A probabilistic sewer sedimentation model

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eawag 75 1936-2011 aquatic research

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Motivation

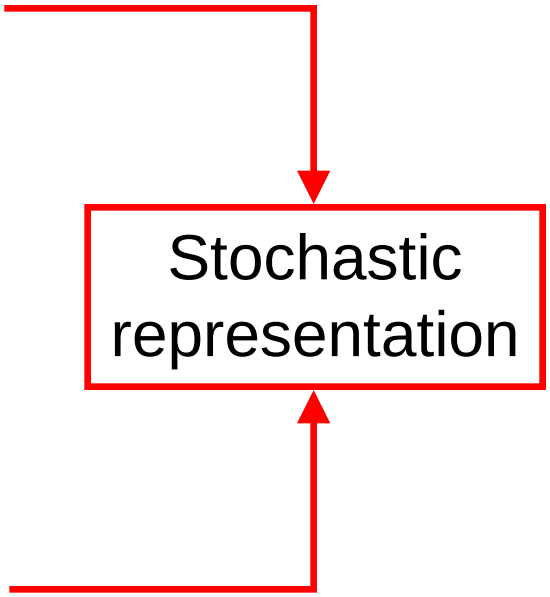
Sediments have detrimental impact on

- Hydraulic capacity
  - Increase roughness
  - Decrease cross-section even blockages
- Aquatic environment
  - Increase loads during wet-weather
  - Flush loads on wastewater treatment plants
- Technical guidelines (UPM, DWA A-128, etc.)
  - How many reaches face sedimentation issues?

Motivation

Knowledge of sediments in a sewer

- Visual investigation
  - Time consuming/ Expensive
  - Weather conditions change sediments characteristics
  - Present situation
- Deterministic modeling
  - Large datasets for calibration
  - Parameter uncertainty
  - Poor models



Aim

Development of a simple stochastic approach to identify the areas with risk of sedimentation

- Comparing to deterministic models
  - Large datasets for calibration
    - A combining a hydrologic model with a stochastic sediment transport model the dataset is reduced to flow measurements.
  - Parameter uncertainty
    - Stochastic variation of parameters
    - (Some) uncertainty is included in the results

Study Catchment

1. Observation of sewer sediments
   (own data and data from operator)
2. Measurements
   (flow – stationary & mobile,
   UV-VIS, automatic samplers)
   - ➡ Sedimentation Tank
   - ➡ Waste water treatment plant
   - ➡ precipitation characteristics

Property	Unit	Value
Area (con)	ha	45
Area (imp)	ha	17
Sewer length	km	12.4

Field study

Impressions of the catchment

Outside...

Field study

Impressions of the catchment

... and inside the sewer

Mathematical modeling

Model development

- Environment: Berkeley Madonna
- Hydrologic Modeling (Euler 1983)
  - Four cascades
  - Variable time-step

Mathematical modeling

Model development

- Environment: Berkeley Madonna
- Hydrologic Modeling (Euler 1983)
- Stochastic sediment transport
  - Surface: Accumulation, Abrasion
    (Schluetter, 1999; Donigian and Huber 1991)
  - Dissolved compounds
  - 4 classes of particles
    (Pernecker and Vollmer 1965; Jacobs *et al.* 1995)
  - Floating materials (Butler *et al*. 2003)
  - Biofilm on pipe wall (Reiff 1992)
- Simplification of the model

