



Model predictive control

Implemented for the Demer basin

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modelling of the Meuse basin
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Halen, September 1998

VERZEKERINGSMAATSCHAPPIJEN BEREIDEN ZICH VOOR OP VERGOEDING OVERSTROMINGSSCHADE

Demerramp kan om de 25 jaar gebeuren

06/10/2001 om 00:00 door Michel Vandersmissen



BRUSSEL -- Je kan maar best niet in Dinant of in de Zwalmstreek wonen. Tenminste als je rekening houdt met het risico op overstromingsgevaar. Als de regering binnenkort een wet goedkeurt die het verzekeren van overstromingen verplicht maakt, zullen de premies in deze gemeenten vermoedelijk duurder zijn dan in drogere gemeenten. Om de hoogte van die premies en het portefeuillerisico in te schatten, bestelden de herverzekeraar St. Paul Re en de herverzekeringsconsulent Aon Re Belgium een studie over het overstromingsrisico in België.

Mitigation strategies

Give space to the river
1970's: Schulensmeer



Early warning systems
2004: Operational basin model
2014: Launch waterinfo.be

Intelligent real time control

Local solutions

Dykes, rectifying river stretches, ...

1959: ir. Roovers "enhanced water flow"

De Overstromingsvoorspeller van de Demer

Demervoorspeller waarschuwt bewoners voor overstroming

WATERINFO.be Vlaanderen is water

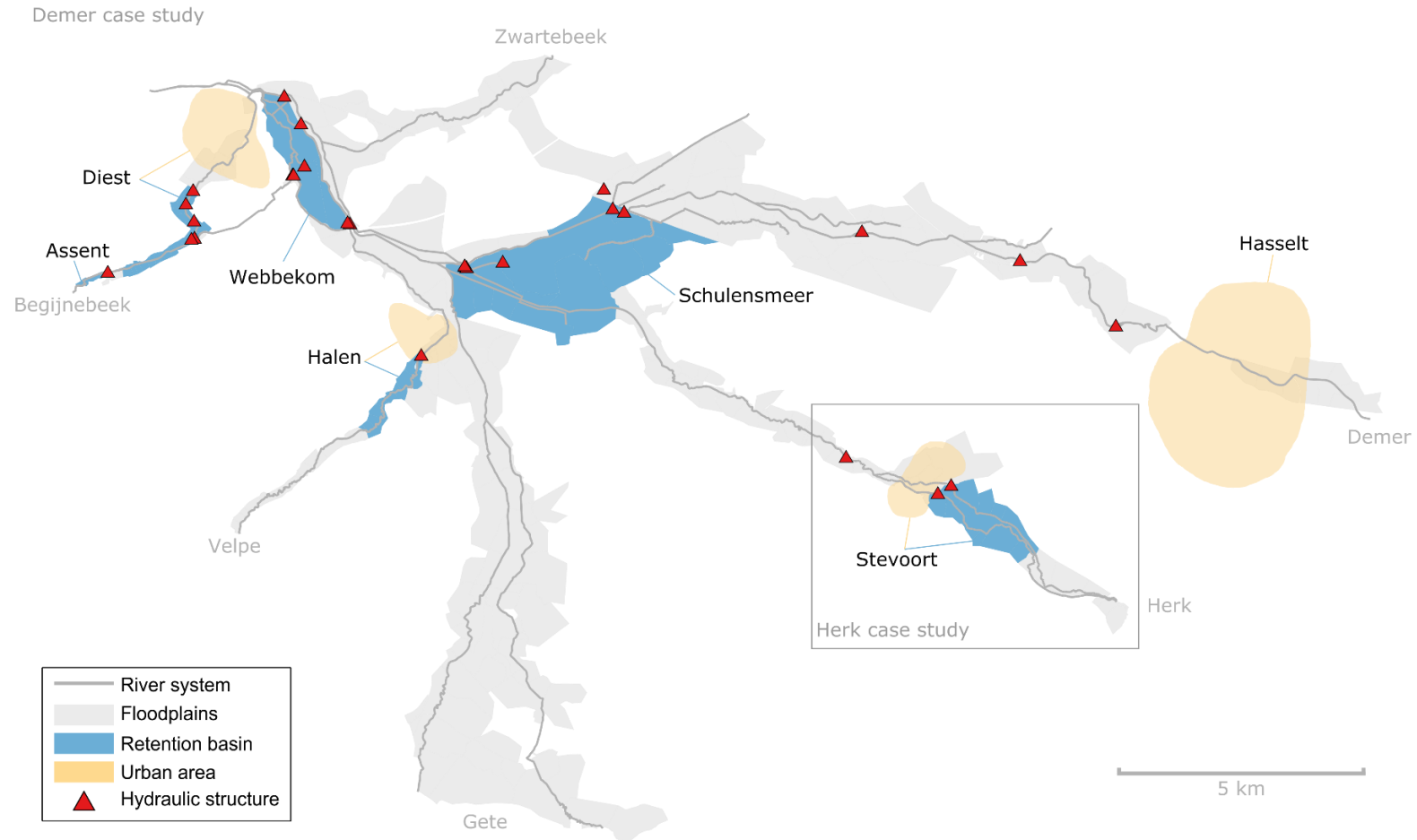
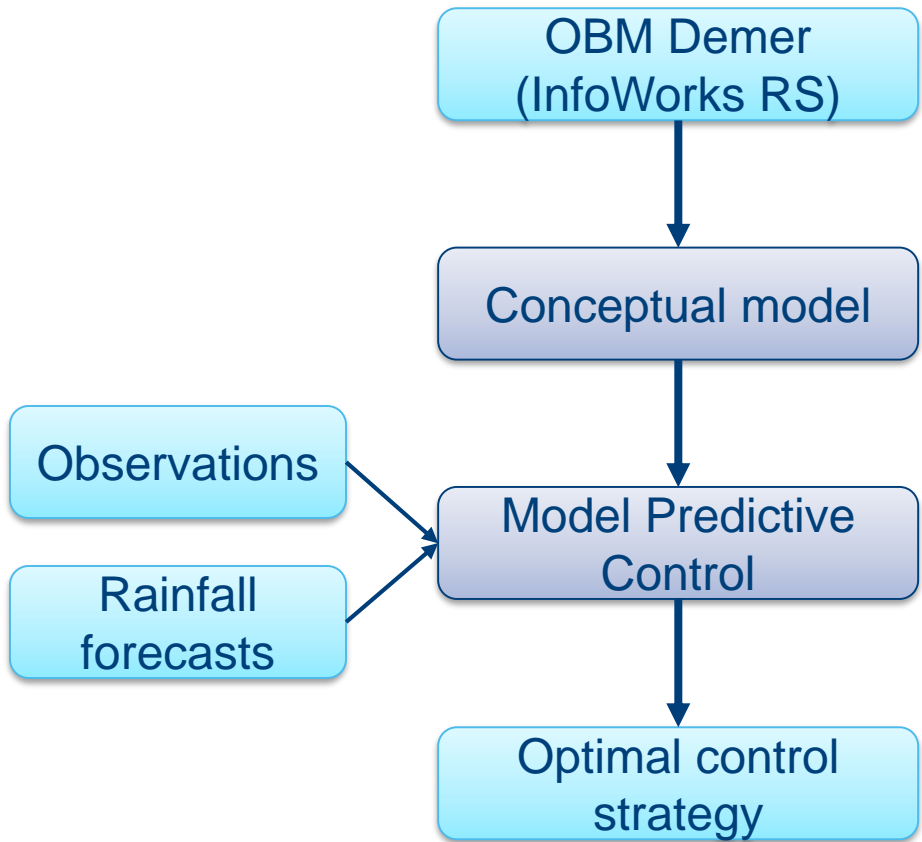
Actuele toestand

Snel naar: overstromingsvoorspelling +48u

Waterinfo berichten

De afvoersituatie op de waterwegen is en blijft de komende 48 u normaal.

