Integrated models as support for the evaluation of stormwater pollution control strategies

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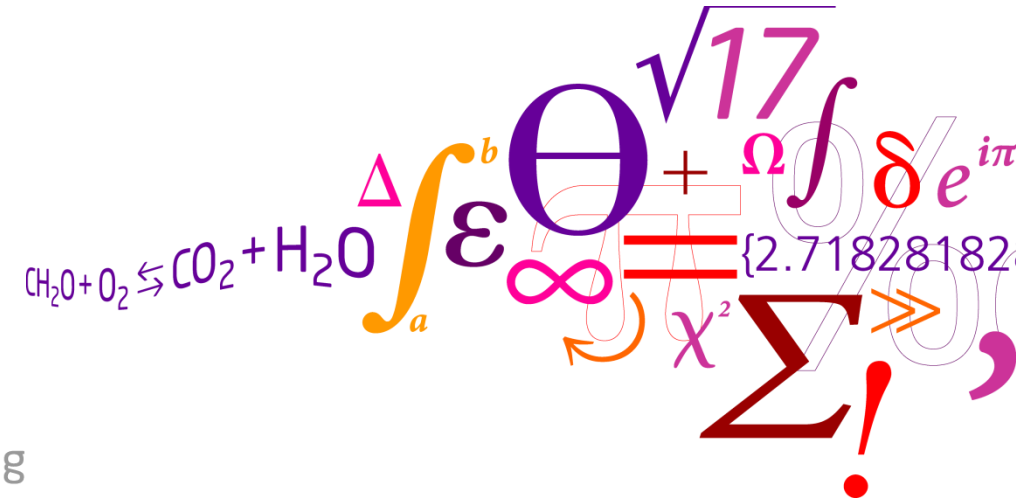
Technical University of Denmark

Integrated models as support for the evaluation of stormwater pollution control strategies

Luca Vezzaro

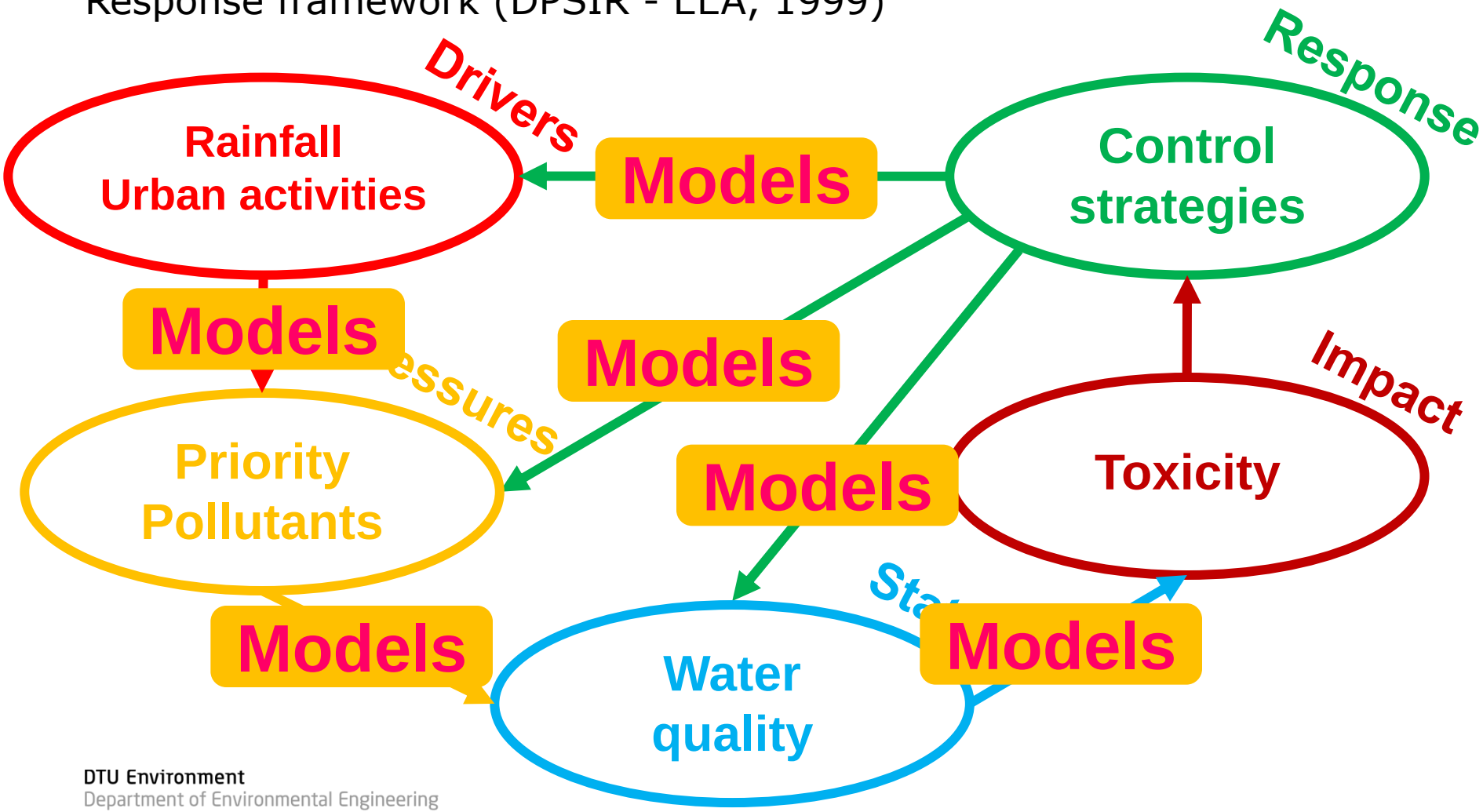
IDAmiljø møde: Vejvand - hvad gør vi ved det?
København, d. 4. Maj 2011



DTU Environment
Department of Environmental Engineering

Stormwater pollution: Why do we need models?

- Description of the issue with the Driver-Pressure-State-Impact-Response framework (DPSIR - EEA, 1999)



Model outputs

Which information are we interested in?

- Legal requirements:
  - *Improvement of status of water bodies (WFD)*
- What is the actual situation?
  - *Loads*
  - *Concentrations*
- What can we do to improve our system?
  - Source control?
  - Treatment (and which treatment)?

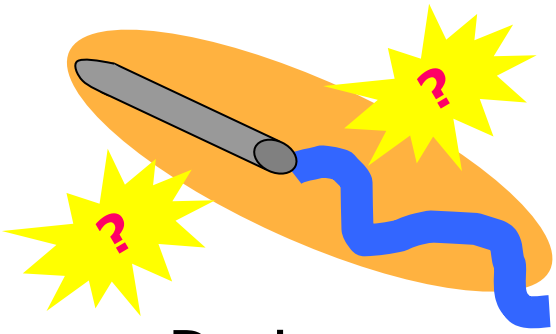
OBS: focus on micropollutants (MP):

Heavy metals, organics, pesticides (~ µg/l-ng/l)

How we can model stormwater systems?