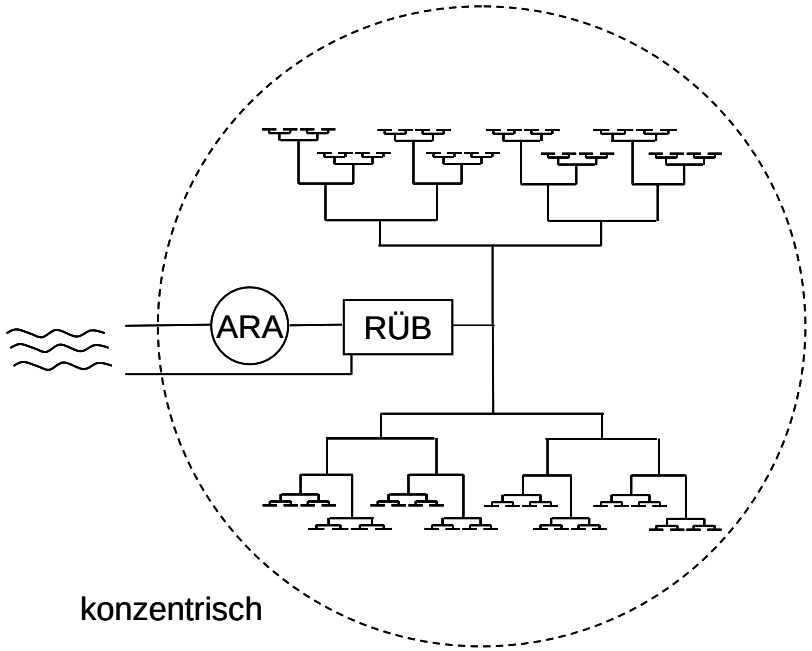
Mathematical modeling

The modeled Catchment

and simplification – structure

- reduction of complexity
  - n classes of diameters with 2^n reaches

real representation



concentric representation

