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Swiss Federal Institute of Aquatic
Science and Technology

Not all SuDS are created equal:

Impact of different approaches on combined sewer overflows

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Co-UDlabs online practice workshop on urban drainage
04 November 2021

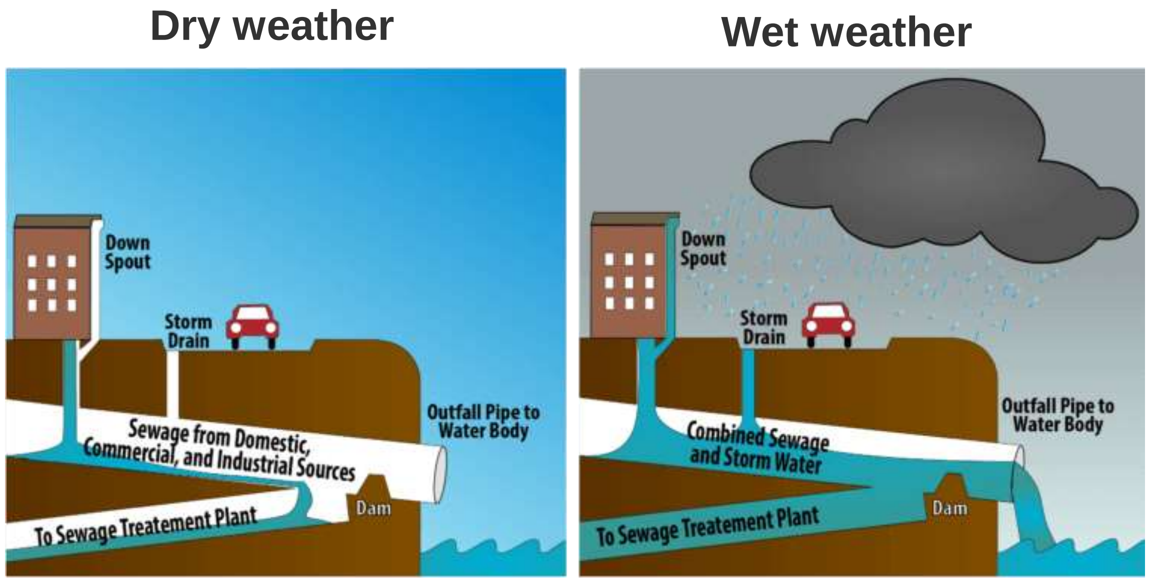
Combined sewer overflows cause significant impacts on receiving waters

Traditional approach: to expand drainage systems

- Extremely expensive
- Unsustainable
- Impractical in dense urban areas

Other solutions are needed!

- Sustainable
- Multi-functional
- Decentralised
- …



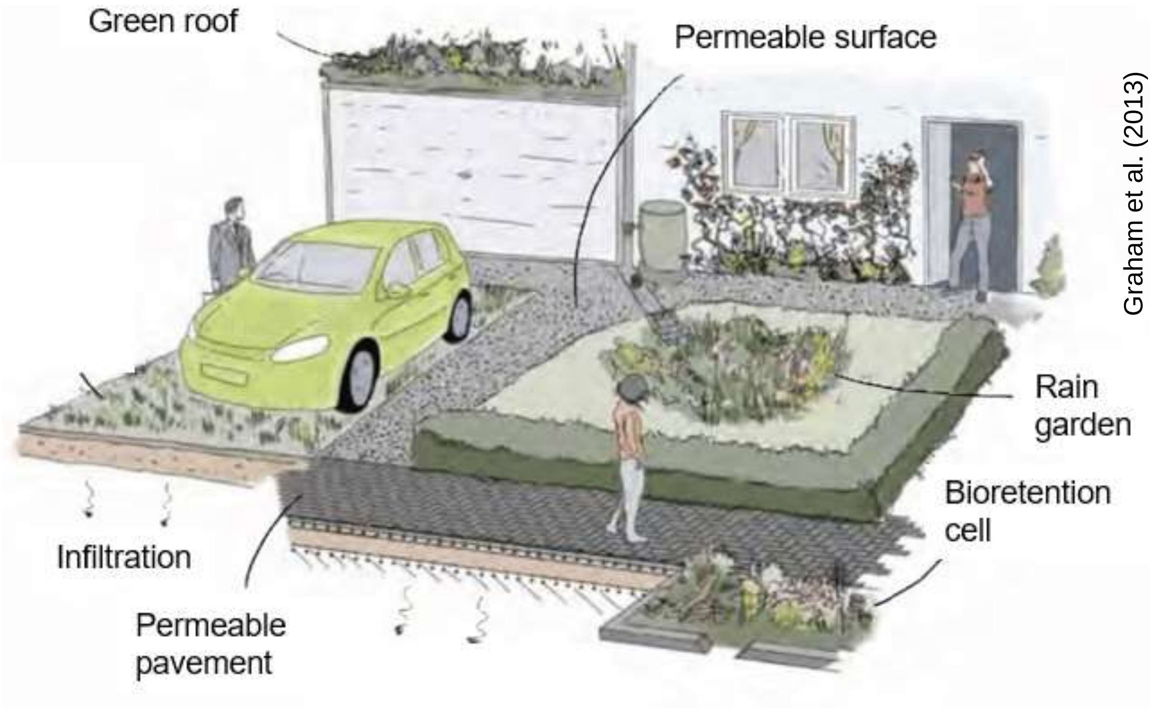
https://sewerequipment.com/sanitary-vs-combined-sewer-systems/

Are Sustainable Urban Drainage Systems (SuDS) an option to reduce CSOs?

SuDS help attenuating runoff volume, increase time of concentration, …

SuDS may reduce CSO frequency and volume!

SuDS may reduce the pollution of receiving water bodies ☺



Graham et al. (2013)

Evaluating the effects of SuDS in reducing CSOs

A. Identifying the most suitable locations to install SuDS

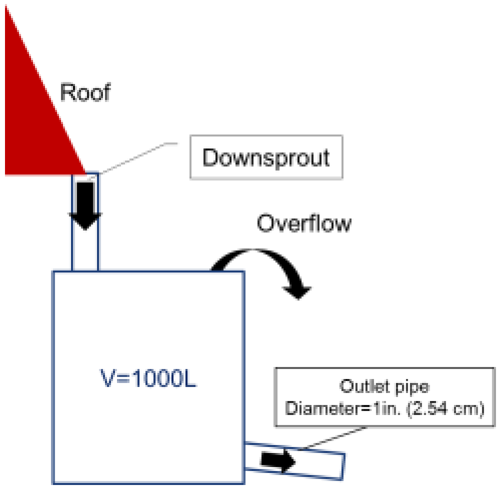
B. Assessing the performance of SuDS for different storm events typical of Swiss rainfall patterns

C. Comparing the implementation cost and efficiency of SuDS with the cost of grey infrastructure (underground reservoirs)

