Urban water-quality modelling: implementing an extension to Multi-Hydro platform for real case studies

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Introduction

Although the rapid worldwide development of hydrological modelling during the last decades, the physically-based and distributed models for the combined modelling of urban surface and networks are rarely applied in the field of urban drainage. In this context, the Multi-Hydro (MH) platform has been developed at Ecole des Ponts ParisTech over recent years (Giangola-Murzyn 2013; Tchiguirinskaia et al. 2014; Gires et al. 2014). This hydro-dynamical model is open-access and has a modular structure, which is designed to be easily scalable and transportable, in order to simulate the dynamics and complex interactions of the water cycle processes in urban or peri-urban environment. In the framework of the ANR (French National Agency for Research) Trafipollu project, the extension of MH called MH-quality, has been preparatively implemented by combining the already available water-quality computational components among different modules, in order to bring in the pollutant transport into the hydro-dynamical platform. The main objective of this paper is hence to introduce the choices and assumptions that we made for the model developments, and also to presente our first results on urban catchments located near Paris.

The structure of Multi-Hydro Model

Multi-Hydro is formed by the interactive coupling of several independent modules, which 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. 1).

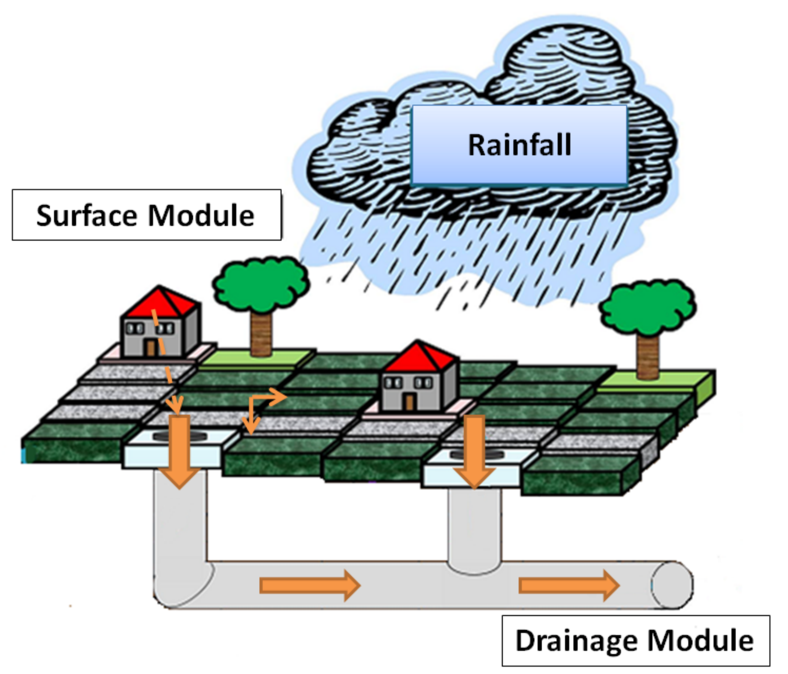

FIG 1, The concept of the Multi-Hydro Platform.

Water quantity processes

Surface: TREX Model	
Water flow:	2D Shallow-Water equations
Numerical method:	Finite Difference
Infiltration method:	Green & Ampt
Interception:	Volume loss
Drainage networks: SWMM model	
Water flow:	1D Shallow-Water equations
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Water and pollutants are transferred from surface module into drainage module through the gullies. In Multi-Hydro, the gullies are the grids where past water is completely "infiltrated".

Pollutant transport modellling

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Sediment advection:	Advection equations.
Settling of suspended particles:	Settling velocity formula.
Particle detachment:	Modified form of Universal Soil Loss Equation (USLE), with urban adaptions.

Particles →

Drainage networks: SWMM model	
Particles routing:	Continuously Stirred Tank Reactor (CSTR).

On the grids of gullies, as all the past water is "infiltrated", all the suspended solids should be "settled" on the surface; the mass of solids entering drainage modules are hence calculated.

