# Modelling of water quality in sewer-WWTP systems during normal and extreme conditions

Period : Oct 2010 – Sep 2013


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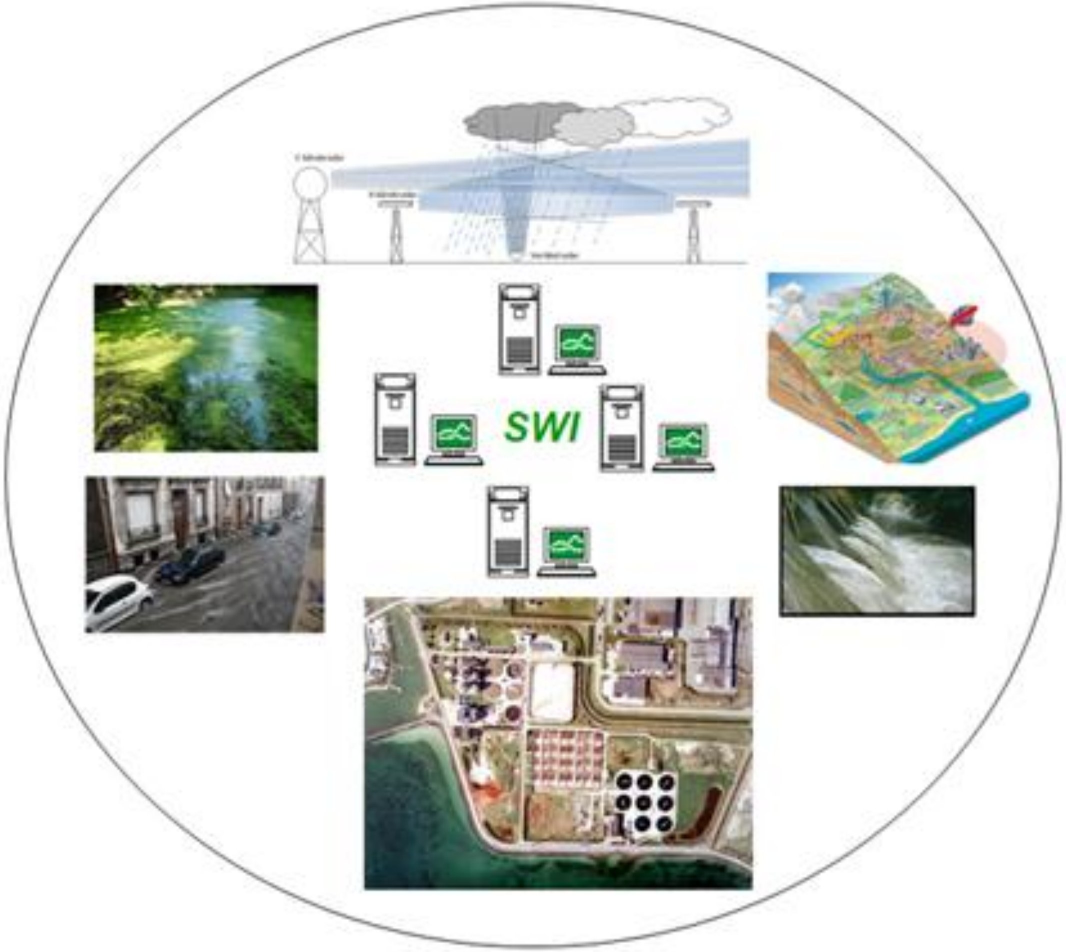
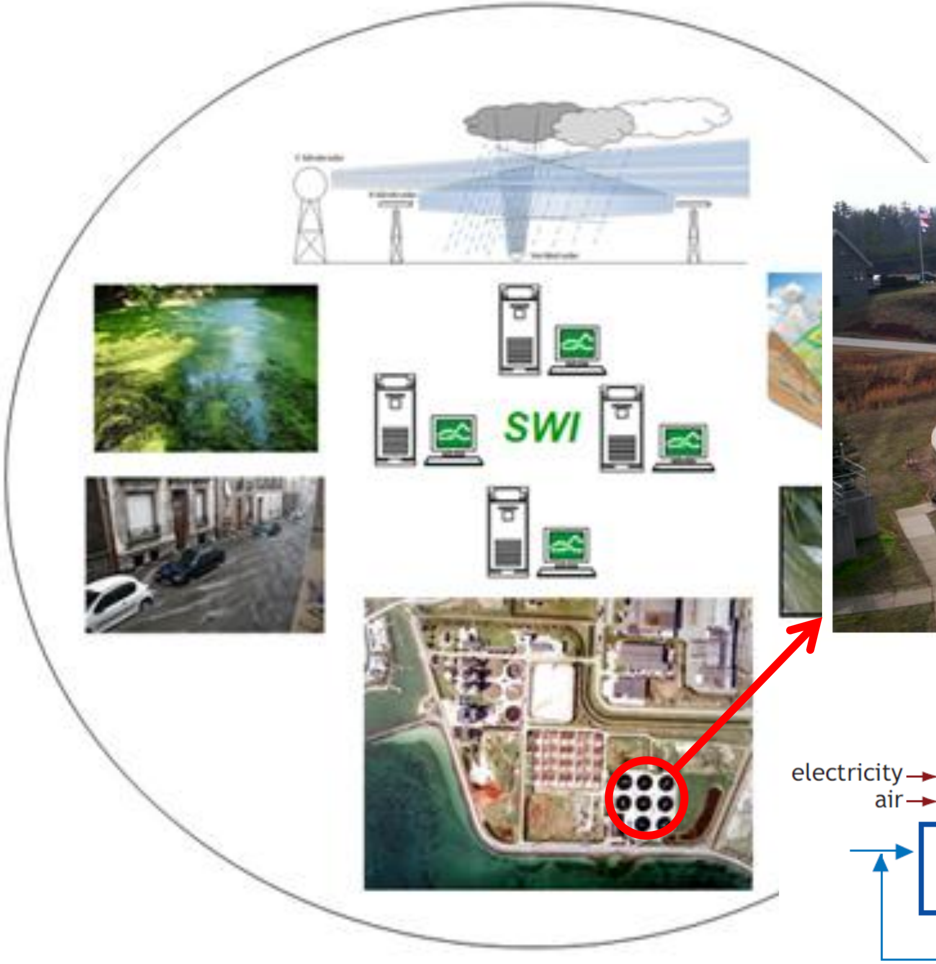
**DTU Environment**

