



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

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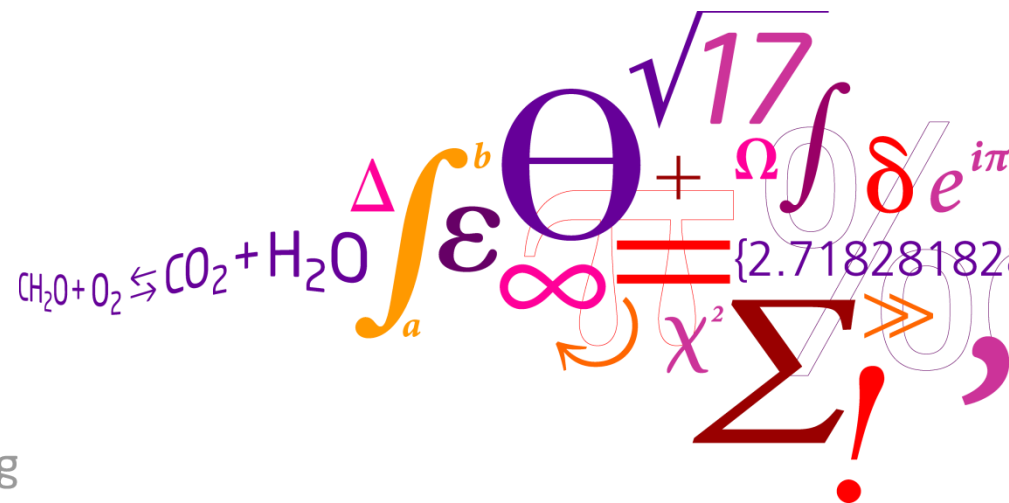
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# Integrated models as support for the evaluation of stormwater pollution control strategies

