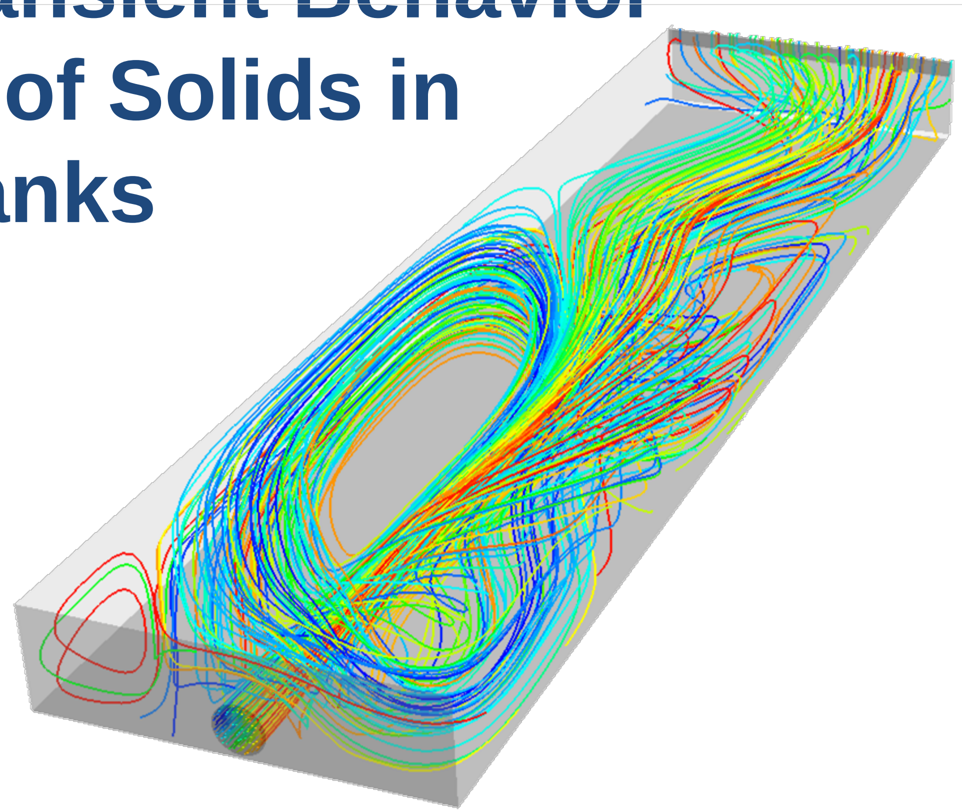
Fachhochschule Münster University of Applied Sciences

IWARU
INSTITUTE FOR WATER·RESOURCES·ENVIRONMENT

Influence of Transient Behavior on the Settling of Solids in Storm Water Tanks

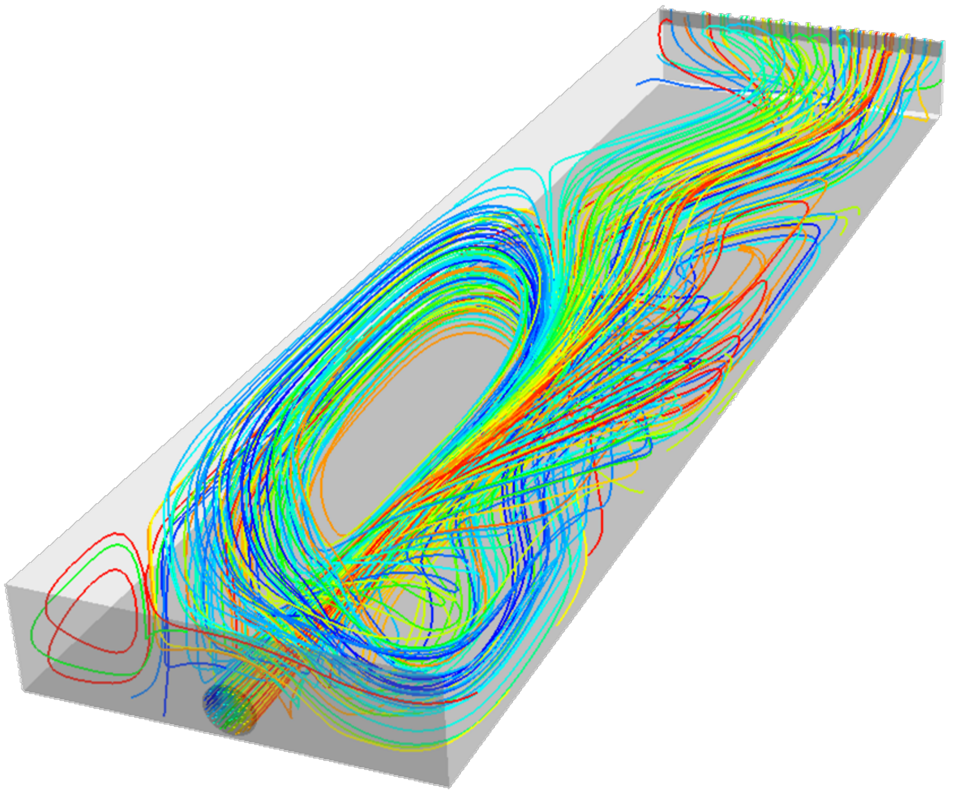


Nina Voßwinkel
Gislain Lipeme Kouyi
Simon Ebbert
Anne Schnieders
Christian Maus
Anne-Gaëlle Laily
Rainer Mohn
Mathias Uhl

9th International Conference on Urban Drainage Modelling, Belgrad 2012

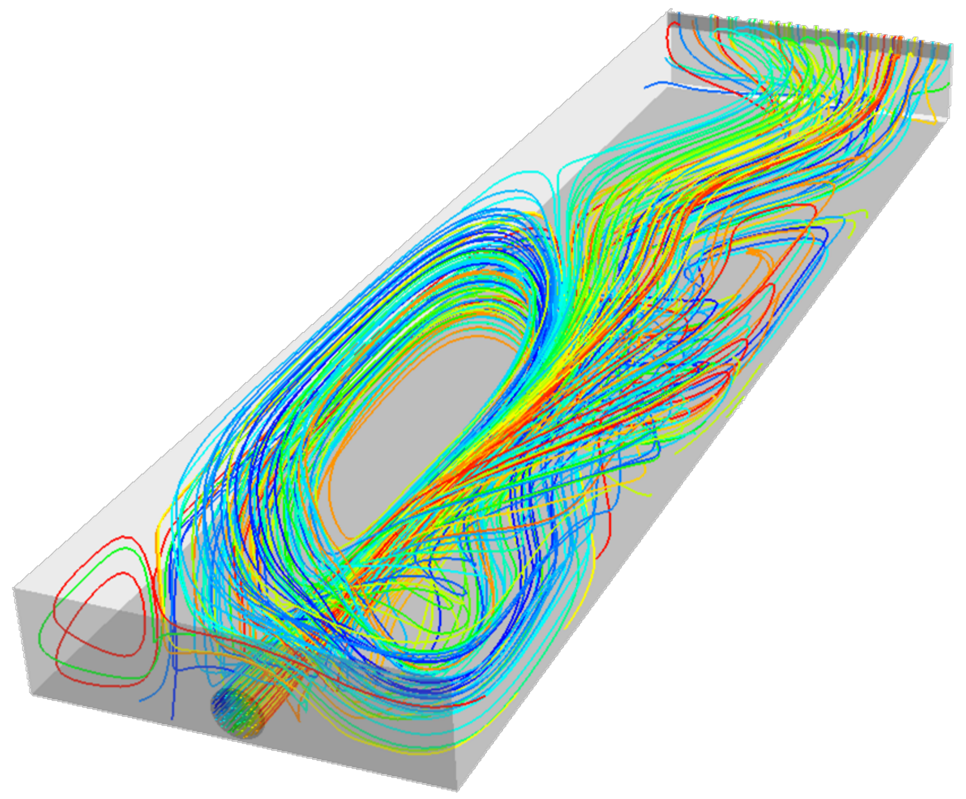
AGENDA

- INTRODUCTION
- METHODS
- MODELS
- VALIDATION
- CONCLUSIONS



Agenda

- Introduction
  - Scope of Work
- Methods
- Models
- Validation
- Conclusions



This investigation is part of the project:
WEREBE "Extended treatment of storm water in separate sewer systems"

Objectives:
- **State of knowledge** about the efficiency **is limited**
- High variability of efficiency; often not explainable

Efficiency of storm water tanks

Literature	WG_{AFS} in %
Grotehusmann et al., 2009	7
Grotehusmann et al., 2005	11
Pfeifer, 1998	43
Terzioglu et al., 1987	62
Krauth, Stotz, 1994	8
Kasting, 2003	13
Krauth, Klein, 1982	85
Kasting, 2003	82

Goals:
- **Increasing understanding** of flow pattern
- **Optimization** of efficiency

