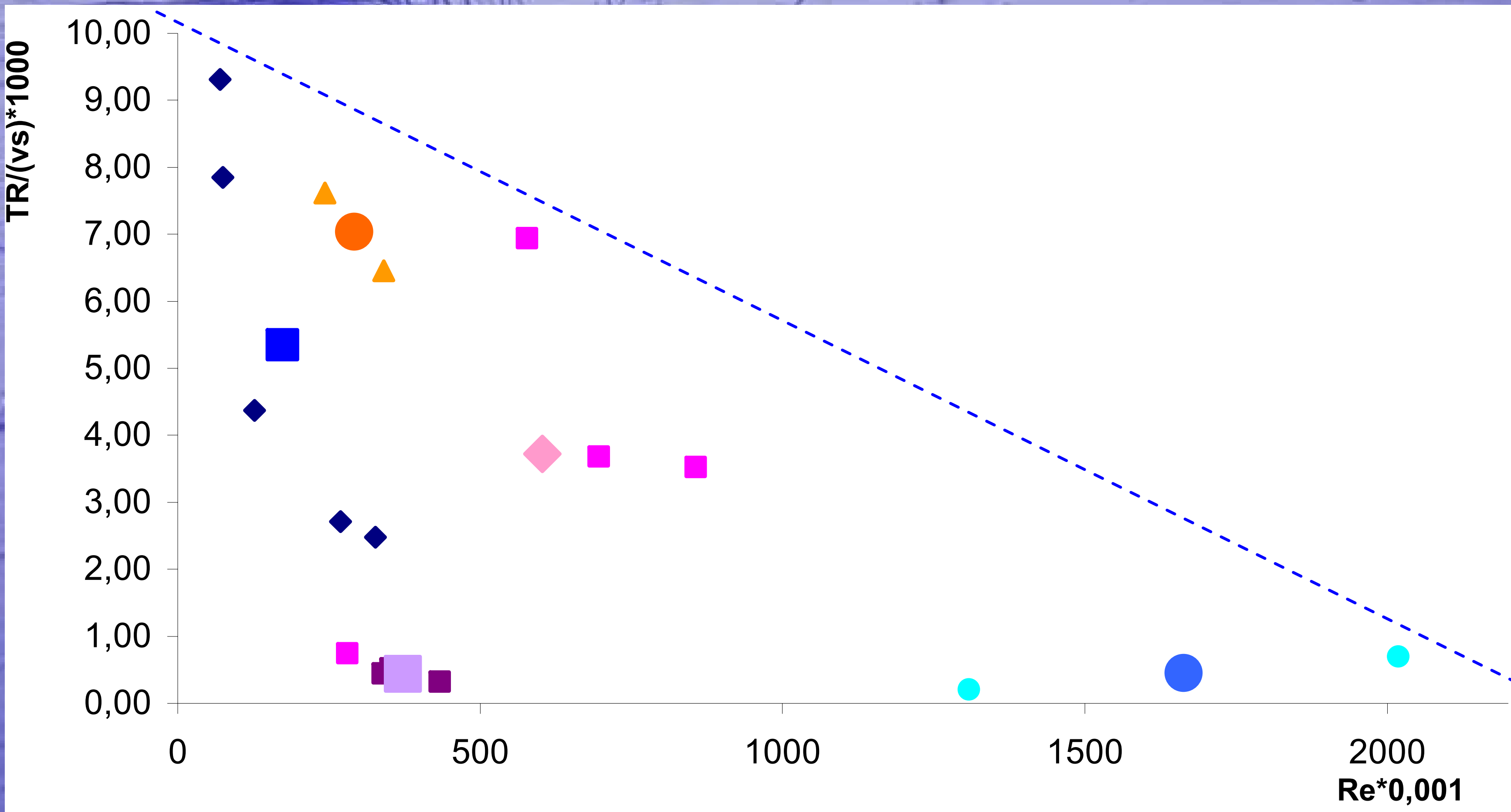
Low water

High water

Correlation between flow velocity *v* and «trapping rate» TR (by Kozerski (2006))

