Distributed simulation of long-term hydrological processes in a medium-sized periurban catchment under changing land use and rainwater management

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INTRODUCTION

▪ **Growing urbanization: increase of surface imperviousness**, **modifications of water flow paths** ➔ increase of surface runoff, rise of storm peak flows and **flood** magnitude, reduction of groundwater recharge and increasing water **pollution.**

• **Periurban catchments** = combination of natural areas, rural areas with dispersed settlements and urban areas mostly covered by built zones and spots of natural surfaces ➔ **especially affected** due to fast anthropogenic modifications (Braud et al., 2013).

• **General guideline:** European Water Framework Directive (2000) and Floods Directive (2007) ➔ **integrated and sustainable solutions needed** to reduce flooding risks and river pollution **at catchment scale**.

• **Our objective: quantify the impact of urbanization and stormwater management on the long-term hydrological cycle of medium-sized periurban watersheds.**

1. CASE STUDY : the Yzeron catchment (150 km²), France

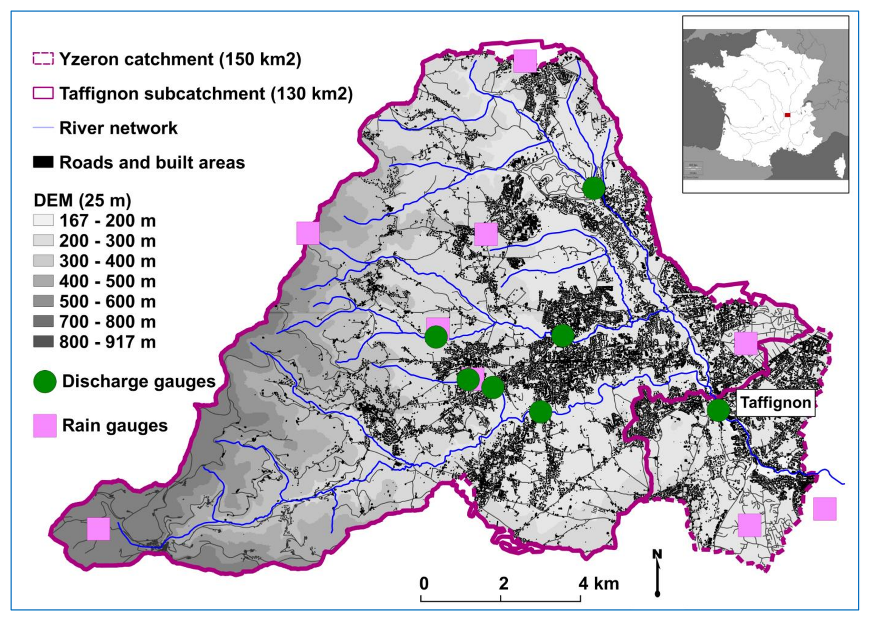

Figure 1: Situation map of the Yzeron and Taffignon catchments with indications of topography, impervious areas and measurement network.

Hydro-meteorological monitoring since the 1990's (OTHU, Fig.1). Mean annual rainfall ≈ 830 mm.

Steep slopes upstream (Fig.1) + low soil water storage capacity ➔ **quick Mediterranean-type floods**

Fast growing urbanization led to an increase of impervious areas since 1980's. In 2008, the catchment was covered by 25% of impervious surfaces, 42% of agricultural areas and 33% of forests (Fig.2).

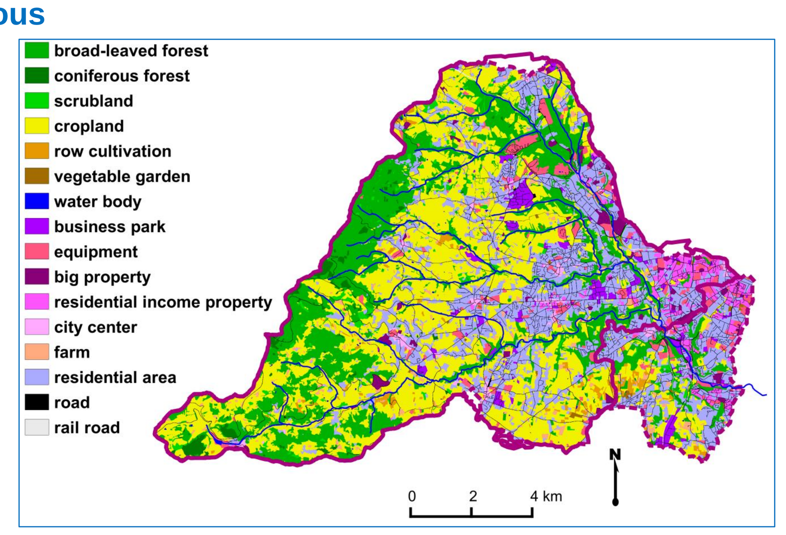

Figure 2: Land use map of the Yzeron catchment derived from very high resolution satellite images (Jacqueminet et al., 2013).