Continuity equation of the concentration of particles on overland plane in 2-D:

$$\frac{\partial C_s}{dt} + \frac{\partial \hat{q}_{tx}}{dx} + \frac{\partial \hat{q}_{ty}}{dy} = \hat{J}_e - \hat{J}_d + \hat{W}_s \quad (1)$$

where:

- C_s = concentration of sediment particles in the flow (M/L^3);
- $\hat{q}_{tx}, \hat{q}_{ty}$ = total sediment transport areal flux in the x- or y-direction (M/L^2T);
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Urban surface Particle detachment

The detachment rate is calculated by substracting the existing particles in the water column from a "transport capacity" (q_s), q_s is accessible by using USLE equation:

$$\begin{cases} q > q_c; & qs = 1.524 \times 10^8 (q - q_c)^{2.035} S_f^{1.66} \hat{K}\hat{C}\hat{P}; \\ q \leq q_c; & q_s = 0 \end{cases} \quad (2)$$

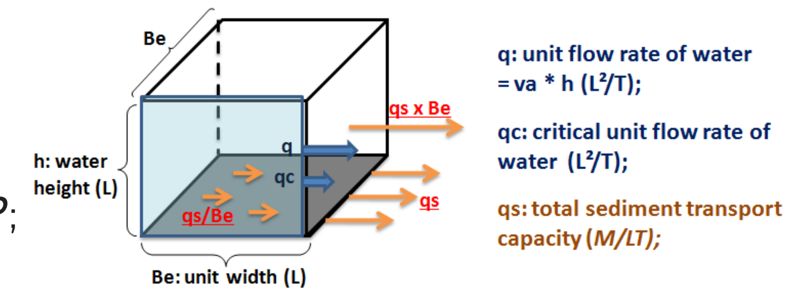

FIG 2, Conceptual view of "transport capacity".

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"Transport capacity" is an **empirical expression** for computing agricutual soil erosion, certains adaptations should be considered, such as sediment caracteristics, soils layers thicknesses as well as the parameters configurations.

Site description

Multi-Hydro was tested on two peri-urban catchments located near Paris, the Villecresnes (France, 0.7 km^2) and the le Perreux-sur-Marne (France, 0.12 km^2).

