Assessing the impact of the development of an urban district on shallow groundwater using the integrated urban hydrological model URBS

emmanuel berthier[1], jérémie sage[1], emmanuel dumont[1], marie-laure mosini[2], fabrice rodriguez[2], and michael toriel[3]

[1]CEREMA, TEAM, France (emmanuel.berthier@cerema.fr)
2 Gustave Eiffel university, GERS department, Nantes, France
[3]PARIS-SACLAY establishment, Orsay, France

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Impact of urbanization on the water cycle

At two levels:

- The surface, with the sealing of the soil → more Runoff and less Infiltration and Evapo(transpi)ration
- In the subsoil, by alteration of the natural soil (compaction, addition of artificial element) and introduction of underground constructions (numerous networks and basements) → modifications in water flows and groundwater

Difficult to simulate, due to the lack of appropriate models

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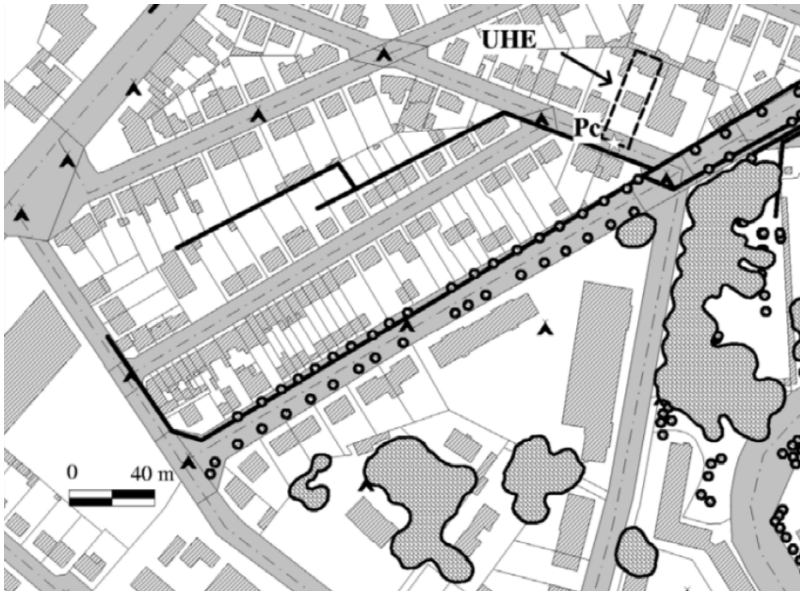
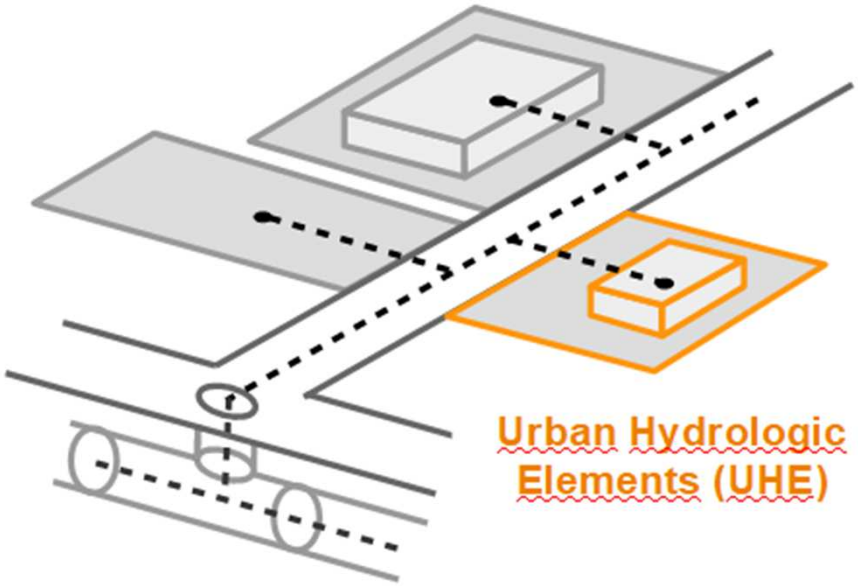
M. O. Gessner *et al.*, « Urban water interfaces », *Journal of Hydrology*, vol. 514, p. 226–232, 2014, doi: 10.1016/j.jhydrol.2014.04.021.
T. D. Fletcher, H. Andrieu, et P. Hamel, « Understanding , management and modelling of urban hydrology and its consequences for receiving waters : A state of the art », Advances in Water Resources, vol. 51, p. 261–279, 2013, doi: 10.1016/j.advwatres.2012.09.001.

