

Navigational experiments to verify a calculational approach for **ship induced bed load**



WDK, 13.10.-25.10.02

Department Hydraulic Engineering in Inland Areas
Section W4 - Interaction ship/waterway, field investigations

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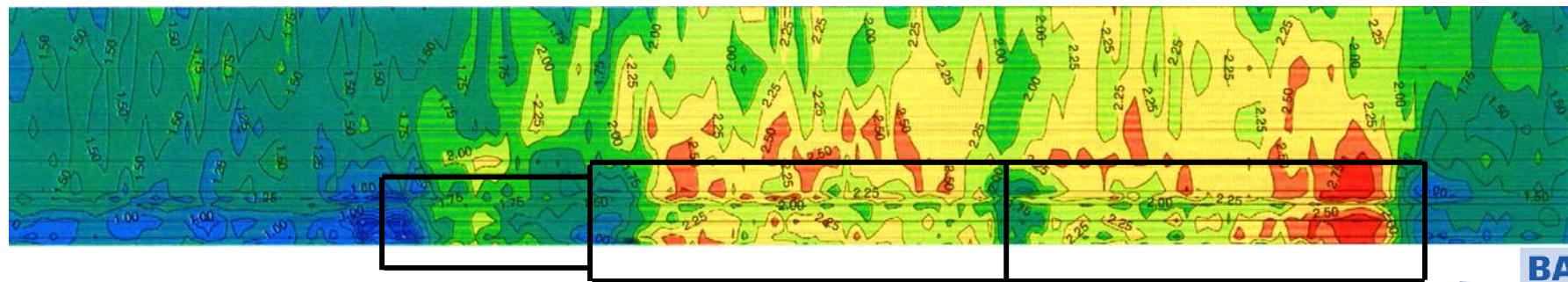
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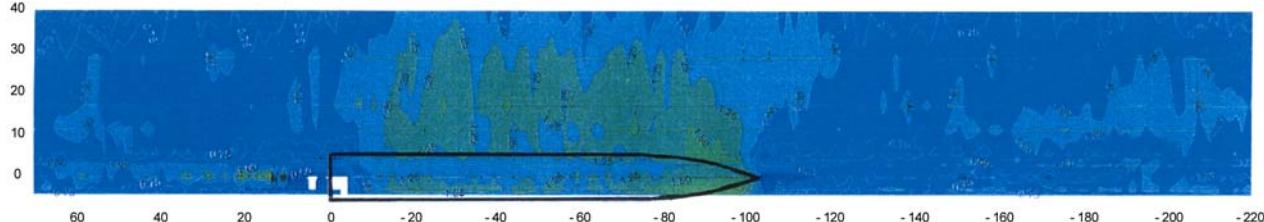
Ship induced bed load - classification of impact components

		ship going upstream				downstream
impact components		return current	propeller jet	wake	sucking in of stones	wake
intensity		increased	strong	strong	high	strong
duration		long	short	average	very short	average
width		ship's length	propeller diameter	beam	vortex diameter	beam
influence on bed load	gravel bed	large	average	average	small	average
	coarse gravel	average	large	large	average	large



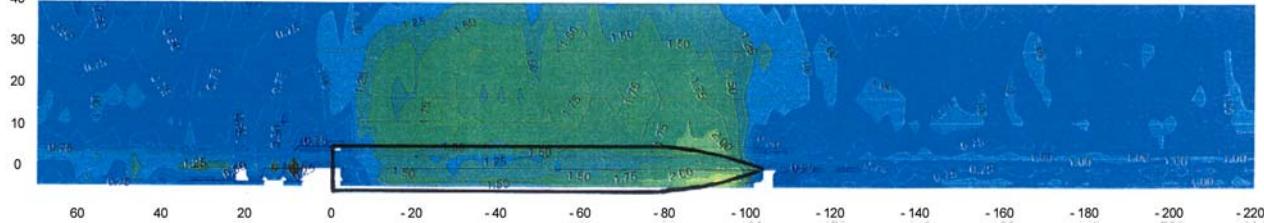
Ship induced bed load - return current field of ships going upstream