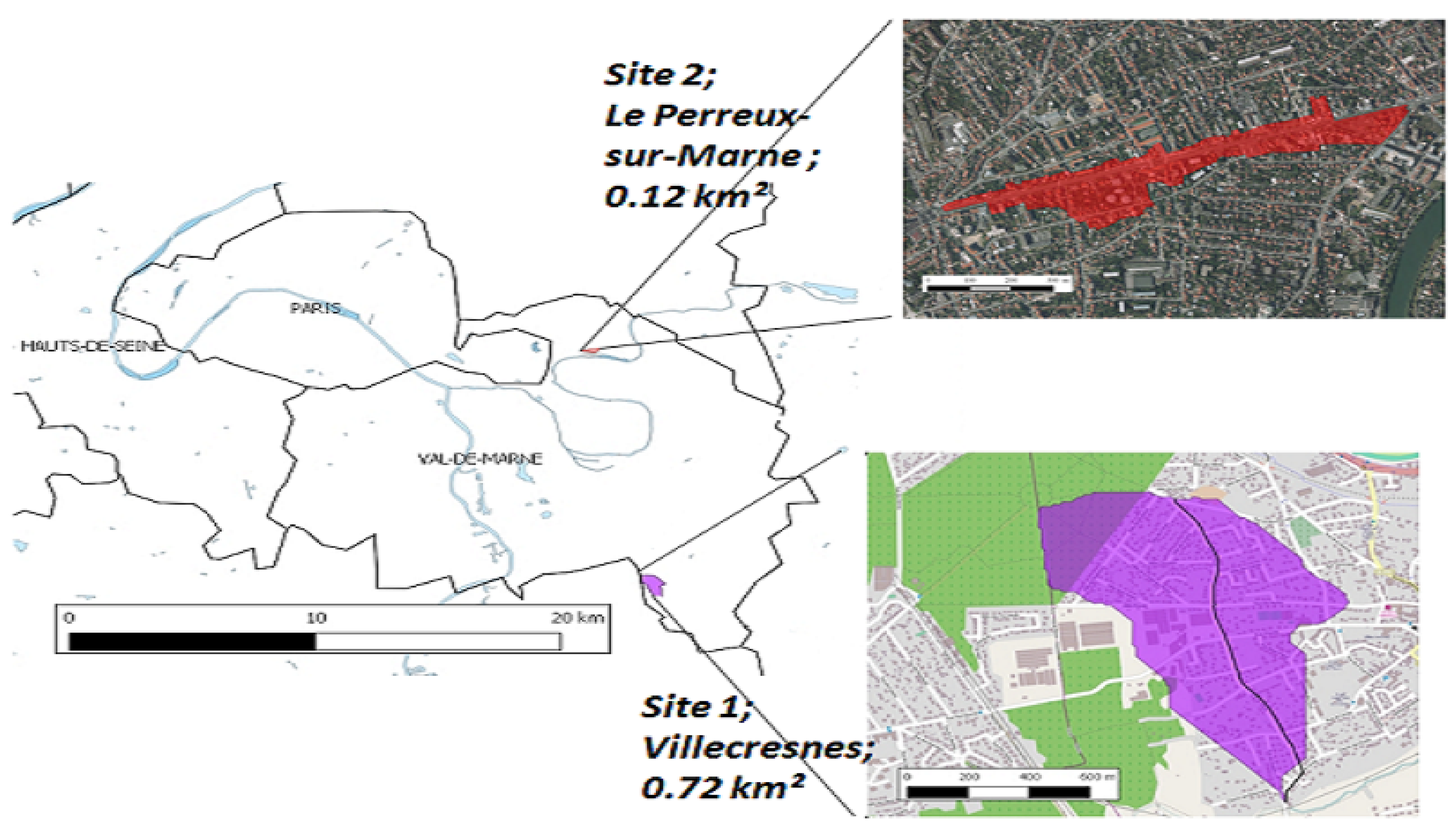

FIG 3, The two different study sites

As the Villecresnes had been analyzed within several European projects, the robustness of the new extension of MH was firstly tested on this basin.

Benefiting from the large dataset, the results of the application of Multi-Hydro on Le Perreux-sur-Marne are generally presented in the other presentation of EGU2015-983 (Friday, poster board R7).

Data descriptions

Owing to the already analyzed results within several European projects (FP7 SMARTeST, KIC-Climate BlueGreenDream, Interreg RainGain), this new extension of MH was tested on the Villcresnes catchment.

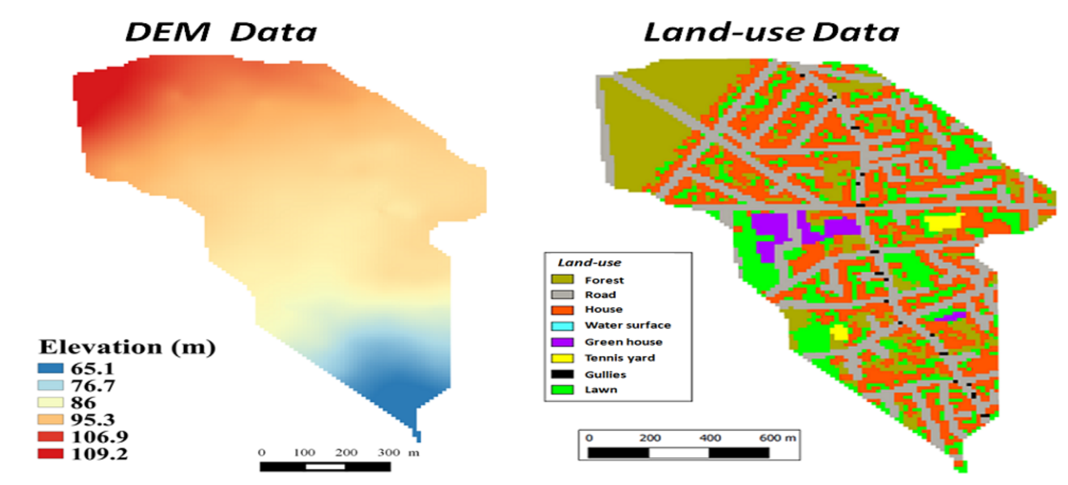

FIG 4,DEM and Land-use input data for Villecresnes catchment

The surface area of this catchment is 0.72 km^2,8 different types of land-uses, input grids resolution is 10m. The separate sewer system of the catchment is described in the FIG.3 (black line of the low-right graph).

Simulation results

The used rainfall intensities, simulated water discharges and Total Suspended Solid (TSS) at the sewer outlet are presented in the FIG.5.

The surface water height (FIG.6) and TSS concentrations (FIG.7) of each grids are presented as well.

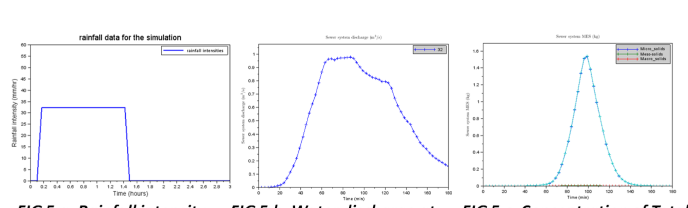

FIG 5.a, Rainfall intensity   FIG 5.b, Water discharge at sewer outlet   FIG 5.c, Concentration of Total Suspended Solid at sewer outlet