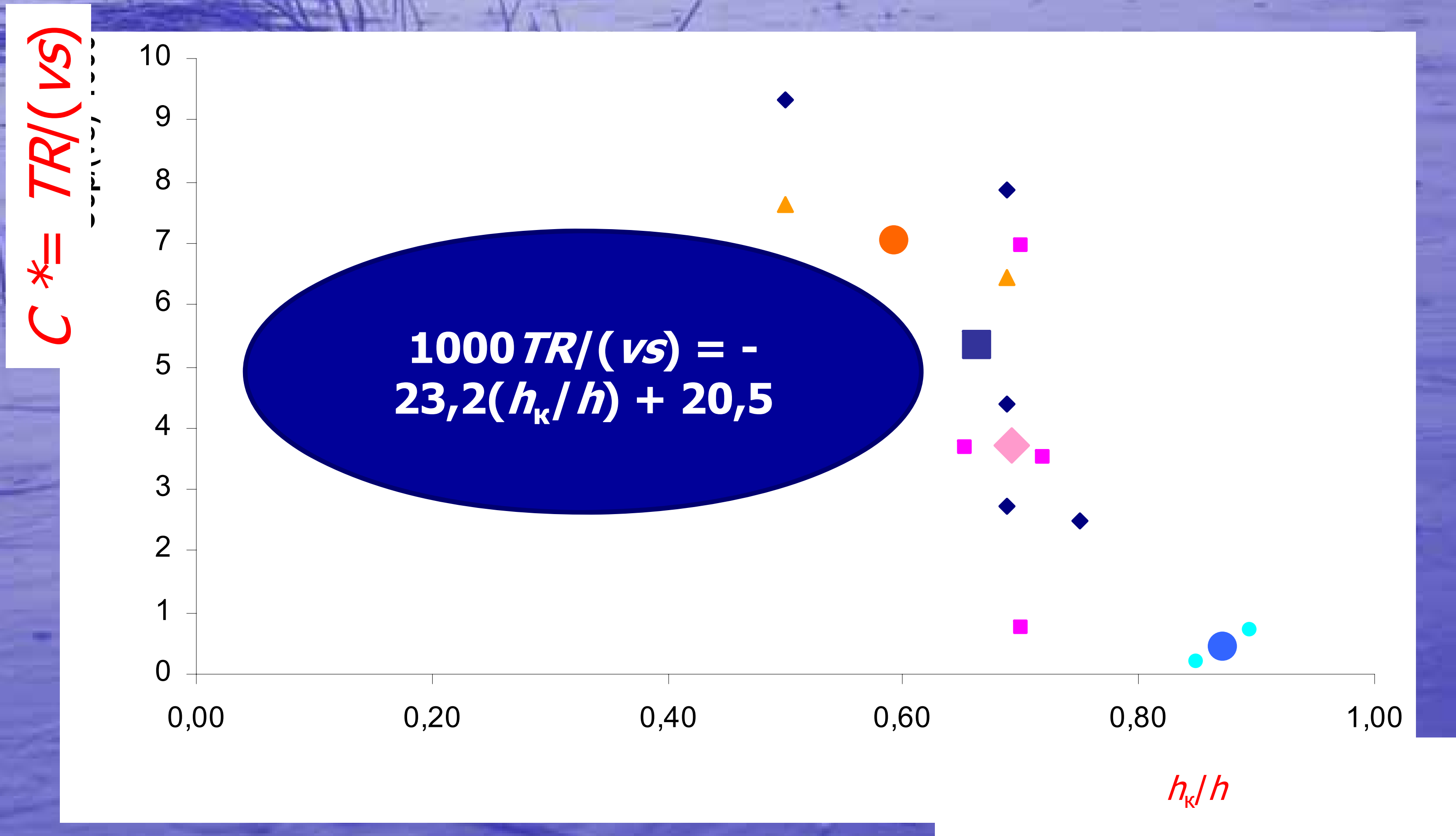


Relationship between Reynolds number and relative settling coefficient from trap installations on various rivers (marked by various symbols)