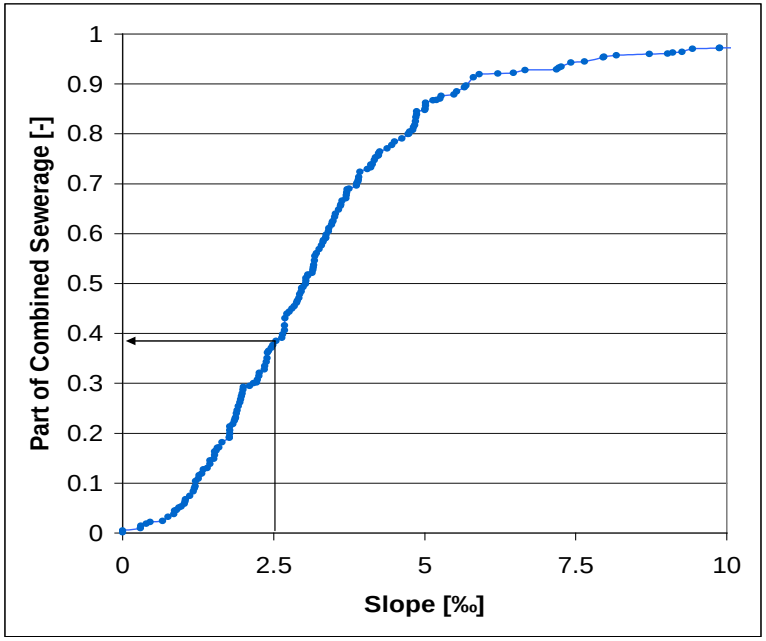
Mathematical modeling

The modeled Catchment

and simplification – properties of reaches

➡ conservation of statistical distribution

- e.g. Slope

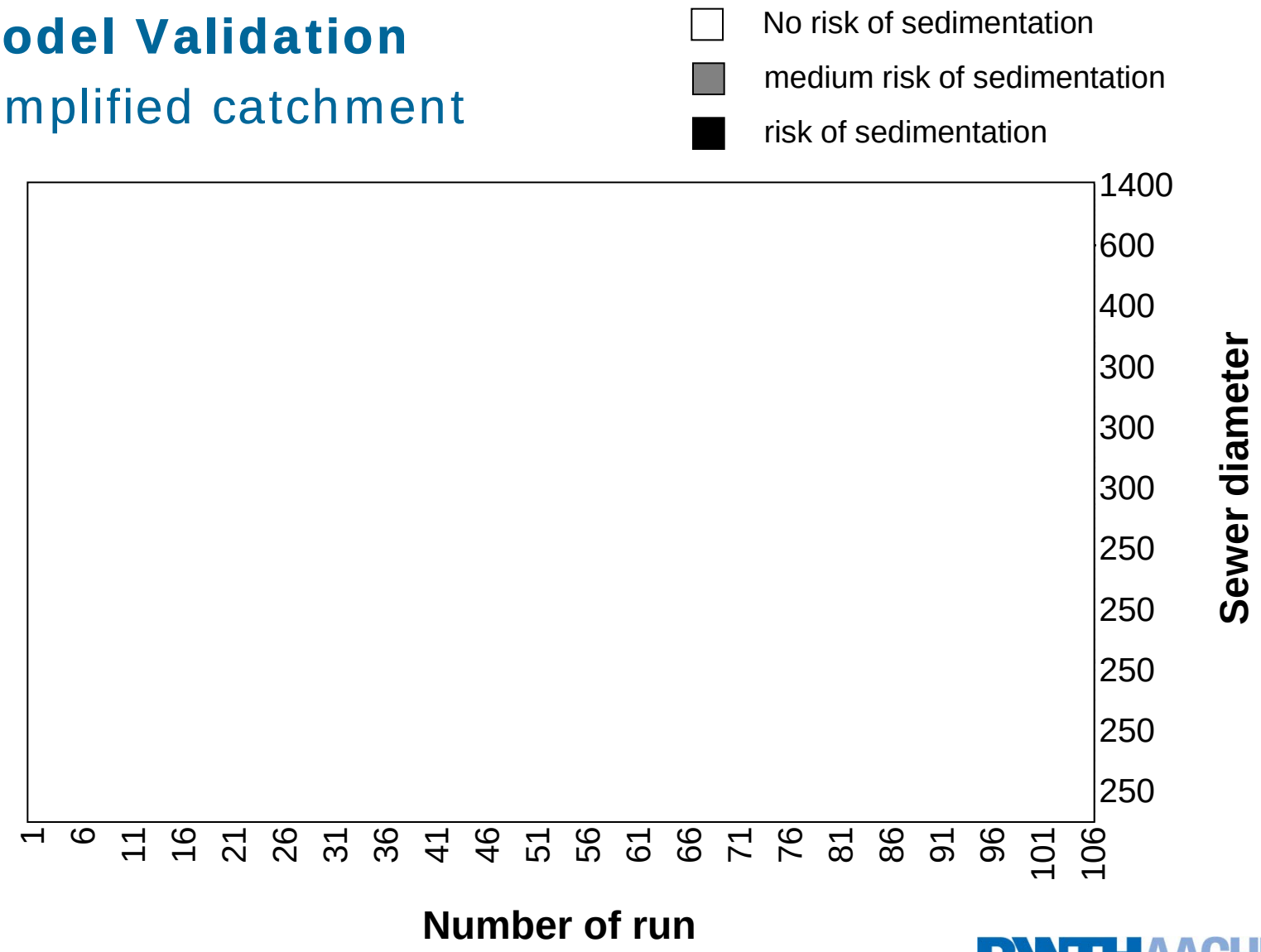


Summary:

- compounds 6
- reaches 4 x 2^6
- Total: 1,536 ODEs

Model Validation

Simplified catchment



Model Validation

Simplified catchment

- Observation

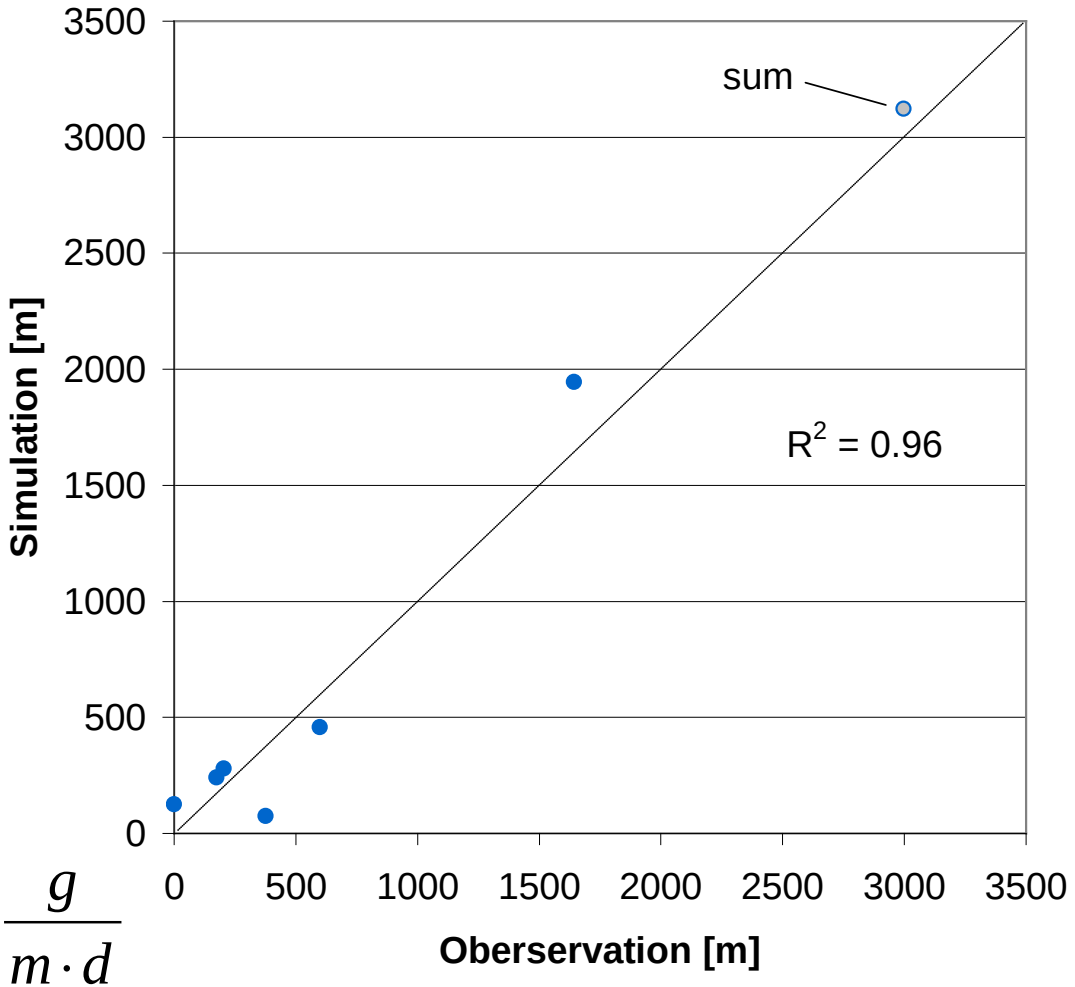
$$l_{s,r} = \sum l_i \text{ for } s > 0$$