Approach



Overview

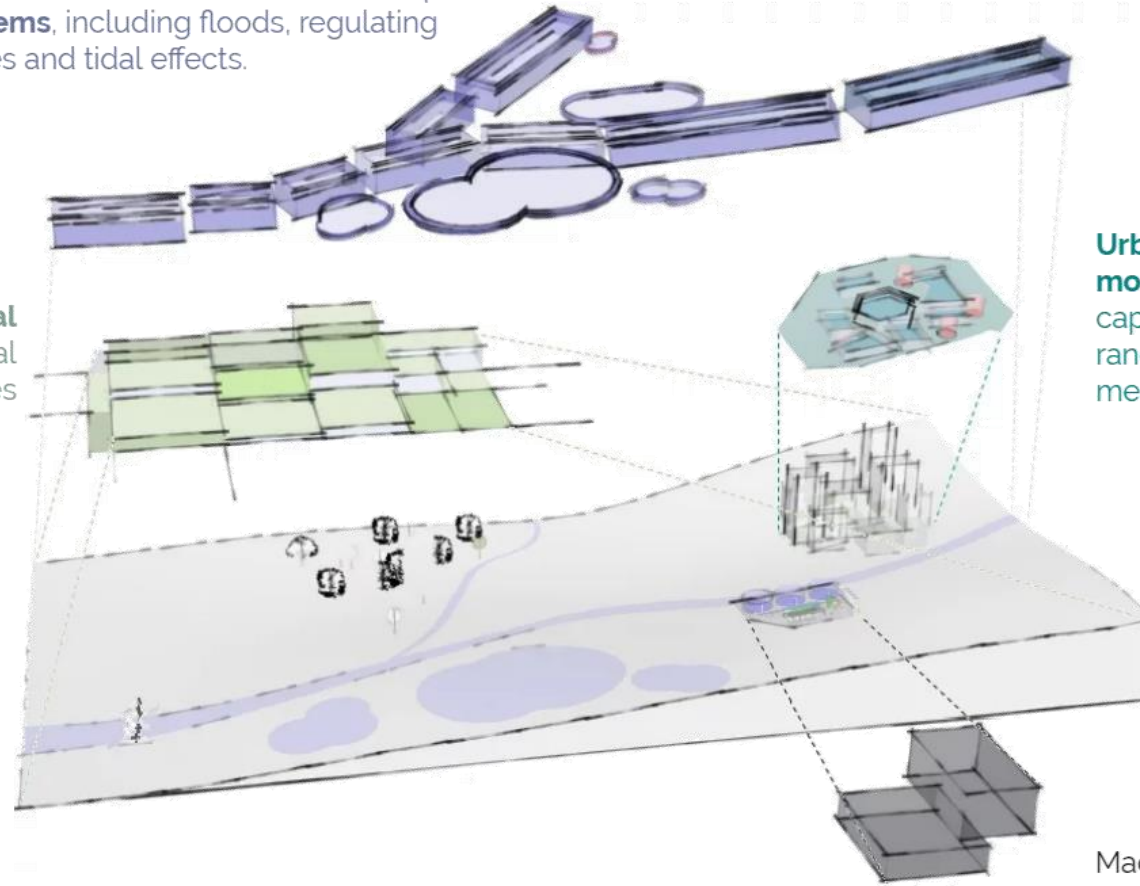
- Introduction
- Conceptual models
 - Methodology
 - Results
- Real time control
 - “Model Predictive Control” (MPC)
 - “Reduced Genetic Algorithms” (RGA)
- Results
- Conclusions

Conceptual models

Conceptual reservoir-type models that can emulate complex dynamics of **river systems**, including floods, regulating structures and tidal effects.

State-of-the-art **hydrological models** suitable for spatial scenario analyses

Urban drainage and flood models using radar data, and capable of simulating a vast range of source control measures



- **Integrated approach**

Include hydrology, rivers, sewers and other processes

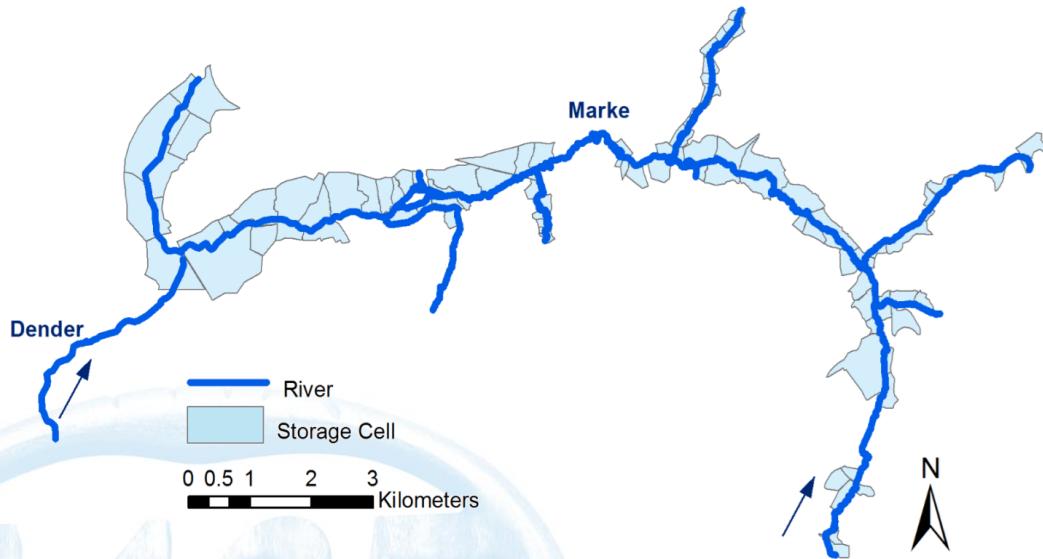
- **Super fast**

- **Accurate**

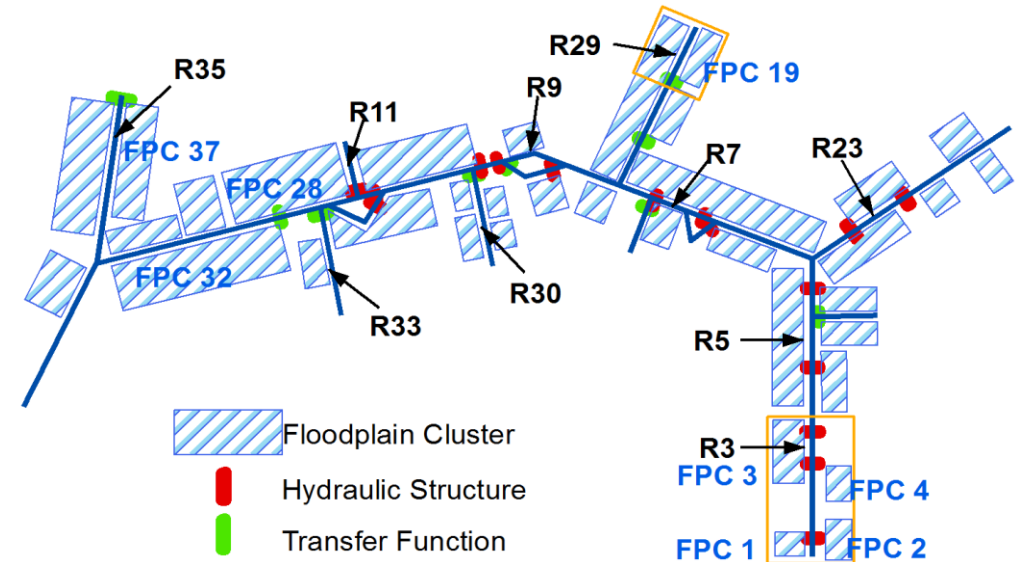
Machine learning techniques to **turn process data from various sources** in powerful predictive models