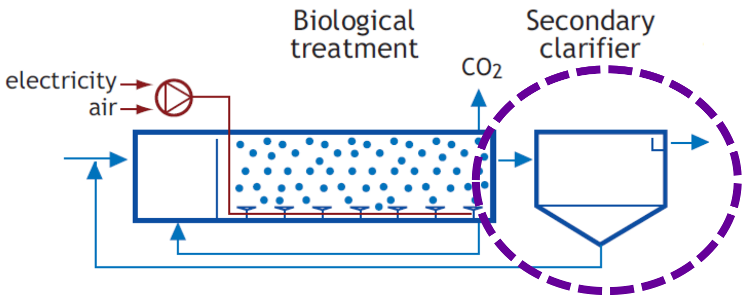
Department of Environmental Engineering

# Introduction

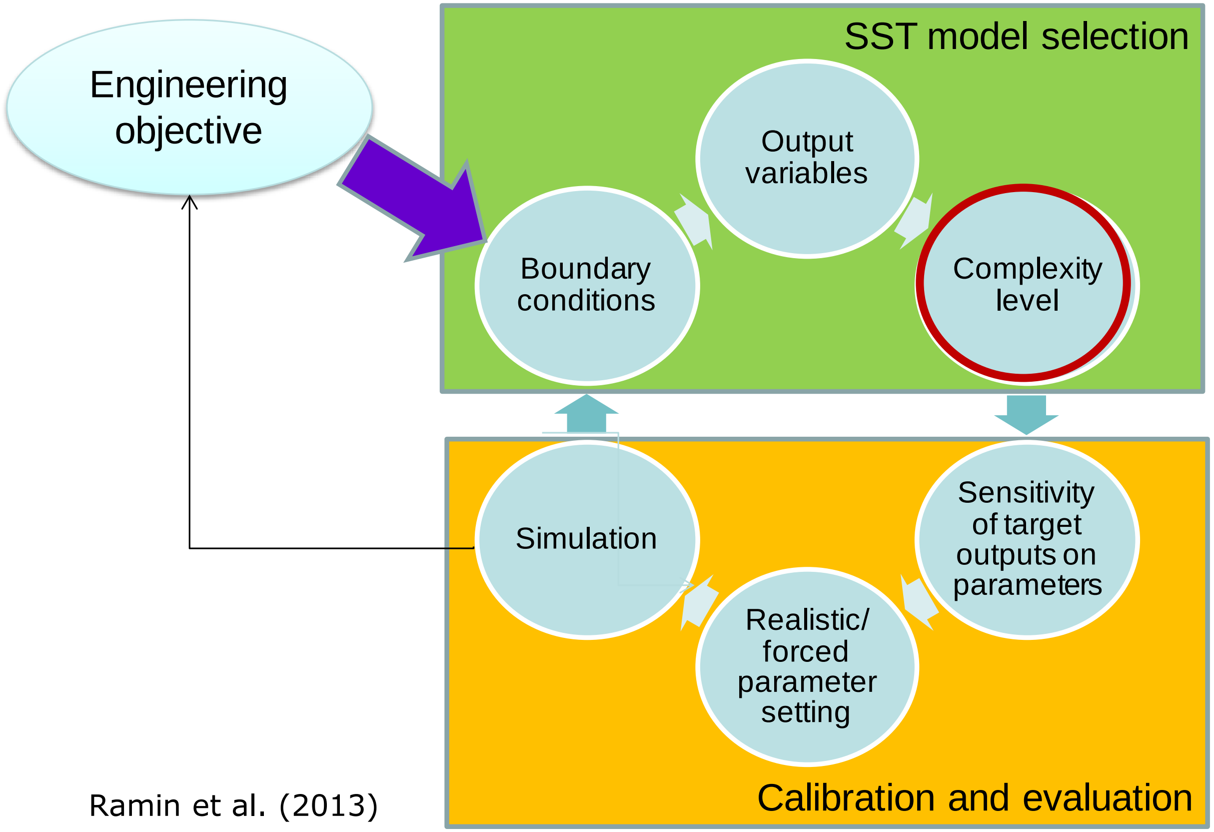


# Introduction



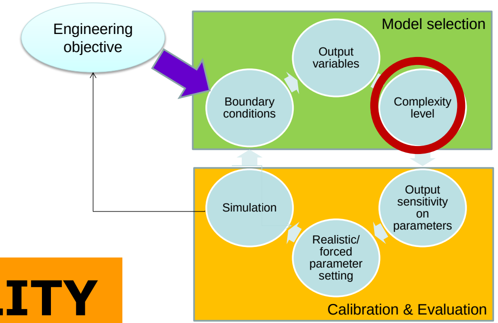
# Modelling of Secondary Settling Tanks




Ramin et al. (2013)

## Secondary Settling Tank (SST) Modelling:

# Complexity level

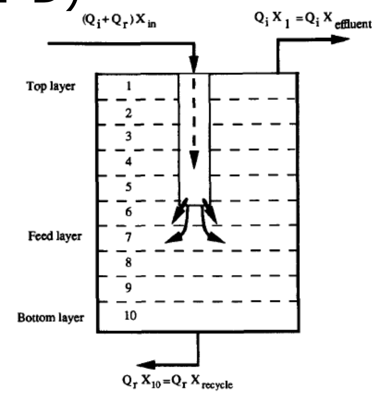



**PROCESS**

- **Advection**
