Preferential flow in partially saturated treatment wetland and its impact on pollutant residence time

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The HYDR'EPUR® System

Outflow controlled by a throttle outflow

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The Life ADSORB project

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

- Main objectives
  - Applicability of a TW capable of effectively reducing pollutant loads (TSS, metallic and organic micropollutants) from runoff water in a natural area
  - Mechanistic modeling: better understanding and identification of mechanisms and parameters influencing water flow, transport and fate of micropollutants → determine key design points

- Specific objective: use modelling to assess the impact of the design of the drainage network on the flows in the TWs of the Life ADSORB project

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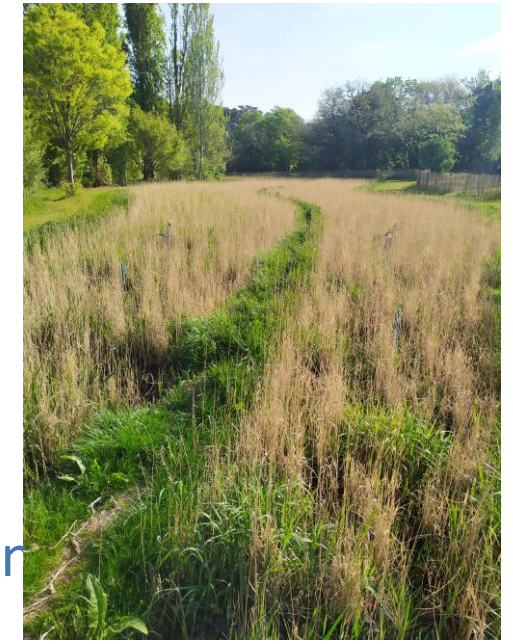
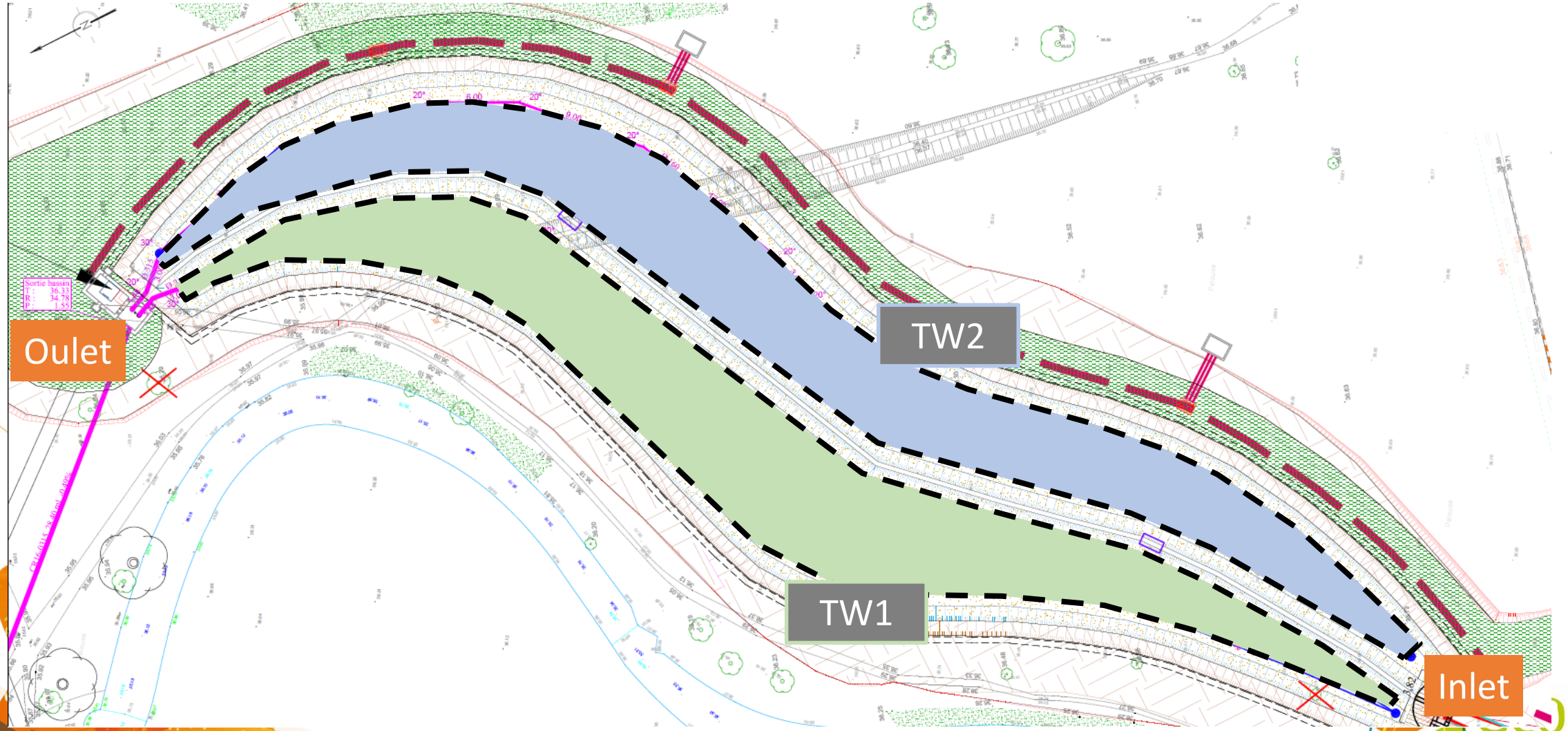
The pilot TWs studied



- 2 pilot TWs of 600 m^2 (Bois de Boulogne park, Paris)
- Treatment of runoff water; Metallic and organic micropollutants
- Similar configuration (100 m long, 1 m deep) and operation. Alternation every month
- 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)
- Transition layer (10 cm) + drainage layer (50 cm)
- 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 (20 L/s max when pilot saturated)