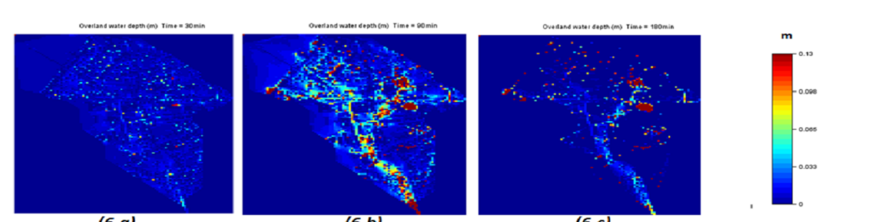

FIG 6, Water height on the surface grids; 6.a, time = 30 min, 6.b, time = 60 min, 6.c, time = 90 min,

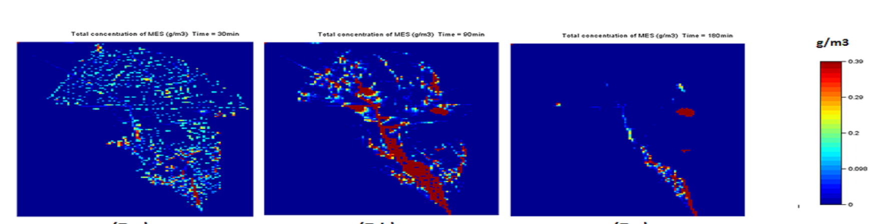

FIG 7, Total Suspended Solid concentrations on the surface grids; 7.a, time = 30 min, 7.b, time = 60 min, 7.c, time = 90 min,

Conclusions and perspectives

In this study, the extension of Multi-Hydro (MH-quality) has been set up to introduce the pollutant transport modelling into the hydro-dynamical platform. Our first reslults on the urban catchment (Villecresnes, 0.72) has confirmed it's robustness in hydrological dynamic modeling.

Furthermore, the MH-quality is then configured for a smaller urban catchment near Paris (Le Perreux-sur-Marne, 0.12 km^2). Thanks to the detailed dataset and the continous observations of rainfall intensitiy, discharge and turbidity at the sewer outlet, the MH-quality is clearly analyzed and improved for the modeling of pollutant transport as well as the water quantity for small urban catchment. For more information, please pay attention to our another presentation (EGU2015-983, Friday Poster board R7).

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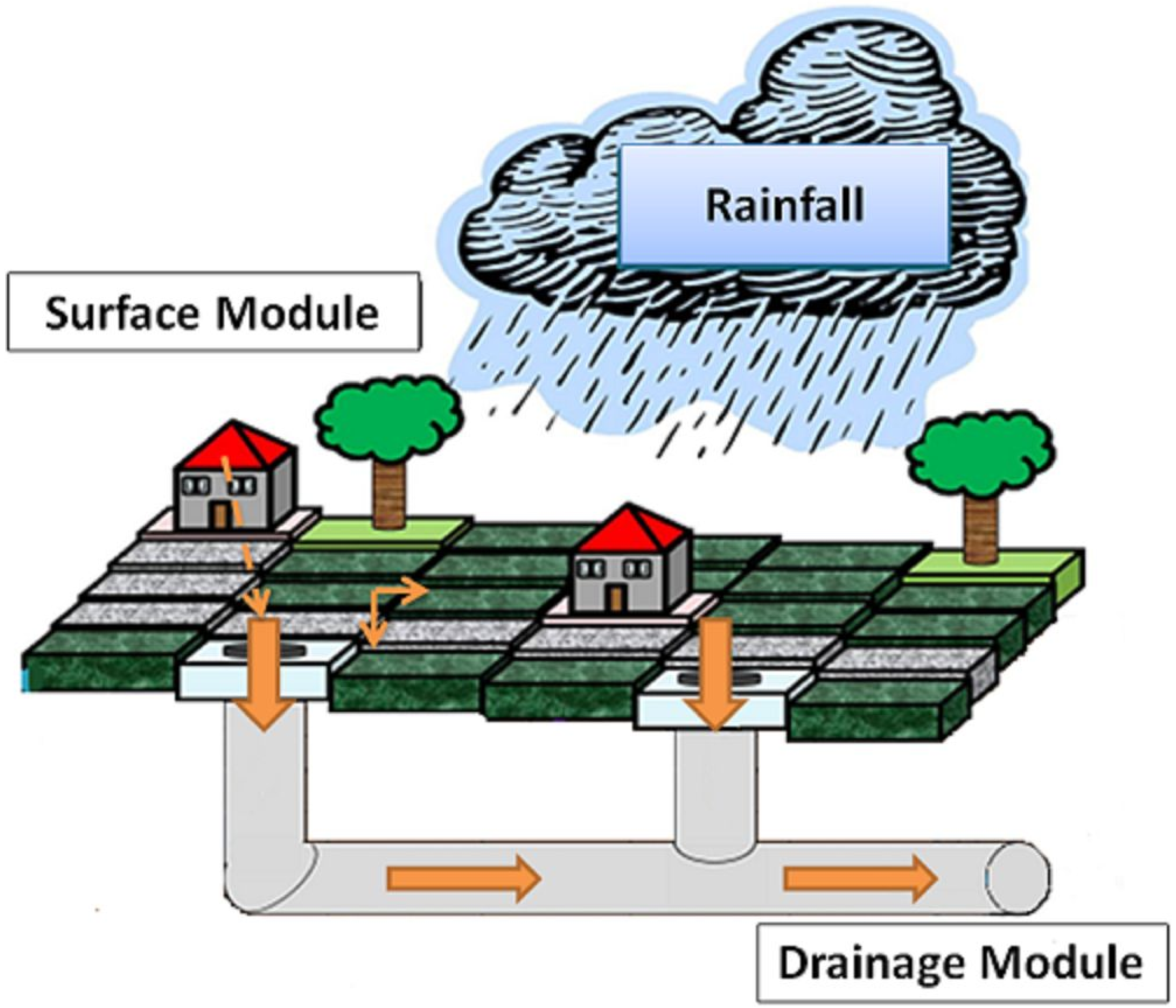