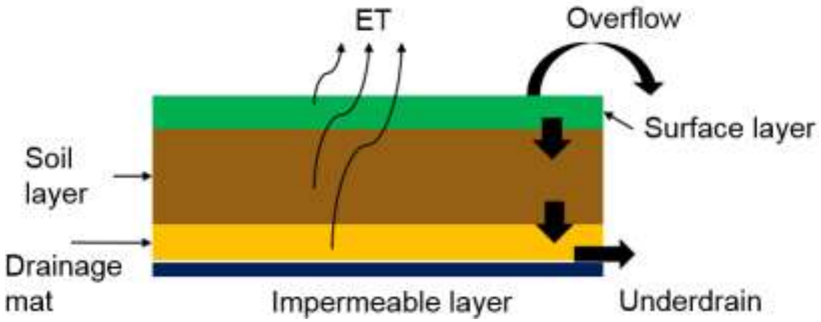
In this study we considered four types of SuDS…

- Rain barrels
- Green roofs
- Permeable pavements
- Bioretention cells

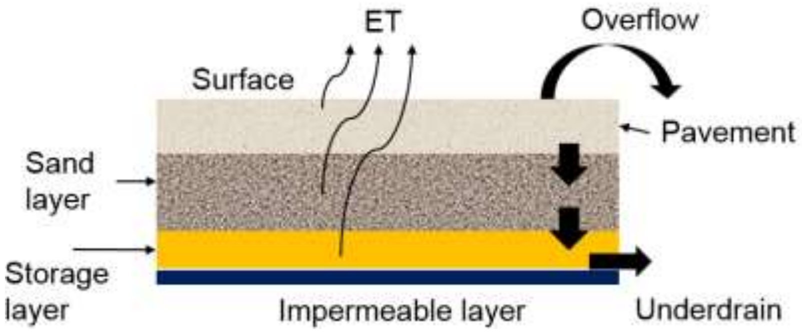
Rain barrel



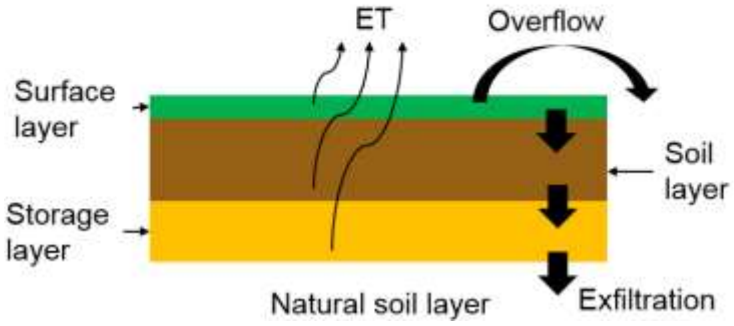
Green roof



Permeable pavement



Bioretention cell



… with different working mechanisms

SuDS type	Dominant mechanism(s)	Surface	Pavement	Soil	Storage	Drain
Bio-retention cell	Evaporation, Infiltration	✓		✓	✓	
Permeable pavement	Infiltration, Storage		✓		✓	✓
Green roof	Surface	✓		✓		
Rain Barrel	Storage				✓	✓

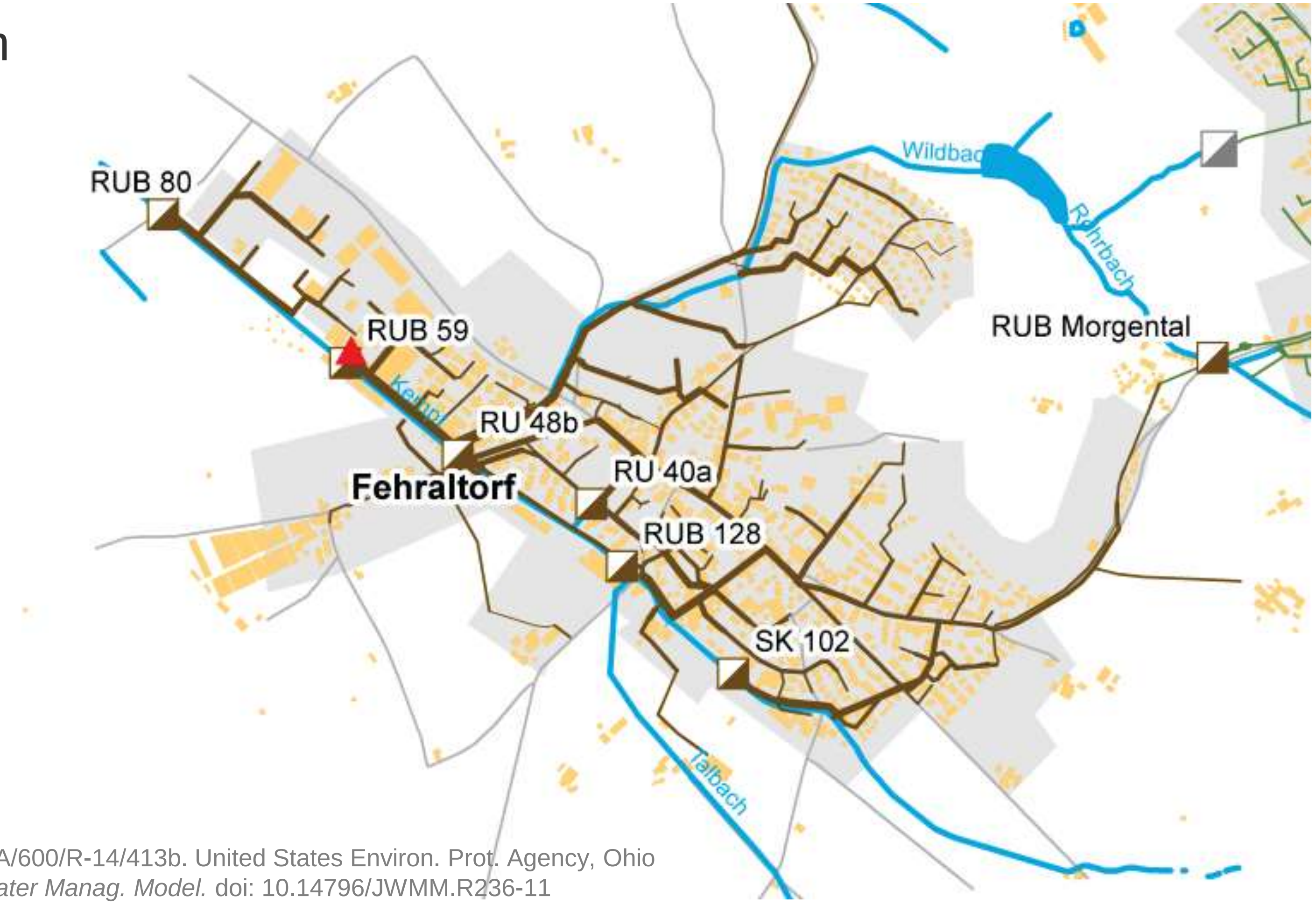
The case study: Fehraltorf (Switzerland)

