universität innsbruck

Towards Smart Water Cities – opportunities arising from Smart Rain Barrels for urban drainage and water supply

Martin Oberascher, Carolina Kinzel, Martin Schöpf, Ulrich Kastlunger, Christoph Zingerle, Samuel Puschacher, Manfred Kleidorfer, Wolfgang Rauch, Robert Sitzenfrei

Motivation

Rain barrels

- Temporary storage volume
- Detention of rain water[1]
- Usage of rain water for “non-drinking water” applications[1]

[1]Campisano, A., D. Butler, S. Ward, M. J. Burns, E. Friedler, K. DeBusk, L. N. Fisher-Jeffes, E. Ghisi, A. Rahman, H. Furumai and M. Han (2017). "Urban rainwater harvesting systems: Research, implementation and future perspectives."

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Information- and communication technology (ICT)

- Low-cost sensors
- Monitoring and controlling of the urban water infrastructure[2]

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The smart rain barrel (SRB) concept

- Real-time monitored and controlled[3]

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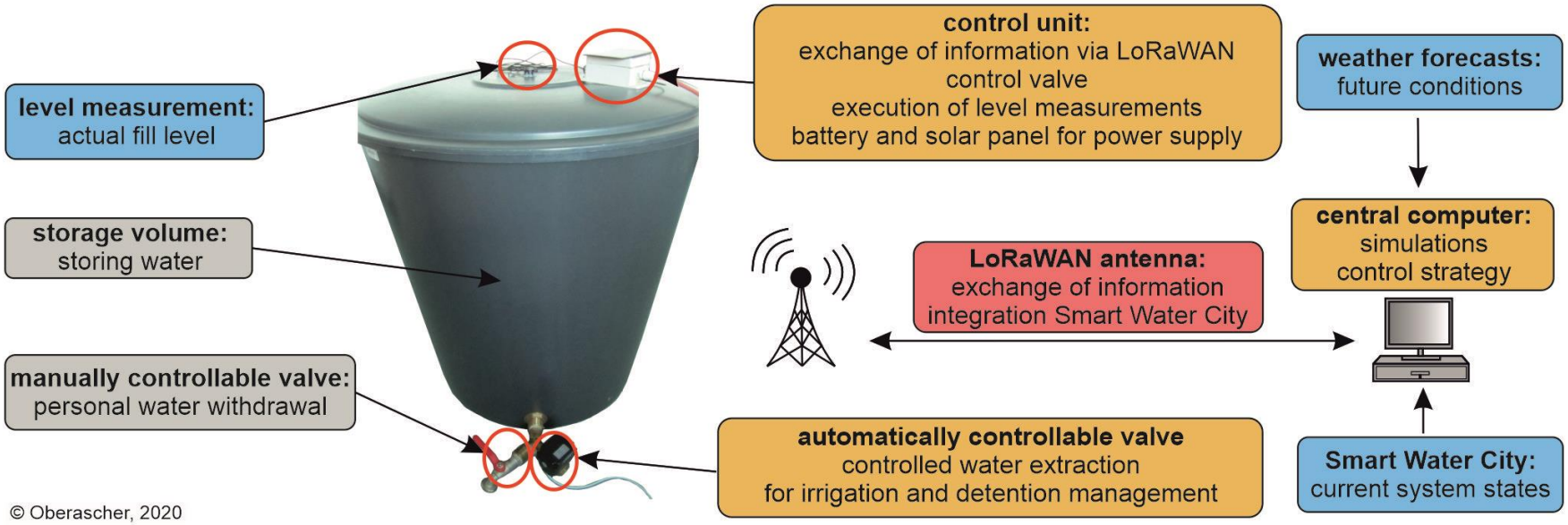
[3]Oberascher, M., Zischg, J., Palermo, S. A., Kinzel, C., Rauch, W., and Sitzenfrei, R. "Smart Rain Barrels: Advanced LID Management Through Measurement and Control." Springer International Publishing, 777-782

Smart rain barrel (SRB)

IoT solution for advanced rainwater harvesting

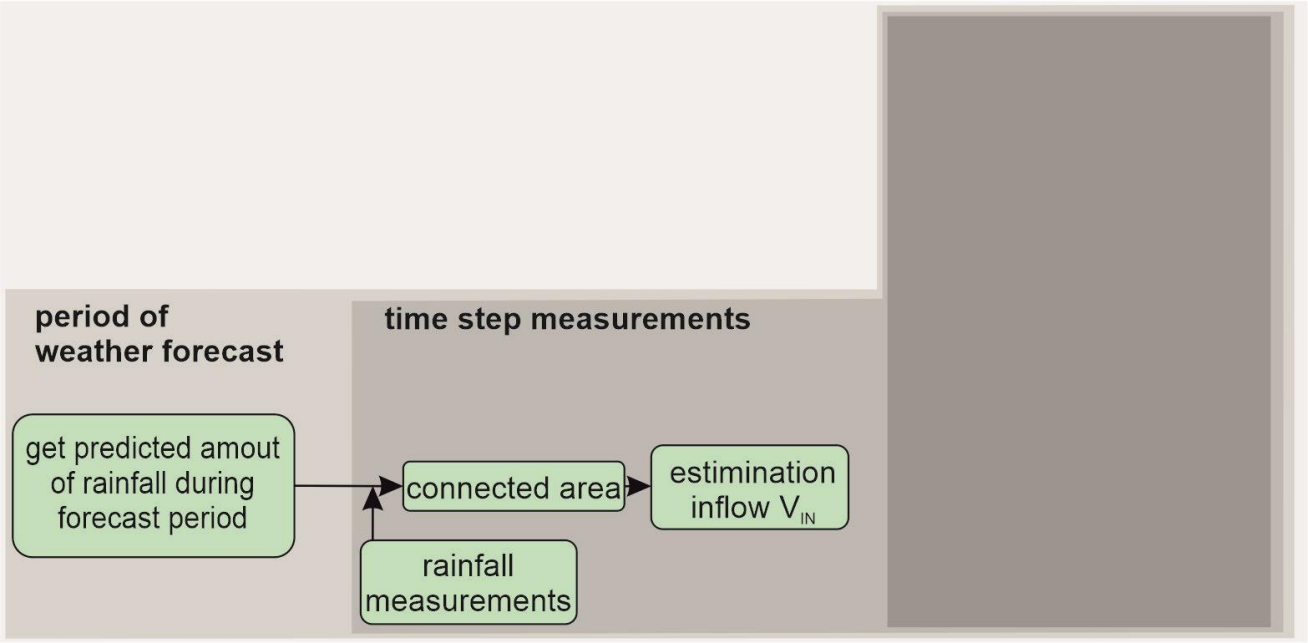


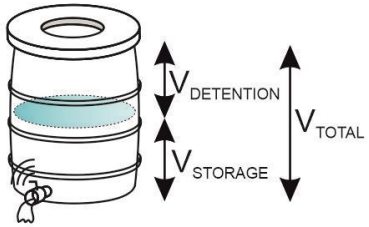
- Volume: 210 l

Management concept[6]

