18th International Conference on Wetland Systems for Water Pollution Control

25 - 29 November 2024

ICWS 2024 Martinique

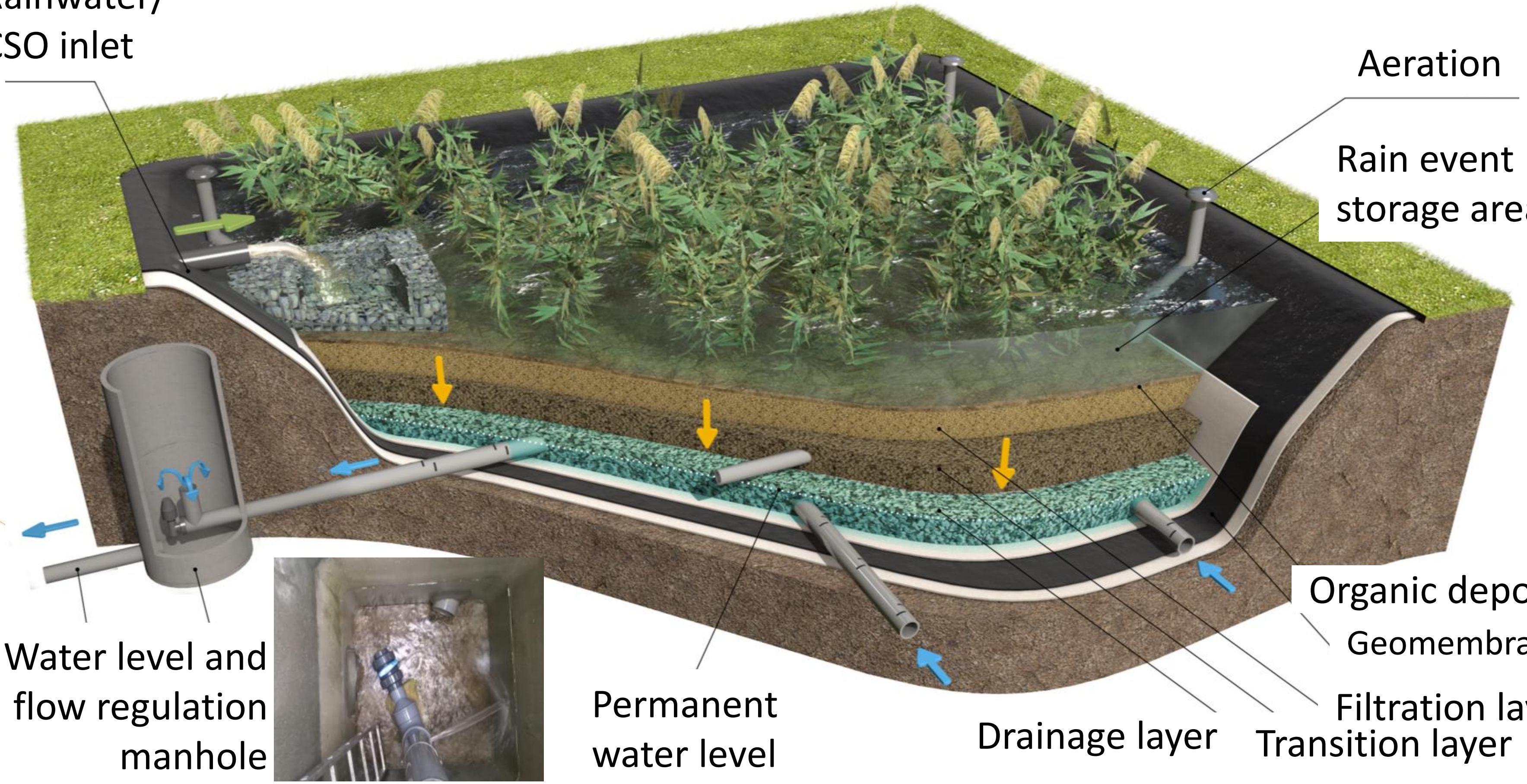
https://life-adsorb.eu/fr/site

Hydraulic modelling of a variably saturated treatment wetland for urban stormwater treatment to ensure resilient operation

Ania Morvannou, Stéphane Troesch, Marie-Christine Gromaire, Nicolas Forquet

25/11/2024

The HYDR'EPUR® System
Nature-based solution for runoff and CSO



Outflow controlled by a throttle outflow

20 references in France

	Removal efficiency (%)	Concentration out (mg/L)
DCO	60	50
MES	90	20

https://ecobird.fr/

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The Life ADSORB project

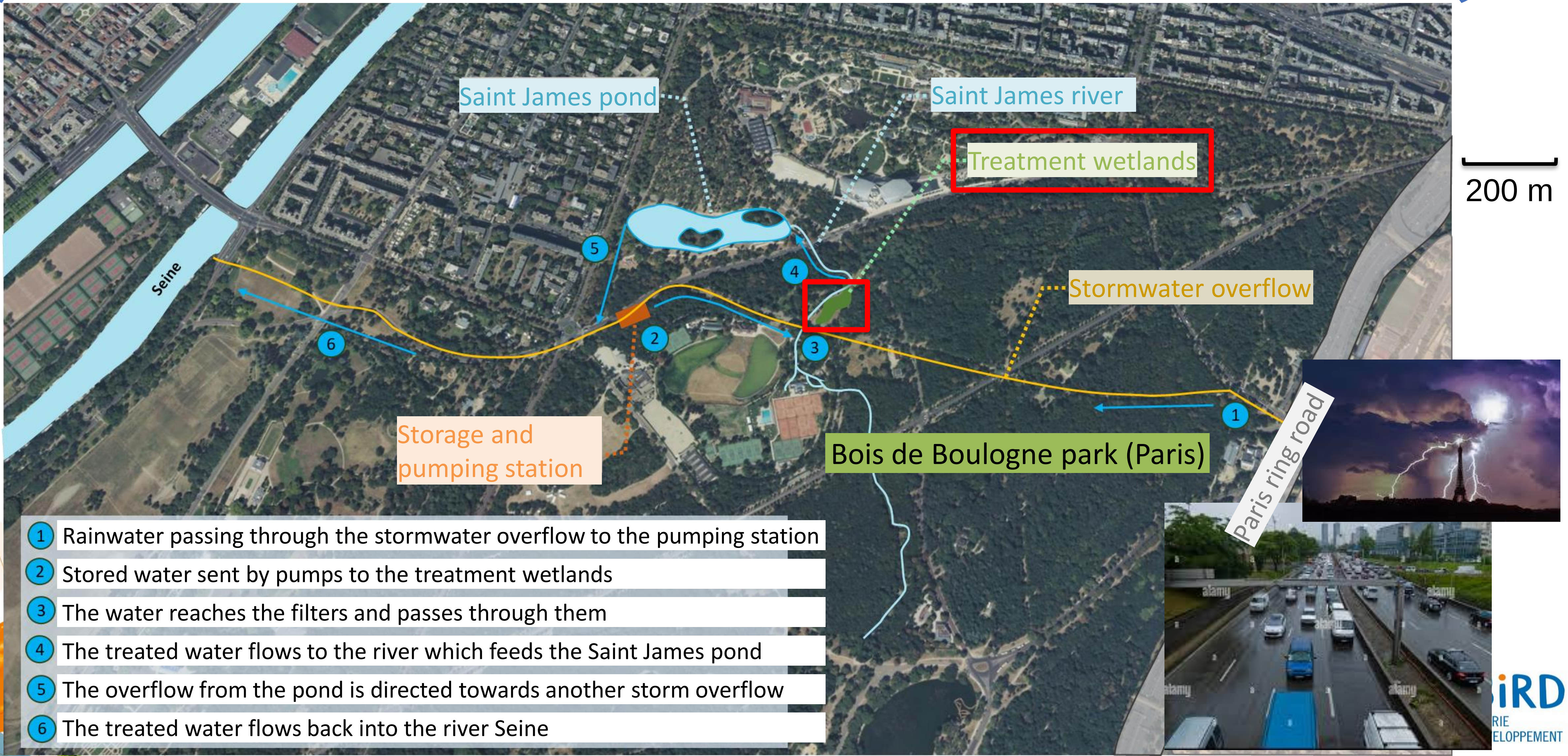
https://life-adsorb.eu/fr/site

Main objectives

- Demonstrate the applicability of a treatment wetland to effectively reduce pollutant loads (TSS, metallic and organic micropollutants) from runoff water in a natural area
- Better understanding and identification of mechanisms and parameters influencing water flow, transport and fate of micropollutants → optimize design and operational

How can modelling contribute ?

