Modelling transport of storm-water pollutants using the distributed Multi-Hydro platform on an urban catchment near Paris

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Introduction

Nowadays, the increasing use of vehicles causes expanding contaminated storm-water runoff from roads and adjacent areas. Besides, the current utilization of city's separated sewer systems underlines the needs for evaluating precisely the transfer of traffic induced pollutants into receiving water bodies through the separate sewer system. Nevertheless, conceptual models of water quality modeling have shown their limits. The attempt of physically based model is an option that could be tested in the framework of urban hydrology. In this study, we found that the application of physically based and fully distributed model Multi-Hydro (MH) coupled with detailed and high-resolution data is a promising approach to model hydrological behaviors at the urban catchment scale.

Study site and catchment delineation

- The study site located in the Val-de-Marne department in the eastern suburbs of Paris, France. A preliminary step is to delineate the urban catchment.

FIG 1, The study site: Le Perreux-sur-Marne, 0.12 km²

- ***Urban catchment delineation:***

Step 1 • Using detailed sewer network data, find contributing sewage portions for the study outlet;

Step 2 • Identify linked gullies;

Step 3 • Using high resolution DEM data (20cm) to delimit the « drainage basin » for each gully.

Step 4 • Reassemble all these « drainage bassins » of step 3 for all the linked gullies.

GIS data

- Model implementation is based on high-resolution Digital Elevation Model (**DEM**) data (20cm), detailed description of urban **Land-Use** features (14 classes),and the GIS information of the **Drainage System** (FIG 2).

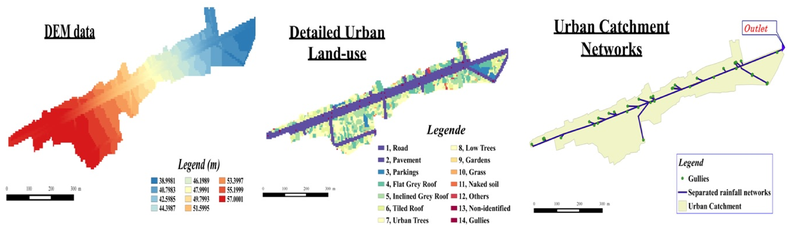


FIG 2, The used GIS data for the implementation of MH platform

Multi-Hydro Model

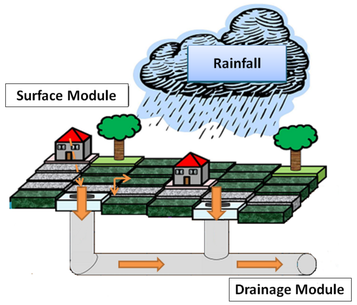


FIG 3, The concept of the Multi-Hydro Platform.

- **Multi-Hydro (MH)** is is composed by 2 core modules interacting with one another. Each module relies on existing and widely validated open source models, such as TREX model (Velleux 2005) for the surface module and SWMM model (Rossman 2010) for the drainage module (FIG. 3).
- **TREX** module use 2D Shallow Water equations for water routing and empirical USLE equations for sediment erosion; The drainage part of MH is adapted from **SWMM**, which use 1D Shallow Water equations for sewer water routing and the Continous Stired Tank Reactor (CSTR) for particles routing.
- ***Water and pollutants are transferred from surface module into drainage module through the gullies.***

Experimental data

- Benefiting from numerous observation projects in the framework of the ANR (French National Agency for Research) Trafipollu project, we could feed the physically-based model with realistic inputs and parameters.

- **Rainfall**: Input data;
- **PSD**: Provide realistic particle parameters;
- **Road dust**: Provide realistic inputs for initial conditions;
- **Discharge and Turbidity**: Used for model calibration and validation.

Local rain gauge	Tipping bucket records every 0.1mm water.
Particle Size Distribution (PSD)	In-site granulometric measurements.
Mass of road dust	Dry weather deposition on experimental sections on road.
Continous discharge measurement	2 min time step at outlet.
Continous Turbidity measurement	1 min time step at outlet, used for generating Total Suspended Solid (TSS) data.

Adaptations for urban area and Particle characteristics

- Generally, the urban soil is represented by two layers in TREX model, the deposited layer (that can be detached in the form of particles) and the asphalt (assumed to be non-detachable). The physical process and properties of each layer are presented in FIG. 4. While the particle characteristics (derived from PSD measurements) are demonstrated in FIG. 5.

- The mobilable and immobilable urban surface layers:
- Particle characteristics derived from PSD measurement:

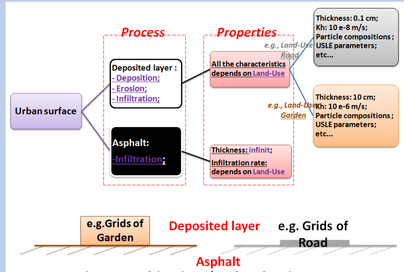
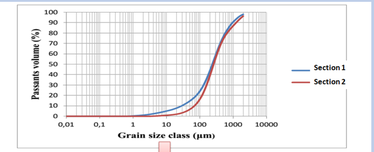


FIG 4, The concept of the adaptation of MH for urban areas.



Name	Diameter (um)	Relative Density (D_particle/D_water)	Settling velocity (m/s)	State
Micro-solids	25	1.5	0.01	Cohesive/non-cohesive
Meso-solids	150	2.65	0.02	Non-cohesive
Macro-solids	650	2.65	0.08	Non-cohesive

FIG 5, Particle characteristics derived from PSD measurements(IFSTTAR 2014)

Results and discussions

- Several rainfall events are selected between September and December 2014, model outputs are then compared to water flows and the concentration of TSS at the catchment outlet. The results of the rainfall event 15 Nov. 2014 are displayed below as an exemple:

- **Water flow simulation** (FIG.6):

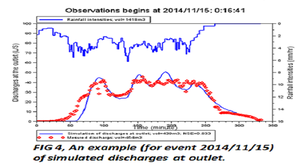


FIG 4, An example (for event 2014/11/15) of simulated discharges at outlet.

- **Water quality simulation** (FIG.7):

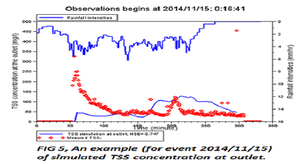


FIG 5, An example (for event 2014/11/15) of simulated TSS concentration at outlet.

- The Nash Sutcliffe-Efficiency coefficient (NSE) shows a good performance of the MH model (**NSE=0.833**) for modeling **water flows**.
- The simulation outputs indicate that the present prototype fails at simulating properly **sediment transport**.
- The model could not reproduce the TSS observation curve in spite of numerous tests of USLE parameters (0-1), particularly for the **first peak** at the beginning of the rainfall event.
- As the sediment detachment is only generated by overland water flow in the present model, **rainfall detachment** effect may explain our difficulty to reproduce correctly the dynamics of sediments at the outlet. Future developments will focus on the implementation of processus linked to splash by rain drops.

Conclusions and perspectives

- High-resolution and detailed GIS data, as well as experimental data like local rain gauge records, granulometric measurements, and dry weather deposition campaigns was applied in order to feed the physically based model with realistic inputs.
- The application of Multi-Hydro is a promising approach to reproduce the various dynamics and interactions of water quantity processes in urban or peri-urban environment.
- The integration of rainfall detachment processes into Multi-Hydro is an essential perspective for the water quality modelling.
- For more information about the model development, please pay attention to my another presentation (EGU2015-975, PICO 3.3).

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