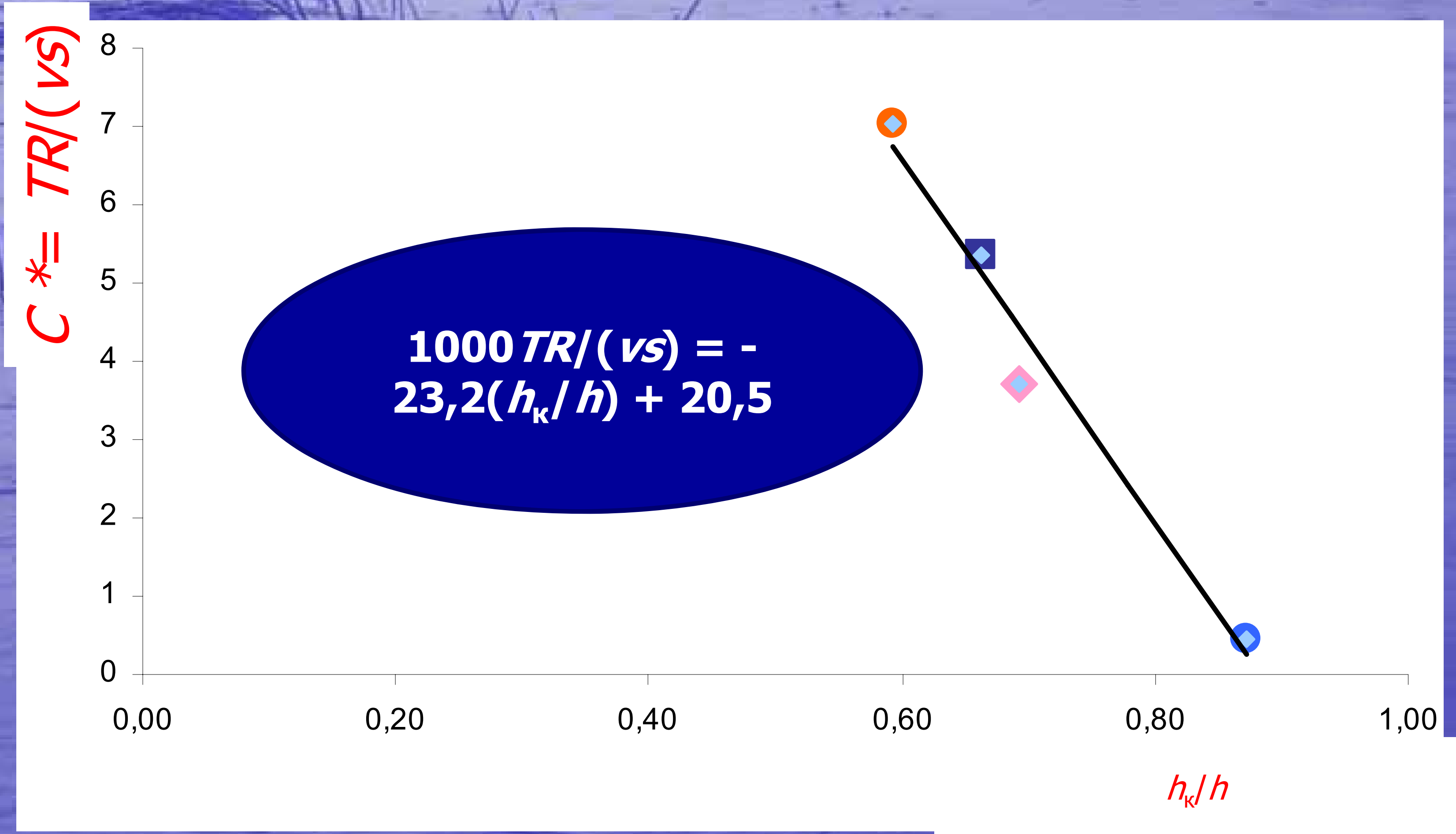


Dotted line – upper curve (corresponded to the highest sedimentation under Re =const)