The Life ADSORB experimental site, in Paris



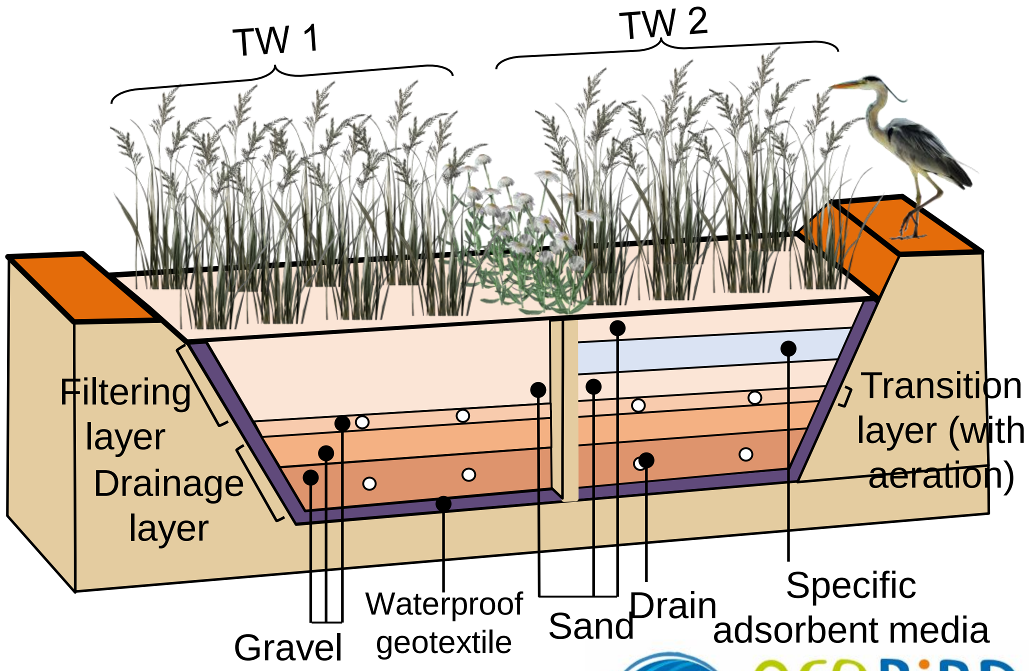
1. Rainwater passing through the stormwater overflow to the pumping station
2. Stored water sent by pumps to the treatment wetlands
3. The water reaches the filters and passes through them
4. The treated water flows to the river which feeds the Saint James pond
5. The overflow from the pond is directed towards another storm overflow
6. The treated water flows back into the river Seine

The treatment wetland pilots

- 2 pilot TWs of 600 m^2
- Treatment of runoff water; Metallic and organic micropollutants
- Similar configuration (100 m long, 1 m deep) and operation
  Alternation every month
- Transition layer (10 cm) + drainage layer (50 cm)
- Single difference between the two pilots:
  composition of the filtering layer

TW1: only sand (40 cm)

TW2: layer of specific adsorbent material (micropollutants, Rainclean®, 20 cm) between two layers of sand (10 cm each)



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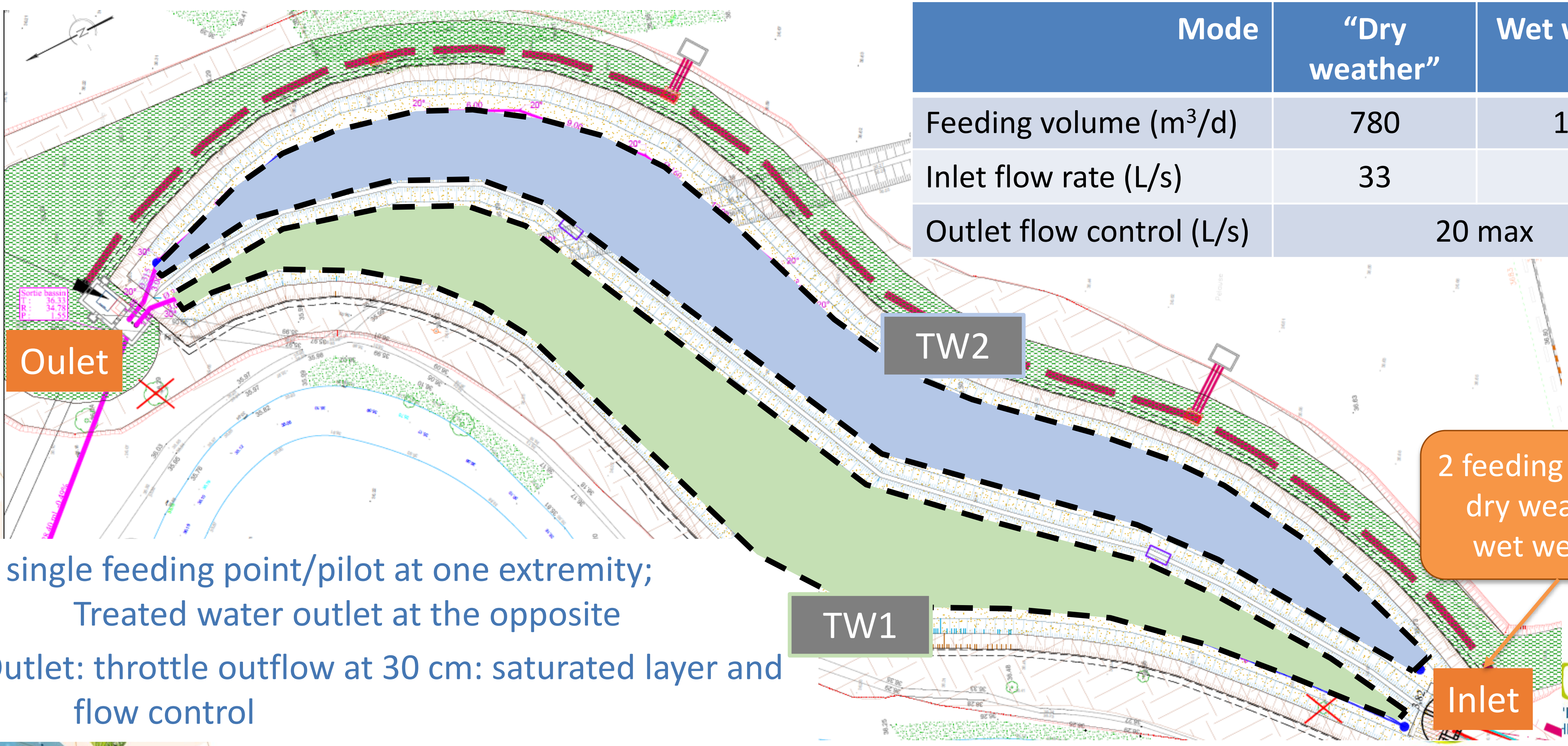
The treatment wetland pilots

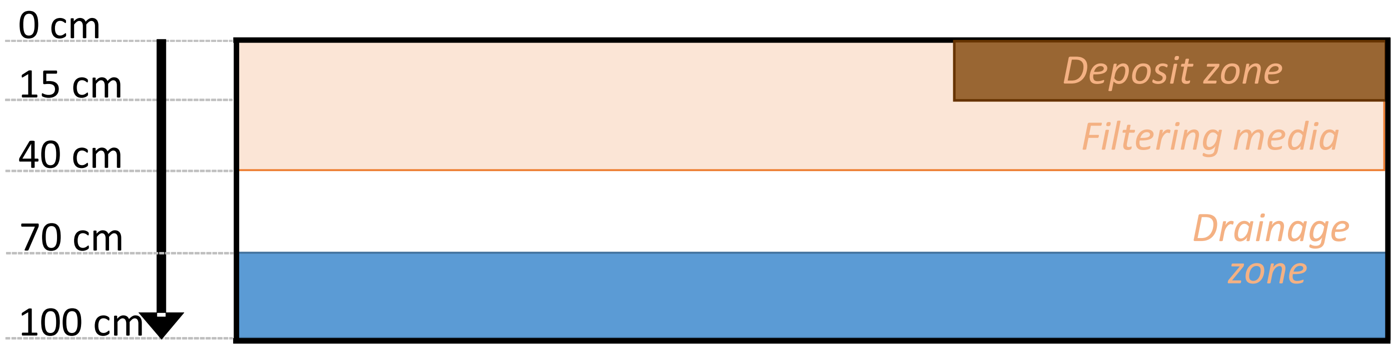
Mode	"Dry weather"	Wet weather
Feeding volume (m^3/d)	780	1900
Inlet flow rate (L/s)	33	72
Outlet flow control (L/s)	20 max	

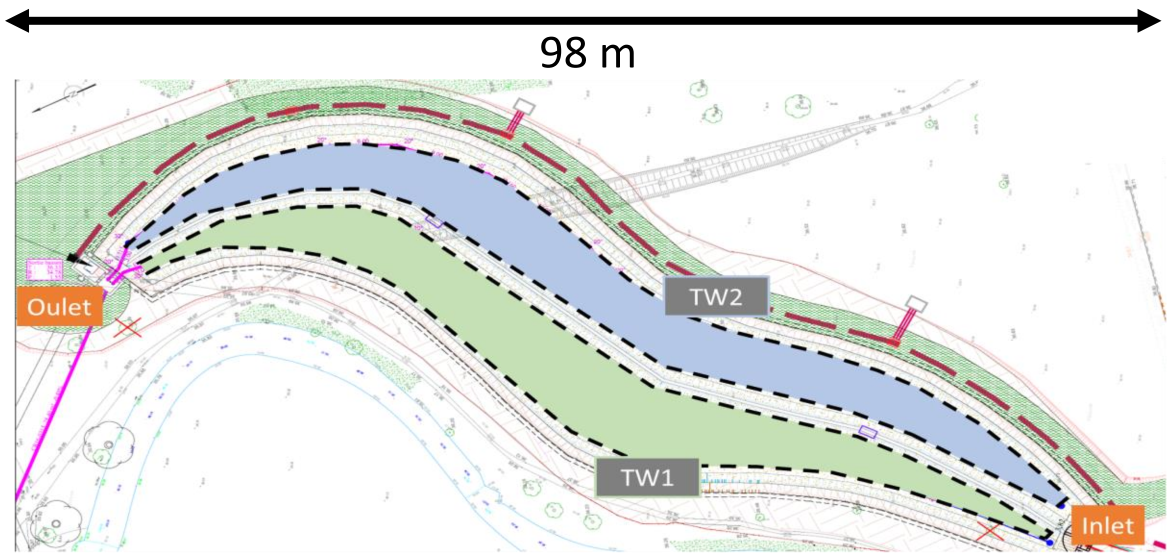


- 1 single feeding point/pilot at one extremity; Treated water outlet at the opposite
- Outlet: throttle outflow at 30 cm: saturated layer and flow control