Conceptual model: network

Hydrodynamic InfoWorks model (OBM)

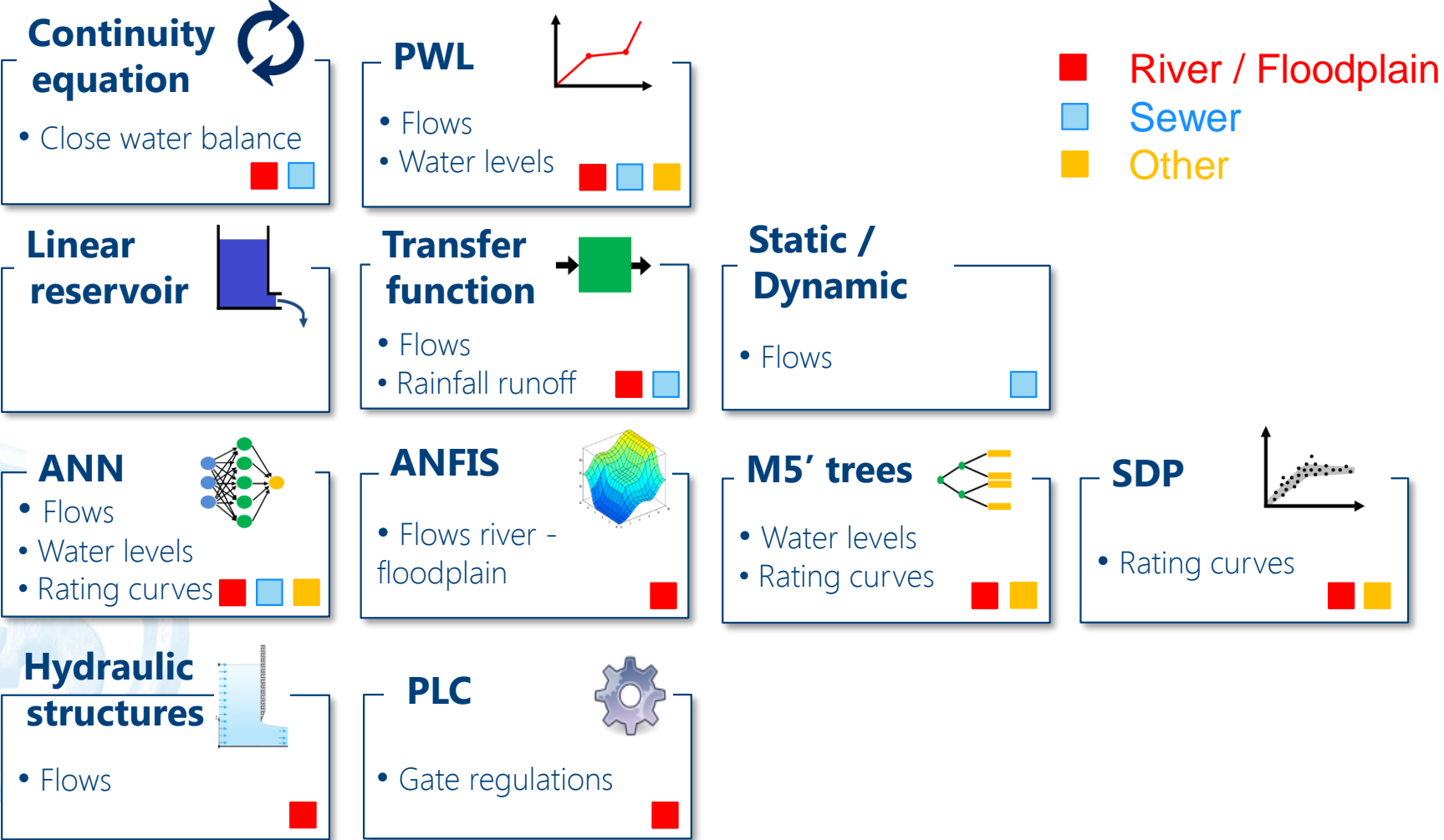


Conceptual model

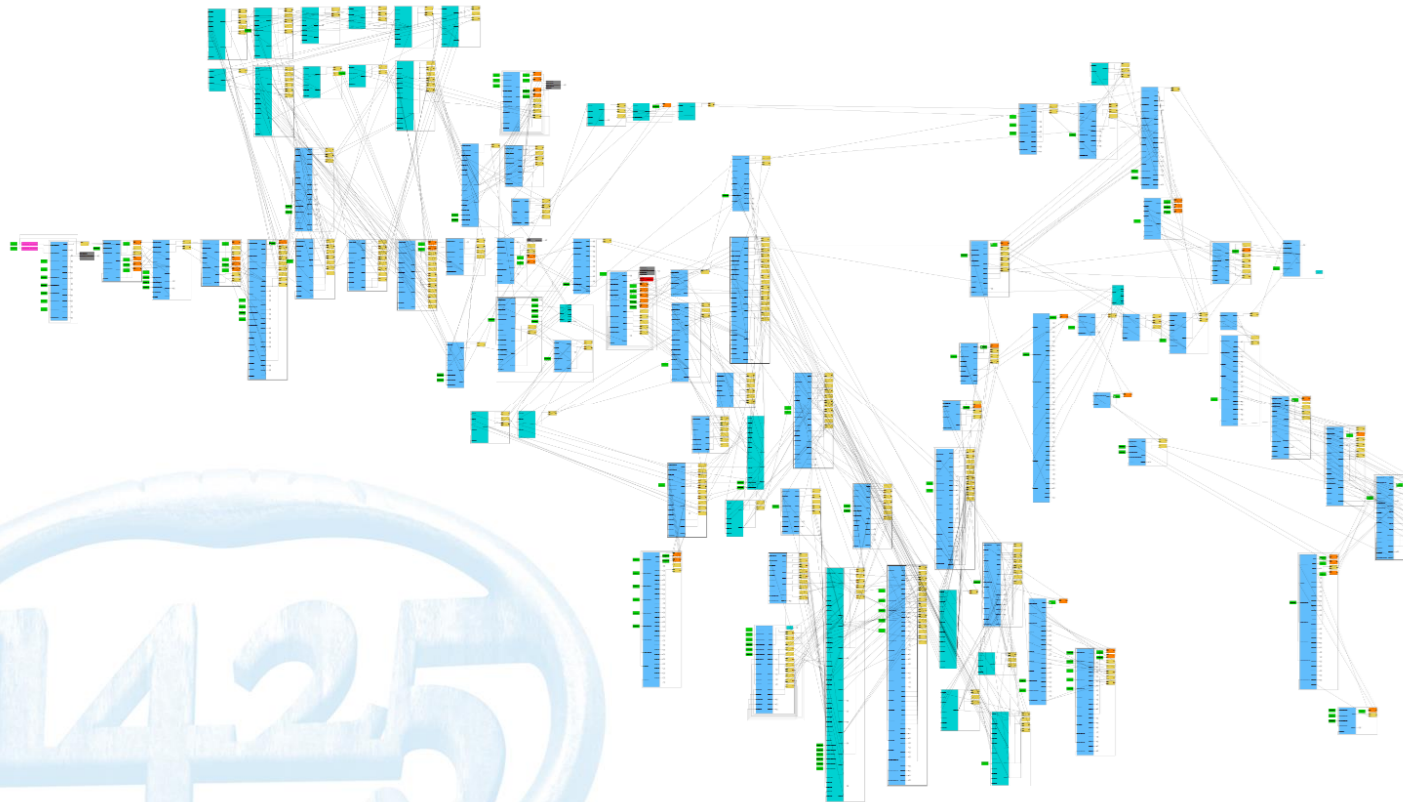


- Data-based mechanistic approach
- Storage cell concept
- Modular setting

Conceptual model structures & parameters