- 150 ha connected to the drainage system
- 6,500 inhabitants

- Mixed combined and separate system
- **7 CSO structures**

- 35 year long rainfall time series
(1981 – 2016)

- **Modelling**: USA EPA's SWMM 5.1
(Rossman, 2010, 2015)



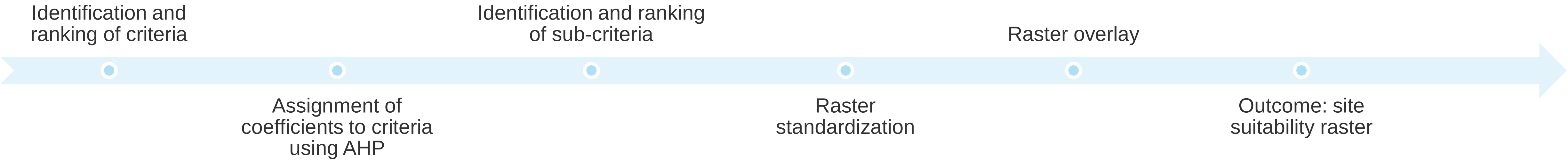
https://www.eawag.ch/en/department/sww/main-focus/urbanhydrologisches-feldlabor/

Rossman, L.A. (2015). *Storm Water Management Model User's Manual Version 5.1*. EPA/600/R-14/413b. United States Environ. Prot. Agency, Ohio
Rossman, L.A. (2010). Modeling low impact development alternatives with SWMM. *J. Water Manag. Model.* doi: 10.14796/JWMM.R236-11

A.

Identifying the most suitable locations to install SuDS

Analytical Hierarchy Process (AHP)



Identification and ranking of criteria

Assignment of coefficients to criteria using AHP

Identification and ranking of sub-criteria

Raster standardization

Raster overlay

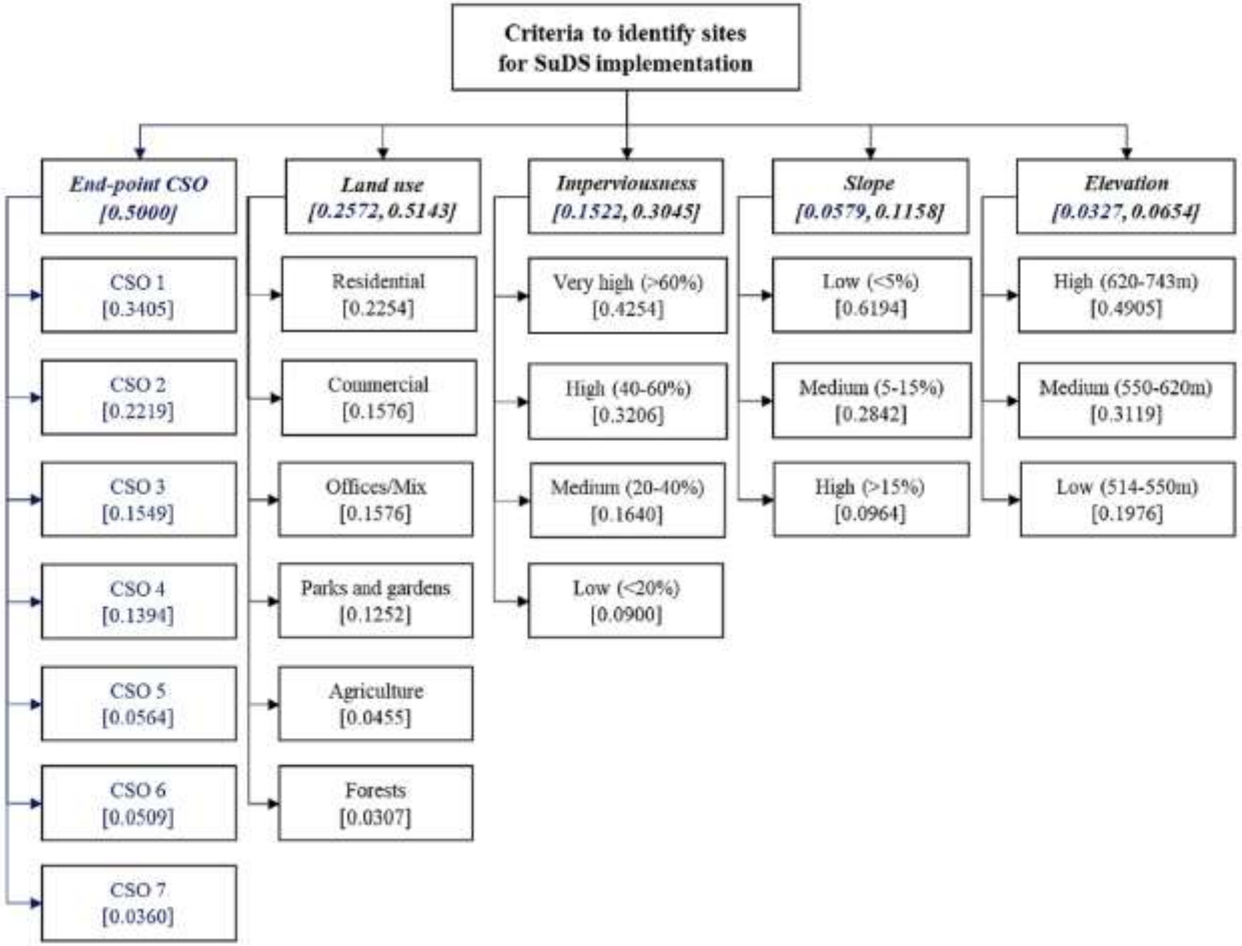
Outcome: site suitability raster

Analytical Hierarchy Process (AHP)