Computational Fluid Dynamics CFD

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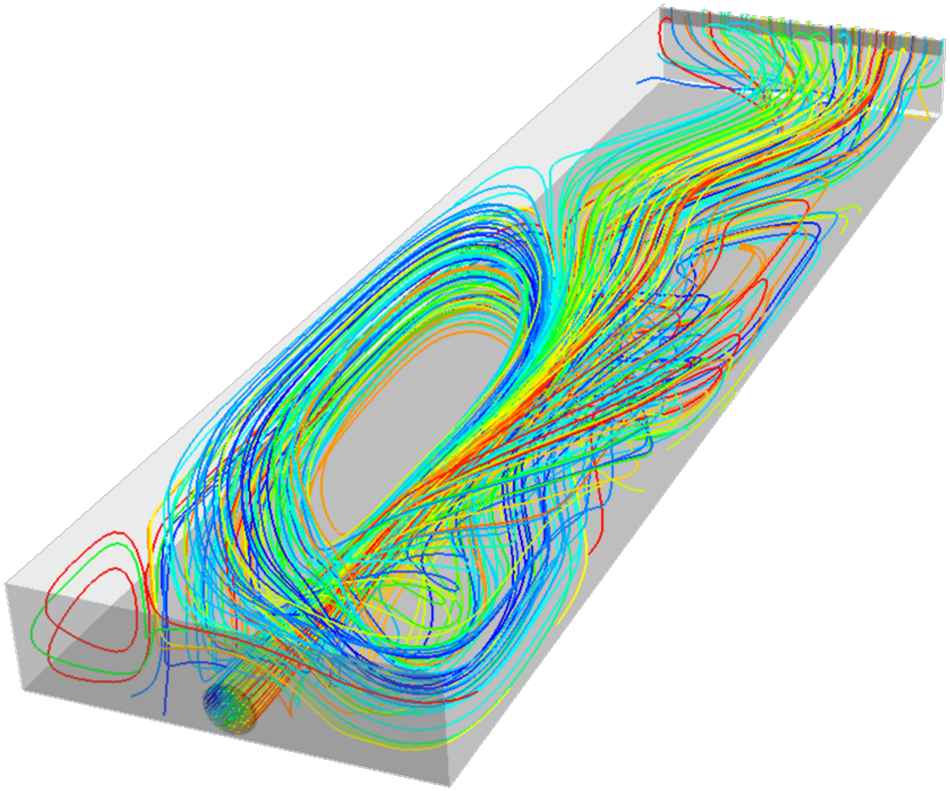


METHODS

Establish a numerical model

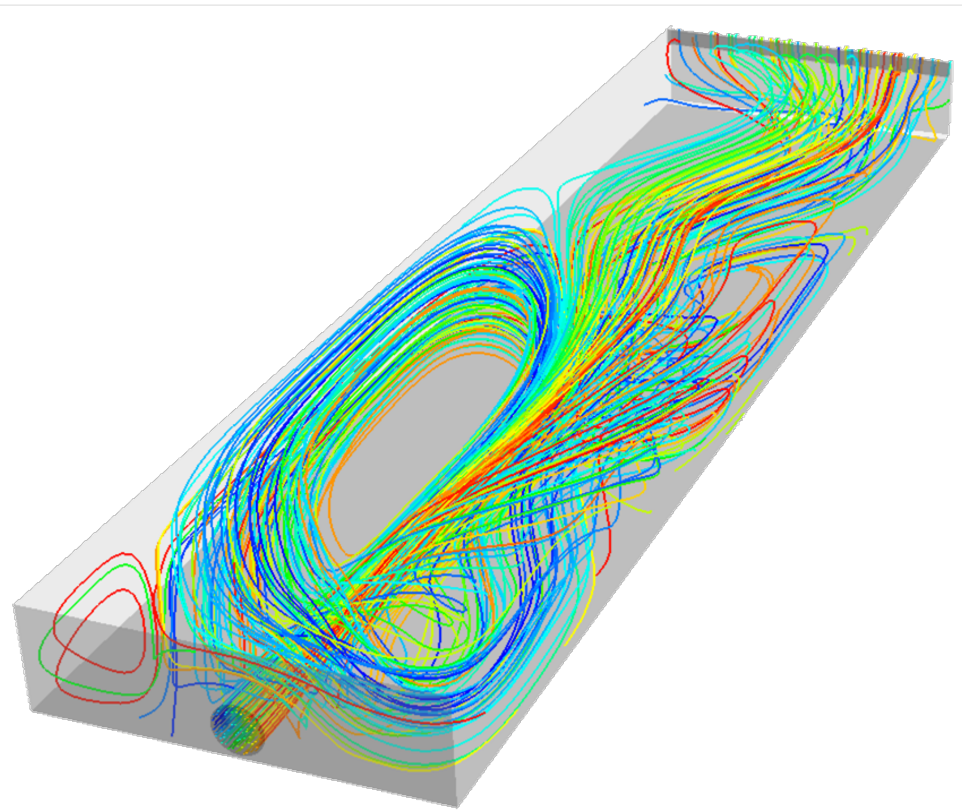
- **Model the characteristic flow pattern (selection of a suitable turbulence model)**
- **Model the solute transport and settling behavior of particles (selection of a suitable multiphase model)**

Validation

- **Validation of solute transport by using a dissolved tracer**
- **Validation of the settling behavior by using a particulate tracer**

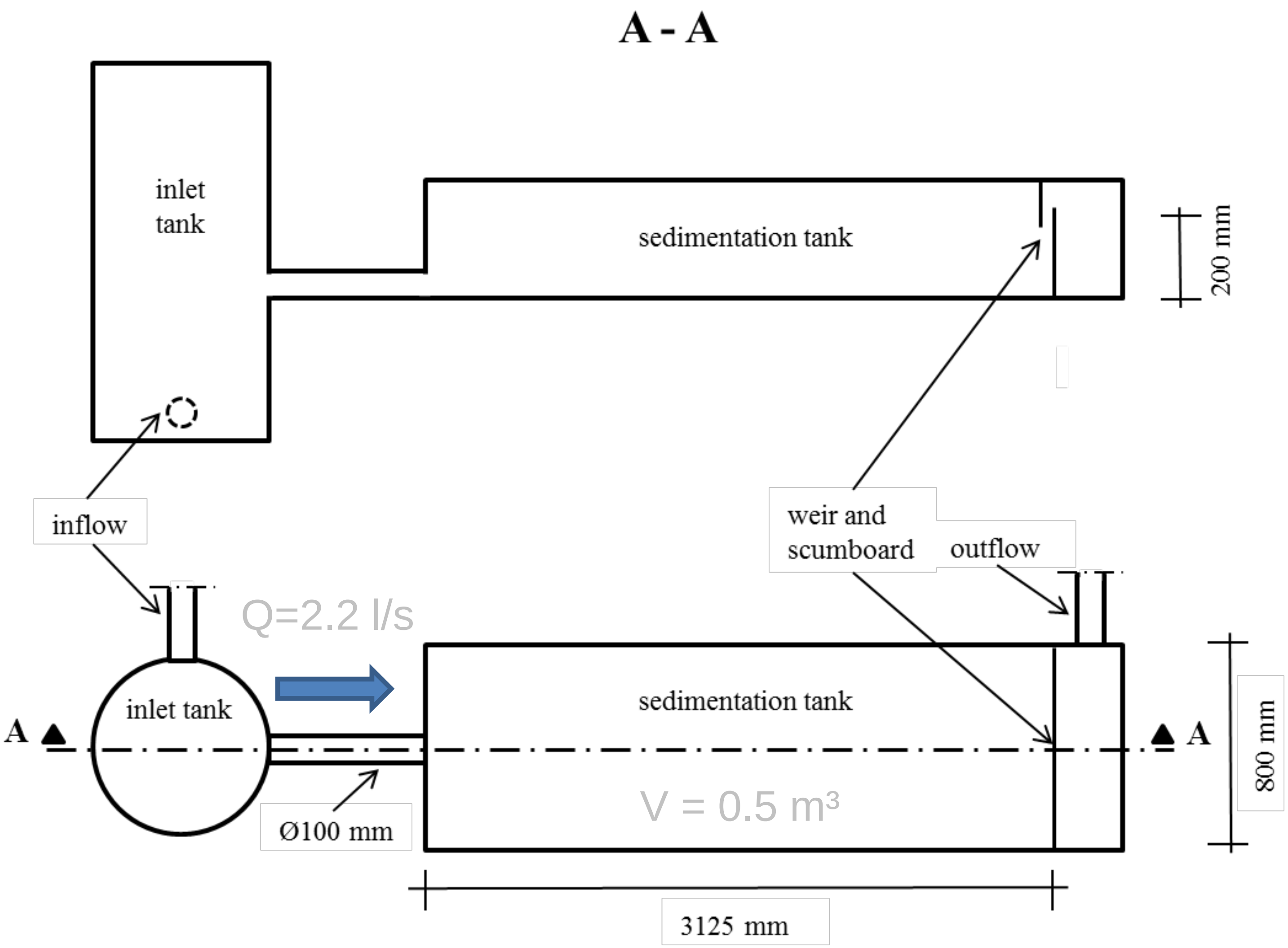
AGENDA

- INTRODUCTION
- METHODS
- MODELS
  - THE PHYSICAL MODEL
  - THE NUMERICAL MODEL
- VALIDATION
- CONCLUSIONS



THE PHYSICAL MODEL

Experimental Setup



Solver
FLUENT-software-package (version 13.0)

Turbulence model
k-ε RNG model (renormalization group)

the k-ε RNG model is more suitable than the standard k-ε model for the calculation of flow regimes with a low Reynolds number

Near wall treatment
Enhanced wall treatment

Water surface
Symmetry plane

Boundary conditions
Inlet: mass flow inlet (constant inflow)
Outlet: pressure outlet

Multiphase modelling
Discrete phase model DPM

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

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

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

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

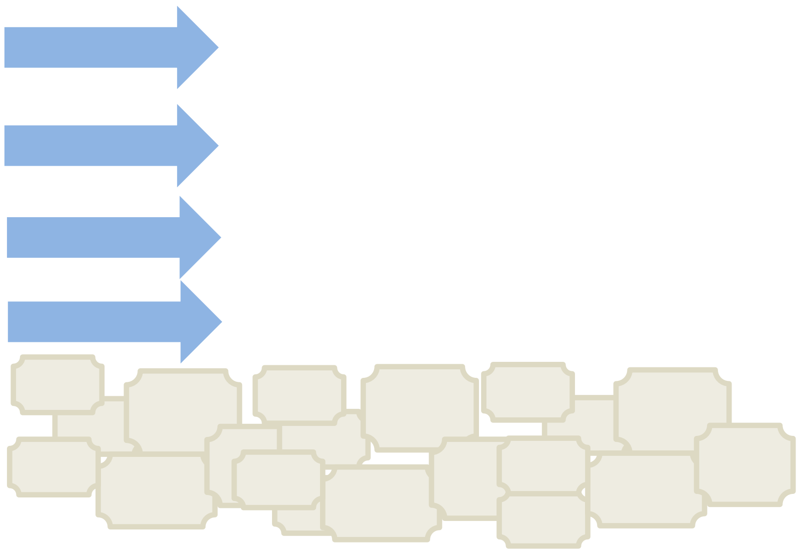
Combination to an UDF (User Defined Function) (Dufresne et. al. [2009]

