Fachhochschule Münster University of Applied Sciences

IWARU
INSTITUTE FOR WATER·RESOURCES·ENVIRONMENT

Comparison of Flow and Sedimentation Pattern for three Designs of Storm Water Tanks by Numerical Modelling

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Agenda

- Objectives and goals
- Storm water tanks
- Requirements in Germany
- Compared storm water tanks
  - Dimensions
  - Hydraulic and particular conditions
- Results
  - Velocity distribution
  - Particle distribution
  - Sedimentation efficiency
- Conclusions

Objectives and goals

Pollution of surface waters:

- Particles in urban runoff
- Heavy metals mostly bounded at particles < 60 µm (0.06 mm)

Treatment by sedimentation tanks

- about 30,000 storm water tanks in Germany
- investment volume 30 billion €
- efficiencies about and less than 30 %

Aim of investigation

- optimize tank design
- flow pattern
- sedimentation efficiency

} different dimensions of tanks

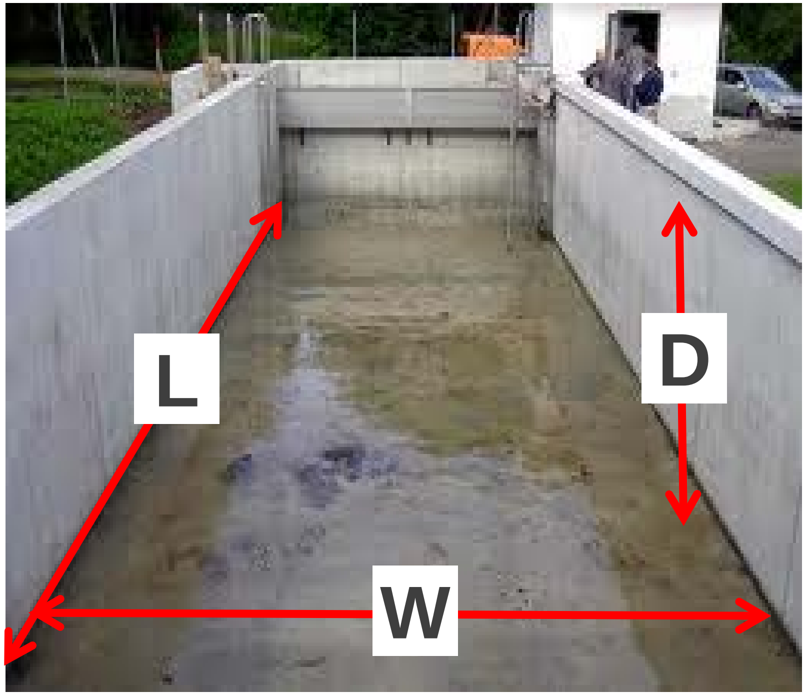
Storm water tanks

- Sedimentation of particular loads in storm water
- Application in combined- and **separate sewer system**
  - combined sewer: e.g. combined sewer overflow tank
  - **separate system:** e.g. **storm water sedimentation tank**