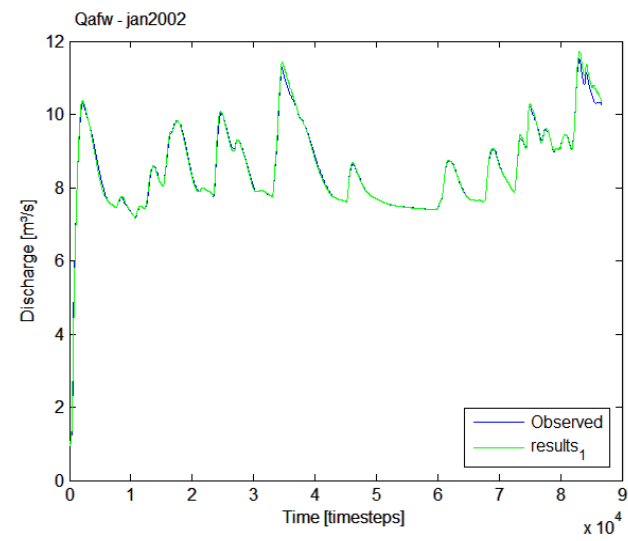
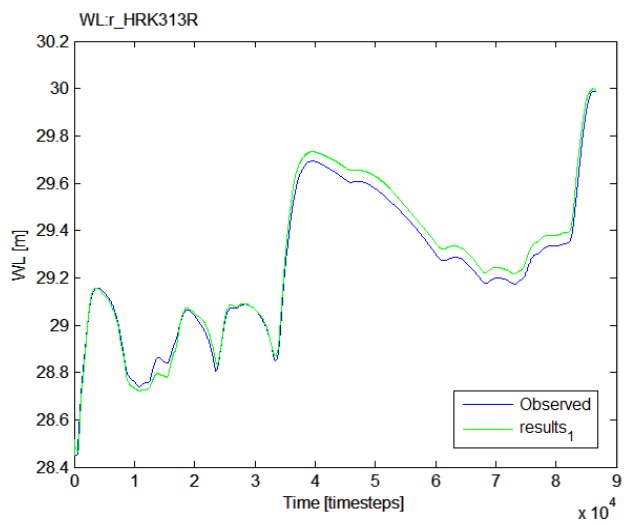
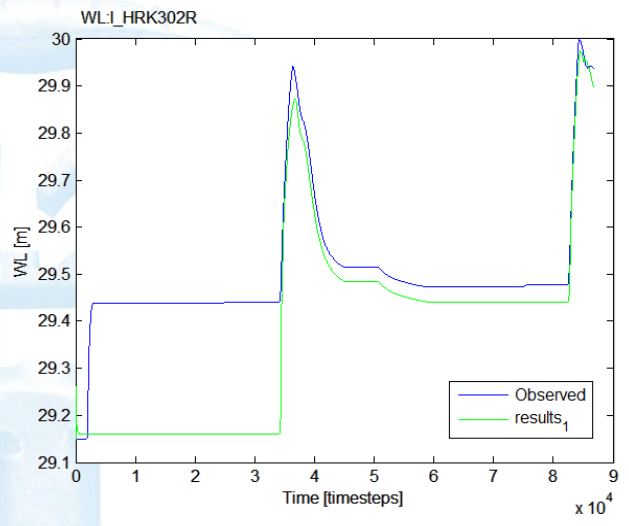
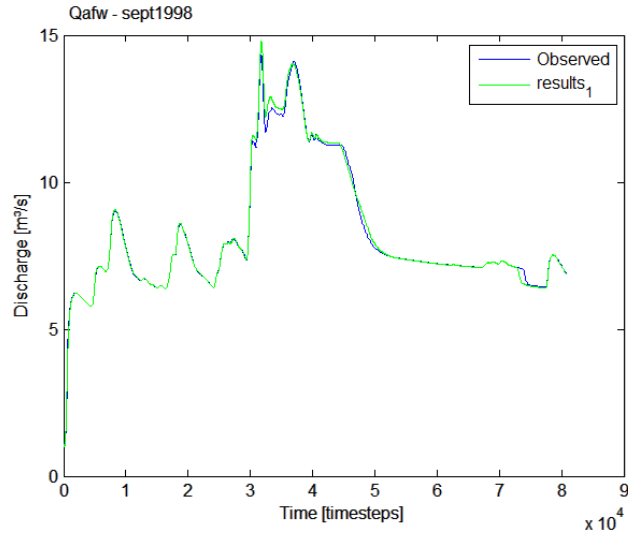
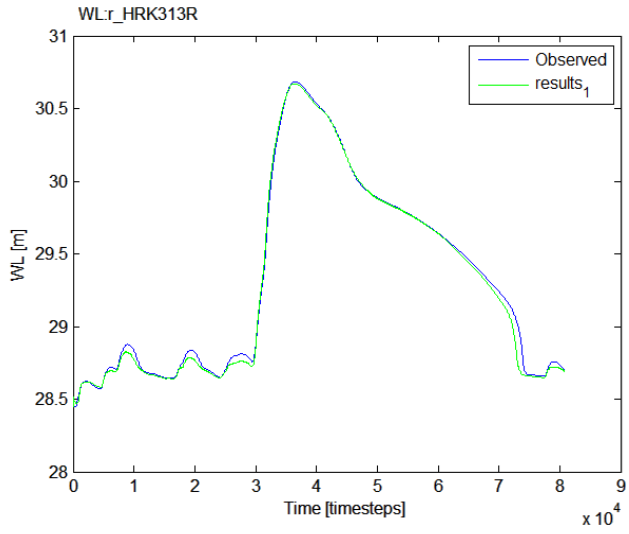
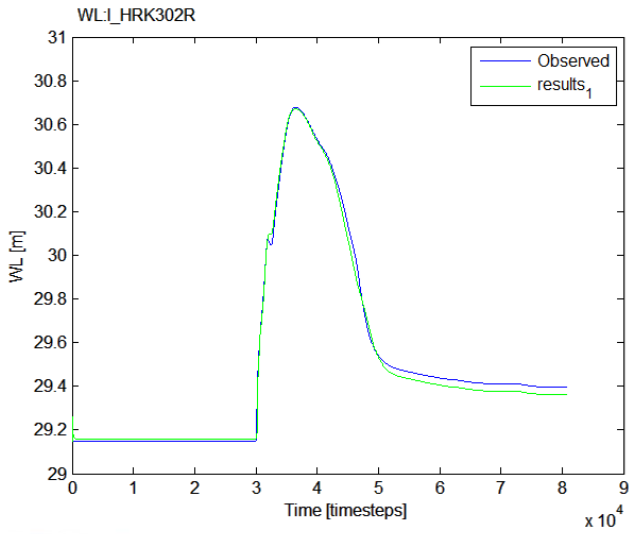
Conceptual model: results