The pilots



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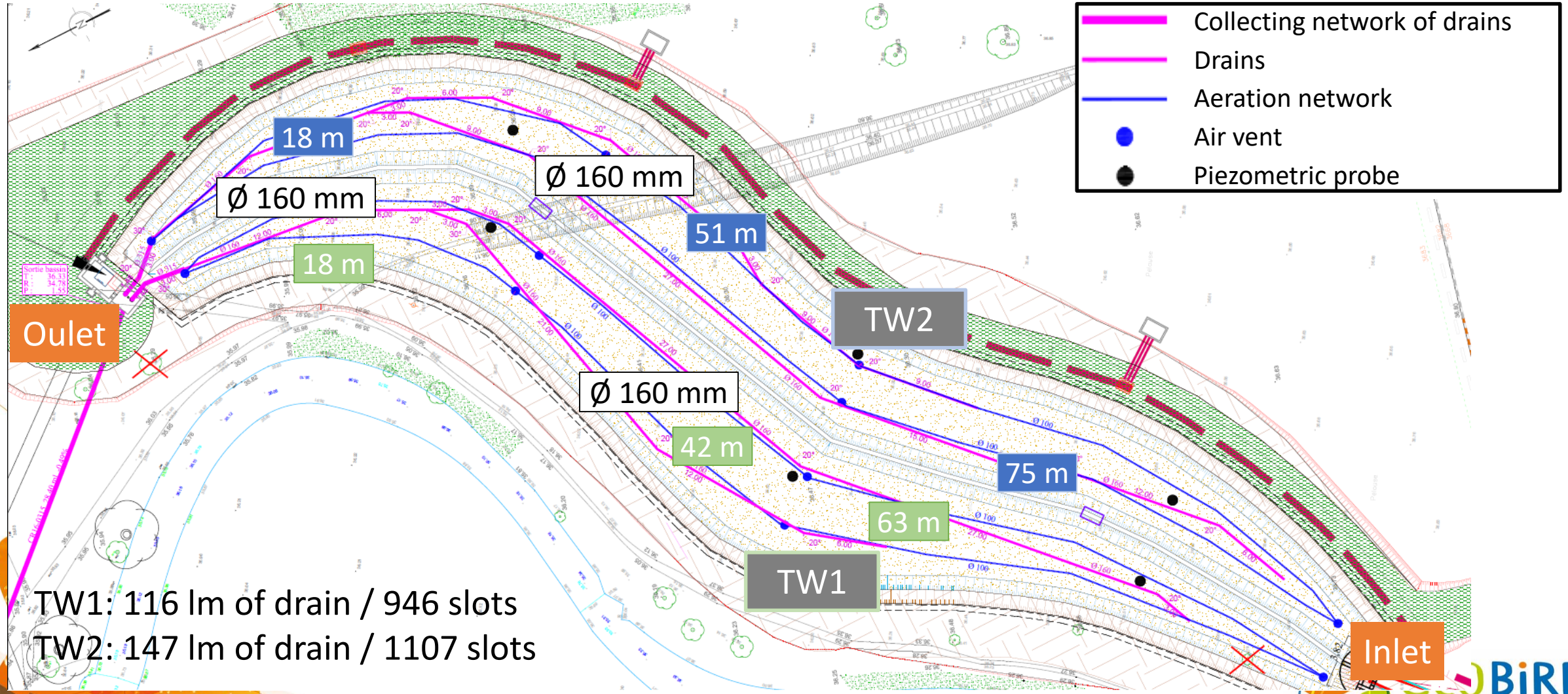
The drainage network



TW1: 116 lm of drain / 946 slots

TW2: 147 lm of drain / 1107 slots

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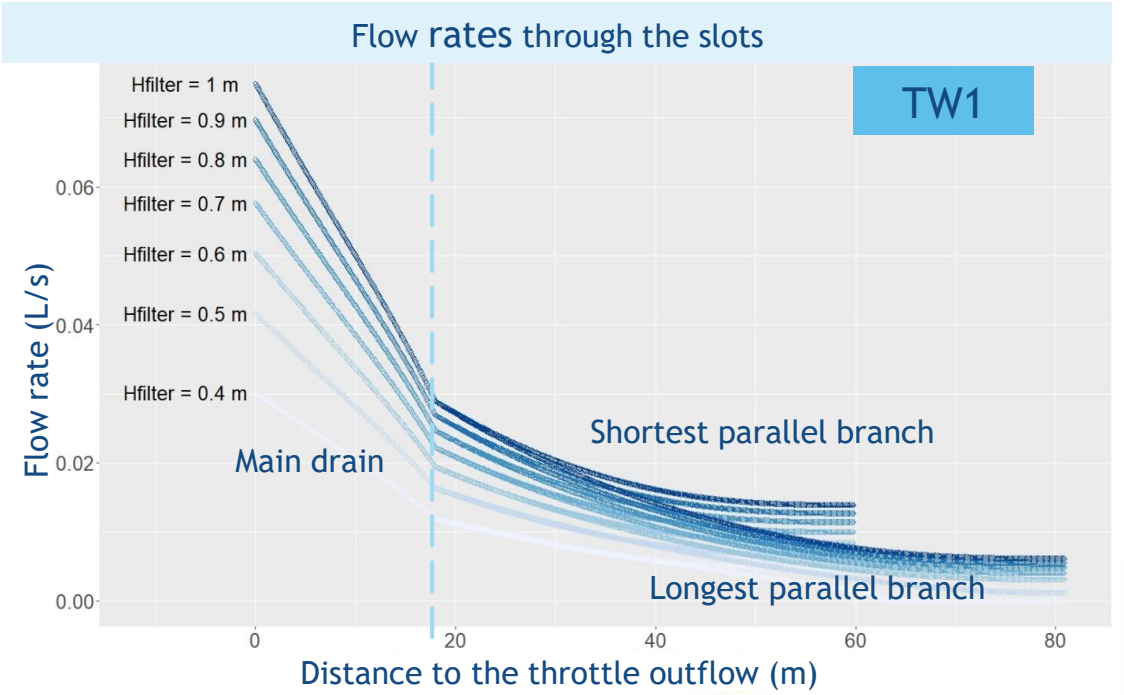
Previously, in the Life ADSORB project…

