# CFD in Waste Water Plants


ADVANCED MODELLING & SIMULATION – AMS –

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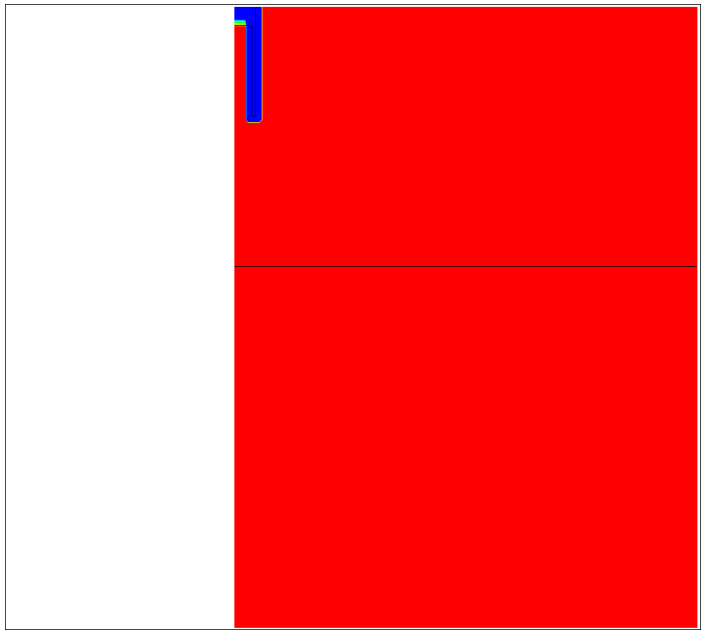
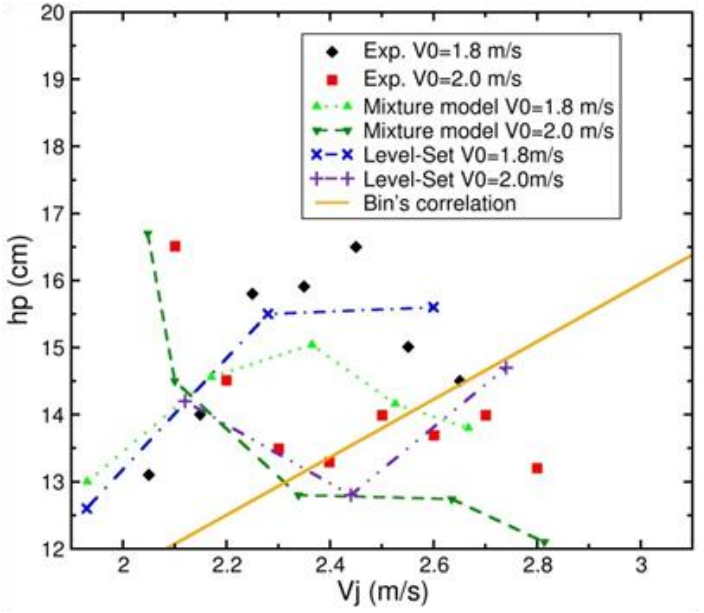
# Pool aeration via downward water jet