Control strategy for stormwater detention

- Estimation inflow smart rain barrel





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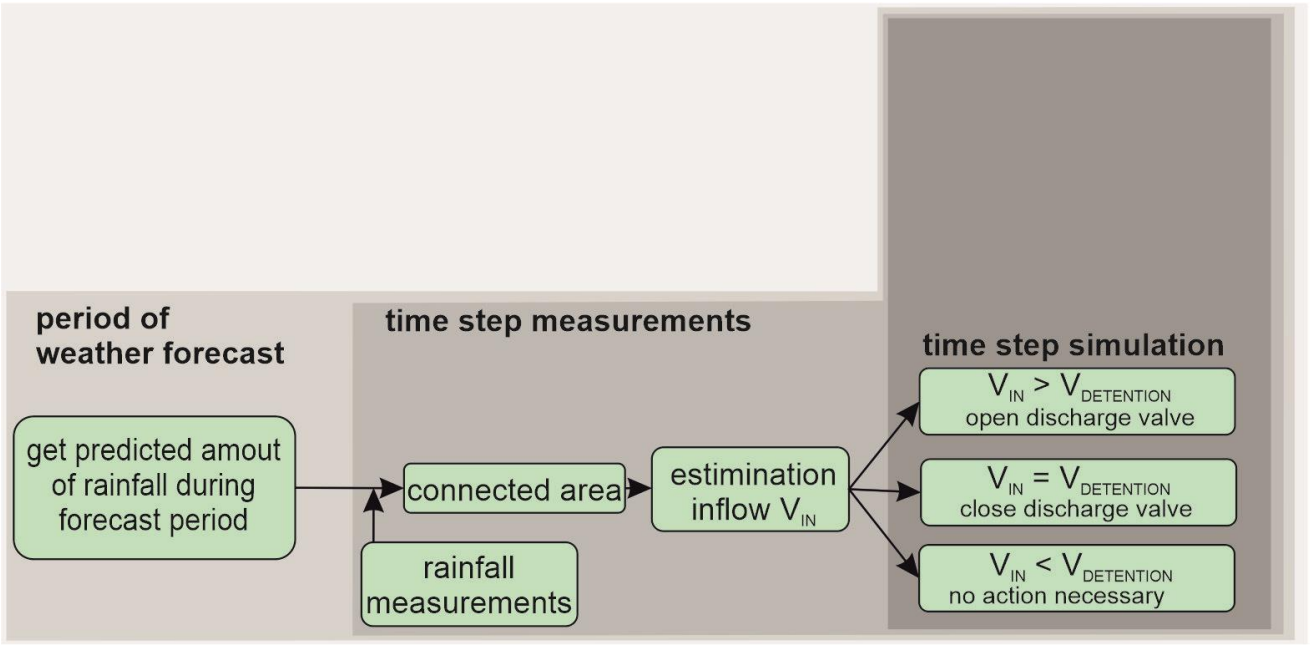
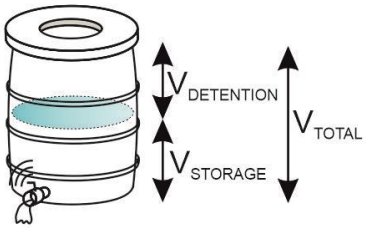
Management concept[6]

Control strategy for stormwater detention

- Estimation inflow smart rain barrel
- Open / close discharge valve





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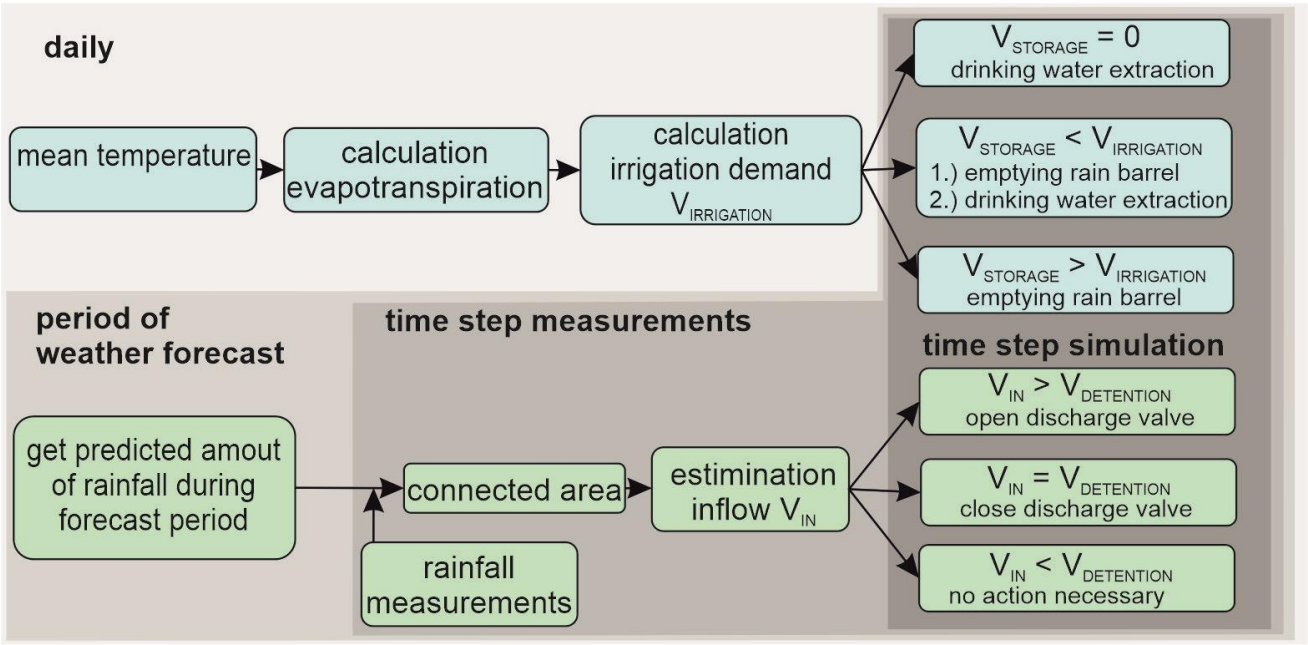
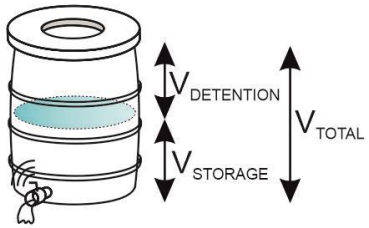
Management concept[6]

Control strategy irrigation

- Calculation irrigation demand
- Withdrawal smart rain barrel





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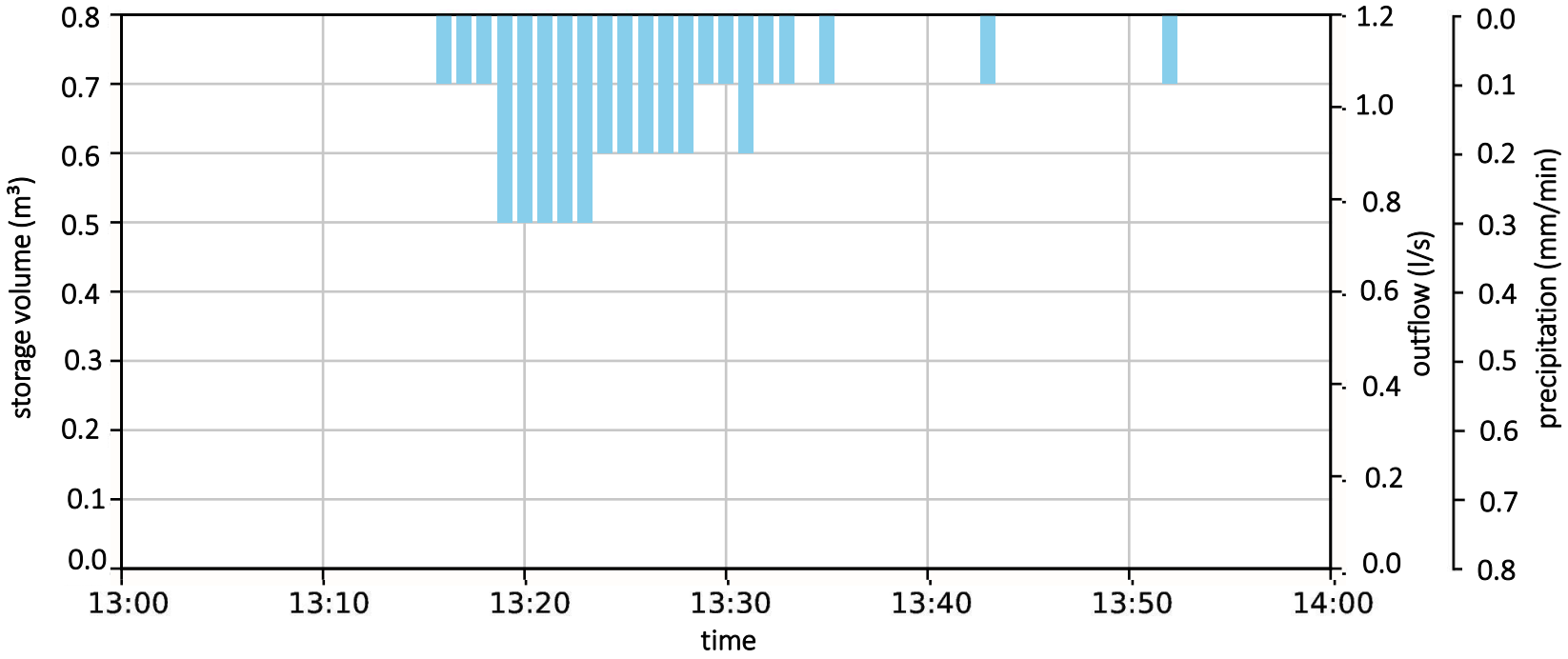
Exemplary functionality