large motor vessel, $V_{SüG} = 5,5 \text{ km/h}$



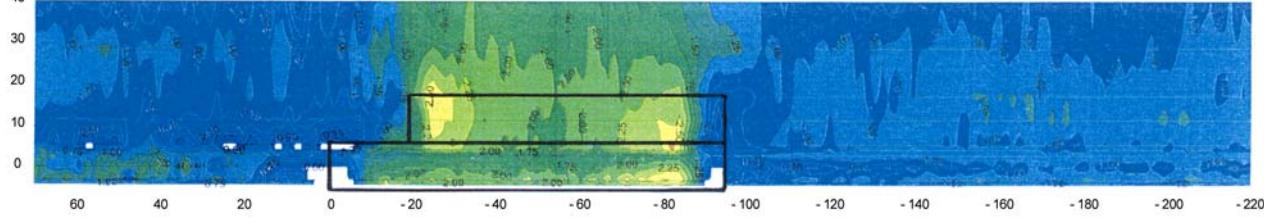
$$\Delta V_{Str} \approx 0,25 \text{ m/s}$$

large motor vessel, $V_{SüG} = 8,1 \text{ km/h}$



$$\Delta V_{Str} \approx 0,50 \text{ m/s}$$

large motor vessel with a barge, coupled side by side, $V_{SüG} = 5,6 \text{ km/h}$



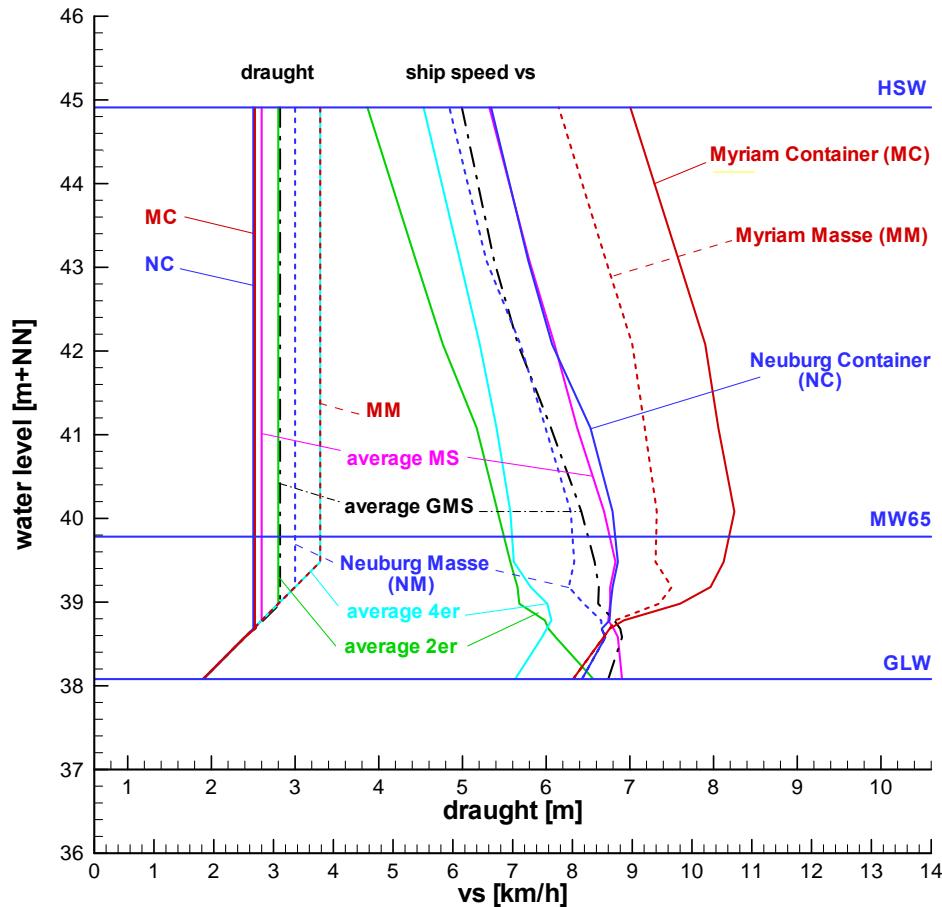
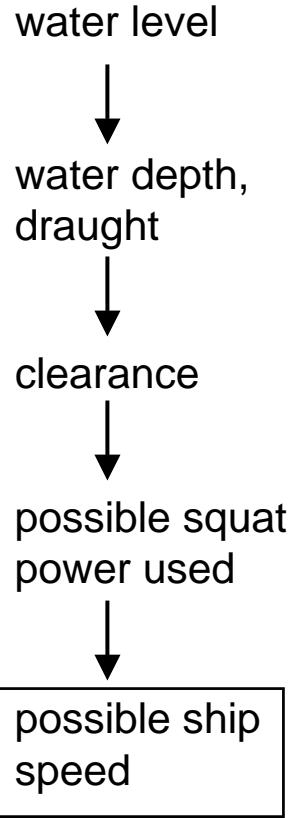
$$\Delta V_{Str} \approx 0,75 \text{ m/s}$$

results of model tests performed in the Institute for Inland Waterways Ship Construction (Duisburg, Germany) Cross section 95x2.8, flow velocity 1.2 m/s, vessel going upstream : 104 x 11.4 x 1.8