ISSUE: PLUME DISPERSION AND SUBSEQUENT COMPONENTS DISTRIBUTION

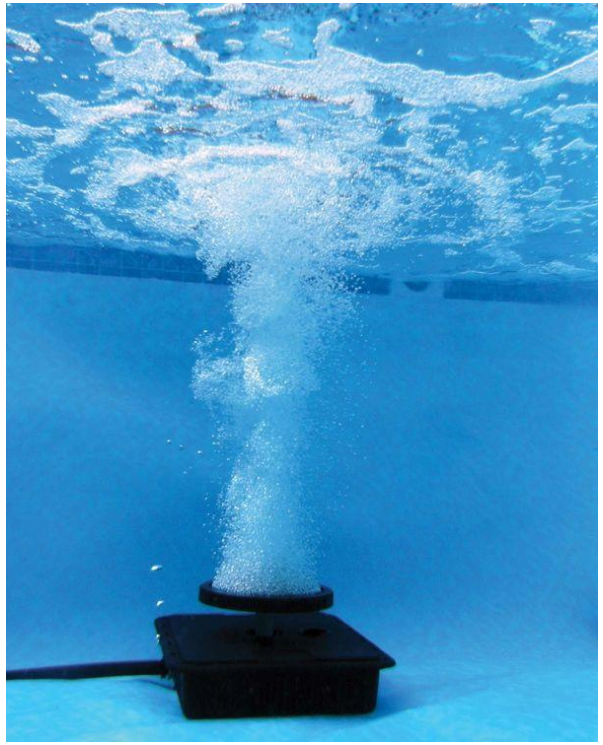


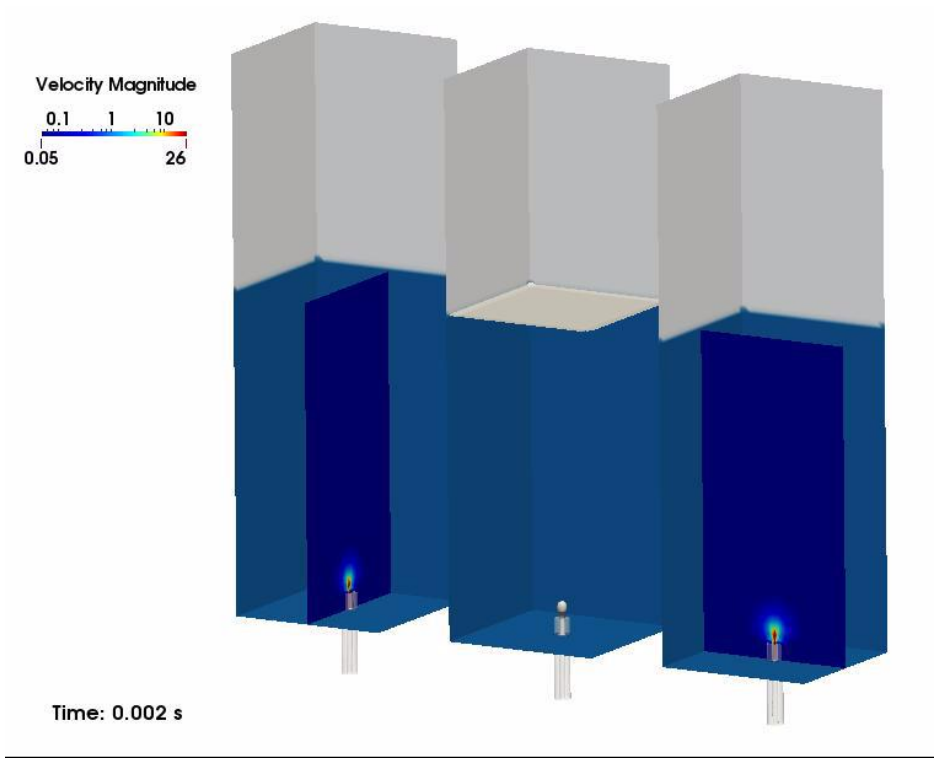



COMPARISON WITH EXPERIMENTS: JET PENETRATION AND ENTRAINEMENT

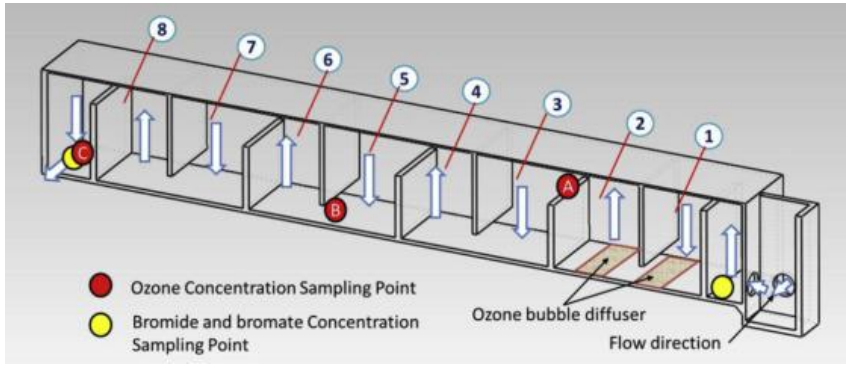
# Pool aeration via upward gaseous jet

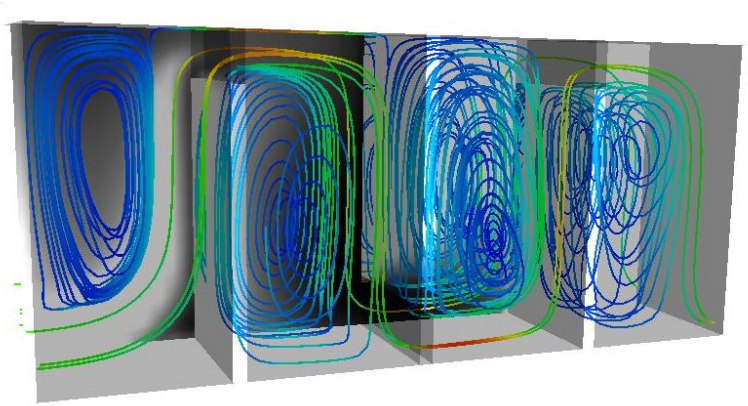
ISSUE: PLUME DISPERSION AND SUBSEQUENT COMPONENTS DISTRIBUTION





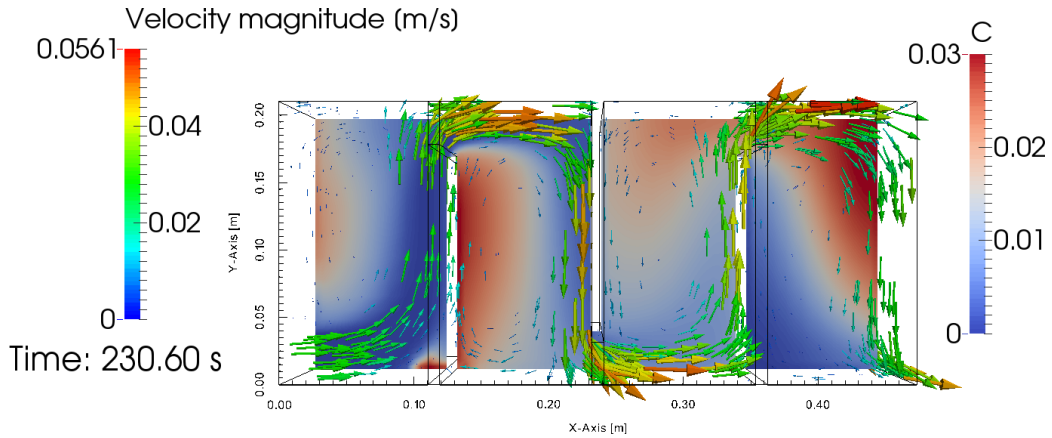
# Water-ozonation in a baffled contactor



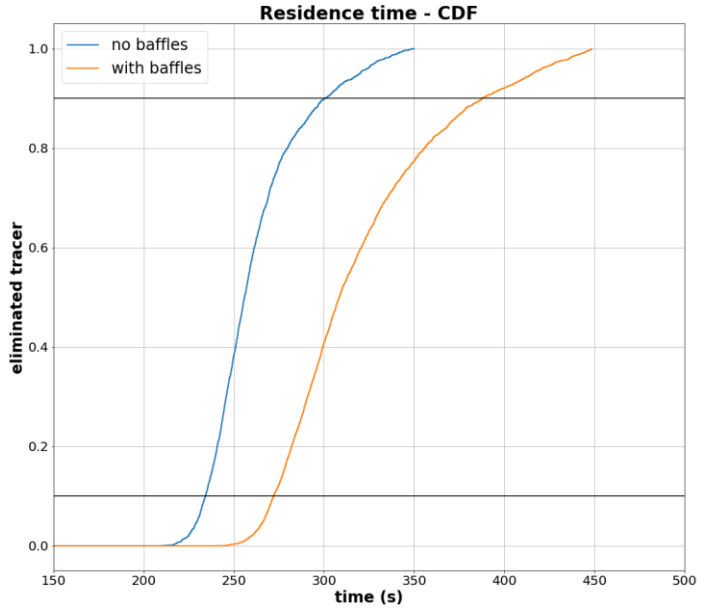
Water treatment contactor

TransAT enables a detailed analysis of the ozone mass transfer in a water flow inside a baffled reactor. It is important in practical application of such type devices to predict well the flow field and especially flow recirculation zones at which contact surfaces the mass transfer of ozone is intensified.

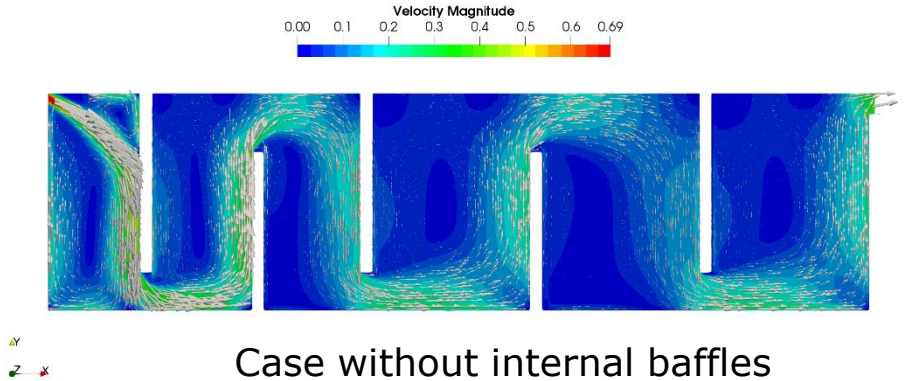


# Water-ozonation in a baffled contactor

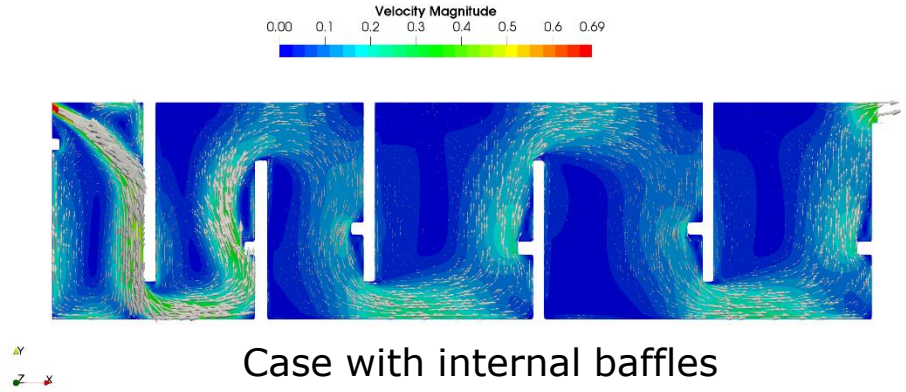
- Hydraulics analysis via CFD
- Diagnostic of different design options
- Flow retention time analysis using particle tracking




Effect of baffles on flow residence time: the tracer is eliminated faster without baffles