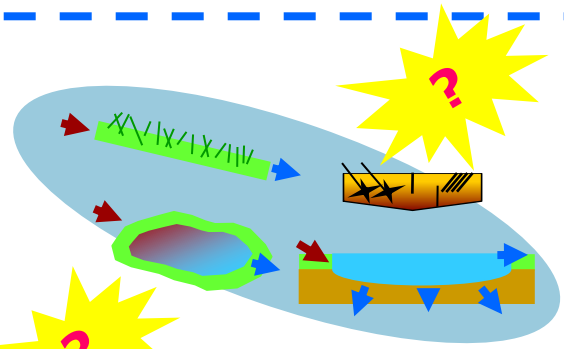
Catchment

Major sources



Drainage System

Conc., loads



Treatment System

Removal efficiency

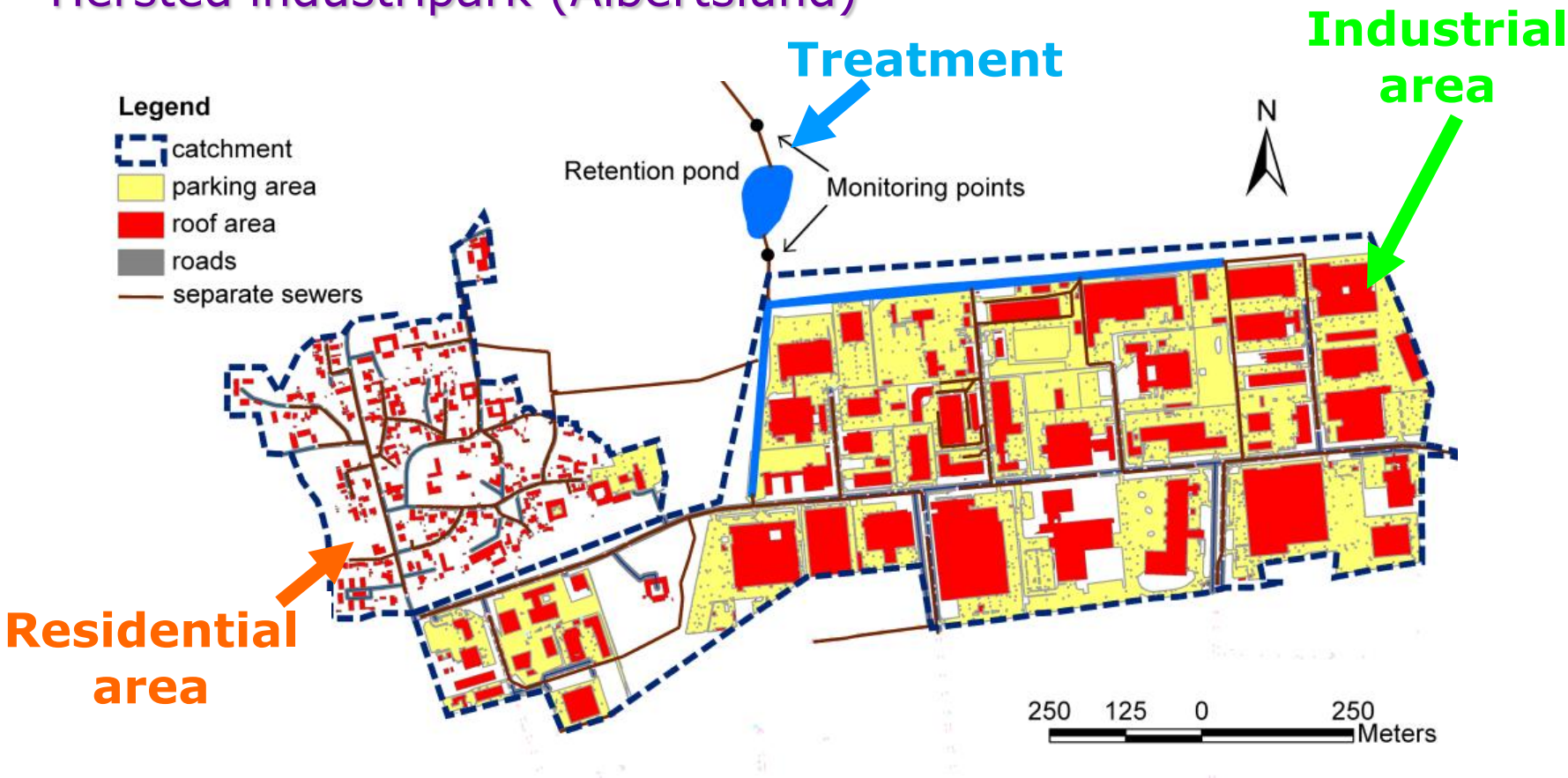
Integrated stormwater quality model

+

Uncertainty analysis (GLUE)

Study area

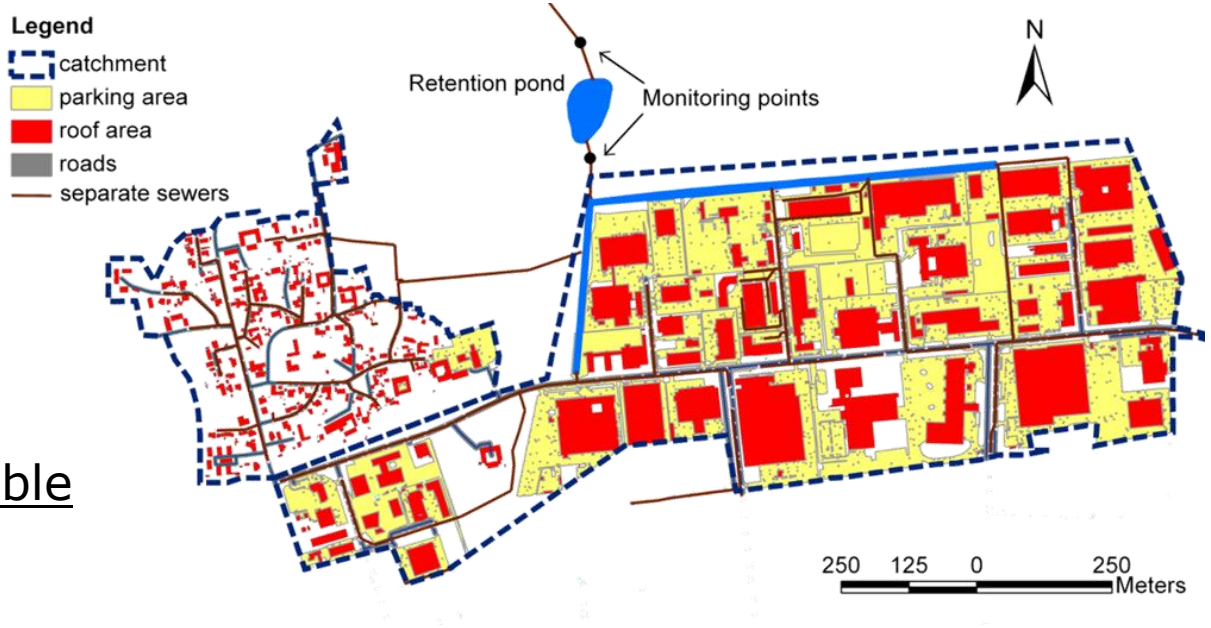
Hersted industripark (Albertslund)



- 92 ha catchment
- Flow data: almost one year
- Quality data: 33 samples (5 events)

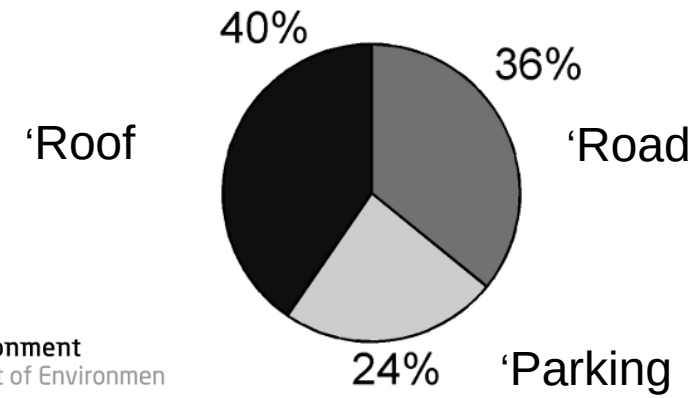
Catchment characterization

What are the sources?