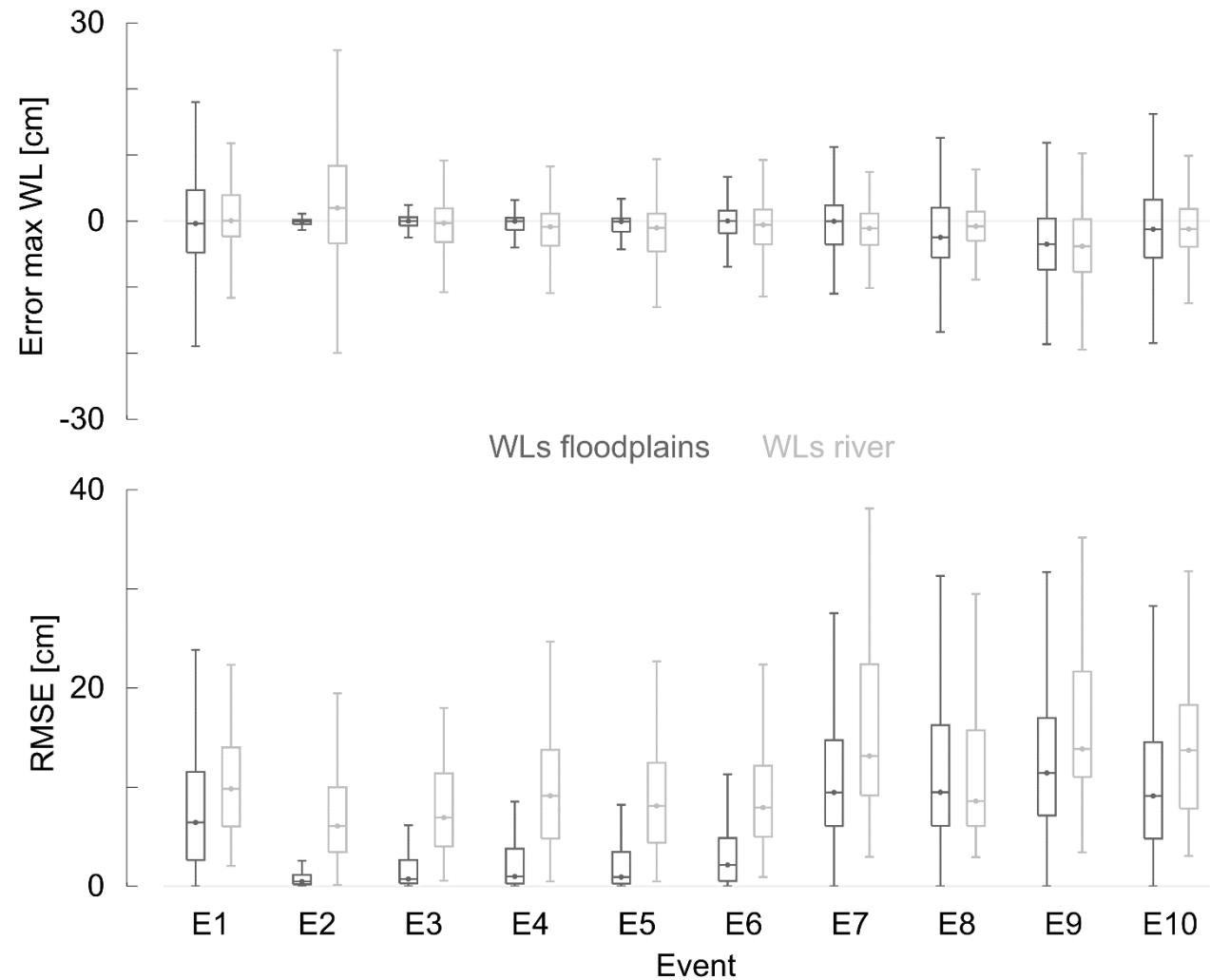
- Floodplain
- Reservoir
- Fixed HS
- Adjustable HS
- Transfer function
- Input (RR, GL)

	InfoWorks RS	Conceptual model
WL nodes	> 3 500	466
Hydraulic structures	> 1 700	391
Reservoirs	/	90
Computation time	1h15m	0.8s