Mechanistic hydraulic modelling

Conceptual model





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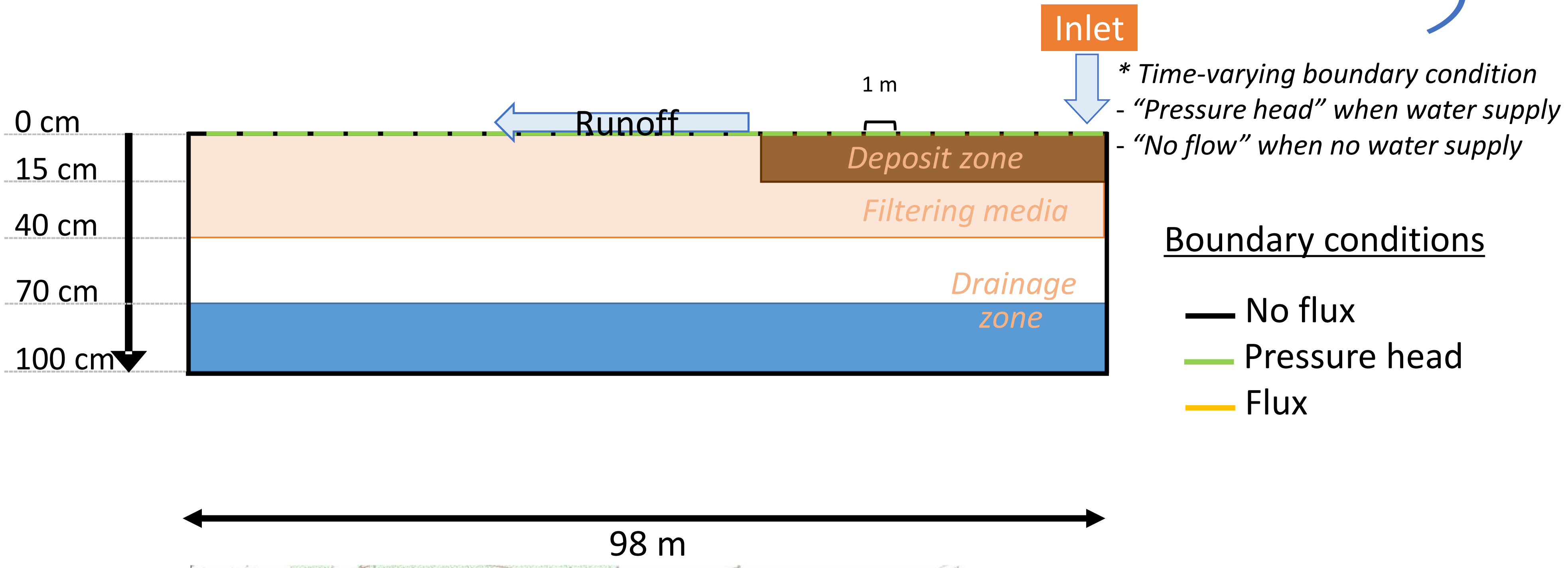
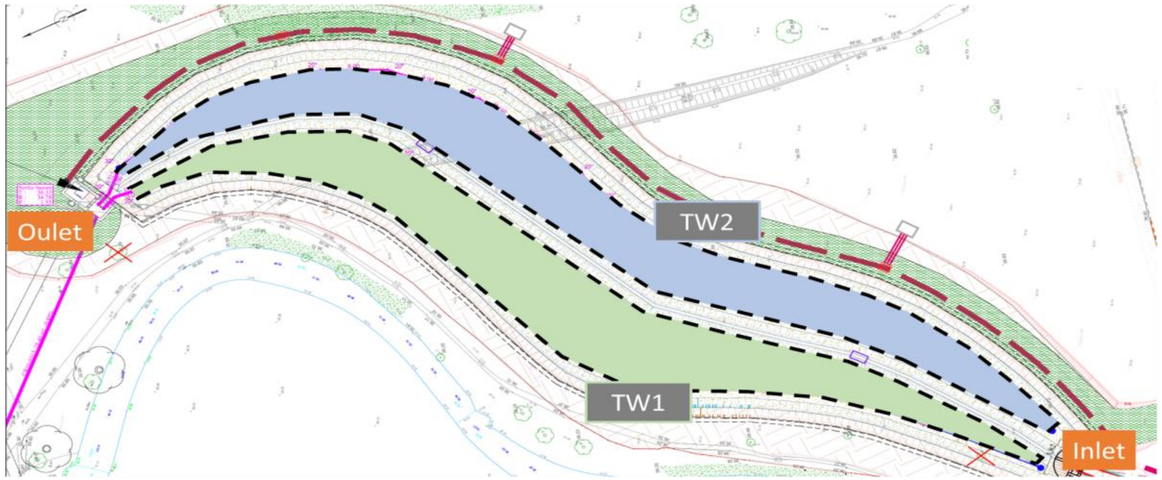
Mechanistic hydraulic modelling

