# Event-scale assessment of SuDS for CSO control in an urbanized district in Northern Italy

## Évaluation à l'échelle de l'événement des SuDS pour le contrôle des déversoirs d'orage dans un district urbanisé du nord de l'Italie

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## RÉSUMÉ

La Directive-cadre sur l'eau (2000/60/CE) promeut une approche intégrée de la gestion de l'eau, considérée comme une ressource partagée, et définit des objectifs de qualité écologiques et physico-chimiques. Dans ce contexte, les systèmes de drainage durable (SuDS) constituent des solutions opérationnelles pour limiter le ruissellement urbain, améliorer la qualité de l'eau et réduire le risque d'inondation en milieu urbain. Cette étude porte sur Sesto Ulteriano, une zone industrielle de 290 ha située à San Giuliano Milanese (Ville métropolitaine de Milan), où le réseau de drainage, relié à des canaux artificiels, est sous-dimensionné et soumis à des déversoirs d'orage fréquents (CSOs). Deux modèles hydrologiques et hydrauliques ont été développés avec SWMM5 : l'un représentant les conditions actuelles du réseau et l'autre intégrant des interventions SuDS réparties sur 24 ha. Les modèles ont été exécutés en utilisant une année complète de précipitations enregistrées par une station proche, avec une évaluation des sorties à l'échelle de l'événement. Pour chaque événement pluvieux, le volume total déversé, le pic de débit maximal et le nombre d'activations de CSO ont été extraits et comparés entre les deux scénarios afin d'évaluer la performance des SuDS. Les SuDS ont amélioré le comportement du système, réduisant respectivement les volumes déversés et les débits de pointe de 31 % et 42 %, et diminuant les activations de CSO de 13 %.

## ABSTRACT

The Water Framework Directive (2000/60/EC) promotes an integrated approach to water management, treating water as a shared resource and defining both ecological and physicochemical quality targets. In this context, Sustainable Drainage Systems (SuDS) offer practical solutions to limit urban stormwater runoff, improve water quality and reduce urban flood risk. This study focuses on Sesto Ulteriano, a 290-ha industrial area in San Giuliano Milanese (Metropolitan City of Milan), where the drainage system, connected to artificial channels, is undersized and subject to frequent CSOs. Two hydrologic-hydraulic models were developed in SWMM5: one representing current conditions of the drainage network and one including SuDS interventions distributed across 24 ha. The models were run using a full year of rainfall recorded at a nearby gauge, with outputs evaluated at event scale. For each precipitation event, total overflow volume, maximum peak discharge and the number of CSO activations were extracted and compared between the two scenarios to evaluate SuDS performance. SuDS improved system behaviour, reducing overflow volumes and peaks by 31% and 42%, respectively, and lowering CSO activations by 13%.

## KEYWORDS

CSO mitigation, Event-scale SuDS performance, Water quality, Sustainable Drainage Systems, SWMM5 modeling

# 1. INTRODUCTION

Urban drainage systems are increasingly stressed by heavier rainfall and widespread surface sealing, which often push networks beyond capacity and trigger combined sewer overflows (CSOs) (Zhou, 2014; Butler et al., 2018; Reyes-Silva et al., 2020). These structures were first designed as safety outlets, yet today they act as one of the main pathways of pollution to receiving waters, a condition worsened by ageing infrastructure and changing precipitation patterns (Dittmer et al., 2020). In recent years, policy and research have leaned toward integrated and nature-based approaches to stormwater management (European Water Framework Directive, 2000/60/EC). Within this shift, Sustainable Drainage Systems (SuDS) have gained attention for their capacity to promote infiltration and temporary storage (Fletcher et al., 2014), though their performance can vary considerably with catchment layout, climate and scale of implementation (Cavadini et al., 2024; Jazayeri Moghanlo and Raimondi, 2025). Evidence under moderate, recurrent rainfall is still relatively scarce, especially for industrial and urban areas in Southern Europe (Gimenez-Maranges et al., 2020), highlighting the need for further evaluation under ordinary operating conditions. This study examines SuDS as a CSO-control measure in Sesto Ulteriano (San Giuliano Milanese, Metropolitan City of Milan), where an undersized combined network hydraulically connected to surrounding artificial channels experiences frequent overflows during wet-weather conditions (D'Ambrosio et al., 2022).

# 2. MATERIALS AND METHODS

## 1.1 The case study and the climate data

Sesto Ulteriano (San Giuliano Milanese, Metropolitan City of Milan) extends for approximately 1100 ha and hosts around 3500 inhabitants. The study area covers about 290 ha within the most urbanized sector of the district, predominantly industrial and characterized by an high level of imperviousness (Figure 1). The area is served by a combined sewer network conveying both wastewater and stormwater to the San Giuliano Milanese Ovest treatment plant. When system capacity is exceeded, 27 CSOs discharge into a network of artificial channels connected to the Lambro River, a configuration that intensifies hydraulic stress and quality of receiving-water bodies.