- **Gravity settling**
- **Compression settling**
- **Lumped dispersion**
- **Flocculation**
- **Molecular viscosity**
- **Turbulent viscosity**
- **Turbulence**
- **Density**
- **Velocity gradient**

**DIMENSIONALITY**

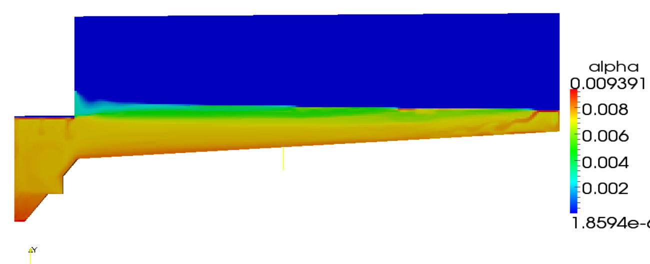
- One dimensional (1-D)




Takács et al. (1991)

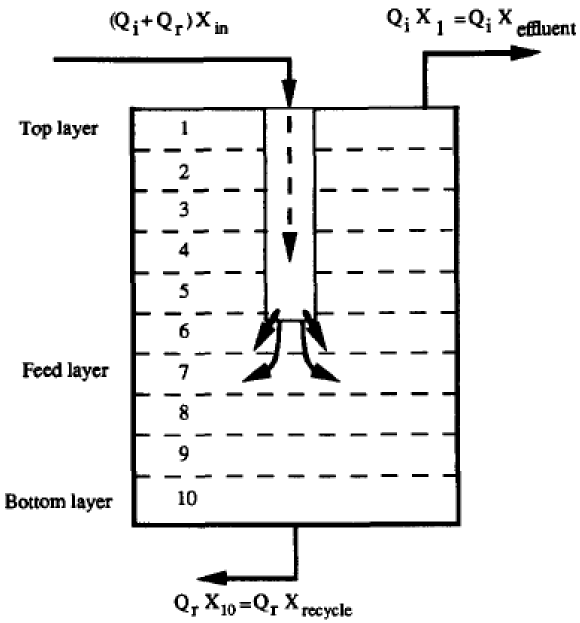
- Two- and three-dimensional models:

Computational Fluid Mechanics (CFD)



# 1-D Secondary settling tank models

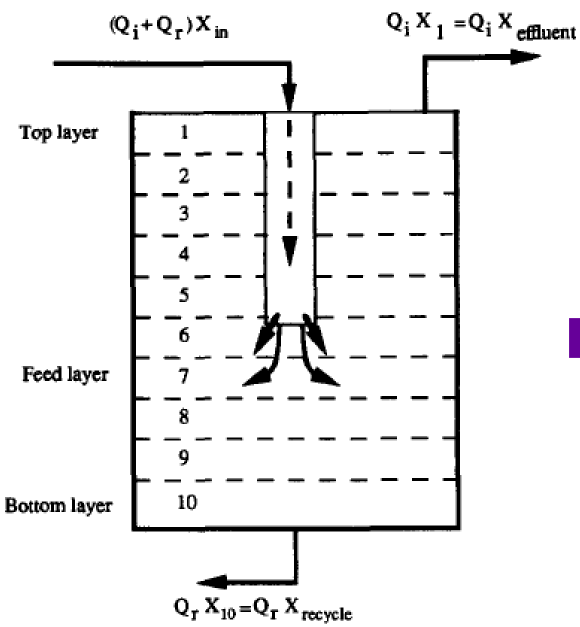
$$-\frac{\partial X_{TSS}}{\partial t} = U\frac{\partial X_{TSS}}{\partial z} - \frac{\partial (v_s X_{TSS})}{\partial z}$$



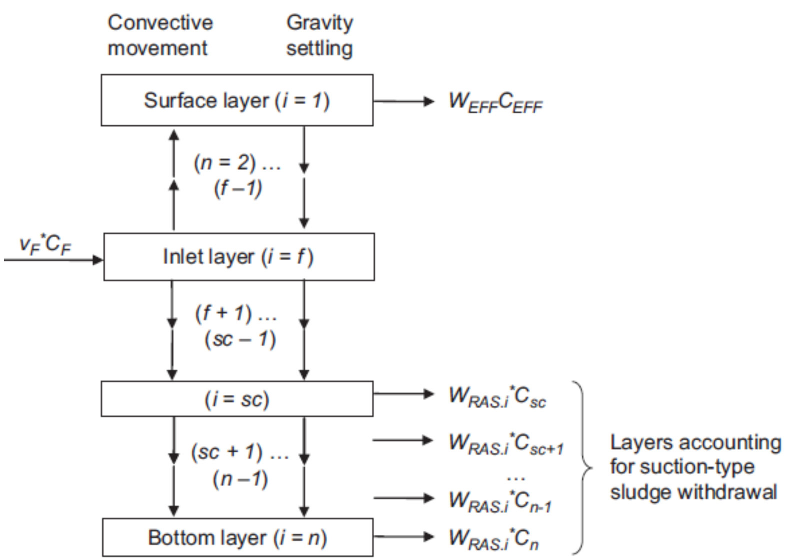

Takács et al. (1991)

# 1-D Secondary settling tank (SST) models

$$-\frac{\partial X_{TSS}}{\partial t} = U\frac{\partial X_{TSS}}{\partial z} - \frac{\partial (v_s X_{TSS})}{\partial z} - D_C \frac{\partial^2 X_{TSS}}{\partial z^2}$$




Takács et al. (1991)




Plósz et al., 2007

# 1-D Secondary settling tank (SST) models

$$-\frac{\partial X_{TSS}}{\partial t} = U\frac{\partial X_{TSS}}{\partial z} - \frac{\partial (v_s X_{TSS})}{\partial z} - D_C\frac{\partial^2 X_{TSS}}{\partial z^2}$$

$$v_S = v_0\left(e^{-r_H(X - f_{NS}\cdot X_F)} - e^{-r_p(X - f_{NS}X_F)}\right)$$

# 1-D Secondary settling tank model parameters

$$-\frac{\partial X_{TSS}}{\partial t} = U\frac{\partial X_{TSS}}{\partial z} + \frac{\partial (v_s X_{TSS})}{\partial z} - D_C \frac{\partial^2 X_{TSS}}{\partial z^2}$$

$$v_S = v_0\left(e^{-r_H(X - f_{NS} \cdot X_F)} - e^{-r_p(X - f_{NS} X_F)}\right)$$

Measurable parameters:
(Settling Characteristics)

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# 1-D Secondary settling tank model parameters

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$$v_s = v_0\left(e^{-r_H(X - f_{NS}\cdot X_F)} - e^{-r_p(X - f_{NS}X_F)}\right)$$

Measurable parameters:
(Settling Characteristics)