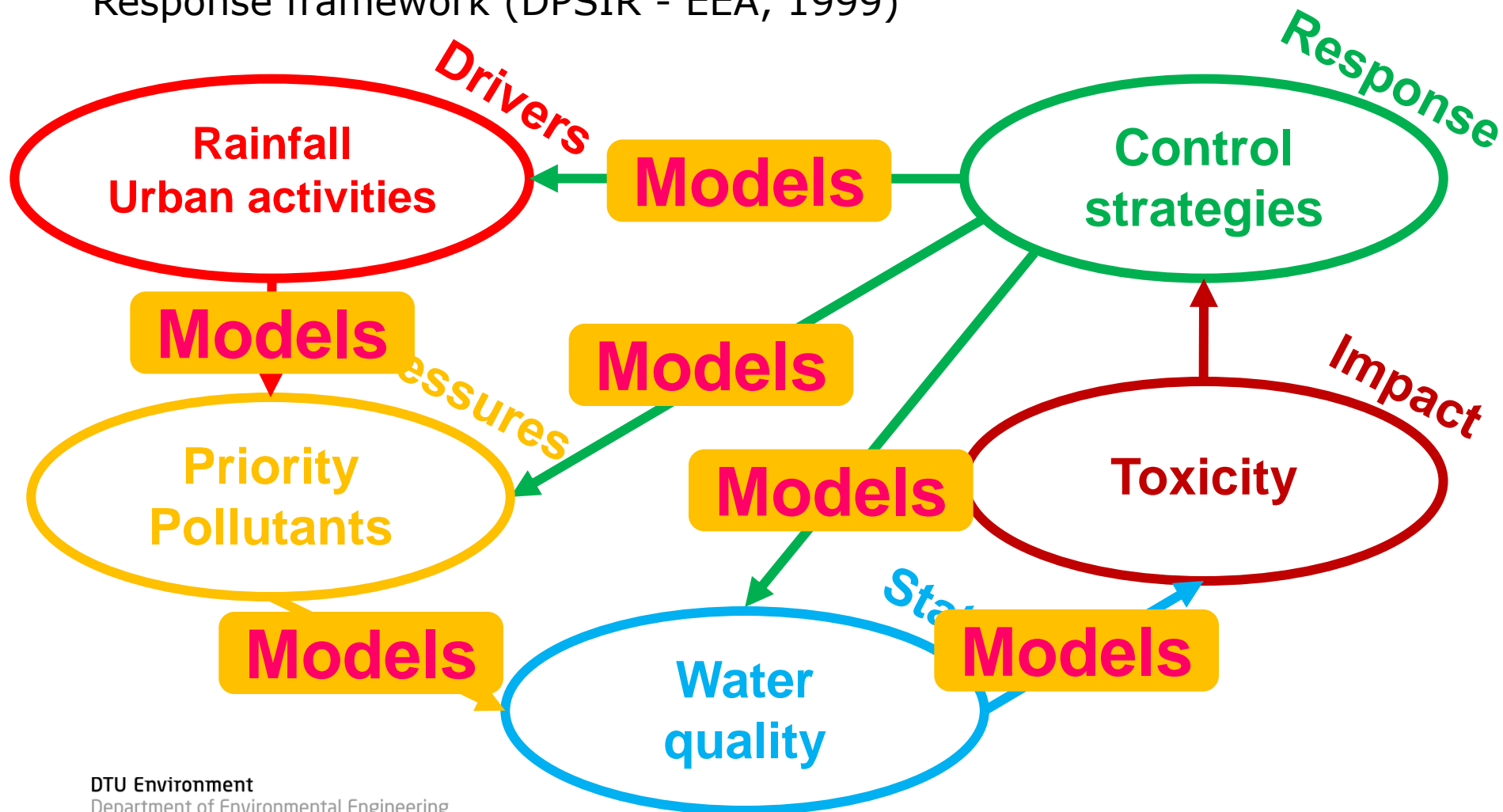
**Luca Vezzaro**

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



# Stormwater pollution: Why do we need models?

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



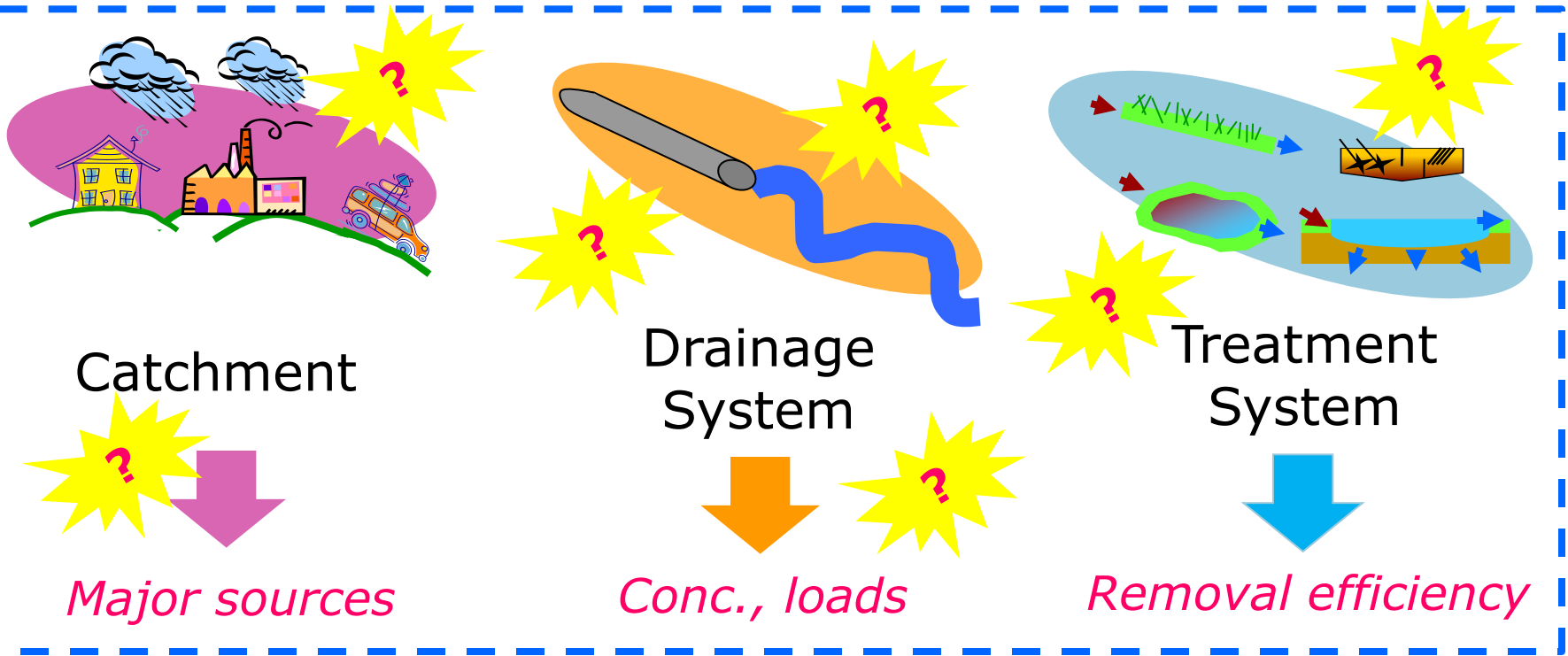
# Model outputs

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?



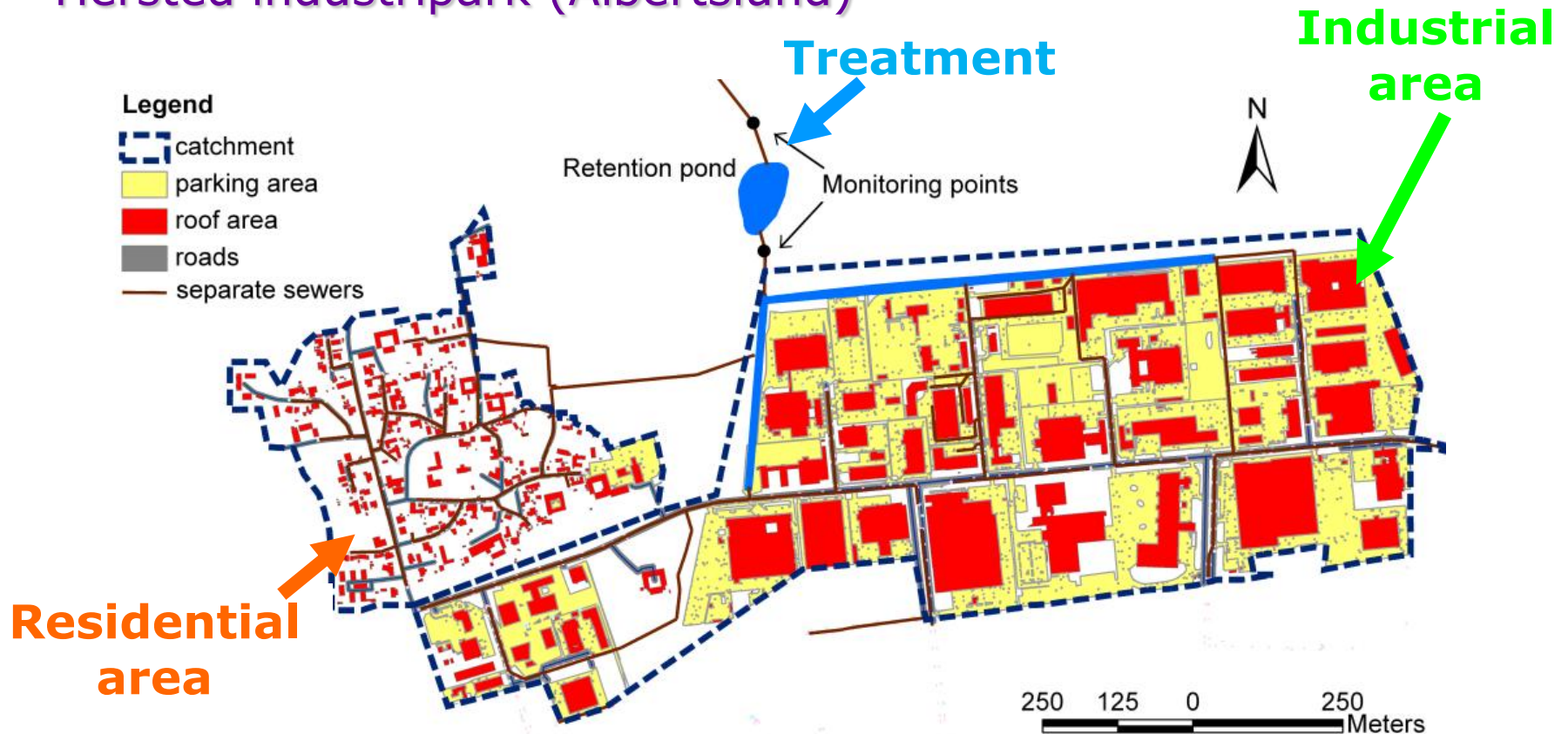
Integrated stormwater quality model



Uncertainty analysis (GLUE)

# Study area

## Hersted industripark (Albertslund)



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

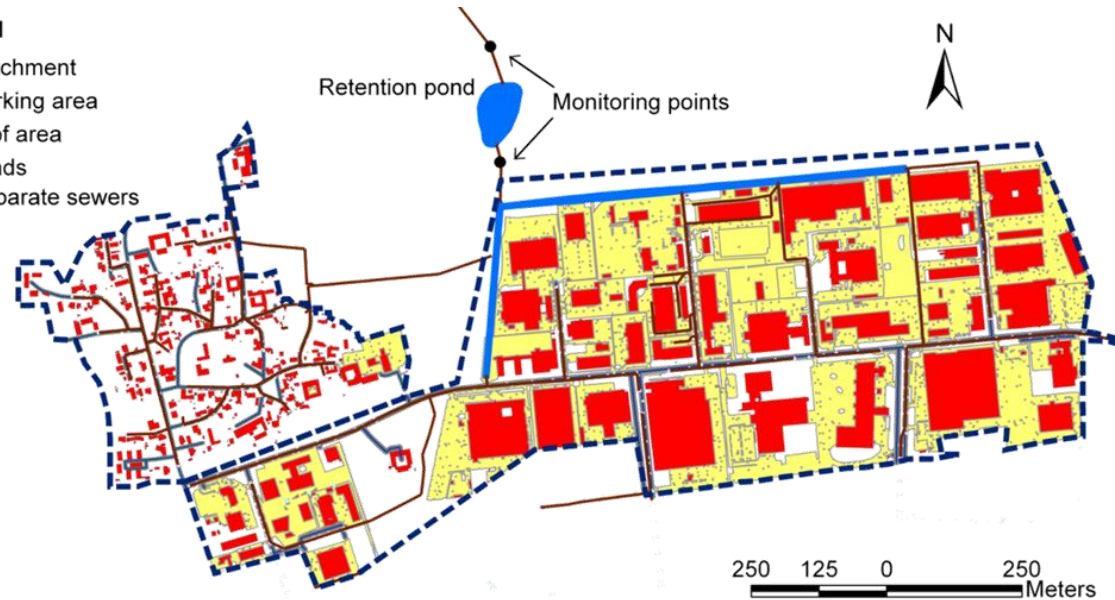


# Catchment characterization

What are the sources?

