Good practices in bedload transport monitoring

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  - Subdivision of the cross-section
  - Samples per vertical
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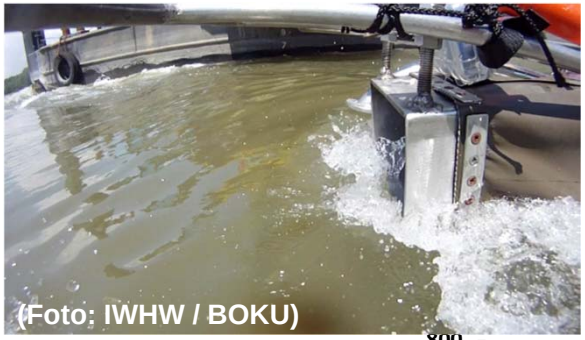
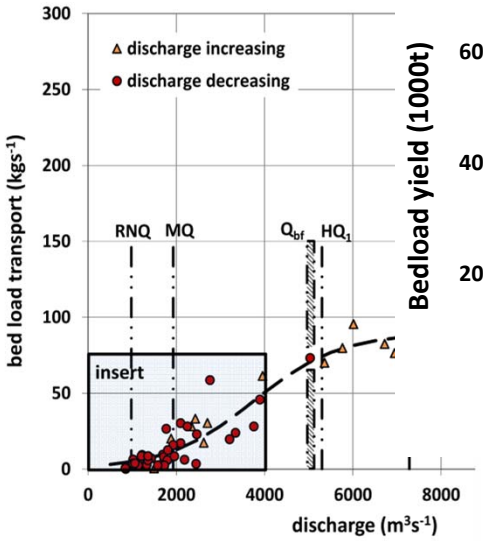
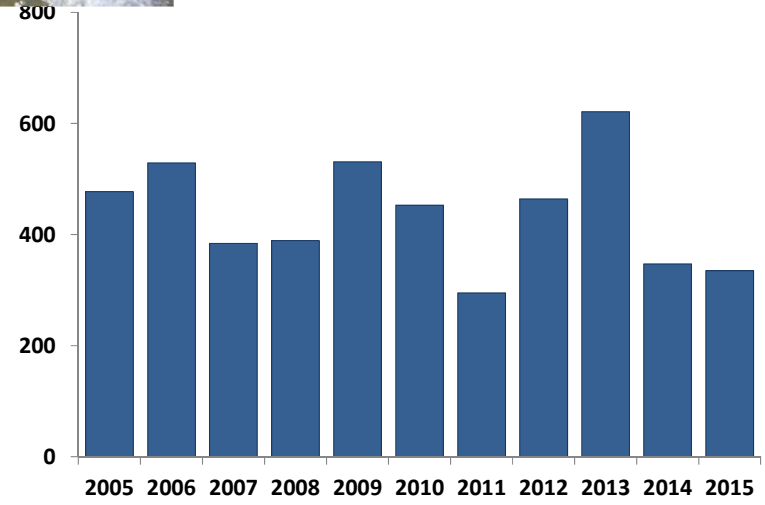
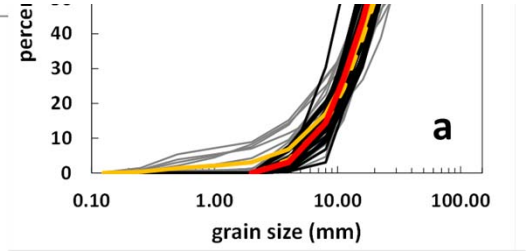
The way and what do we get?

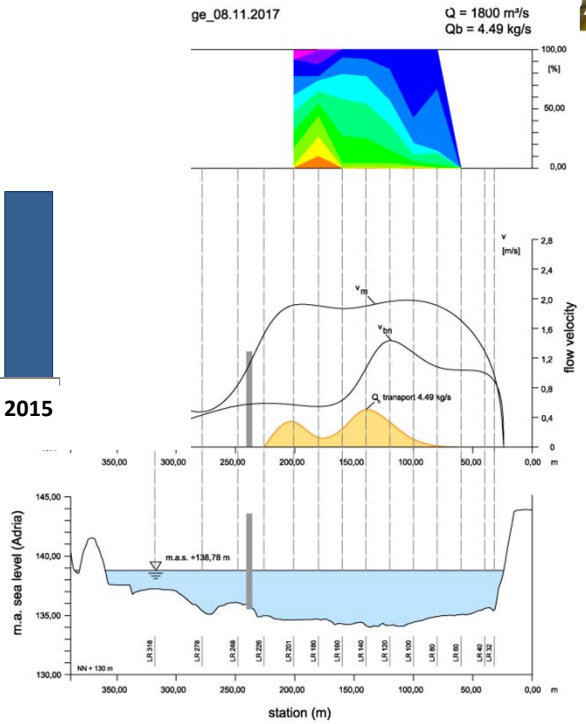




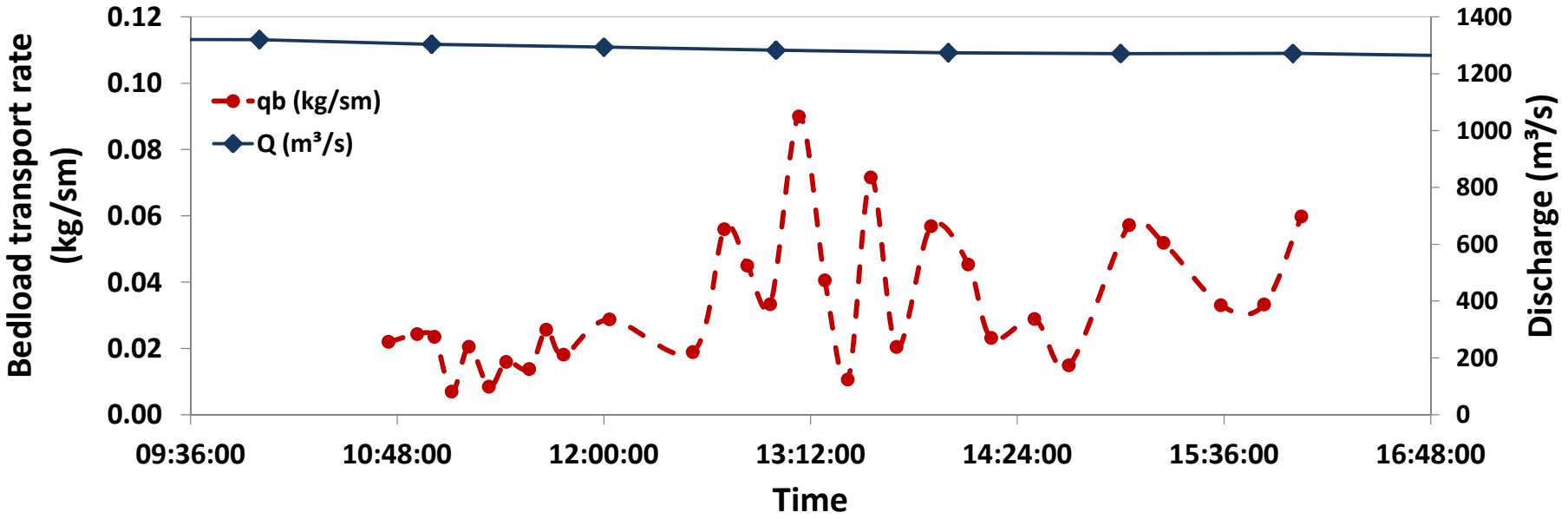
(Liedermann et al., 2017)







Temporal variability



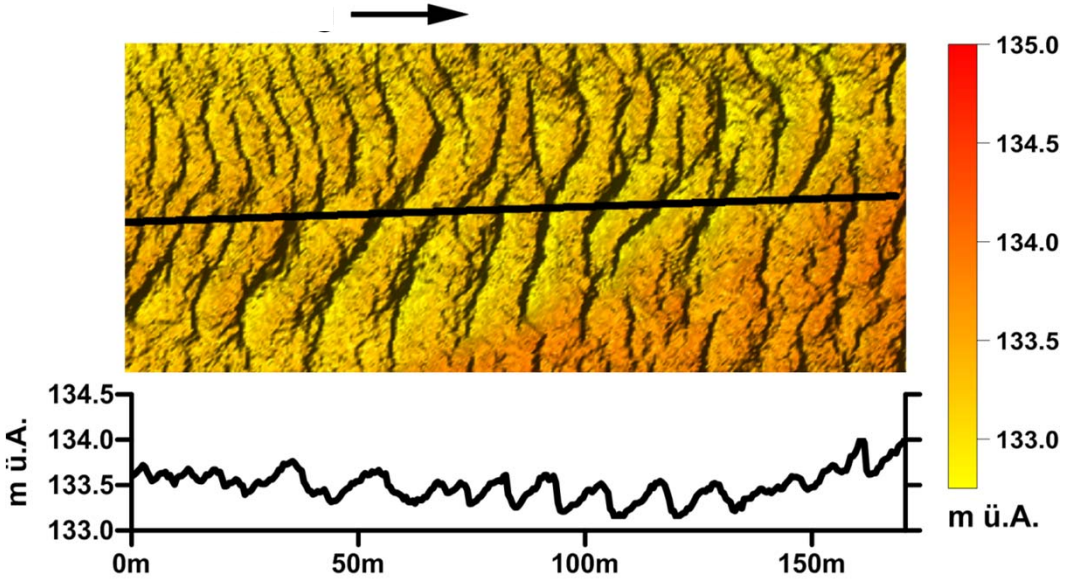
(bed load: IWHW/ BOKU; discharge: viadonau)