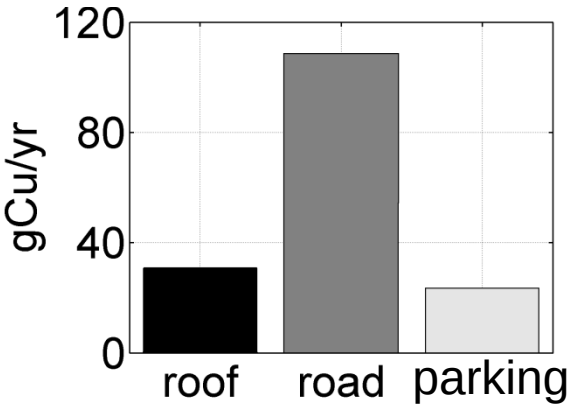


- Classification based on GIS data already available at the municipality

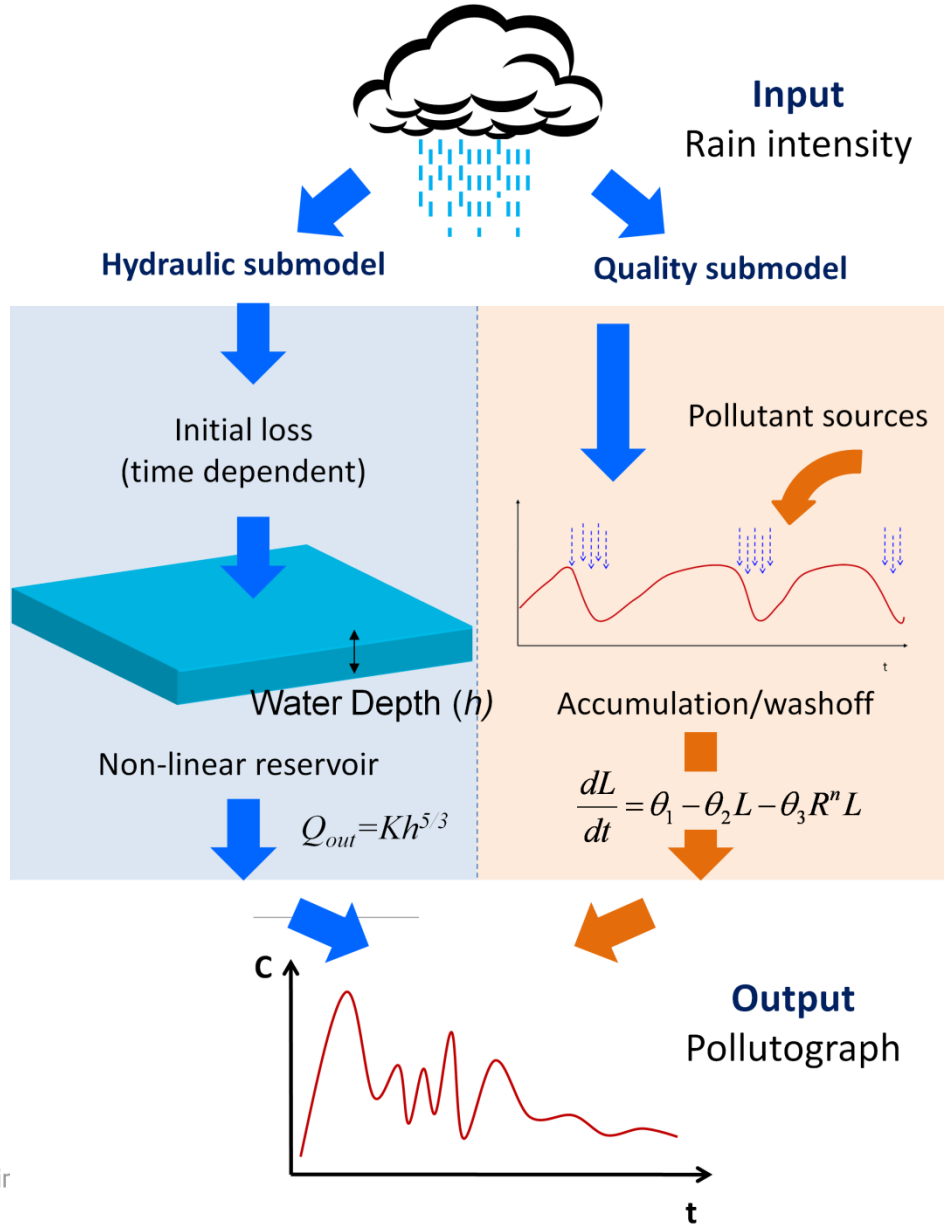
Land usage



Estimated annual Cu load

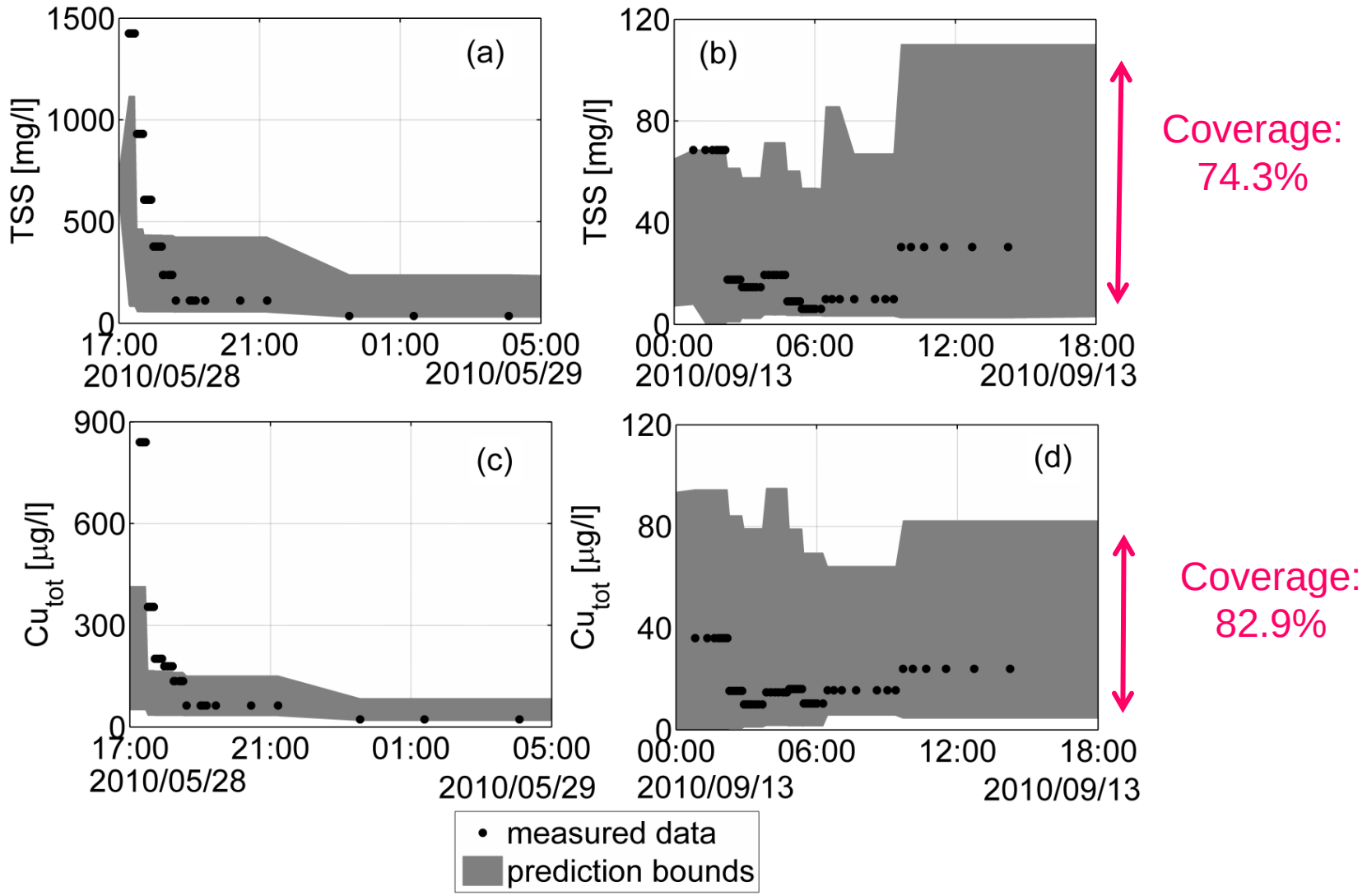


Drainage system
Stormwater quality model



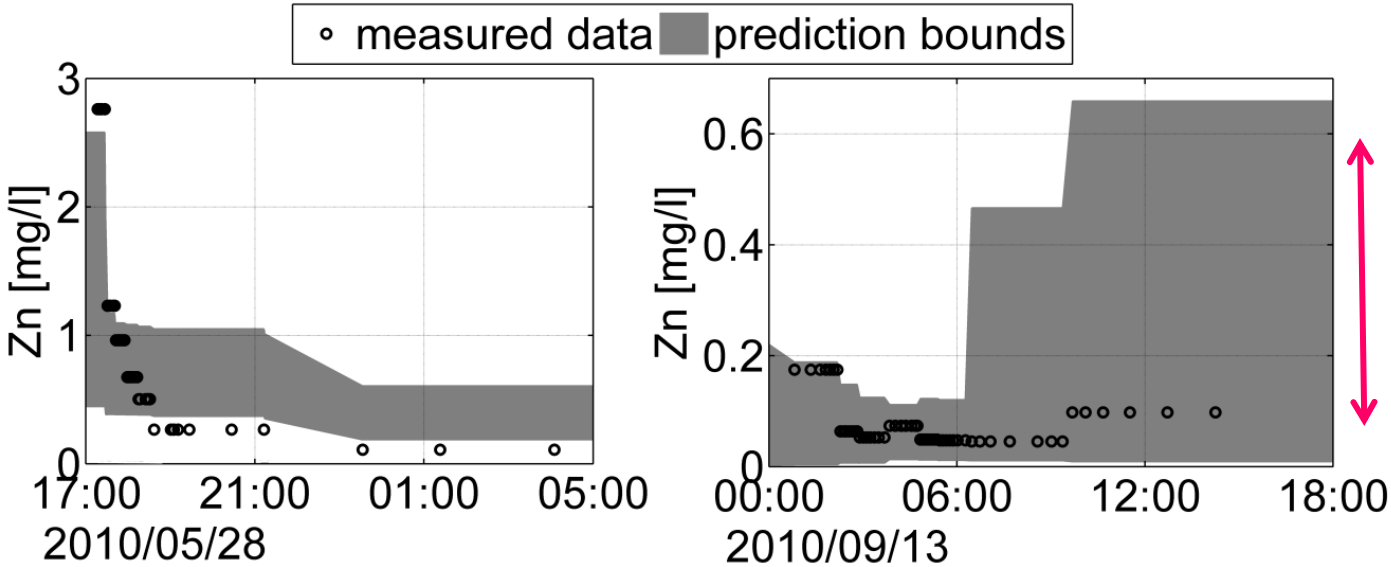
Drainage system
Model performance (TSS, Cu)

- One extreme event affects calibration