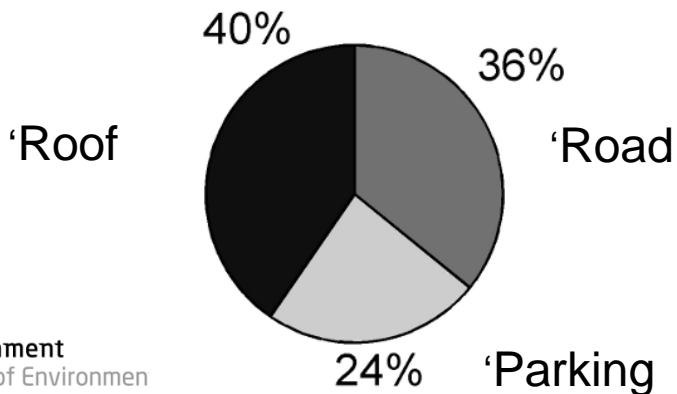
### Legend

- catchment
- parking area
- roof area
- roads
- separate sewers

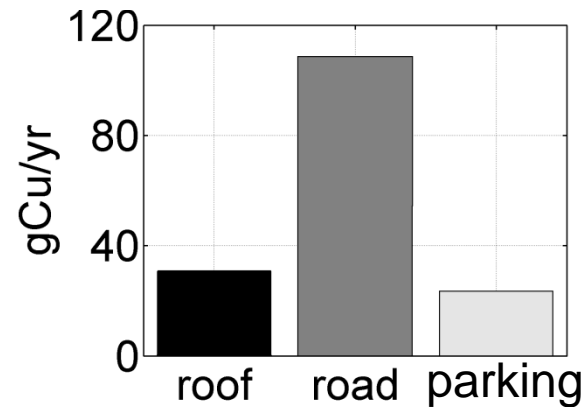


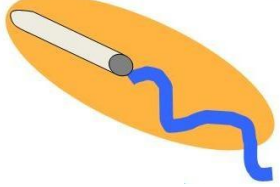
- Classification based on GIS data already available at the municipality

### Land usage



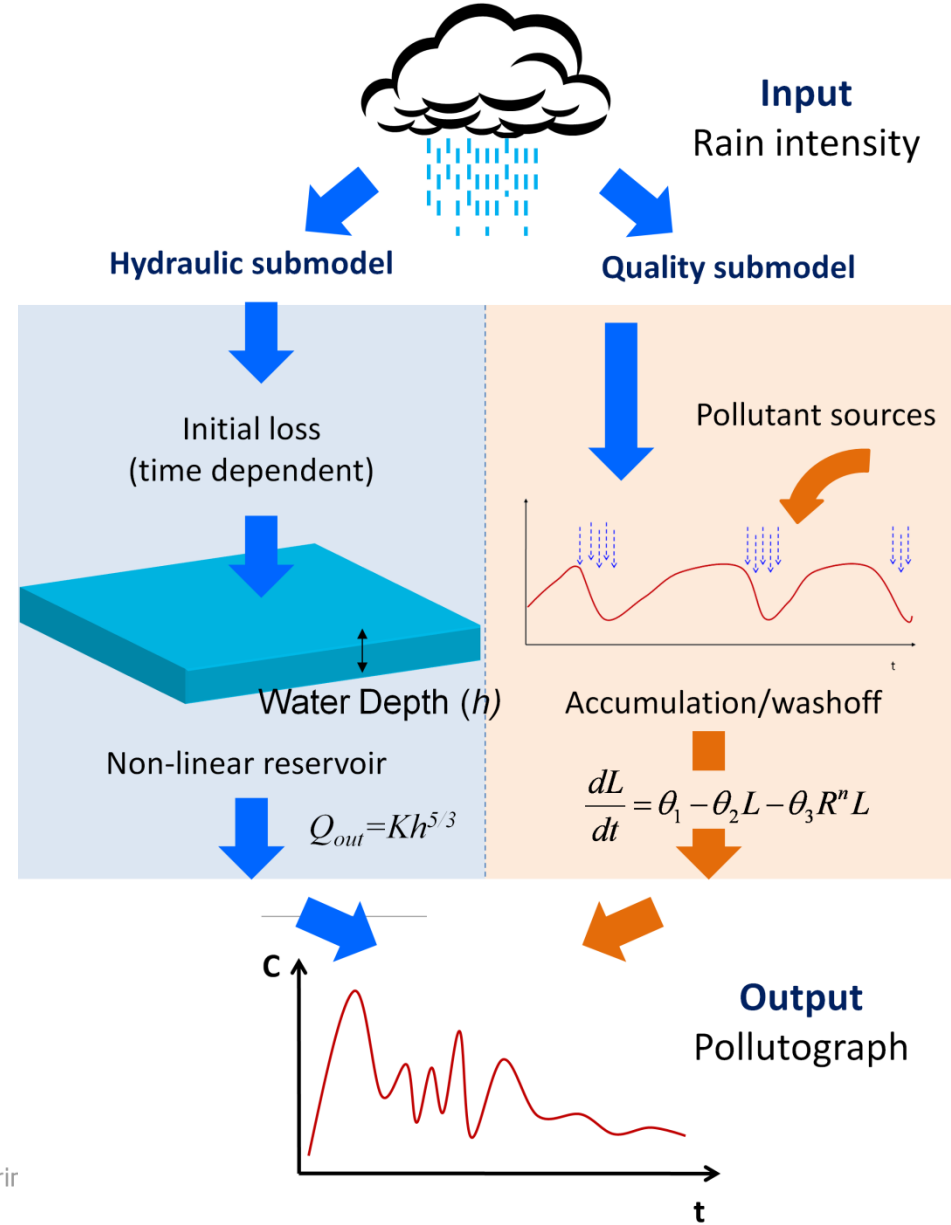
### Estimated annual Cu load



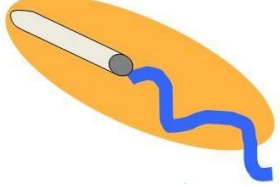


# Drainage system

## Stormwater quality model



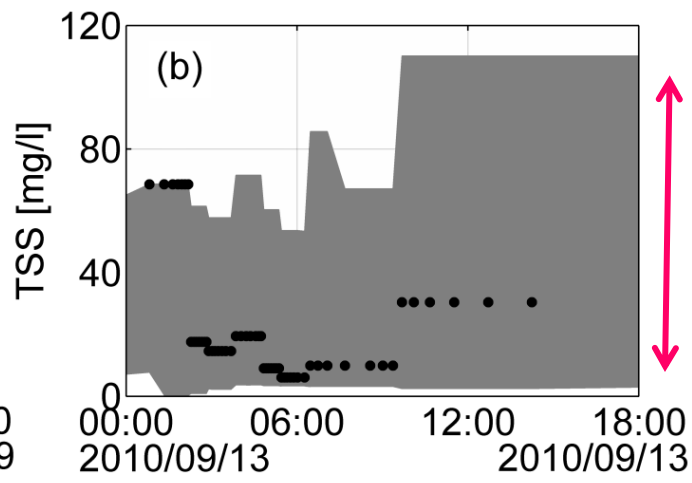
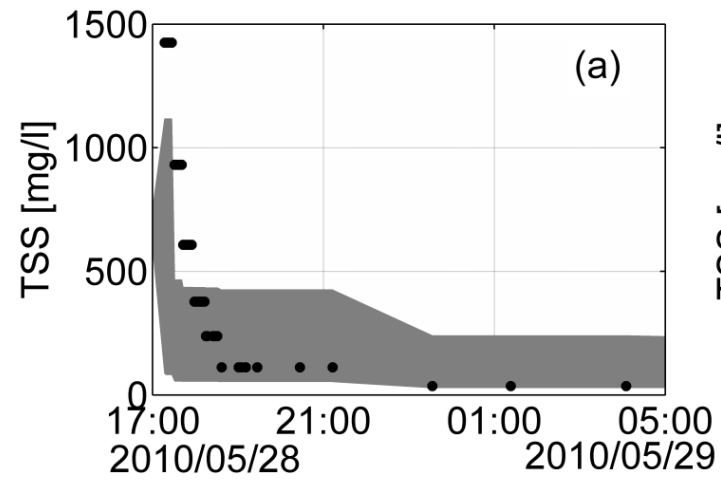