The URBS (Urban Runoff Branching Structure) model

An integrated model developed since several decades for the scale of a district

Spatial discretization is based on UHE connected to the drainage network





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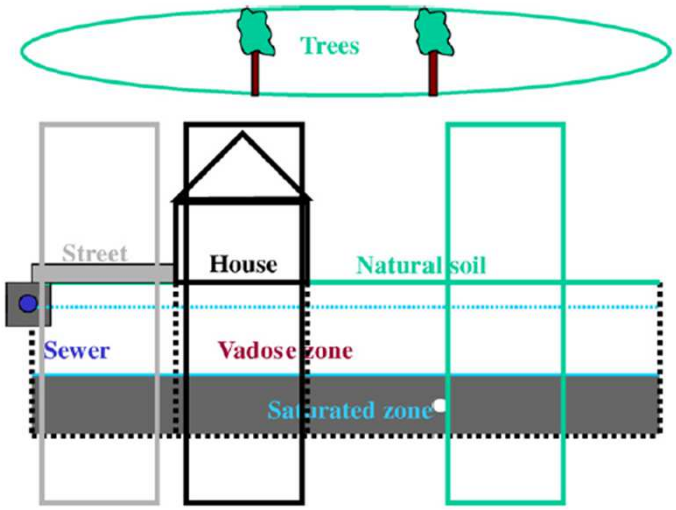
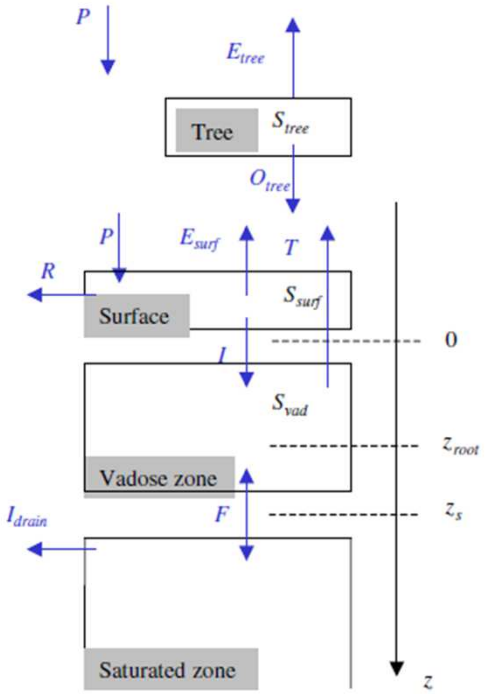




The production of the different water fluxes is calculated for each UHE on 3 different vertical profiles

Taking into account the interception, evapotranspiration, infiltration, redistribution in the vadose zone, drainage by the underground networks, and groundwater flow

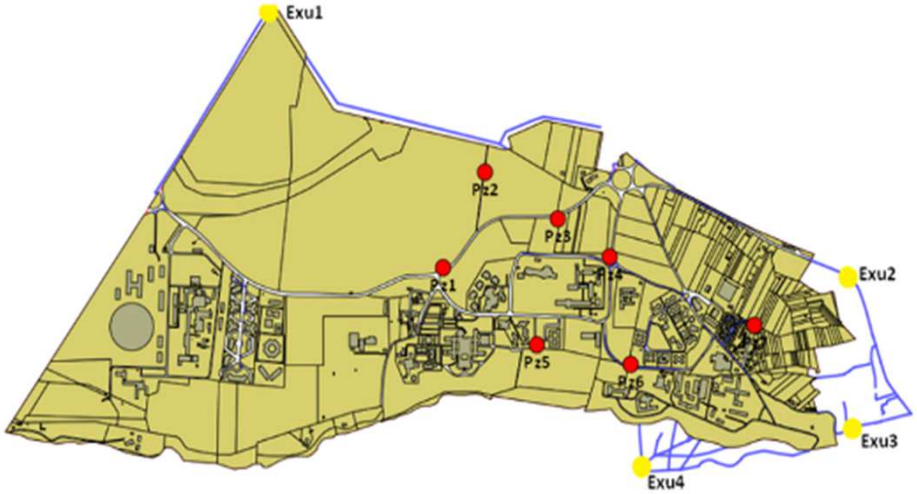
Able to perform continuous and long-period simulations (several years) for small time-steps (few minutes)