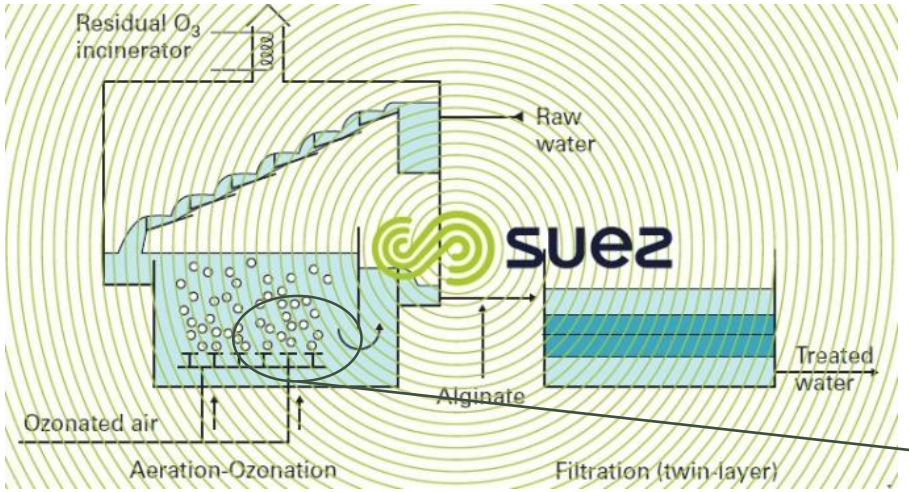


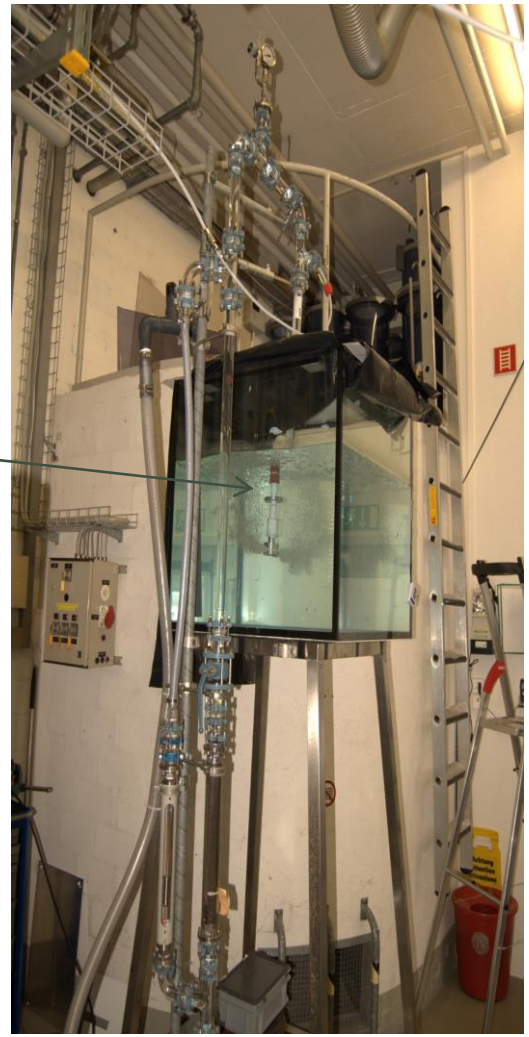

Case without internal baffles




Case with internal baffles

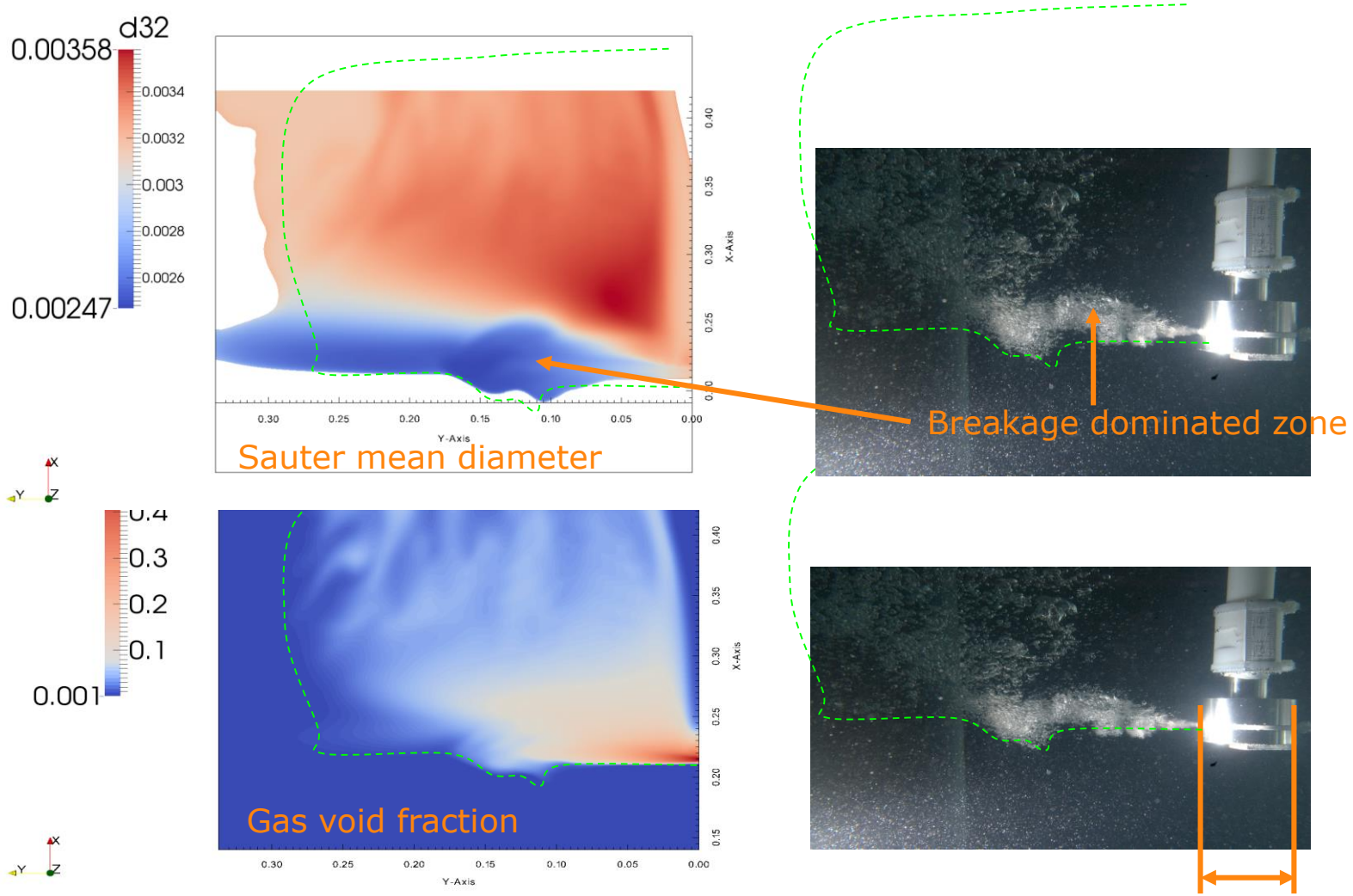
# Ozonation using a radial diffuser



- Q: what are the most efficient  Ozone injectors
- Q: based on feed conditions, what is the efficiency of the chemical reaction → Ozone dissolved rate, which depends on the bubble diameter distribution
- A: In this case, a radial diffuser was tested, in the Lab. and with TransAT CMFD, for different flow rates