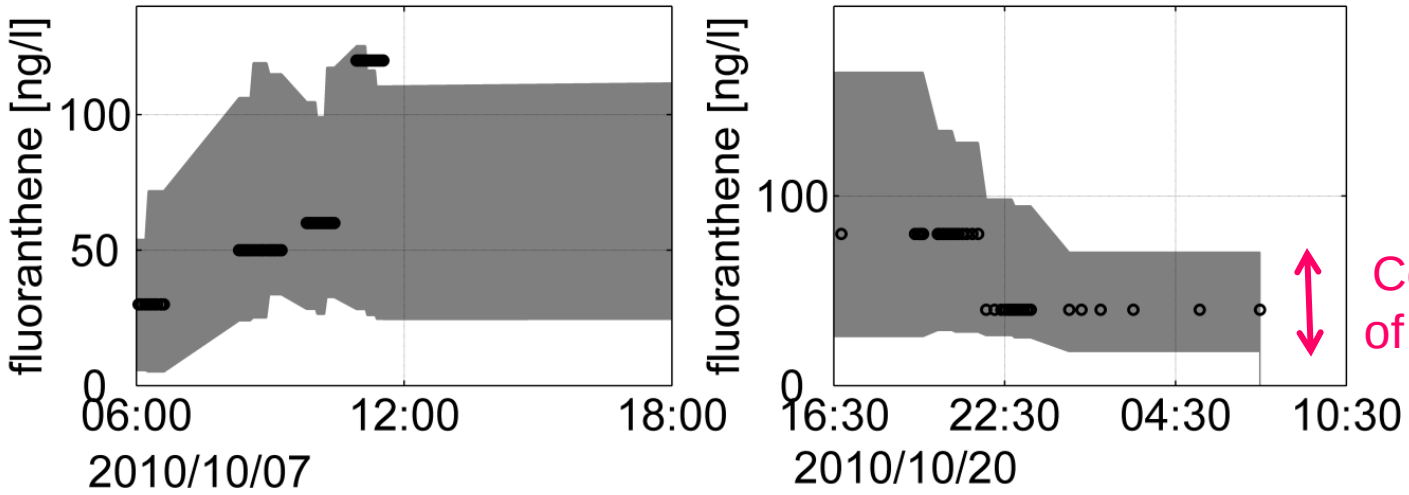


Drainage system

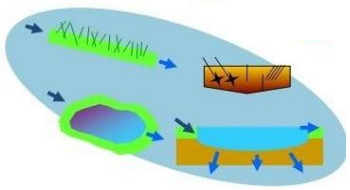
Model performance (Zn, fluoranthene)



Coverage of 82.9% of Zn data



Coverage of 88.9% of fluoranthene data



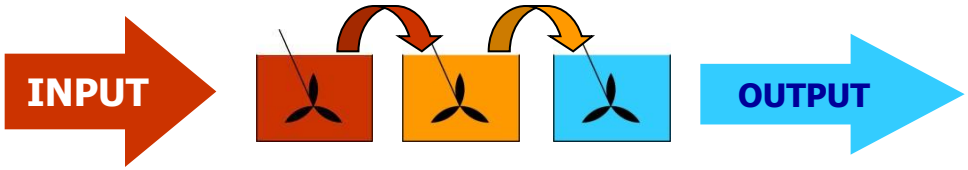
Treatment model

Stormwater Treatment Unit model for MicroPollutants (STUMP)

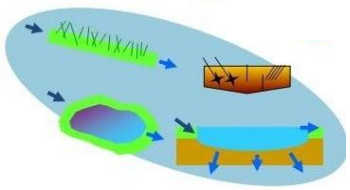
From Vezzaro et al. (2010)