Calibrated parameter:
(Design&flow Characteristics)

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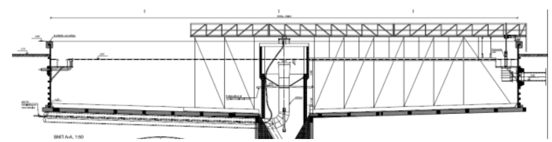
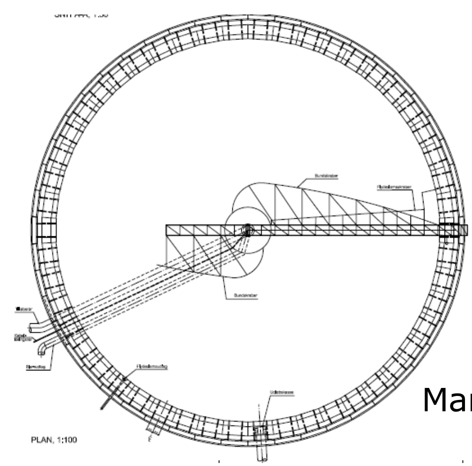





Marselisborg WWTP

# Phase I. Global sensitivity Analysis

**Objective**

Show the **significance** of explicit **model parameters and dynamic behavior** of **1-D secondary settler models** on the biokinetic model **prediction in WWTP models**

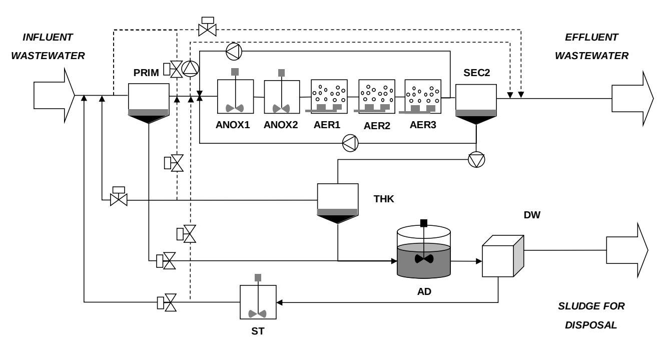
# Relative importance of secondary settling tank models in WWTP simulations – A global sensitivity analysis using BSM2

Elham Ramin, Xavier Flores-Alsina, Gürkan Sin, Krist V. Gernaey, Ulf Jeppsson, Peter Steen Mikkelsen, Benedek Gy. Plósz*

## Parameters

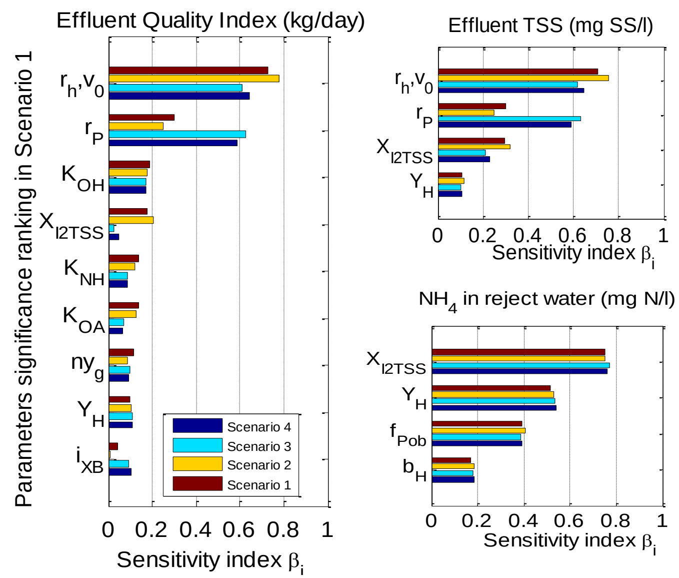
$mu_H$ = [3; 5]
$K_S$ = [5 ;15]
$K_{OH}$ = [0.1; 0.3]
$K_{NO}$ = [0.25; 0.75]
$b_H$ = [0.29 ;0.32]
$mu_A$ = [0.48 ;0.53]
$K_{NH}$ = [0.50 ;1.50]
$K_{OA}$ = [0.3 ;0.5]
.
.
.
**DSVI = [50 ;200]**
**$r_P$ = [2.7e-3;10e-3]**
**$f_{ns}$ = [1.23e-3 ;2.59e-3]**
**$V_{F,CON}$ = [25; 40]**
**$V_{OV,DIS}$ = [10; 22]**