Singly-family house

- Roof area 165 m², discharge coefficient 0.9
- Perfect weather forecast, forecast period of 1 h, update every 30 min
- Rain barrel volume 0.5 m³



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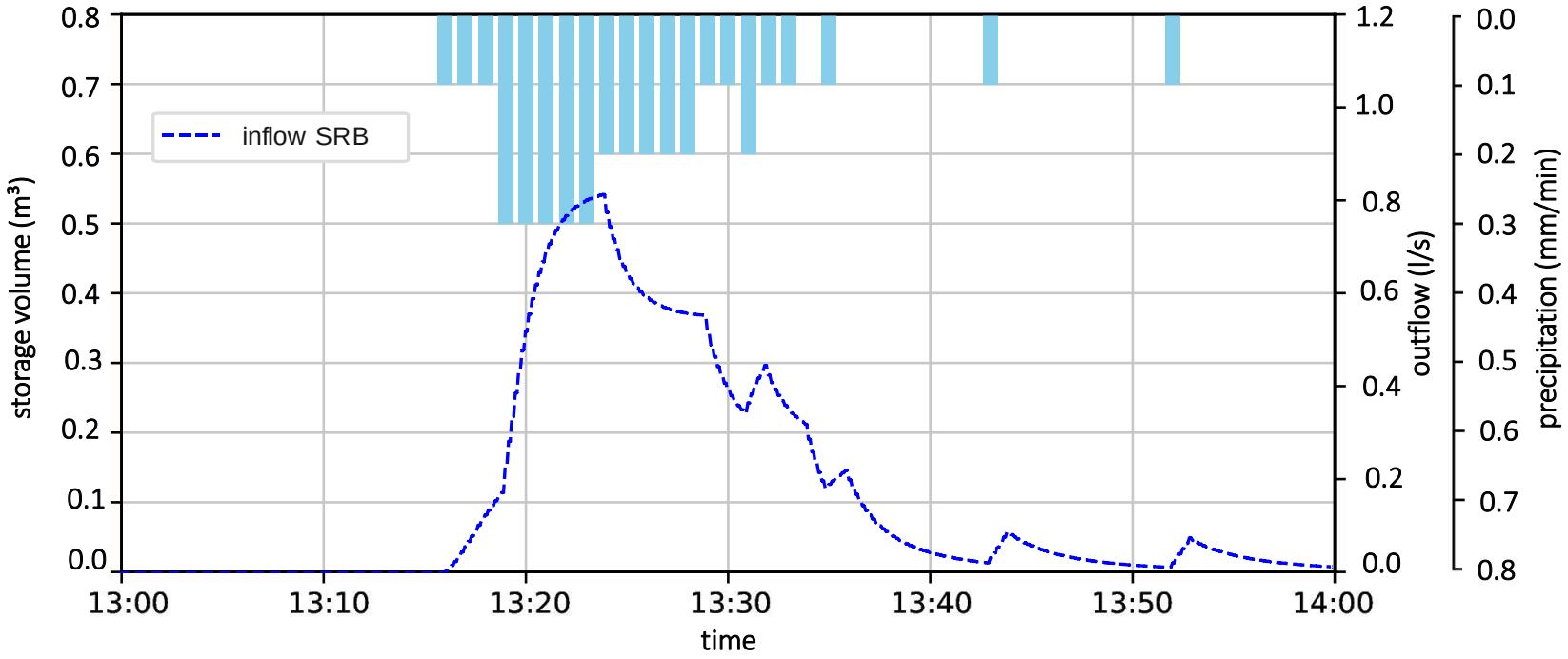

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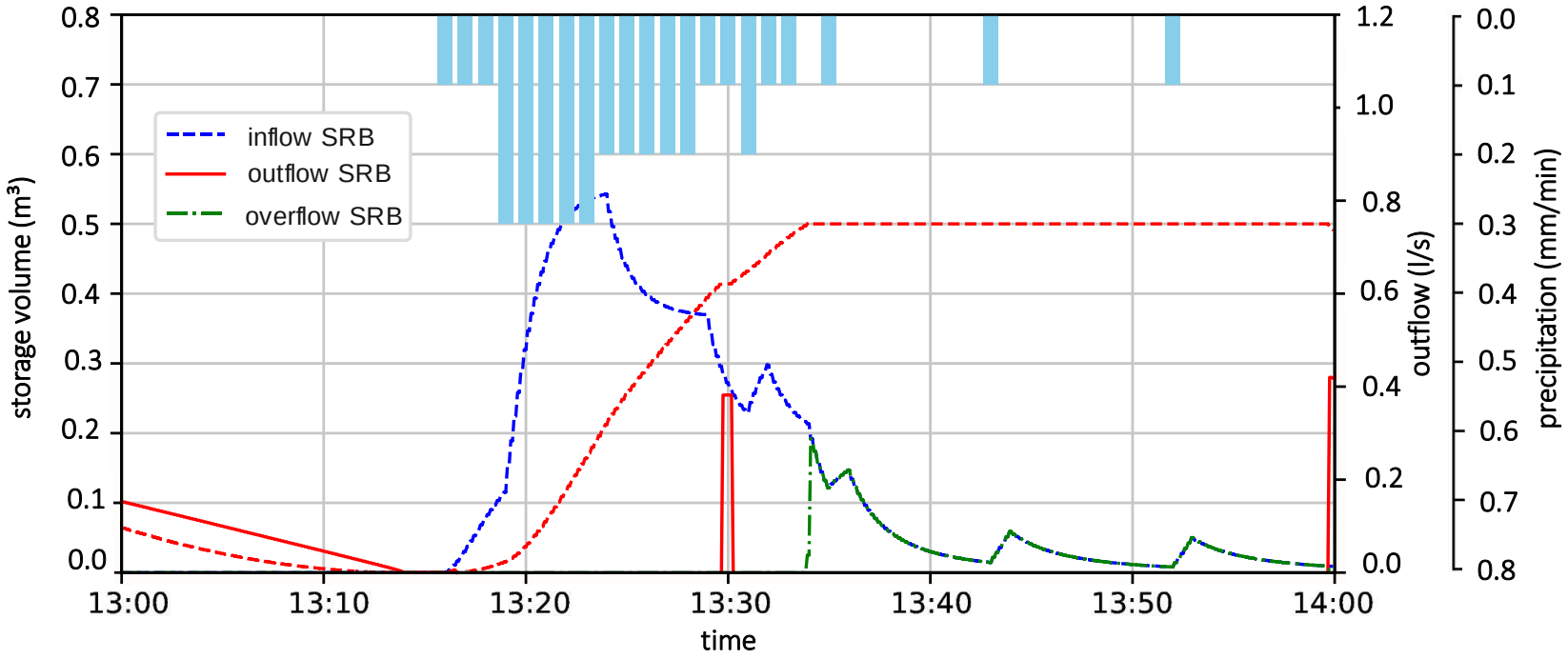