- Serial CSTR

Number of tanks
=
same hydraulic behaviour of the treatment unit



Data:
Flow Measurements and/or Literature



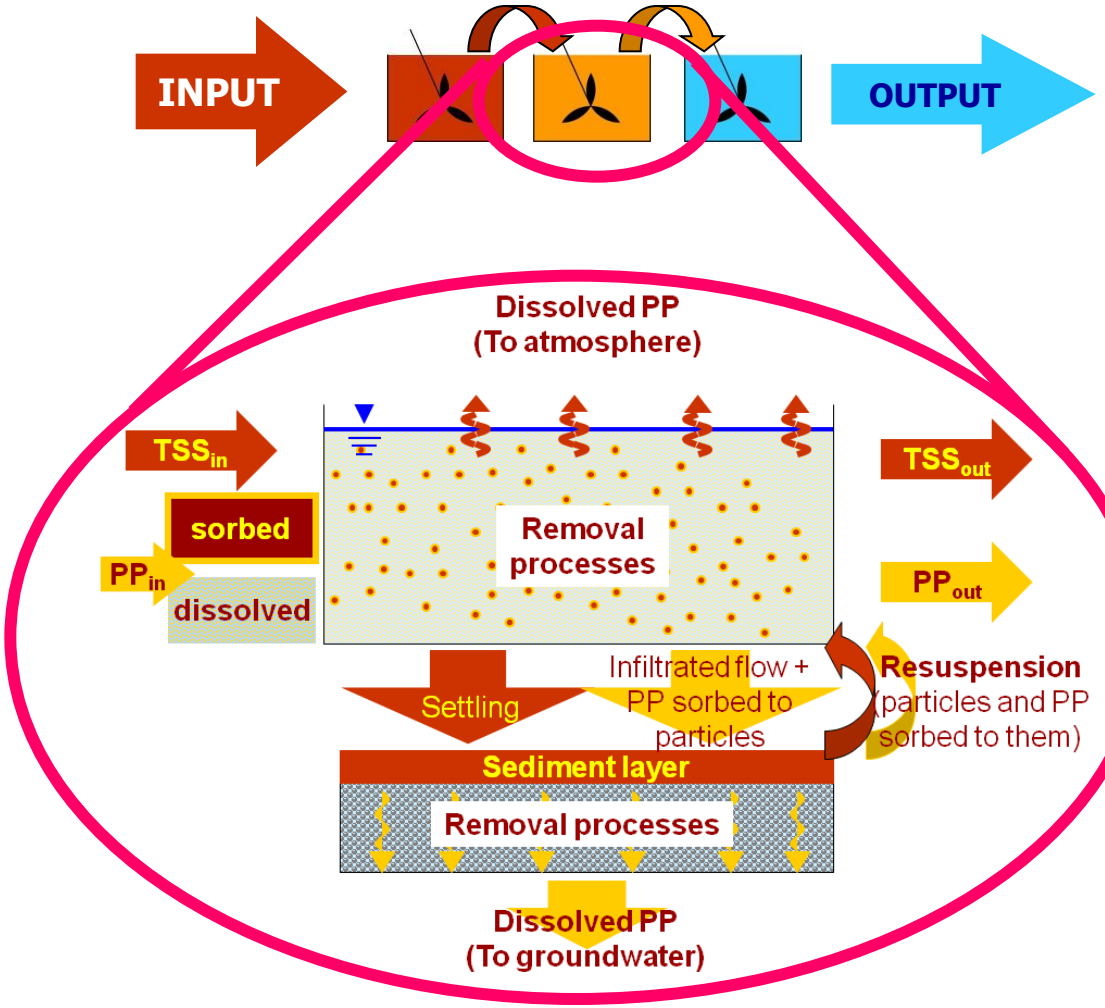
Treatment model

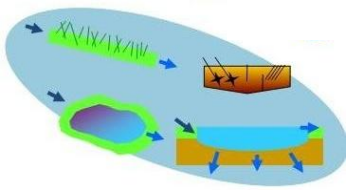
Stormwater Treatment Unit model for MicroPollutants (STUMP)

From Vezzaro et al. (2010)

- Pseudo First order kinetics

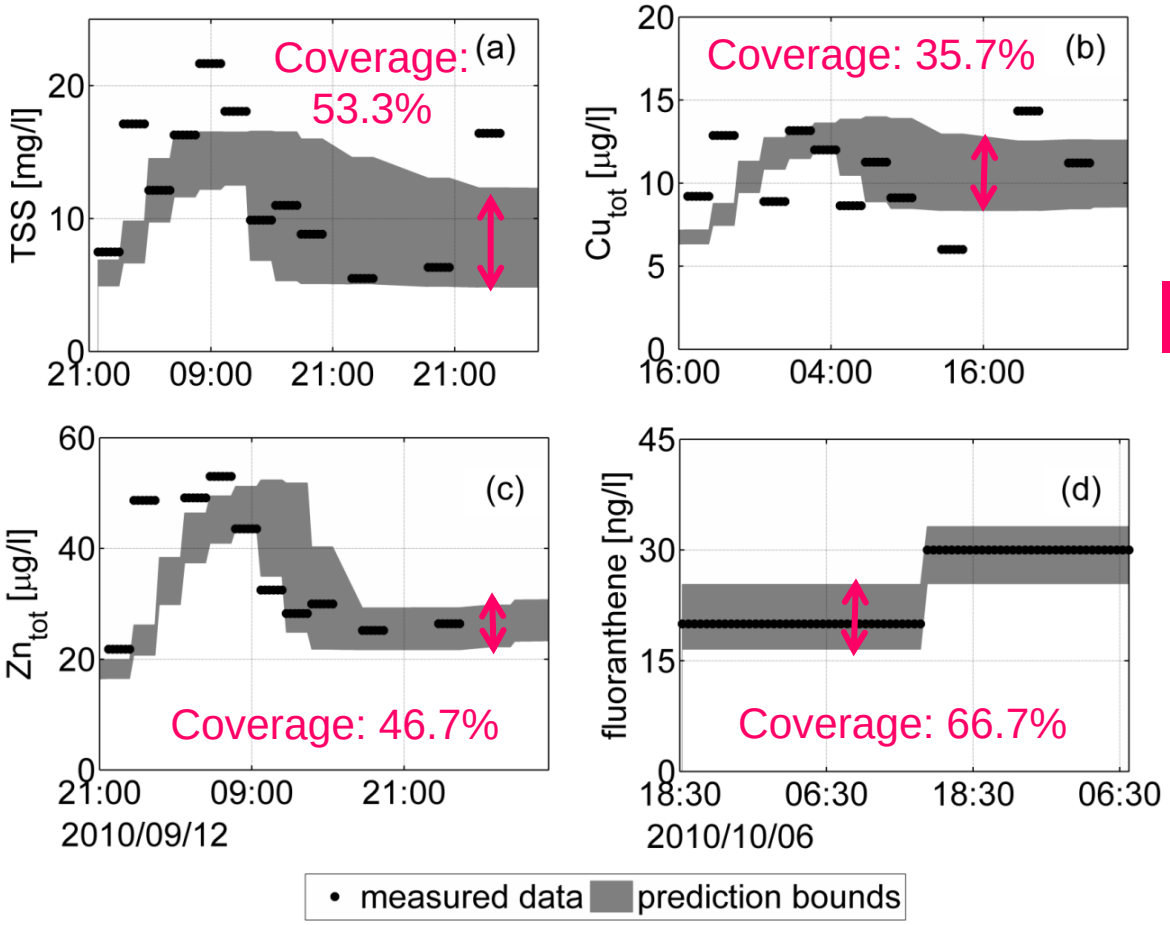
Fate processes based on substance's inherent properties
=
Wide range of substance