The Numerical Model

Calibration of Critical Bed Shear Stress

$$\tau_{crit,\text{grain structure}} > \tau_{crit,\text{glass bottom}}$$

Zanke [1999]
Reduction 1 : 1.9
(movement risk of 1 %)



Grain Structure

Glass bottom with no grain structure

AGENDA

- INTRODUCTION
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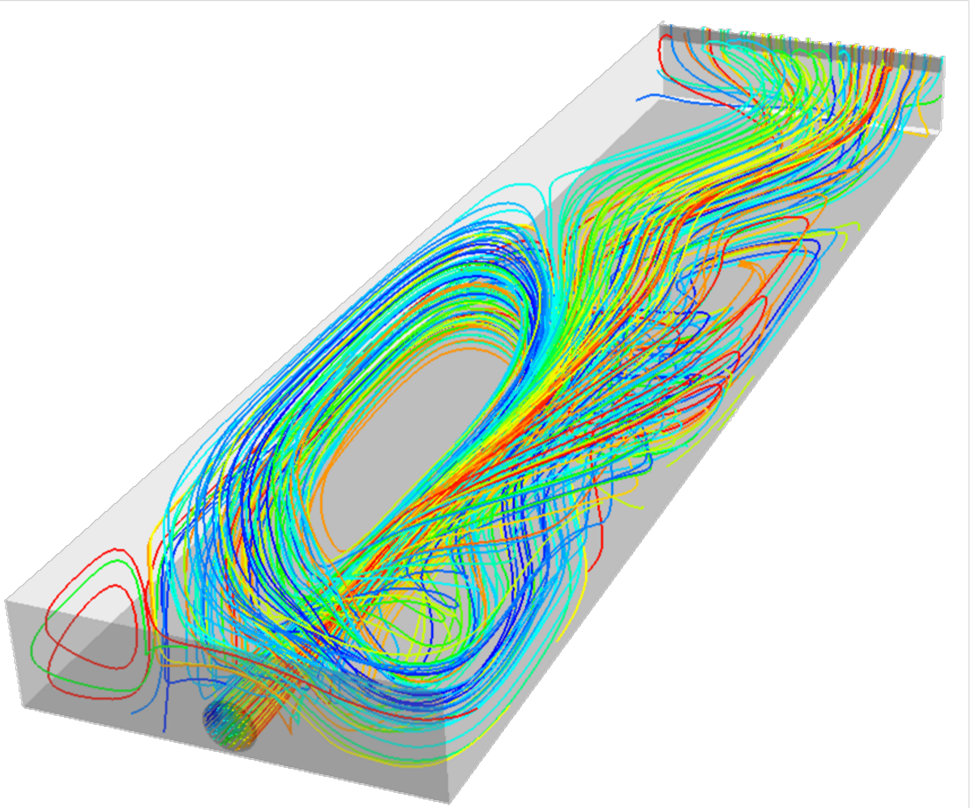
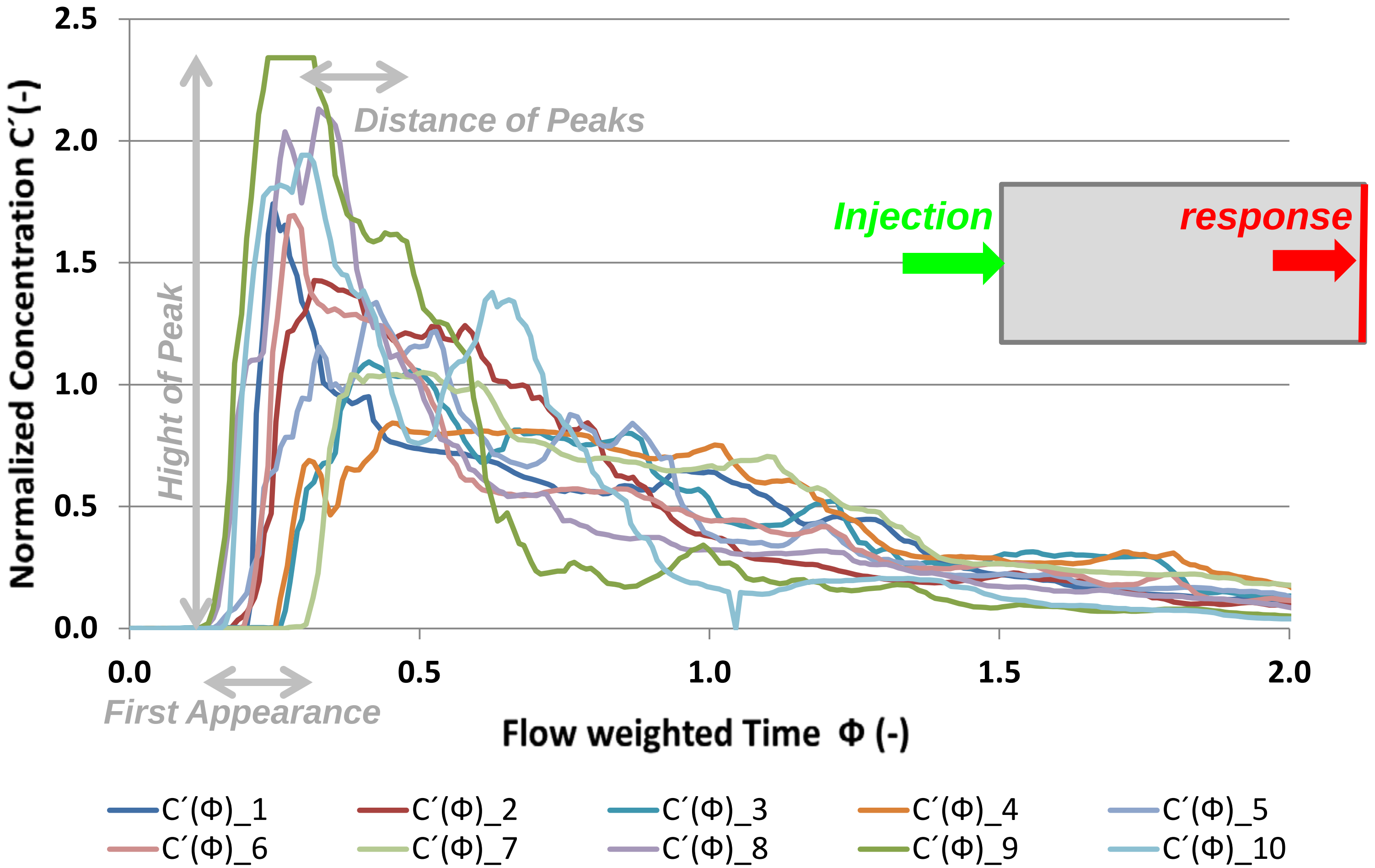
- VALIDATION
  - DISSOLVED TRACER
  - PARTICULATE TRACER
- CONCLUSIONS



VALIDATION

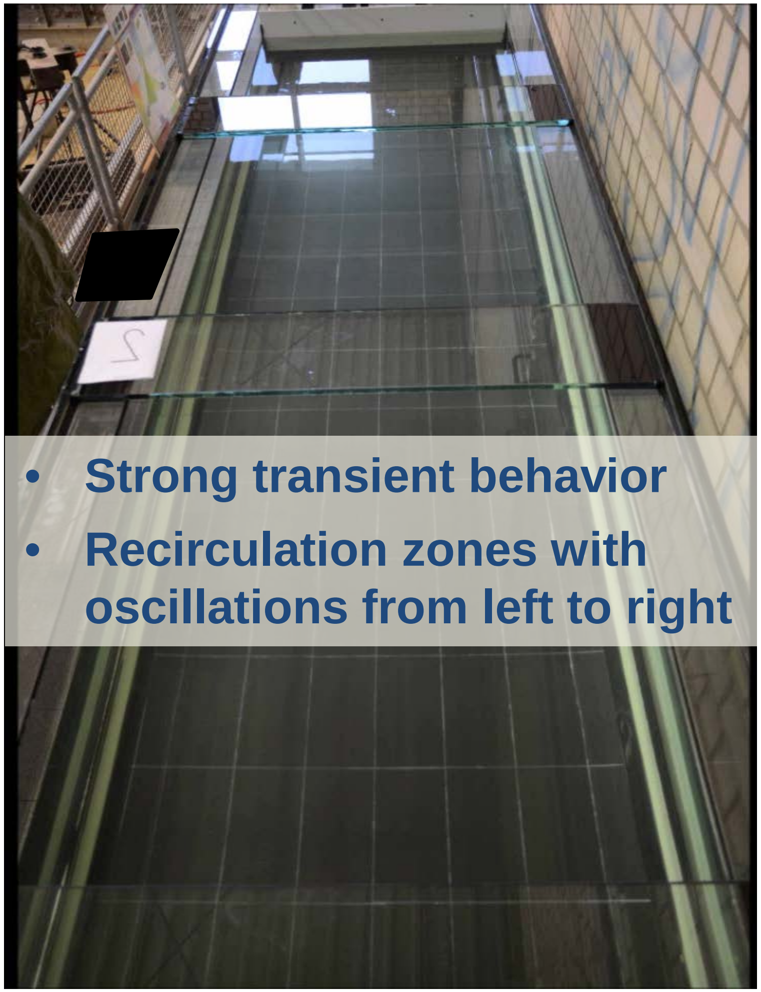
Residence Time Distribution (RDT) of Dissolved Tracer