Conceptual model: results

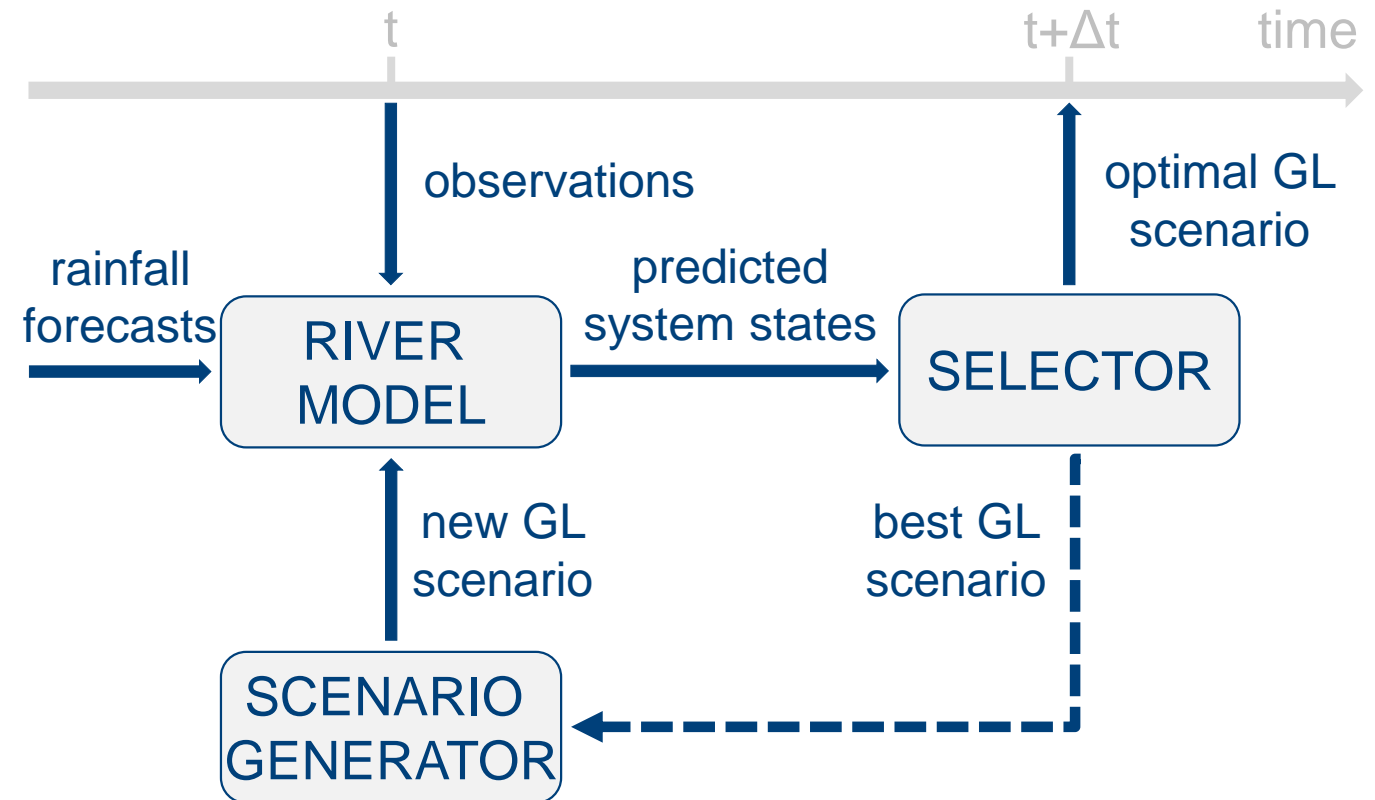


Conceptual model: results



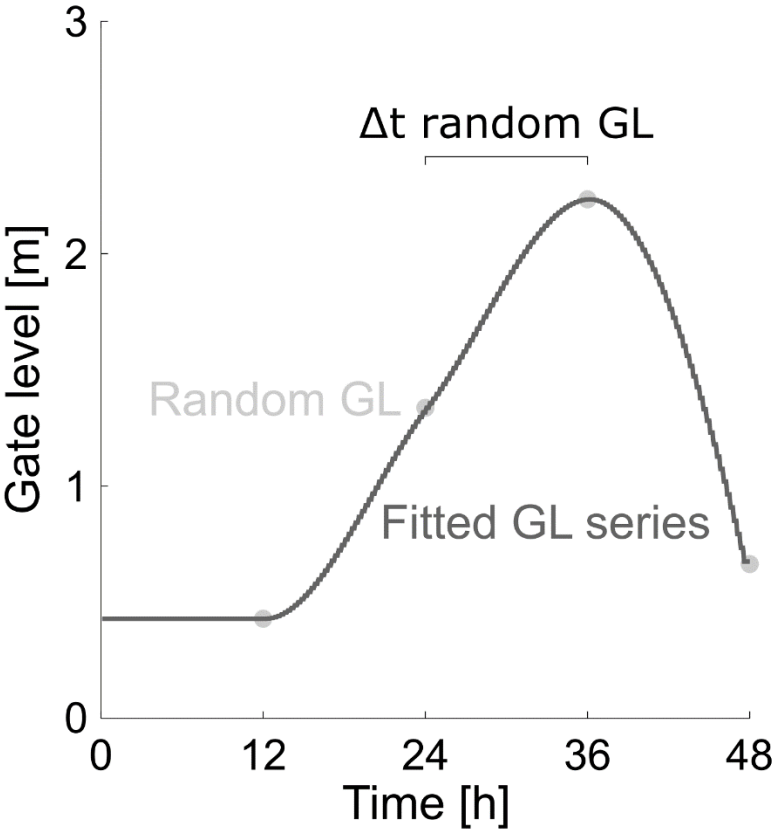
Real-Time Control by means of RGA-MPC

- Model Predictive Control
 - River model
 - Optimizer
- Reduced Genetic Algorithm
 - Based on standard GA
 - Objectives:
 - Retention basin dikes
 - Damage cost
 - Critical dikes
 - Retention basins