Relations

10 < **L : D** < 15
3 < **L : W** < 4,5
2 < **W : D** < 4

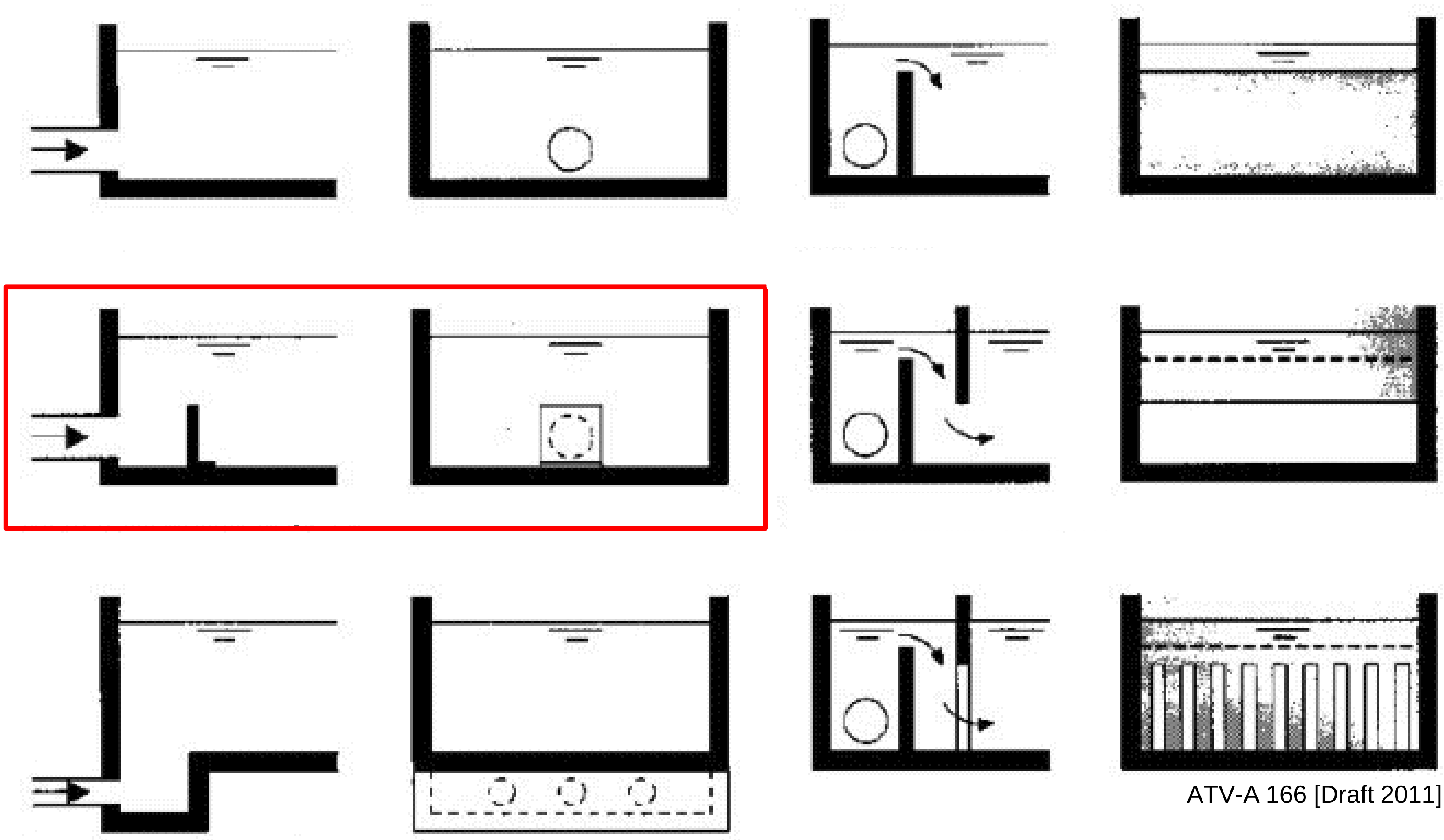
(according to German guidelines)



Requirements in Germany

Design of storm water sedimentation tanks

inlet requirements



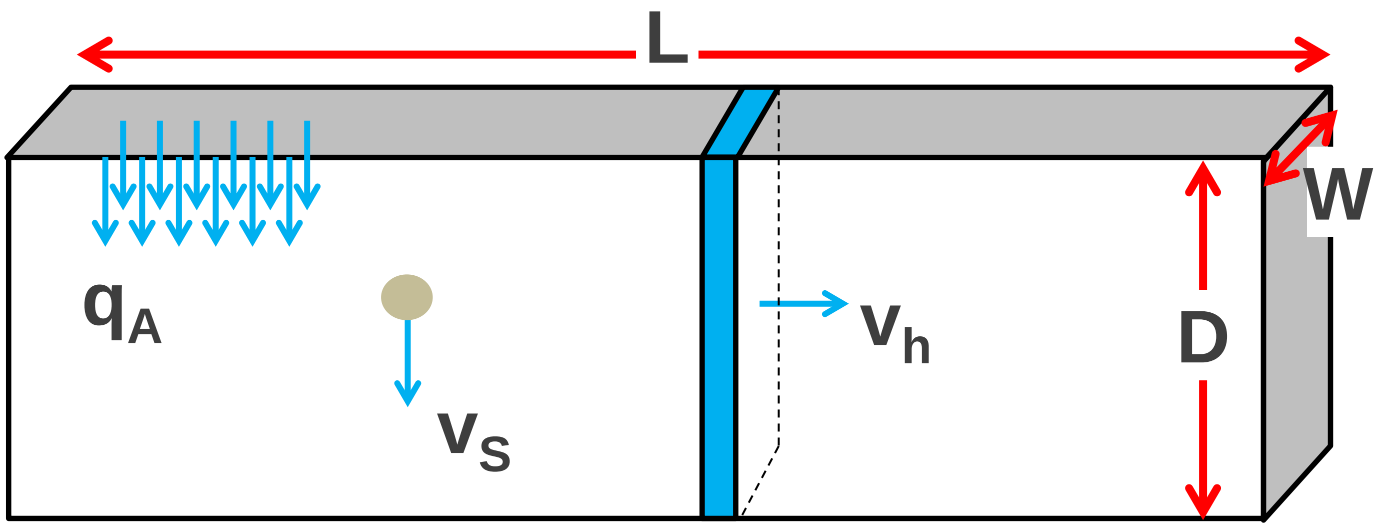
ATV-A 166 [Draft 2011]