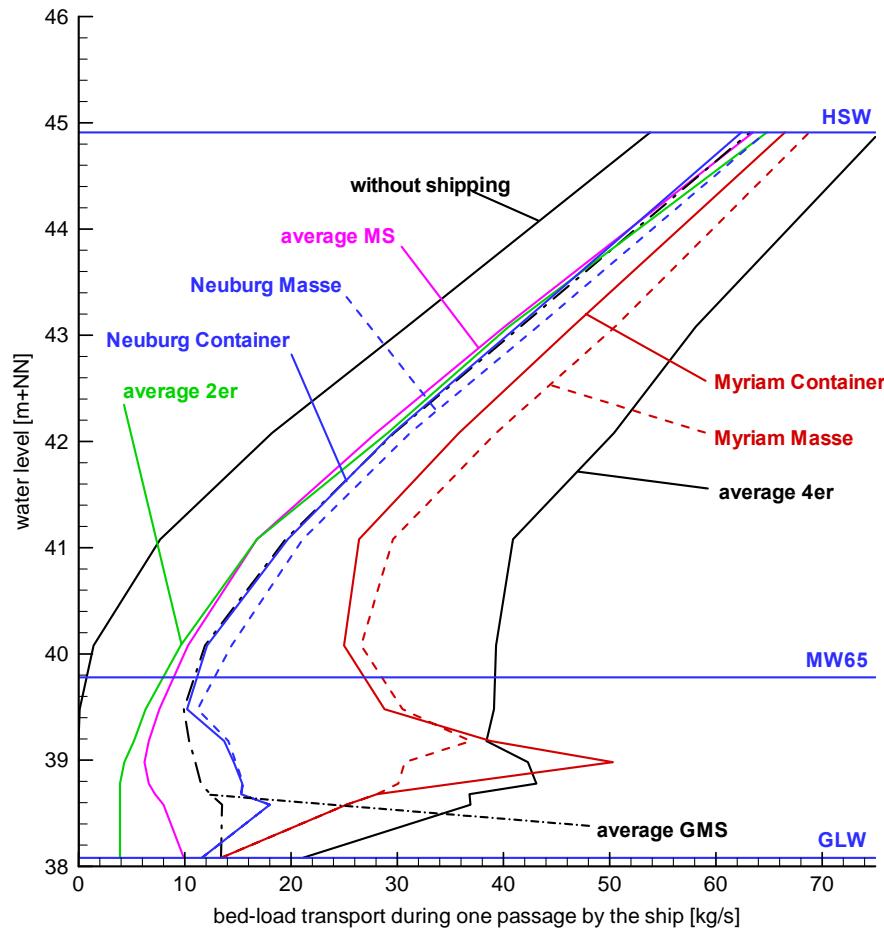
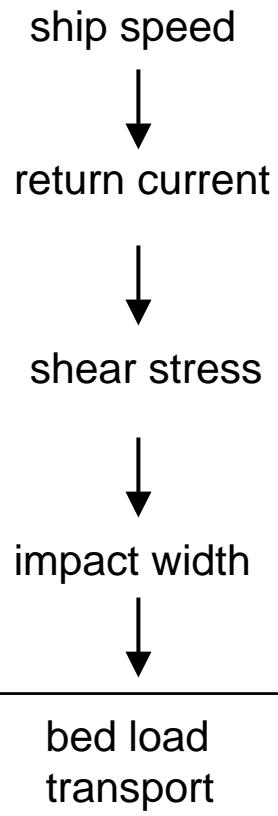


Ship induced bed load - average draughts and ships' speeds

cross section of the Lower Rhine river (Westhofen) near Cologne



Ship induced bed load - bed load during ships' pass



Ship induced bed load - summary for Westhofen/Rhine

bed load transport
during one ship
pass

↓
impact time

↓
number of ships
going upstream

↓
probability of
water level

↓
total bed load
transport in one year

↓
comparison with those of the
natural flow (~160000 t/a)