Conceptual model

3 models

1. Surface flow (Matlab)





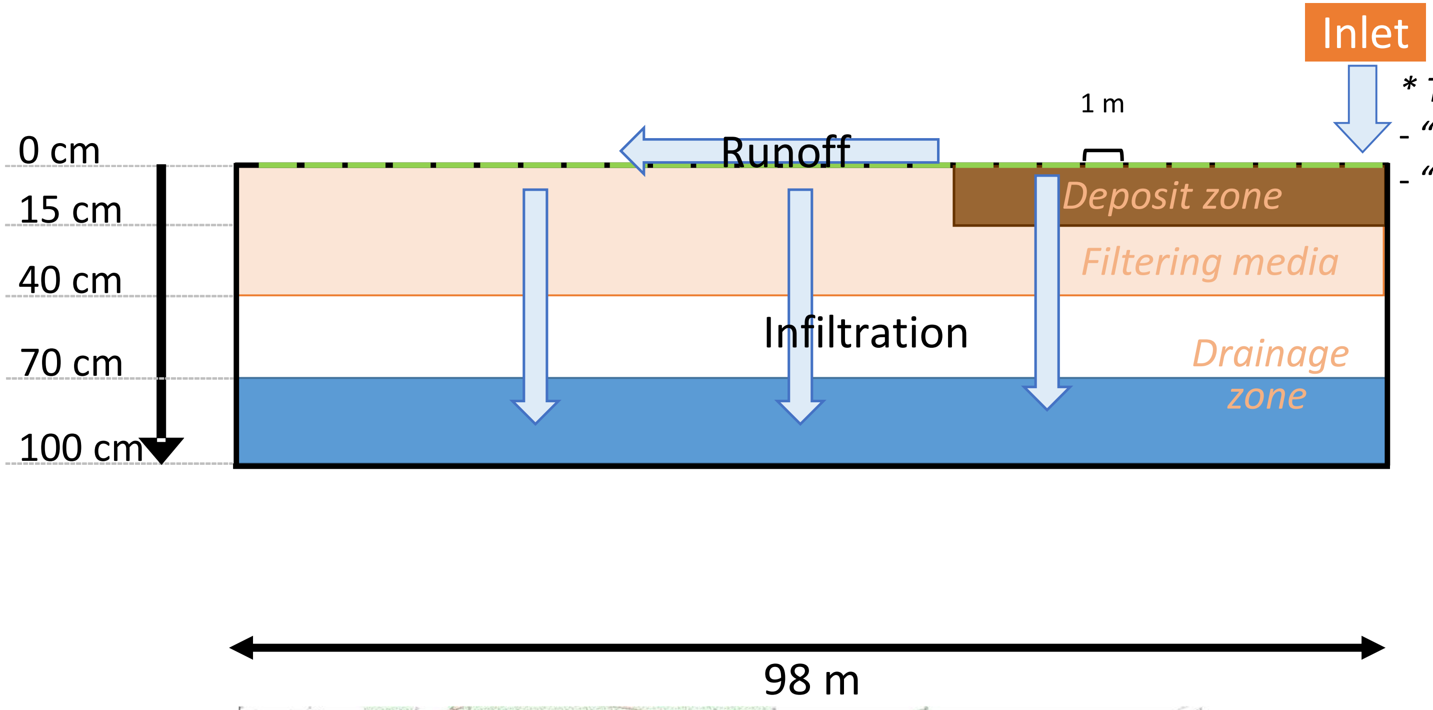
Mechanistic hydraulic modelling

Conceptual model

3 models

1. Surface flow (Matlab)

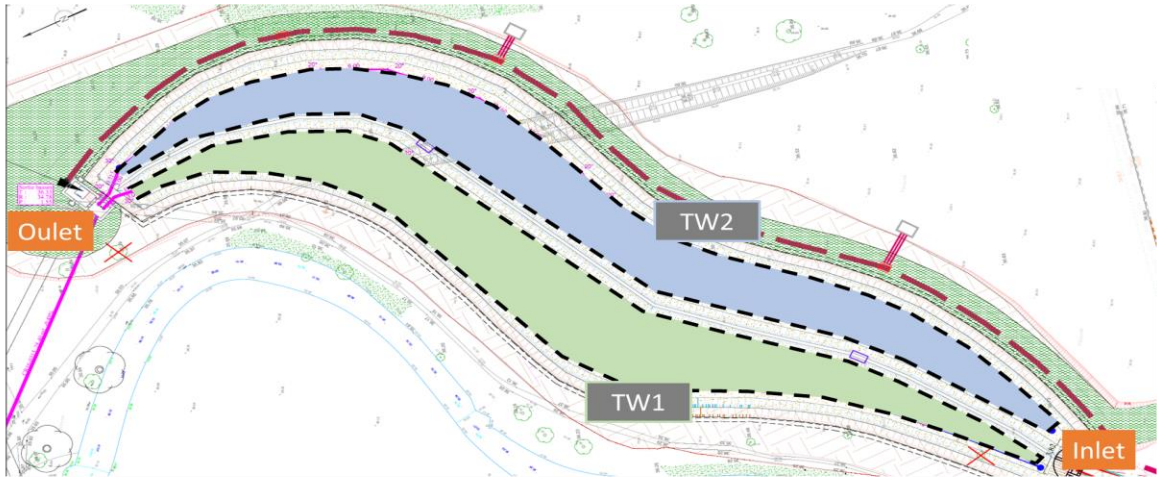
2. Water flow inside the filter (COMSOL)



* Time-varying boundary condition
- "Pressure head" when water supply
- "No flow" when no water supply

Boundary conditions

- No flux
- Pressure head
- Flux



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Mechanistic hydraulic modelling

Conceptual model

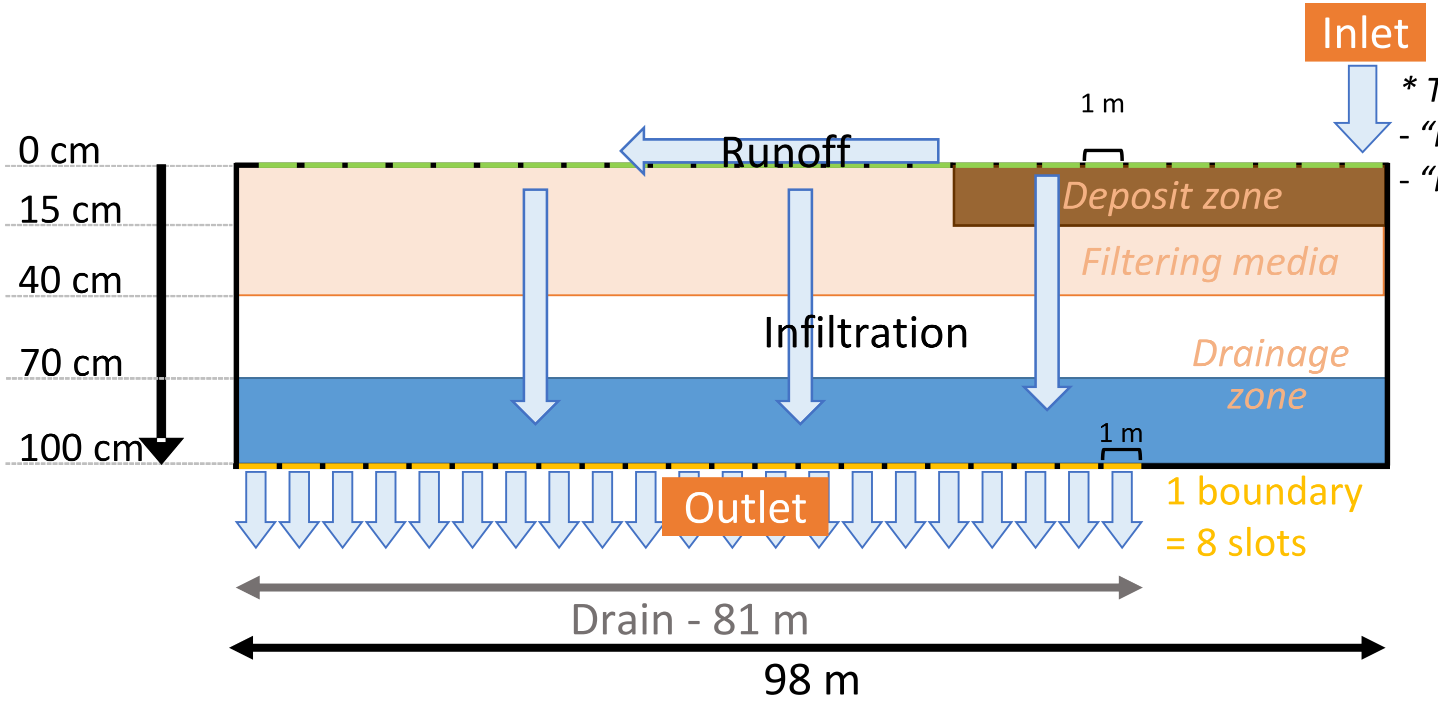
3 models

1. Surface flow (Matlab)

2. Water flow inside the filter (COMSOL)

3. Drain (Matlab)

Significant pressure head losses in the drain that cannot be ignored



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Mechanistic hydraulic modelling

Conceptual model

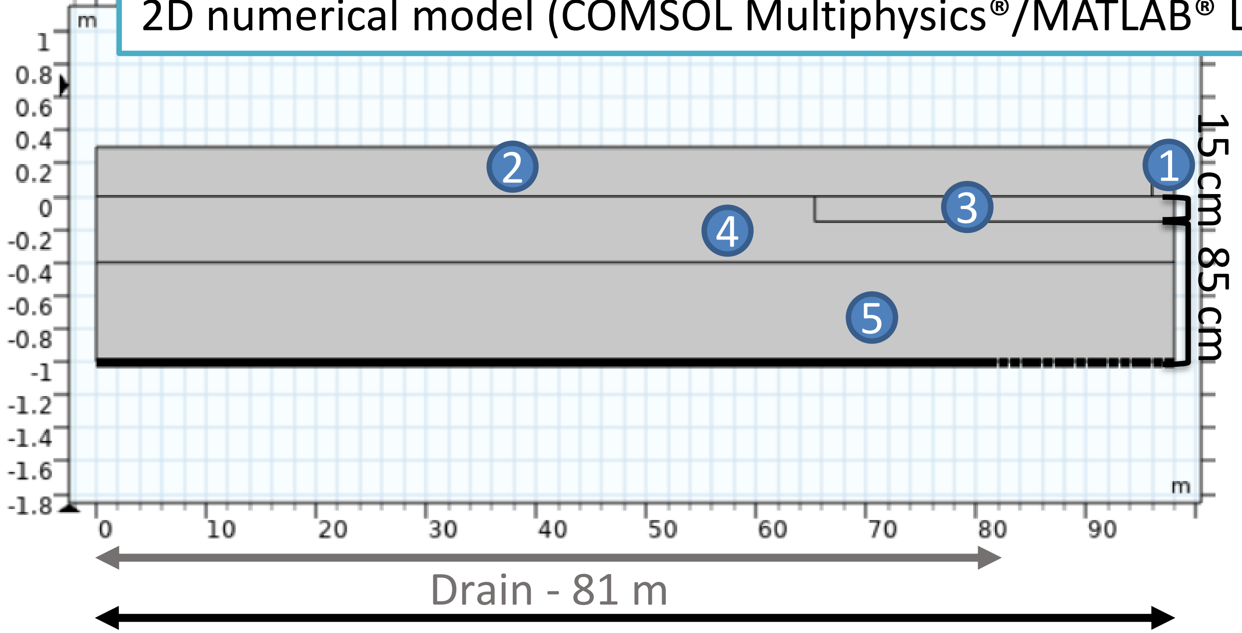
3 models

COUPLING

1. Surface flow (Matlab)
2. Water flow inside the filter (COMSOL)
3. Drain (Matlab)

Significant pressure head losses in the drain that cannot be ignored

2D numerical model (COMSOL Multiphysics®/MATLAB® LivelinkTM)



1 Water inlet area
2 Surface flow area
3 Deposit area
4 Filtration area
5 Drainage area

"Dry weather"
Alternation of feeding phases (59 min / 33.6 L/s) and drainage phases (165 min)

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Mechanistic hydraulic modelling