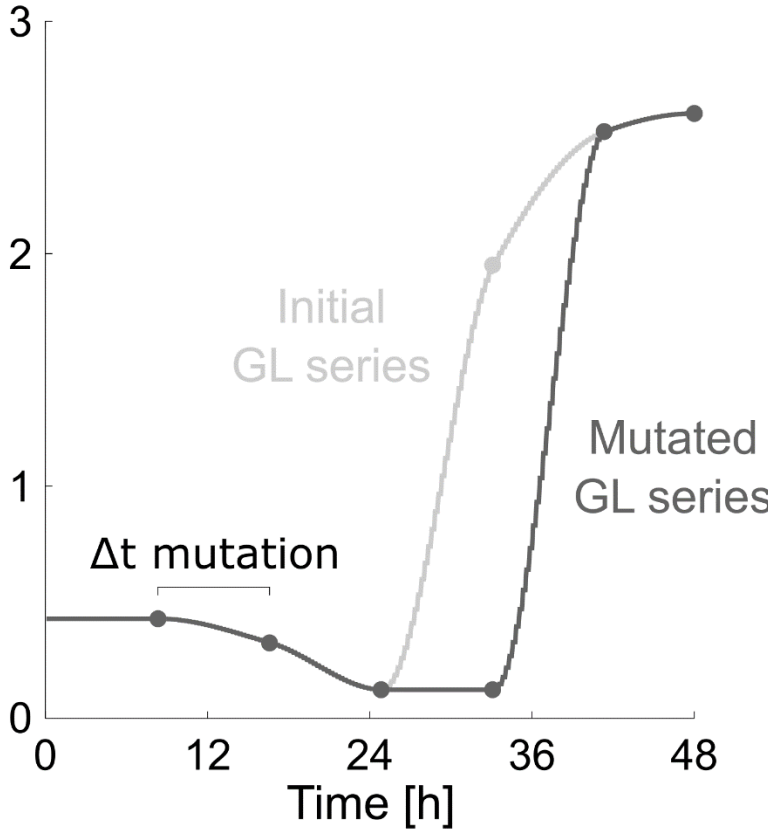


Gate Level scenario generation

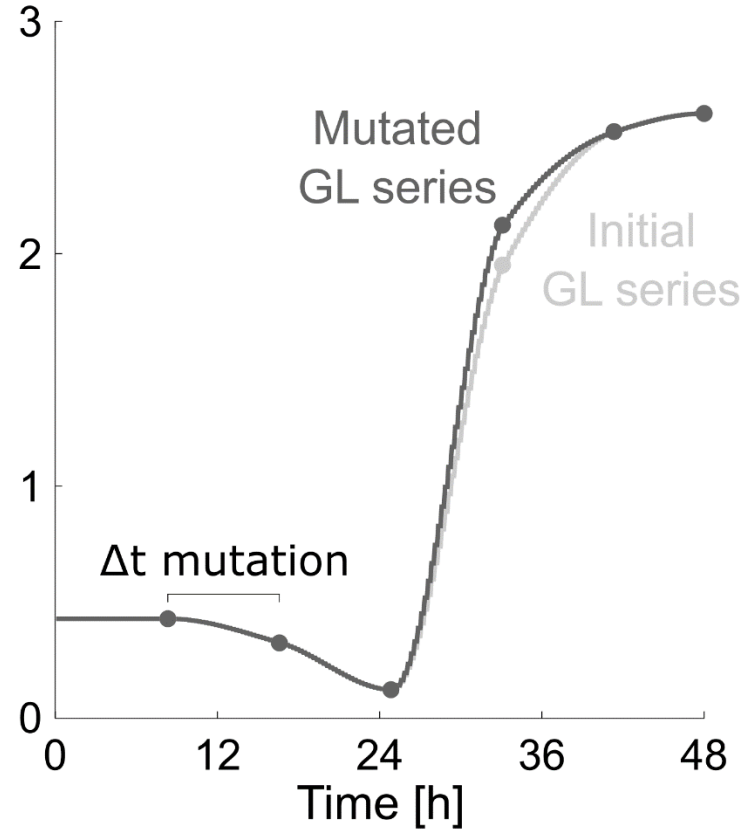
a) Random GL series



b) Diversification

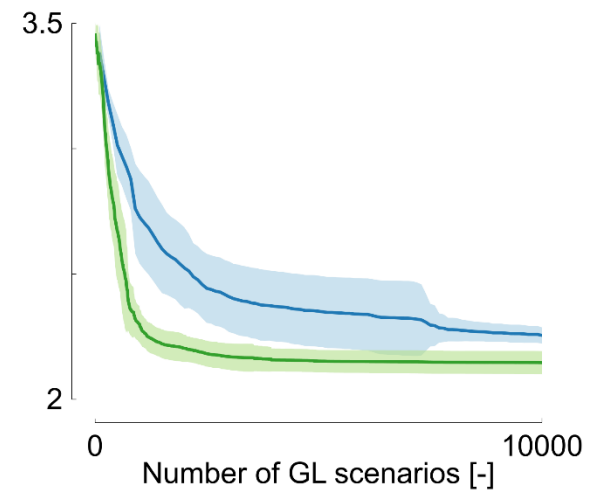
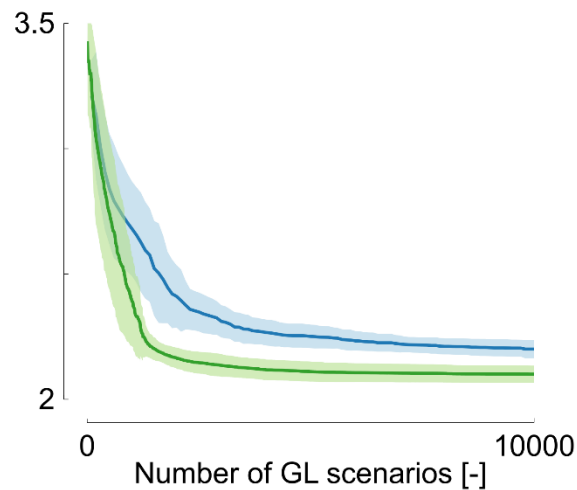
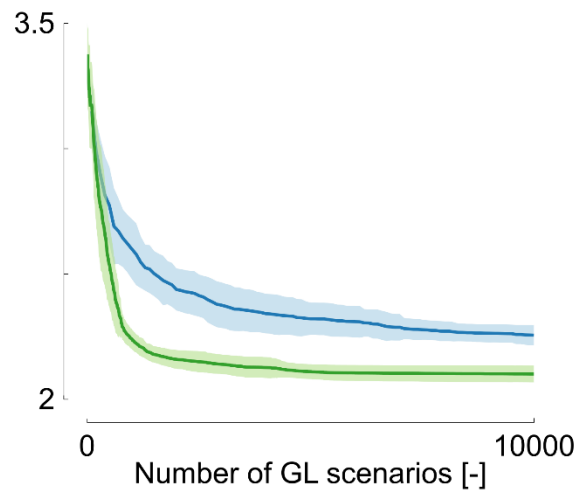
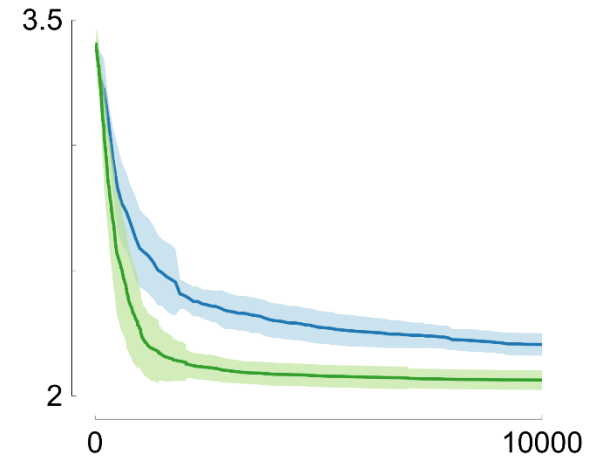
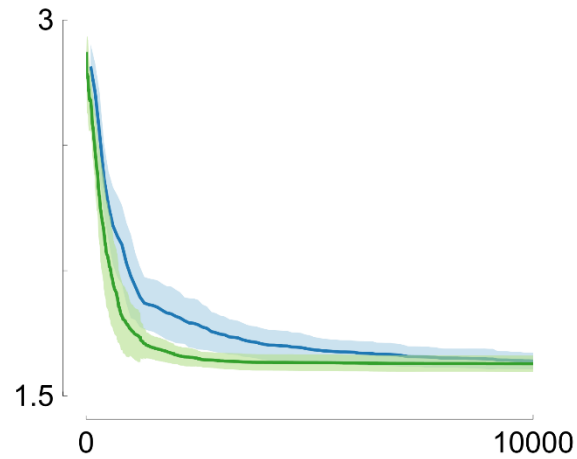
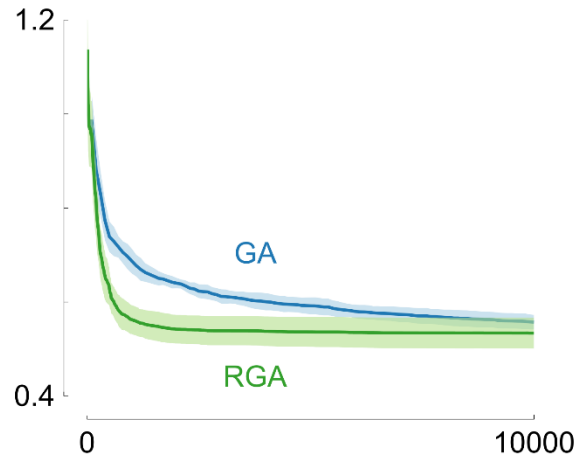


c) Intensification



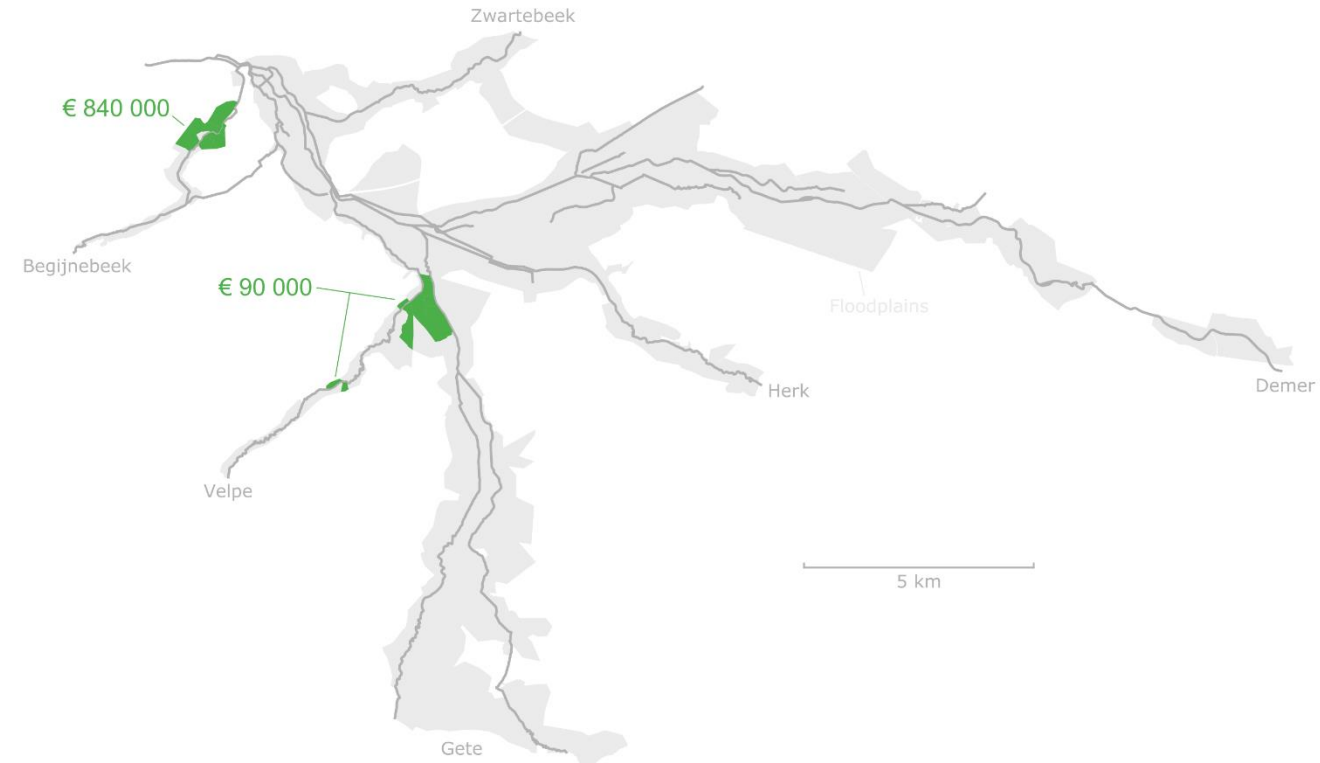
RGA versus GA

Damage cost
[€ 1 000 000]