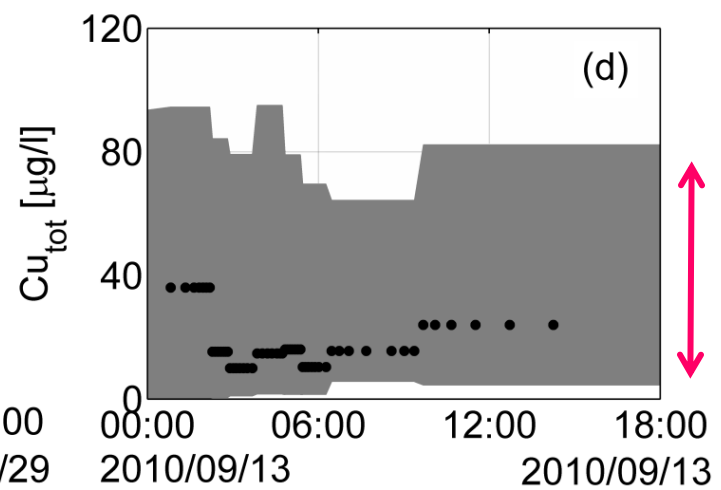
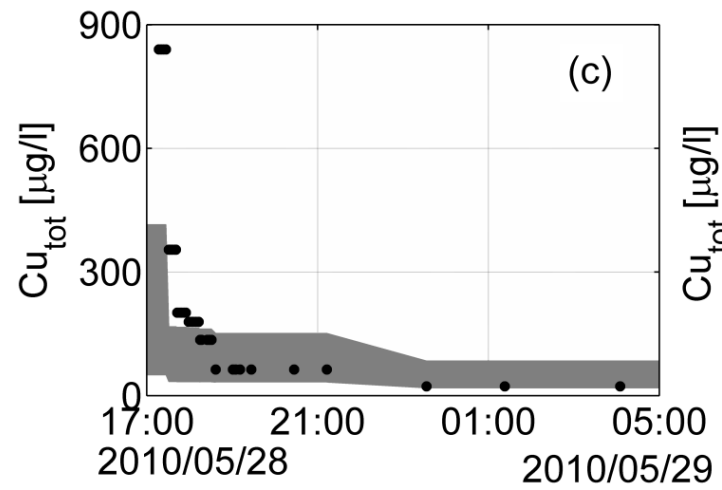
# Drainage system

## Model performance (TSS, Cu)

- One extreme event affects calibration

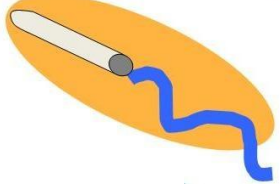


Coverage:  
74.3%



Coverage:  
82.9%

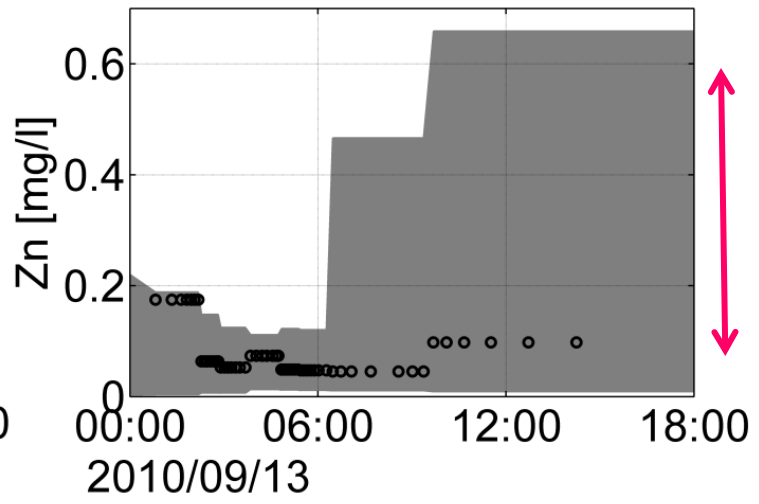
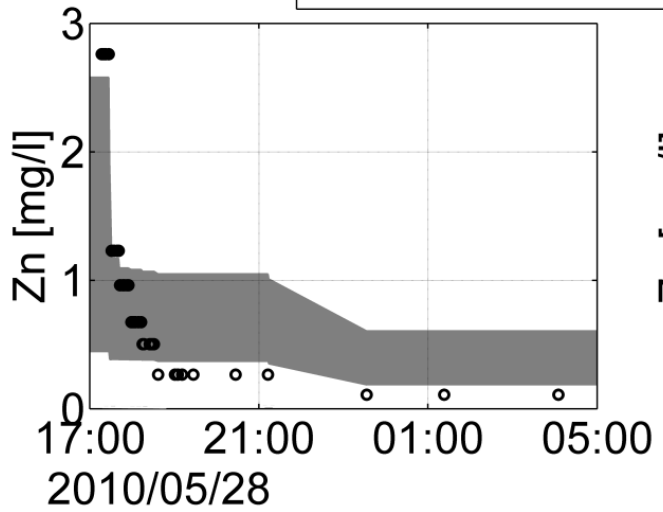
• measured data  
■ prediction bounds



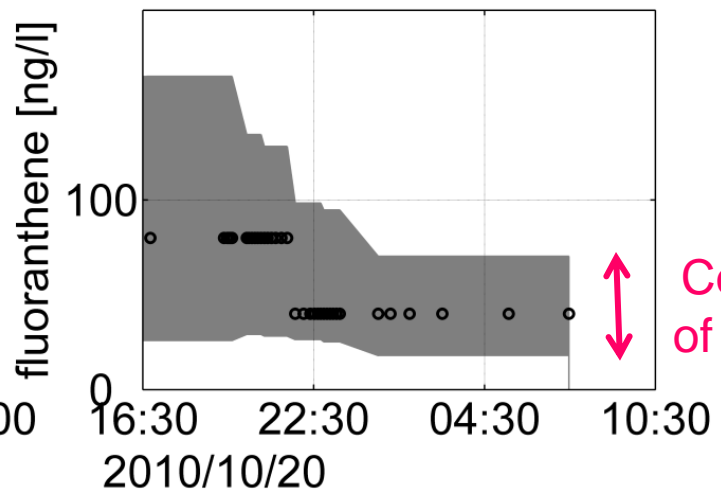
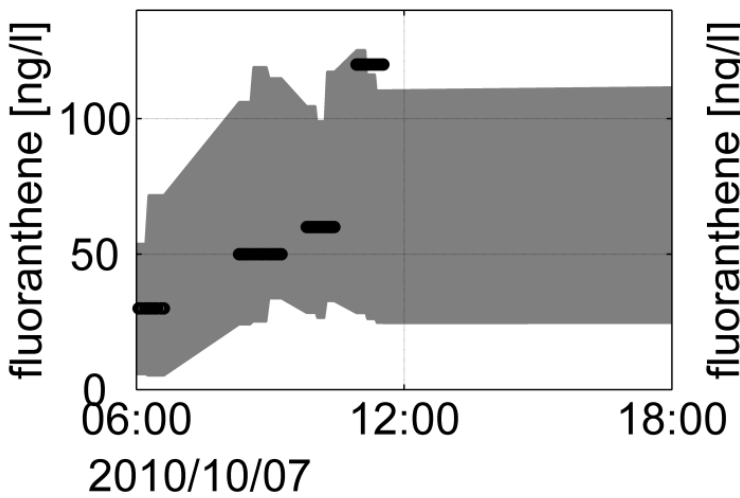
# Drainage system