Danube in Bad Deutsch-Altenburg

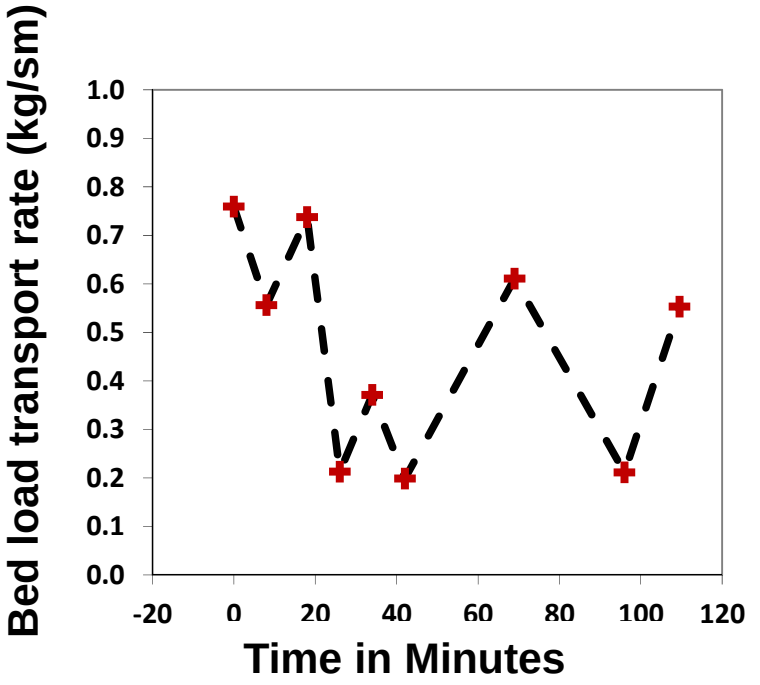
- Periodicities – seconds to hours
- Variation of the transport rate even when the streamflow is constant.

→ Turbulence / Coherent structures
→ Secondary currents
→ Bed forms

Temporal variability



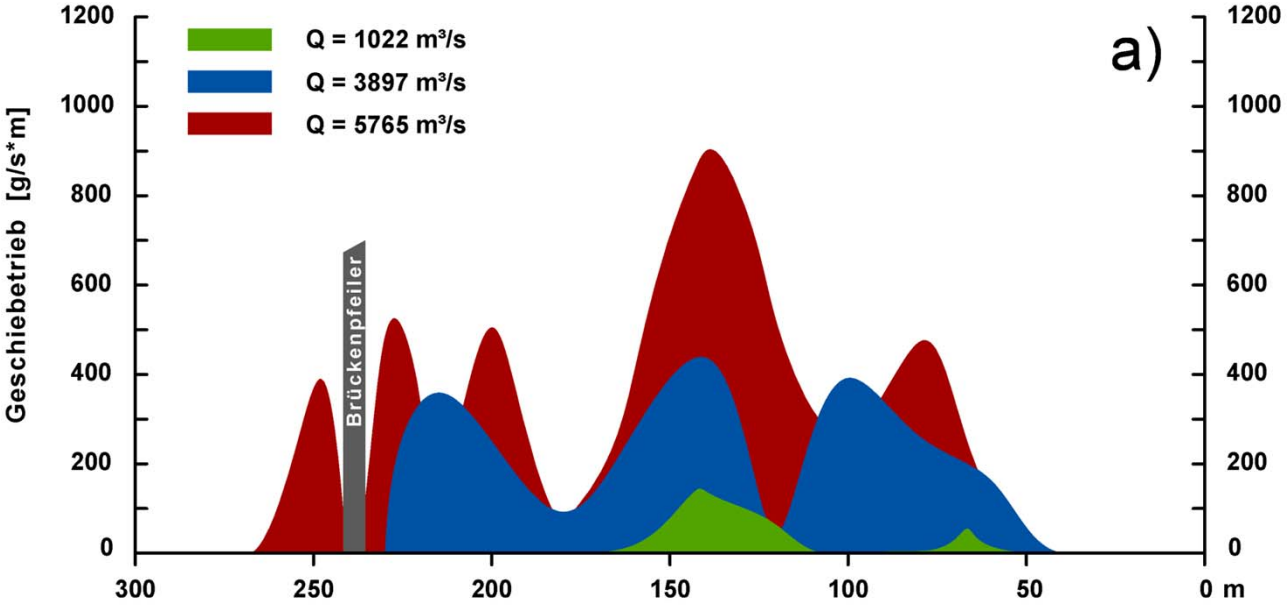
Danube Austria



→ Bed forms

(Gmeiner et al., 2016; modified from Liedermann et al., 2014; bathymetry: viadonau)

Spatial variability



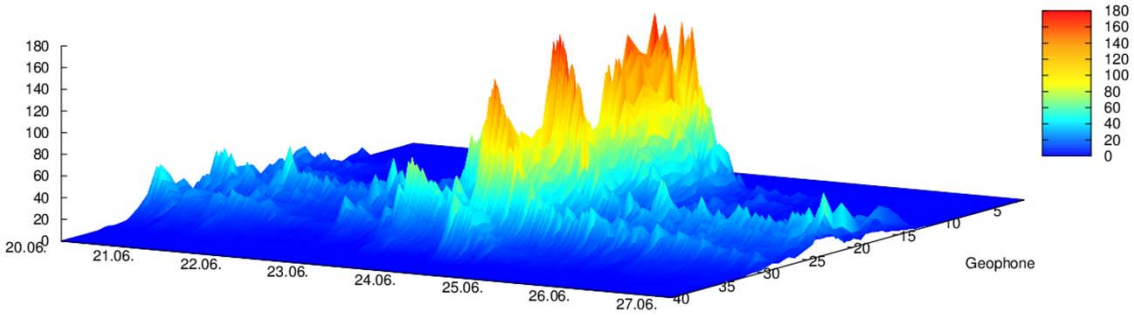
(Liedermann et al., 2012)

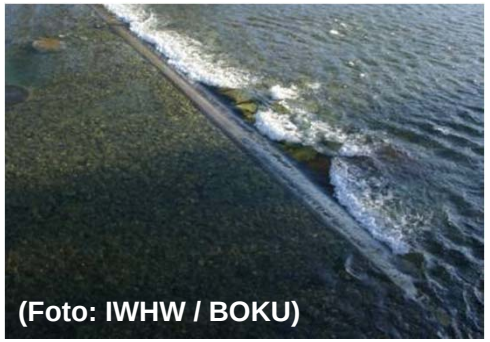
Transport rate in the cross-section → highly variable

- Stronger in gravel than sand bedded rivers
- Gravel bed often limited part of the cross-section with transport
- Location of maximum transport can shift
- Sometimes nearly immobile parts also during floods

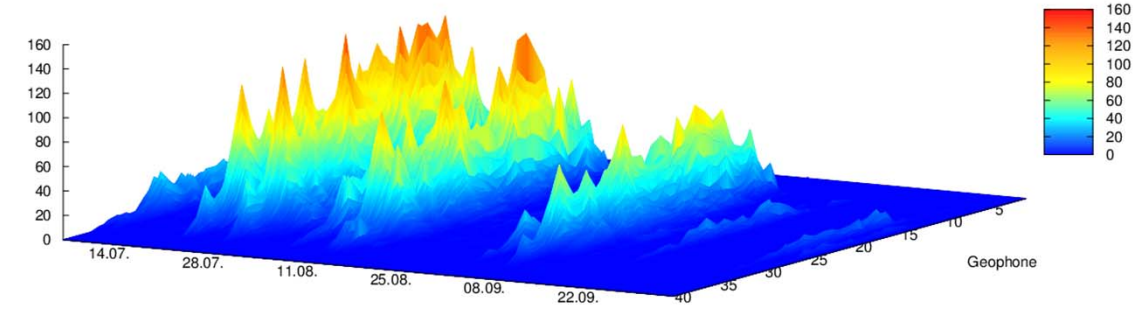
Temporal and spatial variability – all in one

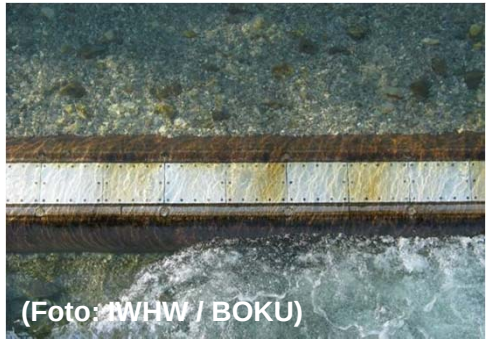
7 Days





3 Months





Geophone Impulses Drau / Dellach (Habersack et al., 2017b)

Measurement methods: Integrated approach

- **direct measurement**

  Quantitative

  - Basket sampler (mobile)
  - Traps

- **other methods**

  - Bed form tracking
  - Bathymetry measurements

- **indirect measurement**

  Qualitative

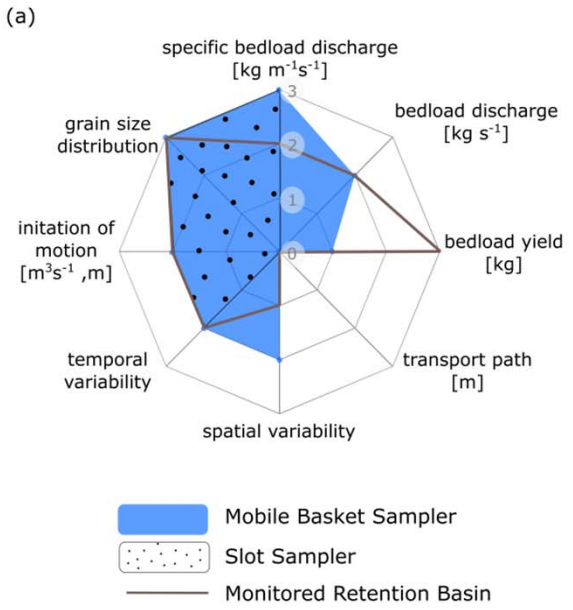
  - Visual (Video / Pictures)
  - Acoustic (e.g. ADCP)
  - Geophone
  - Hydrophone
  - Tracer
  - etc.