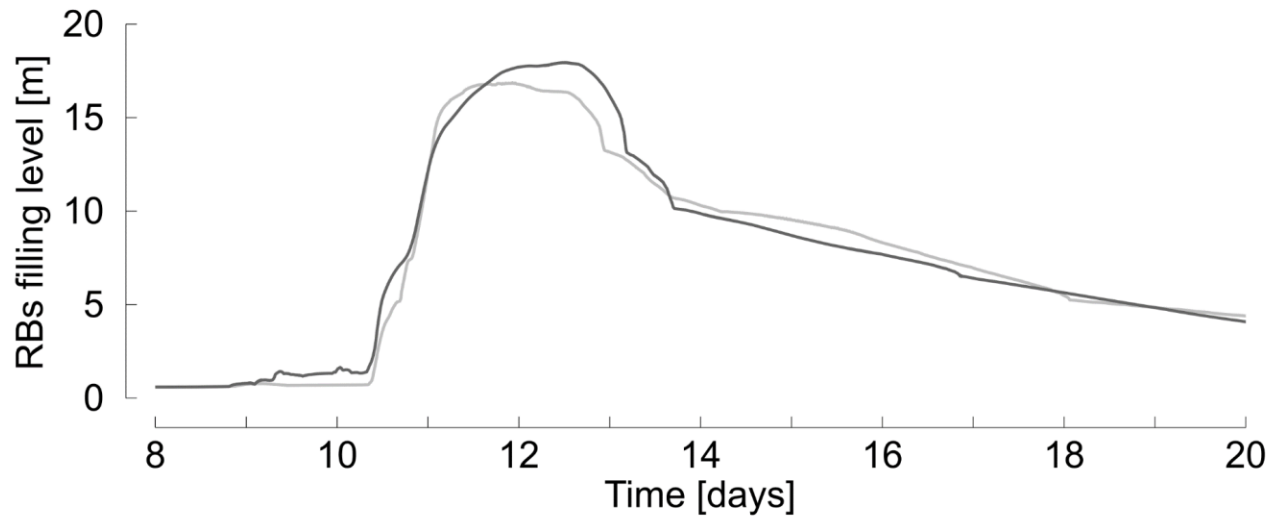
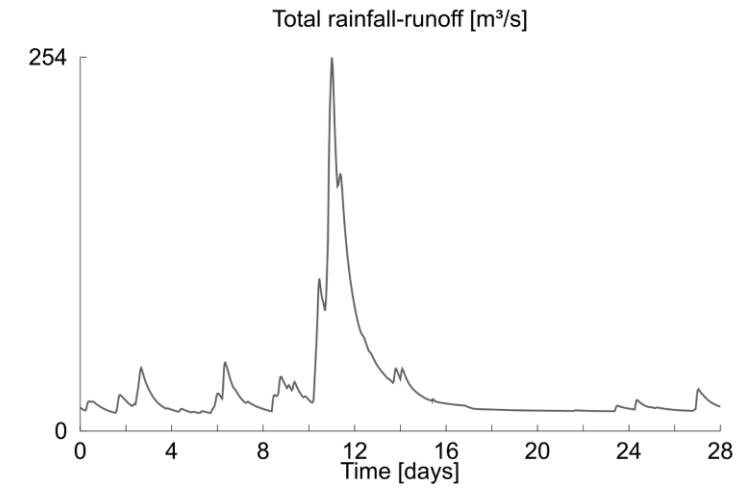
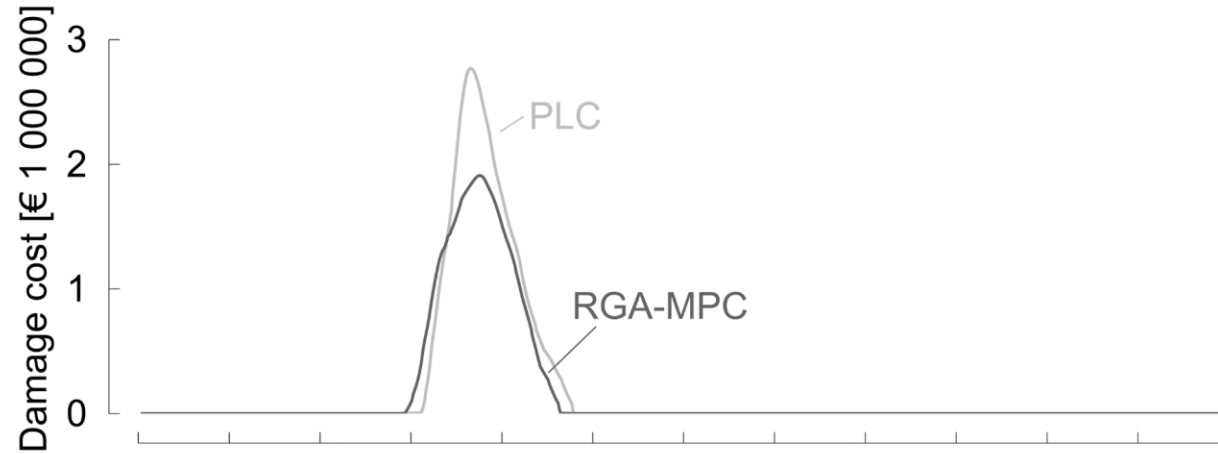


Ideal MPC results

Event	Economic damage cost [€]		Damage reduction [%]
	PLC	MPC	
Sept1998	3.0M	2.1M	30
Aug2003	0	0	/
Dec1999	0	0	/
Jan1995	0	0	/
Jan2002	0	0	/
Nov2010	300	100	(67)
VMM	4.7M	3.5M	26
T1000	2.0M	1.7M	15
Sept1998x1.3	28.0M	26.8M	4
2xSept1998	28.1M	27.5M	2

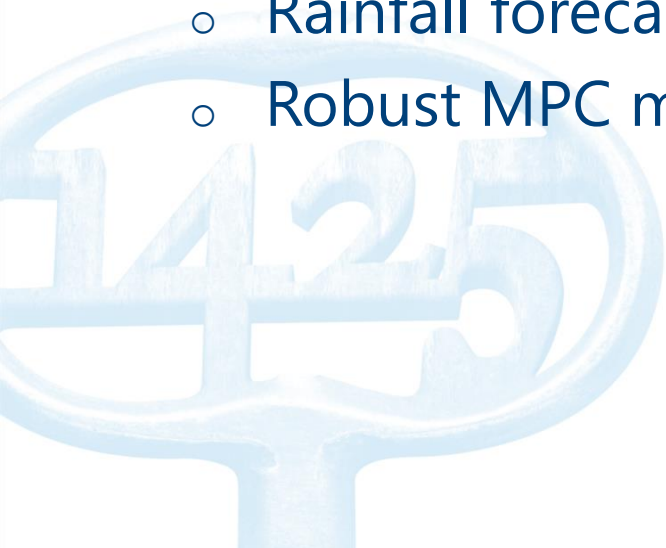


Ideal MPC results Sept 1998



Uncertainties in Real-Time Control

- Hydrodynamic model uncertainty
 - Model structure, calibration errors, seasonal vegetation, ...
 - Data Assimilation: State Estimators, Prediction Error Methods
- Input uncertainty
 - Rainfall forecasts, hydrological model uncertainty, ...
 - Robust MPC methods: MMPC, AMMPC, TB-MPC, ...



Conclusions

- Conceptual modelling
 - Integrated approach
 - Flexible model detail
 - Super fast
 - Several applications
- RGA-MPC for RTC
 - Outperforms PLC
 - Computational efficiency
 - Large and complex networks
 - Uncertainties

References:

On conceptual modelling method:

*Wolfs, V., Meert, P., Willems, P. (2015). Modular conceptual modelling approach and software for river hydraulic simulations. **Environmental Modelling and Software**, 71, 60-77*

On RGA-MPC approach:

*Vermuyten E., Meert P., Wolfs V., Willems P. (2017). Combining model predictive control with a reduced genetic algorithm for real-time flood control. **Journal of Water Resources Planning and Management**. (in press)*

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