## Model performance (Zn, fluoranthene)

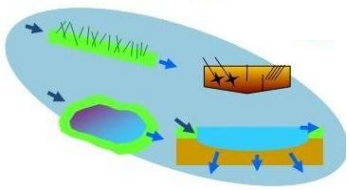
◦ measured data ■ prediction bounds



Coverage of 82.9% of Zn data



Coverage of 88.9% of fluoranthene data



# Treatment model

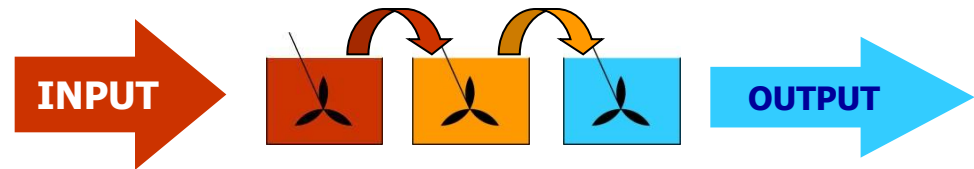
## Stormwater Treatment Unit model for MicroPollutants (STUMP)

From Vezzaro et al. (2010)

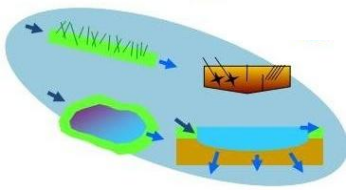
- Serial CSTR

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)

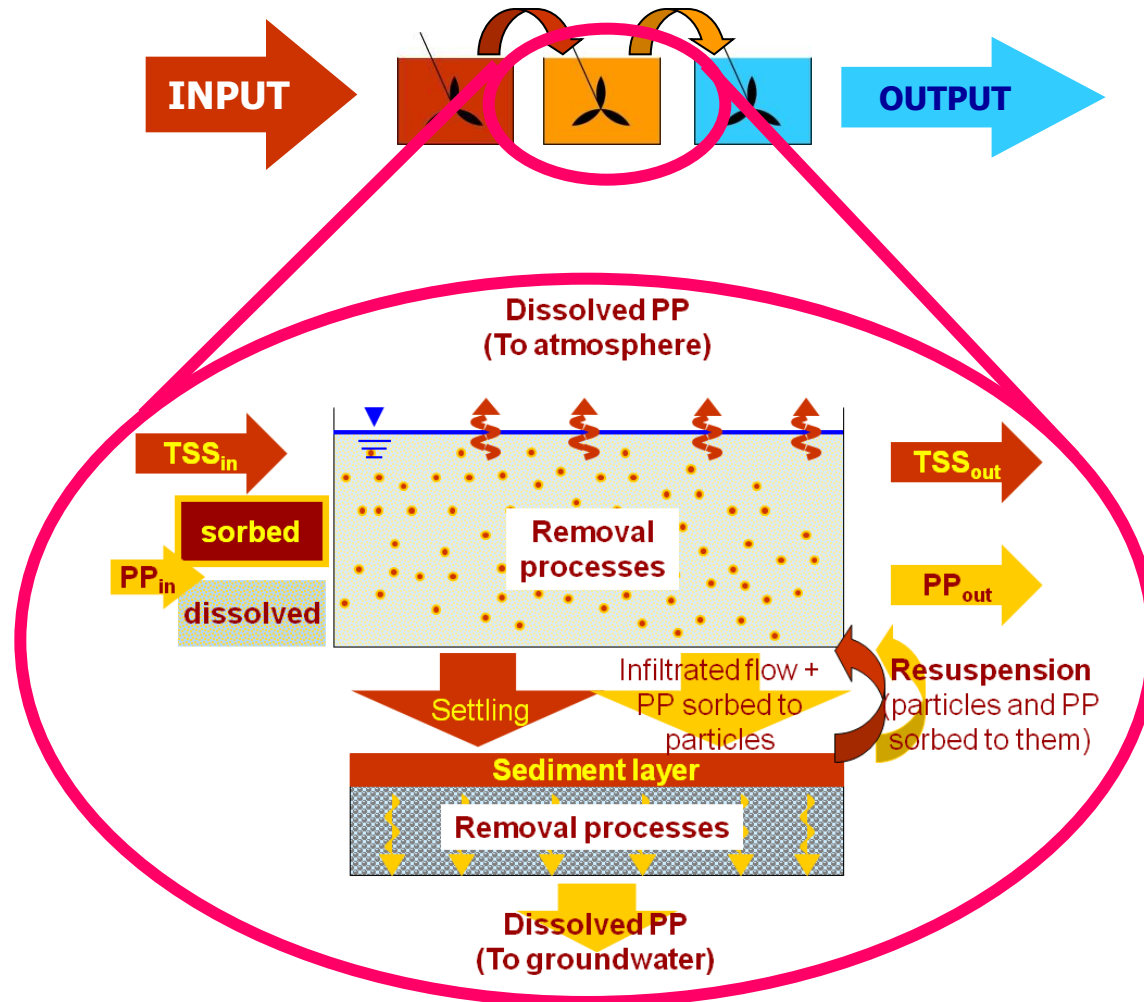
From Vezzaro et al. (2010)