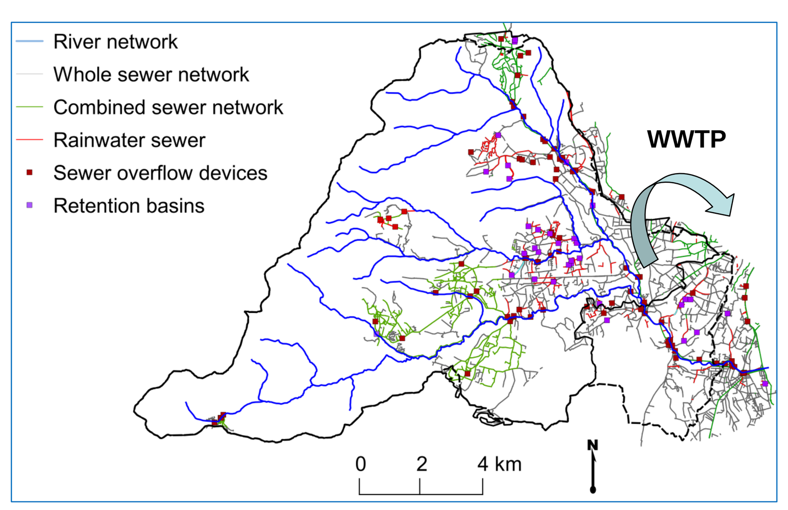

Figure 3: Rainwater management map derived from local authorities data.

In urban areas: rainwater is mainly directed to the **WWTP outside of the basin** using **combined sewer network** (Fig.3).

ACKNOWLEDGMENTS

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2. MODEL DESCRIPTION

• **The distributed hydrological model J2000** (Krause et al., 2006)
- process-oriented / fully distributed / irregular meshes (HRU-based (Flügel, 1995))
- open source/ modular based on JAMS framework (Kralisch et al., 2007)
- long-term continuous simulation with fixed time steps (month, day, hour)

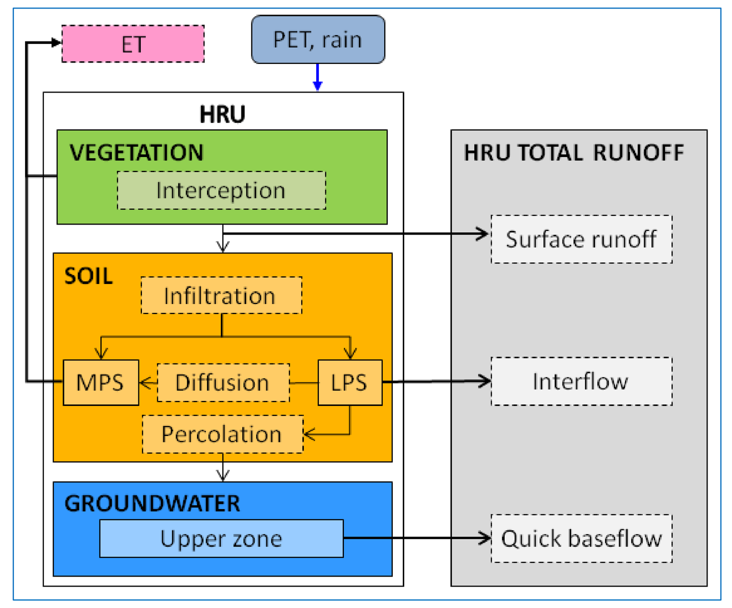


Figure 4: Physical processes and runoff contributions simulated at each time step and for each HRU.

• Infiltration/surface runoff partition controlled by HRU's surface sealing grade and average soil saturation + a maximum infiltration rate.

• Infiltrating water distributed to two reservoirs with different soil porosities (Fig.4): middle pore storage (MPS) / large pore storage (LPS).

• Percolation into a groundwater compartment parameterized by a size and a recession constant.