- Study of water flows in the drainage networks of the two pilots
- **Because of the length and diameter of the drains --> different water flow at each slot, even if the pressures in the filter are the same over the entire surface**

- An analogous numerical model was built: evaluation of linear/singular head losses and flow rates through the drainage network slots



Objective and method of the study

- What happens when the water pressure head is not constant over the entire length of the filter?
  - During a feeding phase
  - During a drainage phase

- Simulate water flows in the whole filter and assess possible impacts on pollutant transport, taking into account the hydraulic limits created by the drainage network

- 2D numerical model (COMSOL Multiphysics®/MATLAB® LivelinkTM) of one of the two pilots TWs (longitudinal cross-section) with specific boundary condition for the outlet

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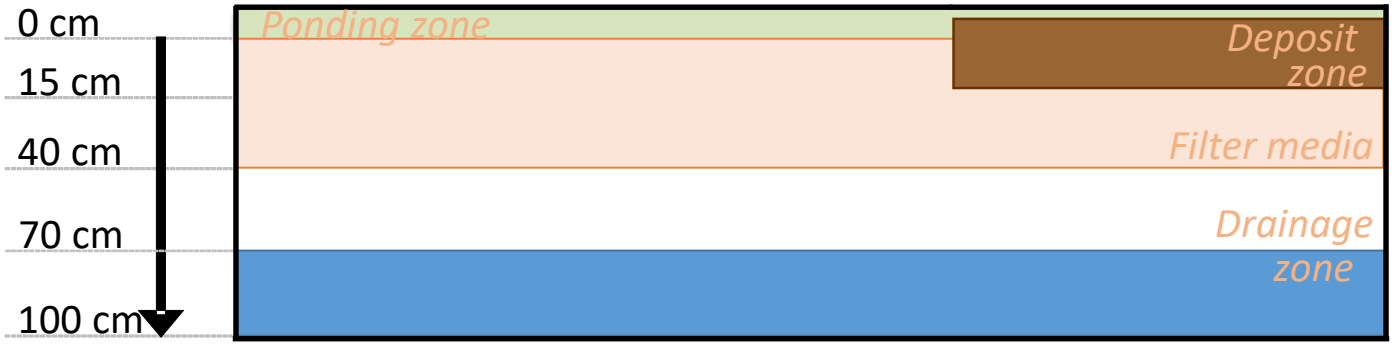
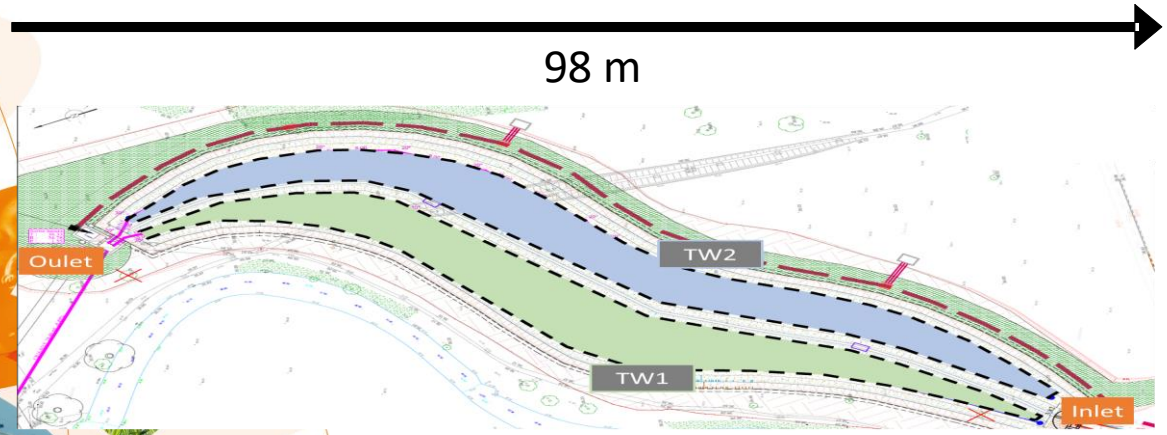
Conceptual diagram





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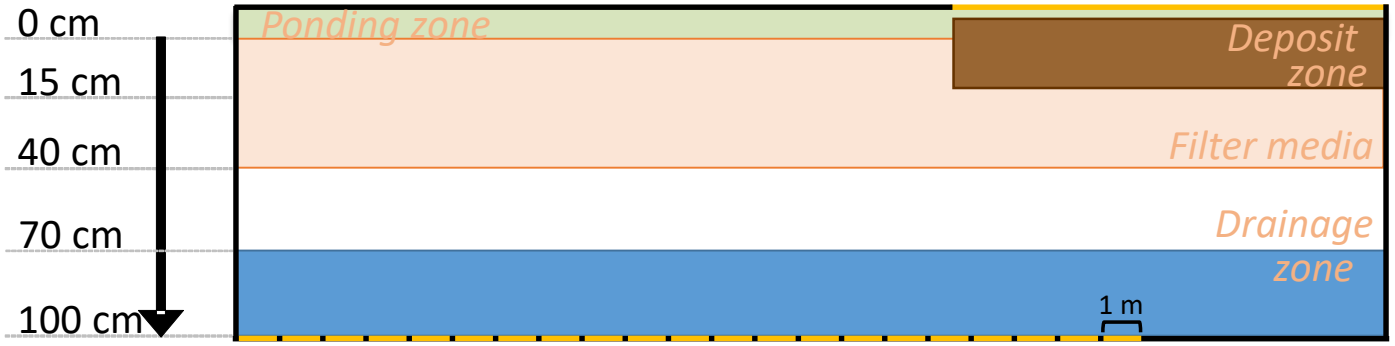