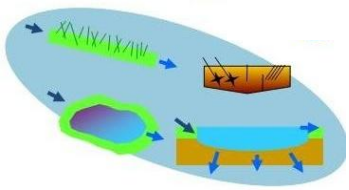
- Pseudo First order kinetics

Fate processes based on substance's inherent properties

=

Wide range of substance

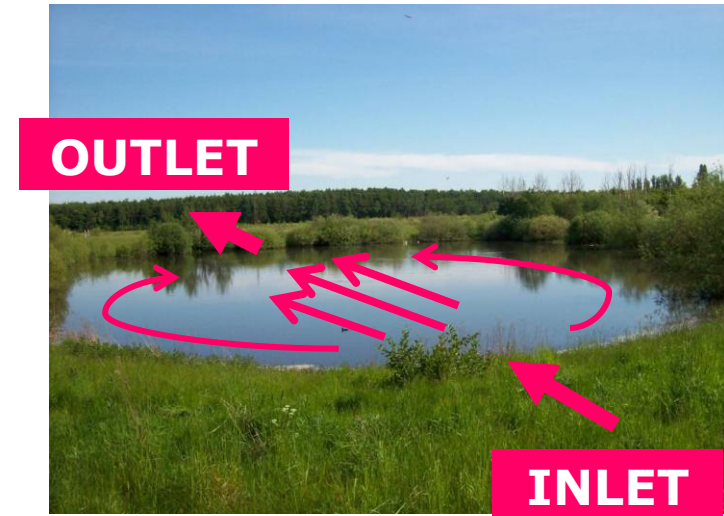
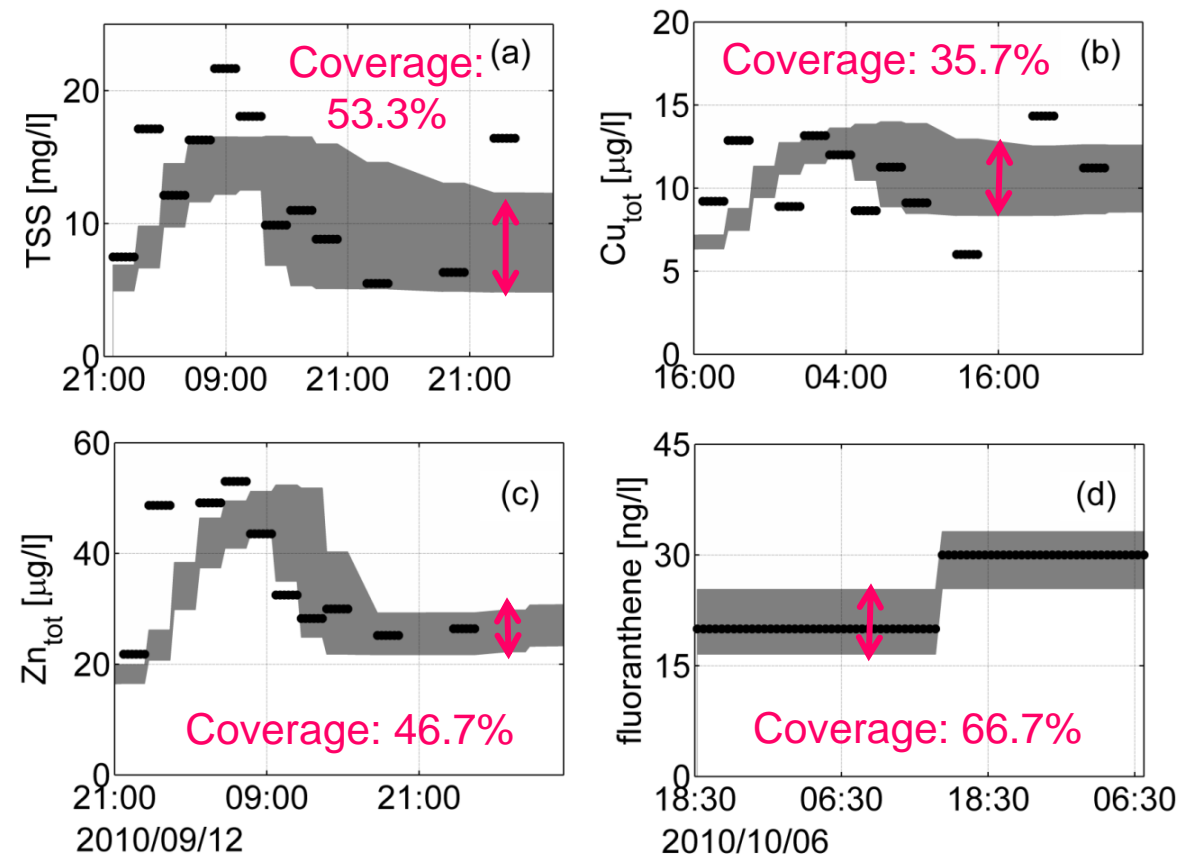




# Treatment model

## Model performance

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



• measured data ■ prediction bounds



# Evaluation of control strategies

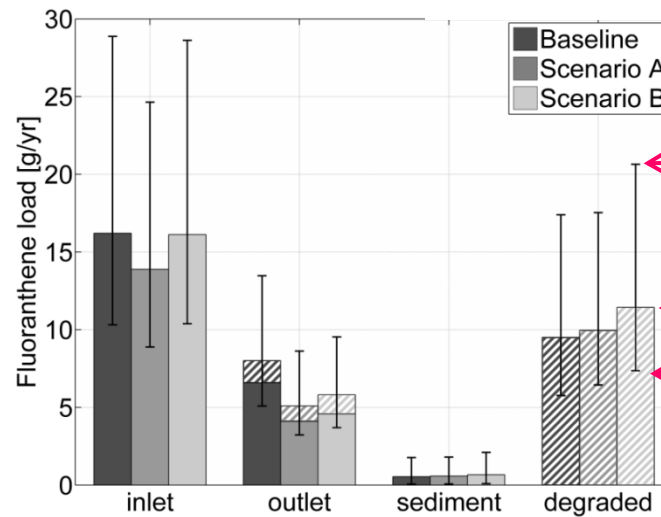
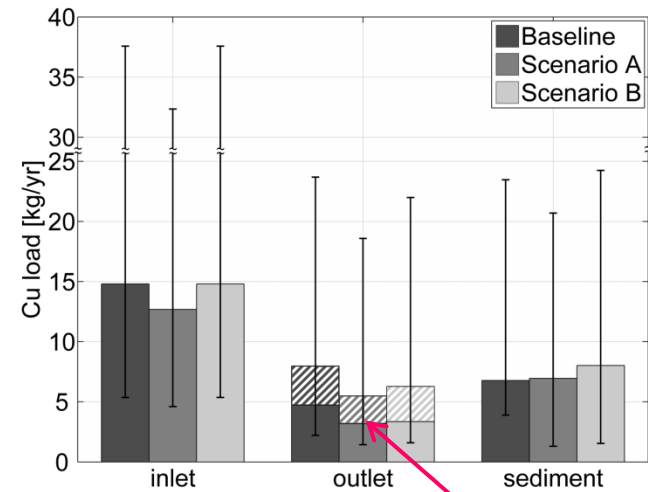
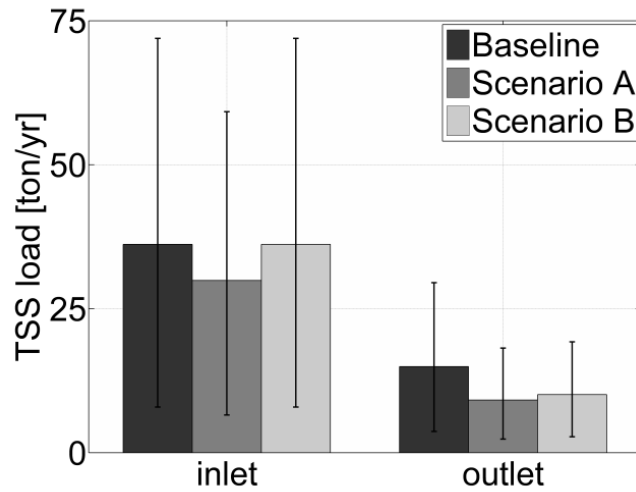
How can we improve our system?

- The integrated model was run with a 10-year rain series (1994-2004)
- Three scenarios 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 treatment): 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