Rainfall and potential evapotranspiration as input data

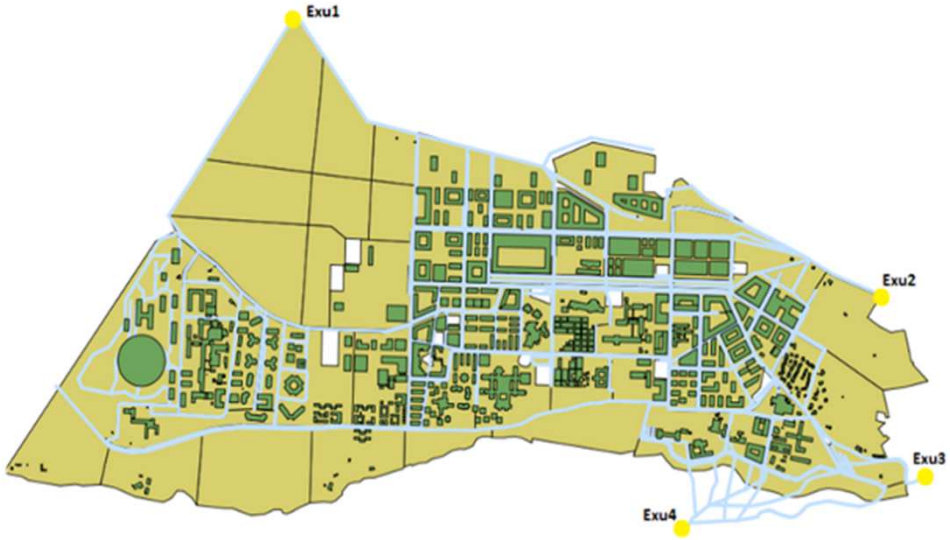
The study case: the Moulon district layout

A 200ha development operation of the Paris-Saclay Cluster (currently underway)

Increase of sealed surfaces from 14% to 35% and a densification of underground constructions such as networks and basements



predevelopment situation



development situation

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The study case: the Moulon district layout