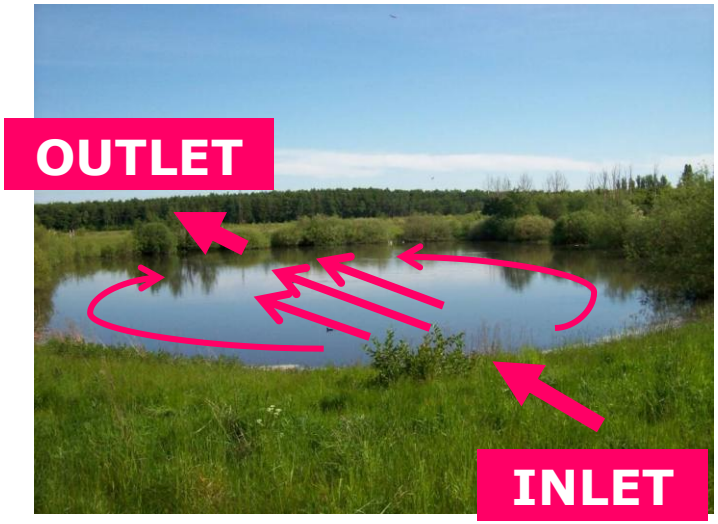




Treatment model
Model performance

- Modelled peaks smoother than measured
  - *Pond hydraulic short-circuit higher than expected*





Evaluation of control strategies

How can we improve our system?

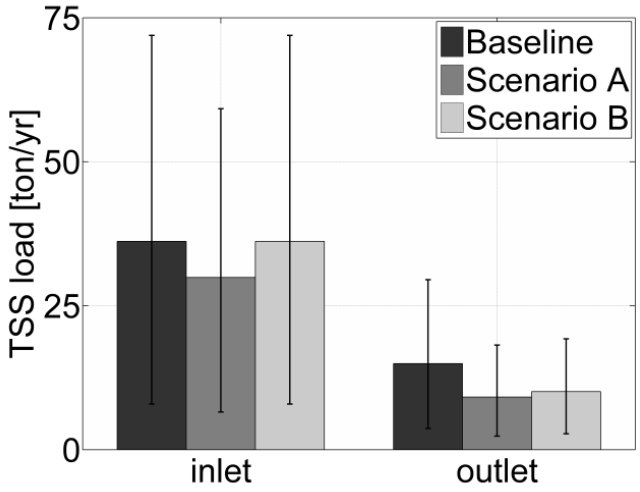
- The integrated model was run with a 10-year rain series (1994-2004)
- Three scenario were simulated
  - Baseline scenario: actual situation

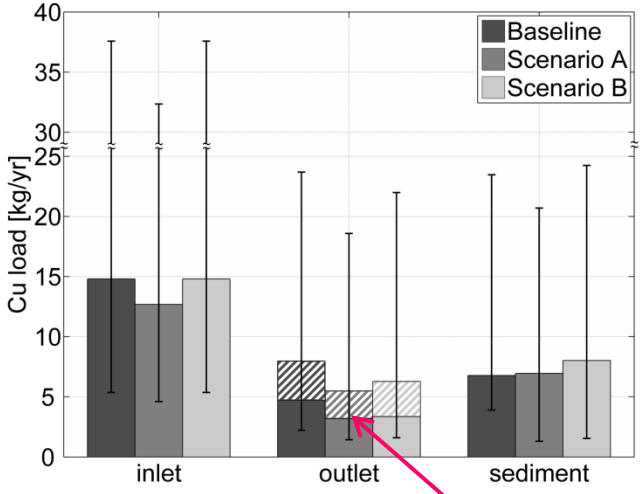
    What is the actual situation?
  - Scenario A (source control) disconnection of **50% of the roof areas** and **30% of the roads and parking areas** (40% of the impervious area)

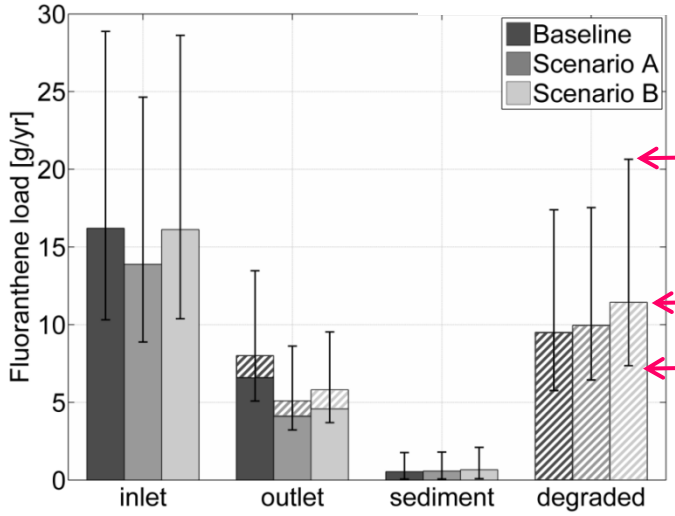
    What happens if we remove some sources?
  - Scenario B (end-of-pipe treatement): doubling of the pond volume (double) nominal HRT) and modification of layout (higher effective HRT)

    What happens if we improve the existing system?