Determination of hydraulic parameter values (parametric study)

Parameters	Values
n (Manning-Strikler coefficient linked to roughness)	0.01 – 0.025 – 0.05 – 0.075
K_s deposit [m/s]	8.10^{-5} – $2.55.10^{-4}$ – 1.10^{-3} – $2,5.10^{-3}$
α deposit [1/m]	1 – 5 – 9
θ_s deposit [-]	0.38 – 0.8
K_s filtration zone [m/s]	3.10^{-4} – 8.10^{-4} – 1.10^{-3} – $2.5.10^{-3}$
α filtration zone [1/m]	1 – 5 – 13 – 17

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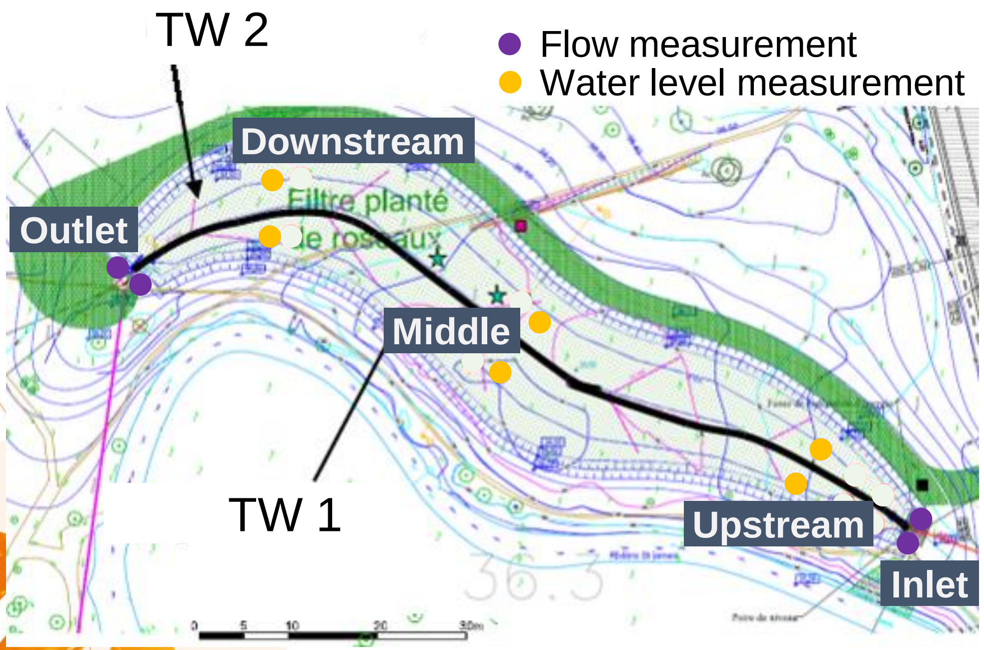
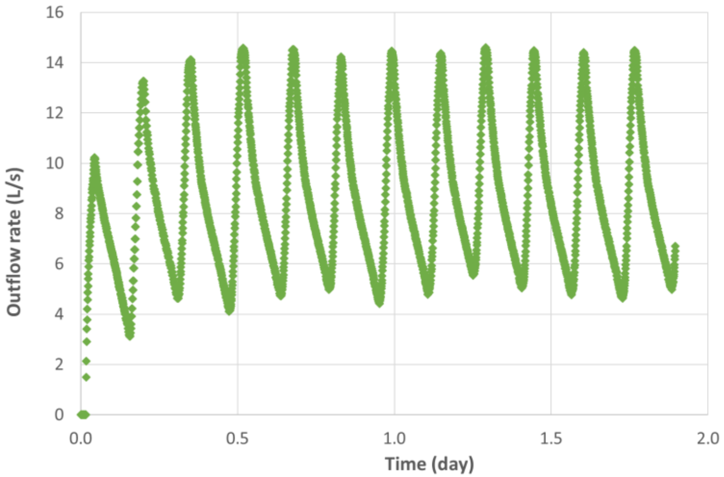
Mechanistic hydraulic modelling

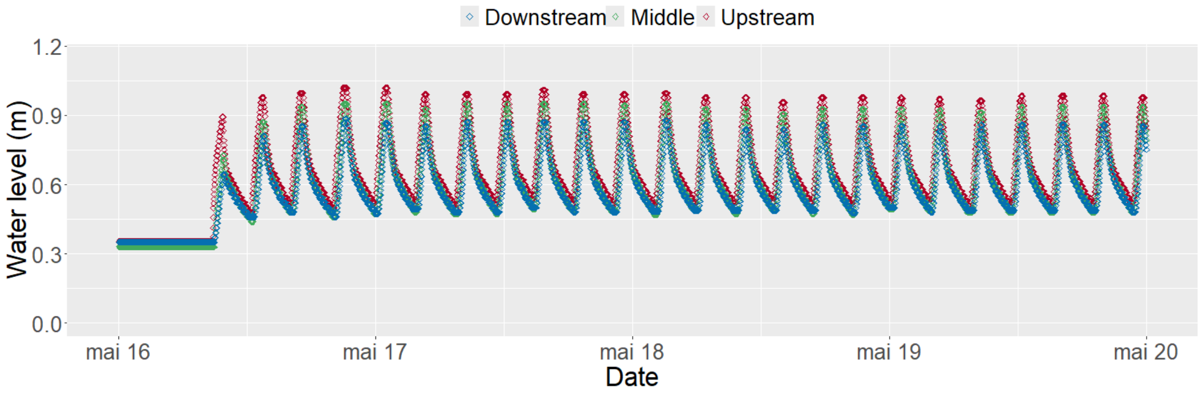
Determination of hydraulic parameter values (parametric study)

Adjustment to the values of :

- Outflow rates
- Water level (Upstream / Middle / Downstream)



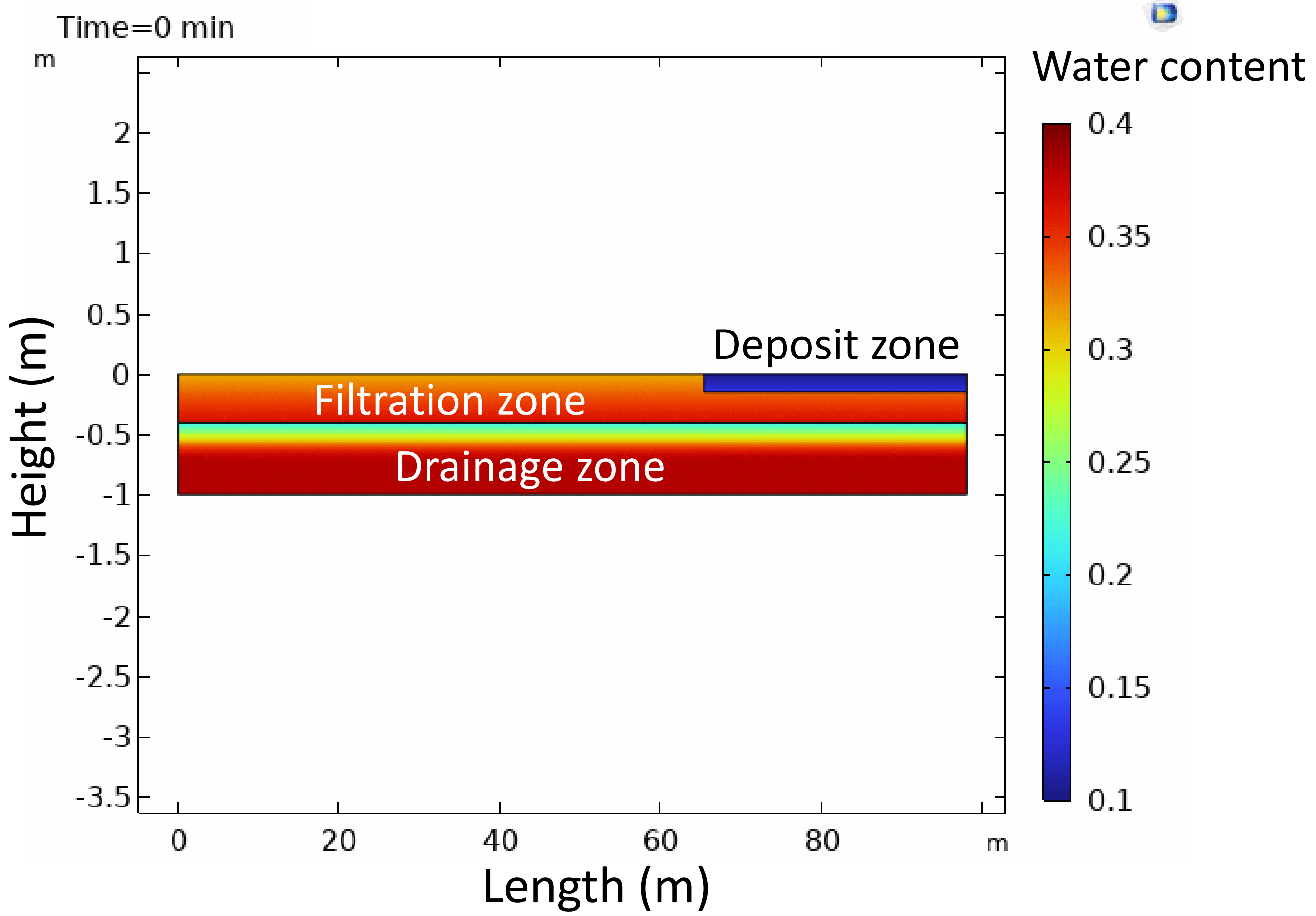




Mechanistic hydraulic modelling

Results – Changes in water content

Alternation of feeding phases (59 minutes / 33.6 L/s) and drainage phases (165 minutes)