Identification and ranking of criteria

Assignmen
coefficients to
using AH

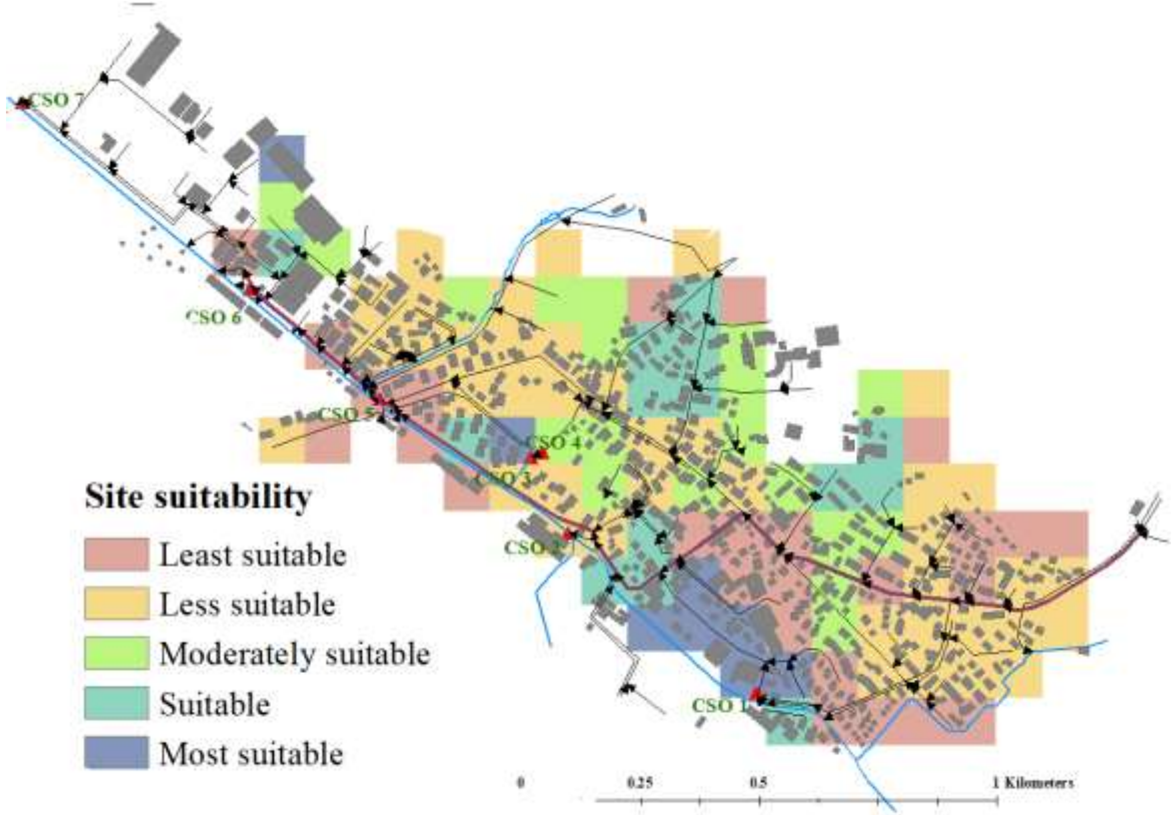
Outcome: site suitability raster



Some locations are better suited to install SuDS than others

(this result does not include the location of the CSO structures criterion)

14% of the area identified to be either “Most suitable” or “Suitable” for SuDS implementation



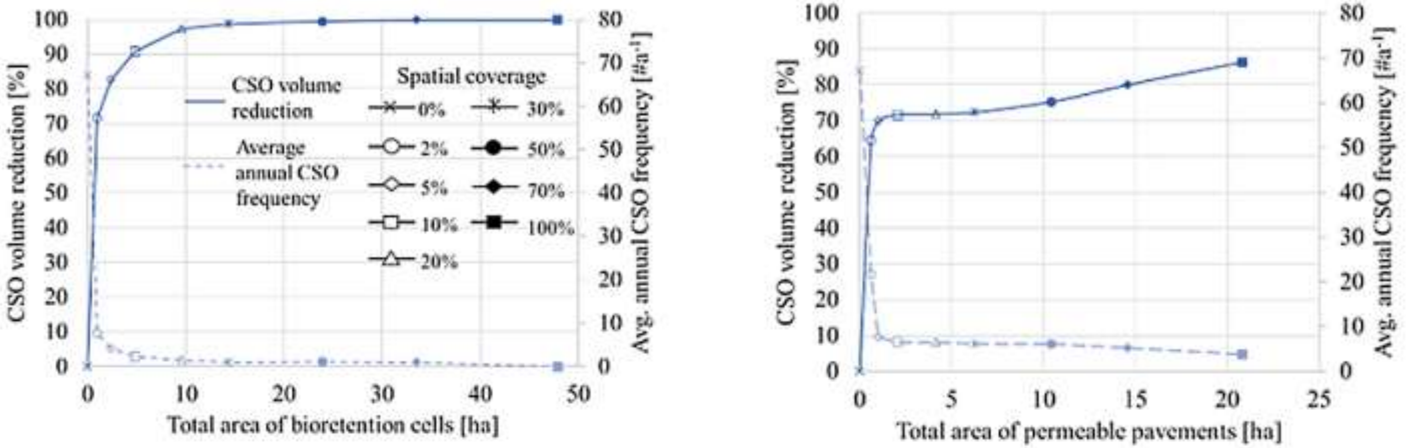
B.

Assessing the CSO reduction performance of SuDS for different storm events typical of Swiss rainfall patterns

Some details that can explain part of these results

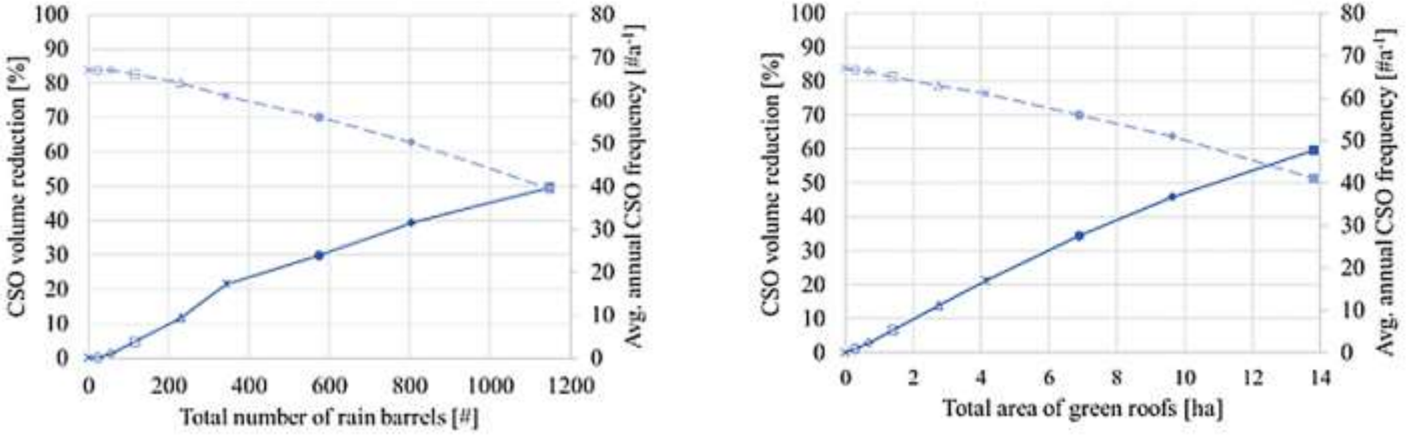
SuDS types	**Coverage [%]**												
	3	**5**	**7**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Bioretention cell [ha]	1.4	2.34	3.4	4.8	9.6	14.4	19.2	23.9	28.7	33.5	38.3	43.1	**47.9**
Green roof [ha]	0.4	0.7	1.0	1.4	2.8	4.1	5.5	6.9	8.3	9.6	11.0	12.4	**13.8**
Rain barrels [m^3]	34	57	80	115	230	344	459	574	689	804	918	1033	1148
Permeable pavement [ha]	0.6	1.0	1.5	2.1	4.2	6.3	8.4	10.4	12.5	14.6	16.7	18.7	**20.8**

SuDS performance are different!