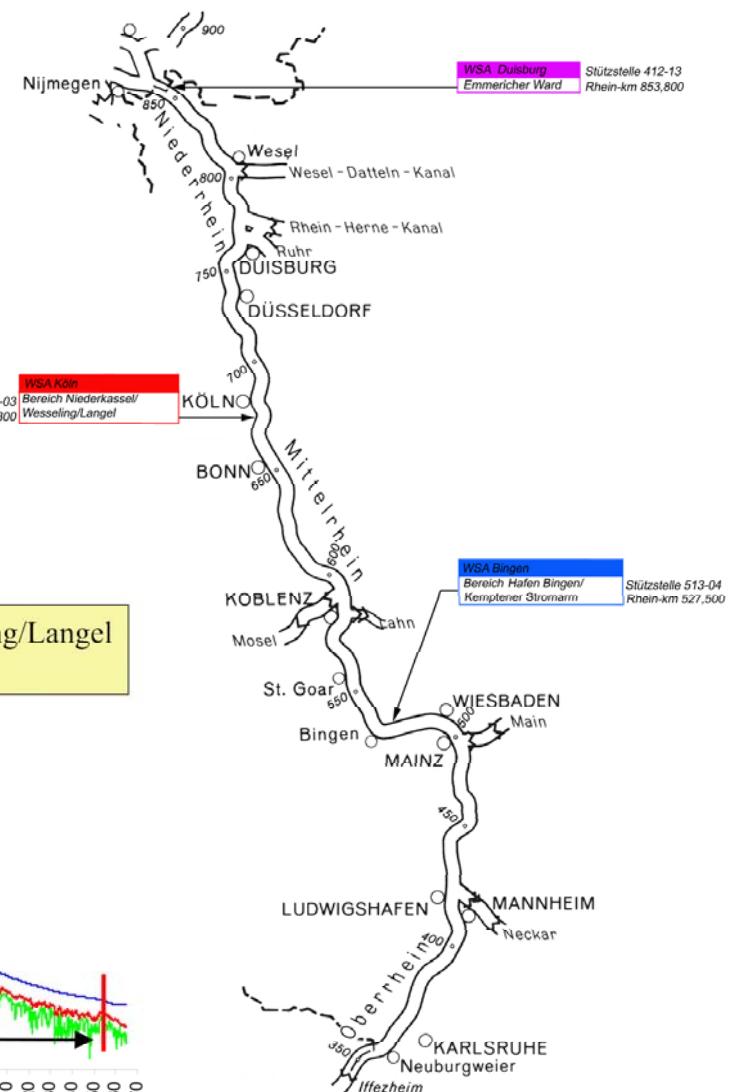
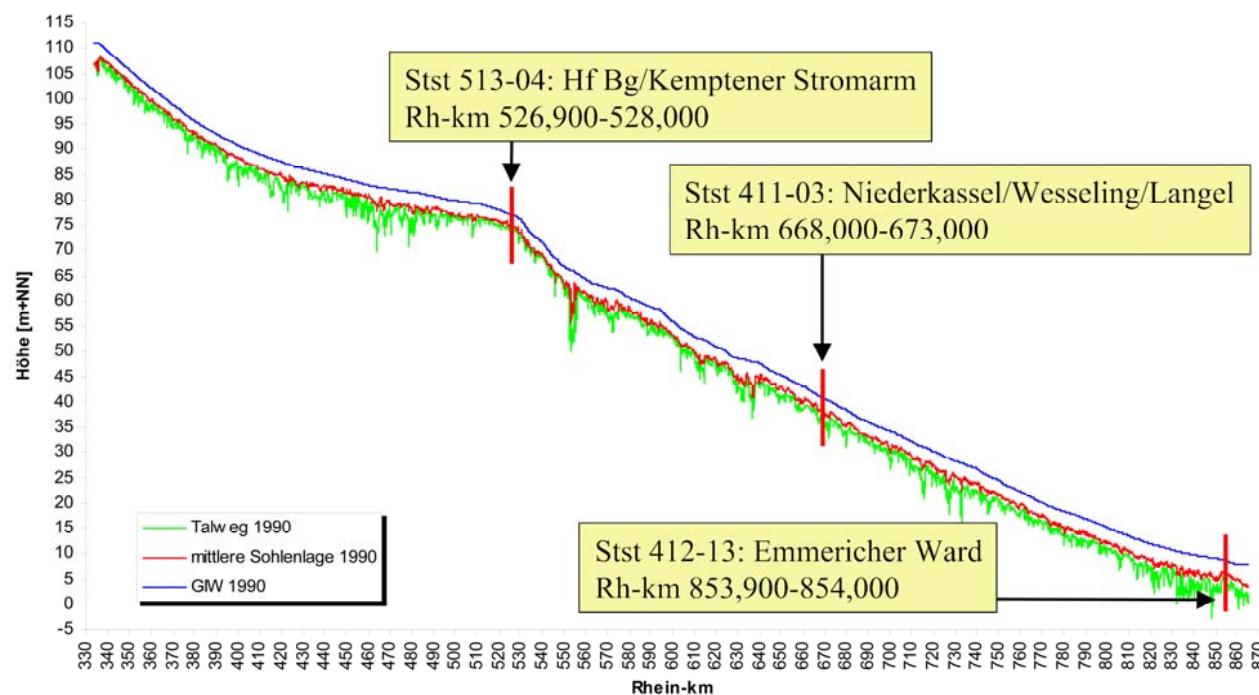
increase in bed load capacity
due to the whole fleet in 2010
(69×10^6 t/a cargo going
upstream) ~ 10 %