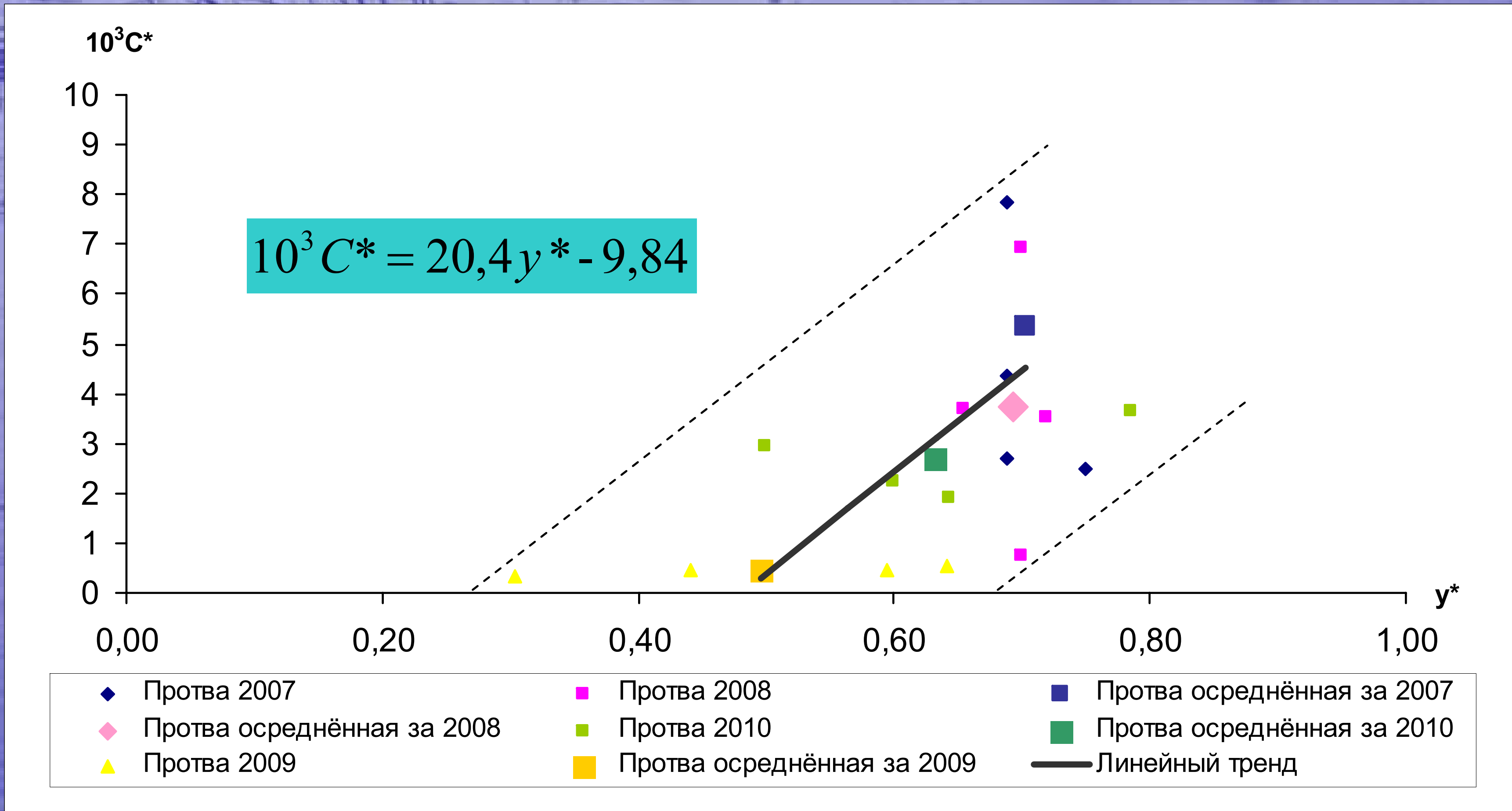
Correlation between relative sediment trapping C *and relative depth $h_к/h$ *(different size rivers)*