VALIDATION

Flow Pattern

Experiment

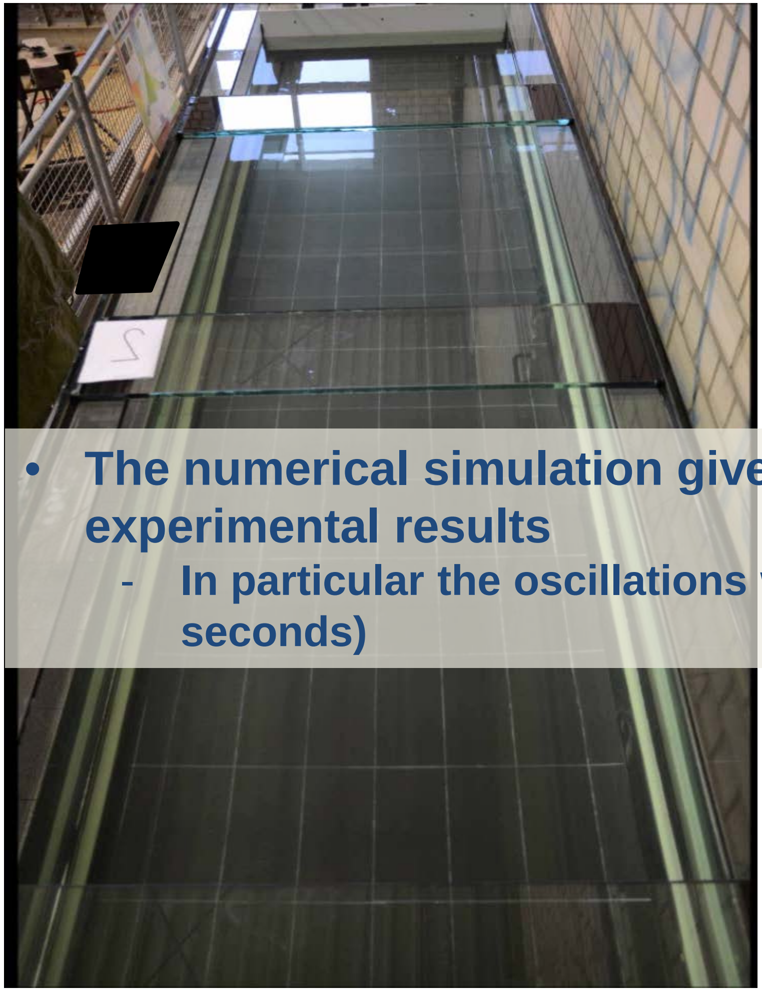


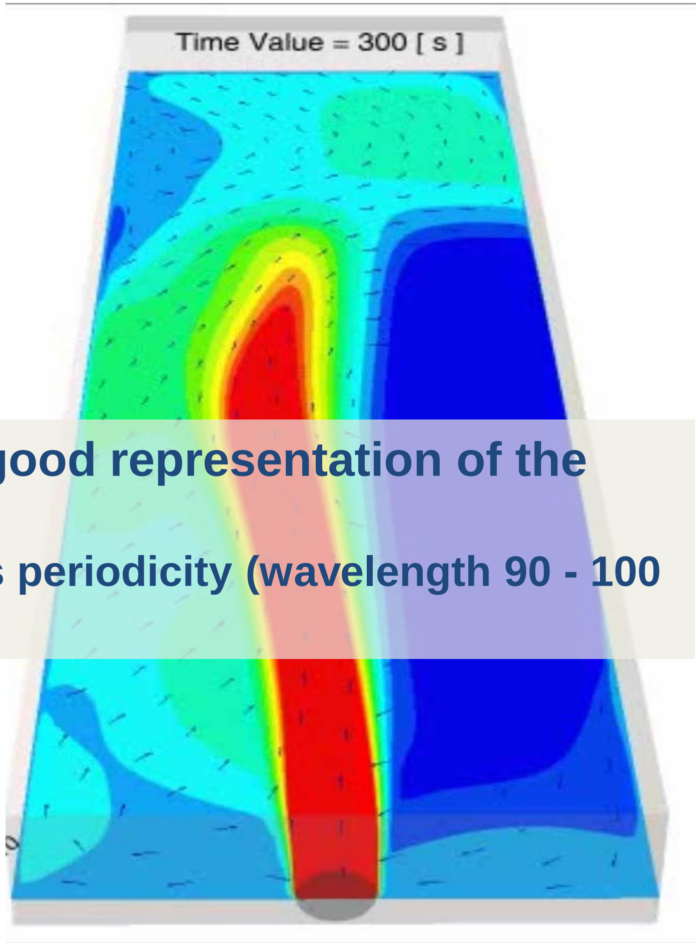
- **Strong transient behavior**
- **Recirculation zones with oscillations from left to right**

VALIDATION

Flow Pattern

Experiment	Simulation

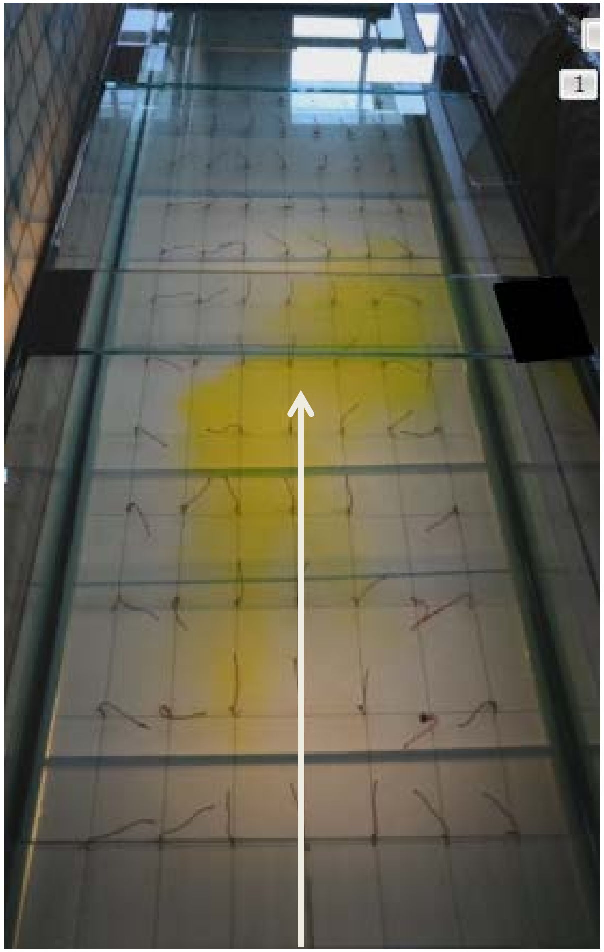




- **The numerical simulation gives an good representation of the experimental results**
  - **In particular the oscillations with its periodicity (wavelength 90 - 100 seconds)**