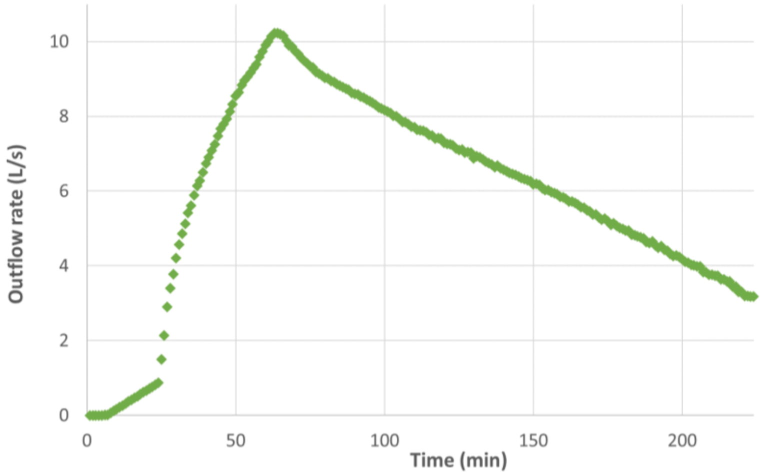


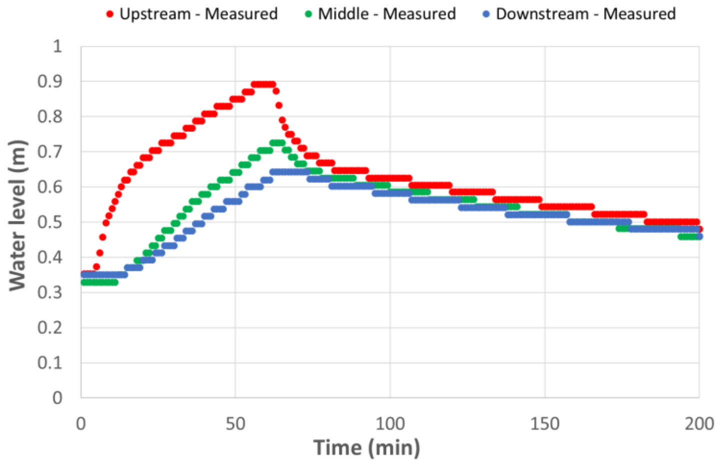
n = 0.075
K_s filter = 2.5.10^{-3} m/s
α filter = 1 m^{-1}
K_s deposit = 2.5. 10^{-3} m/s
α deposit = 1 m^{-1}
θ_s deposit = 0.38

Mechanistic hydraulic modelling

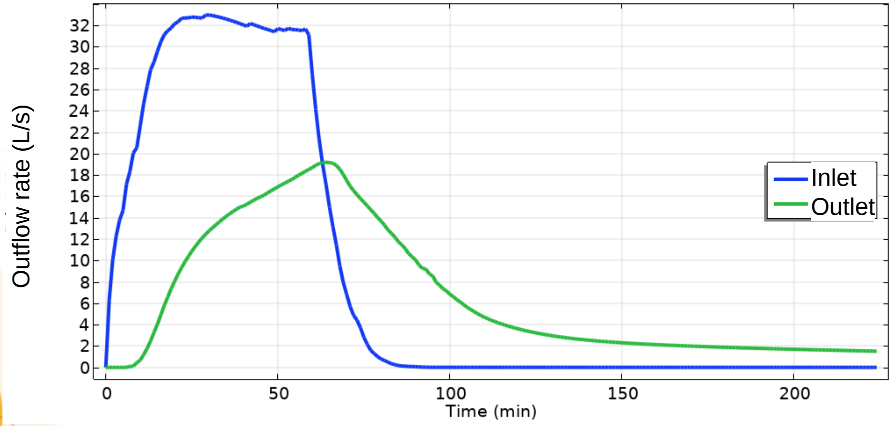
Results – Outflow rate and water level inside the filter – First batch

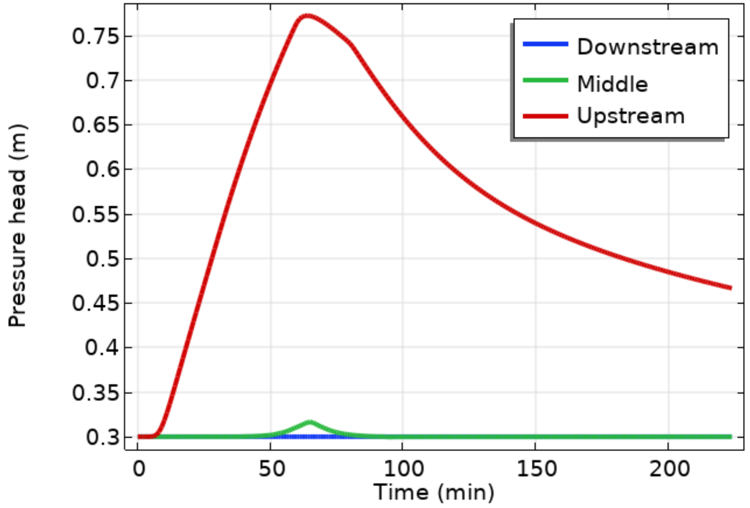
Measured





Simulated





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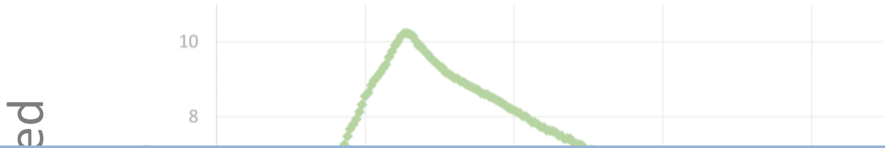
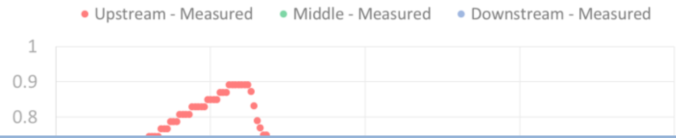


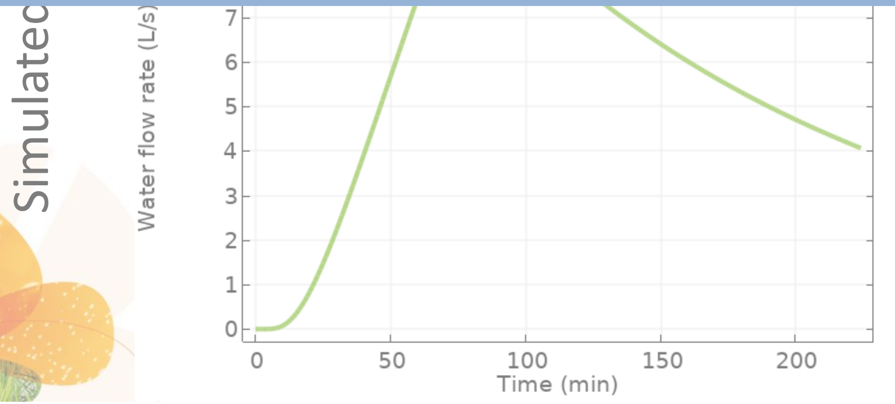


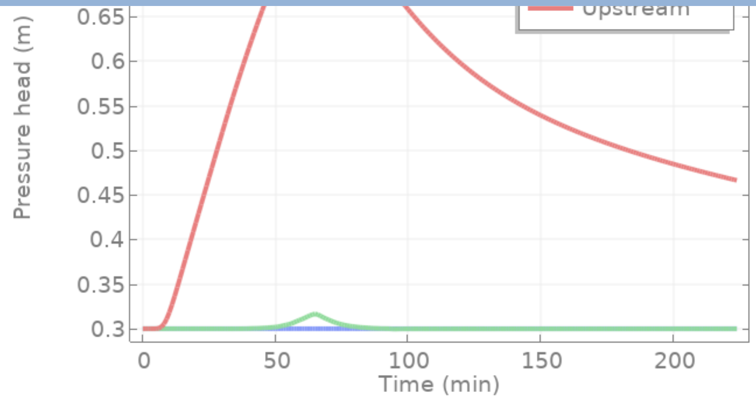
n = 0.075

K_s filter = $2.5.10^{-3}$ m/s

Field: due to the length of the drain, pressures increase in the drain → water exits the drain towards the porous medium → water heights increase in the filter

Model: the direction of flows entering the drain has been constrained: water can only enter the drain and not leave it → simulated outlet flows > observed AND simulated water depths < observed





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Mechanistic hydraulic modelling