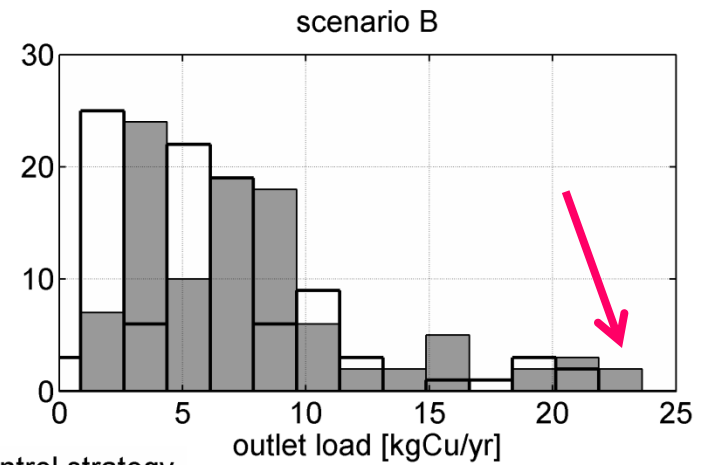
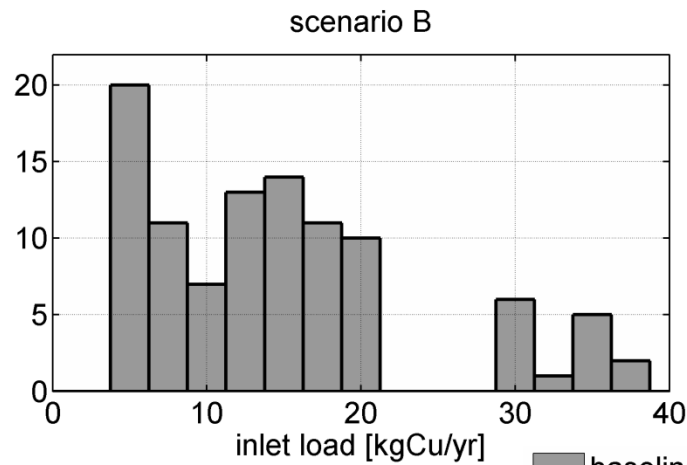
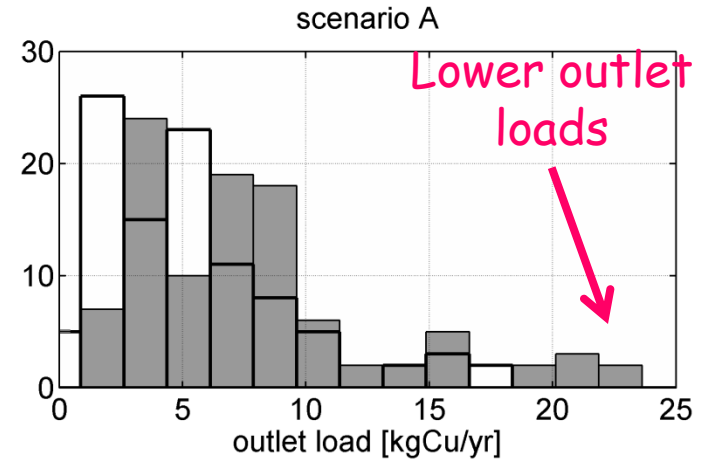
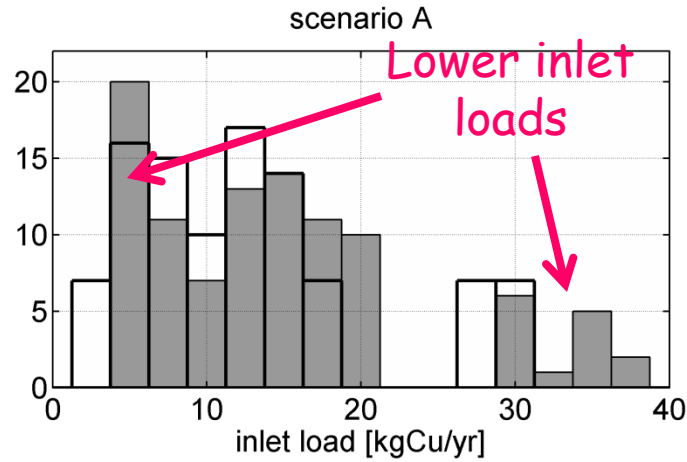
median

min



# Control strategies

## Discharged loads



■ baseline □ control strategy



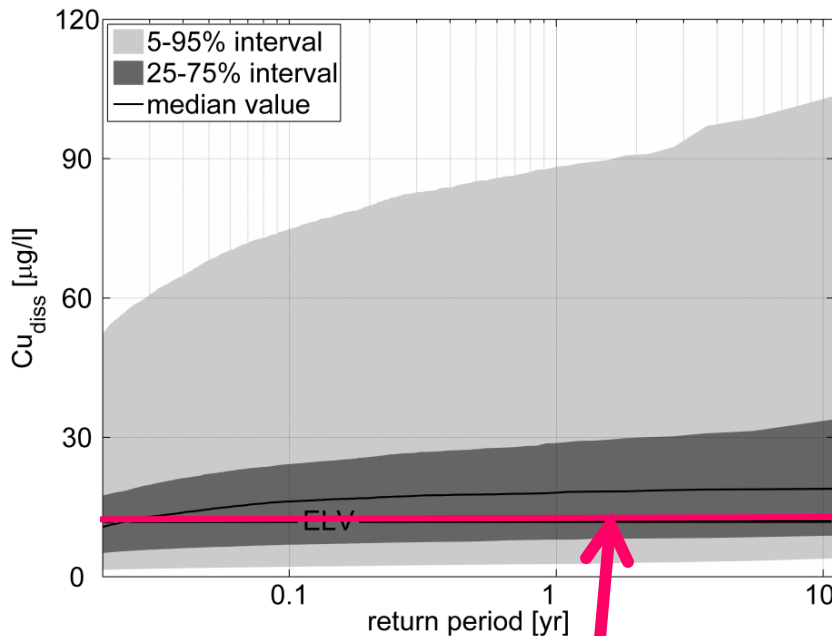


# Control strategies

## Discharged concentrations

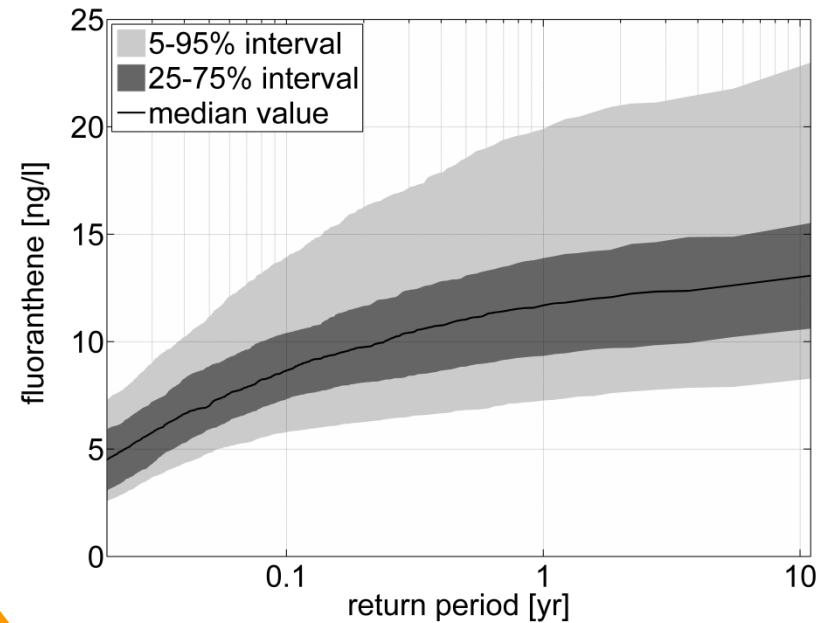
- Model results provide estimation of compliance with legal limits

### 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

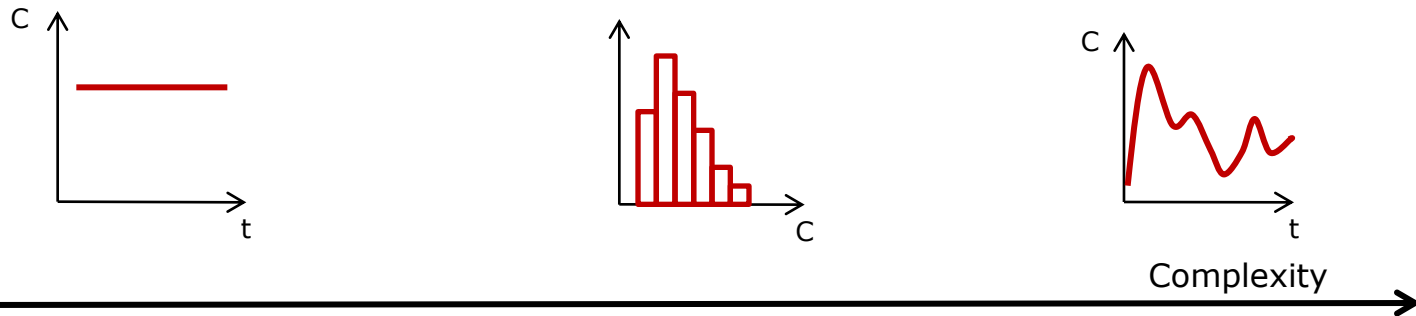
## Results comparison

- 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)