Boundary conditions

— No flux

— Flux

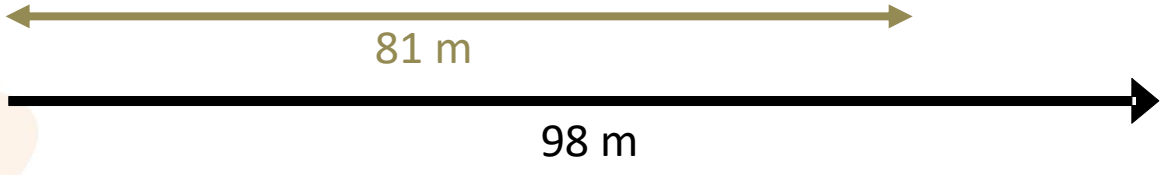
INLET

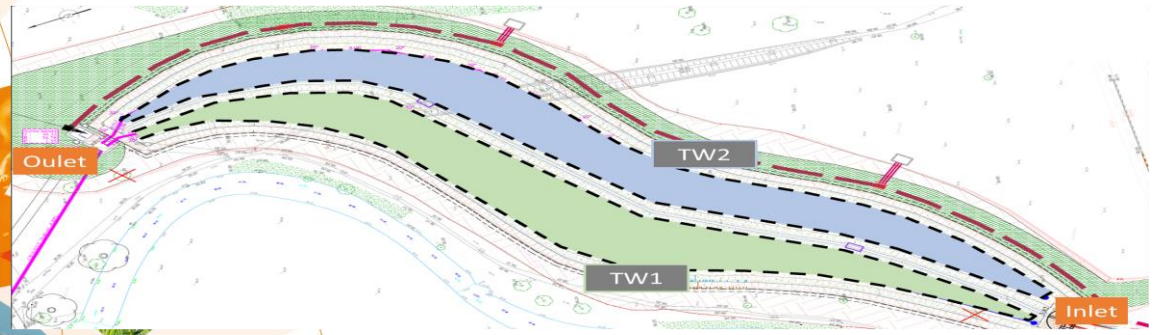
OUTLET

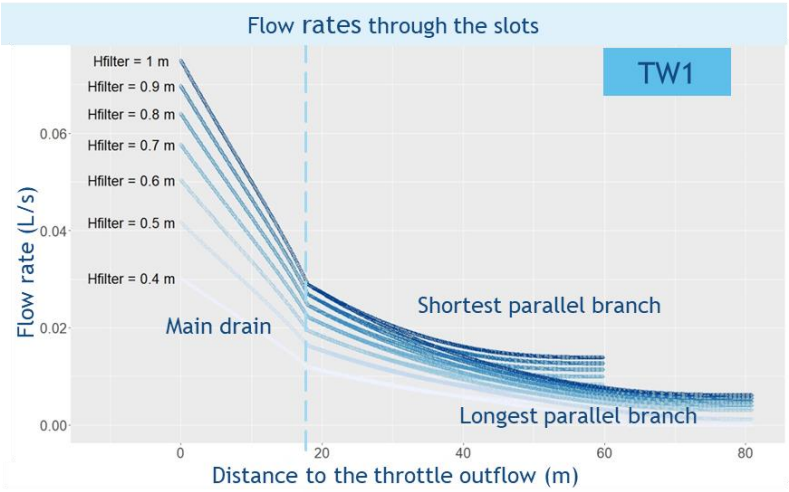
WATER FLUX

ANALOGOUS HYDRAULIC MODEL with time-varying water heights in the TW pilot

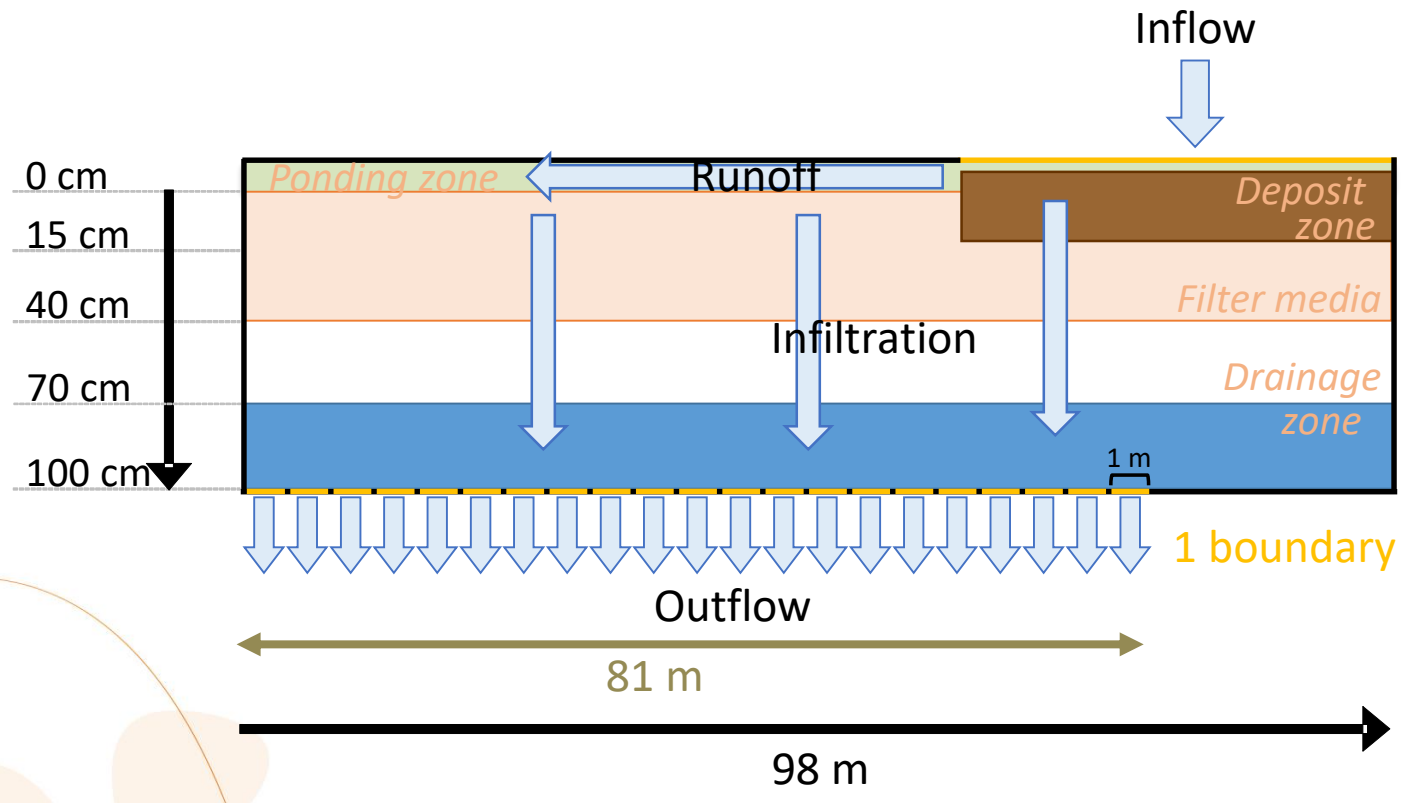