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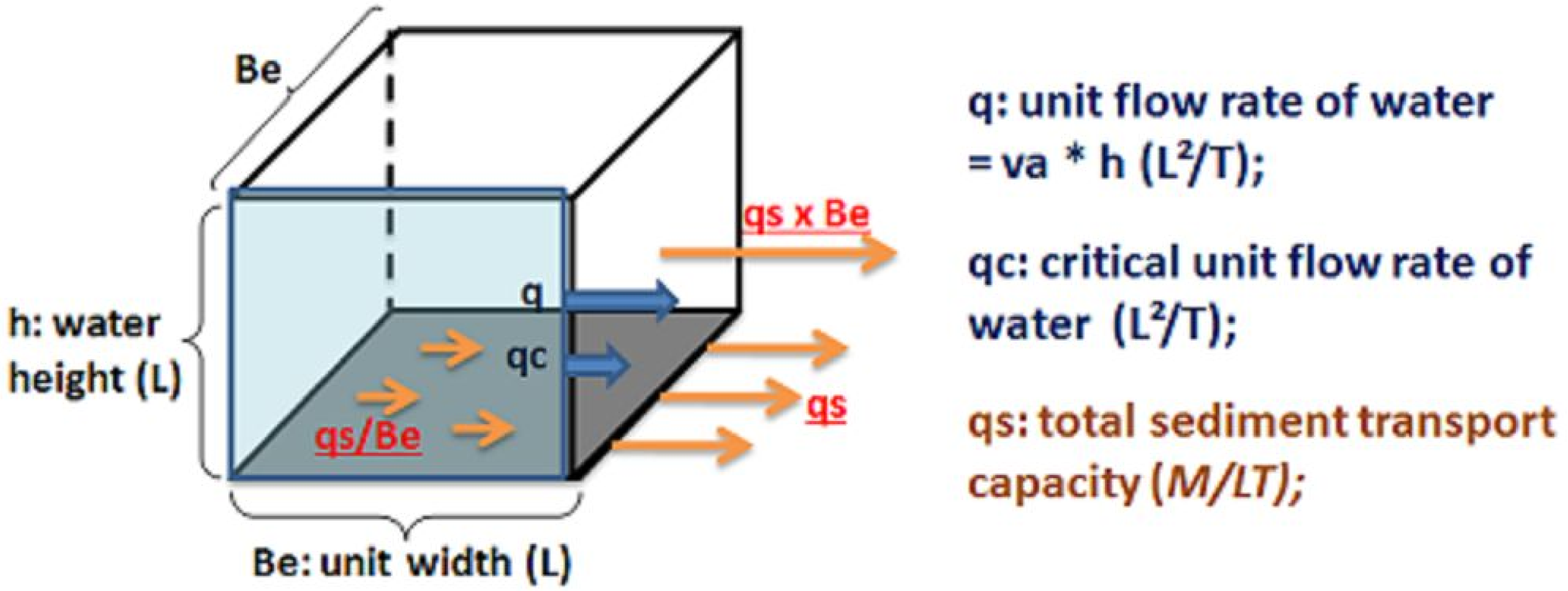