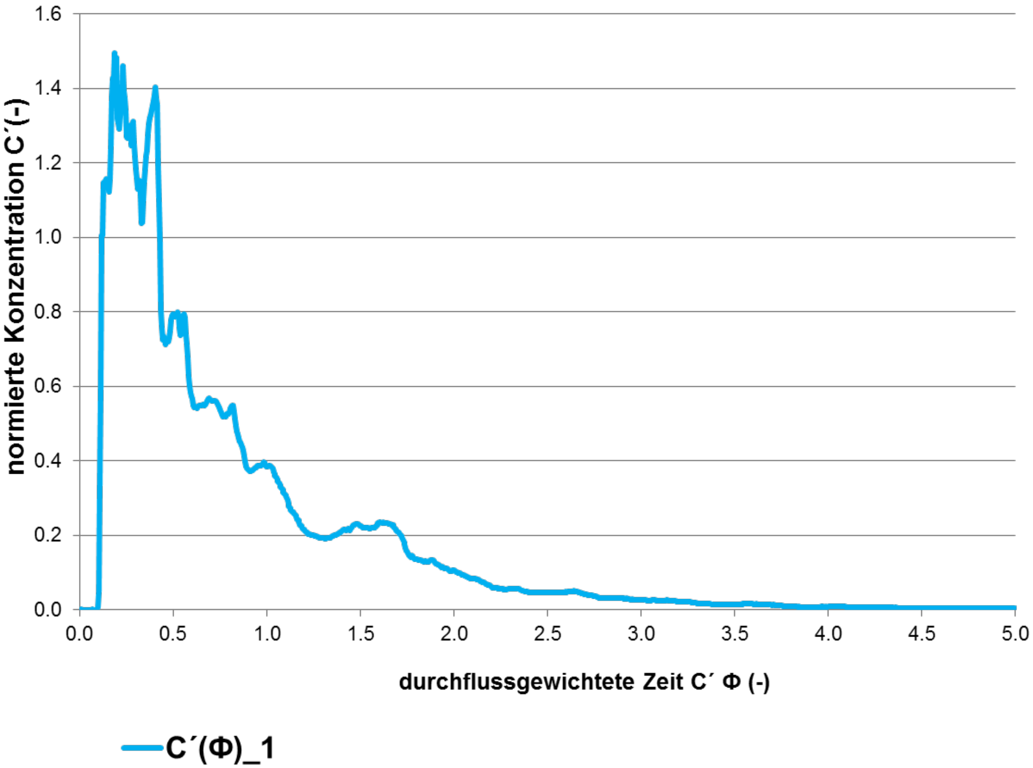
Transient solution

Experiment

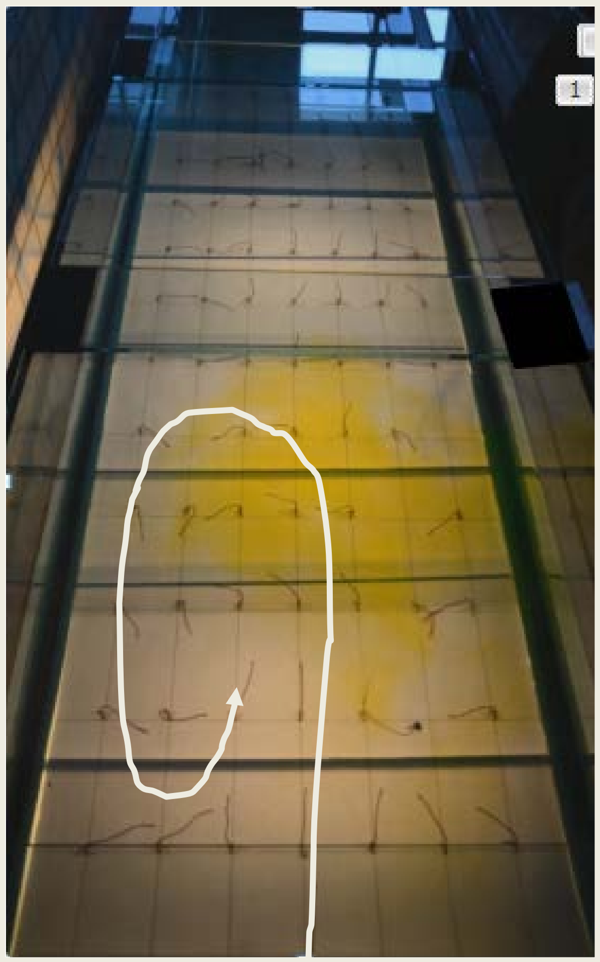


flow conditions which are present at the time the tracer was injected

Residence time distribution of dissolved Tracer



Experiment



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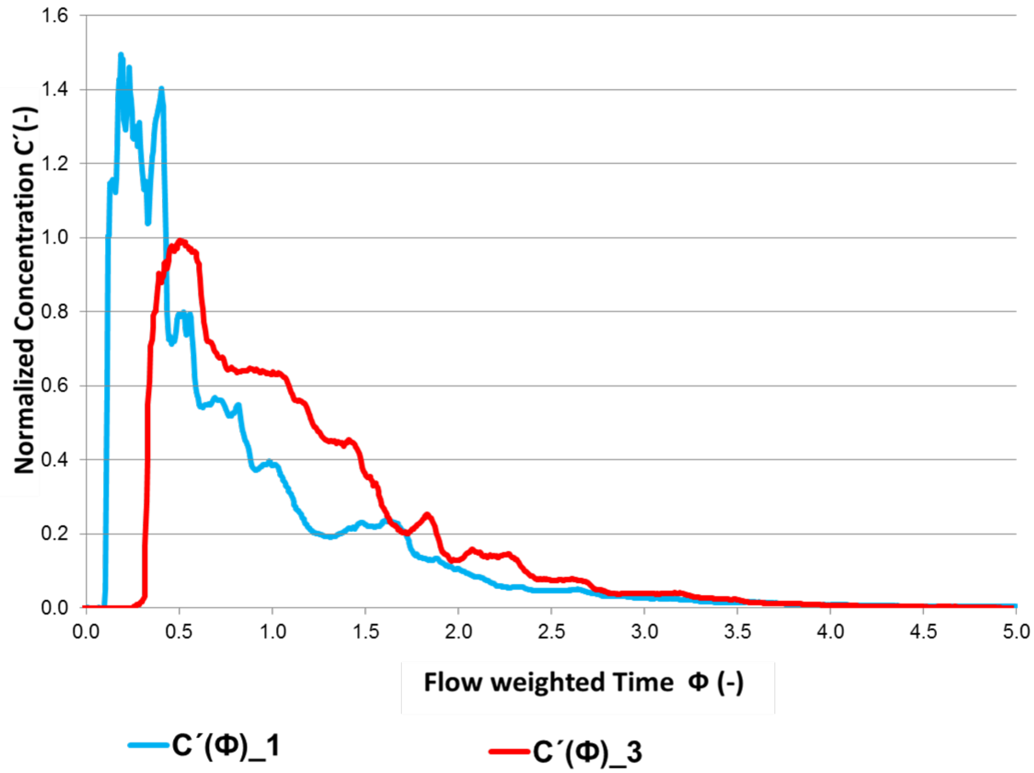
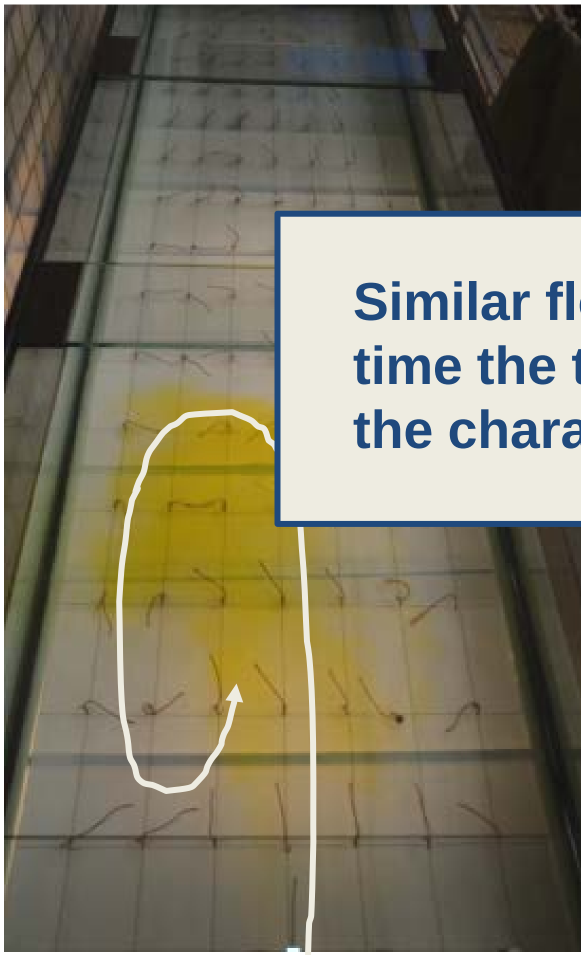


VALIDATION

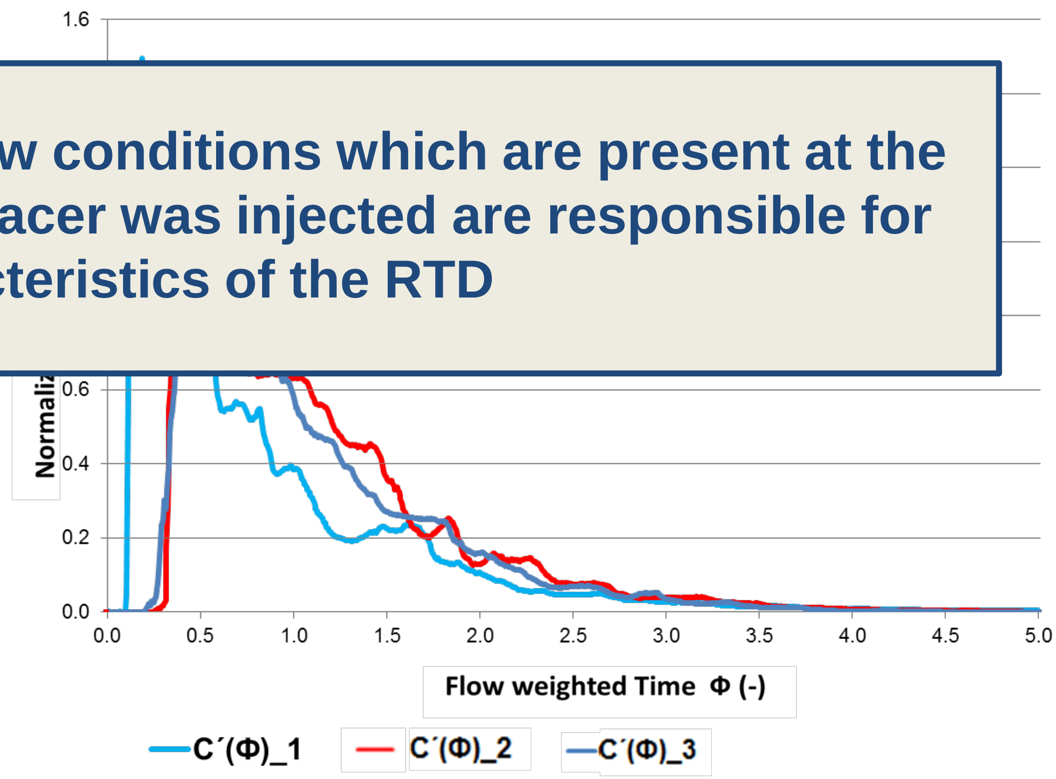
Dissolved Tracer

Experiment



flow conditions which are present at the time the tracer was injected

Residence time distribution of dissolved Tracer

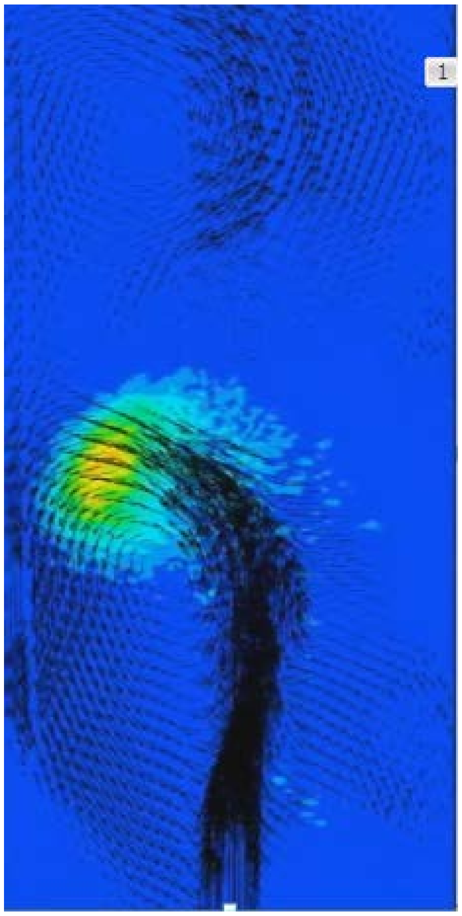


Similar flow conditions which are present at the time the tracer was injected are responsible for the characteristics of the RTD