INTEGRATED BEDLOAD TRANSPORT MEASUREMENT

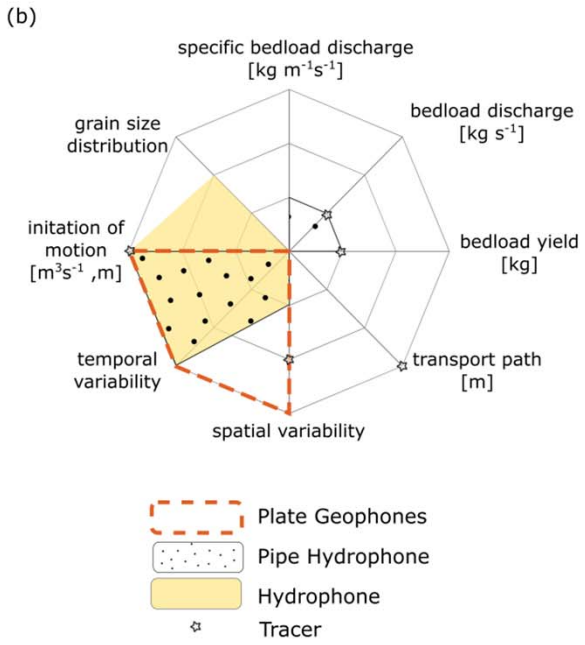
BEST PRACTICE

Measurement methods: Integrated approach

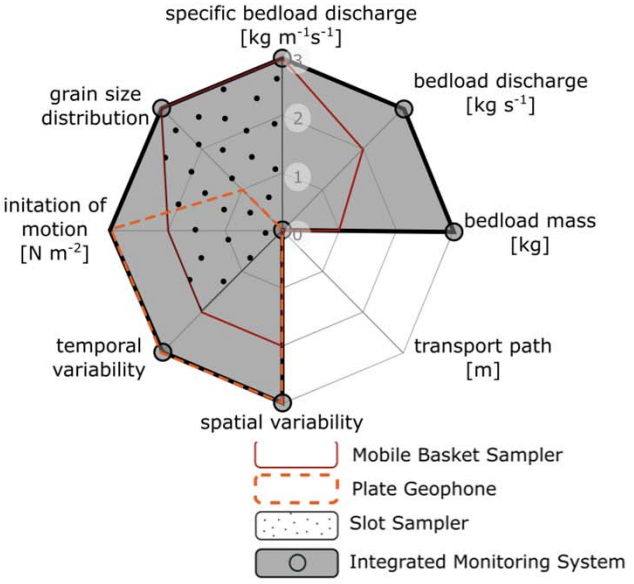
direct measurement



indirect measurement

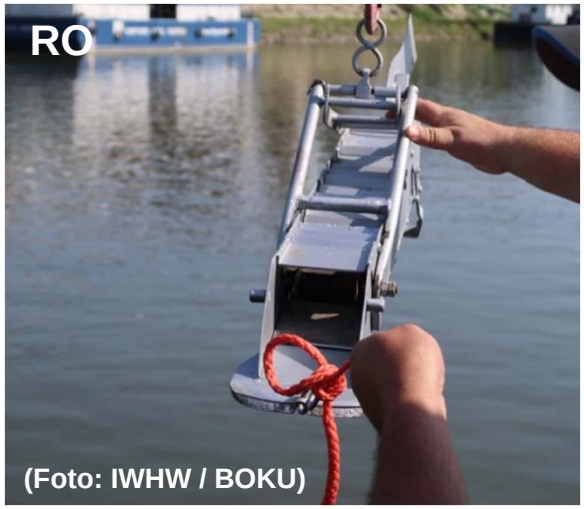


integrated



(Habersack et al. 2017a)

Basket / Pressure difference samplers: Danube



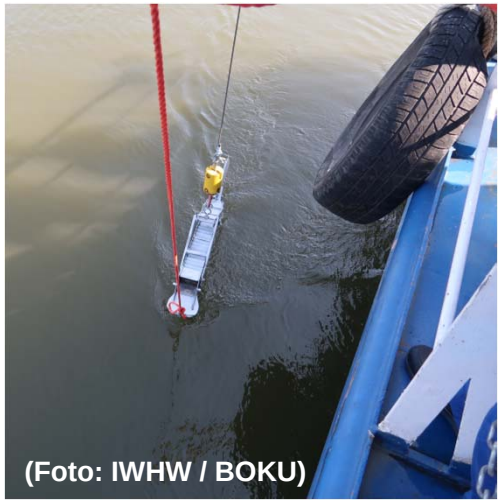
- Different design
- Different mesh sizes
- Different substrate (gravel / sand)

Performing the measurement: Ship or Bridge

- Bed load sampling
  - + flow velocity
  - + discharge
  - + stage
  - + bed material

(Foto: BME)


(Foto: IWHW / BOKU)


(Foto: IWHW / BOKU)

Measurement protocol

- Example from a recent project (SEDDON – AT-HU Interreg)
  - Sampler
    + location
    + discharge
    + water level
    + river
    + start – end time
    + mesh and intake size
    + sample ID
    + sampling duration
    + remarks
    + …

SEDDON

creating the future
Programm zur grenzüberschreitenden Kooperation ÖSTERREICH - UNGARN 2007-2013
AUSZTRIA - MAGYARORSZÁG Határon Átnyúló Együttműködési Program 2007-2013

Bedload Measurement									
Method:								Sheet No. ____/____	
Date:					Measurement team:				
River:					Project:				Miscellaneous:
River-km:					Country:				
Station:					Region:				
Identification (No. of sample)	Distance from reference point: L / R	Water depth	Sampling time (CET/CEST)	Sampling duration	Bedload	Bedload (dry mass)	Water level	Flow velocity/ file name	Remarks (ship traffic , No. of buckets/sample, samples merged, No. of stones,...)
	(m)	(m)	(hh:mm)	(sec)	(yes/no)	(g)	(cm)	(m s^{-1})	

SEDDON

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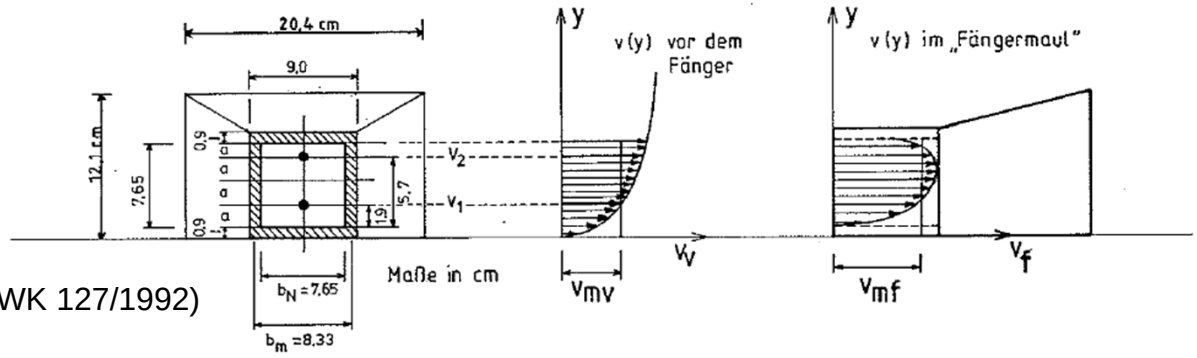
Bedload Measurement					
Method:				Sheet No. ____/____	
Measurement procedure:				Date:	
Monitoring device:		Mesh size .....mm		Intake .....mm	
River:		Project:			
River-km:		Country:			
Station:		Region:			
Measurement team:					
Bridge / Boat / Cable way /					
Accompanying measurements: flow velocity, discharge, suspended sediment, ...					
Spatial & height reference system:					
Reference point cross section:					
Distance to waters edge L / R bank ..... m		River width ..... m			
Gauge ..... (upstream)					
	Water level	Discharge	Water temperatur	Turbidity	Time (CET/CEST)
Start	..... cm	..... m^3s^{-1}	..... °C	..... mg l^{-1}	..... h
End	..... cm	..... m^3s^{-1}	..... °C	..... mg l^{-1}	..... h
Gauge ..... (downstream)					
	Water level	Discharge	Water temperatur	Turbidity	Time (CET/CEST)
Start	..... cm	..... m^3s^{-1}	..... °C	..... mg l^{-1}	..... h
End	..... cm	..... m^3s^{-1}	..... °C	..... mg l^{-1}	..... h
Miscellaneous:					