1 boundary = 8 slots







Conceptual diagram



Boundary conditions

- No flux
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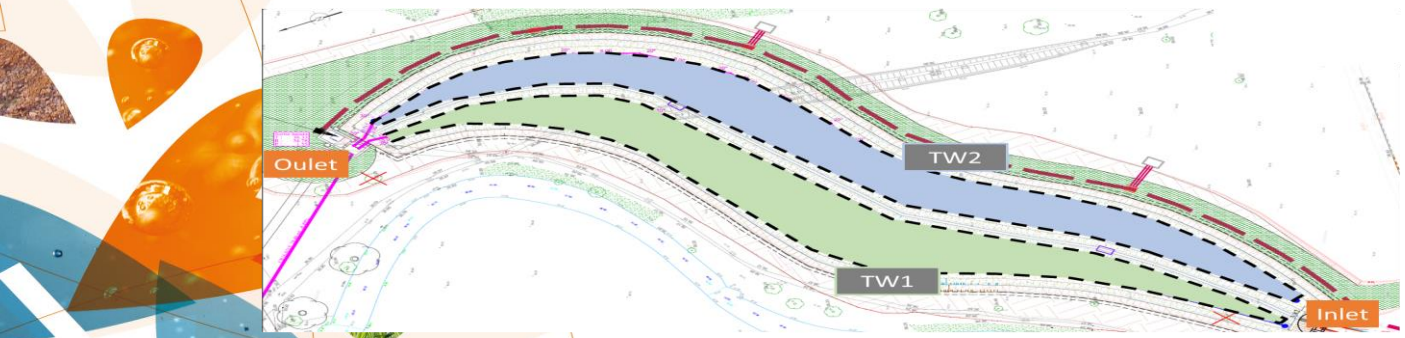
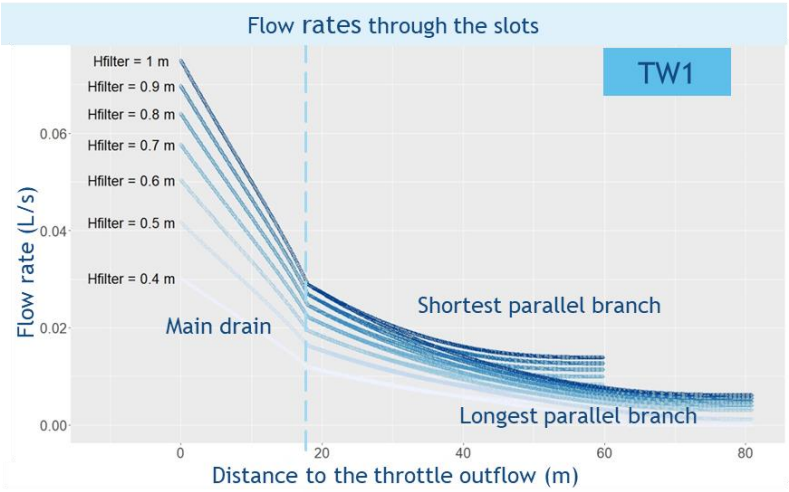
ANALOGOUS HYDRAULIC MODEL with time-varying water heights in the TW pilot