increase due to modern and
highly powered ships in 2010
(5×10^6 t/a $\hat{=}$ 8 % of 69×10^6
t/a) ~ 1 %

increase nearly proportional to
the rate of freight

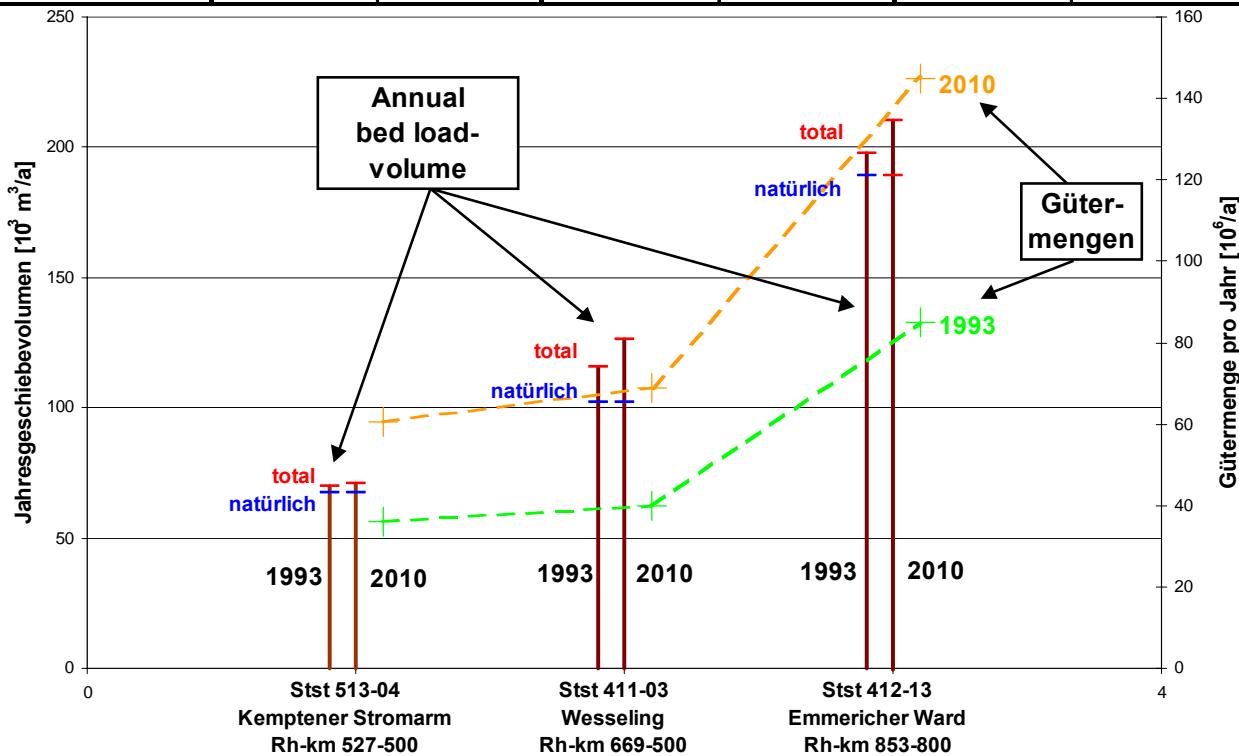


Further investigated characteristic cross sections, Rhine river



Calculations

Annual bed load transport volume	Kemptener Stromarm/Rheingau		Wesseling		Emmericher Ward				
	Stst 513-04 Rh-km 527,500	1993 [%]	2010 [%]	Stst 411-03 Rh-km 669,300	1993 [%]	2010 [%]	Stst 412-13 Rh-km 853,800	1993 [%]	2010 [%]