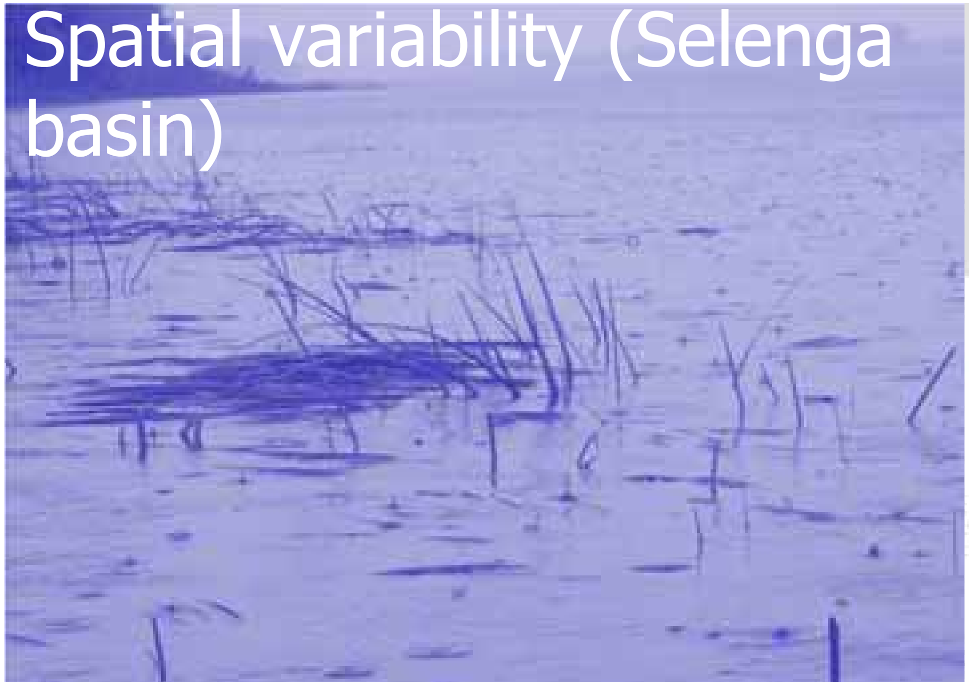
Correlation between relative sediment trapping C *and relative depth $h_к/h$ *(different size rivers)*