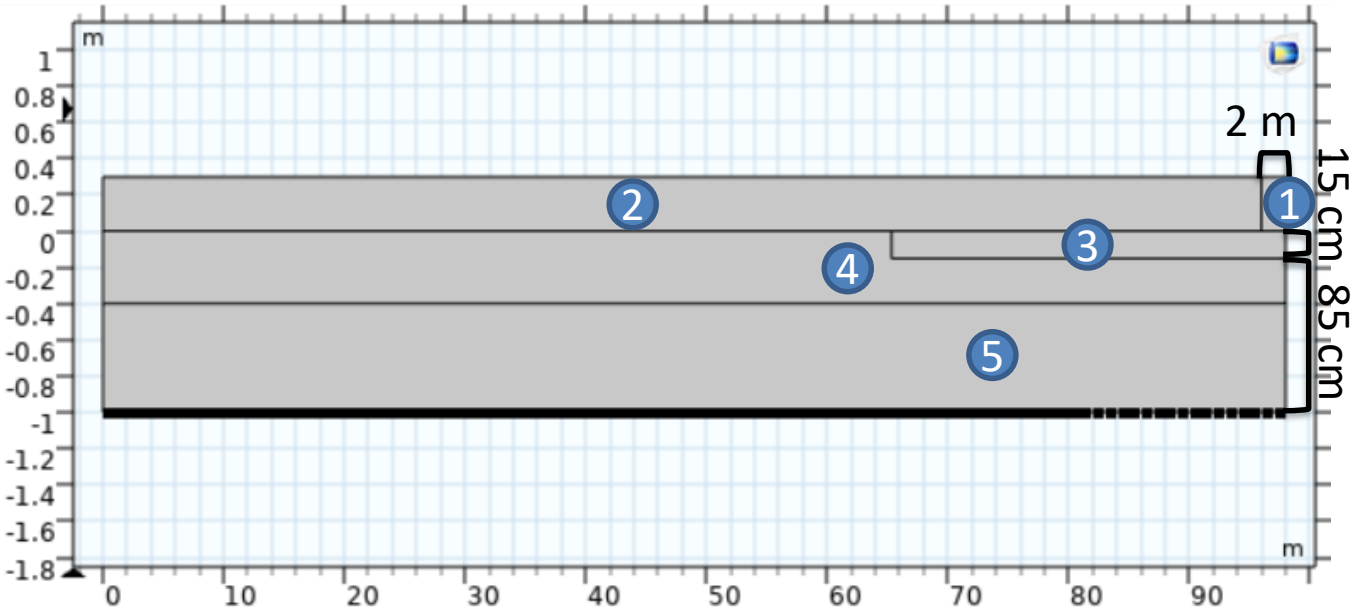




The 2D numerical filter model

- Application to TW1 (sand)

- 1. Feeding phase (64 minutes)
- 2. Drainage phase (180 minutes)



1. Water inlet area 2 m
2. Surface flow area
3. Deposit area - 1/3 length – 15 cm
4. Filtration area
5. Drainage area

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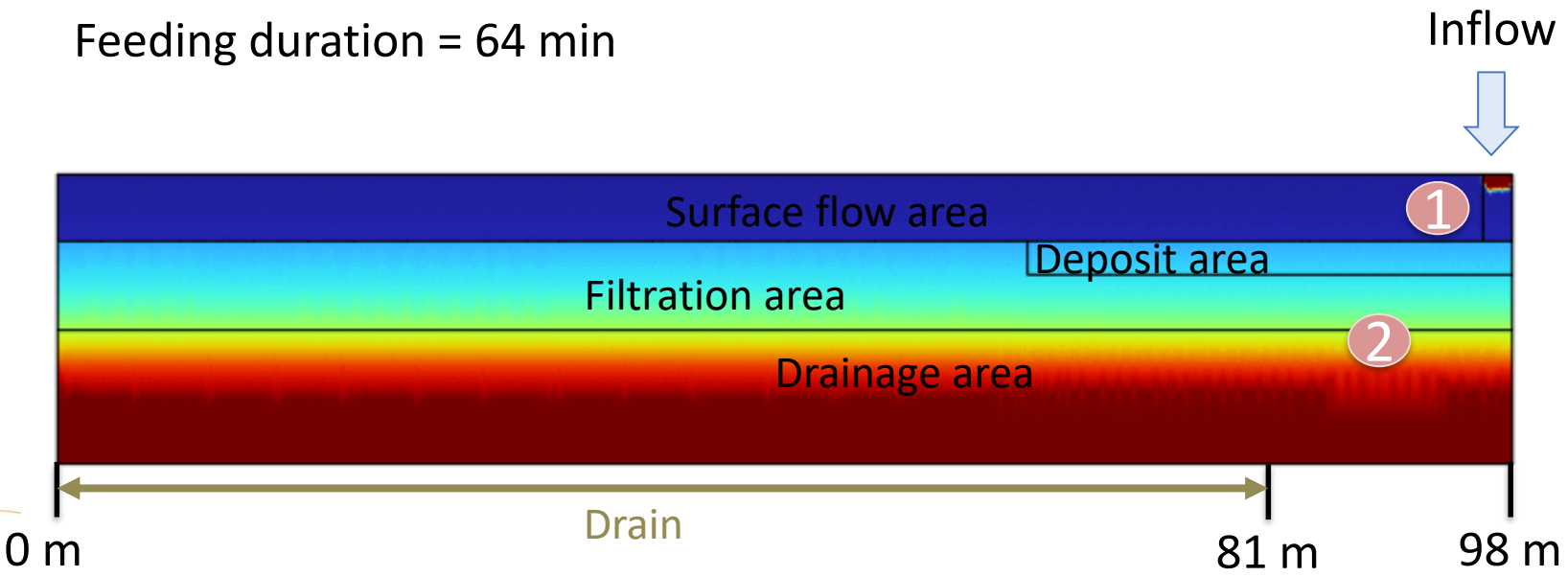
Preliminary results – FEEDING PHASE

Feeding duration = 64 min



1. Surface runoff

2. Water flows directly to the firsts slots of the drain

- For small batches → only the beginning of the filter used → strong shortcut in the first meters
- With higher water flow at the inlet → the filter fills up and the entire drain used until the filter completely full → drainage phase