(a) Bioretention cell

(b) Permeable pavement

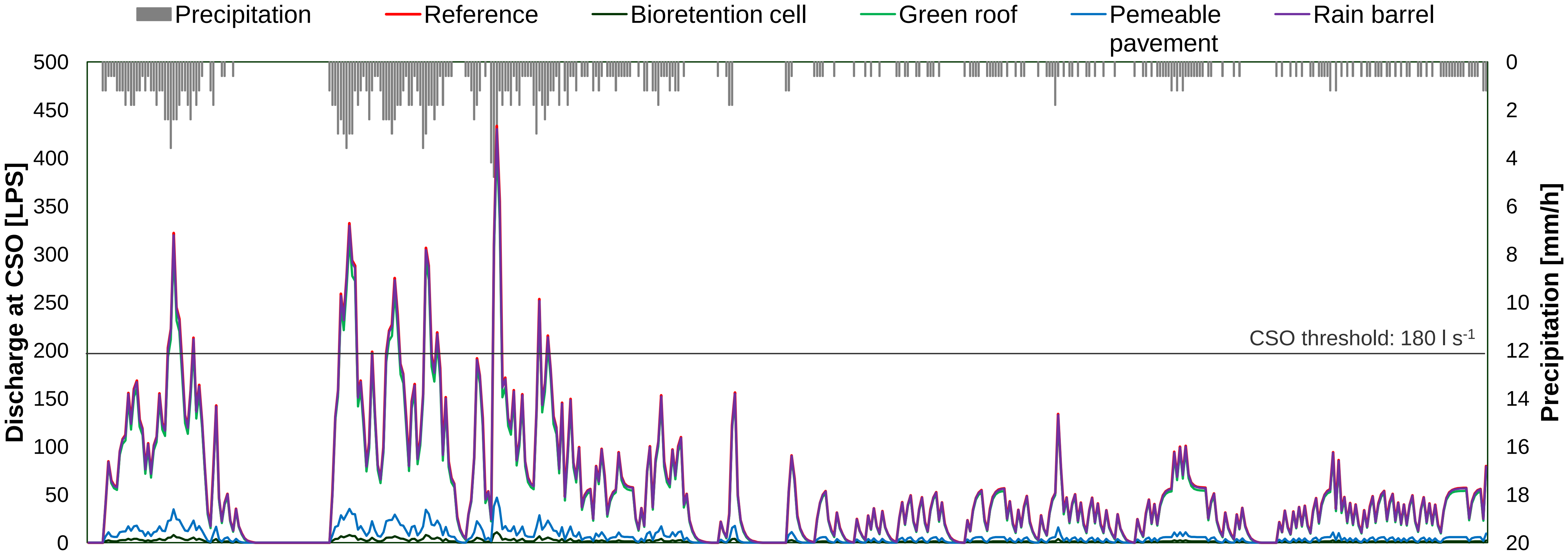


(c) Rain barrel

(d) Green roof

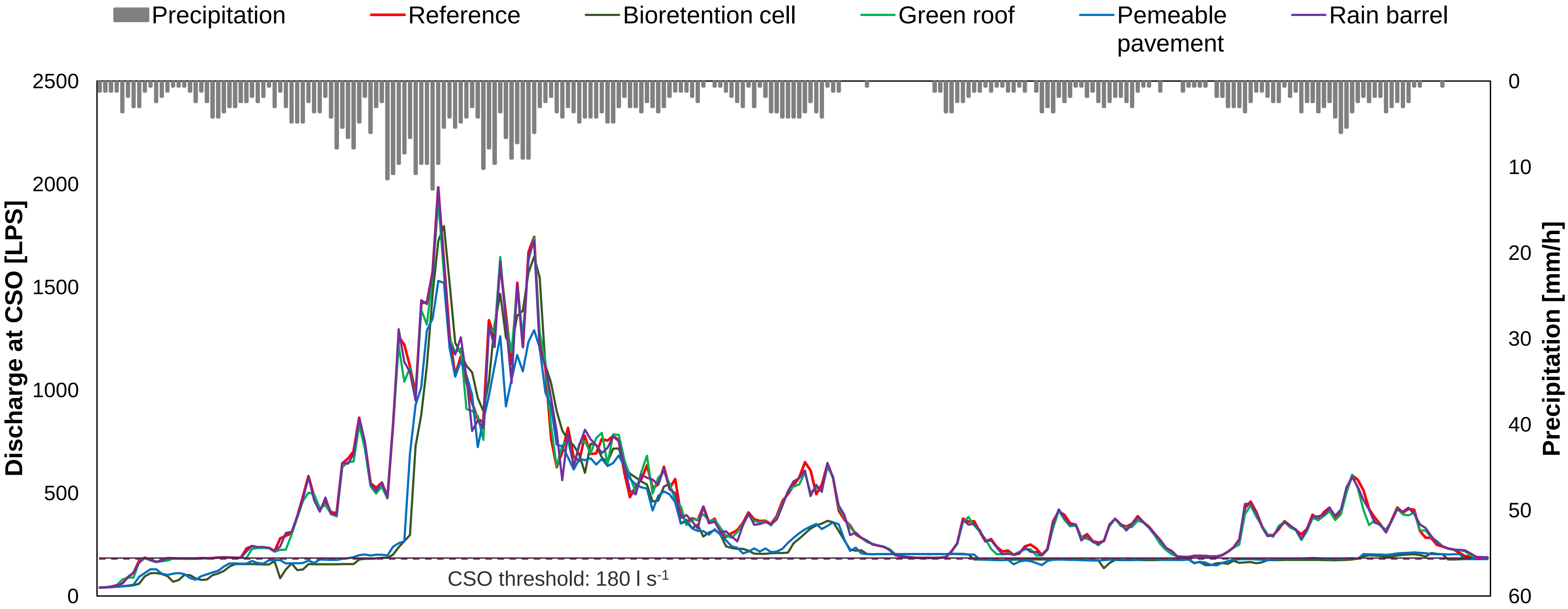
Different SuDS have different impact on CSOs...