Sampler design – systematic uncertainty



(DVWK 127/1992)

$$\alpha_H = \frac{v_{mf}}{v_{mv}}$$

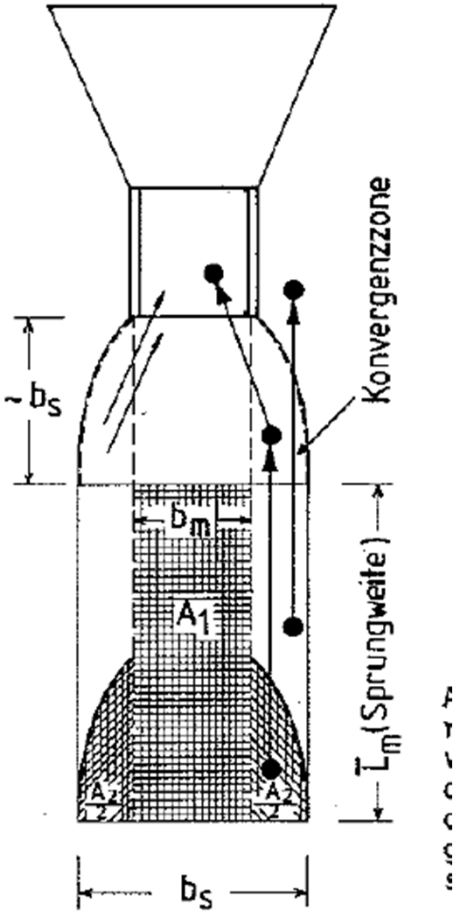
Hydraulic efficiency

$$\alpha_G = \frac{m_{G,Fänger}}{m_{G,natürlich}}$$

Trapping efficiency
- function of α_H

→ not averaged out

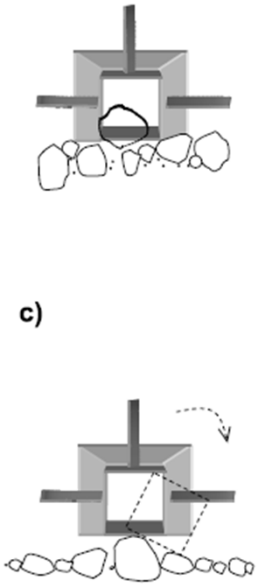
→ Need of a calibration factor / relation



(DVWK 127/1992)

Sampler operation – systematic uncertainty

- Measurement errors:
  - Clogging of the mesh
  - Imperfect seating on the river bed
  - Sinking in of the sampler
  - scooping (shoveling)
  - Particles are to small / big
  - Overfilling



(Vericat et al., 2006)

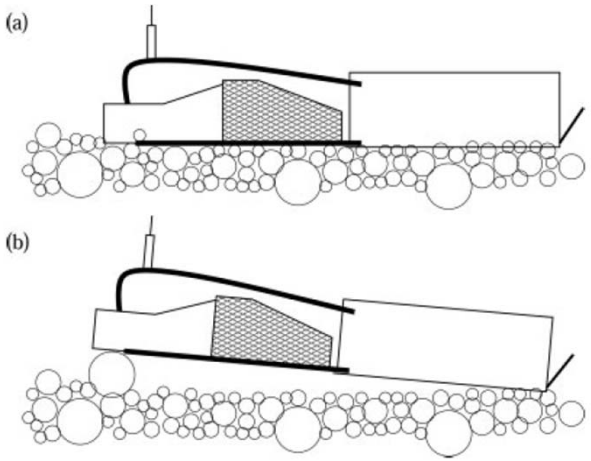


Figure 6. Position of the sampler on the river bed: (a) correct, (b) biased because of the presence of a large particle.

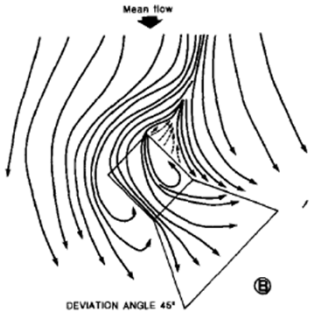
(Camenen et al., 2012)

→ **not averaged out**

→ Give proper attention during measurement

→ Ensure proper and stable position (camera)

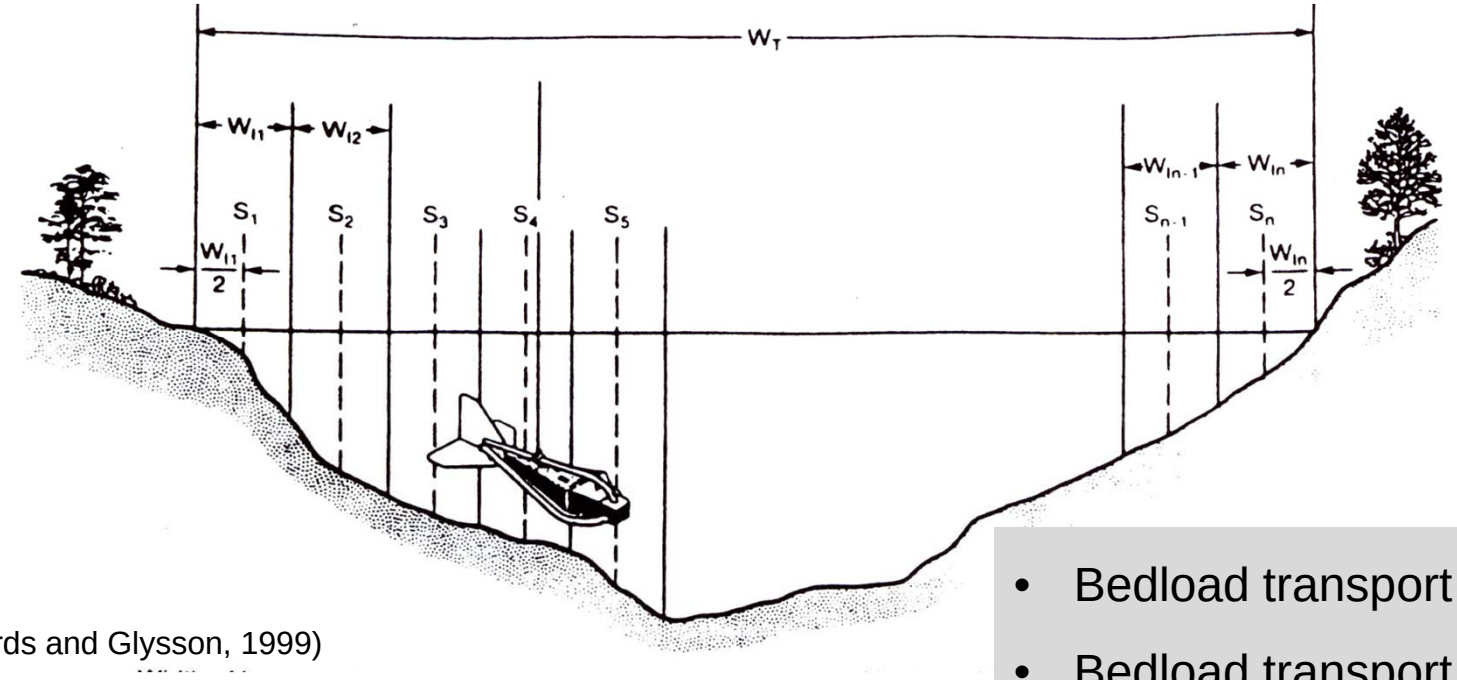
→ Reduce measurement duration



(Gaudet et al., 1994)

How to sample in a cross-section

- Divide cross-section into verticals and take repetitive samples → **at the point sampling** over the **whole section**

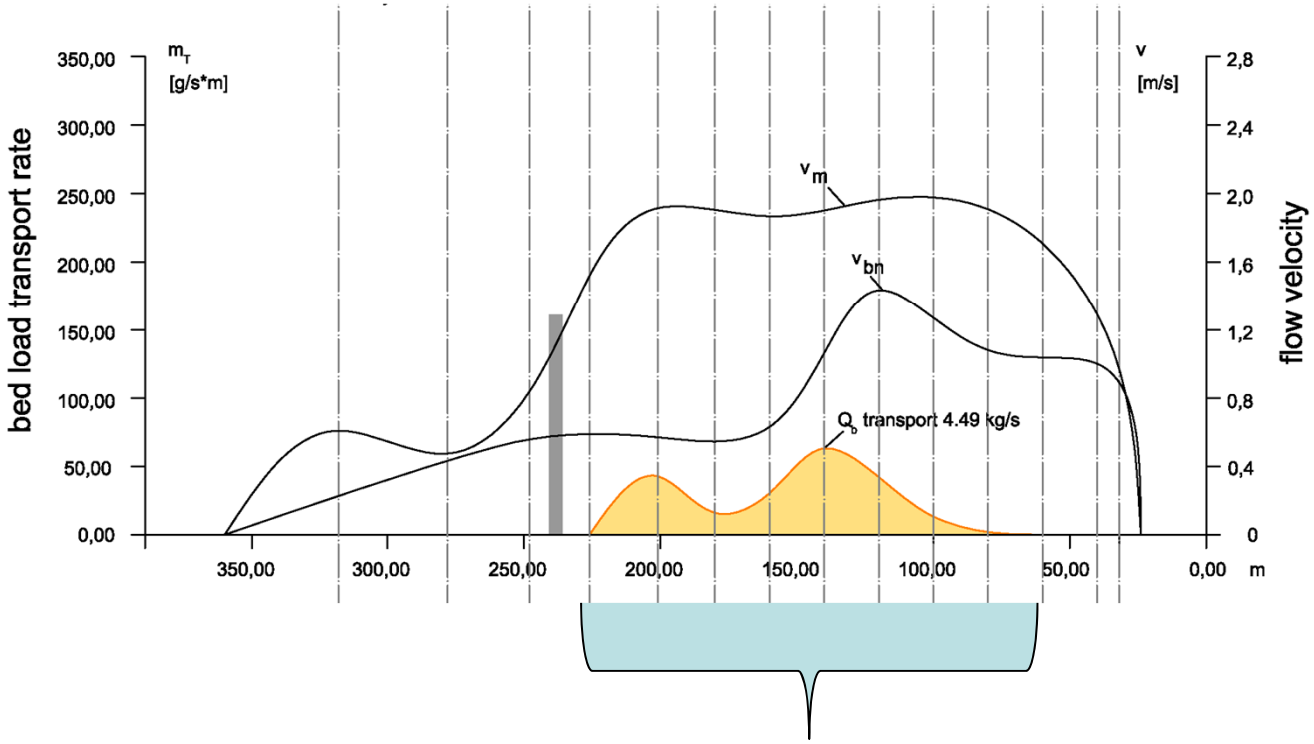


(Edwards and Glysson, 1999)