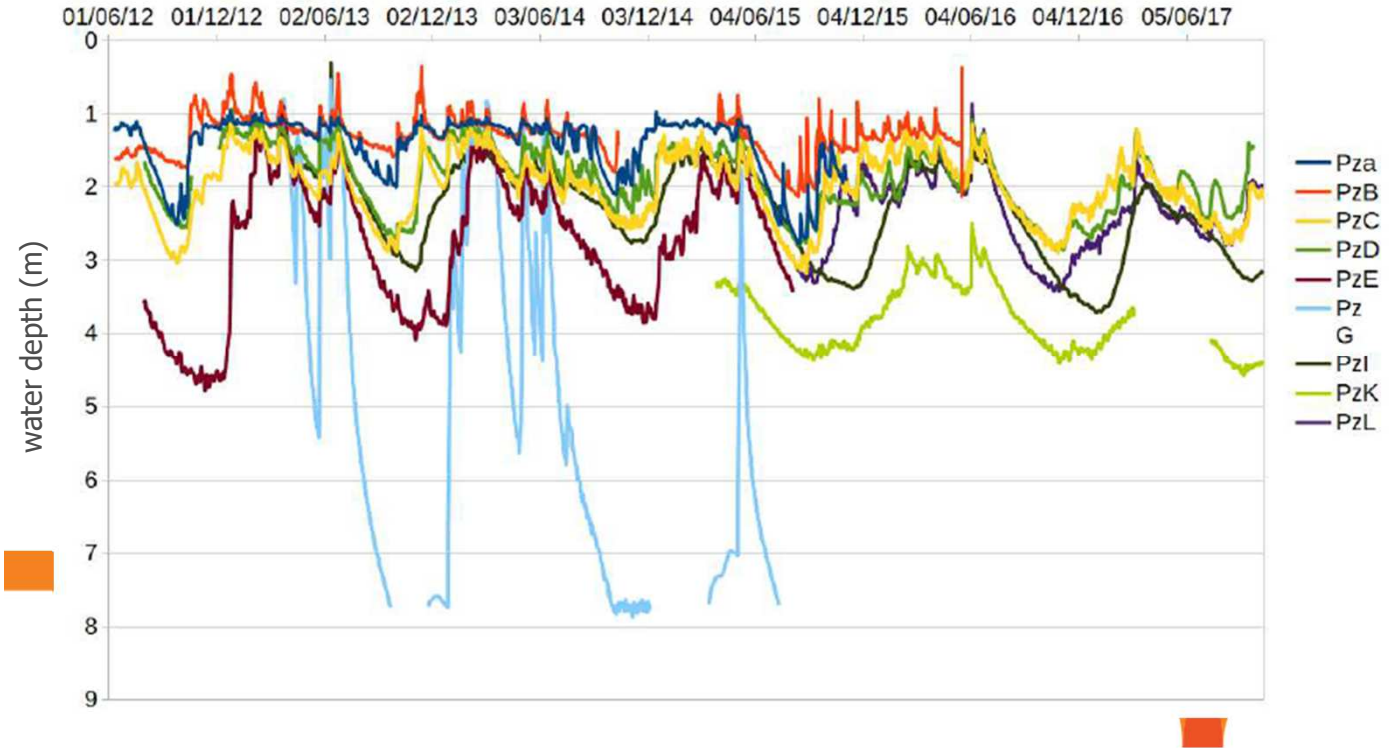
A rainwater system with a lot of low-impact-development technics as rain-garden, swale, trench ….

The study case: the Moulon district layout

a shallow groundwater extending on the whole area, with frequent saturation at the surface and unknown relation at the bottom

fluctuations of groundwater levels have been monitored at an hourly time-step with 8 piezometers since 2012

piezometers do not all exhibit the same dynamics



Calibration of the URBS model on the predevelopment situation

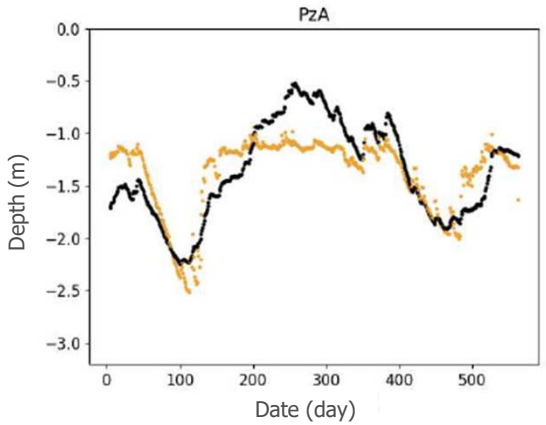
On 7 selected piezometer and for a 1,5-years period (start on June)

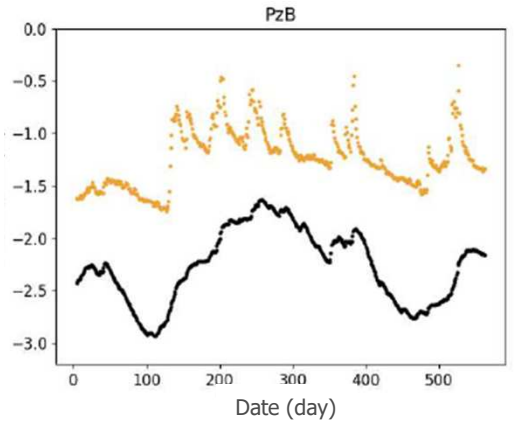
For the parameter influencing the soil: permeability, sewer infiltration process, lower boundary condition