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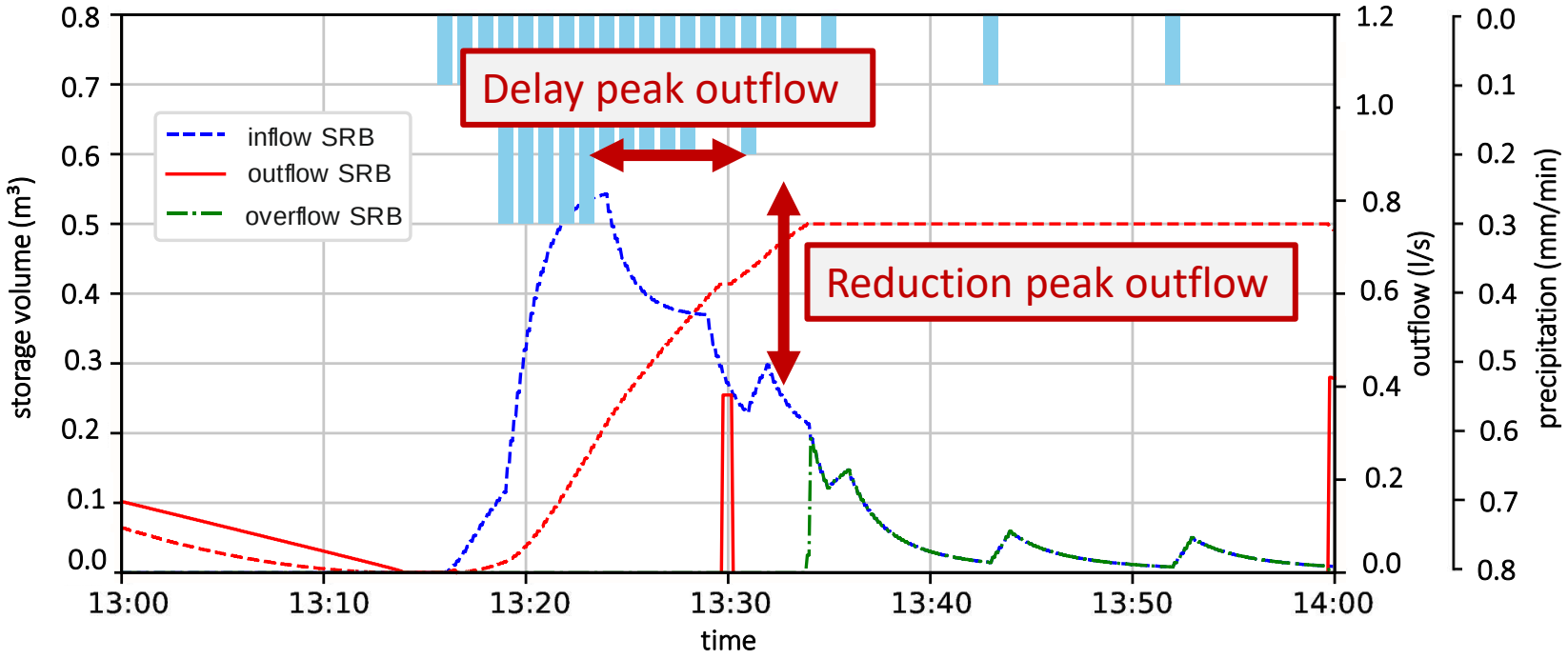

Idea: alternative to combined sewer overflows

Austrian design guideline: RB19 (2007)

- 15 m³ per 10.000 m² reduced connection area for combined sewer overflows[4]
- 150 m² reduced roof area per single-family house[5]

➢ 66 single-family houses per 10.000 m²

- Each equipped with a SRB (250 l)

[4]RB 19, 2007. Guidelines for the design of combined sewer overflows. Only available in German: Richtlinien für die Bemessung von Mischwasserentlastungen. ÖWAV. Wien, Österreich.
[5]Statistik Austria (2018): Completed apartments and buildings 2005 to 2017. https://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/wohnen/wohnungs_und_gebaeudeerrichtung/fertigstellungen/index. html. Retrieved on 01.03 2018.

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➢ 66 single-family houses per 10.000 m²

- Each equipped with a SRB (250 l)

➢ 16,5 m³ additional detention volume

➢ Cost-effective alternative

➢ Ca. 10 % precipitation amount of 15 min of rain with 2-yearly return

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Prove of concept - two-stage approach

- **Development of a SRB prototype**
  - Real-word operation at the “Smart Campus”
  - Testing functionality

- **Numerical simulations**
  - Evaluating the effects at household scale
  - Development of different control strategies
  - Investigation of large-scale implementation

- For ease of development
- To demonstrate the effectiveness

Prototype SRB

Implementation at „Smart Campus“ Technik, University of Innsbruck

- Pilot project for „Smart Water Cities“
- Integration of water supply and urban drainage into a joint controlled system
- Used as demonstration object and experimental framework for smart applications

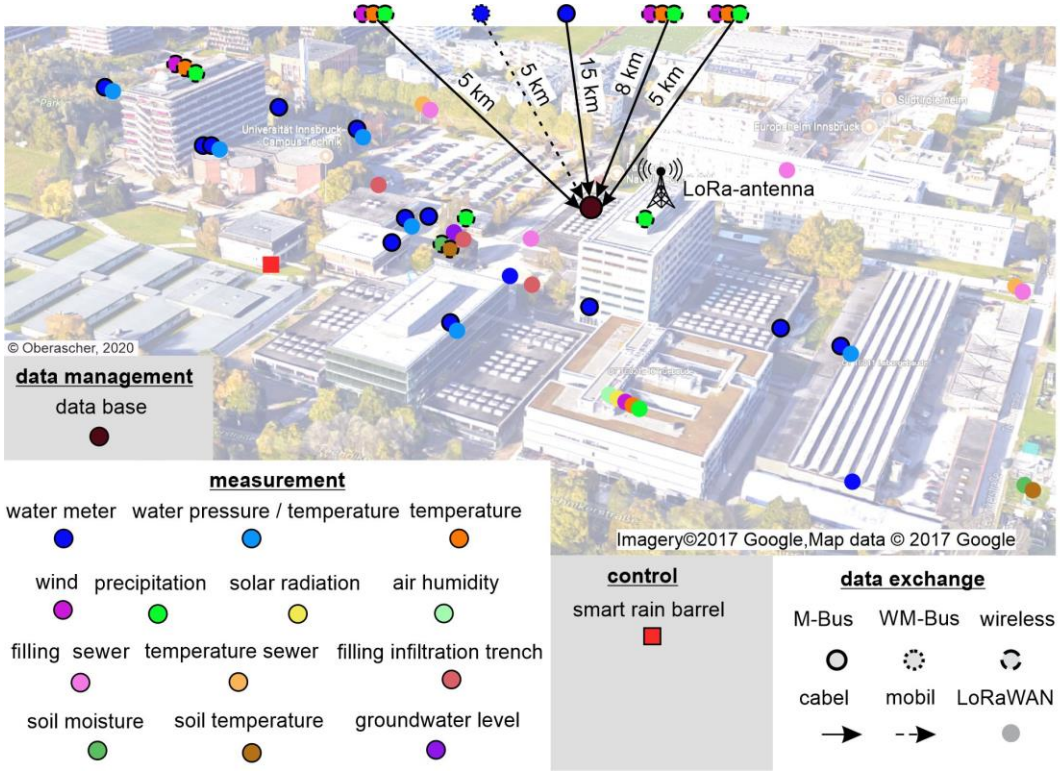
Real-time monitoring

- Distribution system: water consumptions and pressures
- Drainage system: filling levels in the drainage system as well as levels and soil moistures of decentralized stormwater retention and infiltration systems
- Meteorological data at different locations
- Temporal resolution: 1 – 15 min

Prototype SRB

Implementation „Smart Campus“ Technik, University of Innsbruck

- Current Measurement and Control Network



- Online measurement data: https://umwelttechnik-swc.uibk.ac.at/ui/sensors/

Prototype SRB

„Smart Camus = ideal testing ground for the SRB concept

- Real-word implementation

- Online: https://umwelttechnik-swc.uibk.ac.at/ui/sensor/128/
- Volume: 210 l

Numerical simulations – Household level

Single-family house with irrigation demand

Impacts SRB:

- Stormwater detention
- Substituting drinking water with rain water

Evaluating SRB volume:

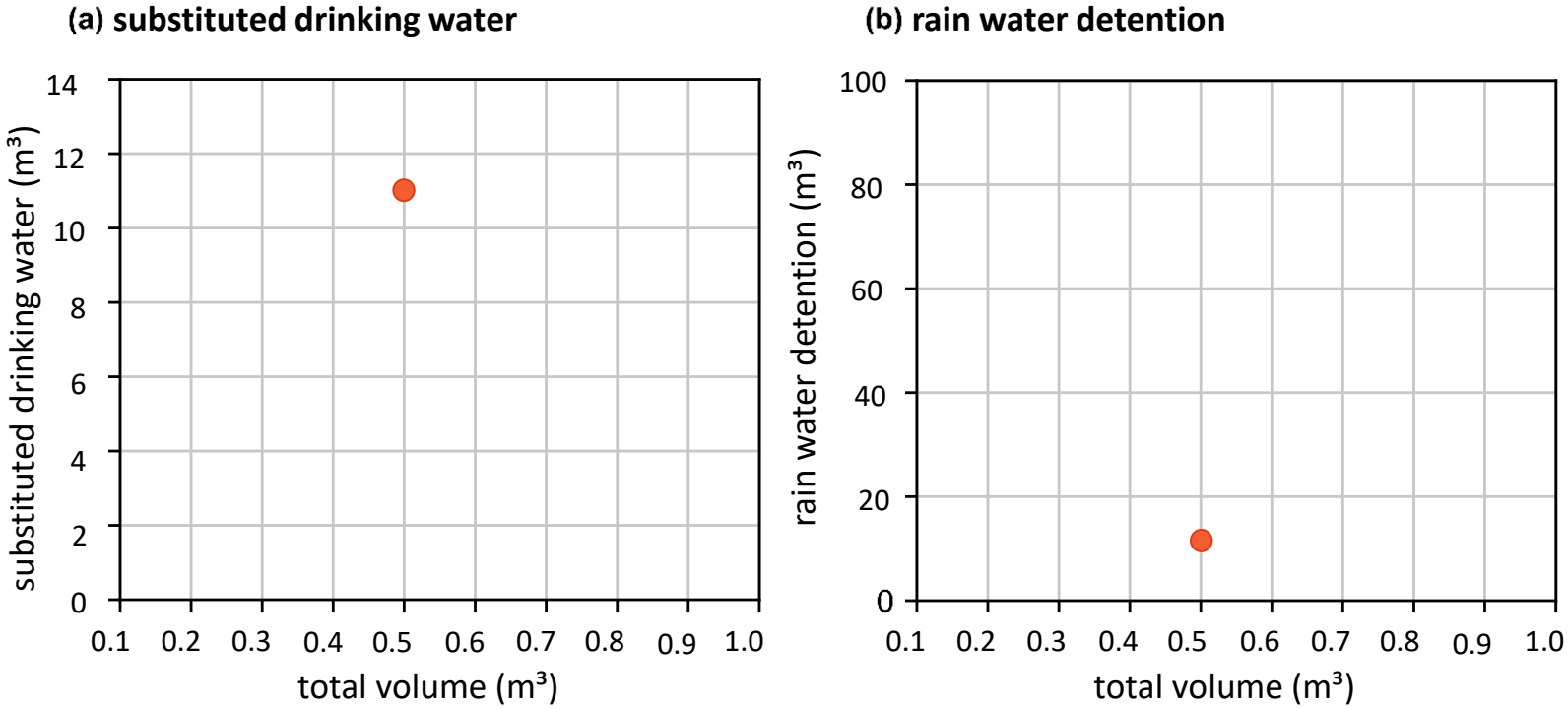
- Storage volume: 0.1 – 1m³

Testing different control strategies based on historical weather data

- precipitation (1 min)
- INCA – weather forecasts (15 min – time period 24 h)
- Forecast period 1 h, 4 h und 12 h
- perfect – real weather forecast

Results single-family house

- Roof area 165 m², discharge coefficient 0.9
- Rain barrel volume 0.5 m³, uncontrolled



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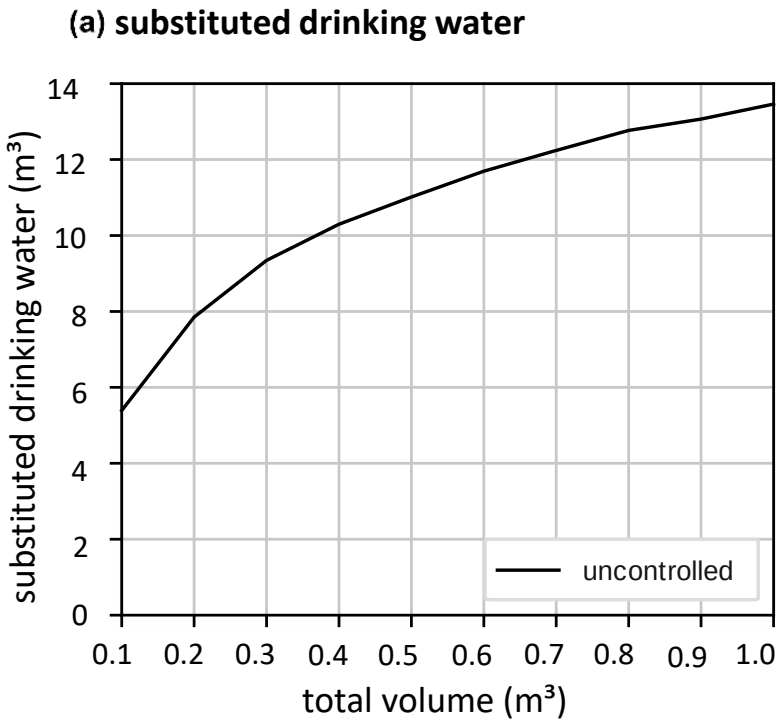