# Ozonation using a radial diffuser

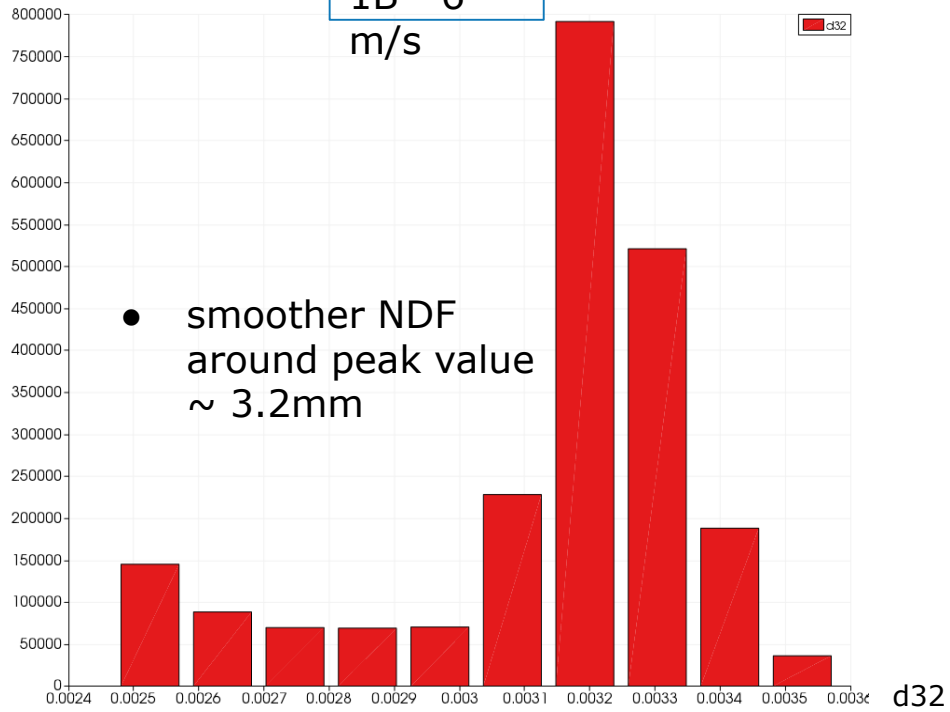


# Ozonation using a radial diffuser

Sauter mean diameter histogram
- spatially averaged values

Nr of samples

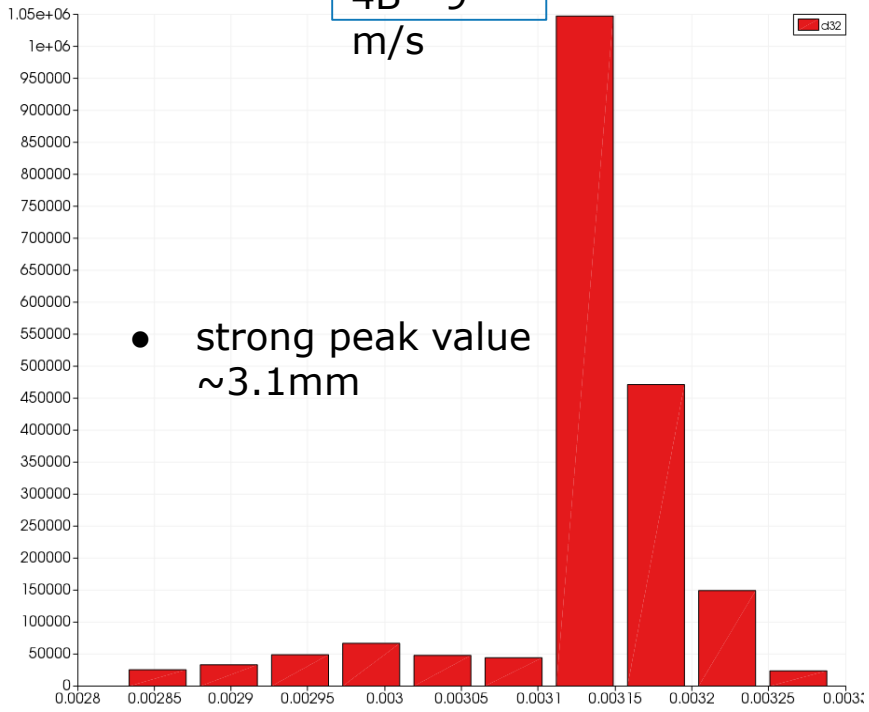
1B - 6 m/s




d32

- smoother NDF around peak value ~ 3.2mm

4B - 9 m/s

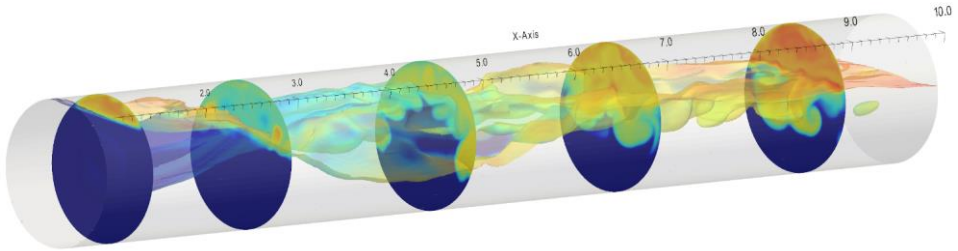



- strong peak value ~3.1mm

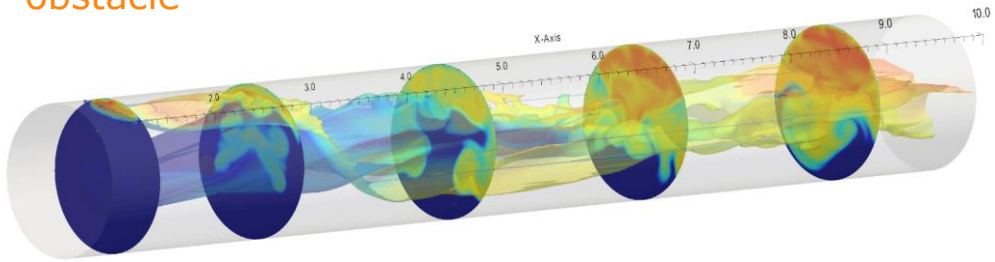
# Ozonation using a radial diffuser

Isosurface vol fr. O3g = 0.001

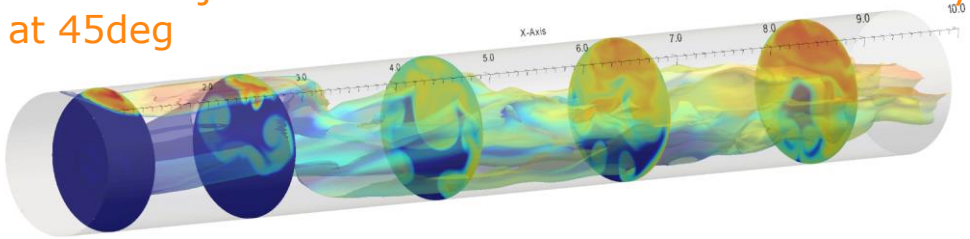
Case 2: VLES, inlet perturbation, full diffuser

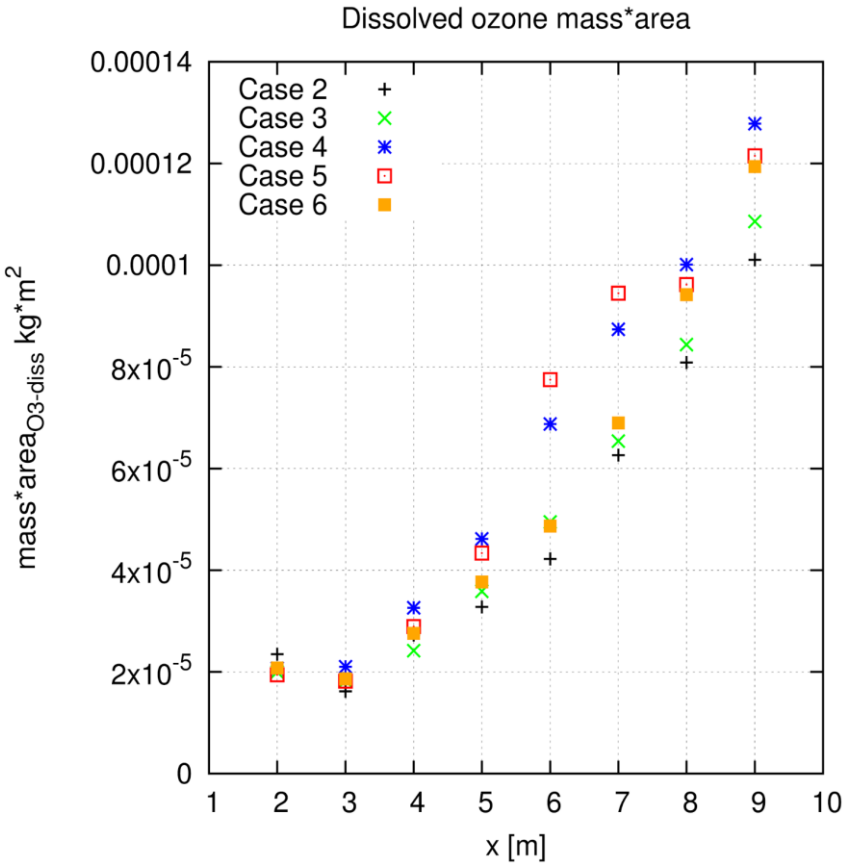



Case 5: Injection at bottom half and cylindrical obstacle

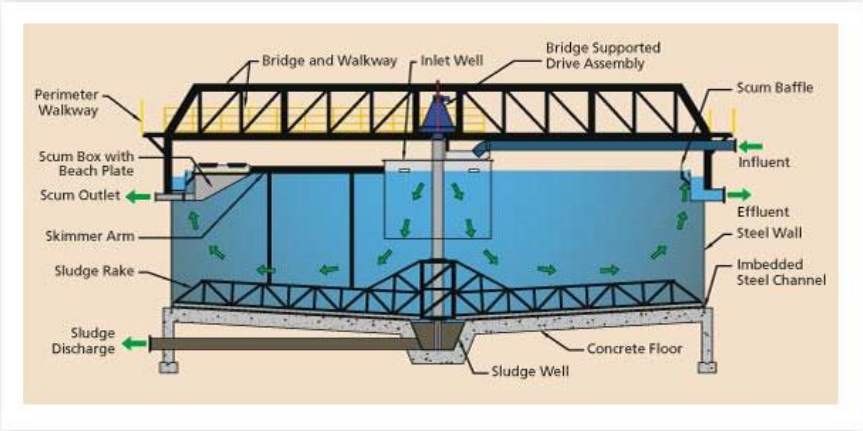



Case 4: injection at the bottom half of diffuser only at 45deg

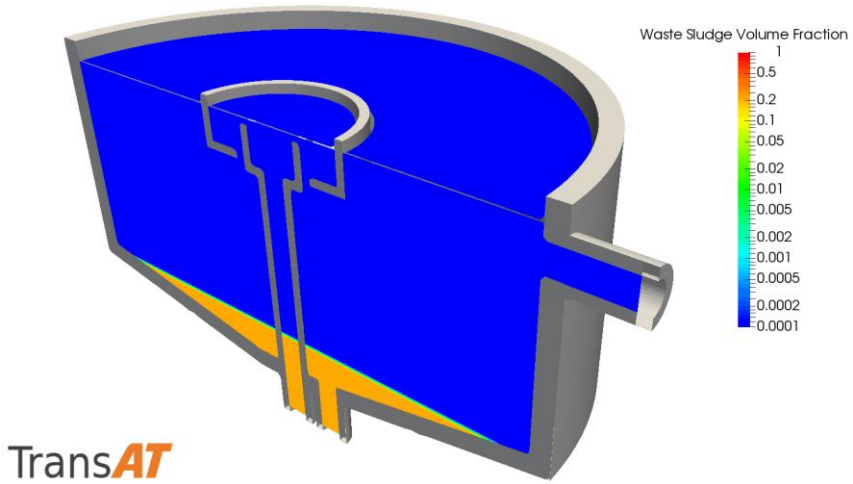


# Separation in secondary clarifiers (example)



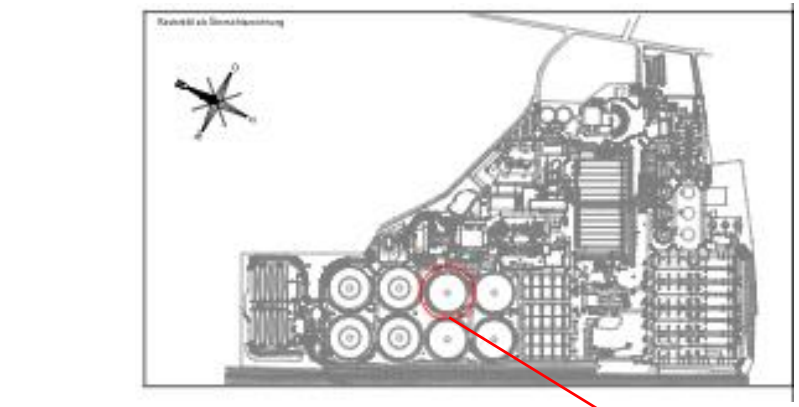

- Basic dimensioning
- Optimized working conditions, incl. Resident time
- Operation under dry and wet conditions
- Overall flow quality