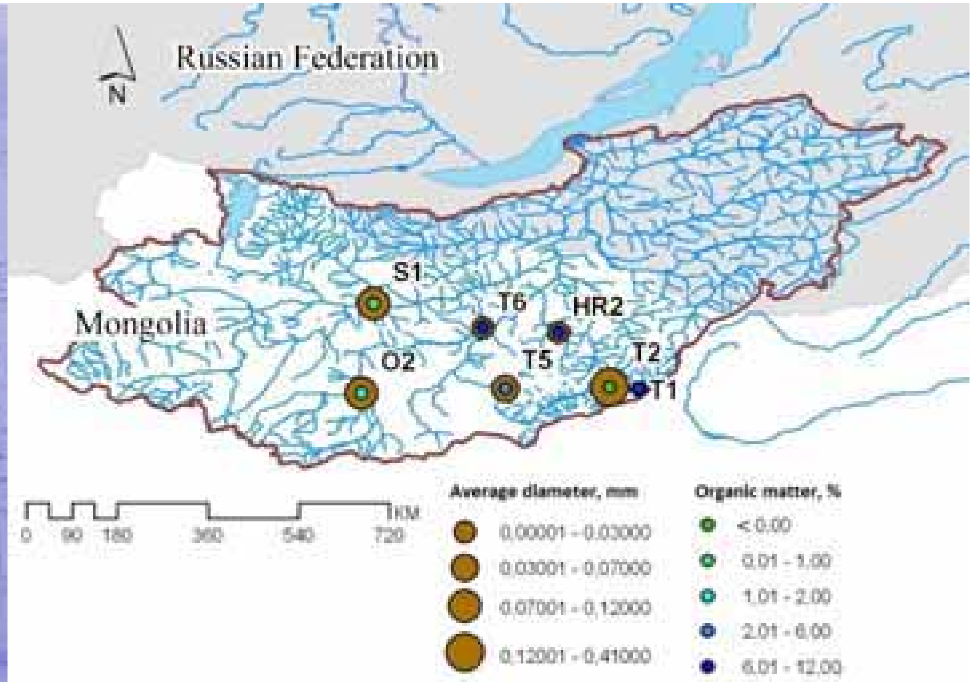


Correlation between relative sediment trapping and relative depth $h_к/h$ *(one river, different time)*



Spatial variability (Selenga basin)





Site	Description	*SSC*, g/m³	Settling rate *C*, g/(m²hour)	Suspended sediment load *R*, kg/s	Vertical sediment flux R_z, kg/s	R_z/R, %	Human impact
T1	Tuul river 20 km upstream from Ulaanbaatar	1.68	6.38	0.050	0.00003	0.06	low
T2	Tuul river 1 km upstream from Ulaanbaatar	8.36	87.5	0.22	0.00028	0.13	average
T5	Tuul river upstream from Zaamar	107	2048	3.56	0.027	0.75	average
T6	Tuul river downstream from Zaamar	289	1364	8.22	0.017	0.21	high
O2	Orkhon river upstream from the confluence with Tamir river	1699	2675	204	0.102	0.05	average
S1	Selenga river near Hutyk village	114	465	20.0	0.026	0.13	low

Comparison of sedimentation values obtained by trapping and direct measurements

Placer-mined rivers in the Kamchatka peninsula

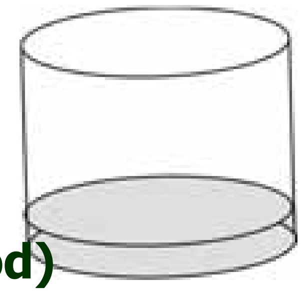
Direct measuring thickness of fine sediments layer at stream bottom

3-5 mm

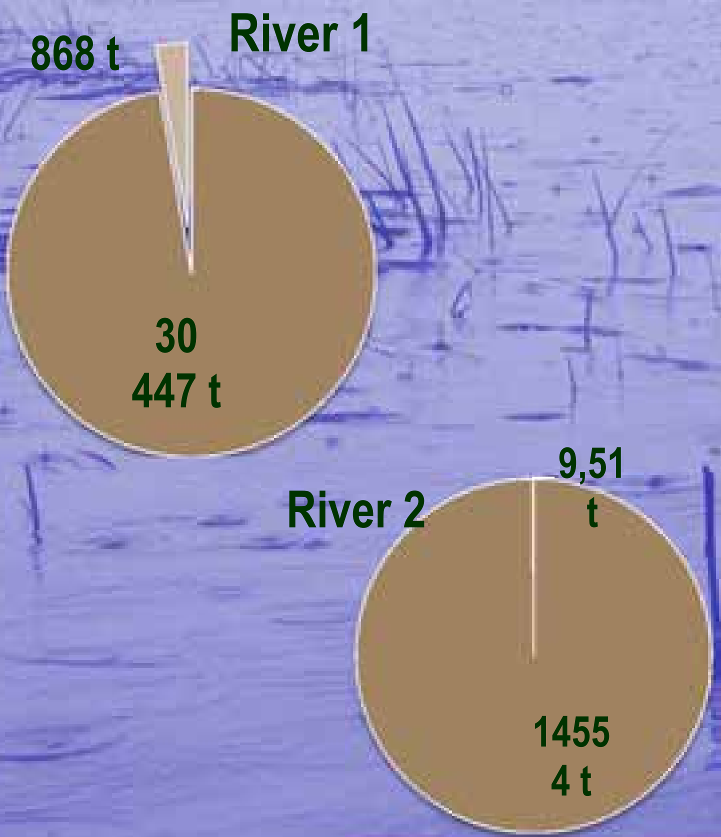
Obtained values of fine sediments layer thickness at the bottom

