Uncertainty in river water quality modelling: Application to the river Dender in Flanders, Belgium

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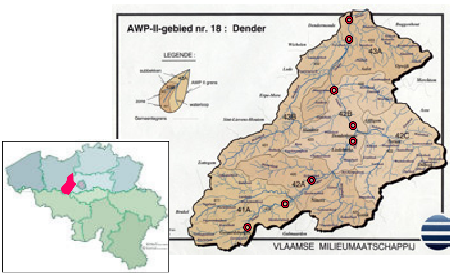
Objectives

The effect of pollutant loads can be evaluated using models. However, for several reasons those model outputs are uncertain. **The aim of this research** is to reduce the uncertainty in the final model outputs by reducing the uncertainty on model parameters. A **three step procedure** is proposed and illustrated with a case study.

THE DENDER RIVER BASIN IN FLANDERS

The Dender basin covers an area of +/ - 700 km² and has a length of ca. 50 km



THE DENDER MODEL

Pollution sources

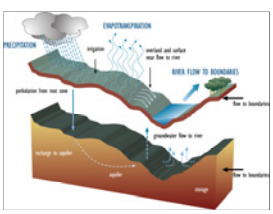
- Agriculture (up to 70 % of the area)
- Industrial emissions (30 firms, causing 90 % of the industrial pollution)
- Domestic pollution (density > 500 inhabitants per km²; 10 % treated)

	inhabitants	flow m³/day	bod kg/day	ss kg/day	N kgN/day	P kgP/day
domestic	360000	54000	20000	32350	3600	720
industrial		16200	1100	500	350	280
agricultural			?	?	4600	1000

- ESWAT model: 16 subbasins (7 for main channel, 9 for tributaries)
- 80 Hydrological Units (HRU´s), defined by land use and soil type

THE ESWAT SIMULATOR

- ESWAT is an extension of SWAT (van Griensven and Bauwens, 2000), the Soil and Water Assessment Tool developed by the USDA.
  ESWAT was developed to allow for an integral modelling of the water quantity and quality processes in river basins.
- **Water quantity**: precipitation, evapotranspiration, surface run-off and lateral ground water and river flow
- **Water quality**: extended QUAL2E
- **Point source pollution**: hourly time step
- **Diffuse pollution**: crop and soil processes
- **Spatial variability**: link with GIS



STEP 1: SENSITIVITY ANALYSIS

- Efficient Monte Carlo method based on Latin Hypercube sampling
- Sensitivity measure: Normalised Regression Coefficient (NRC)

9 most influential parameters , their NRC and their rank (Vandenberghe et al. 2001)

Parameter	NRC	rank
Ai5, O_2 uptake per unit of NH_3 oxidation	0.261	1
Bc1, Rate constant for biological oxidation of NH_4 to NO_2	0.162	2
Ai4, O_2 uptake per unit algae growth	0.143	3
Rk1, BOD deoxygenation rate coefficient	0.130	4
Ai3, O_2 production per unit algae growth	-0.110	5
Ai6, O_2 uptake per unit of HNO_2 oxidation	0.072	6
Rk3, rate of loss of BOD due to settling	-0.071	7
Rk2, oxygen reaeration rate	-0.070	8
Rktem, rate constant for heat exchange	-0.043	9

STEP 2: UNCERTAINTY ANALYSIS

- After detection of the most influential parameters, the model is calibrated with those parameters while the others remain fixed on a literature value.
- Calibration based on a Gauss-Marquardt-Levenberg Method (PEST-program).

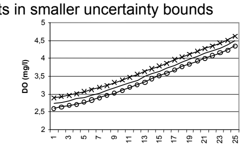
➡ Calculation of the Covariance matrix

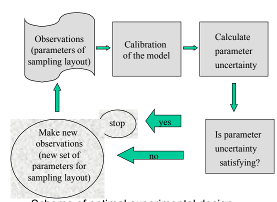
➡ Calculation of the parameter uncertainty

➡ Calculation of the uncertainty on final results

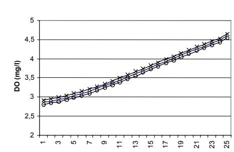
STEP 3: OPTIMAL EXPERIMENTAL DESIGN

- Aim: find the best measuring points that make the parameter uncertainty as small as possible (Vandenberghe et al., 2002)
- A smaller parameter uncertainty results in smaller uncertainty bounds around the model results
- The optimal experimental design methodology used here is the D-optimal design





Scheme of optimal experimental design



Comparison of a detail of dissolved oxygen model output with 95 % confidence bounds for the river Dender

CONCLUSIONS

- Three steps, sensitivity analysis, uncertainty analysis and optimal experimental design are applied to river water quality modelling to achieve better modelling accuracy.
- Following this strategy it becomes possible to sample a river in a way that the parameters have an acceptable uncertainty after calibration of the water quality model.
- The sampling strategies can be evaluated in view of the limitations of costs and other practical limitations.

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