Conceptual model

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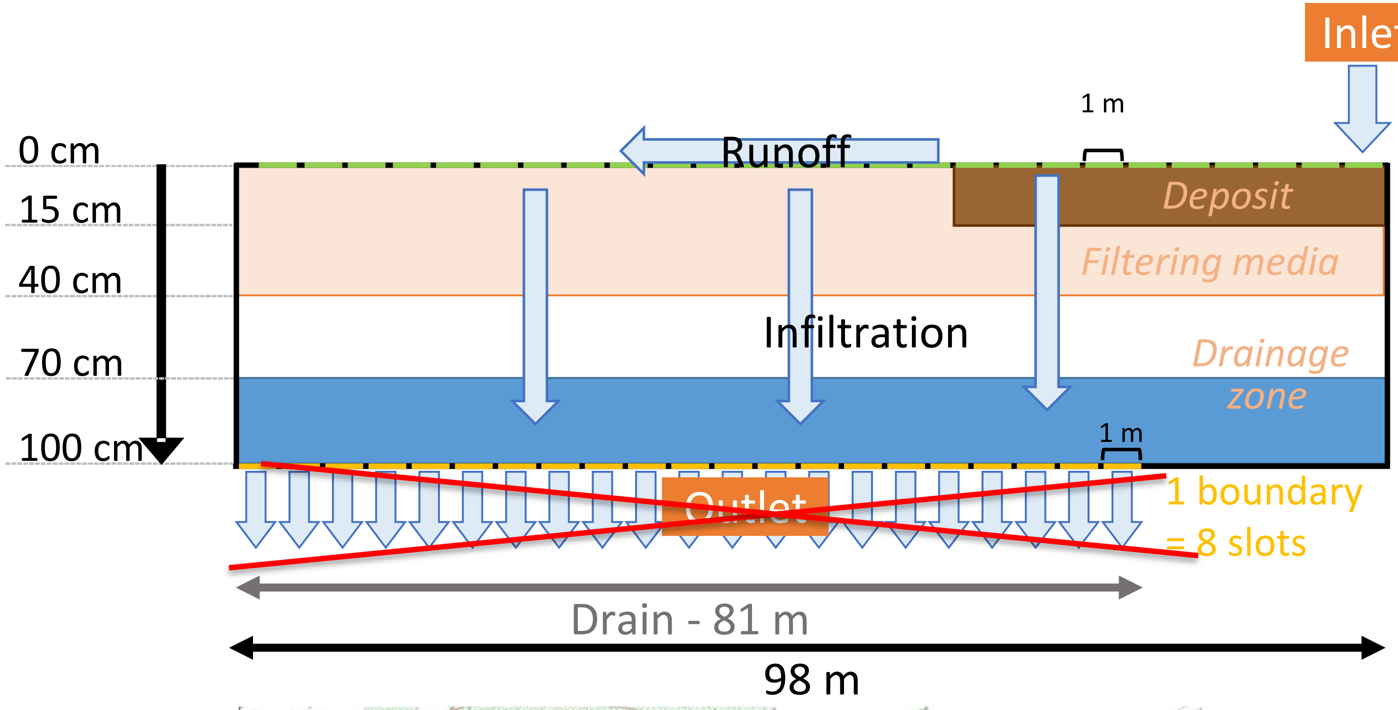
~~3. Drain (Matlab)~~



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1. Surface flow (Matlab)

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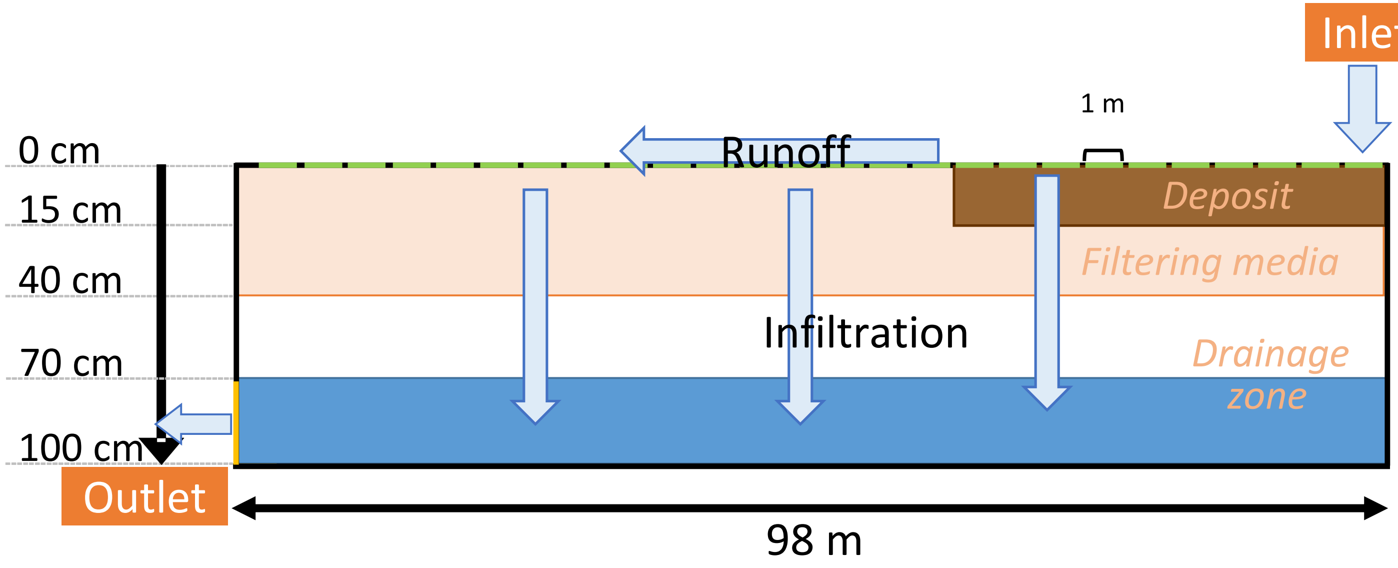
3. Torricelli's formula (Matlab)



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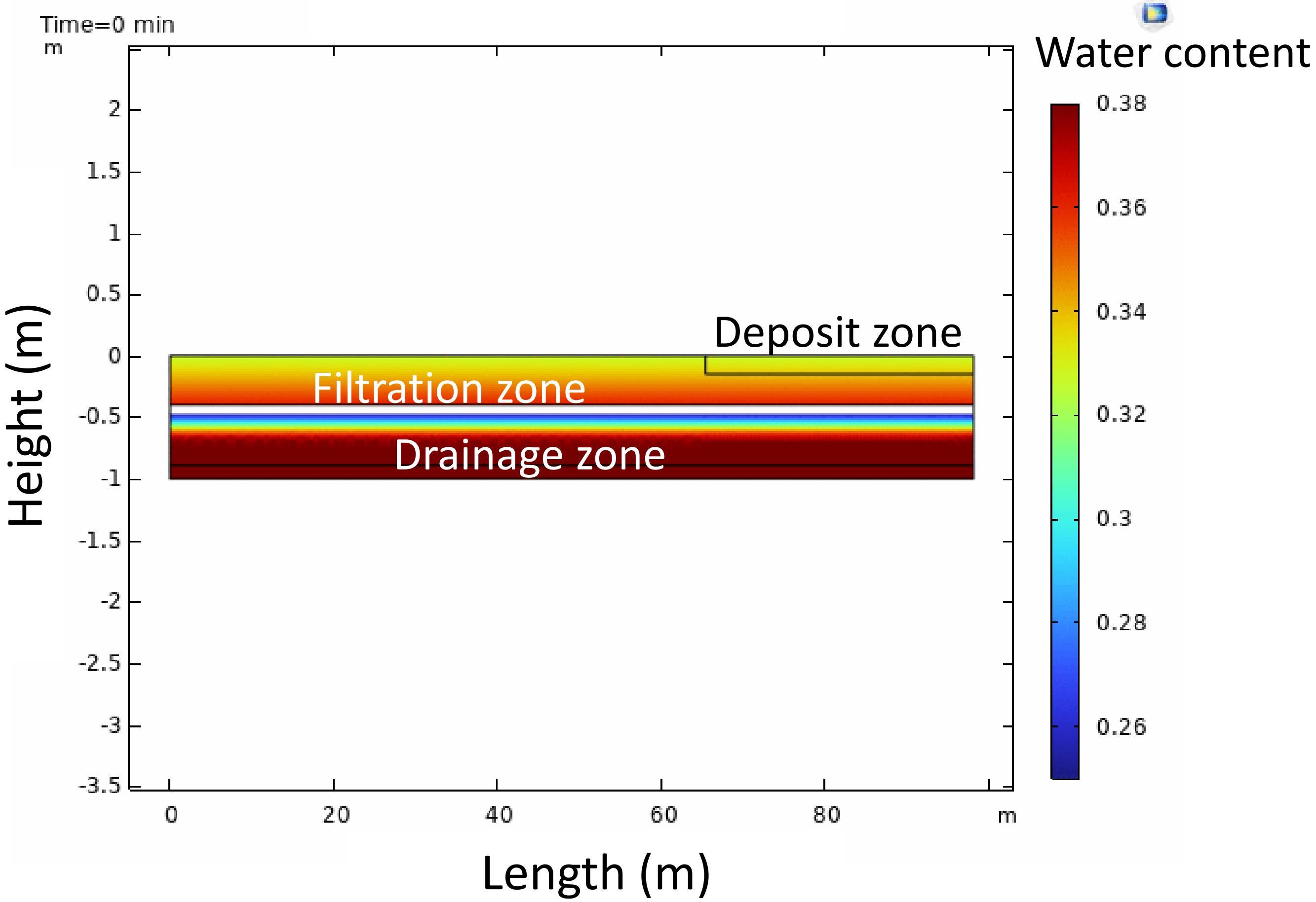