- Simulation

$$l_{s,m} = \sum l_i \cdot k$$

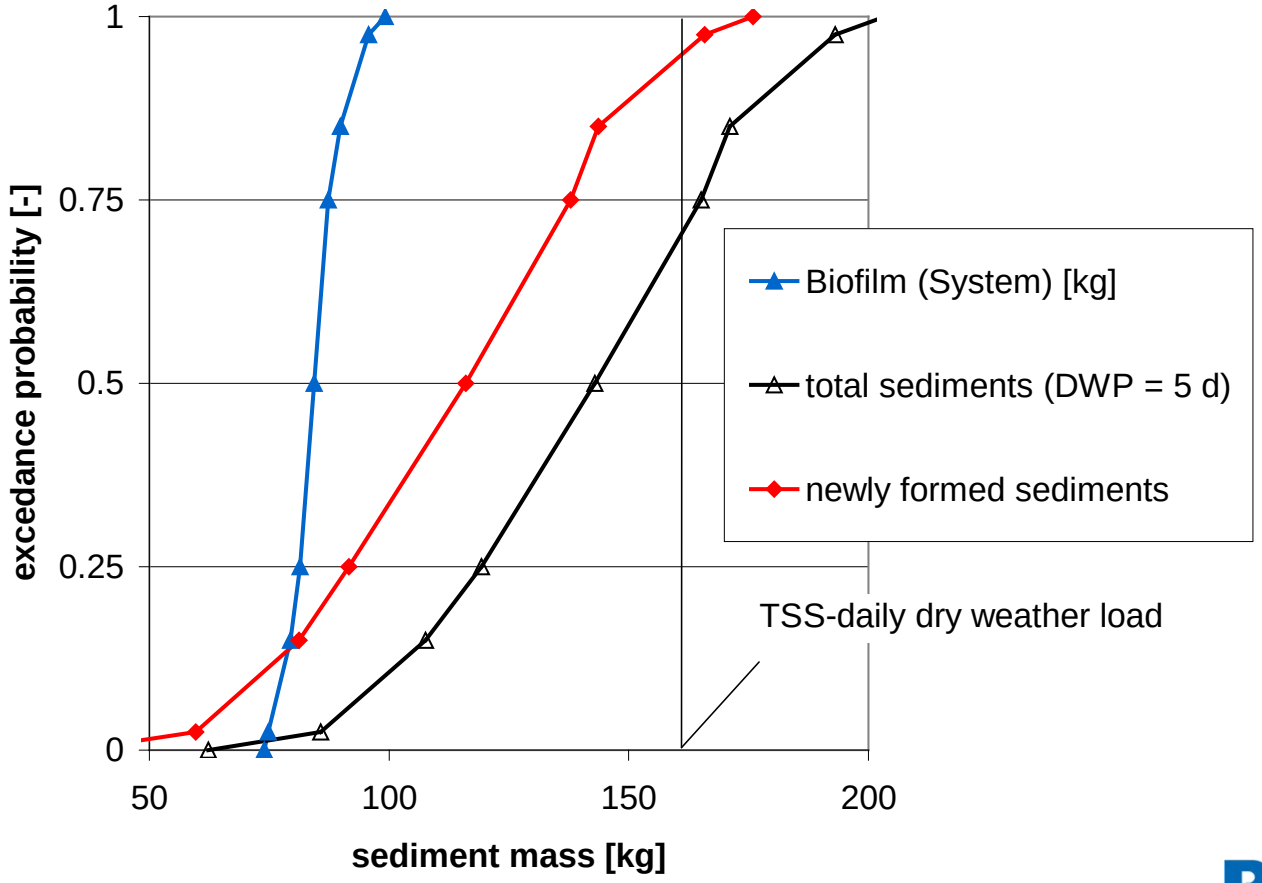
$$\text{with } k = 1$$

$$\text{if } \left(\frac{s_{min}}{s_{MW}} \right) > 0.5 \wedge \frac{\partial s}{\partial t} > 2 \frac{g}{m \cdot d}$$



Results

Probability distribution of sediment mass after rain event and 5 days of dry weather



Conclusions and summary

- Sediments have a detrimental impact of water quality through CSO and wwtp load variations
- For optimized storage tank development or cleansing strategies whereabouts of sediments have to be known.
  - Observations and deterministic model have large data needs. Hence, they are expensive
- Solution:
  Semi-stochastic sediment transport modeling

Conclusions and summary

- The results show good agreement with observed data
- The methodology can be applied for
  - Demographic changes
  - Climate change
  - Optimization of CSO treatment
  - Development of cleaning strategies

Thank you for your kind attention !