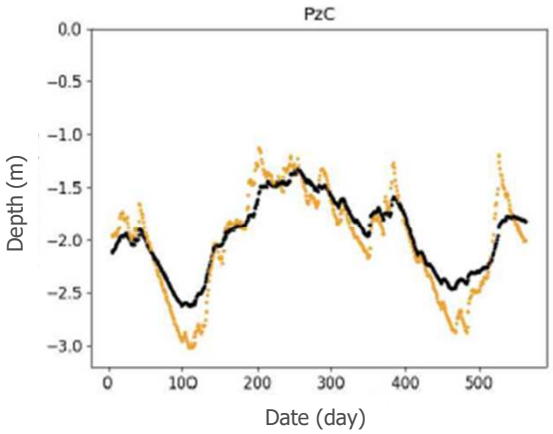
Based on Monte-Carlo simulations until obtain 150 "acceptable" simulations

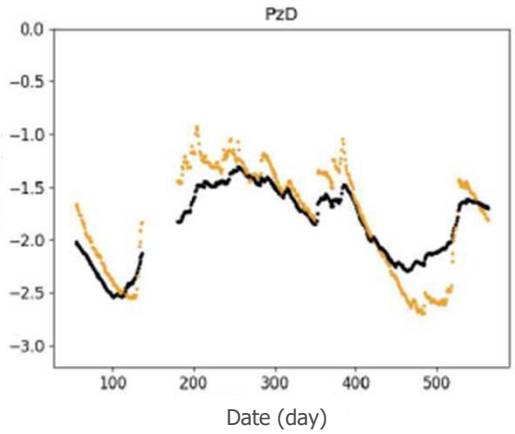
A simulation is "acceptable" if the Nash-Sutcliffe criteria E is:
≥ 0,4 for at least 4 piezometer
≥ 0,5 for at least 3 piezometer
≥ 0,6 for at least 2 piezometer
≥ 0,75 for at least 1 piezometer

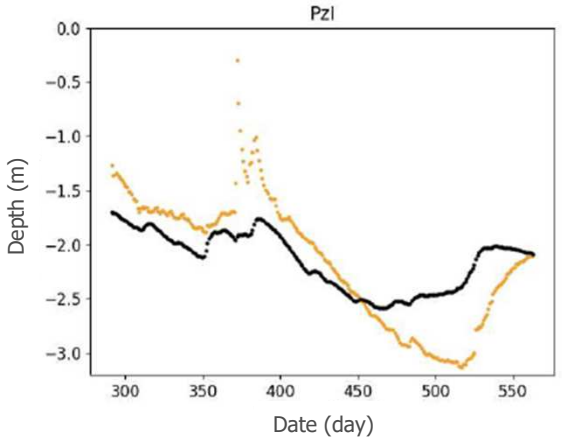
Results for the "optimal" simulation (in black): …