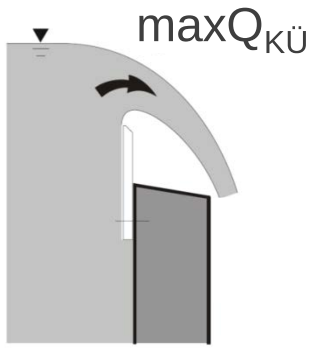
Requirements in Germany

Design of storm water sedimentation tanks

hydraulic requirements

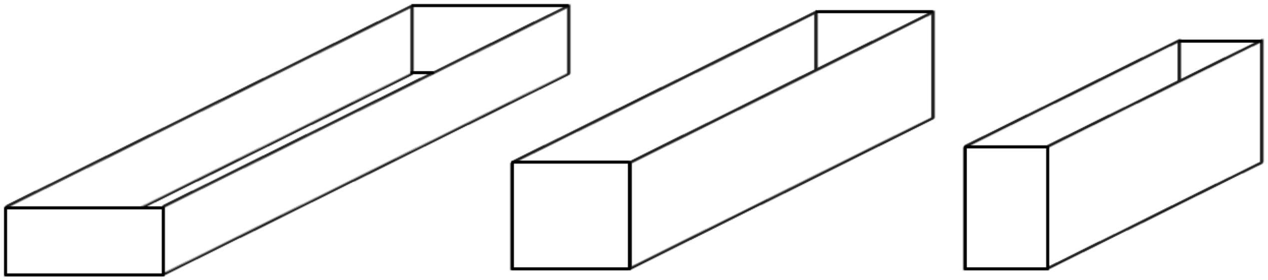
mean horizontal velocity (tank)	surface flow rate (mean vertical velocity)	settling velocity (STOKES)
$v_h = \frac{maxQ_{KÜ}}{W*D}$ (m/s)	$q_A = \frac{maxQ_{KÜ}*3.600}{W*L}$ (m/h)	$v_S = \frac{1}{18}\rho' g d \frac{d}{\nu}$ (m/h)





Compared storm water sedimentation tanks

Tank relations

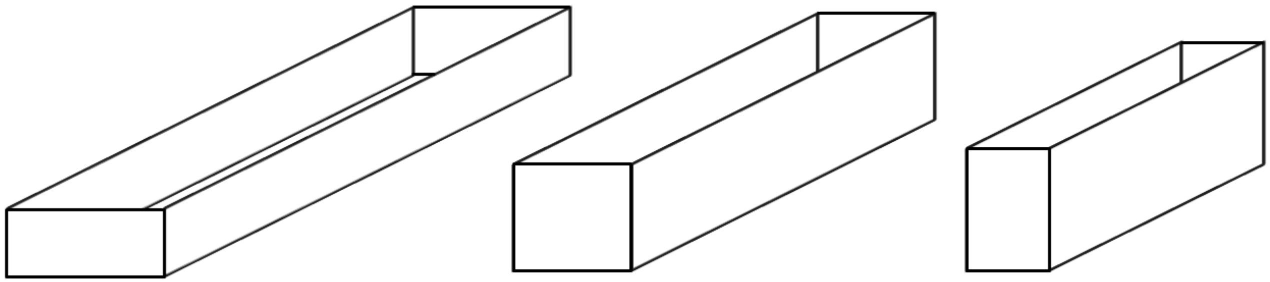


	Tank 1	Tank 2	Tank 3
Length L (m)	31,25	29,74	28,23
Width W (m)	8,00	7,14	6,27
Depth D (m)	2,00	2,36	2,82
L/D	15,6	12,6	10,0
L/W	3,9	4,2	4,5
W/D	4,0	3,0	2,2