<i>total</i>	100	100	100	100	100	100	100	100	100
<i>flow field</i>	96,5	94,7	88,3	80,8	95,6	89,9			
<i>shipping</i>	3,5	5,3	11,7	19,2	4,6	11,2			
d ₅₀ [mm]	0,8		6,0		2,0				



Results

Percentage of ship induced bed load of total bed load

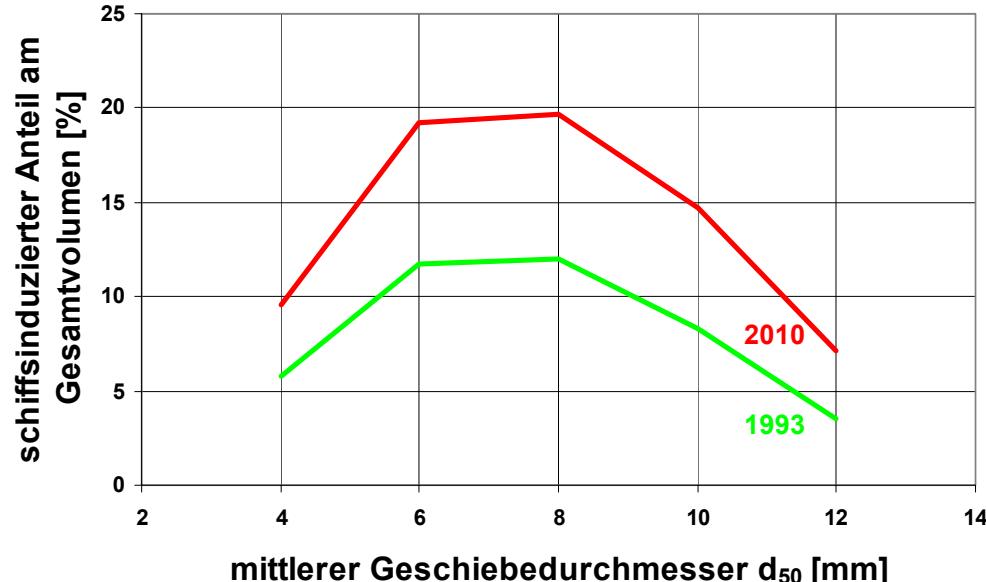


Sensitivity tests

Calculations

*Percentage of ship induced bed load of total bed load -
cross section Wesseling (Rh-km 669,300)*