Longest rainfall event (41.1 mm, 5% SuDS coverage)

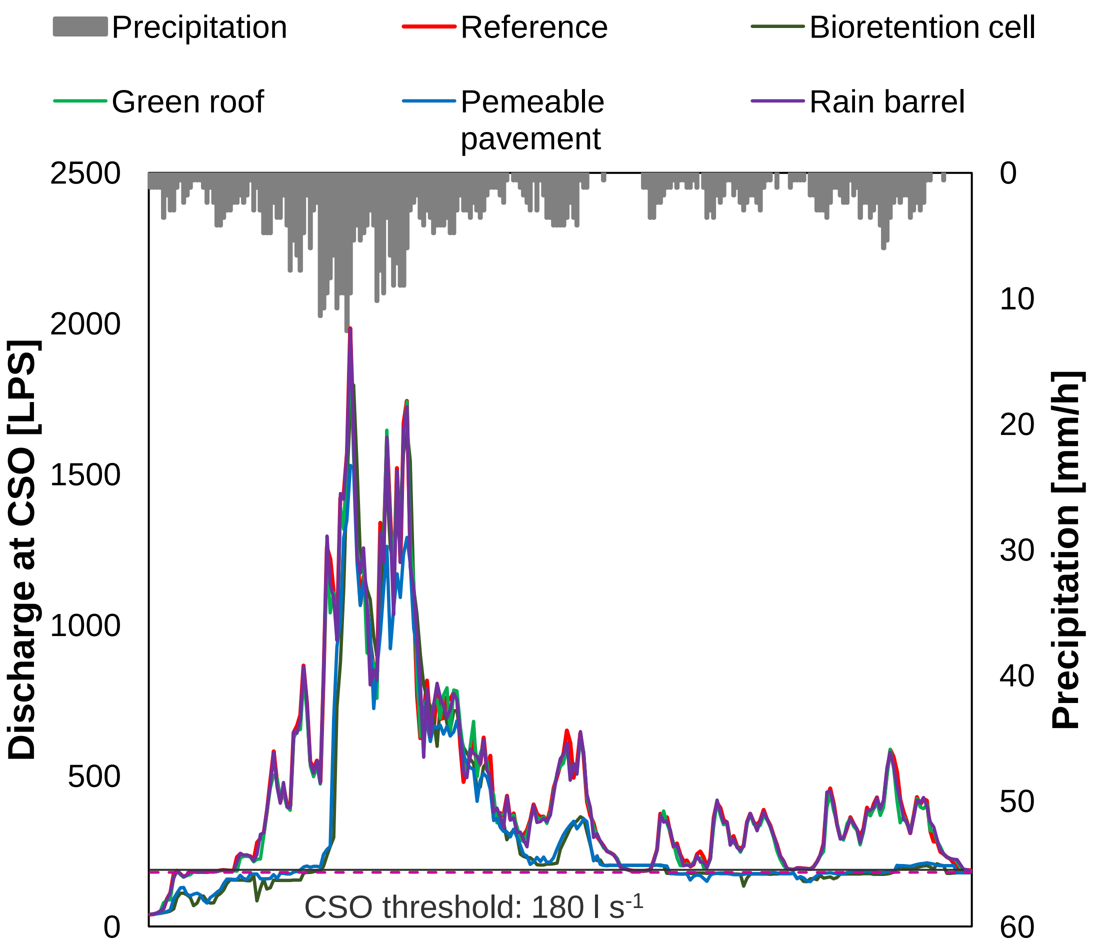


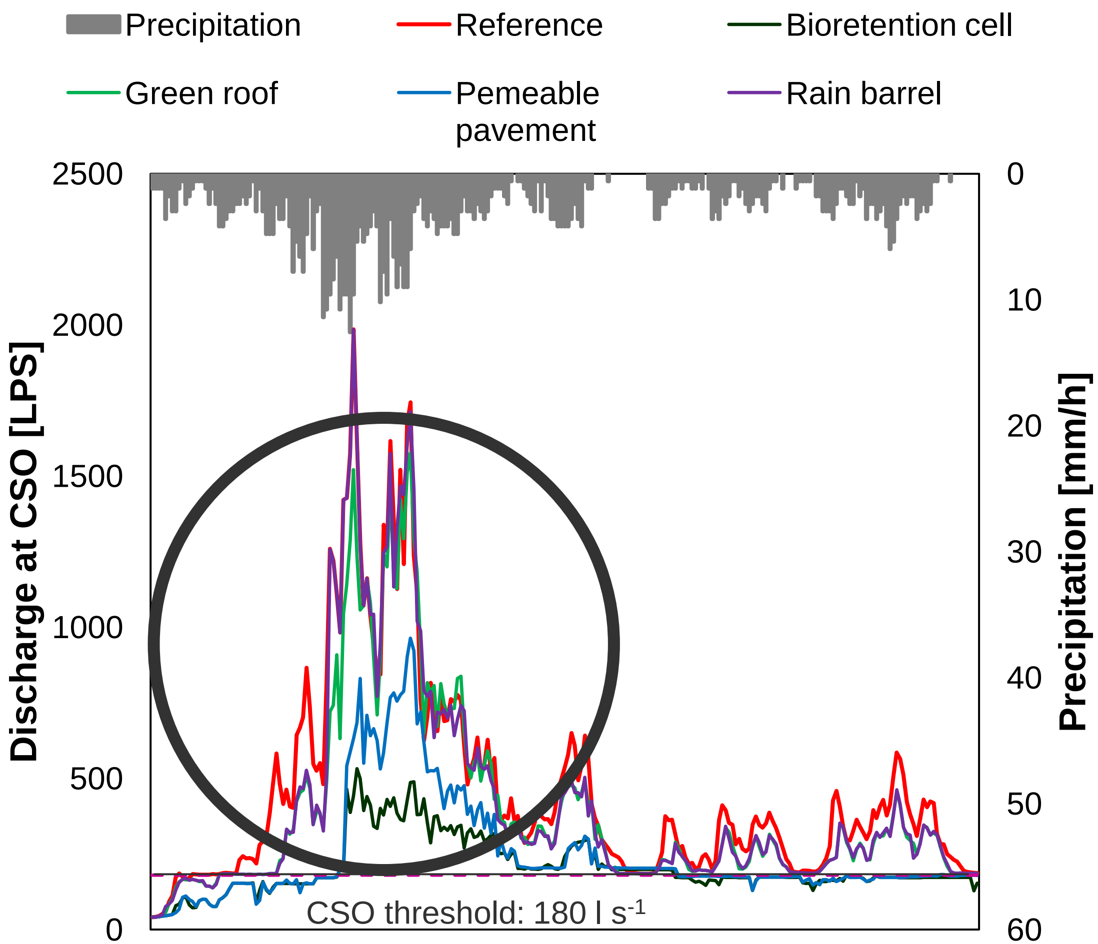
... no matter the type of rainfall event...

Highest intensity rainfall event (107.9 mm, 5% SuDS coverage)



... and as expected, the larger coverage the larger the reduction...