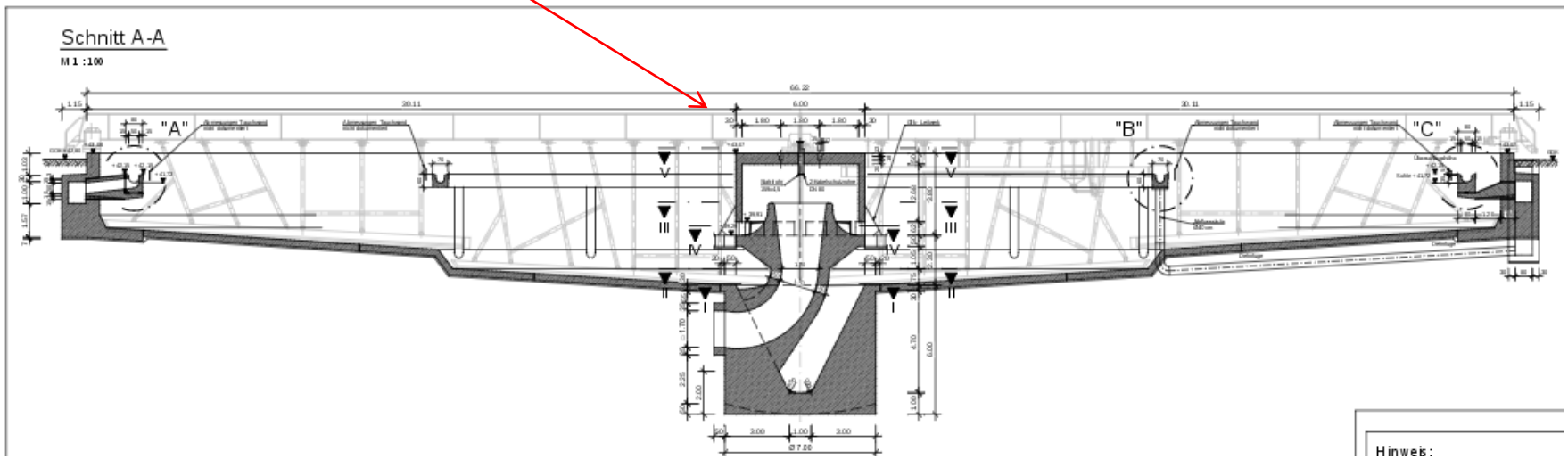



- 3D Simulation
- Transient (unsteady)
- Three-phase flow
- Sludge deposition and packing

# Separation in secondary clarifiers (example)

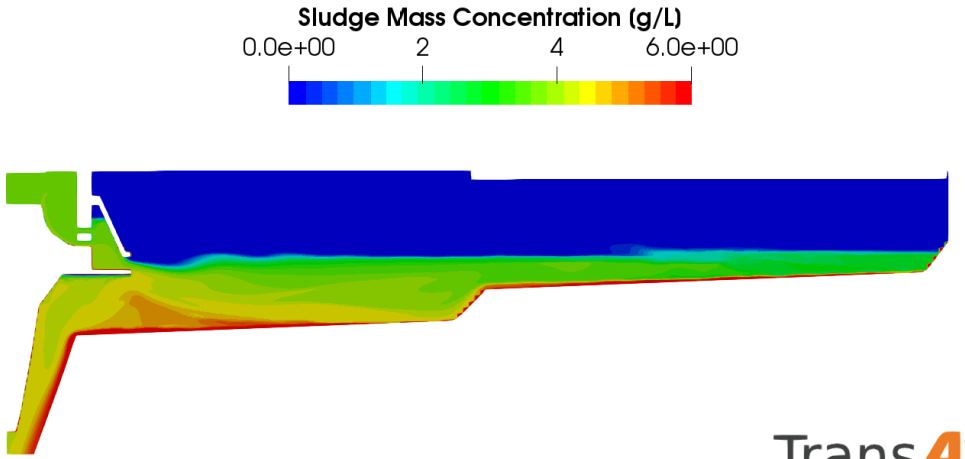
CASE STUDY: WASTE-WATER PLANT IN KÖLN STAMMHEIM, GERMANY






- Köln Stammheim Anlage
- 08 KB
- Maximum hydraulic loading
- Check differences in inflow

# Separation in secondary clarifiers (example)

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- Basic dimensioning
- Optimized working conditions, incl. Resident time
- Loading under dry and wet conditions with unsteady inflow
- Scrapping mechanism
- Overall flow quality

- 2D axisymmetric Simulation
- Transient (unsteady)
- Two-phase flow
- Sludge deposition
- Packing and thickening
- Bingham Rheology of the sludge



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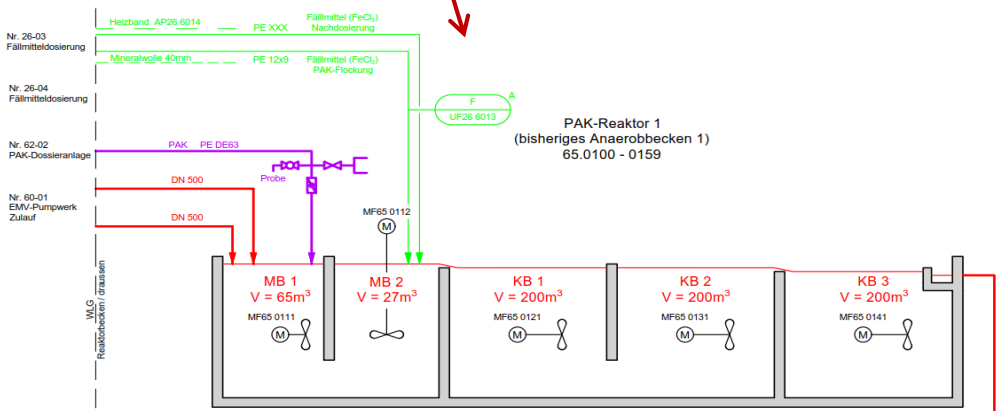
# Particle activated carbon (PAC) WWTP

AN EXISTING PLANT/PROJECT IN ZUG (CH)




- Basic dimensioning (change the size and position of the bassin)
- Premixing of Water with PAC in bassin (MB1)
- Mixing of Product with Fe(III)CL  in bassin (MB2)
- Flocs formation (avoid separation) and efficient complete removal … KB3

- 3D Simulation
- Transient (unsteady)
- Three phases: water & PAC, air, and flocs
- Flocs production via chemical reaction (Fe(III)+PAC)
- Flocs deposition and non-Newtonian Rheology

# Particle activated carbon (PAC) WWTP

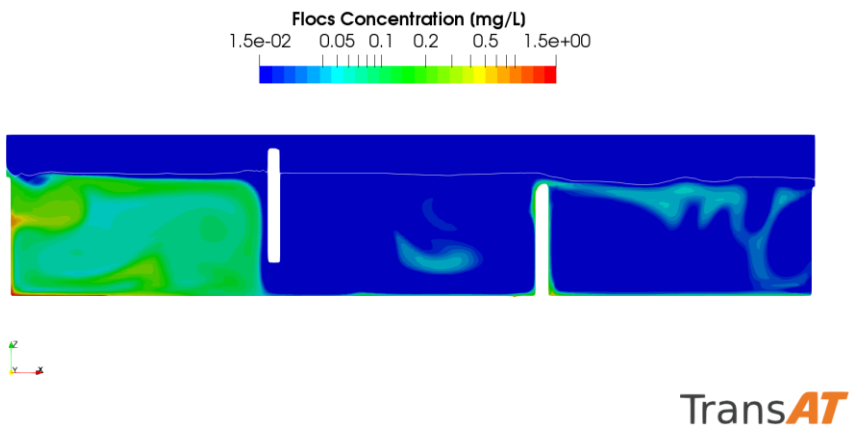
ADVANCED MODELLING OF (3 STEPS) REACTIONS SET: FLOCS PHOSPHATE REMOVAL

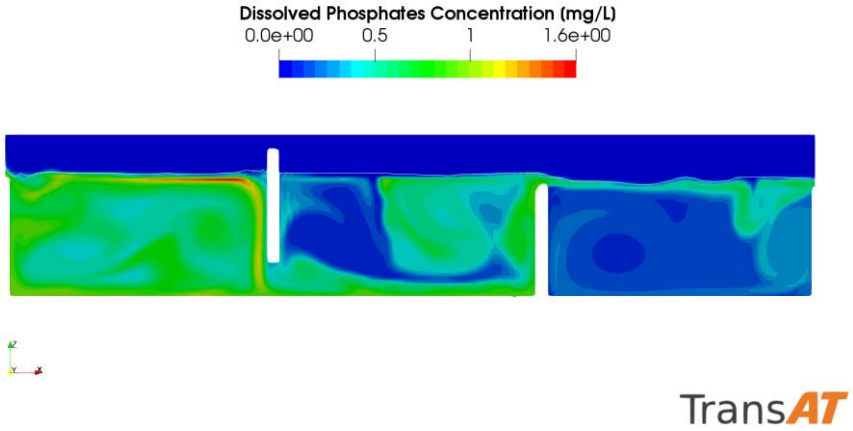
1. **Precipitation** of ferrite oxides:
   HFO (aq) → HFO(s)
2. **Complexion** of Phosphates (small flocs formation):
   HFO(s) + P(aq) → HFOP(s)
3. **Flocculation** (further complexion of Phosphates):
   HFOP(s) + n.P(aq) → HFOPn (s)