Variation of d_{50}



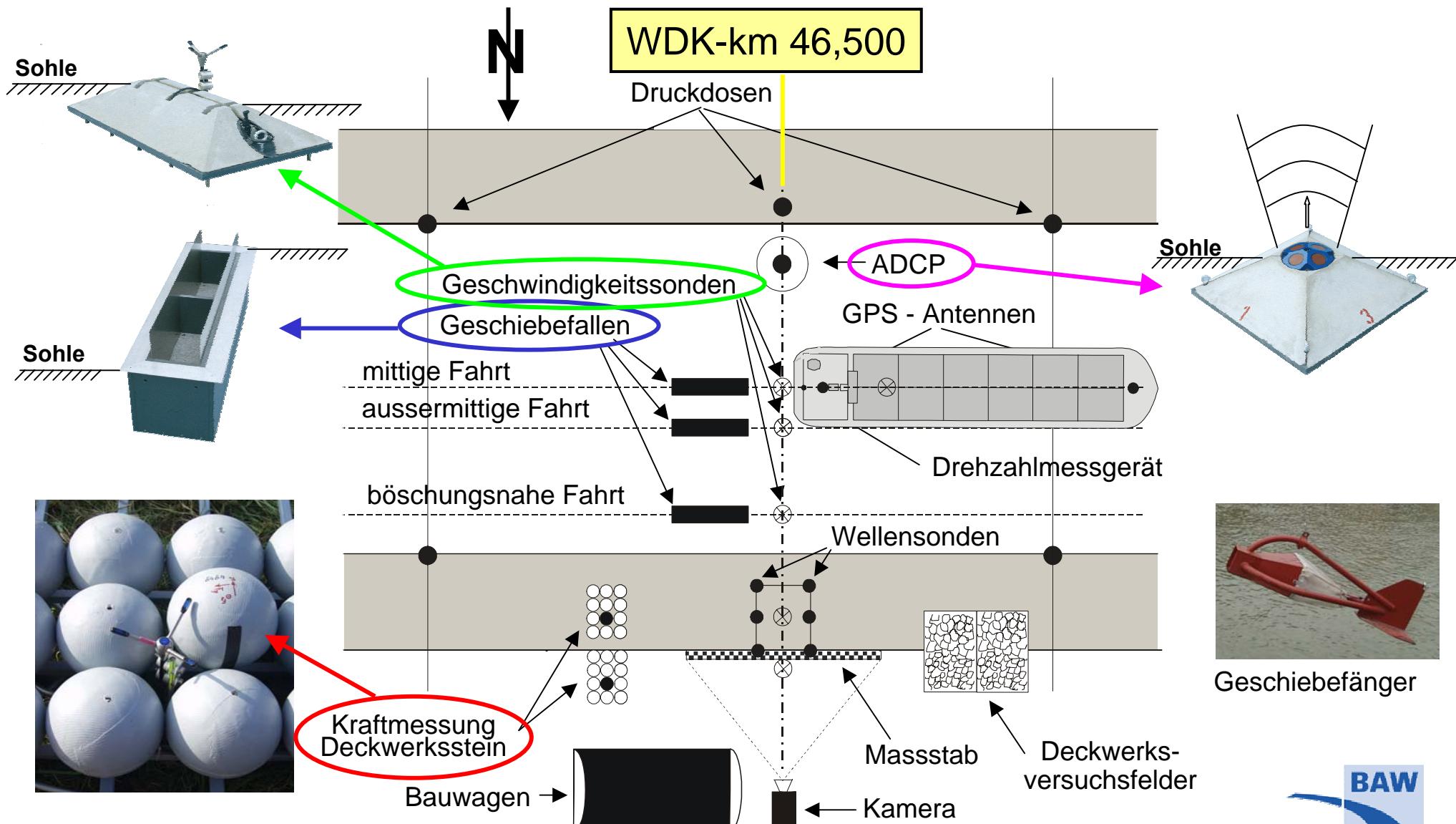
Variation of the fleet

Grundfall	Variante V1: Einzelfahrer Schubverbände	V2: E 1500 SV 2000 SV 2000 +	V3: E 1500 SV 1500 100%
19,2 %			
		19,3 %	17,9 %
			17,8 %