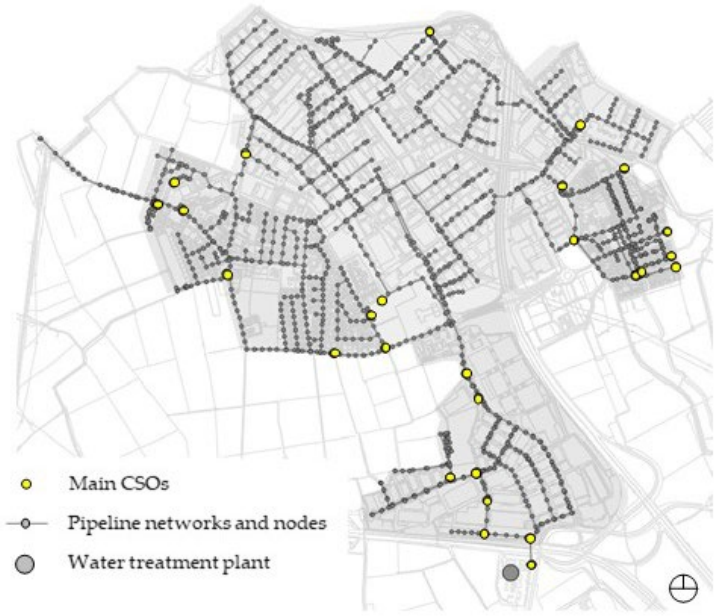


Figure 1. Case study drainage network and localization of main CSOs

In total, 86 independent rainfall events were identified during the year, separated by a minimum inter-event period of 9 hours and with total precipitation greater than 1 mm. The cumulative rainfall associated with these events was 1322.60 mm. The largest cumulative event (112 mm) occurred in November, while the longest event (89 hours) was observed in January. The maximum hourly intensity reached 32.40 mm/h and the average hourly intensity was approximately 5 mm/h. Summary statistics are reported in Table 1.

Table 1. Precipitation events dataset characteristics

| | depth mm | duration h | max intensity/1h mm/h |
|---|---|---|---|
| Average | 15.4 | 14.9 | 5.0 |
| Maximum | 112.2 | 89.8 | 32.4 |
| Minimum | 1.0 | 0.5 | 0.2 |
| Variance | 371.9 | 240.3 | 46.5 |

## 1.2 The SWMM5 drainage network models

Two SWMM5 hydraulic-hydrological models of the Sesto Ulteriano drainage system, previously developed for research purposes, were here adopted (D'Ambrosio and Longobardi, 2023). The Business-as-Usual (BAU) scenario reproduces the current condition of the combined sewer network. It reflects the conventional stormwater management approach and it is used as benchmark. The Green Drainage Scenario (GDS) represents an improvement of the BAU configuration through the retrofitting of selected impervious surfaces with SuDS. Implemented measures include infiltration trenches, rain gardens and permeable parking areas, covering about the 8% of the study area (D'Ambrosio et al., 2022; D'Ambrosio and Longobardi, 2023).

## 1.3 Model simulations and SuDS performance assessment

Two continuous simulations were carried out in SWMM5 using as rainfall input the 10-minute time-step series recorded at the Lodi gauge in 2014, which contains the full set of 86 independent rainfall events described above. Both configurations, BAU and GDS, were run under the same climatic forcing. Model outputs were evaluated by analysing inflow rates (L $s^{-1}$) at the 27 CSOs. For each storm event, the inflow time series were extracted to derive: I) total overflow volume from all CSOs ($V_{TOT}$); II) maximum peak overflow among the 27 CSOs ($Q_{MTOT}$); III) number of CSOs activated during the event ($N_{CSOs}$). Based on the synthetic metrics obtained for both configurations (BAU and GDS), a comparative evaluation was carried out using the BAU scenario as benchmark. For each rainfall event, SuDS effectiveness was evaluated in terms of reduced overflow volumes ($RV_{TOT}$), lowered peak overflow ($RQ_{MTOT}$) and decreased CSO activation at catchment scale ($RN_{CSOs}$). For each indicator, an annual mean, variance and extreme values were computed to outline the general behaviour of SuDS over the reference year, thus supporting the interpretation of the results.

# 3. RESULTS AND DISCUSSIONS

Table 2 reports the main statistics of the three performance indicators used to assess SuDS. The average values provide a first general picture: total overflow volumes are reduced by about 31%, maximum overflow peaks by 42% and the number of activated CSOs by roughly 13%. The maximum values show that, for several events, SuDS can completely eliminate overflow volumes and peaks, and reduce CSO activations by up to 92%. The minimum values require some additional clarification. The cases showing 0% reduction do not correspond to intense storms but to very mild rainfall events in which CSOs are not triggered even in the BAU configuration. These are events that the existing network is already able to manage without additional control measures; in such conditions, SuDS cannot produce a measurable improvement. Including these events in the dataset therefore tends to lower the overall averages, providing a conservative estimate of SuDS effectiveness. The high variance observed for $RV_{TOT}$ and $RQ_{MTOT}$ reflects the strong variability across the different storm events, driven by rainfall heterogeneity, whereas the much lower variance of $RN_{CSOs}$ indicates a more consistent reduction in CSO activations. This behaviour likely reflects the tendency of CSOs to activate, even marginally, during most events, which limits the spread in activation frequency and leads to lower variability compared to volume- and peak-based indicators. Overall, the results indicate that SuDS provide substantial benefits under most ordinary rainfall conditions. A more detailed classification of rainfall events could help refine the relationship between event characteristics and the system response in the presence of SuDS.

Table 2. SuDS performance indexes

| $RV_{TOT}$ | $RQ_{MTOT}$ | $RN_{CSOs}$ |
|---|---|---|

| | % | % | % |
|---|---|---|---|
| Average | 31 | 42 | 13 |
| Maximum | 100 | 100 | 92 |
| Minimum | 0 | 0 | 0 |
| Variance | 1053 | 1170 | 429 |

## 4. CONCLUSIONS

This preliminary analysis shows that, over the reference year, SuDS provided a consistent reduction of overflow volumes, peak and CSO activations, confirming their potential as an effective mitigation measure within the study area. Although the evaluation focused on quantitative indicators, the observed reductions suggest possible benefits that extend beyond hydraulic performance, potentially contributing to improved water quality in the receiving channels. Further researches will be required to clarify the role played by ordinary rainfall events in shaping overall SuDS performance and to assess how alternative SuDS layouts may influence their effectiveness under ordinary operating conditions.

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