• **Routing**: laterally to the connected neighbouring HRU or river reach, according to the topology and a simplified kinematic wave approach (Fig.5).

• **The periurban version J2000P takes into account:**

- **Local context and data availability**
- **Fast hydrological dynamics in urban areas**
→ hourly time step
- **Water flow paths modifications** (Fig.5)
→ explicit description of the sewer network
- **Overflows from the sewer to the river** (Fig.5)
→ implementation of a Sewer Overflow Device (SOD) module

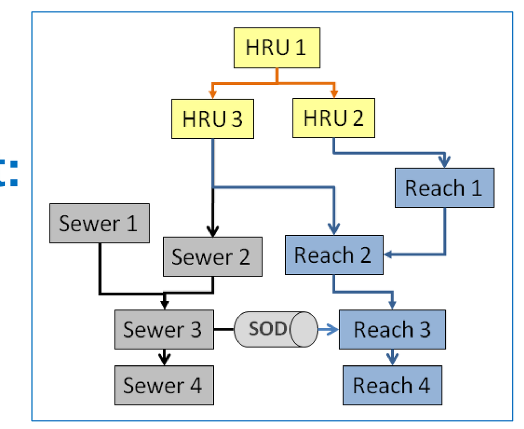


Figure 5: Routing in J2000P. Addition of a sewer network. Some SODs can connect sewer reaches to river reaches.

3. MODEL APPLICATION

• **Mesh delineation based on the topography and the sewer network**

96 HRUs = 47 **rural** and 49 **urban subcatchments** (Fig.7)
→ Rural outlet = a river reach
→ Urban outlets = a river and a sewer reach

• **Parameterization of land use**

For each land use class were assigned (Fig.6):
→ **average vegetation parameters** (leaf area index, crop coefficient, root depth) set according to FAO (1998) and Ecoclimap database (Masson et al., 2003),
→ **a runoff coefficient** equal to the average percentage of impervious land use.

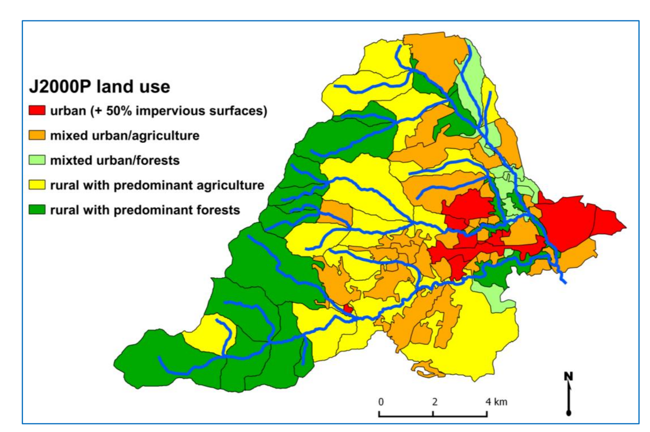
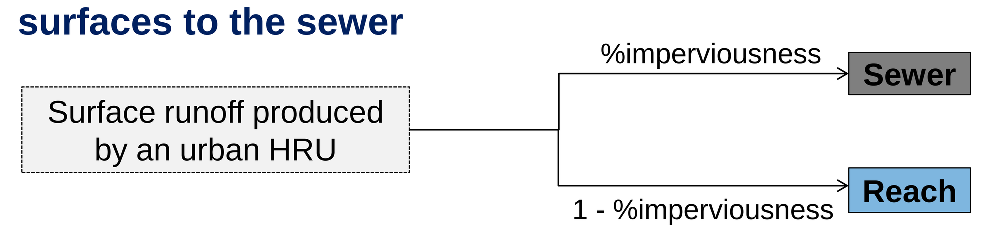


Figure 6: Land use based on remote sensing images and re-classified into 5 classes.

• **Sewer network and SOD parameterization**

110 sewer reaches (Fig.7): roughness=100, slope=1%,width=0.4m
29 SOD: threshold = 50cm

Assumption: in urban HRU, connection of all impervious surfaces to the sewer



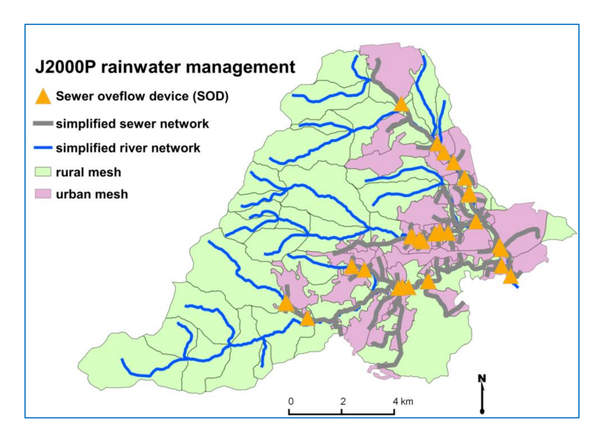


Figure 7: HRU delineation, sewer network and SODs.