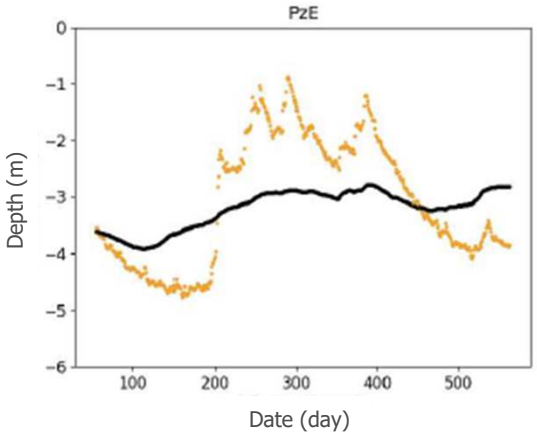


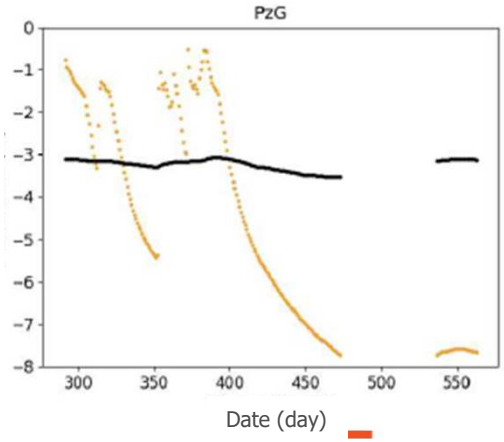










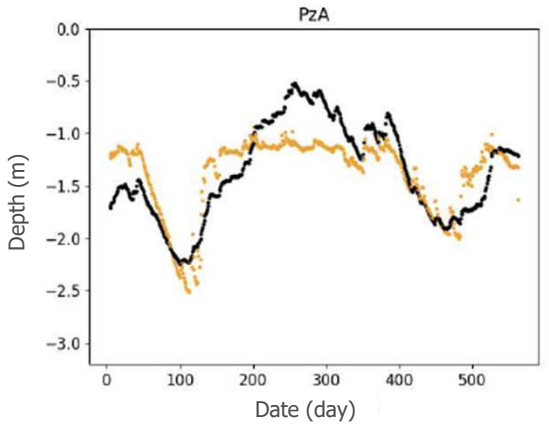


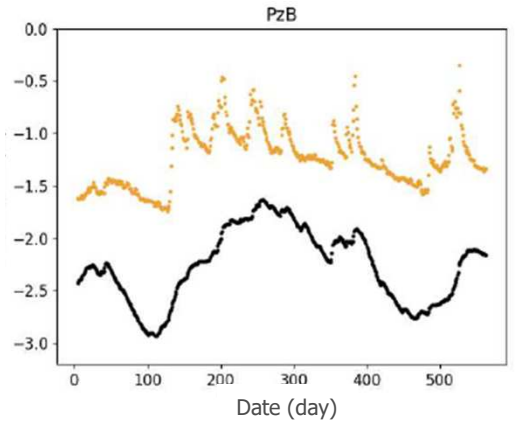
Calibration of the URBS model on the predevelopment situation

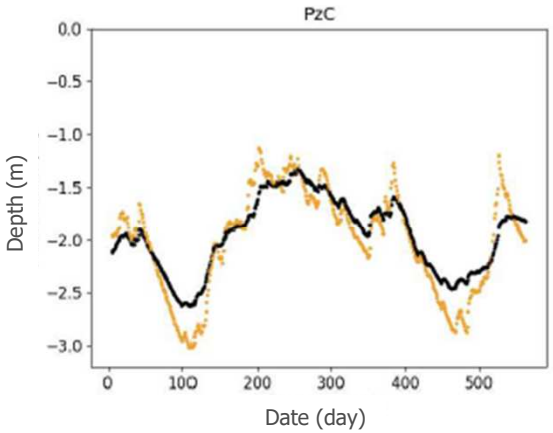
Results for the "optimal" simulation (in black):

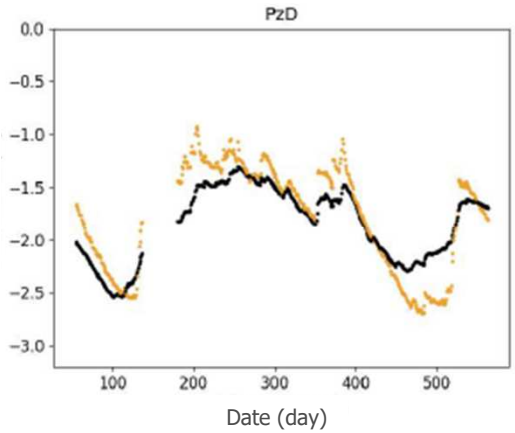
rather satisfactory with good representation of the observed levels for several piezometers (A, C, D and I)