Volume of each Tank: 500 m³

Compared storm water sedimentation tanks

Hydraulic and particular conditions



Hydraulic boundary conditions

	Tank 1			Tank 2			Tank 3		
q_A (m/h)	2	6	10	2	6	10	2	6	10
v_h (m/s)	0.01	0.03	0.04	0.01	0.02	0.04	0.01	0.02	0.03

Properties of particles

Specific Density (kg/m^3)	1020				1460				2650			
v_s (m/h)	1	2.3	5	10	1	2.3	5	10	1	2.3	5	10
Diameter (µm)	181	275	405	573	38	58	85	120	20	30	45	64

CFD Modell Setup

Simulations by using FLUENT 13.0 CFD

- **boundary conditions:**
  - **inlet:** mass flow inlet
  - **outlet:** pressure outlet
  - **Wall-treatment:** no slip and standard wall functions
  - **roughness of the wall:** 5 mm
  - **Water surface:** symmetry plain
- **Solution method**: steady *(const. inflow)*
- **Turbulence model:** k-ε RNG modell
- **Sedimentation of solids:** uncoupled DPM *(Discrete Phase Model)*
- **Mesh size:** 600,000 cells (after a mesh study)

CFD Modell Setup

Wall-Treatment bottom of the tank

Limitations

- **Resuspension based on the variability of the flow pattern cannot be modelled**
- **Shields does not apply for very small particles, since other effects like cohesion occur**

Shields relationship

Vanoni [1975]

τ_{crit} critical shear stress [Pa]
τ_0^* dimensionless shear stress
β parameter

$$\tau_{krit} = \tau_0^* \cdot (\rho_p - \rho) \cdot g \cdot d$$

$$\tau_0^* = 0{,}22 \cdot \beta + 0{,}06 \cdot 10^{-7{,}7 \cdot \beta}$$

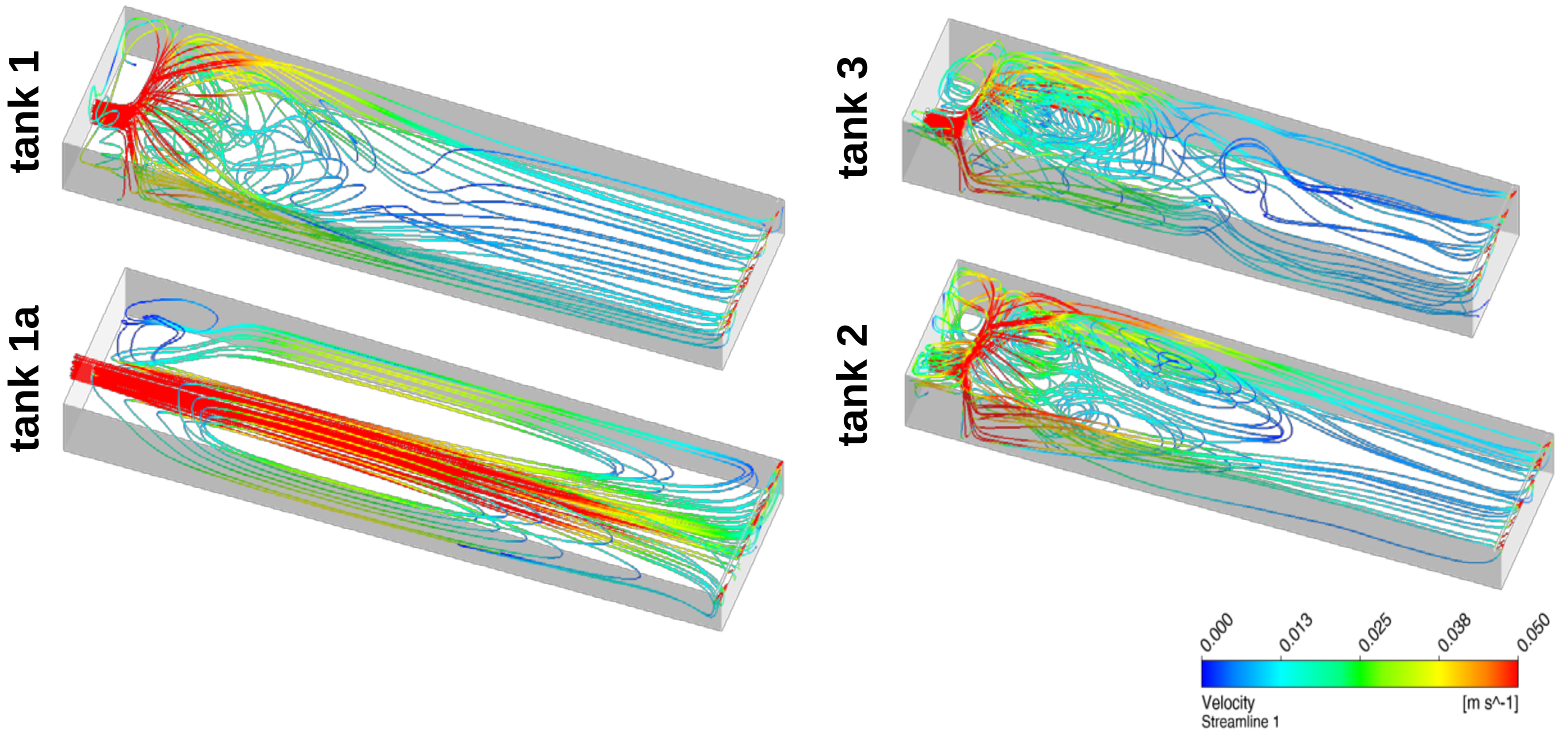
$$\beta = \left[\frac{\rho}{\mu} \cdot \sqrt{\left(\frac{(\rho_p - \rho)}{\rho} \right) \cdot g \cdot d^3} \right]^{-0{,}6}$$