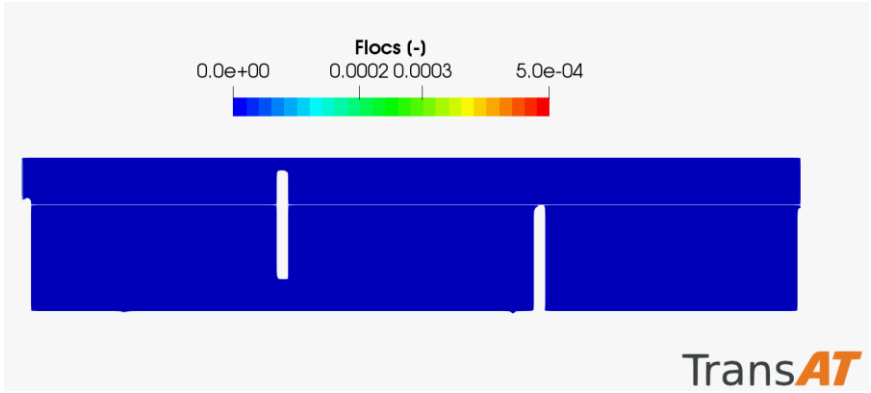
**Summary of CFD modelling for this problem:**

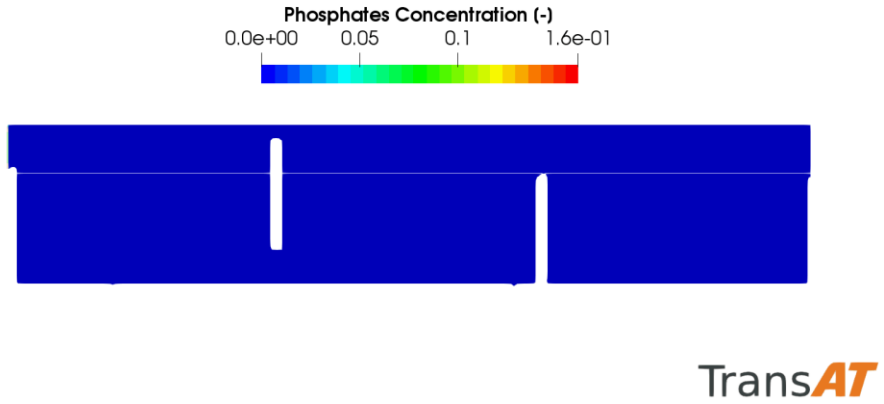
- All chemicals are represented as phases in a mixture models
- Adding new reactants and reactions is easy
- Inter-phasic reactions can be modelled as desired by the user (kinetics, stoichiometry) via a UDF routine

# Early results with mixing enhancement

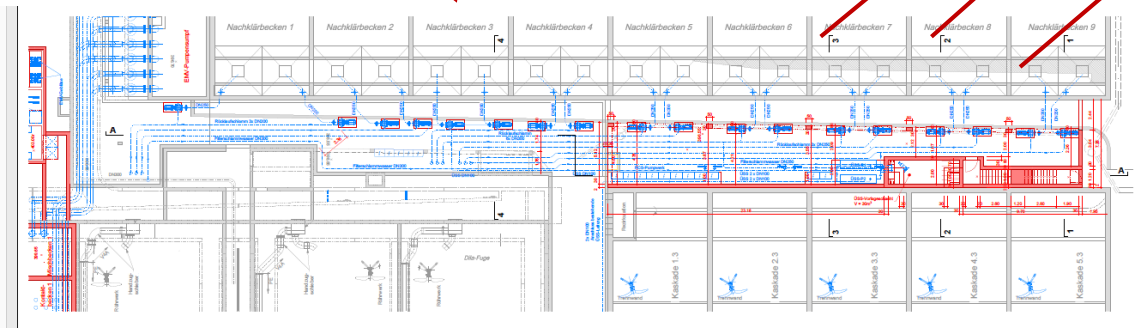


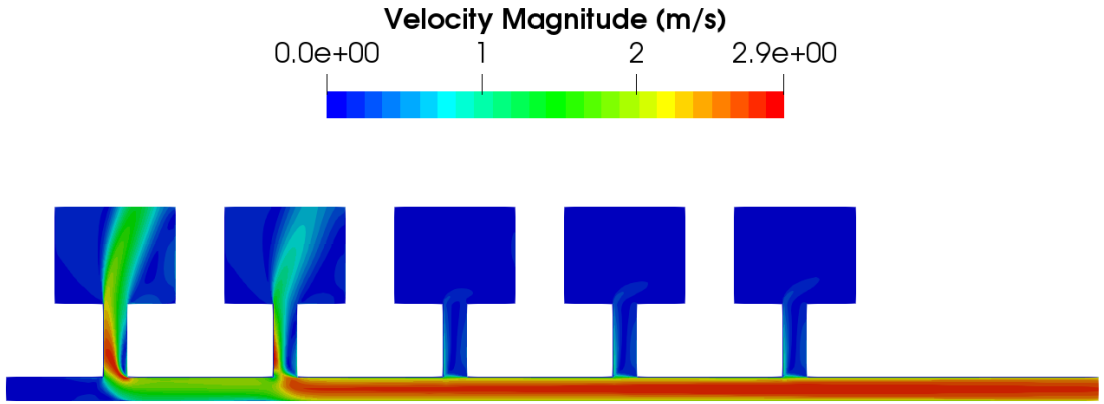



# Flow maldistribution in secondary clarifiers



# Flow maldistribution in secondary clarifiers

UNDER STORM CONDITIONS, UP TO 30% OF MALDISTRIBUTION CAN BE OBSERVED!




… Flow mal-distribution increases with resistance to the flow, and with hydraulics loading of the bassins.

… the situation is different under multiphase flow conditions, and for sludge (particle suspension) flows.

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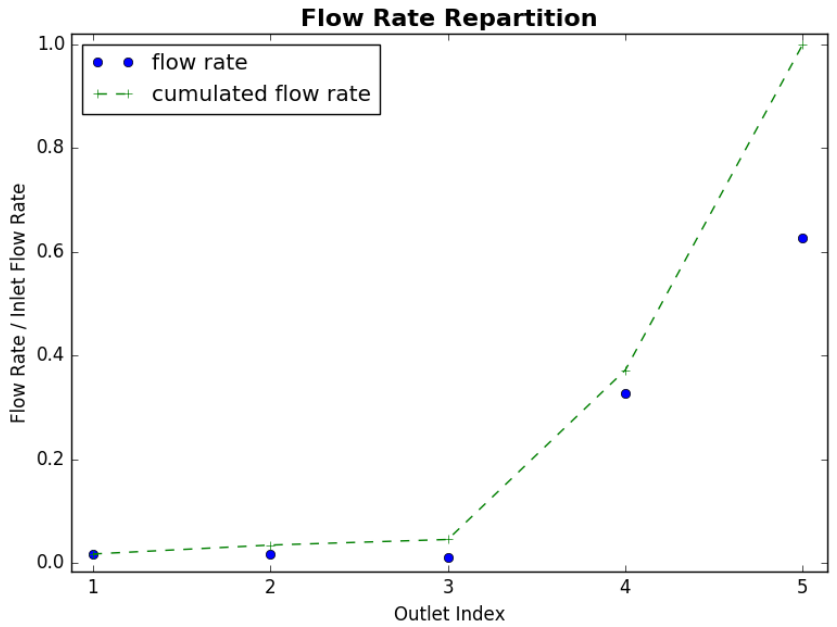




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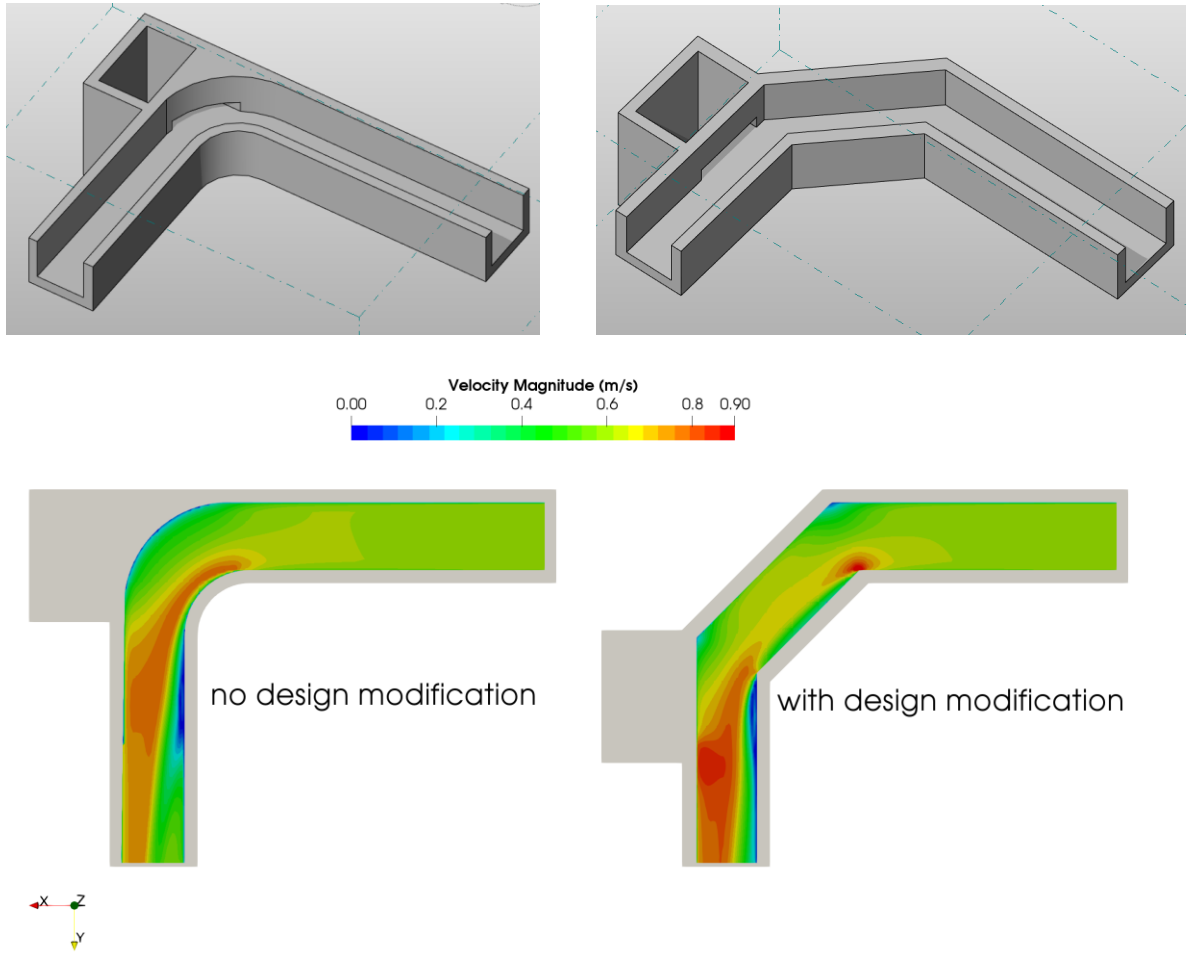
# Gravel collection design in water clarifier