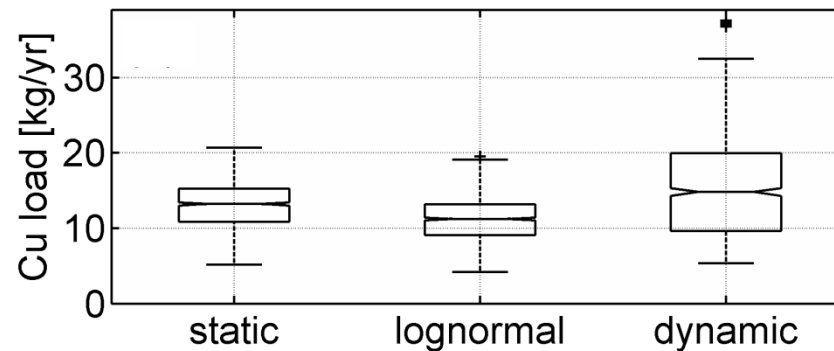
- What if less (or no) measurements are available?
  - Stormwater quality data can be retrieved from databases
  - Less complex stormwater quality model can be used



+ (No) Measurement needed  
- No variability

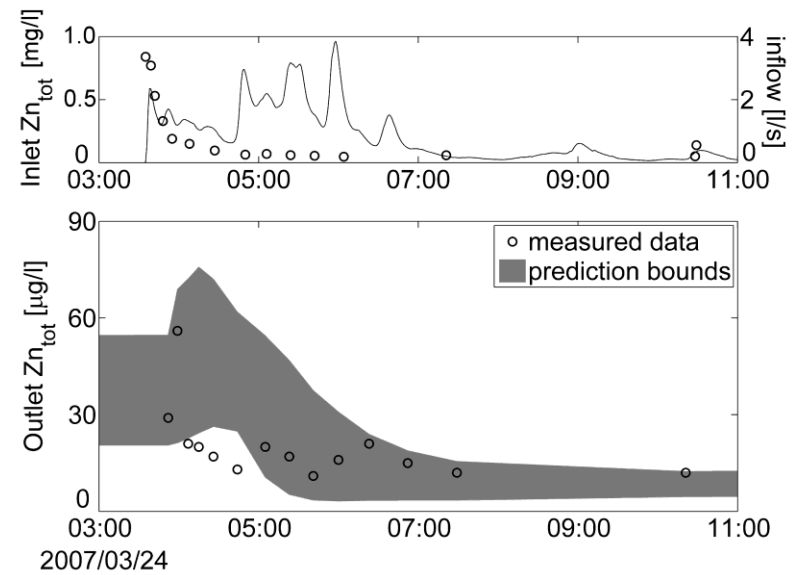
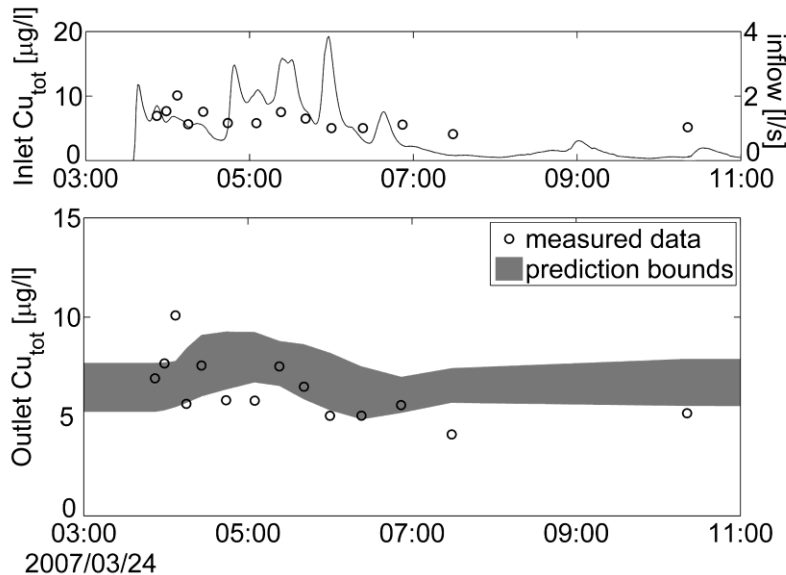
+ (No) Measurement needed  
= Inter- event variability

- Measurement needed  
+ Inter- Intra-event variability



# Other potential applications (2)

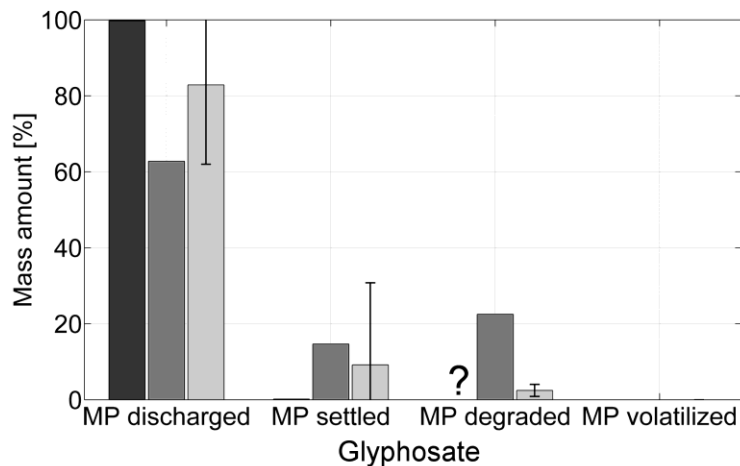
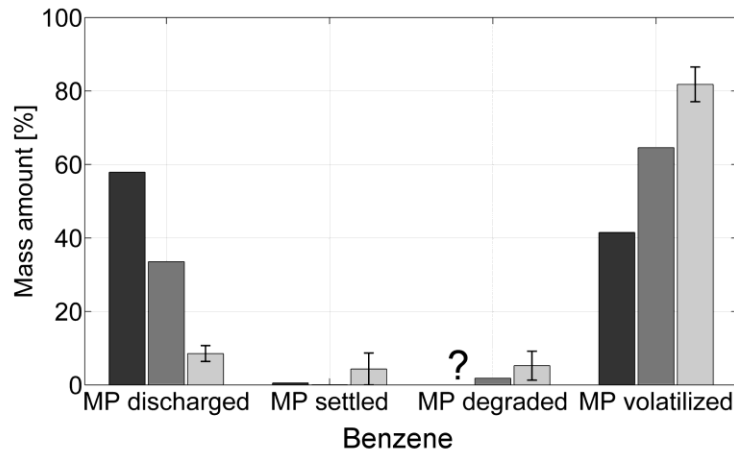
- What if we want to use other treatment units?
  - Model tested also for biofilters (= infiltration through soil)



# Other potential applications (3)

- What if we have no measurements?
  - Model applied to different organic micropollutants
  - 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 of pollution control strategies

More on this topic in my PhD thesis:

[orbit.dtu.dk](http://orbit.dtu.dk) or [www.env.dtu.dk](http://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.