- Bedload transport rate (kg/sm)
- Bedload transport (kg/s)
- Spatial variability
- Grain size distribution

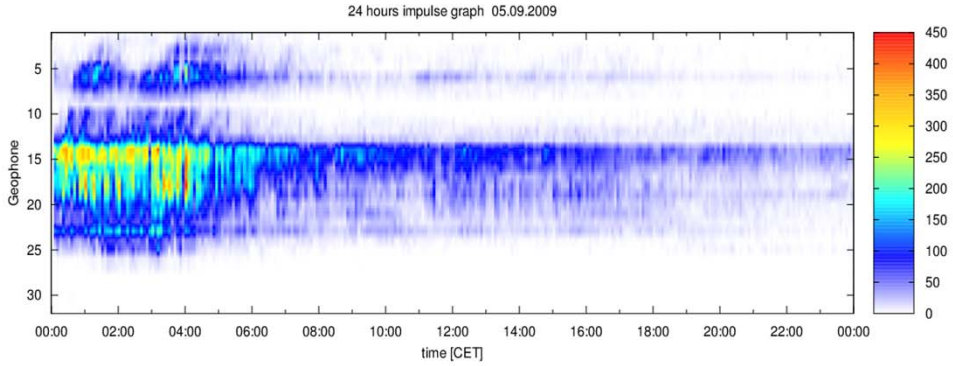
Which part to sample in a cross-section

- Need to cover the **complete active width**
- Avoid extrapolation to point with zero transport



How many verticals?

- Depends on the cross-sectional variation of bed load transport
  - Sand bedded rivers often at full width active
  - Gravel-bed rivers often a part of the width active
- Is the whole cross-section mobile?



(Iselsteg/Isel; Habersack et al., 2017b)

- Active area unknown: Need more verticals (**approx. 10 - 20**)
- Active area known: need less verticals (**approx. 5 - 7**)

(Frings and Vollmer, 2017; Edwards and Glysson, 1999; Gomez and Troutman, 1997)

How to reduce the verticals / subsections

- Try to **localize the active part** of the cross-section
- Concentrate the measurements in that part

- How to identify
  - Channel morphology
  - Acoustic methods
  - Visual
  - Hydrophone
  - Geophone

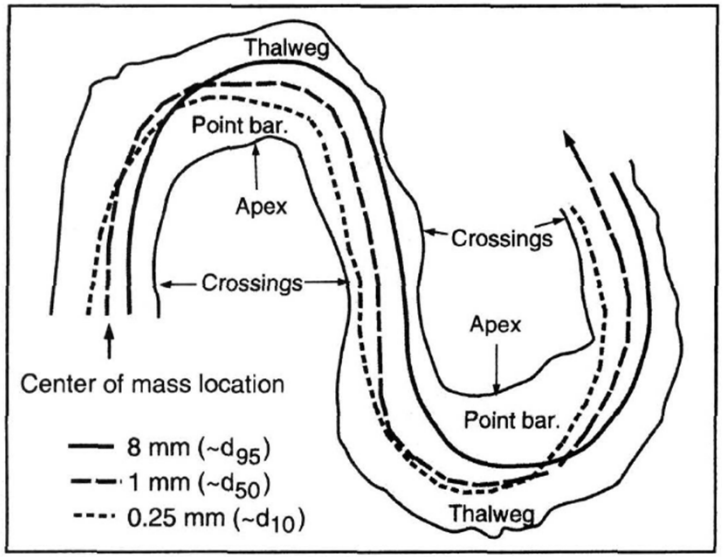


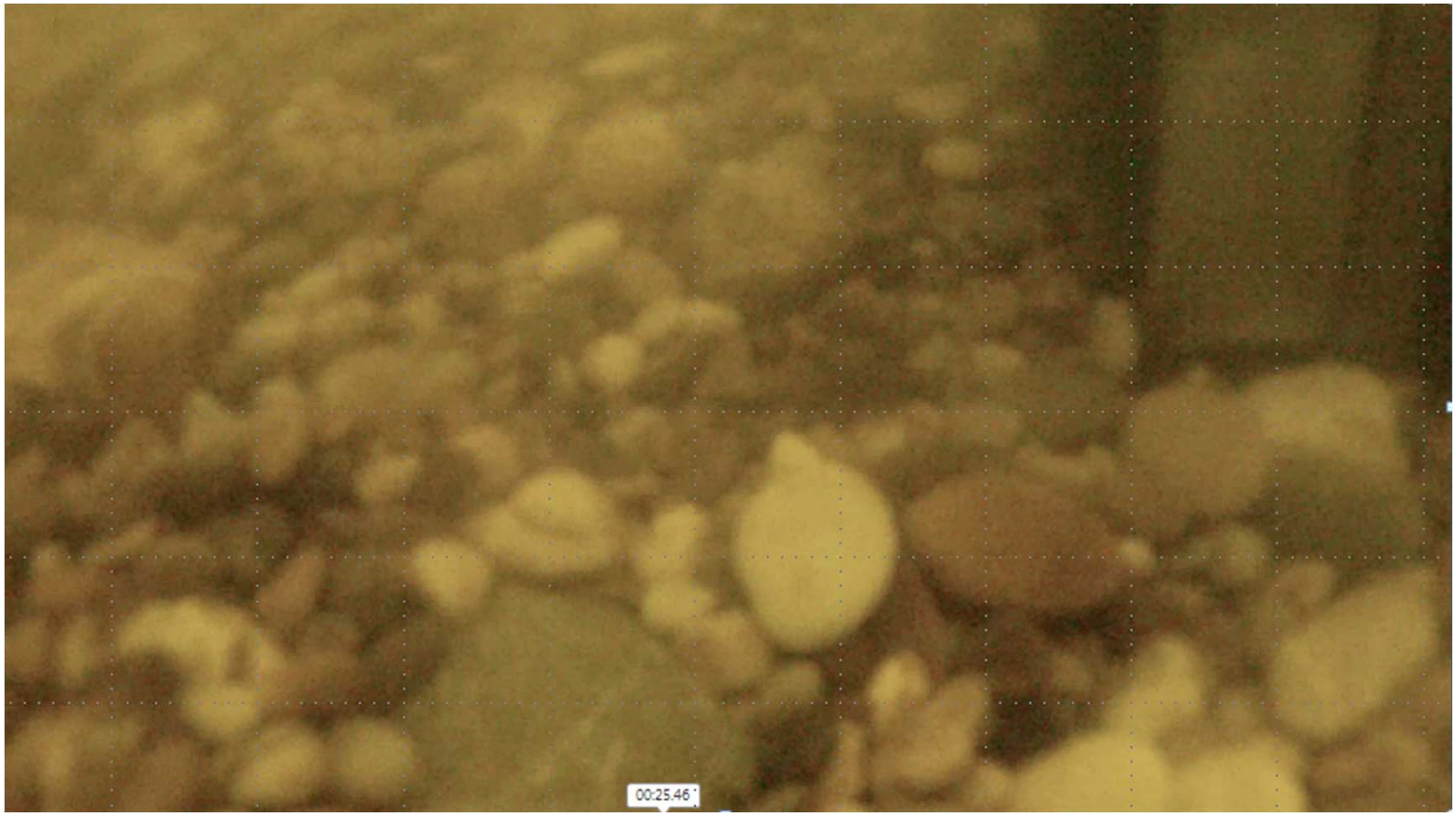
Fig. 5 Center of mass curves for three bedload size fractions

(Julien and Anthony, 2002)

→ BUT: This might change over time; transport area can shift

How many sampling points/times in one vertical?