- Gravel collector is conceived differently in the channel of a water clarification plant
- The flow of water informs about wether design is acceptable or not, and where it should be placed in the channel to remove efficiently the gravel

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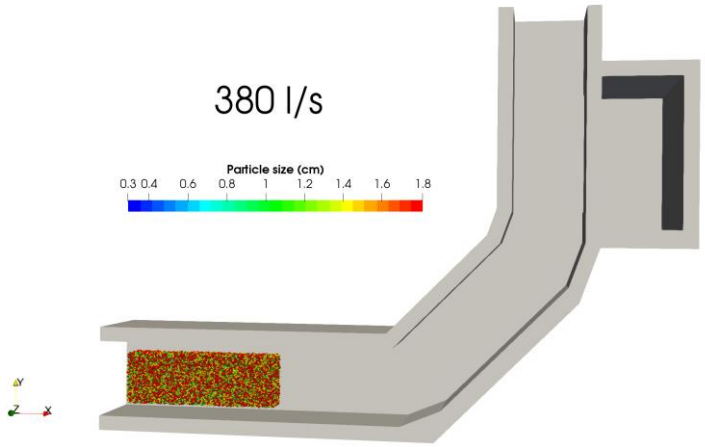
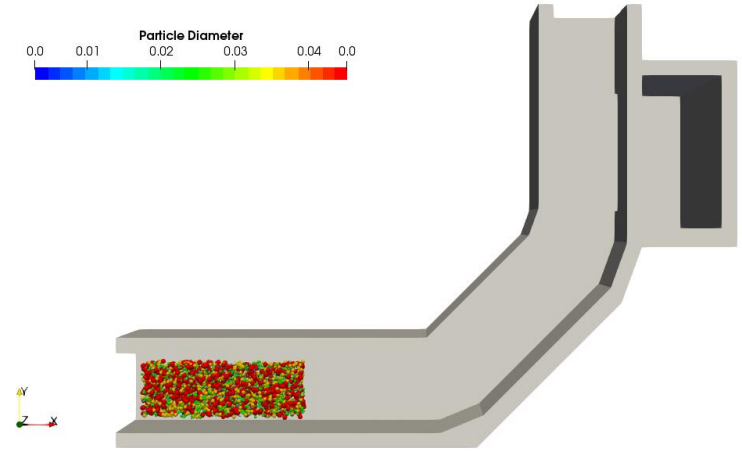
# Gravel collection design in water clarifier




- Simulation with gravel travelling with the flow shows that the particles located at the bed of the channel do not follow the flow streamlines towards the collector, as though from the earlier simulations
- Bundary layer effects deviate the gravel away from the collector indeed. Only suspended particles subject to higher fluid velocity field can be trapped in the collector
- The design has been abondoned in favour of another alternative

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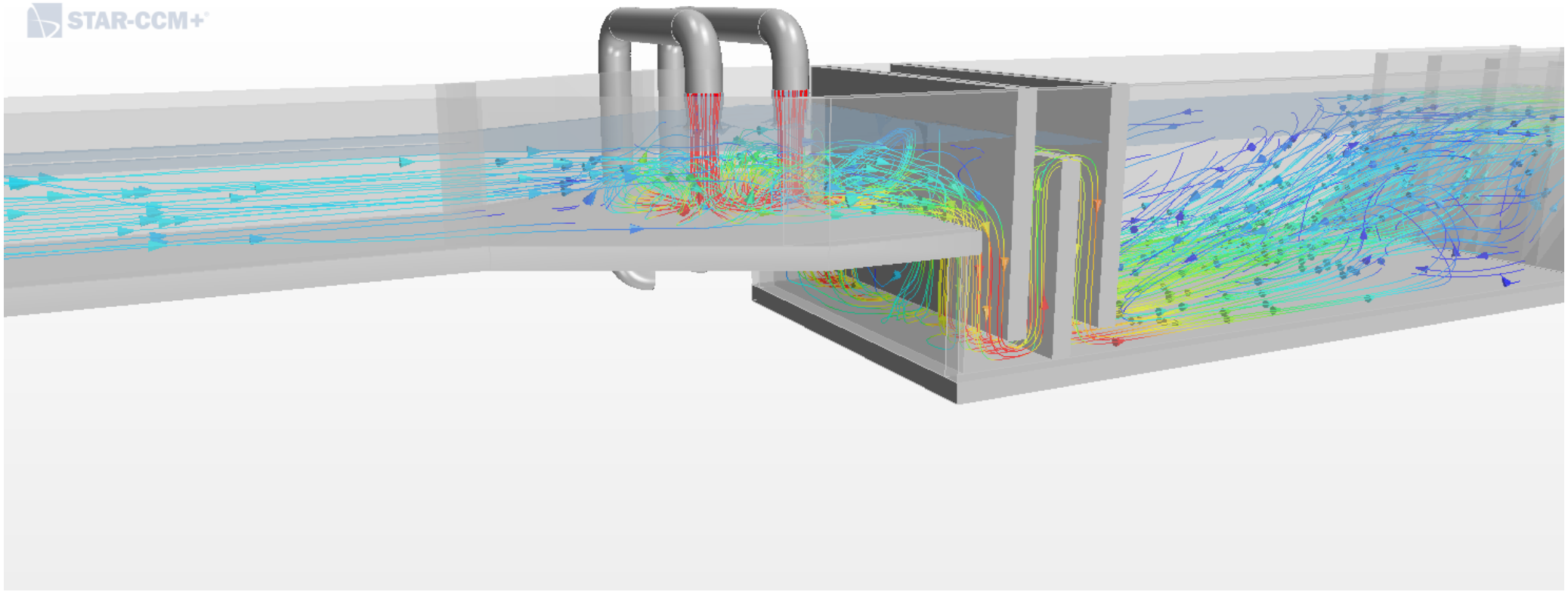
EVEN DISTRIBUTION OF WATER



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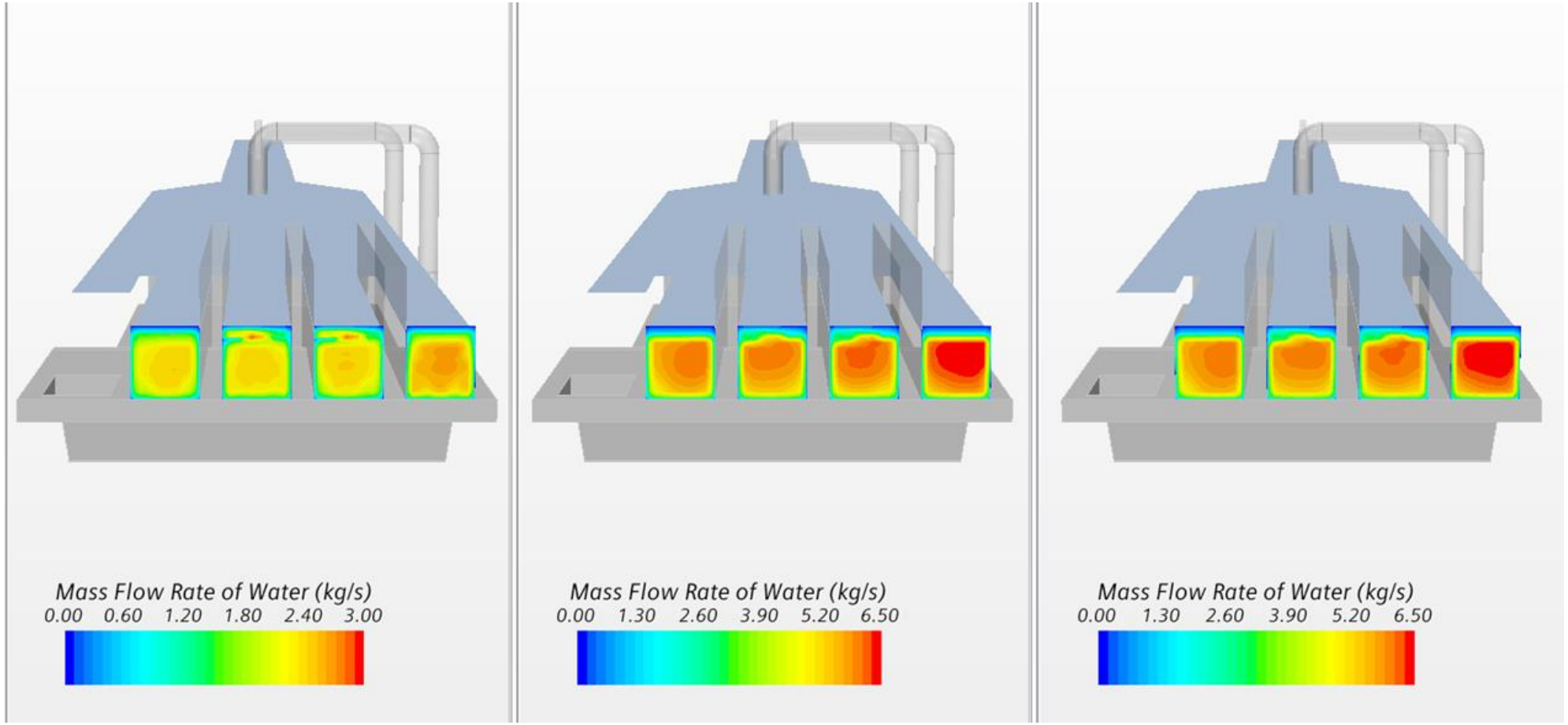
DISTRIBUTION STUDY