Combination to an UDF (User Defined Function) (Vanoni after Dufresne et. al. [2009]

Velocity distribution

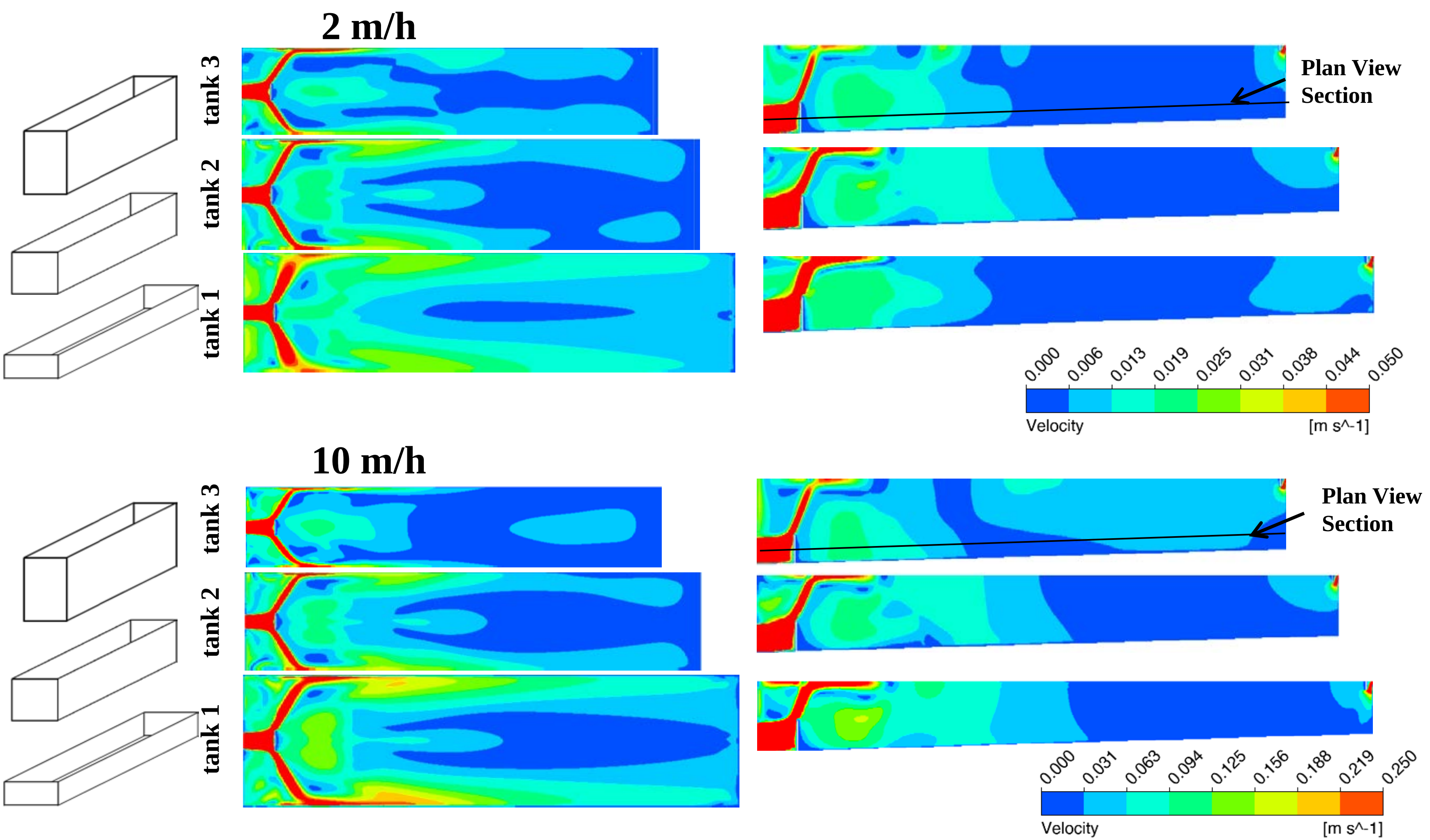
Streamlines