Control strategies
Discharged loads







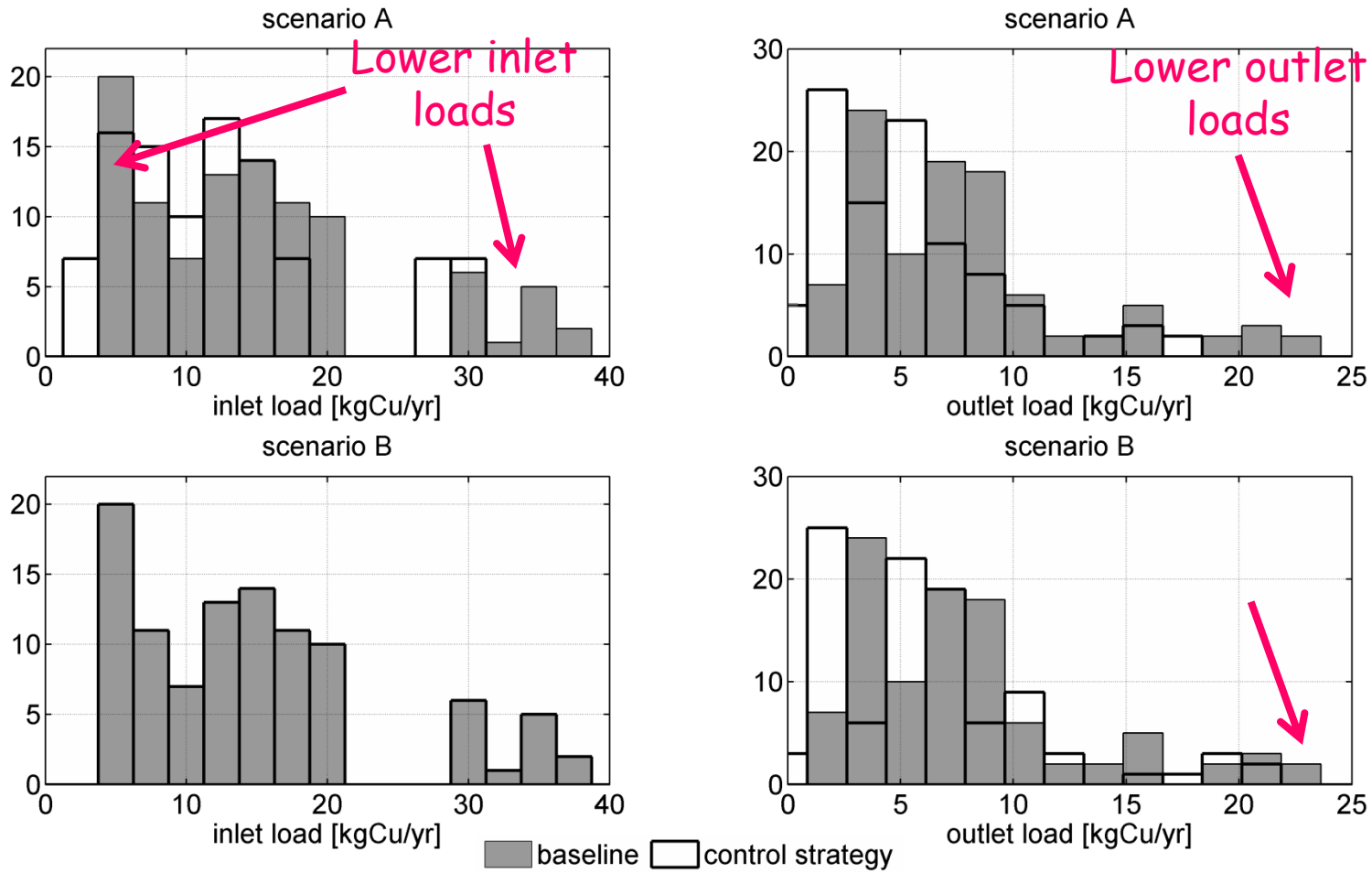
Dissolved fraction

max

median

min

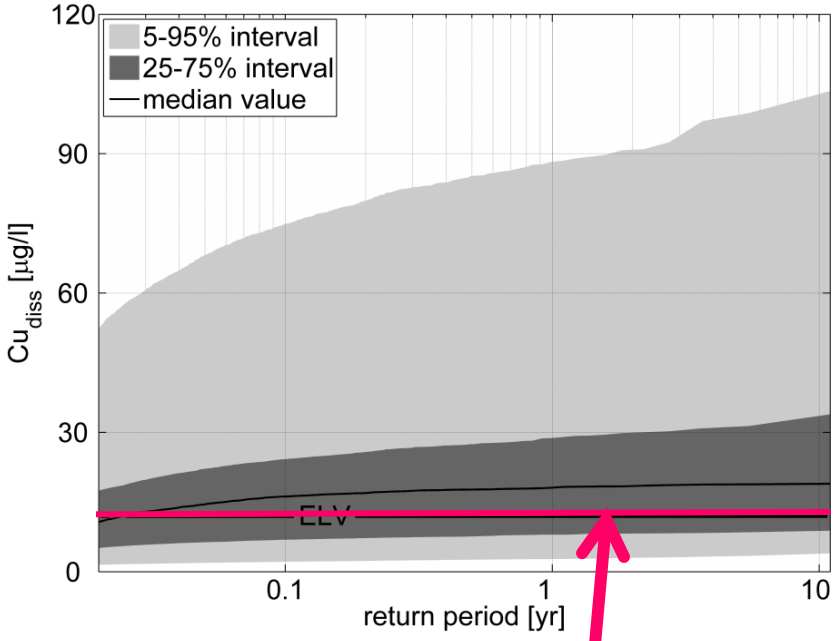
Control strategies
Discharged loads



Control strategies
Discharged concentrations

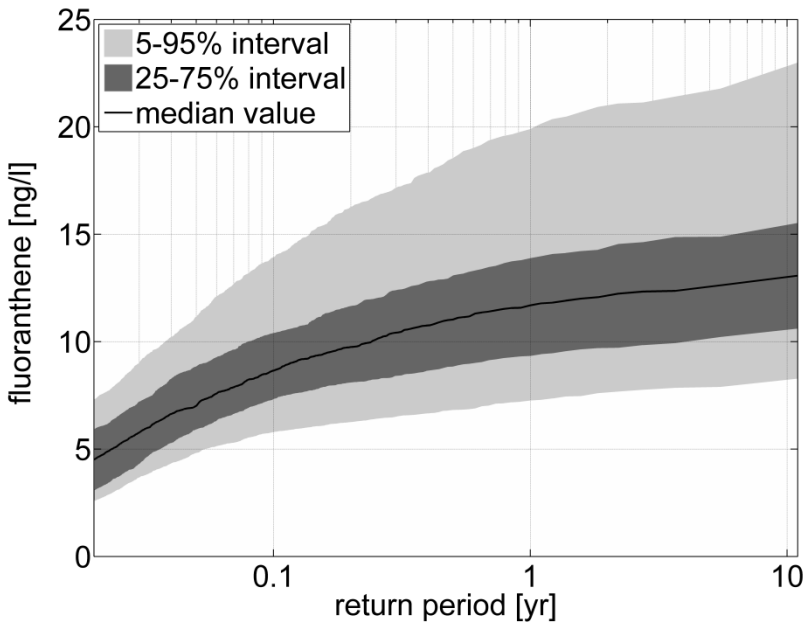
- Model results provide estimation of compliance with legal limits

Cu EMC return period



Emission Limit Value for Cu_{diss}

Fluoranthene EMC return period



Emission Limit Value

Dissolved MP can cause an impact on downstream environment

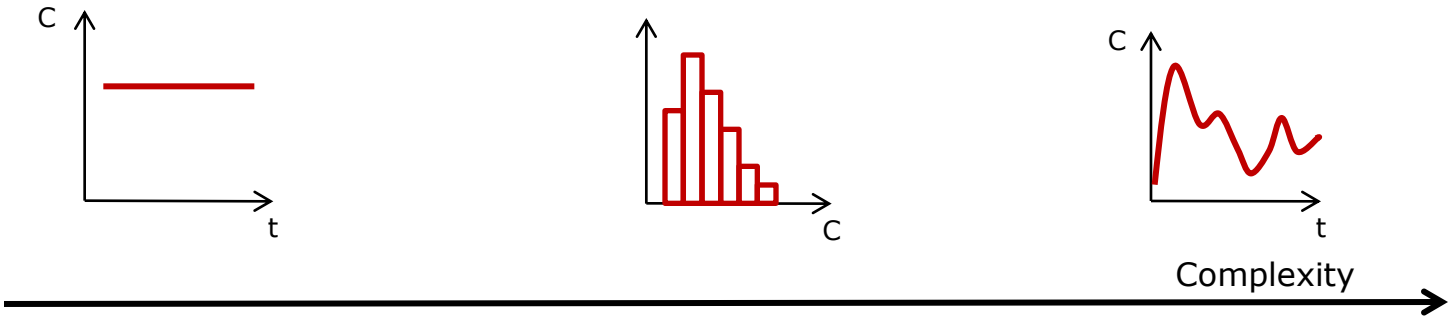
Control strategies
Results comparison

- Scenario A (catchment disconnection)
  - Lower loads to the pond
  - Better settling condition (lower max flow)
  - Dissolved concentration not affected
- Scenario B (pond improvement)
  - Higher sediment load (for metals)
  - Increased removal for biodegradable MP
  - Dissolved metal concentrations not affected

Example of how the model can be applied

Other potential applications (1)