• **Parameter specification based on available information:** model use as a hypothesis testing tool. No calibration performed. Daily model J2000 evaluated (Branger et al., 2013).

• **Climatic forcing:** uniform hourly ET0 calculated from SAFRAN reanalysis (Vidal et al., 2010), hourly rainfall regionalized using 7 gauges. Simulations performed for the 1997-2010 period (1997 as warming-up period) .

4. RESULTS

• **Influence of the rainwater management modelling on the river runoff at the outlet**

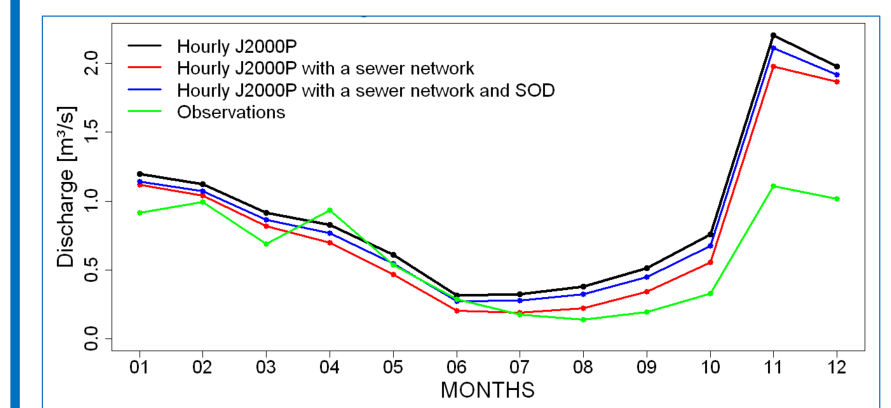


Figure 8: Mean interannual monthly river runoff at Taffignon between 1998 and 2010.

• The simulations mostly overestimate the runoff (Fig.8) because of a low simulated evapotranspiration which seems to be limited by a small soil water availability.

• At present, the most important peak events (April, Nov., Dec.) are not well estimated by the model.

• The simulation of the sewer network decreases the river runoff as expected (Fig.8). The introduction of SOD generates occasional overflows from the sewer to the river.

• **Sewer runoff and SODs overflows**

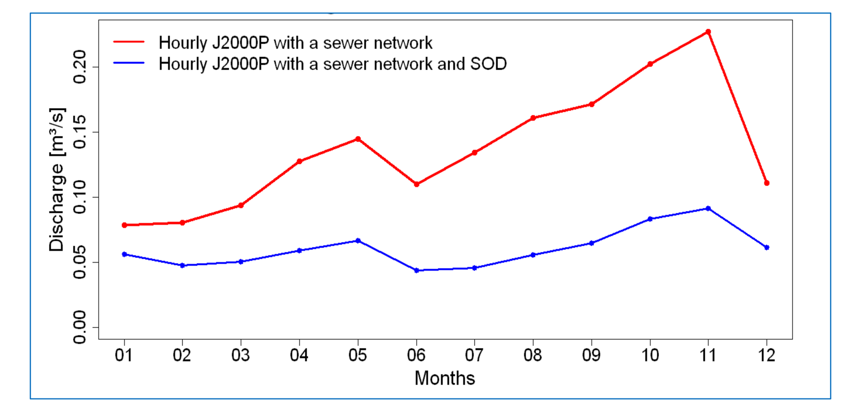


Figure 9: Mean interannual monthly sewer runoff at Taffignon between 1998 and 2010.