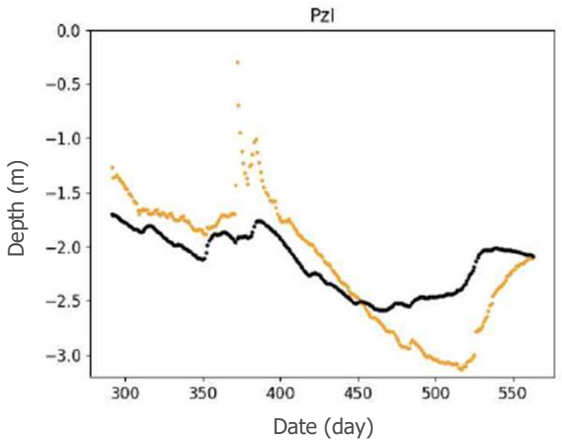
despite difficulties for the piezometer B (shift), E (non-representation of the observed typical variations) and G (observations exhibit atypical variations)

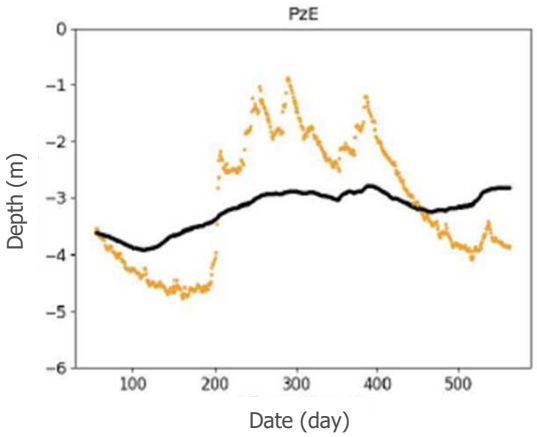


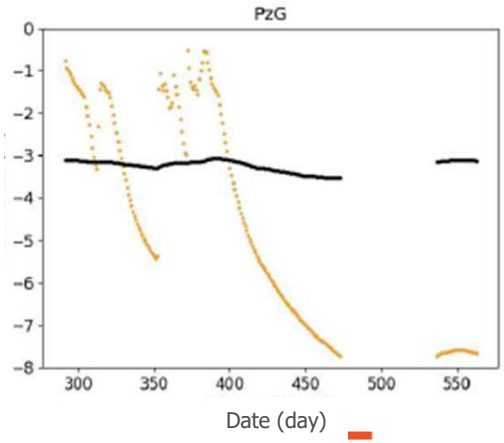












Hydrological impact of the development of the district

New simulations in the development situation (excepted for 2025), accounting for the land-use modification and underground construction

On a 3-years period, with a total rainfall about 1800mm

Impact on the water budget of the district:

	ET	R_{imp}	R_{nat}	I_{net}	Q_{LBL}	Δstock
Predevelopment	64	8	1	4	19	5
Development	51	18	0	11	19	2

Simulated budgets in % of rainfall. ET: evapotranspiration, Rimp: runoff on impervious surfaces, Rnat: runoff on pervious surfaces, Inet: infiltration of soil water in the sewer networks, QLBL: flux at the lower boundary, Δstock: difference of the water stored in the model between the final and initial time

→ Increase of impervious runoff and infiltration of soil water in the sewer network, balance by an evapotranspiration reduction