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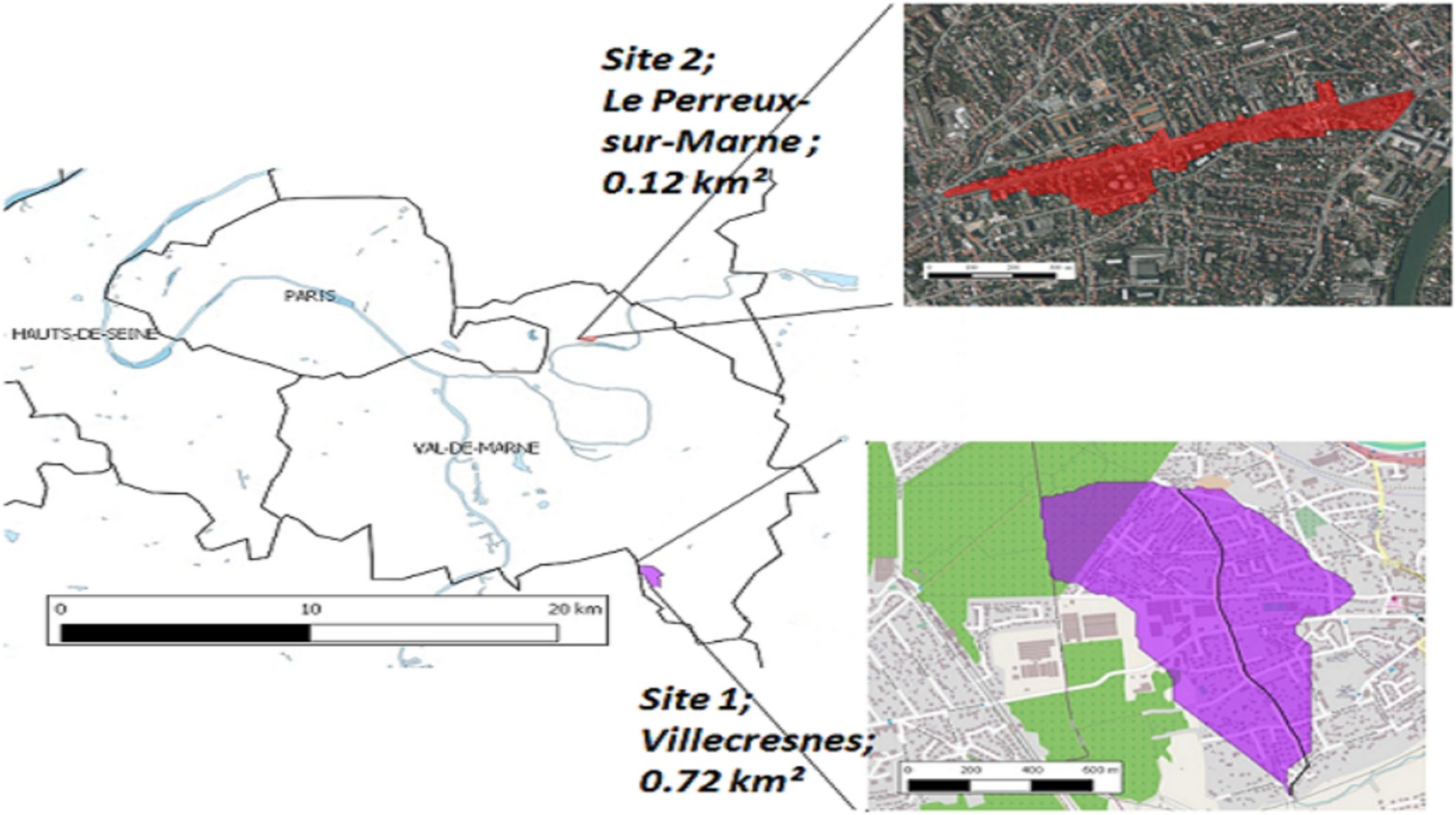