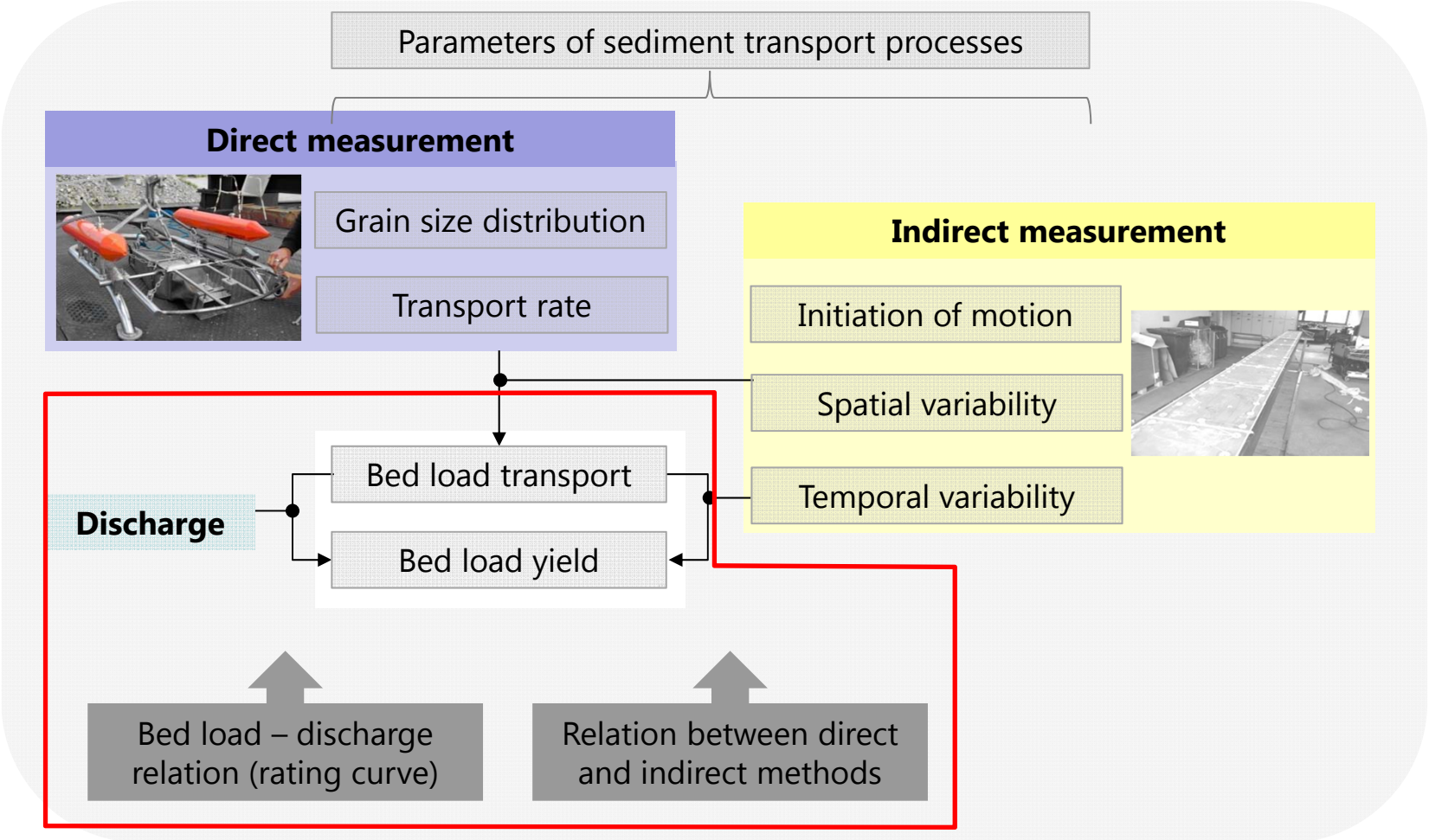
- Aim is to average out small scale natural temporal variations



(Foto: IWHW / BOKU)

- Minimum of three repetitions in one vertical

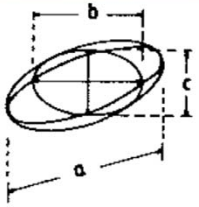
Grain sizes, transport and load



(Habersack et al. 2017b)

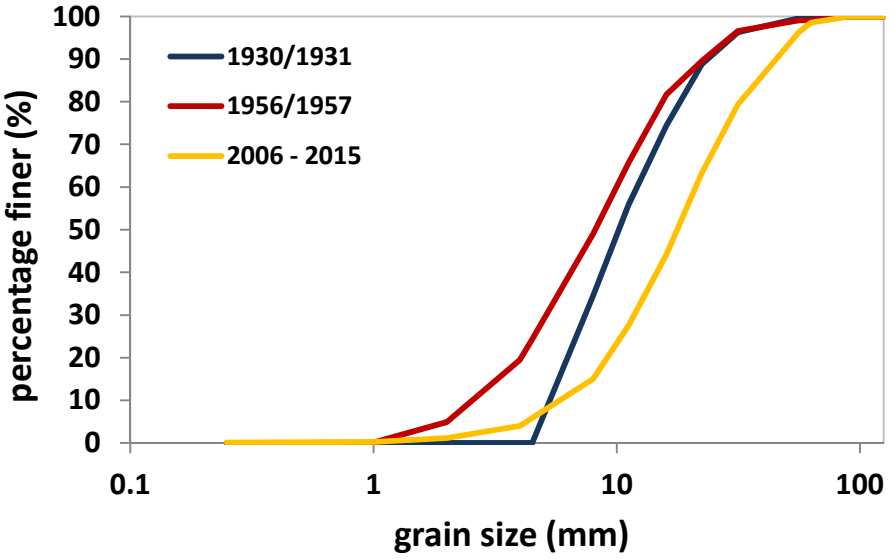
After the sampling: Analysis

- Sample:
  - Drying
  - Weighing
  - Sieving (plus size of biggest stone b-axis)
  - Grain size distribution plus char. grain sizes

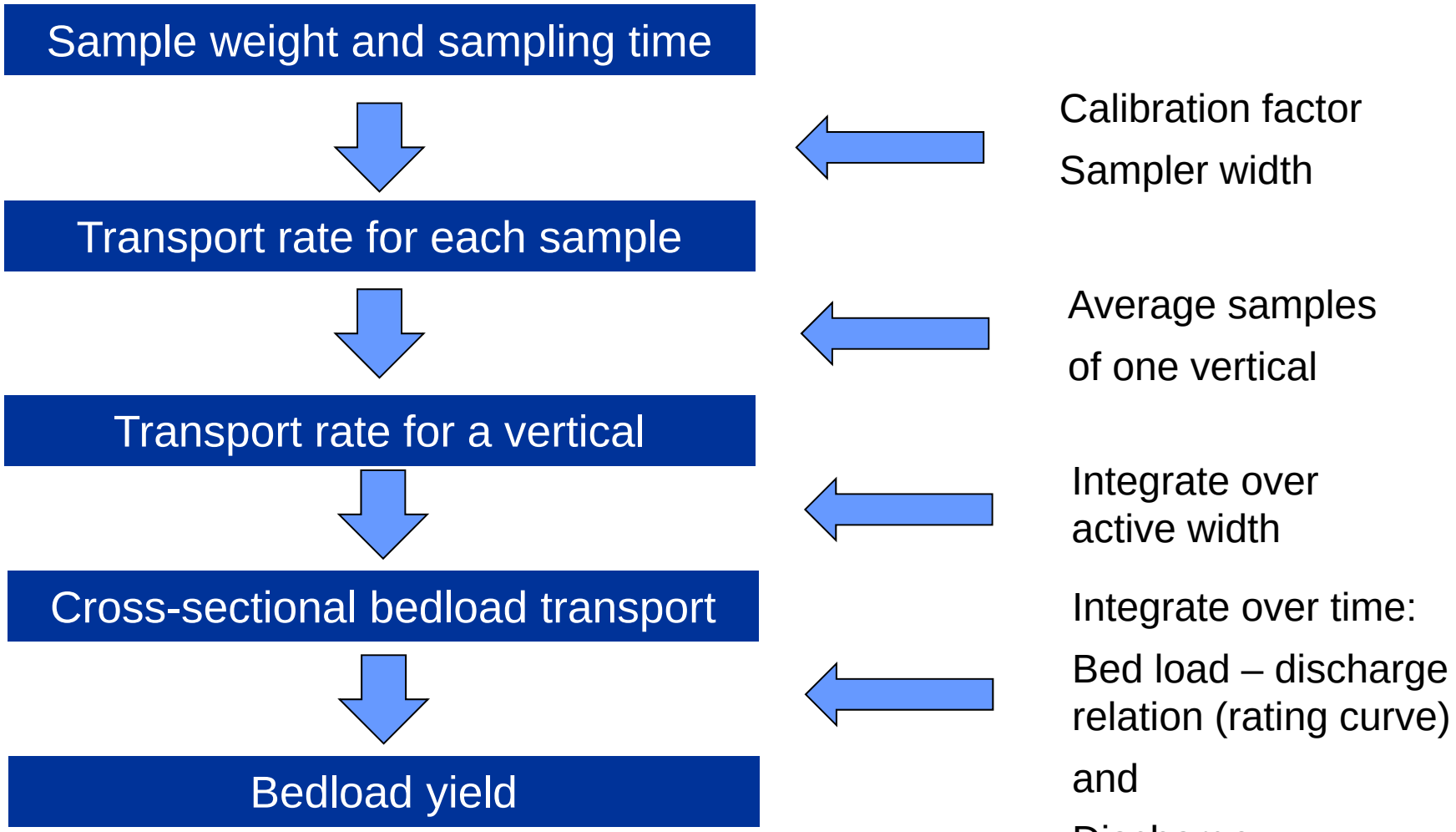


(DVWK 127/1992)

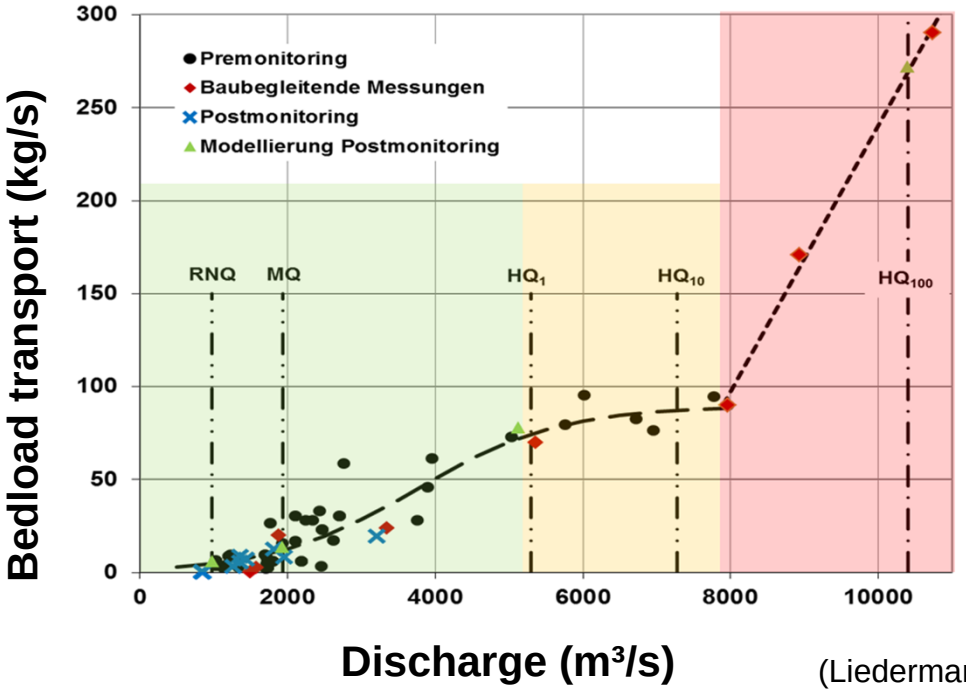
- Characterize transported material
- Assess changes
- Input for transport formulae
- Input and calibration for sediment transport models