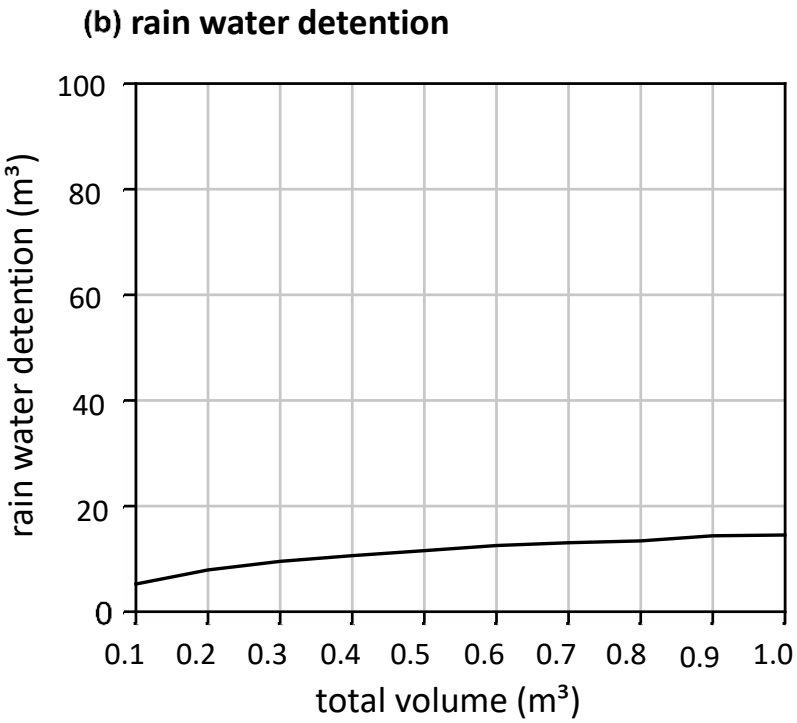

Results single-family house

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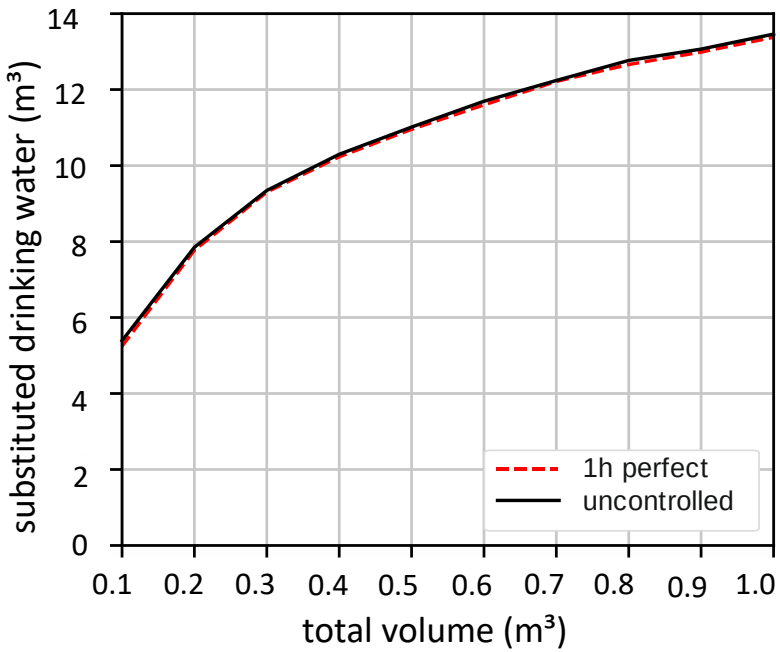
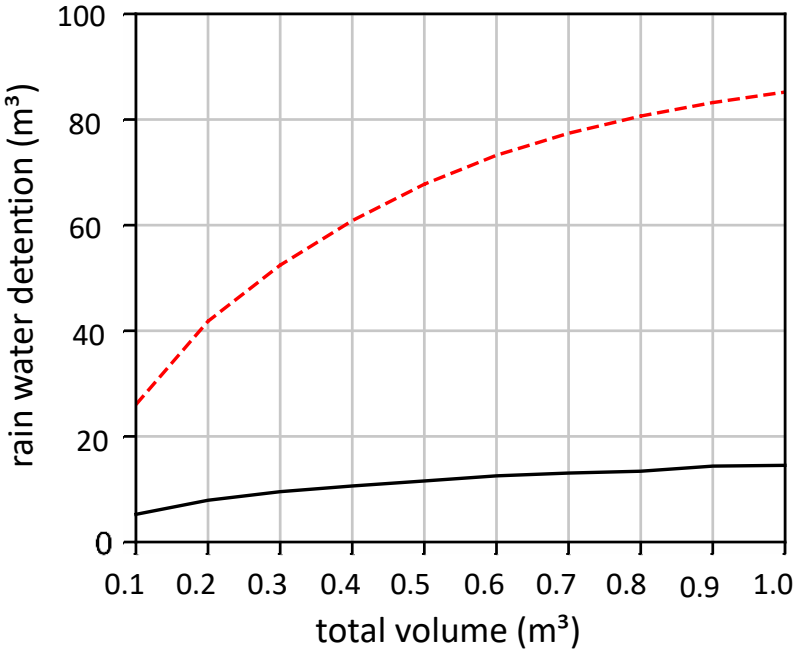
- SRB: 1 h forecast period, perfect weather forecast