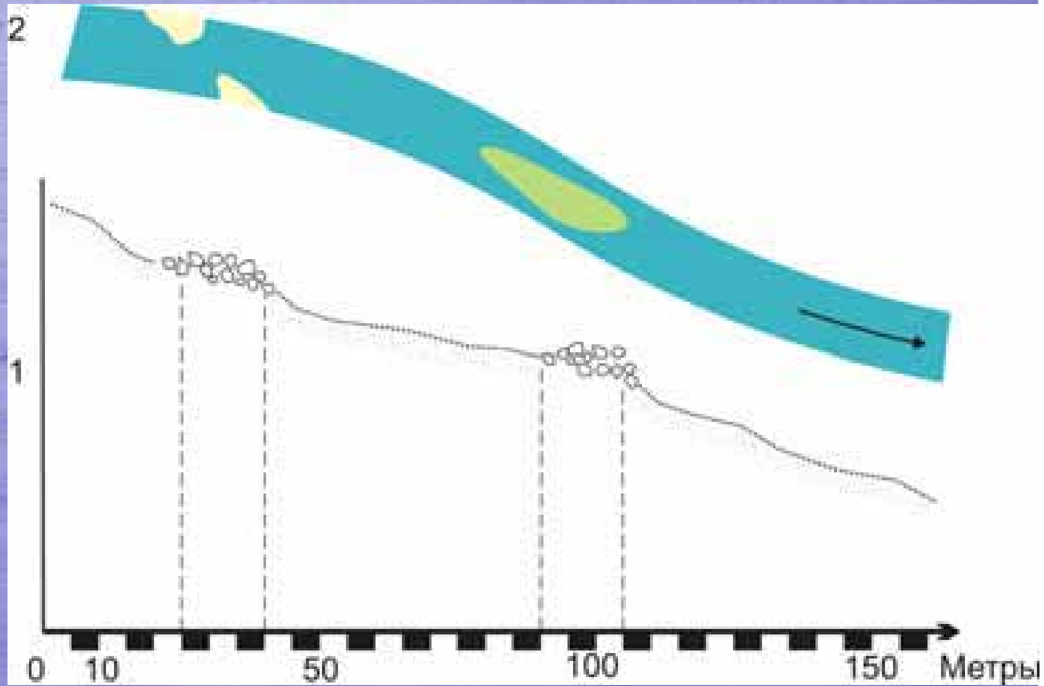
6 mm

Using point trap measurements *TR* (according to the average density of fine material, duration after high water period)



Contribution to sediment fluxes





River	Relative settling rates, kg/m²		Settlled particles layer, m		Volume of settled particles, m³		MAss, t	
	Low water period duraton, days							
	30	75	30	75	30	75	30	75
1	1,98	4,94	0,0025	0,0062	434	1085	347	868
2	1,16	2,91	0,0015	0,0036	4,76	11,9	3,80	9,51

Conclusion

- Any attempt to provide a definitive assessment of the sedimentation processes in rivers causes faces a number of important constraints. Firstly it is instrumental error of trapping techniques which leads to the few apparent inconsistencies of the results obtained. Nevertheless absence of the analogue methods determines perspectives of the sediment trapping. It is regarded to be the only way in in-situ direct measurements of sedimentation.

- Future experiments will lead to the expanding of the data. Further multistatictical analyses will lead to describe exact laws and factors of sedimentation. Further investigations to introduce a method for the estimation of the average areal sedimentation flux for a section of a river based upon a series of point trap measurements should be done.

Thank you for your attention!

The study reported in this paper was undertaken with financial support from the Russian Fund of Basic Research