2 m/h



Velocity distribution

Velocity magnitude



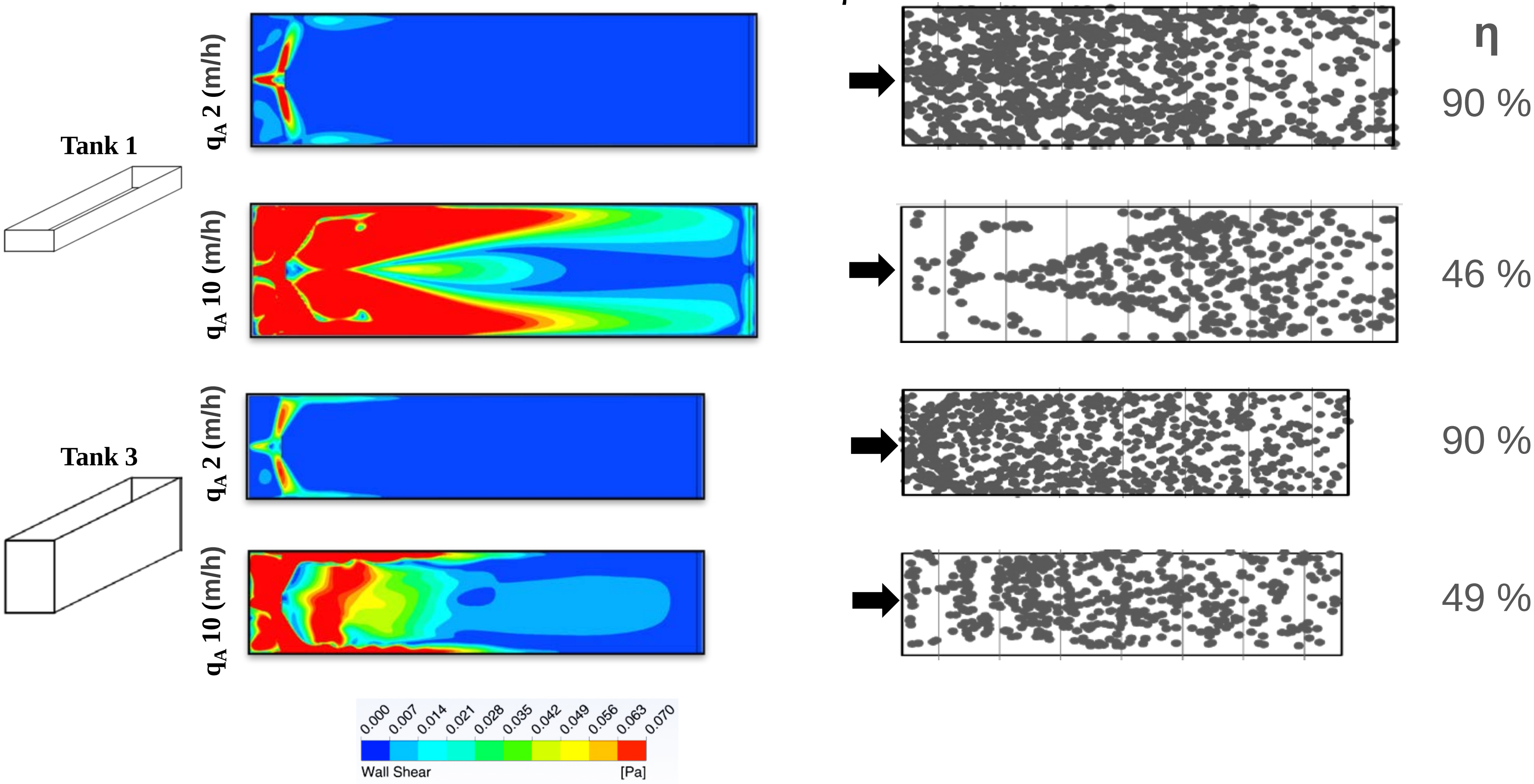
Particle distribution

Bed shear stress

Density **1460 (kg/m³)**