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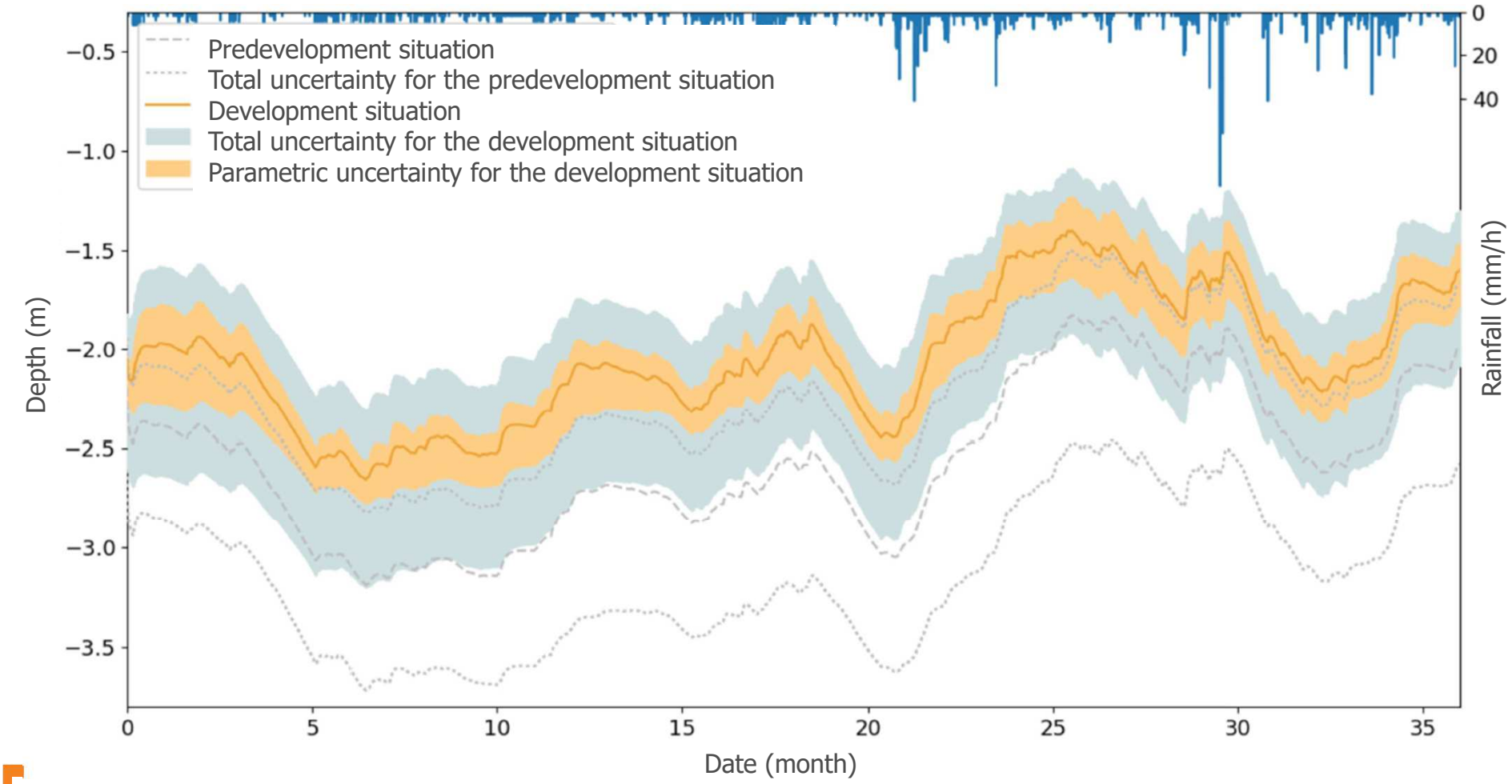
Hydrological impact of the development of the district

Impact on the groundwater, taking into account model uncertainties:



simulated level of groundwater (mean value on the whole district)

uncertainties = parametric (obtain with the different parameters set of the "acceptable" simulations) + total (obtain with the difference between observed and simulated piezometric levels)

Conclusion

The integrated urban hydrological model URBS continue to be developed and has been appropriate to study the impact of the development of the Moulon district

The analysis of the first simulations suggests that an increase of water table levels might be expected after the development of the district : this somehow surprising result may partly originate from the decrease of evapotranspiration fluxes associated with the increased of sealed surfaces

A simplified uncertainty analysis (based on Monte-Carlo simulations) has been conducted to evaluate and distinguish uncertainties associated with model parameters and the total uncertainties in model outputs: while the results clearly evidence the importance of total uncertainties (although the uncertainties due to the model parameters remain low), they also confirm that groundwater depths could be reduced by the construction of the Moulon district

Contact: Emmanuel Berthier, Cerema, emmanuel.berthier@Cerema.fr

Cerema PARIS-SACLAY Université Gustave Eiffel