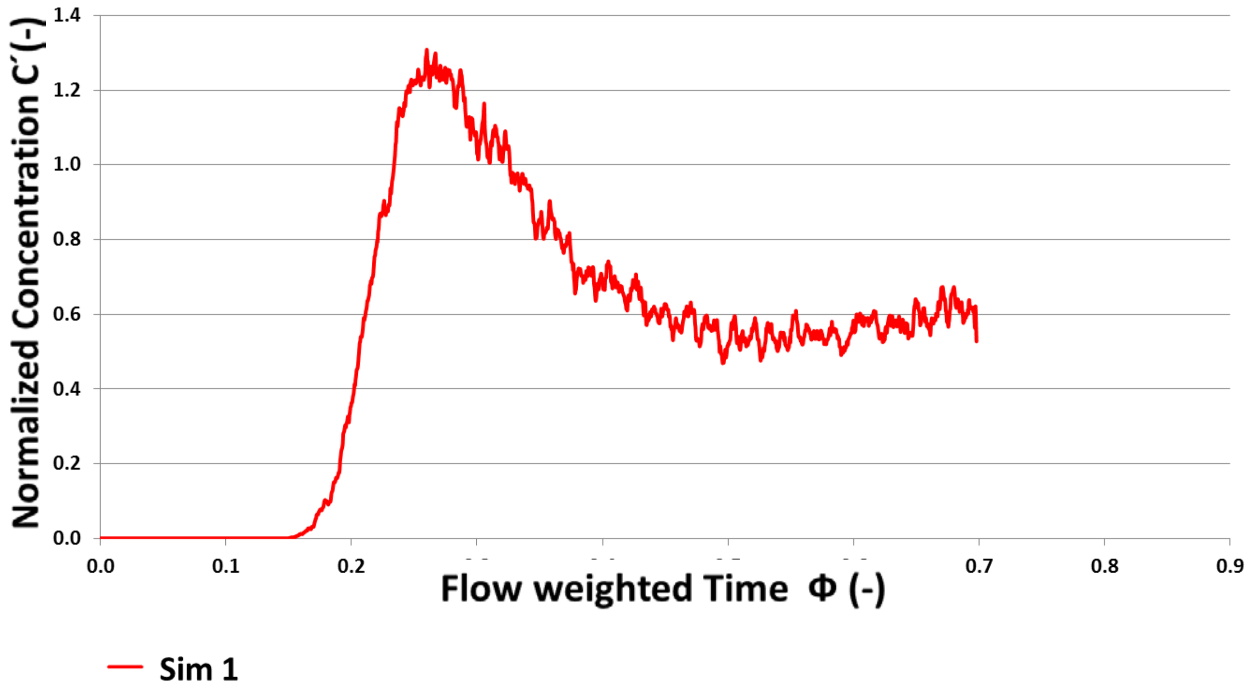
VALIDATION

Dissolved Tracer

Simulation

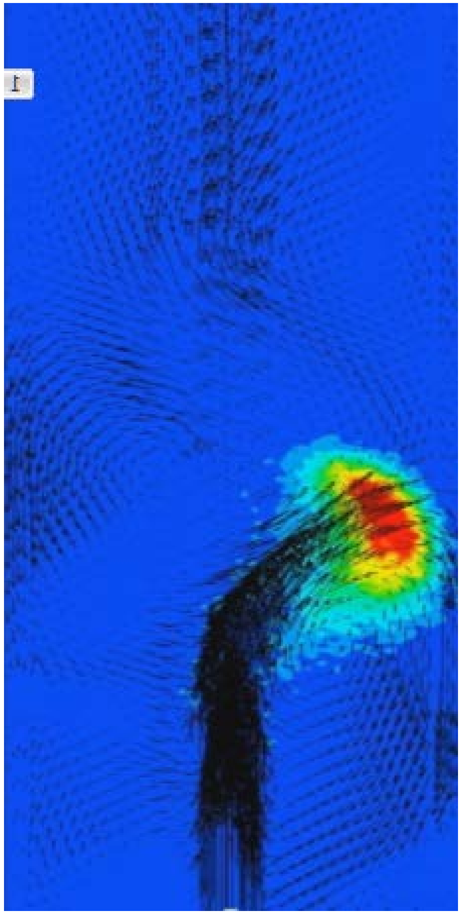


Residence time distribution of dissolved Tracer



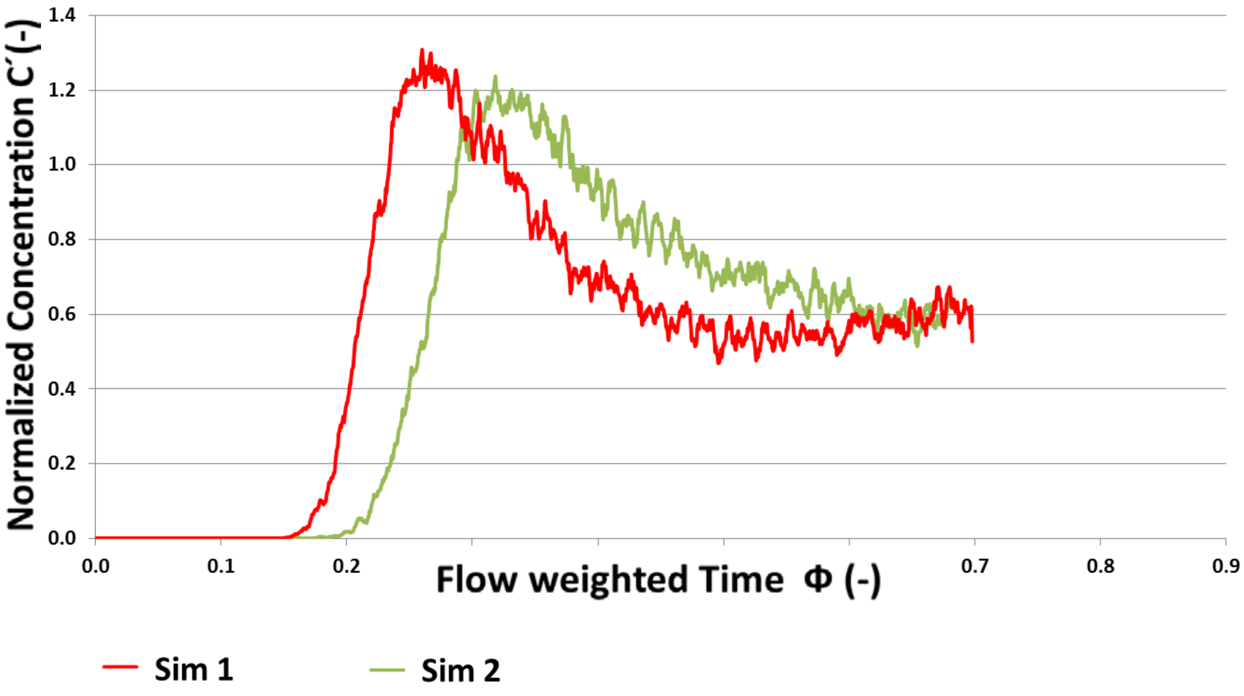
flow conditions which are present at the time the tracer was injected

Simulation



flow conditions which are present at the time the tracer was injected

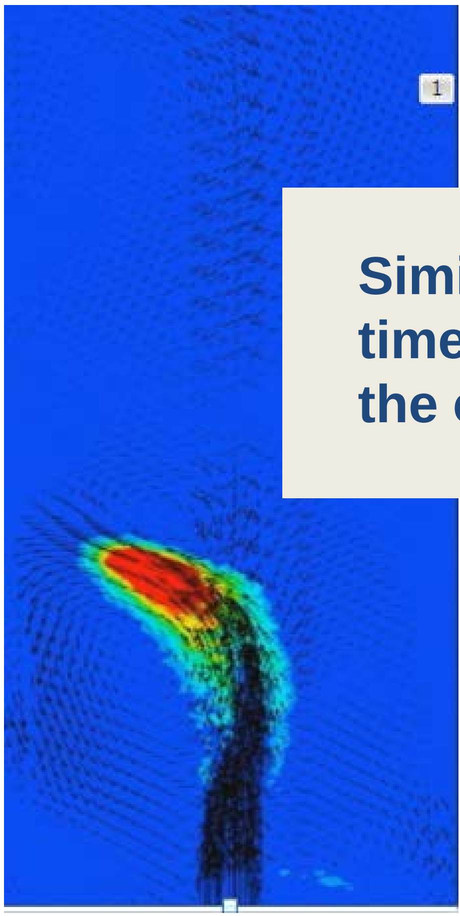
Residence time distribution of dissolved Tracer

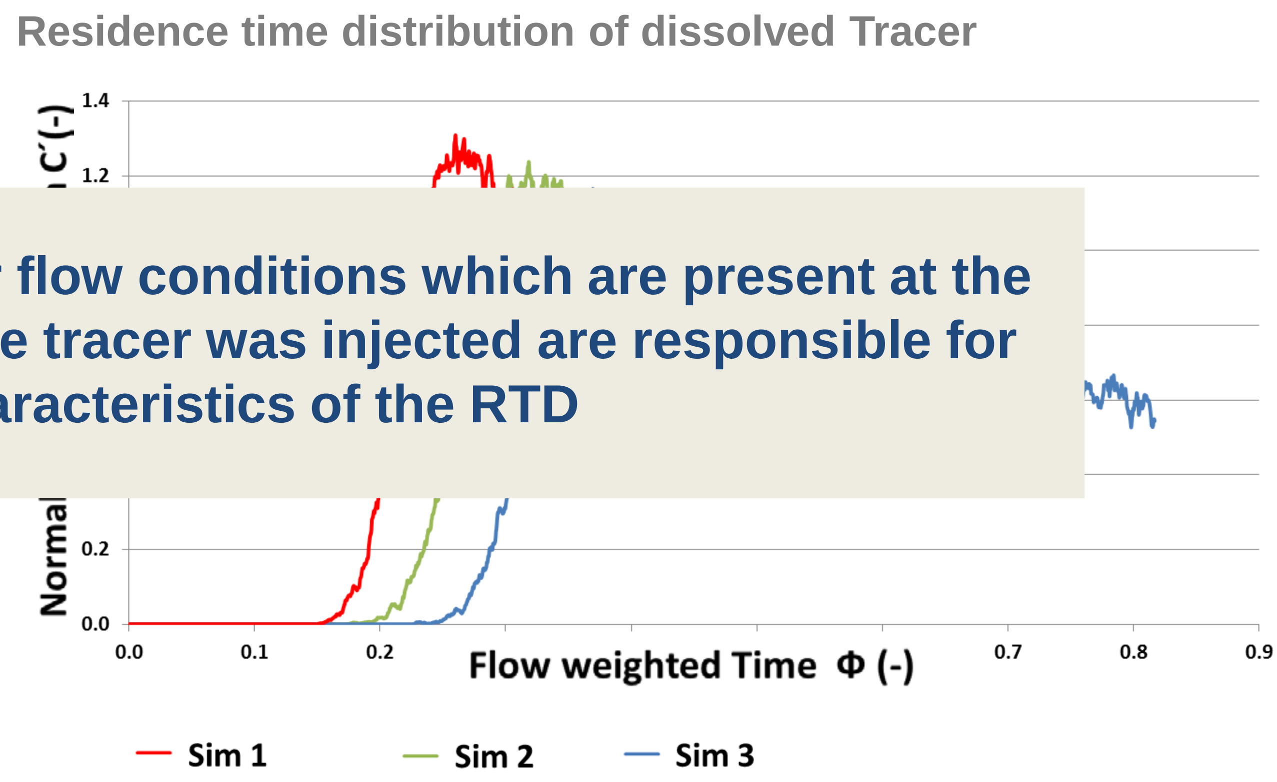


VALIDATION

Dissolved Tracer – Numerical Modell

Simulation





Similar flow conditions which are present at the time the tracer was injected are responsible for the characteristics of the RTD