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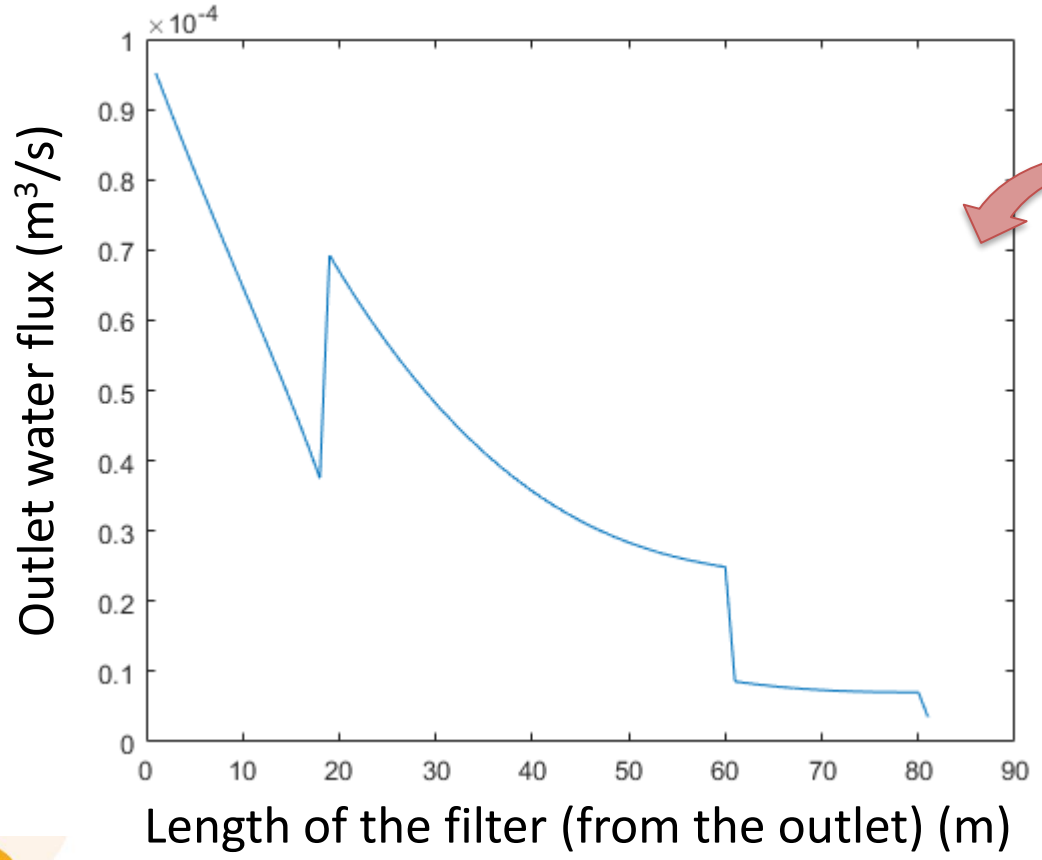
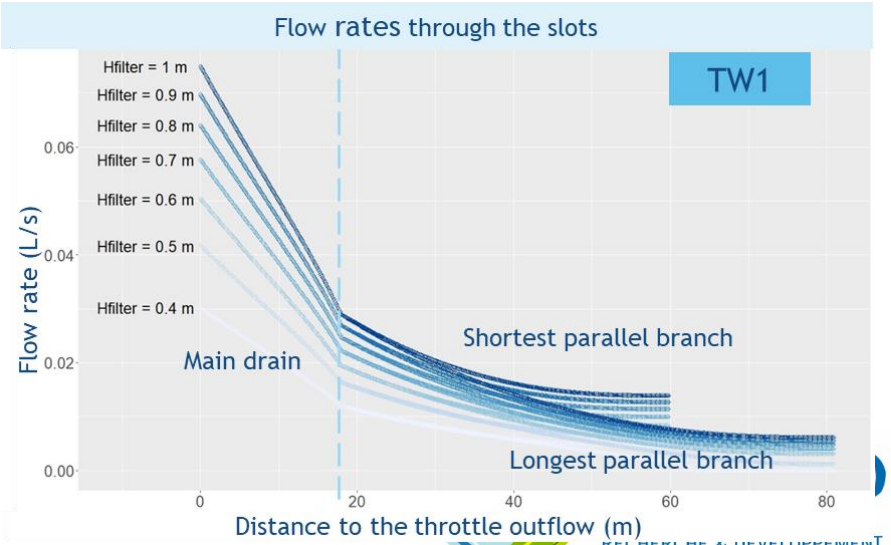
Results – DRAINAGE PHASE