(a) substituted drinking water

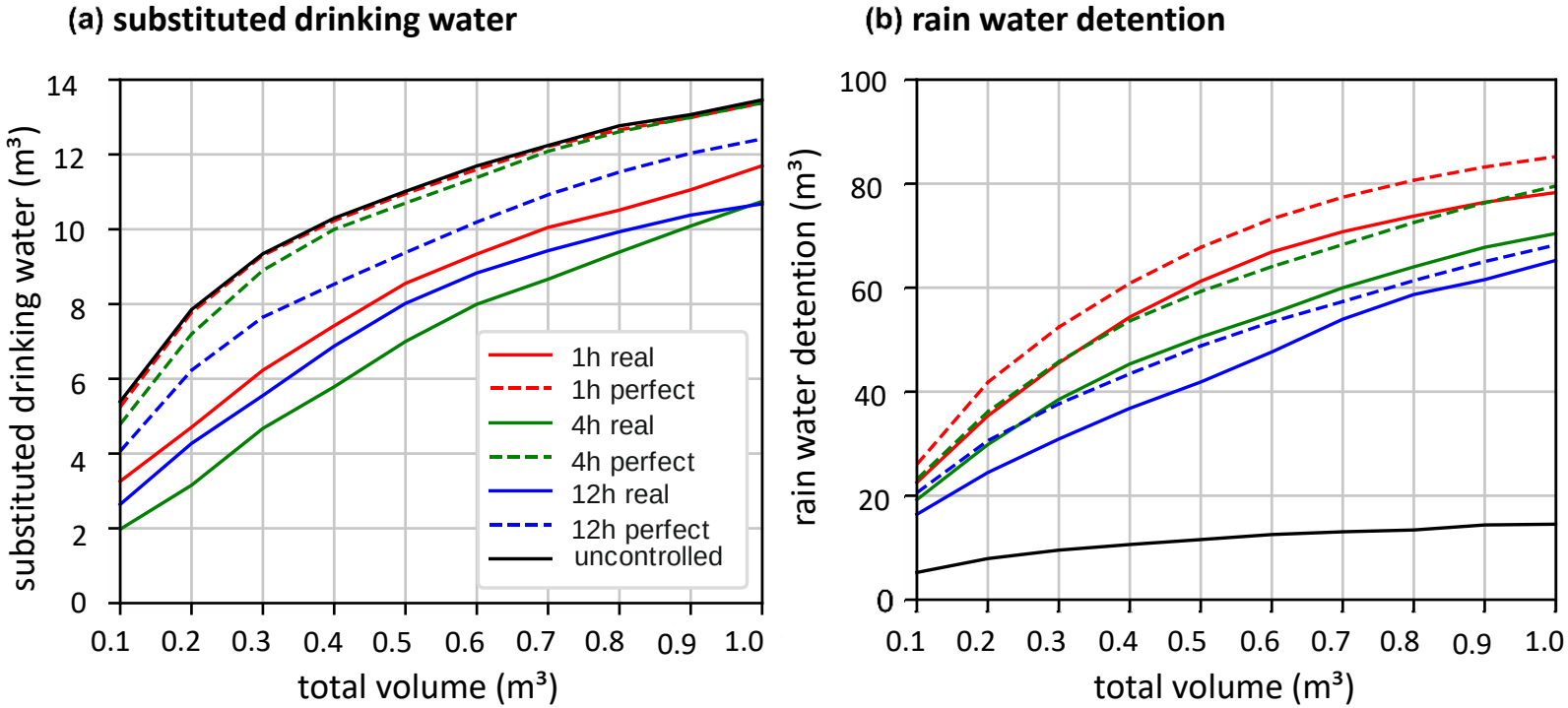


(b) rain water detention



Results single-family house

- Roof area 165 m², discharge coefficient 0.9
- SRB: different weather forecasts



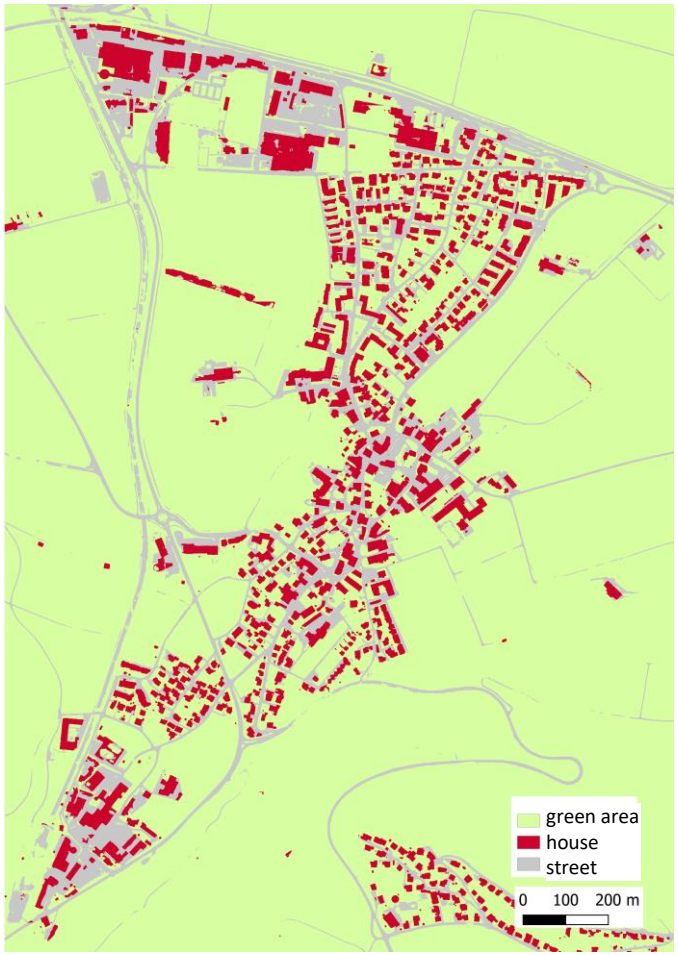
➢ Increasing detention volume through usage weather forecasts

➢ Substituted drinking water – reference uncontrolled rain barrel

Numerical simulations – Large scale implementation

Alpine municipality

- 2900 inhabitants (2019)
- Sea level 610 m ü. A.
- Austria
- 628 buildings
- 15,2 ha connected area
- Combined sewer system



Impacts:

- Rain barrel (substituted drinking water, stormwater detention, switching operations)
- Sewer (combined sewer overflow, flooding)
- Drinking water supply (water pressure, age)

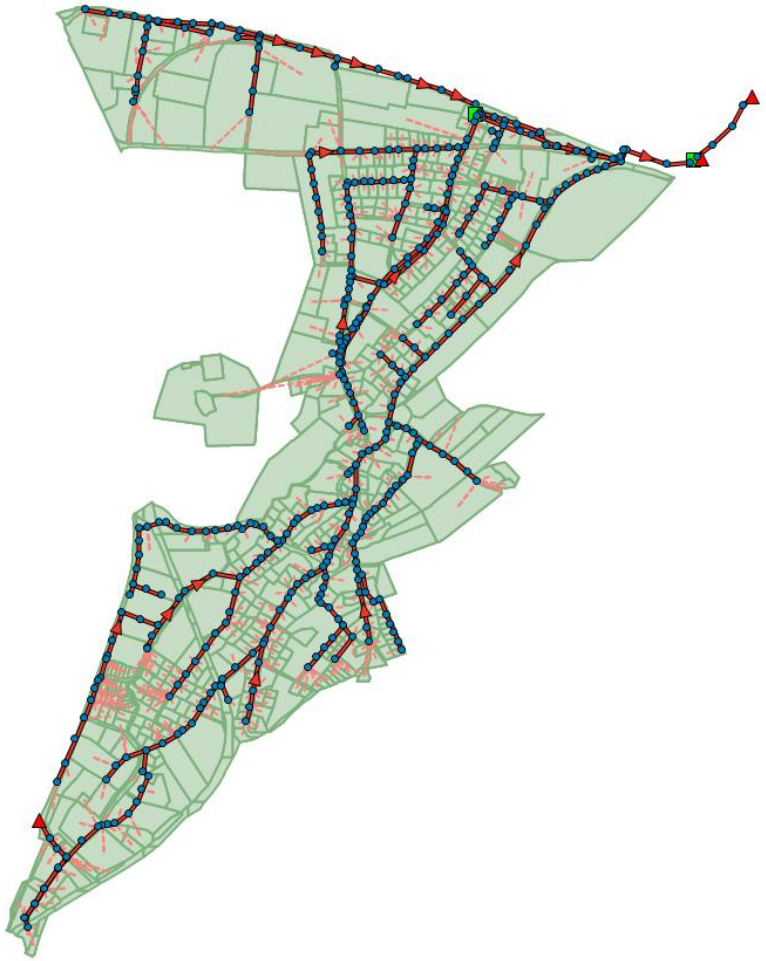
Coupled hydraulic simulation

SWMM - Model

- Green area, traffic area, house area

PySWMM[7]

- Python Wrapper for SWMM5
- Step-for-step simulation
- RTC micro storages



[7]https://github.com/jennwuu/pyswmm

Coupled hydraulic simulation

SWMM - Model

- Green area, traffic area, house area

PySWMM[7]

- Python Wrapper for SWMM5
- Step-for-step simulation
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EPANET - Model

- Connection per house

Python EPANET – Toolkit[8]

- Long-term simulation

[7]https://github.com/jennwuu/pyswmm
[8]https://github.com/OpenWaterAnalytics/epanet-python

Simulationen[9]

Smartin-Toolbox[9,10]

- Simulating RTC micro storages in urban water infrastructure

Testing different control strategies based on historical weather data

- precipitation (1 min)
- INCA – weather forecasts (15 min – time period 24 h)
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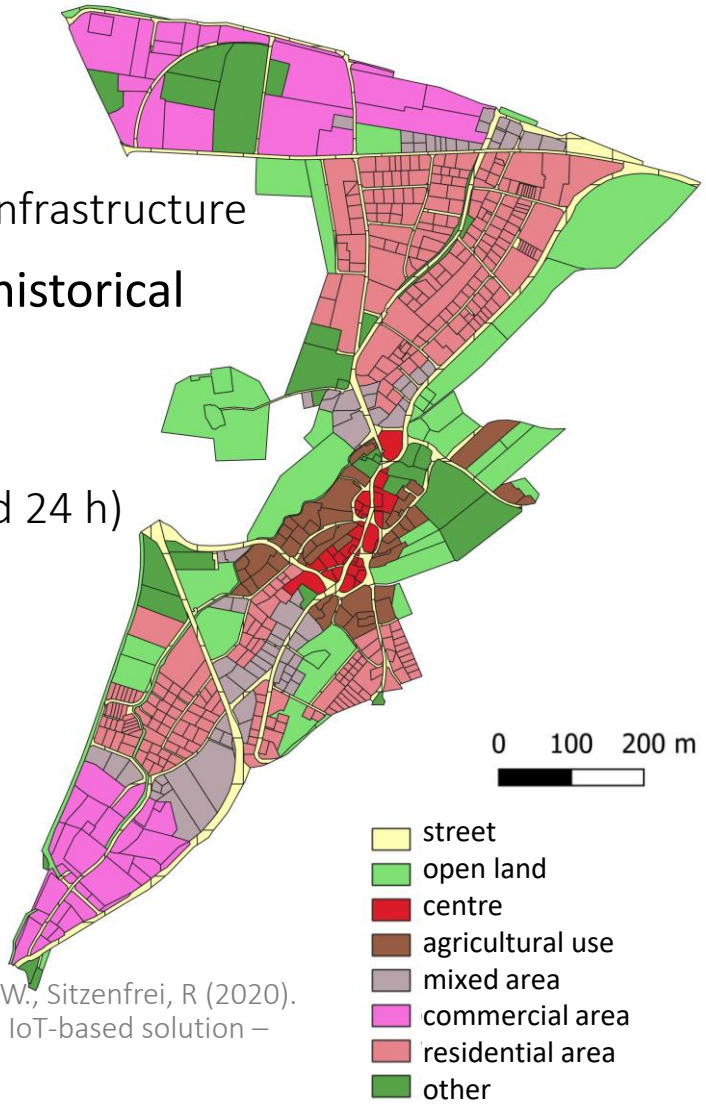
Rain barrels