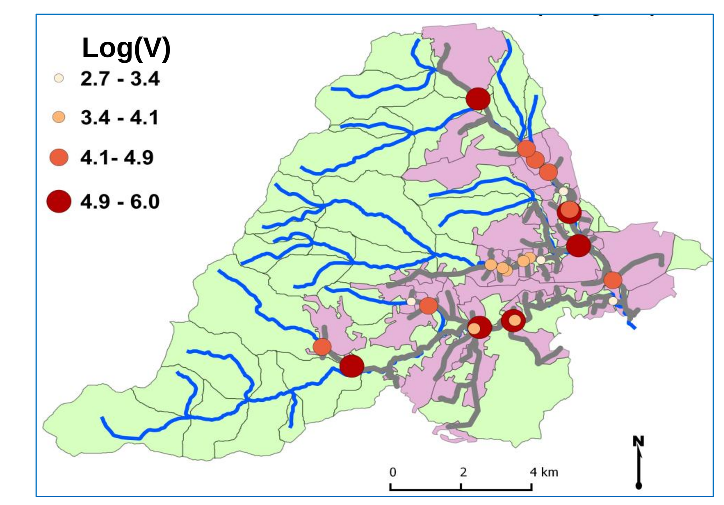


Figure 10: Mean interannual volume from SODs (m3/year).

The sewer flow is affected by the presence of SOD (Fig.9). Overflows happen for almost all the SODs (Fig.10) and some can really impact the environment, especially during low flow periods.

• **Impacts on the river runoff**

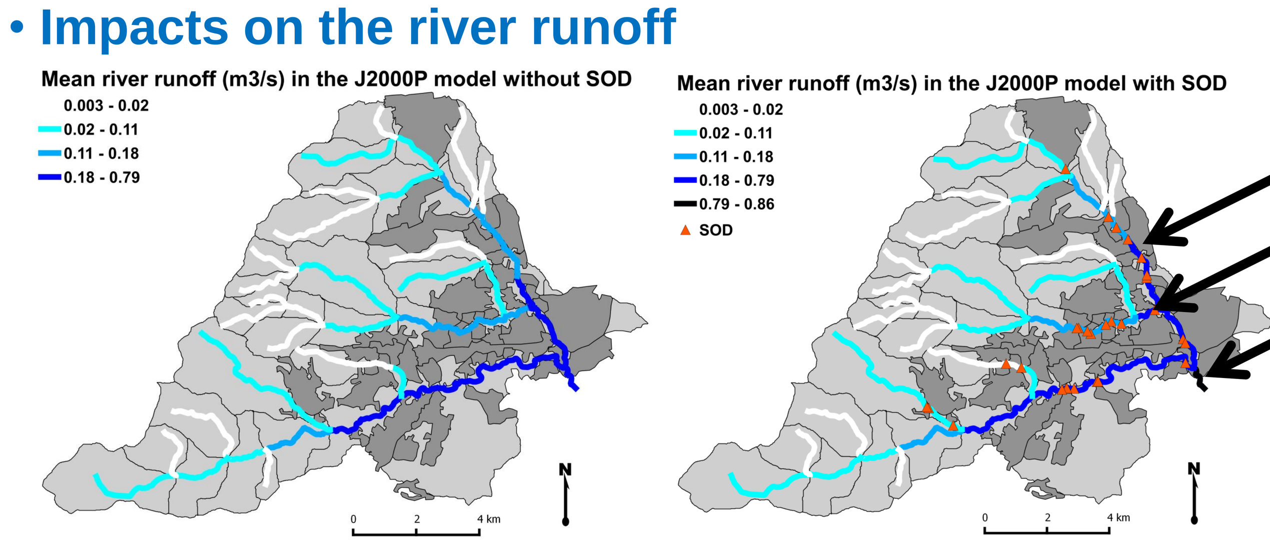


Figure 10: Mean river runoff between 1998 and 2010 simulated without or with SODs.

The **global river regime** seems to be affected by the presence of SOD overflows locally in 3 places.

CONCLUSION and PERSPECTIVES

• The daily **J2000** model is an **appropriate simulation tool** for studying the water balance of the Yzeron catchment. To model **periurban** hydrology, structure and parameters need to be **adapted** → model **J2000P.**

Although no comparison with measured sewer runoff and overflow data was made yet to assess the model performance, it can be concluded that the model **reproduces qualitatively well** the **expected urban behavior** of the catchment.

• **Ongoing work** will focus on the HRUs delineation which has to take into account the different hydrological objects in periurban areas and their optional connections to the rainwater system. More studies have also to be conducted on the routing inside the HRUs.

Final objective of the development of the J2000P model is to test the effects of different hydrological scenarios (land use and rainwater management at different dates) on the long-term hydrology of a medium-sized periurban catchment.