v_s 2.3 (m/h)

Ø 58 µm



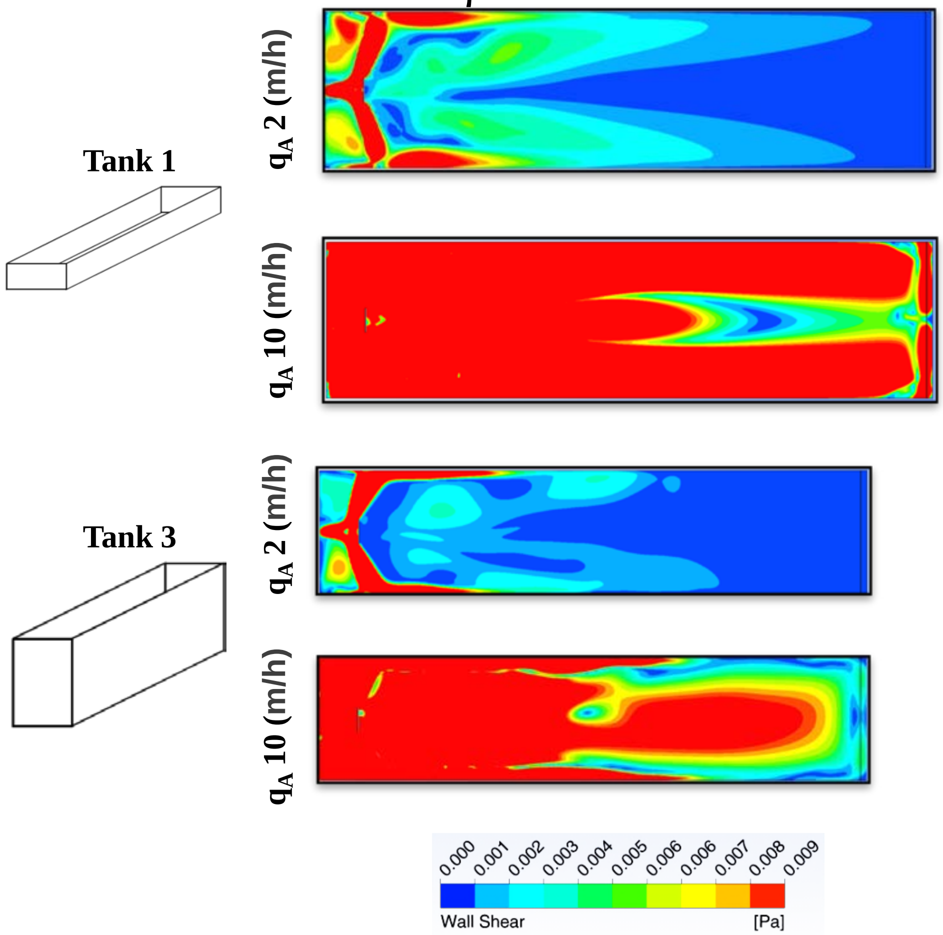
Particle distribution

Resuspension

Density **1020 (kg/m³)**

v_s 2.3 (m/h)