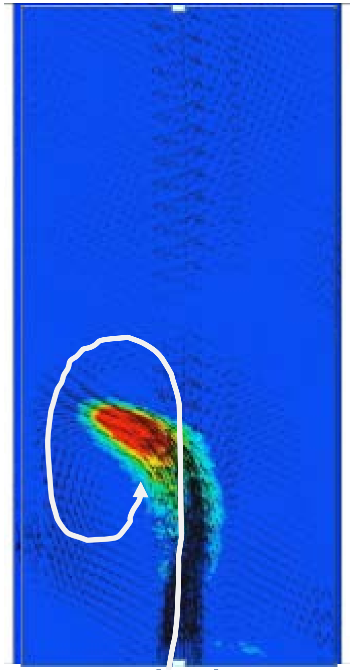
flow conditions which are present at the time the tracer was injected

VALIDATION

Dissolved Tracer

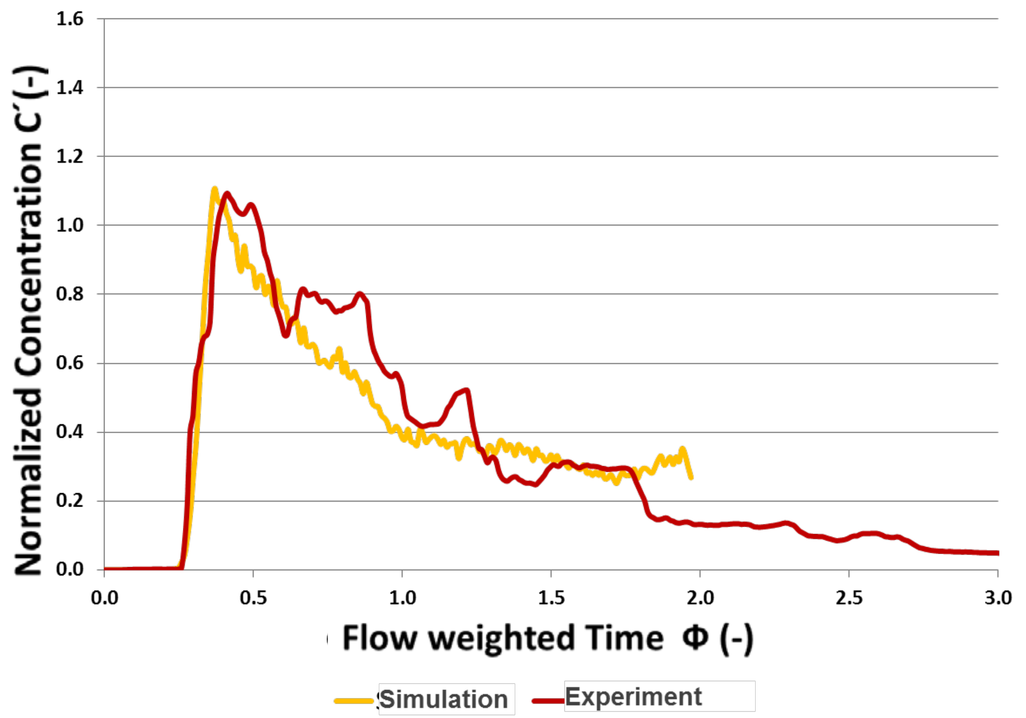
Experiment

Simulation



flow conditions which are present at the time the tracer was injected

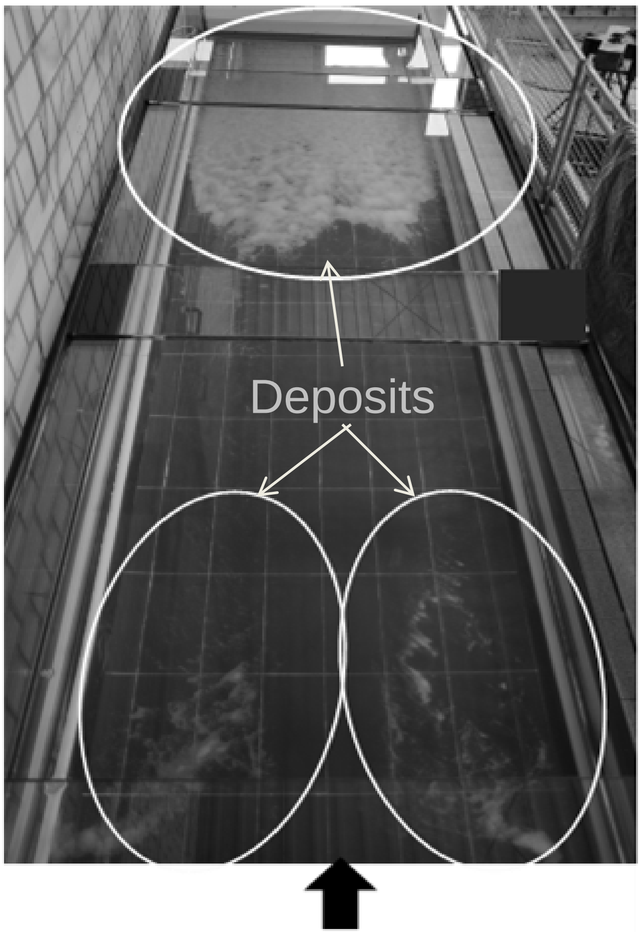
Residence time distribution of dissolved Tracer



- **Residence time distribution is directly linked to the flow characteristics**
- **Same flow characteristics at the time of injection of the tracer, leads to a comparable residence time distribution**

Experiment

Spartial distribution of particles



Substrate

Polystyrene particles (P 426, manufacturer BASF)

Density	***1020 kg·m^{-3}***
Grain sizes	***300 to 700 µm***

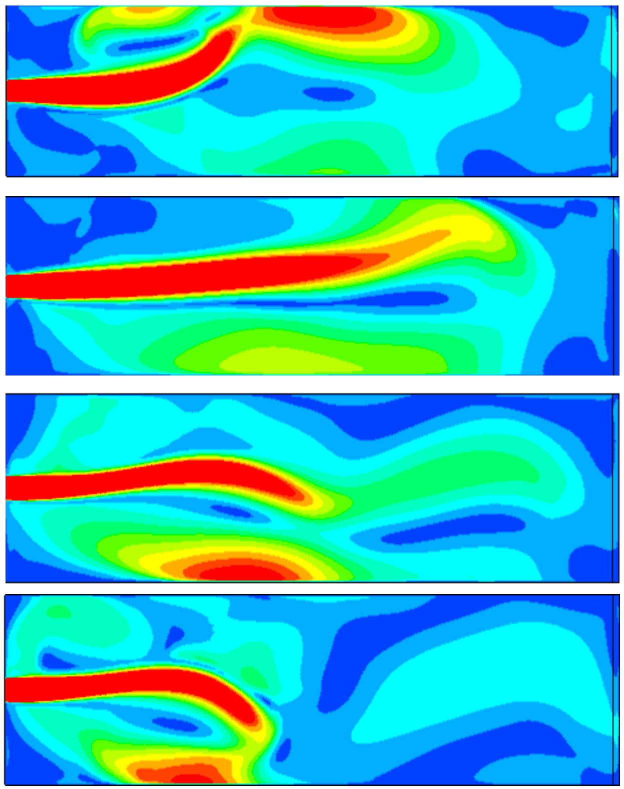
Suspended particles were added in the form of impulses through the injection mechanism

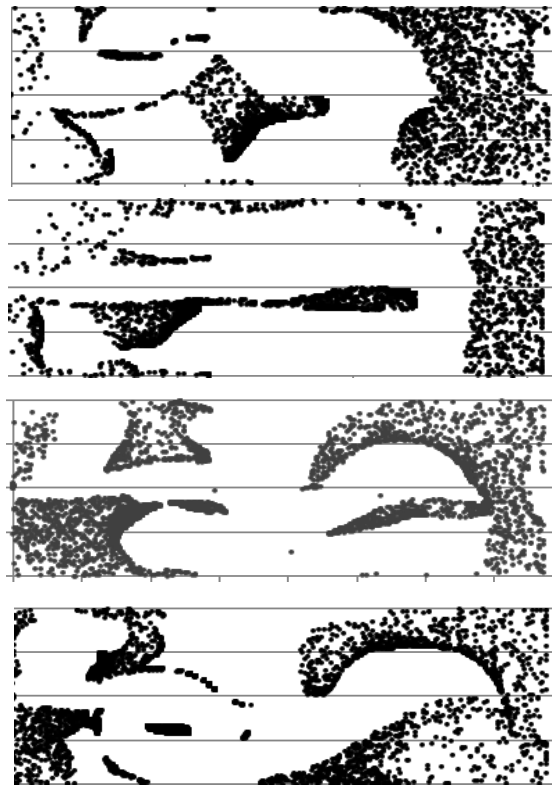
- **Deposits sideways the inflow stream and in the rear part of the tank**
- **Remaining parts of the tank are relatively free of sediment because of the transient behavior**