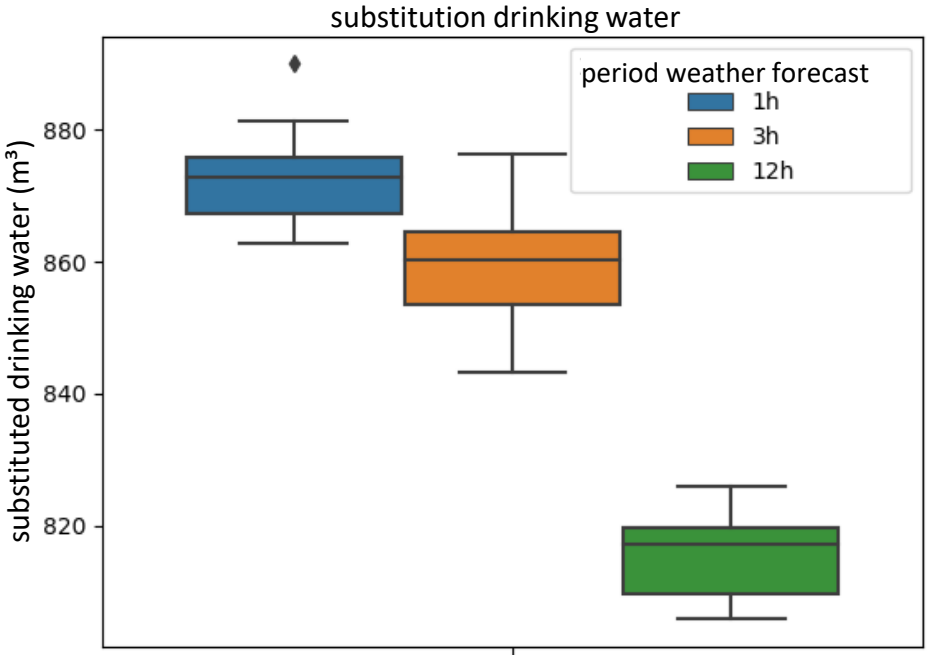
- Implementation in residential area, mixed area and agricultural use

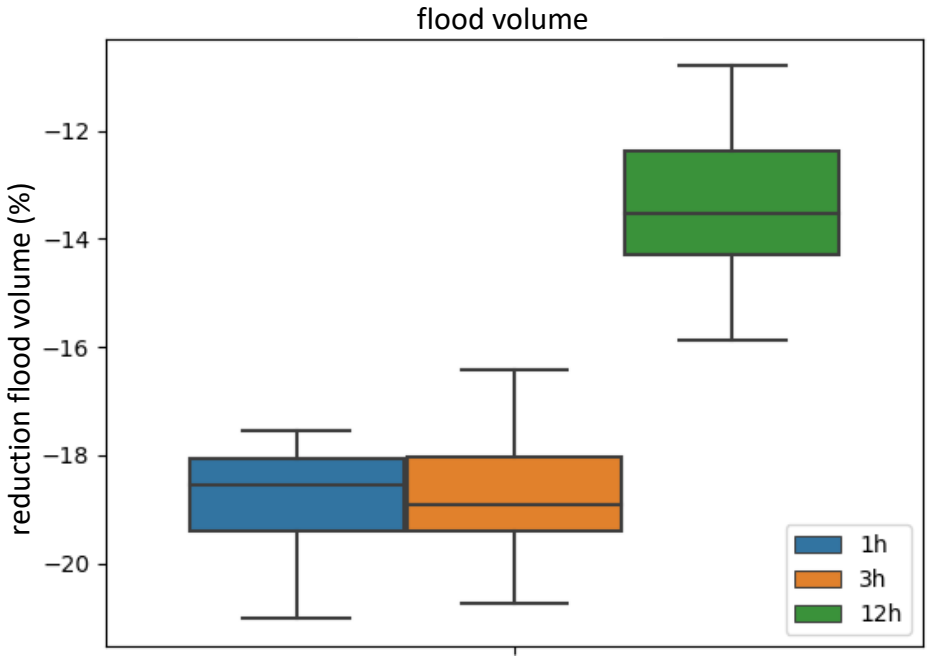


[9]Oberascher M., Kinzel C., Kastlunger U., Kleidorfer M., Zingerle, C., Rauch, W., Sitzenfrei, R (2020). Integrated urban water management with micro storages developed as an IoT-based solution – the smart rain barrel. Manusript submitted for publication.
[10]https://github.com/iut-ibk/Smartin-Toolbox

First results case study

- 100 smart rain barrels (additional storage volume 45m³)
- Perfect weather forecast, different forecast periods
- 25 simulations





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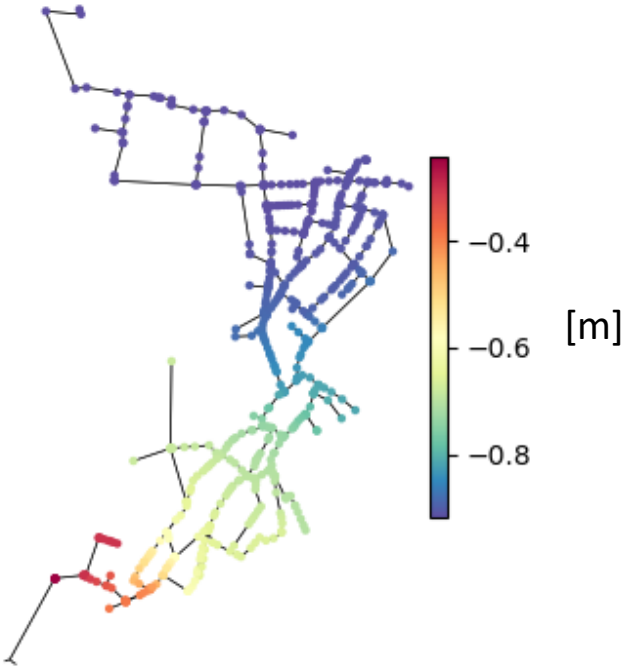
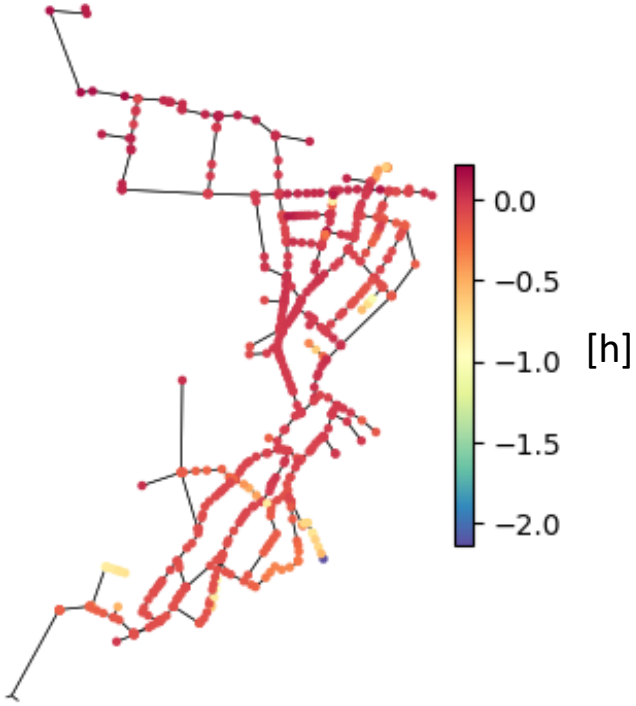
change water pressure 02.07.2015 23:00:00 through filling the SRBs



change water age 02.07.2015 23:00:00



Conclusion

- Weather forecast: increasing detention capacity, errors affecting substitution of drinking water
- High-number of smart rain barrels -> integrative management in the context of "Smart Water Cities" required
- Future work: instead of perfect control -> consideration of LoRaWAN characteristics (e.g. duty-cycle, packet losses)

Further information

Visit:

- https://umwelttechnik-swc.uibk.ac.at/
- https://www.uibk.ac.at/umwelttechnik/research/projects/smartwatercity.html.en

Contact:

- umwelttechnik@uibk.ac.at
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Thank you very much for your attention!

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