T = 0 min → Outlet boundary condition

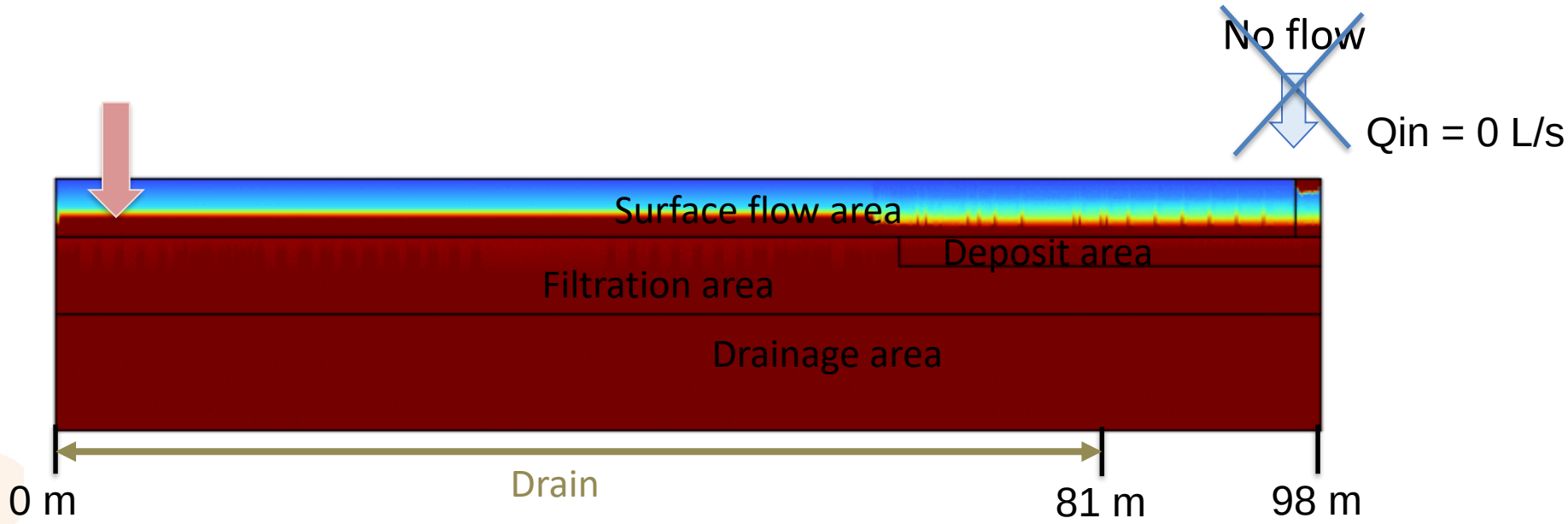


Analogous numerical model



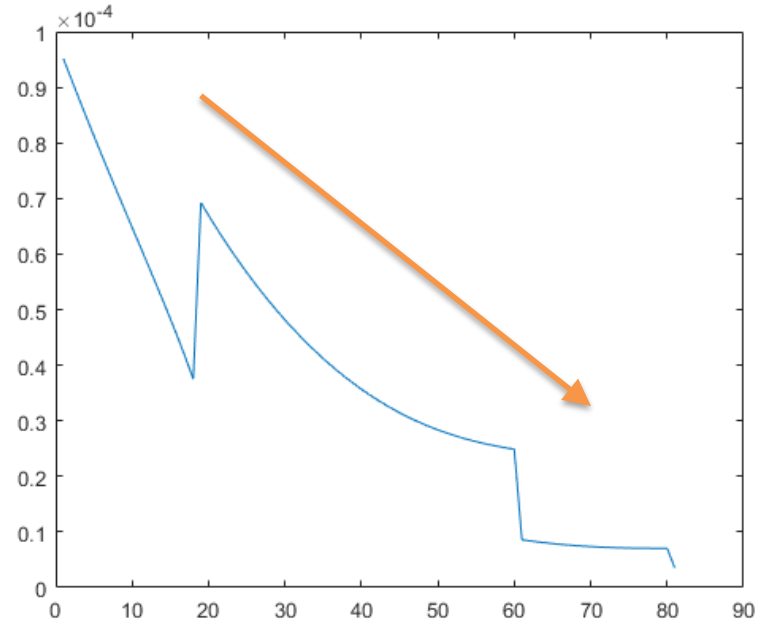
Results – DRAINAGE PHASE

Drainage duration = 180 min

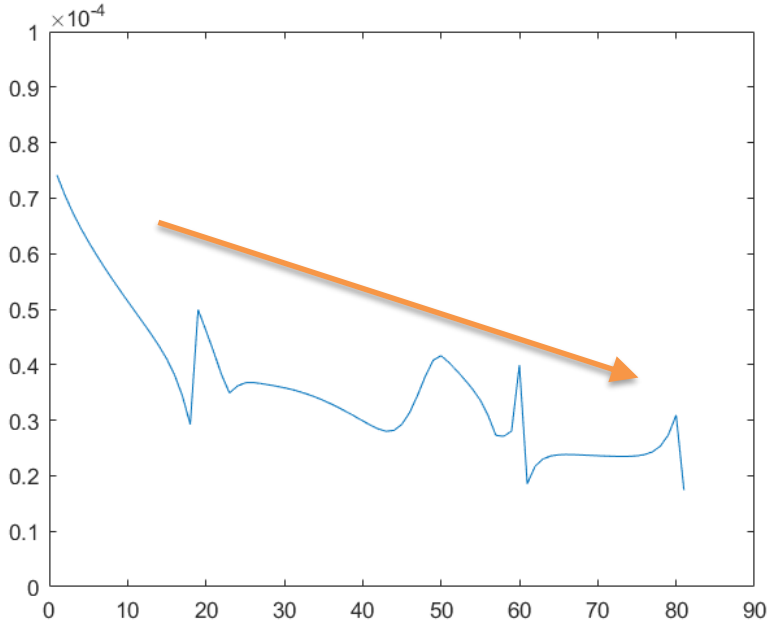


Results – DRAINAGE PHASE

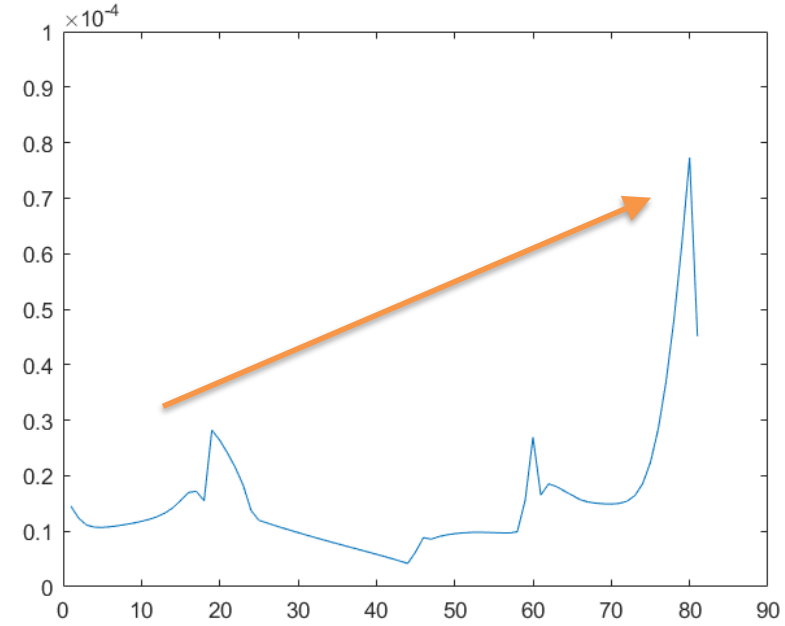
T = 0 min (Outlet boundary condition)



T = 15 min



T = 180 min



Outlet water flux (m^3/s)

Length of the filter (from the outlet) (m)

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Conclusions

- Analogous numerical model: evaluation of flow rates through the drainage network slots → outlet boundary condition for the 2D model
- Design of the drainage networks: strongly influences the flow patterns (preferential flows and dead zones) and consequently the treatment efficiency

- With the 2D model: which parts of the filter are solicited by the flow
- Modeling the hydraulics = crucial first step before the fate of micropollutants

- To be continued: modeling of a tracer test / modeling of the removal of micropollutants by adsorption and biodegradation

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for your attention