VALIDATION

Particulate Tracer - Best Practise

Flow pattern | **Spartial distribution** | **Superposition**



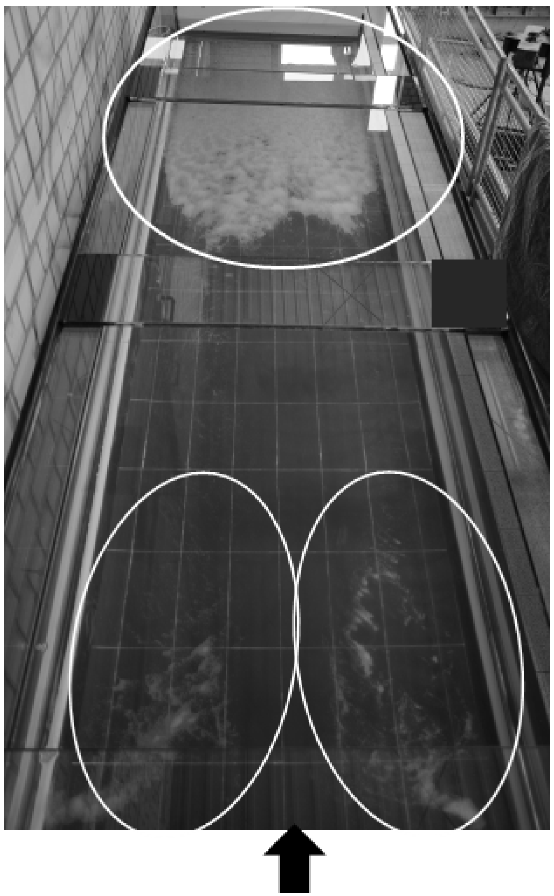


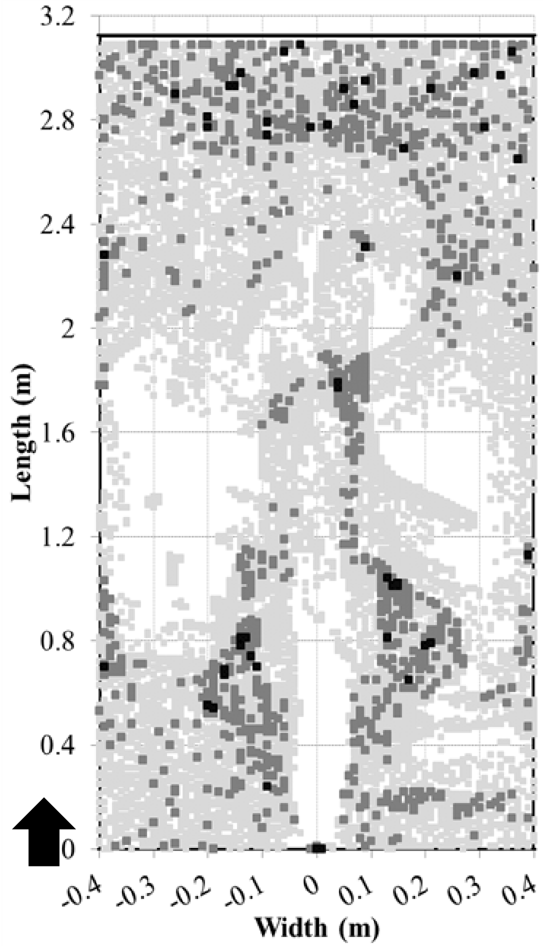
Snapshots of the flow from different time steps of an unsteady simulation

VALIDATION

Particulate Tracer

	Experiment	Simulation
Efficiency	85 %	85 %





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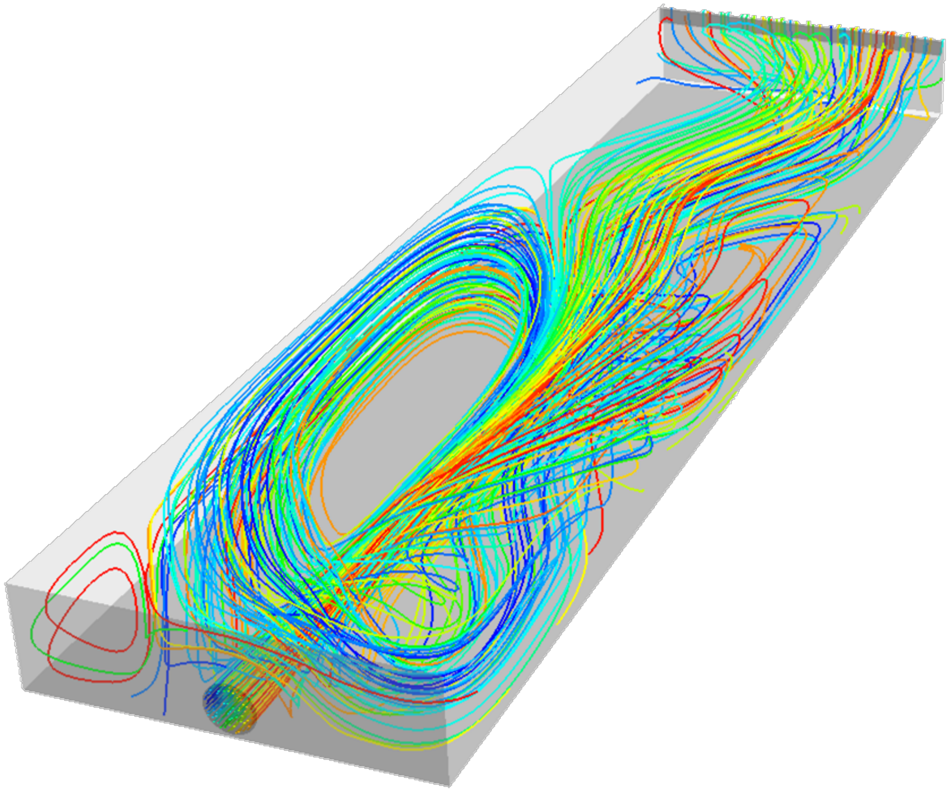


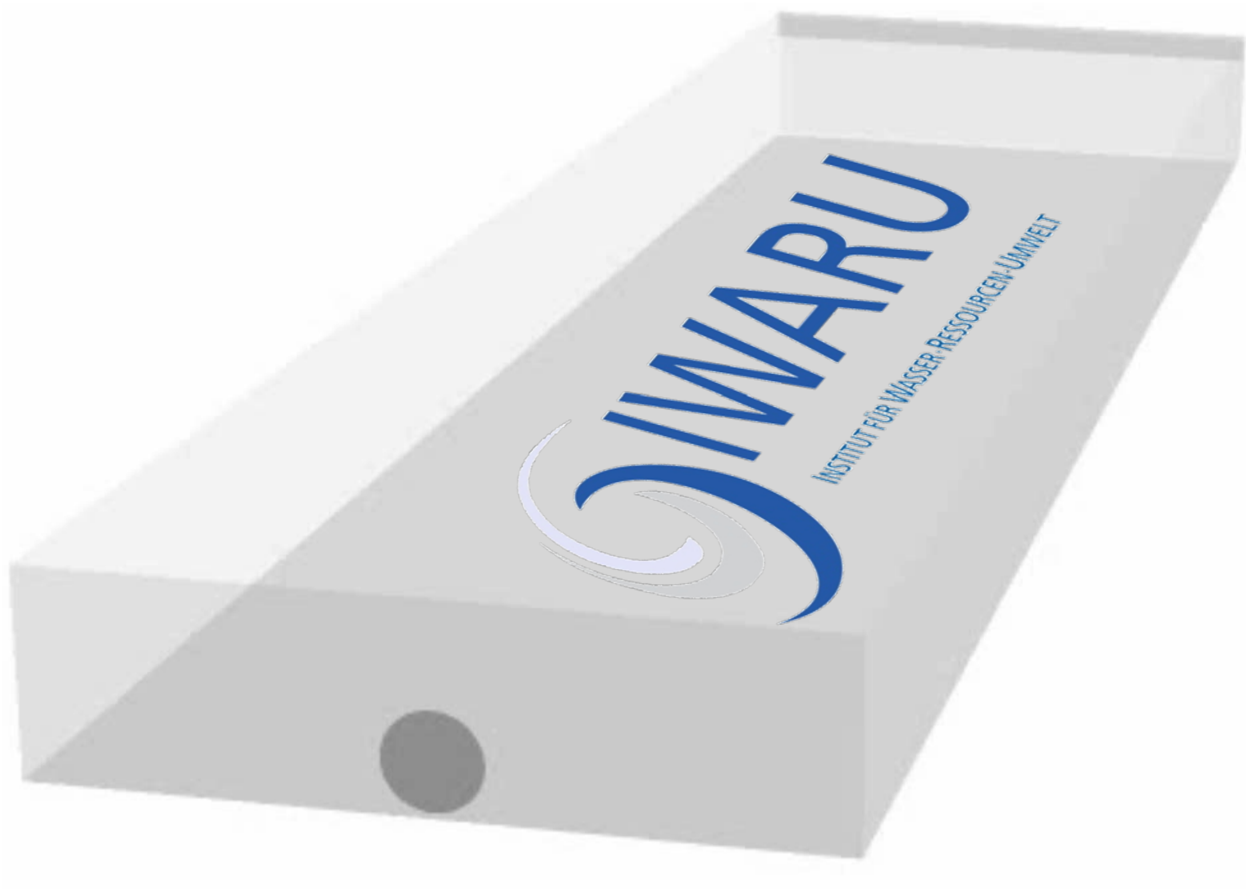
CONCLUSIONS

Dissolved Tracer

- **Similar flow conditions** which are present at the time the tracer was injected **are responsible for the characteristics of the RTD**. For this procedure, a good correlation between simulation and experimental observations has been observed.

Particulate Tracer

- When spatial distributions of particles generated at different time intervals are **superimposed** on each other, a good correlation has been noticed.
- **Redistribution and remobilization effects** on solids can only be represented with limited success when an uncoupled DPM is used because of the steady character and form of the wall treatment of particles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