Ø 275 µm



η

91 %

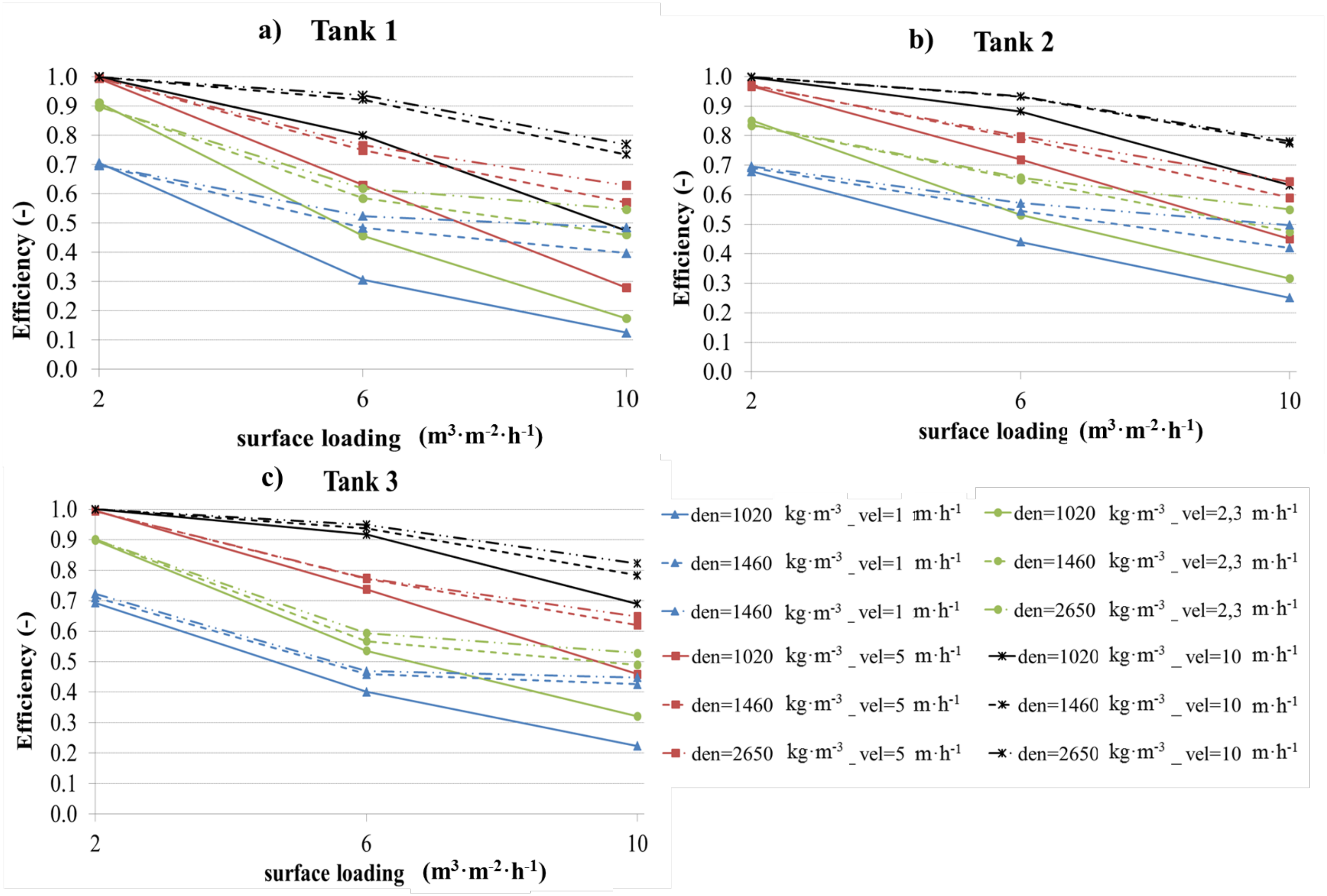
17 %

90 %

32 %

short hydraulic load → sediment gets resuspended

Overview of all simulation results



Conclusions

Low surface flow rate:

– efficiency is **independent** from geometry and density - similar for all tanks

High particle density:

– no differences in efficiency between high and low flow rates for all tanks

Low particle density:

– best sedimentation efficiency in **deep** tank- especially for higher surface flow rates

➡ The deeper the tank the higher the sedimentation efficiency for organic matter

➡ No effect on the efficiency, when there is low organic matter, by varying the dimensions in the ranges given by German standards