## Monte Carlo Simulation




MATLAB SIMULINK

## Sensitivity rankings



# Phase II. Fluid dynamics in secondary settling tanks (CFD simulations)

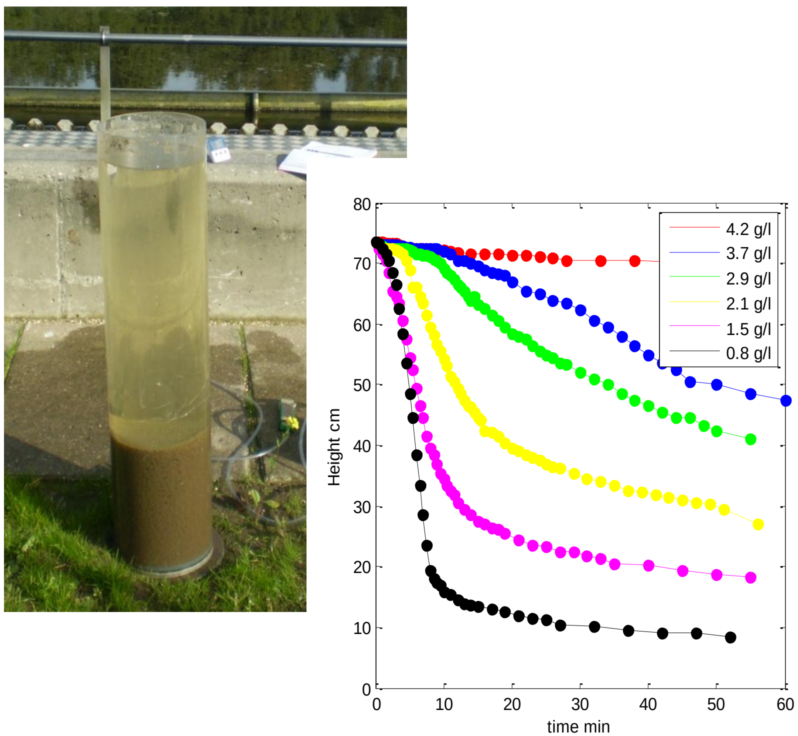
## Objective

To generate **numerical experimental data** sets using transient-to-steady-state (and, if possible, dynamic) CFD simulations for secondary settling tanks with **different design and flow boundary conditions**. We then use the obtained data sets to **optimize and calibrate 1-D secondary settling tank models**.

