EPFL

Design Project – SIE 2025

SUEZ

Modeling the Management of Infiltration and Runoff at Watershed Scale

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Problem Description

This project examines how modeling tools can help assess the impact of natural infrastructure on watershed-scale water management. It focuses on integrating Nature-Based Solutions (NBS) into open-source hydrological models to better understand their effects on runoff, flooding, and infiltration. The case study was done in Sainte-Anne-sur-Gervonde, France, a rural area facing muddy runoff on the street during heavy rain. The steep, mostly agricultural landscape lacks features to slow water flow, leading to erosion and flood risks.

Fig: Muddy Runoff in Sainte-Anne-sur-Gervonde.

Model Comparison

Open-source watershed models were compared based on type, scale, inputs, functions, ease of use, documentation, adaptability to nature-based solutions, etc. The models tested included HEC-RAS 2D, HEC-HMS, Gardenia, WaterSed (using SAGA GIS), Hydra (QGIS Plugin), GRASS GIS, SWAT, CASC2D, iRIC (Nays2D+), and OpenLISEM. The final choice of distributed models that suits the study area's runoff-driven landscape without a main river channel:

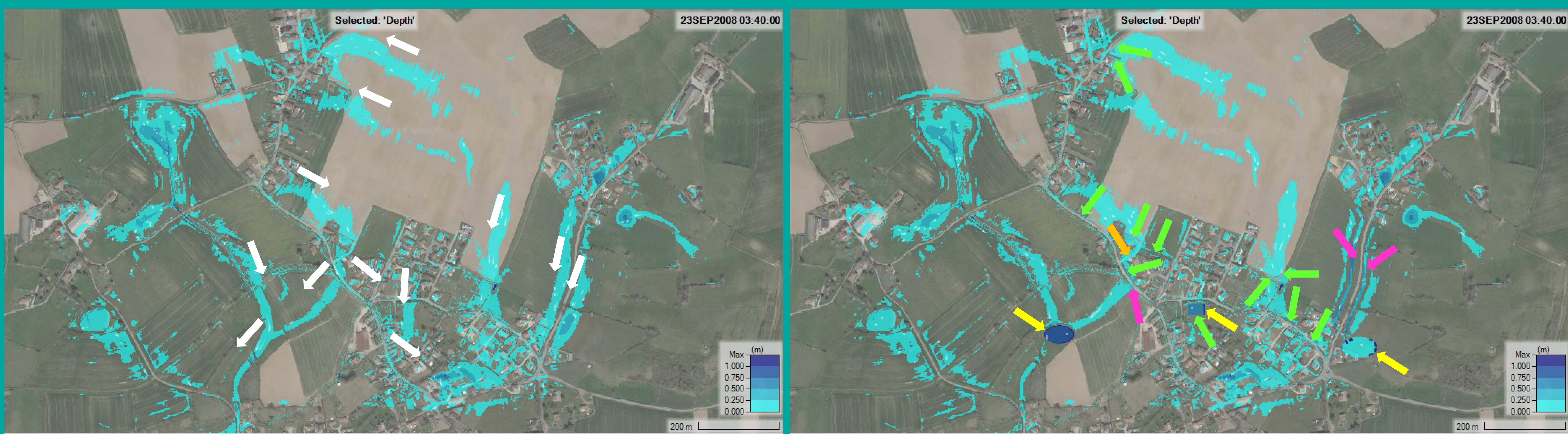
- WaterSed (SAGA GIS)
- GRASS GIS
- HEC-RAS 2D

Nature-Based Solutions

- **Agricultural practices:** Using cover crops to increase soil roughness, reduce runoff, and improve infiltration in the large field.
- **Permeable pavement:** Replacing an impermeable path with perforated slabs with perforated slabs to increase infiltration and reduce runoff.
- **Fascines and hedgerows:** Installing these across runoff paths to stabilize soil and reduce erosion.
- **Stormwater retention ponds:** Multiple small ponds to temporarily store runoff, promote sedimentation, and reduce flooding.
- **Vegetated roadside ditches:** These shallow, planted ditches slow runoff, prevent erosion, and include sediment traps to keep flow paths clear.
- **Runoff redirection:** Redirecting road runoff to reduce pressure on critical areas, paired with retention ponds or slope modifications.

Practical Implementation

WaterSed: Due to the absence of a defined river network, generating required input files was difficult. Using minimal search distances led to unusable or empty outputs and significantly slowed processing. Finally, the model failed to run, preventing practical simulation of NBS in this case.
GRASS GIS: Due to time, this model could not be implemented, and no results were produced.
HEC-RAS 6.5: Modifications included adjusting terrain elevations and surface roughness to simulate practices like soil conservation, fascines, ditches, and ponds.



Flow direction | Retention pond | Vegetated ditches | Fascines/hedges | Permeable pavement

Fig: Simulated water depth across the project area without (left) and with (right) NBS applied, shown in blue shades. White particles indicate flow direction.

Limitations

- Hedges and fascines were represented as impermeable barriers, though in reality they are semi-permeable.
- Retention ponds and ditches were modeled as simple geometric depressions, omitting key processes like infiltration and overflow.
- Soil conservation was modeled by adjusting surface roughness, ignoring seasonal and crop variability.
- Sediment transport was not modeled.
- The analysis focused primarily on water depth, as velocity outputs were relatively uniform.

Conclusion & Future

This project assessed the use of open-source models to simulate nature-based solutions for runoff and erosion control in a small agricultural watershed. HEC-RAS 2D was the only model successfully applied, offering simplified yet useful insights into NBS effectiveness. WaterSed failed due to technical issues, and GRASS GIS was not implemented due to time constraints.
Despite limitations, the results show that NBS can help manage local flooding and erosion. Open-source tools, though imperfect, hold strong potential for supporting sustainable water management at small scales, especially with improved data and model integration.
Future research should focus on refining input datasets, improving model interoperability, and enhancing the representation of key processes such as sediment dynamics and interactions between soil, plant, and atmosphere.