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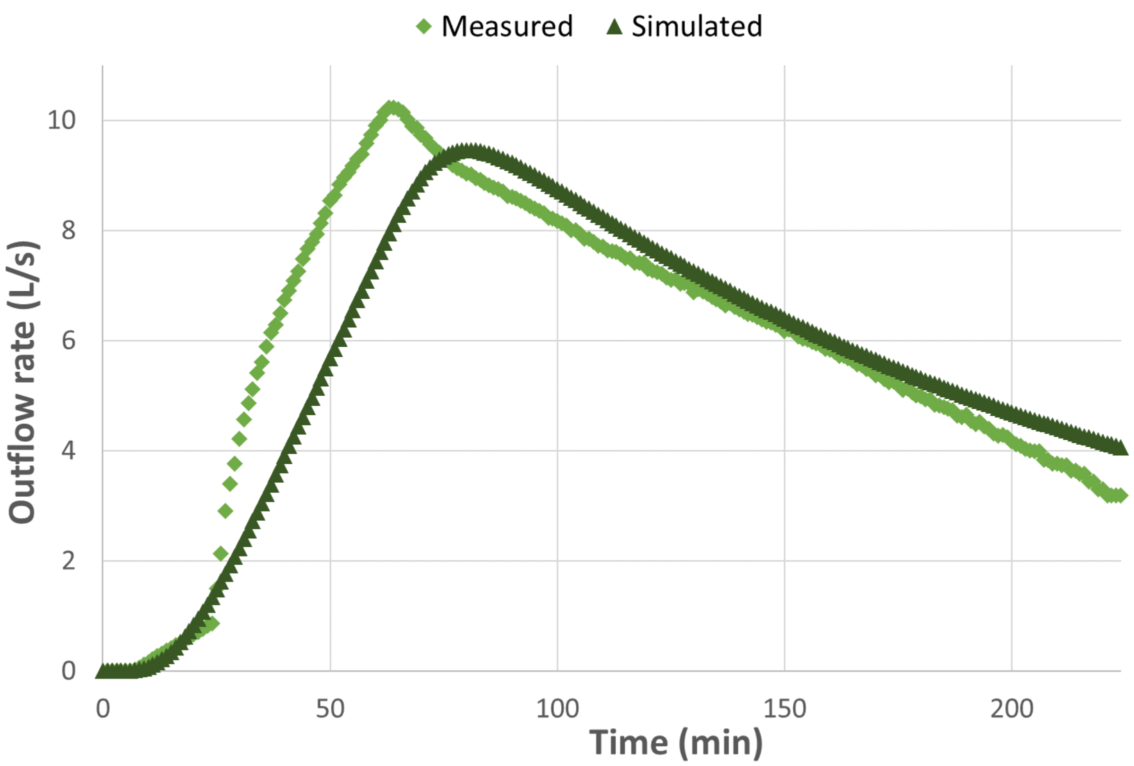

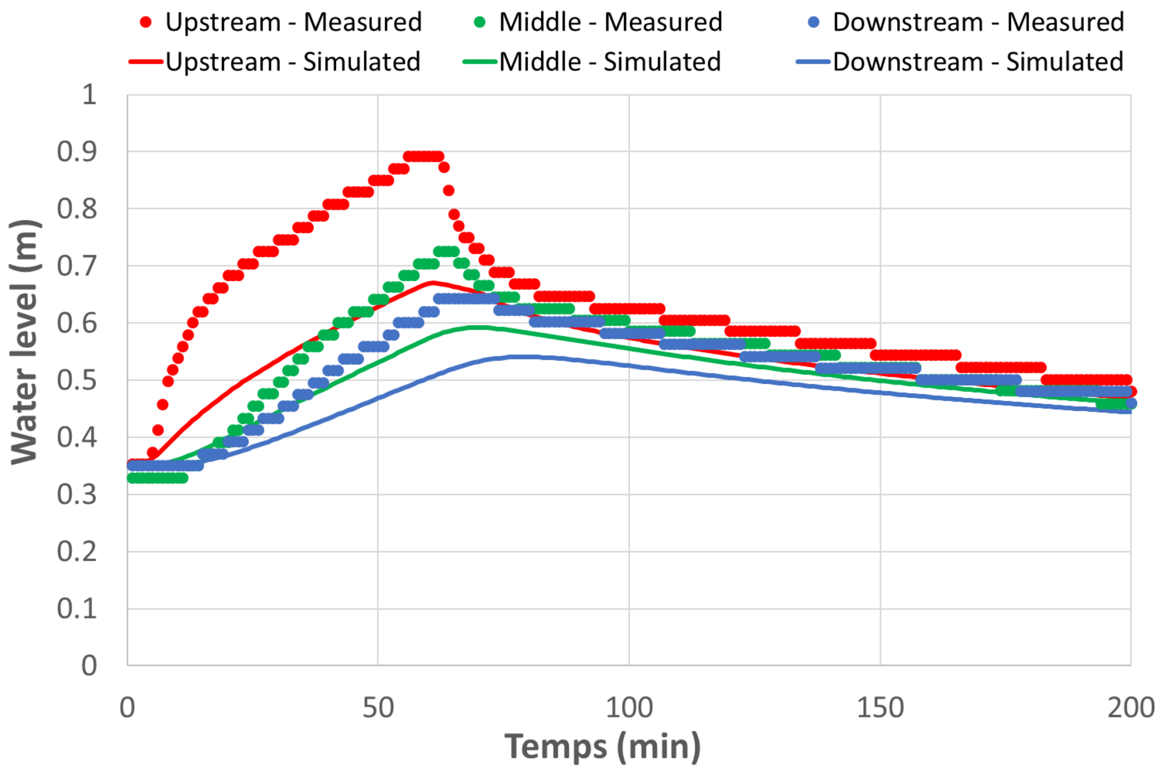

Even if the absolute values are not exactly reproduced, the dynamics are represented

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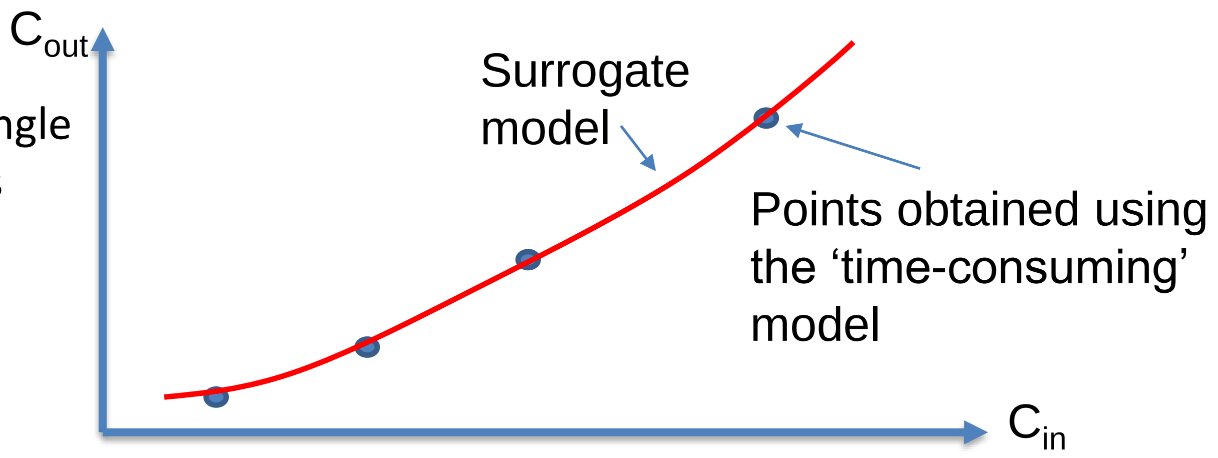
The surrogate model

- **Problem**: calculation code representative of the complexity of the system but costly in terms of calculation time
- **Solution 1**: simplifying assumptions are made to build a faster model while ensuring that it does not deviate too much from the original model
- **Solution 2**: model variables are explored in space: input conditions, initial conditions and operating parameters → a ‘regression’ model is fitted to the model outputs

Example in 1 D, with a single input variable that varies



Conclusions

- With the 2D model: we know which parts of the filter are solicited by the flow and therefore where the micropollutants will be retained
- The problem with this approach: a calculation code representative of the complexity of the system BUT costly in terms of calculation time (! Long term)
- To be continued: construction of the surrogate model and modelling of the removal of micropollutants by adsorption and biodegradation
- This approach will facilitate the design of TWs that treat the micropollutants contained in stormwater and CSO

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Thank you
for your attention