5% SuDS coverage

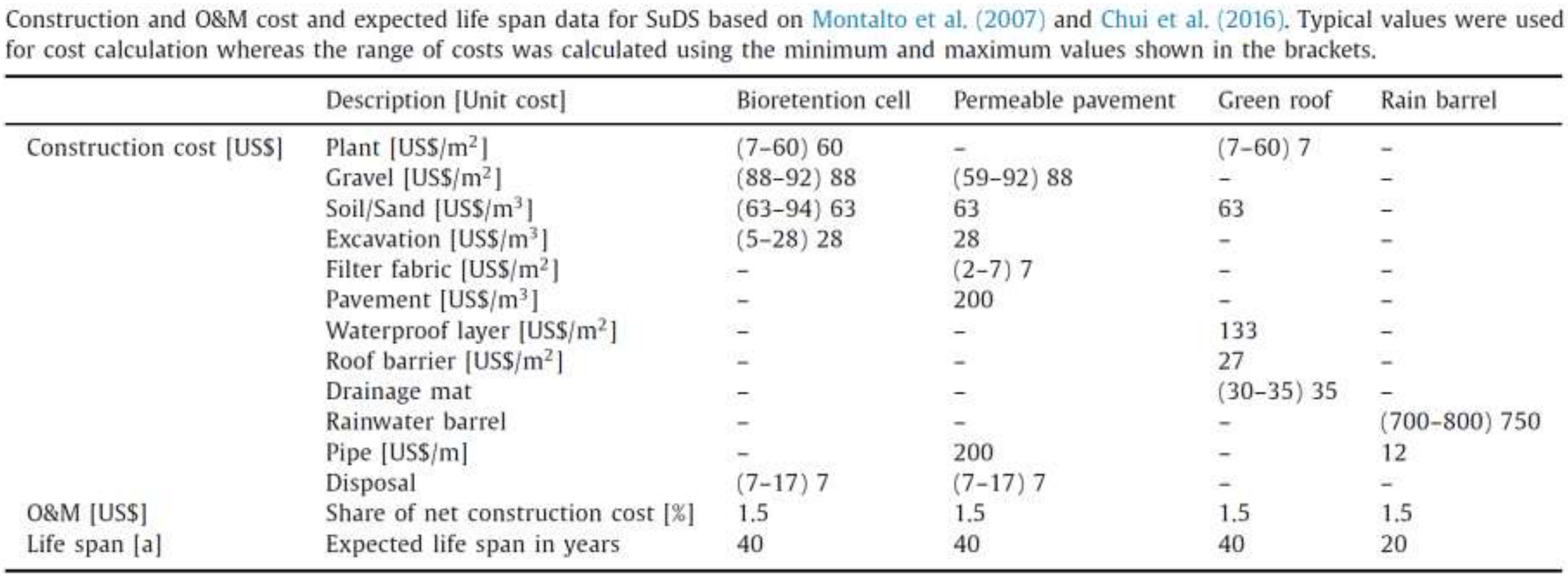

100% SuDS coverage

C.

Comparing the implementation cost and efficiency of SuDS and grey infrastructure (underground reservoirs)

Economic analysis to determine cost-effectiveness

- Planning horizon: 40 years
- Life cycle cost (construction cost, O&M, disposal)
- Comparisons using NPV (all costs for the year 2019, discount rate: 2%, land cost not included)

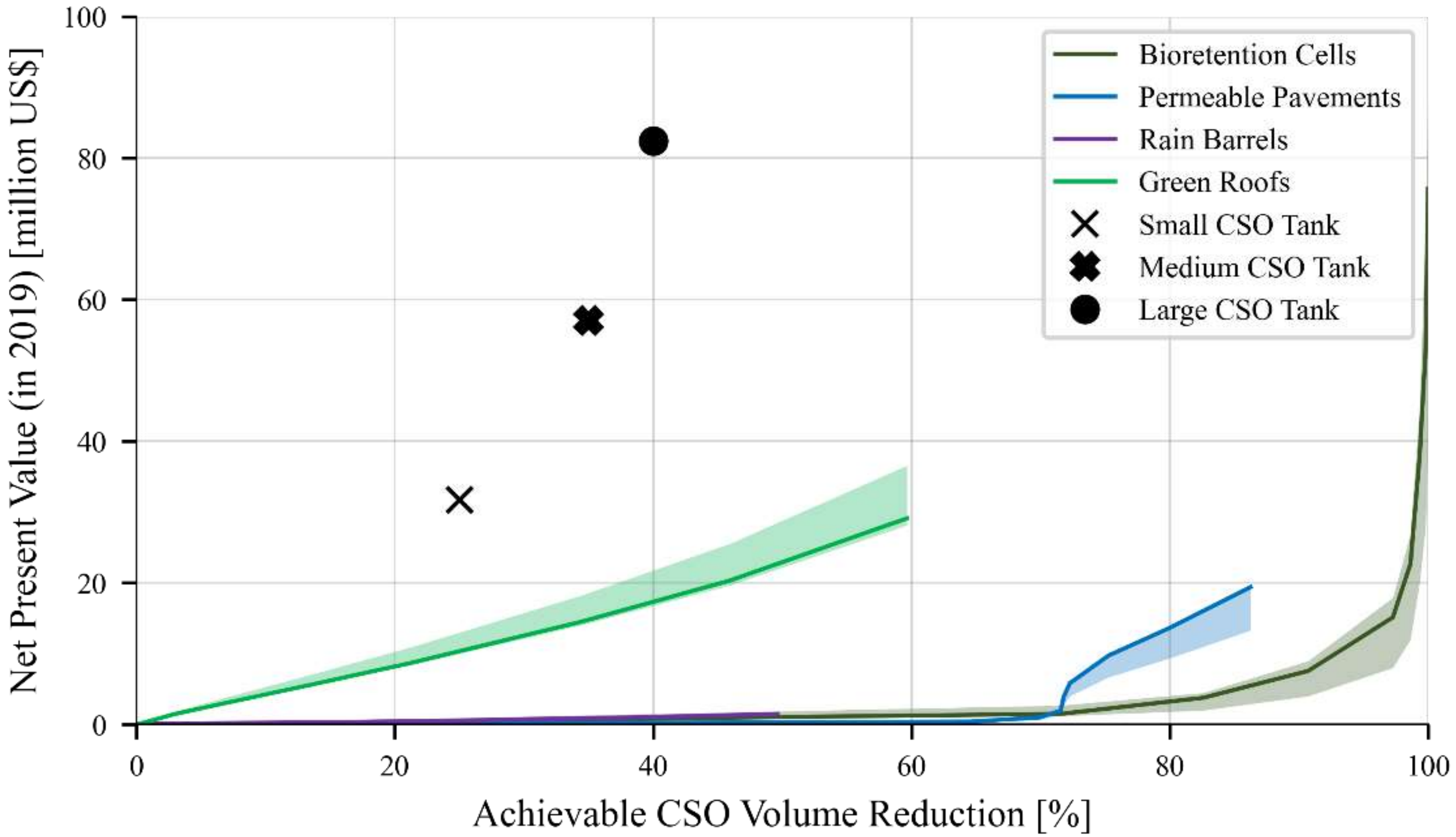


Construction and O&M cost and expected life span data for SuDS based on Montalto et al. (2007) and Chui et al. (2016). Typical values were used for cost calculation whereas the range of costs was calculated using the minimum and maximum values shown in the brackets.