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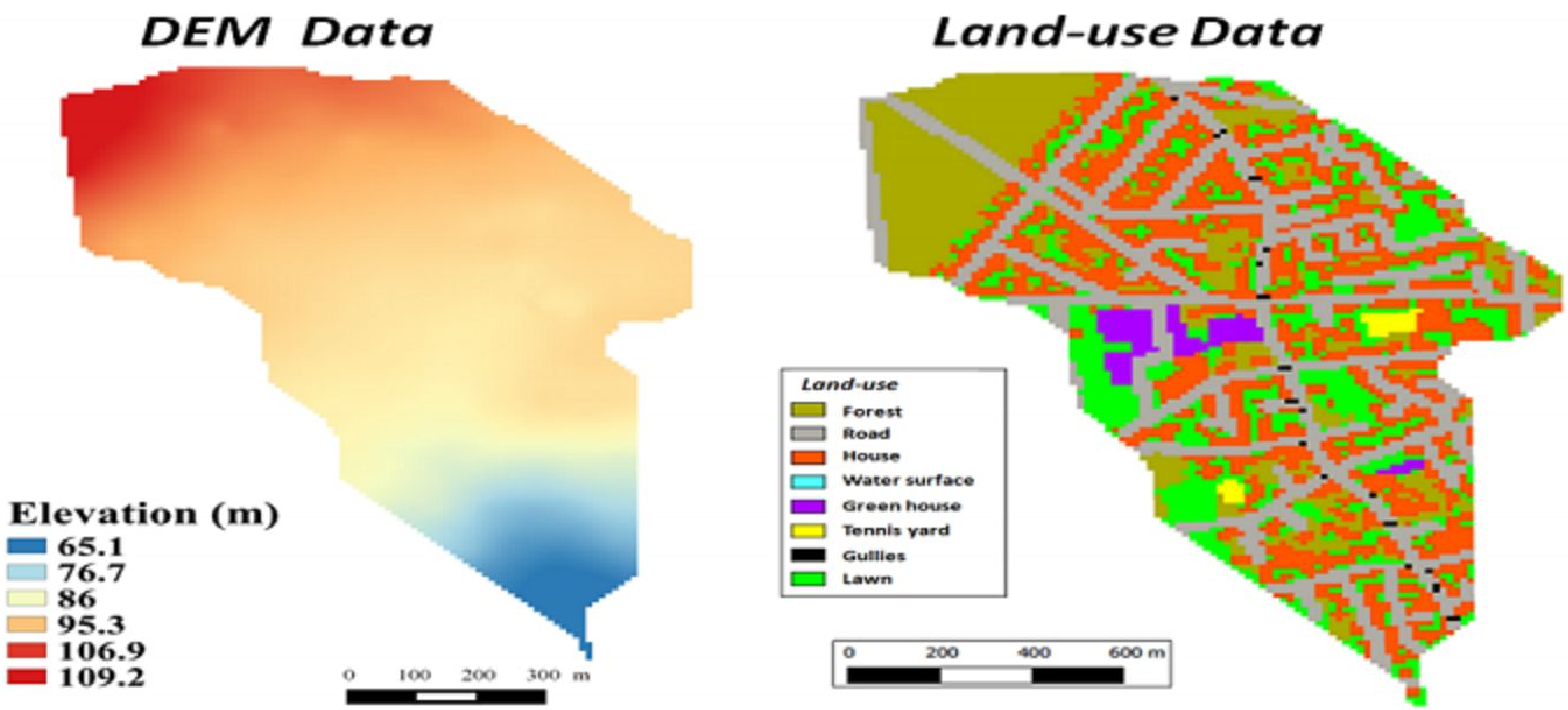

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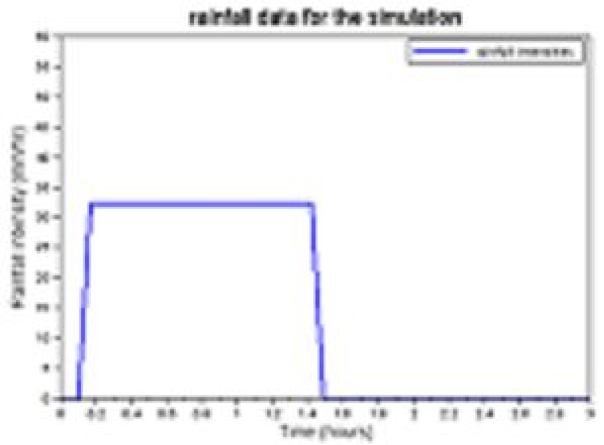

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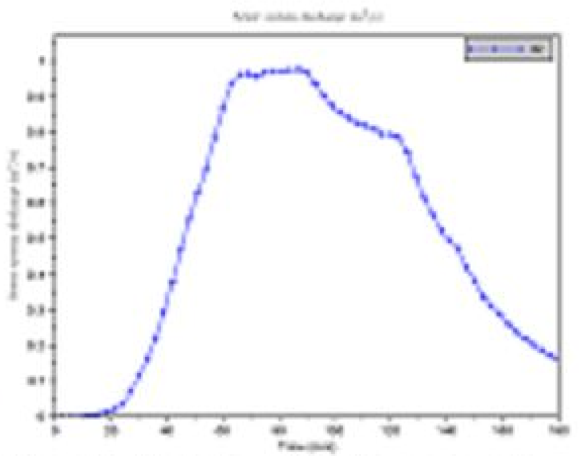