Gauging methods

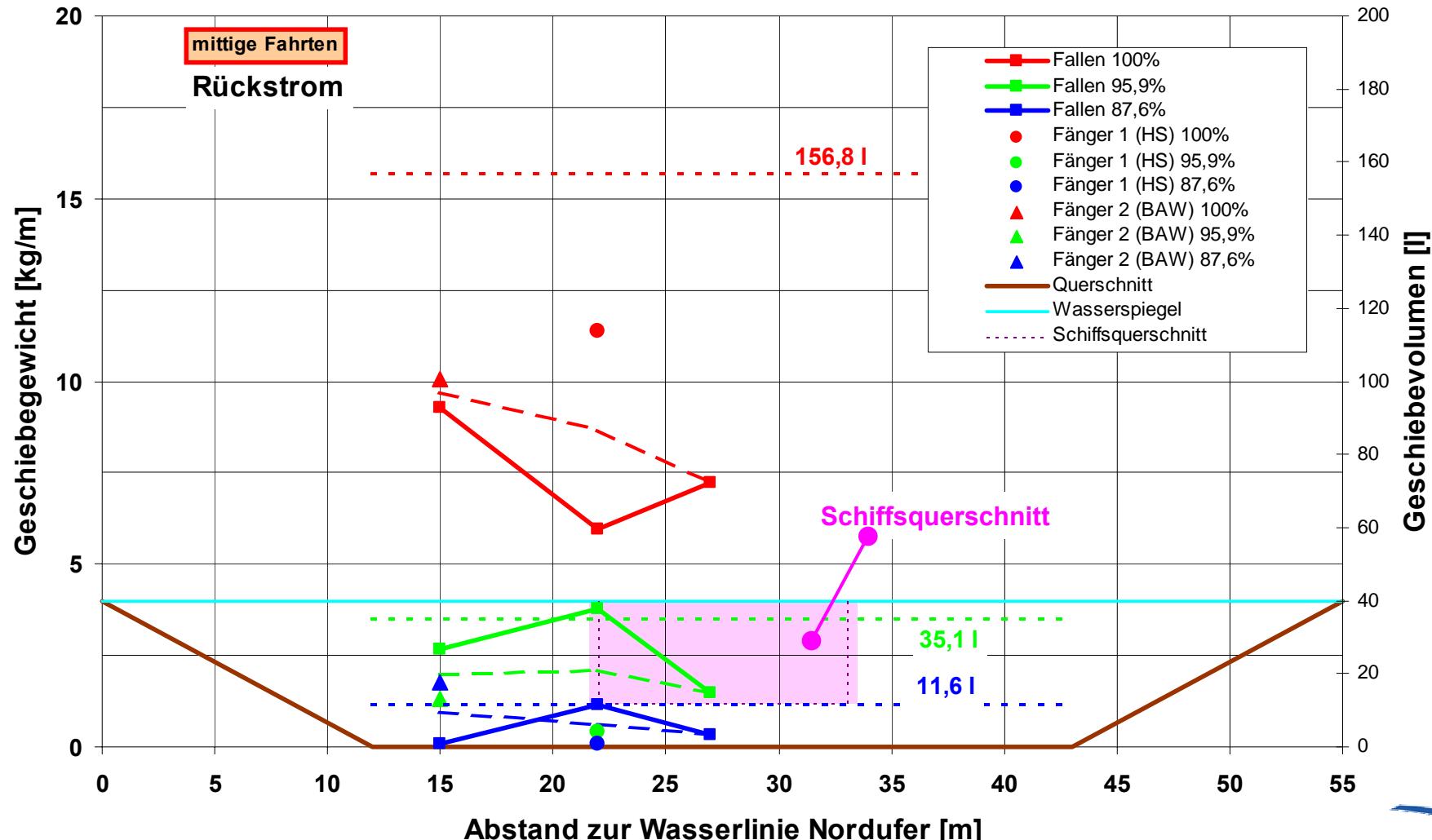
Site investigations



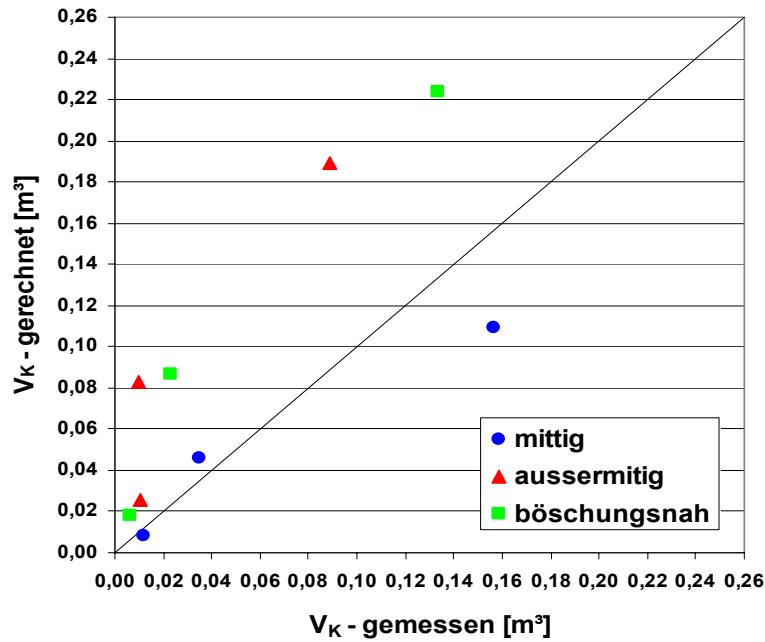
Bed load transport volume

Site investigations

Measurements with samplers and traps, averaged over 5 drives



*Calculated versus measured (abszissa)
bed load transport volume V_K*



Conclusions for the Rhine river

The ship induced bed load is approximately one order of magnitude smaller than the total bed load

The ship induced bed load is nearly linear proportional to the annual tonnage

The percentage of the ship induced bed load of the total load is very much dependent on the bed grain size

The 1D-apoach used fits the measurements satisfactory