	Description [Unit cost]	Bioretention cell	Permeable pavement	Green roof	Rain barrel
Construction cost [US$]	Plant [US$/$m^2$]	(7–60) 60	–	(7–60) 7	–
	Gravel [US$/$m^2$]	(88–92) 88	(59–92) 88	–	–
	Soil/Sand [US$/$m^3$]	(63–94) 63	63	63	–
	Excavation [US$/$m^3$]	(5–28) 28	28	–	–
	Filter fabric [US$/$m^2$]	–	(2–7) 7	–	–
	Pavement [US$/$m^3$]	–	200	–	–
	Waterproof layer [US$/$m^2$]	–	–	133	–
	Roof barrier [US$/$m^2$]	–	–	27	–
	Drainage mat	–	–	(30–35) 35	–
	Rainwater barrel	–	–	–	(700–800) 750
	Pipe [US$/m]	–	200	–	12
	Disposal	(7–17) 7	(7–17) 7	–	–
O&M [US$]	Share of net construction cost [%]	1.5	1.5	1.5	1.5
Life span [a]	Expected life span in years	40	40	40	20

Again, different SuDS showed different results

... and SuDS showed to be interesting solutions compared to grey infrastructure!



Take home messages

- **Bio-retention cells** showed highest CSO volume reduction (approx. 14%)
- Rain barrels and green roofs showed little impact on reducing CSOs (rain barrels have a very low unit cost!)

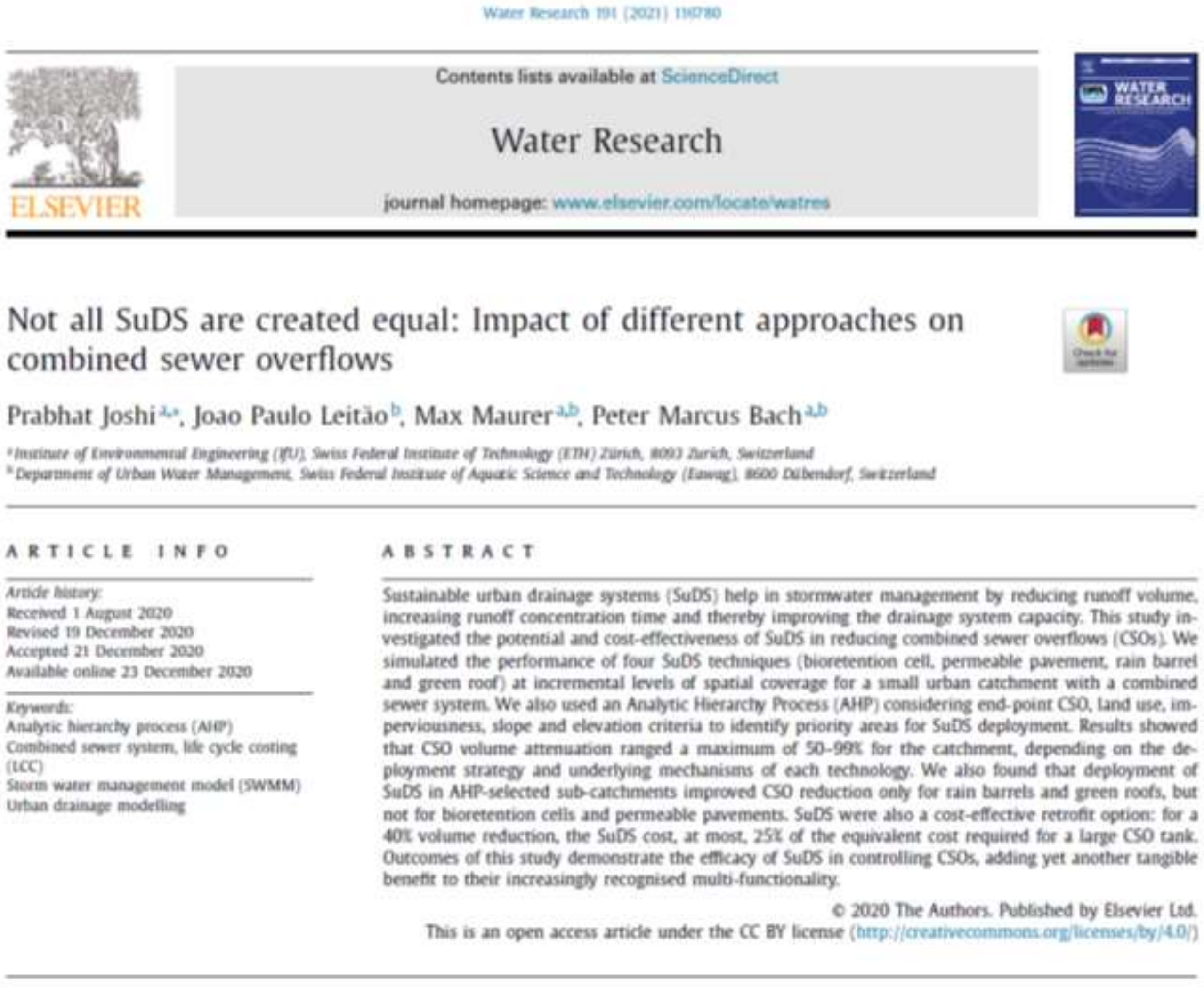
- **Location and distribution** of SuDS are crucial in reducing CSOs

- Bio-retention cells were the most cost-effective option, despite their high unit cost

Follow-up steps: monitor the actual impact of SuDS, i.e., **field experiments**

- Challenging but Important!

More details can be found in the recent publication



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Not all SuDS are created equal: Impact of different approaches on combined sewer overflows

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ABSTRACT

Sustainable urban drainage systems (SuDS) help in stormwater management by reducing runoff volume, increasing runoff concentration time and thereby improving the drainage system capacity. This study investigated the potential and cost-effectiveness of SuDS in reducing combined sewer overflows (CSOs). We simulated the performance of four SuDS techniques (bioretention cell, permeable pavement, rain barrel and green roof) at incremental levels of spatial coverage for a small urban catchment with a combined sewer system. We also used an Analytic Hierarchy Process (AHP) considering end-point CSO, land use, imperviousness, slope and elevation criteria to identify priority areas for SuDS deployment. Results showed that CSO volume attenuation ranged a maximum of 50–99% for the catchment, depending on the deployment strategy and underlying mechanisms of each technology. We also found that deployment of SuDS in AHP-selected sub-catchments improved CSO reduction only for rain barrels and green roofs, but not for bioretention cells and permeable pavements. SuDS were also a cost-effective retrofit option: for a 40% volume reduction, the SuDS cost, at most, 25% of the equivalent cost required for a large CSO tank. Outcomes of this study demonstrate the efficacy of SuDS in controlling CSOs, adding yet another tangible benefit to their increasingly recognised multi-functionality.