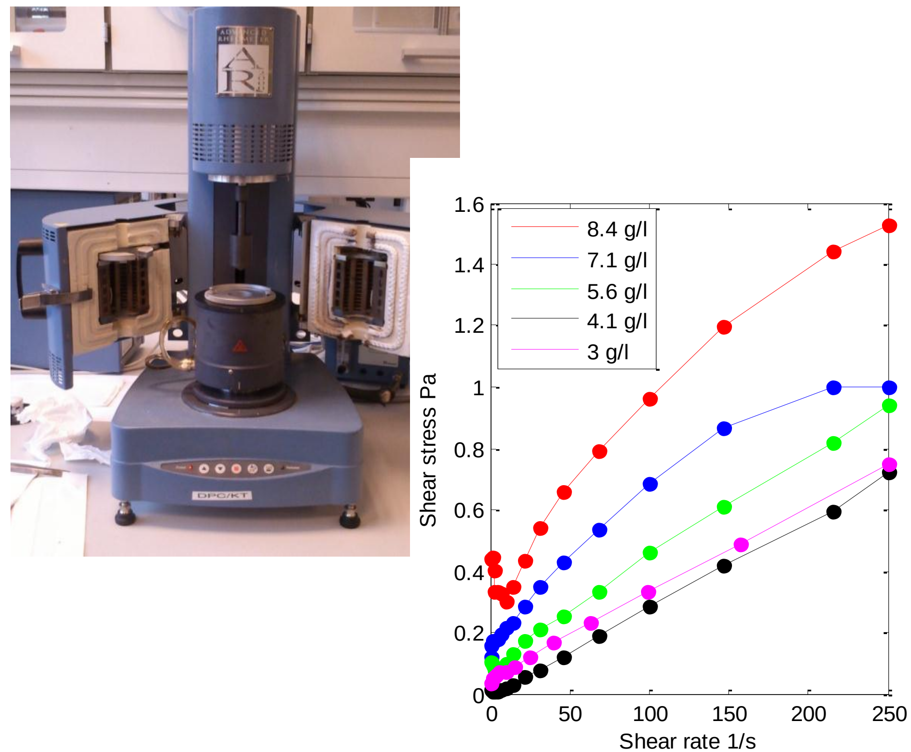
# Phase II. CFD simulations

## 1. Sub-model optimization and calibration

Settling test



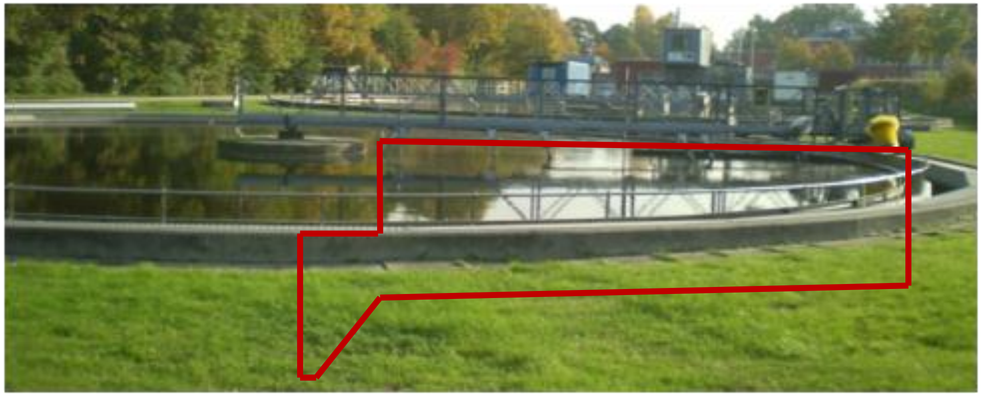

Rheology test



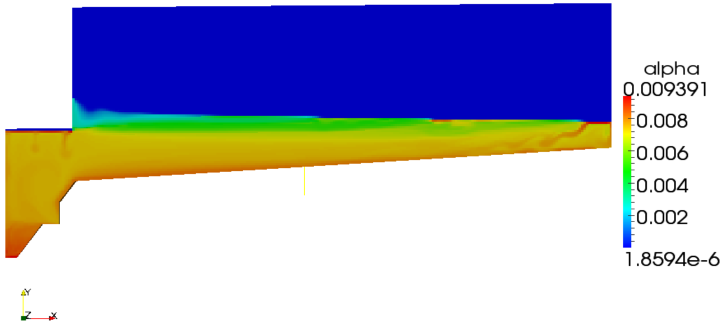
# Phase II. CFD simulations


## 2. CFD simulation of the settling tank

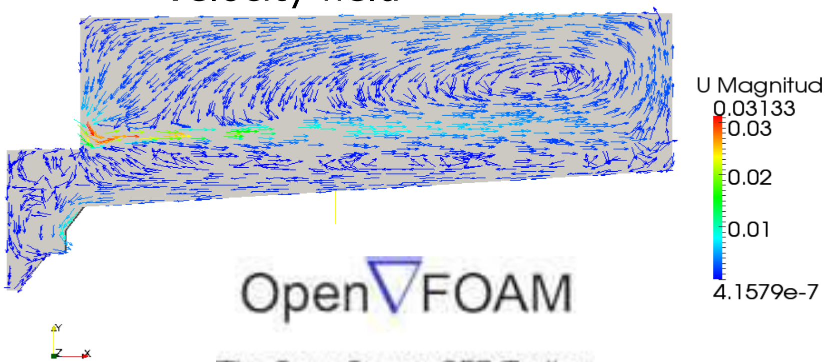
Lundtofte WWTP, Clarifier number 3



Sludge distribution




Velocity field




OpenFOAM

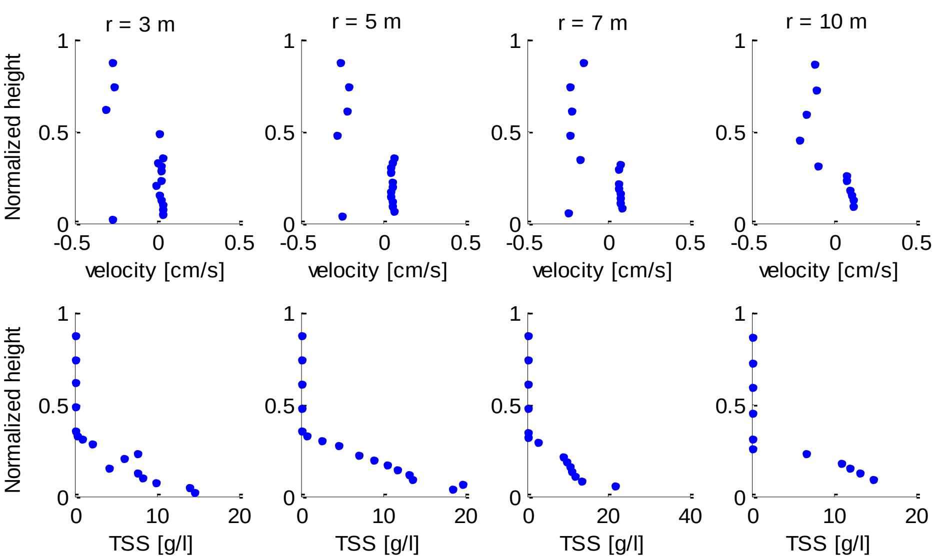
The Open Source CFD Toolbox

# Phase II. CFD simulations

Lundtofte WWTP, Clarifier number 3

## 3. Model evaluation

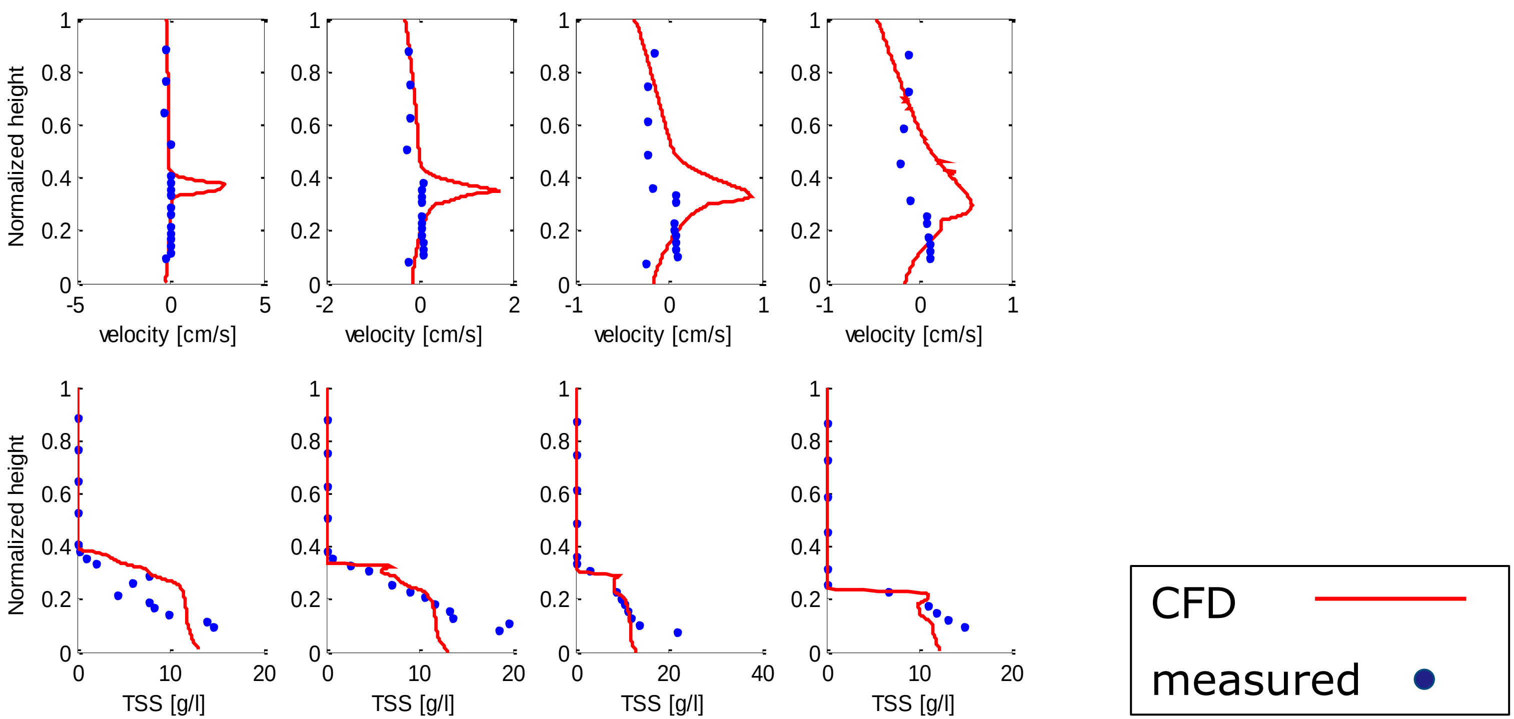
Measurement campaign on a full-scale secobdary settling tank




TSS and velocity sensors used for profile measurements

# Phase II. CFD simulations


Measured vs. simulated profiles



# Phase II. CFD simulations

## 4. Creating an inventory of CFD simulations

In terms of design and flow boundary conditions

# Phase III. optimize and calibrate 1-D secondary settling tank models

**Objective**

A more **mechanistic** way for hydrodynamics modeling in 1-D that could account for **different design and flow** boundary conditions

# 1-D model optimization

**Approach I**: calibrate dispersion, downward convection and dynamic-feed layer position models to account for different clarifier design.

**Approach II**: Testing theories that could unify 1-D hydrodynamic model calibrations obtained for different SST structure

# Thank you!