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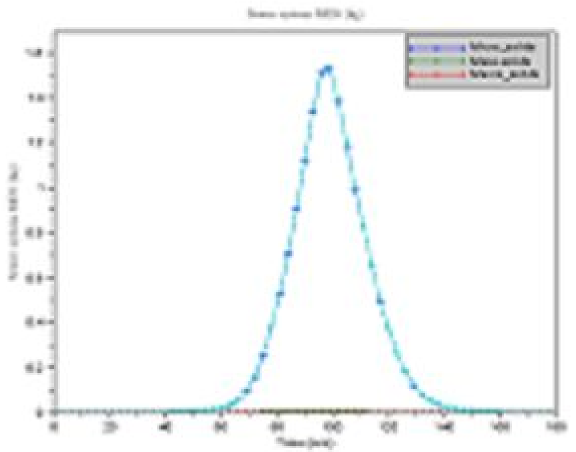
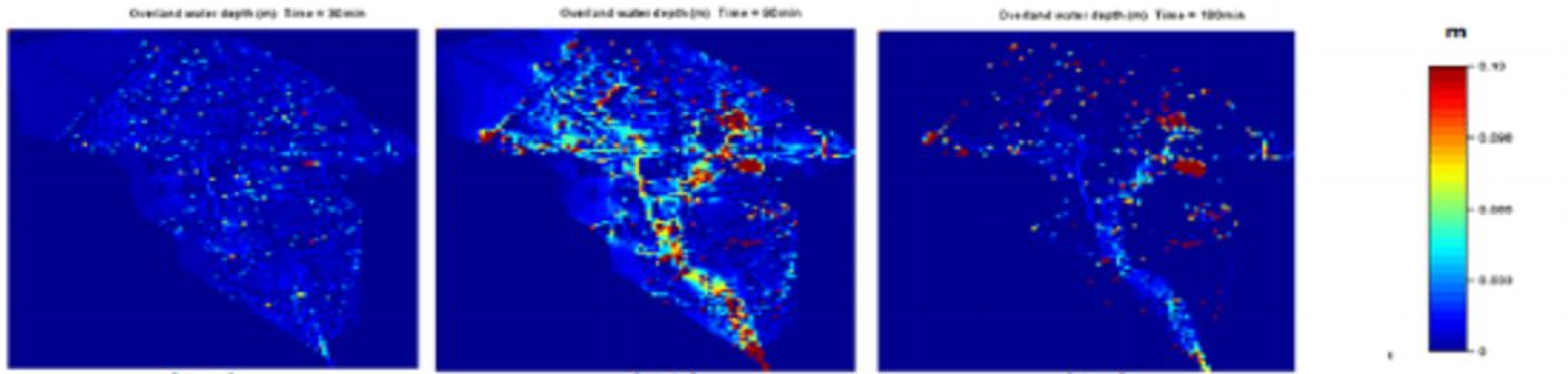


FIG 5.c, Concentration of Total Suspended Solid at sewer outlet



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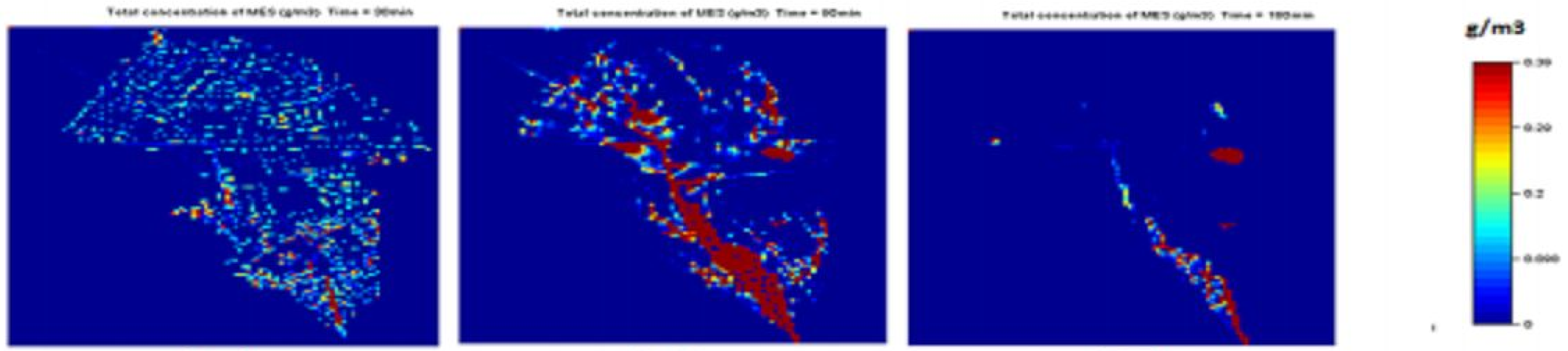

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