## Pipe placement, Chicanes and Design for optimal distribution



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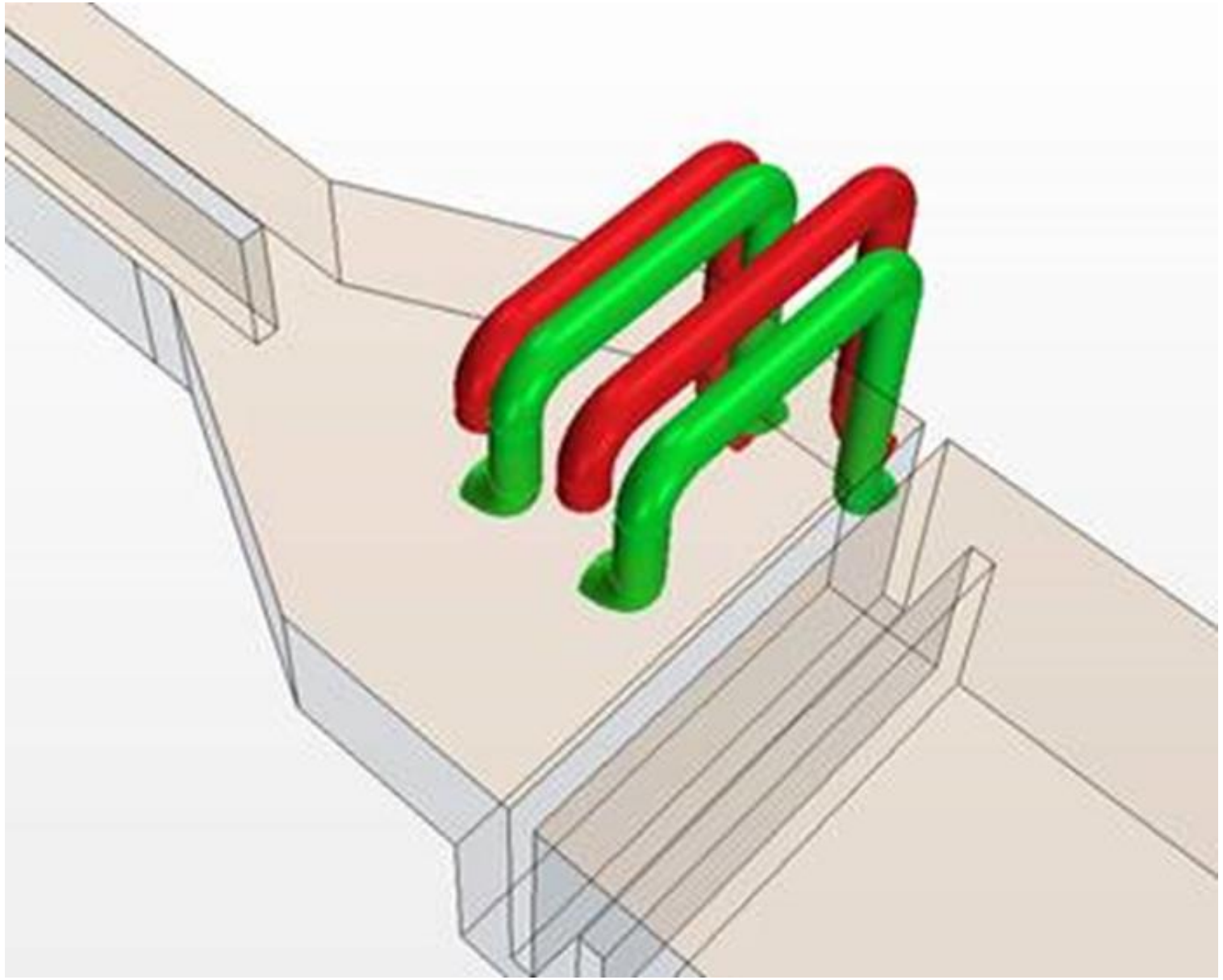
DISTRIBUTION STUDY

Design Change of Pipes

- Original (directed downward)
- New (directed upstream)



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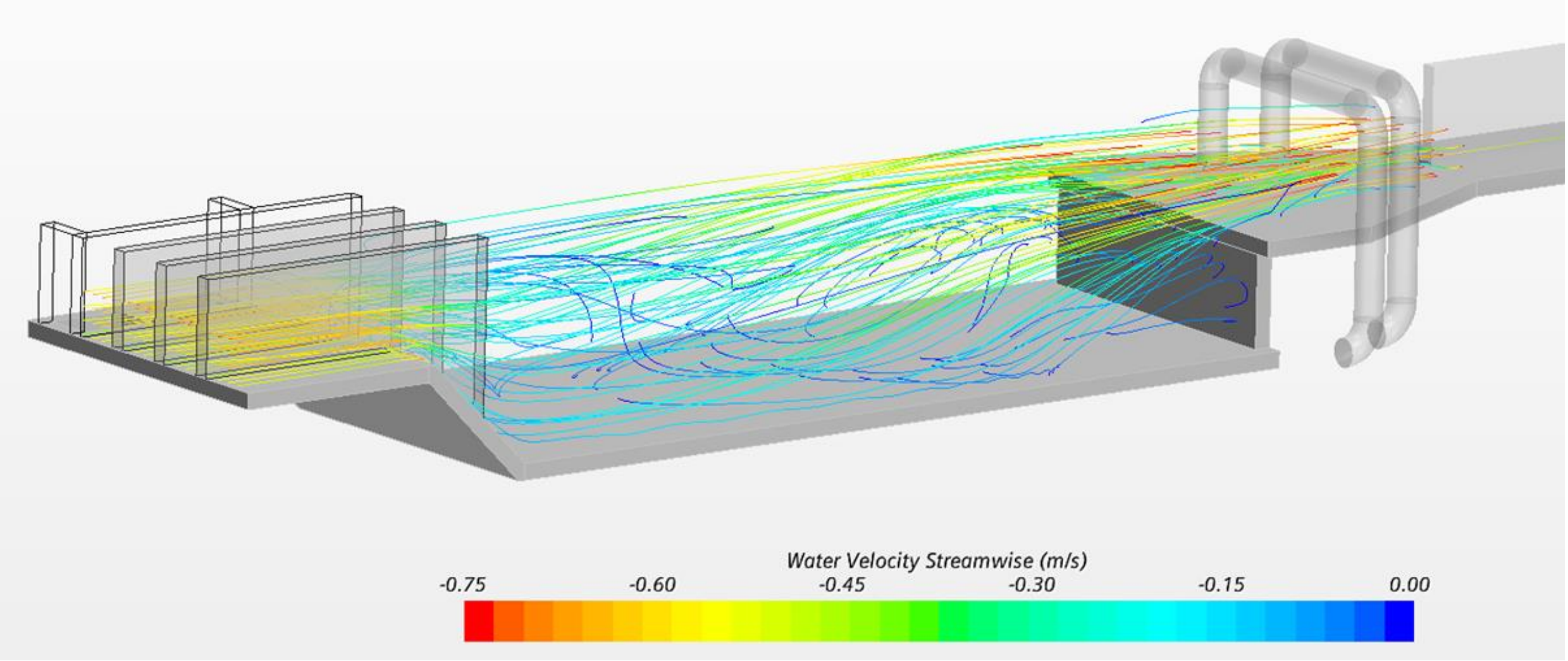
DISTRIBUTION STUDY

## Streamlines, and Identificaiton of Recircluation Zones



# Making Future