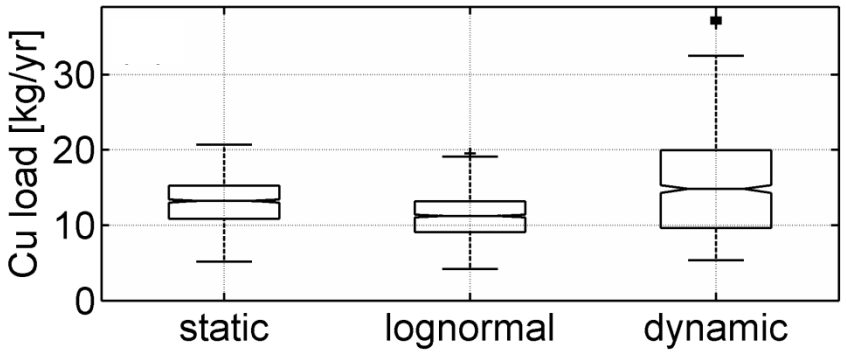
- What if less (or no) measurements are available?
  - Stormwater quality data can be retrieved from databases
  - Less complex stormwater quality model can be used



+ (No) Measurement needed
- No variability

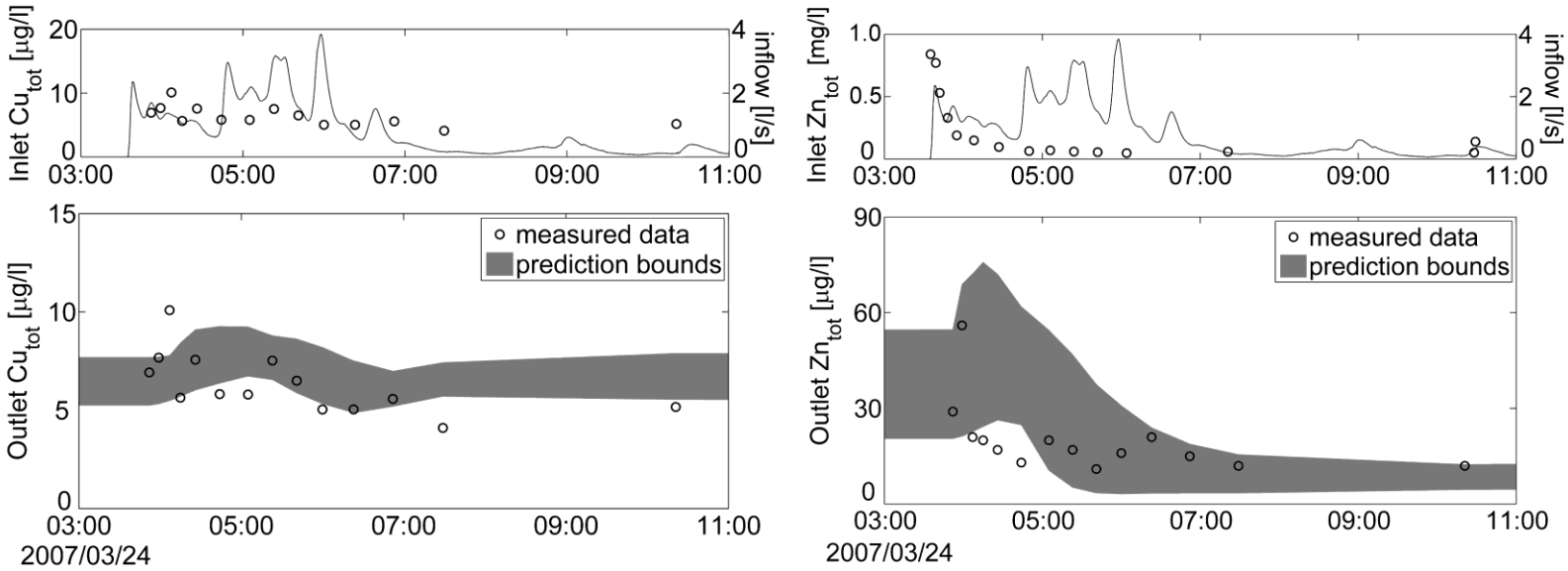
+ (No) Measurement needed
= Inter- event variability

- Measurement needed
+ Inter- Intra-event variability



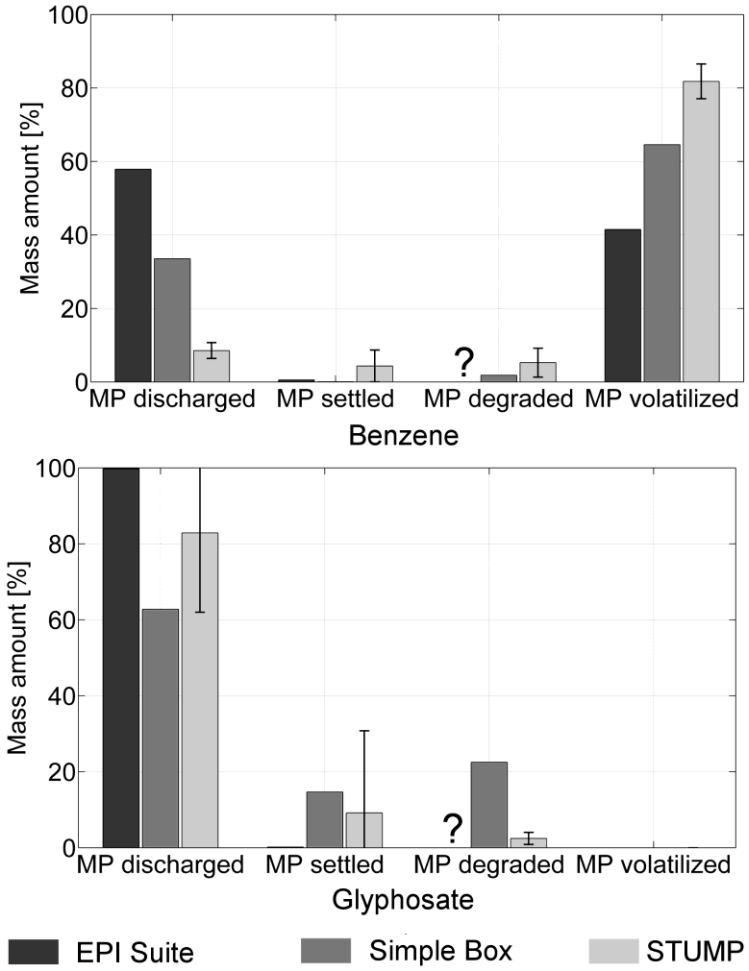
Other potential applications (2)

- What if we want to use other treatment units?
  - Model tested also for biofilters (= infiltration through soil)



Other potential applications (3)

- What if we have no measurements?
  - Model applied to different organic micropollutans
  - Good estimation of potential removal of a wide range of pollutants



From Vezzaro et al. (2011)

Conclusions

Can we use models to evaluate stormwater pollution strategies?

- Integrated dynamic models can be used to estimate MP fluxes in stormwater systems
- Uncertainty analysis is essential to evaluate the results
- The flexibility of the proposed models can simulate a wide range of substances in various catchments
- Data requirement is as low as possible
- The integrated model can provide a support for scenario analysis and comparison od pollution control strategies

More on this topic in my PhD thesis:

orbit.dtu.dk or www.env.dtu.dk

References

- EEA - European Environmental Agency (1999). *Environmental indicators: Typology and overview*. Report Technical report No 25, European Environment Agency, Copenhagen, Denmark.
- Vezzaro, L., Eriksson, E., Ledin, A., Mikkelsen, P.S. (2010); Dynamic stormwater treatment unit model for micropollutants (STUMP) based on substance inherent properties. Water Science and Technology; **62**(3), 622-629.
- Vezzaro, L. (2011); Source-Flux-Fate modelling of stormwater Priority Pollutants. PhD Thesis. Department of Environmental Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark.
- Vezzaro, L., Eriksson, E., Ledin, A., Mikkelsen, P.S. (2011); Modelling the fate of organic micropollutants in stormwater ponds. *Science of the Total Environment;* **409**(13), 2597-2606.