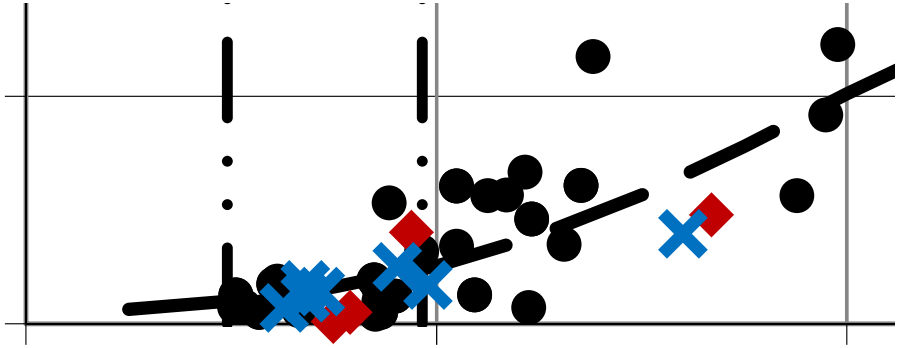


Calculation of transport and load



Calculation of transport and yield: Rating Curve





In bank flow

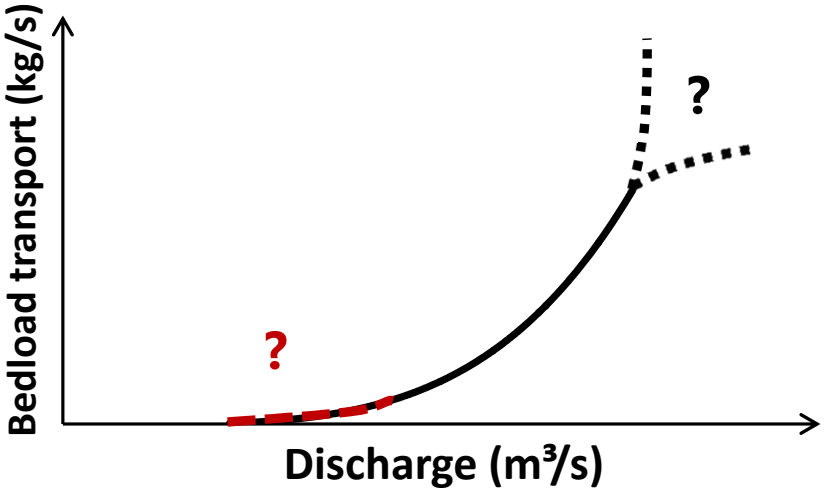
Flooding of inundation area

Inundation area flooded

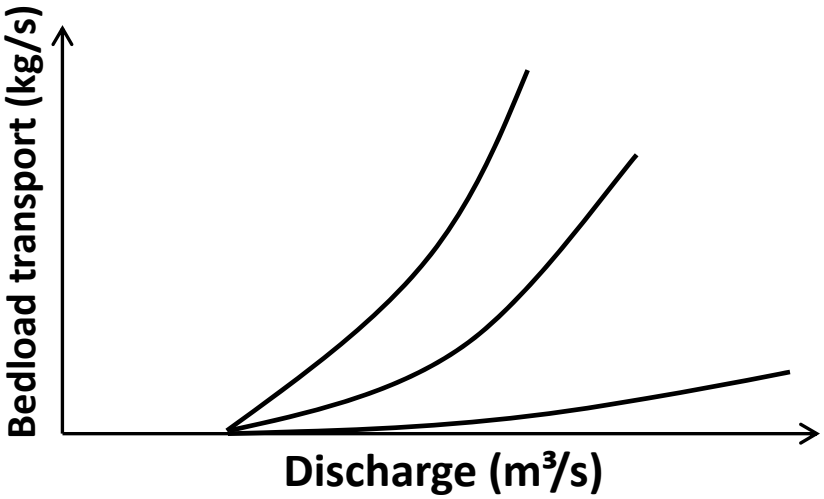
(Liedermann et al. 2017)

Calculation of transport and yield

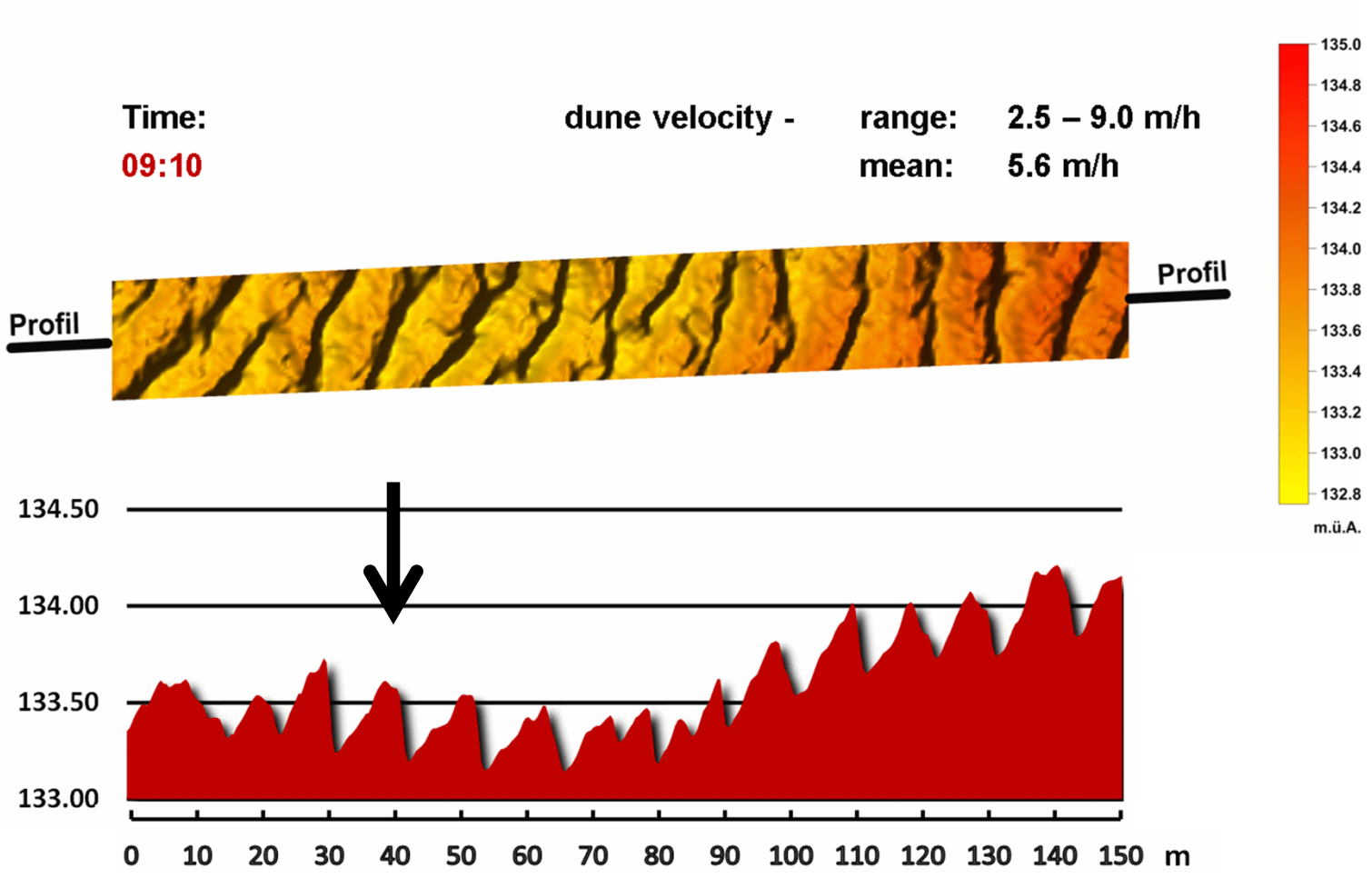
- Sample the whole discharge range
  - Low flow conditions
  - High flow conditions

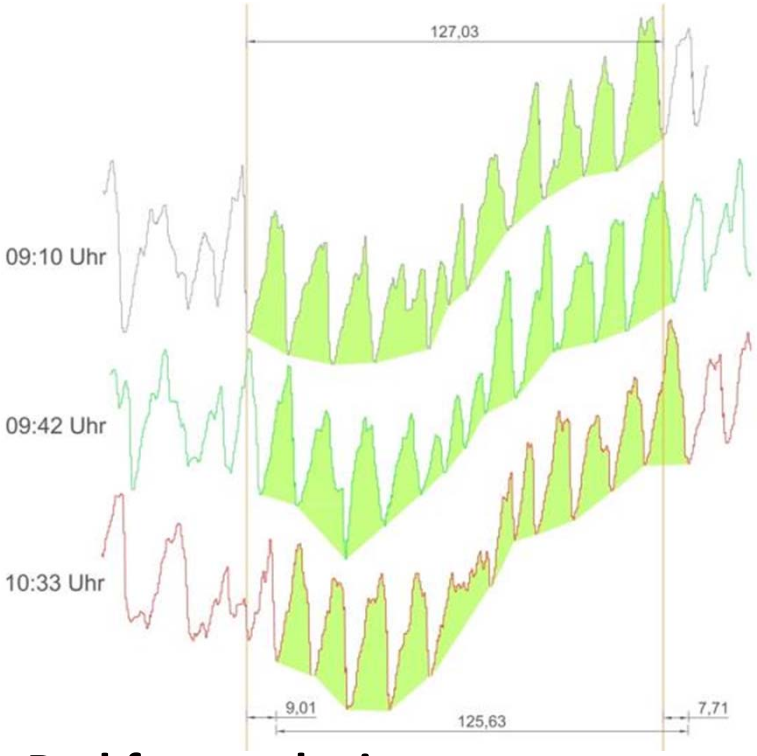


- Assess if bedload-discharge relation is changing



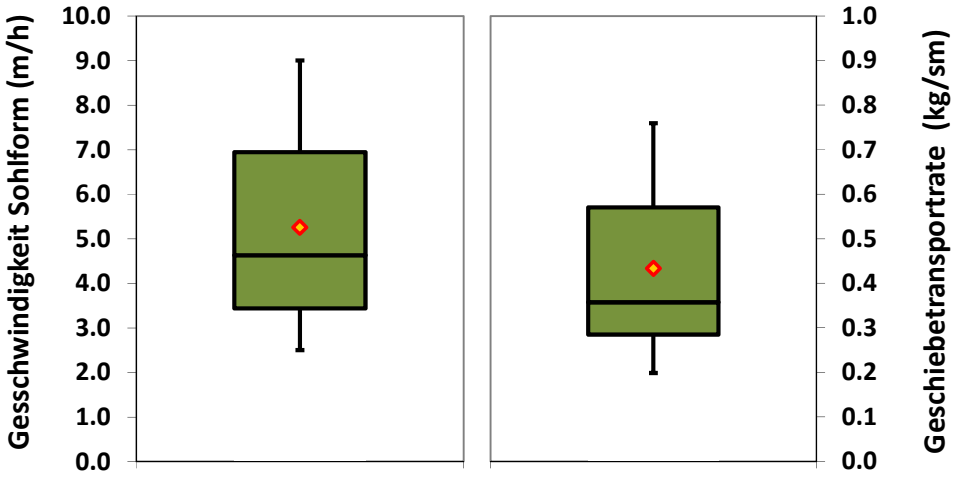
Surrogate method: Dune tracking

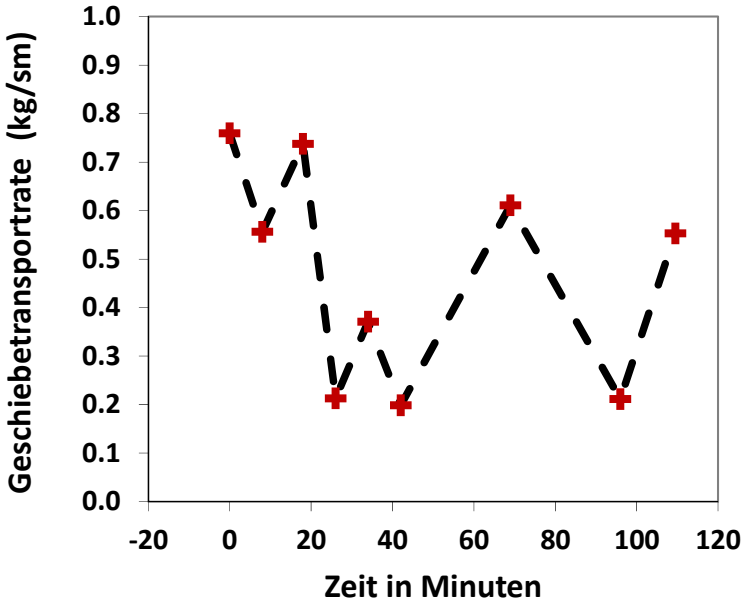




- **Bed form velocity:**
  2.5 m/h - 9.0 m/h
  average 5.6 m/h
- **Bed load transport rate:**
  0.20 kg/s m - 0.76 kg/s m
  average 0.43 kg/s m

(Liedermann et al., 2014)

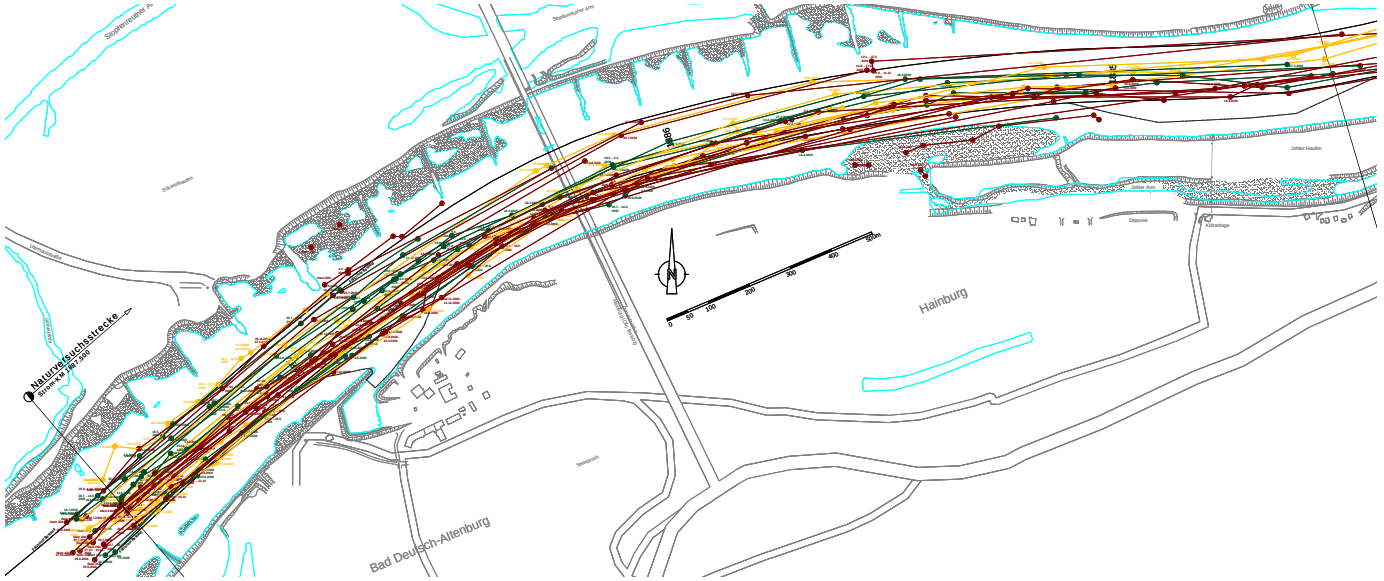


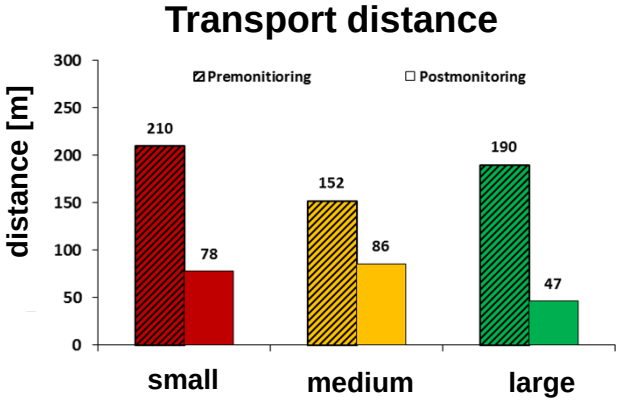


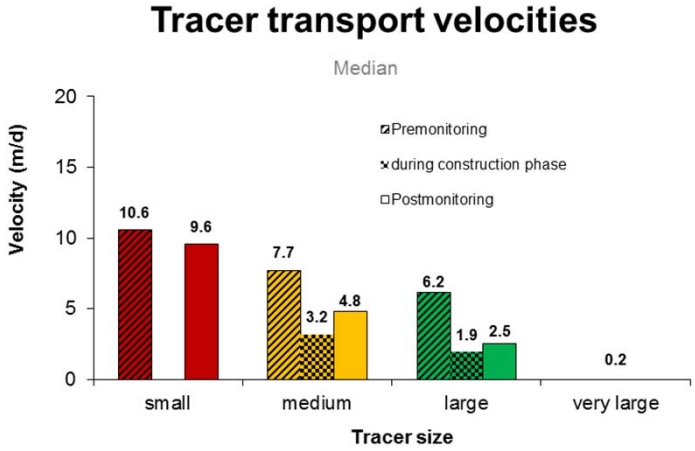
(Gmeiner et al., 2016; modified from Liedermann et al., 2014)

Surrogate method: active tracers

(Liedermann et al., 2013)







(Habersack et al., 2016)

Recommendations

- Capture the temporal and spatial variability in the measurements
- Suitability of bedload sampler instruments must be ensured
- Define hydraulic and sampling efficiency
- Cover full range of discharges (from initiation of motion to floods)
- Establishment of rating curves, i.e. Q-Q_{BL}, τ-Q_{BL} relationships
- Surrogate techniques (e.g. acoustic based, sonar, tracer) can contribute → integrated approach
- Define standard bedload monitoring approach for the gravel bed and sand bed reaches of the Danube (see comparative/joint measurements)
- Integrate bedload monitoring data into National Hydrographic Data Bases and guarantee quality and access for practical application to improve planning of engineering measures

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Thank you for your attention!

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