From Rainwater Harvesting to Rainwater Management Systems

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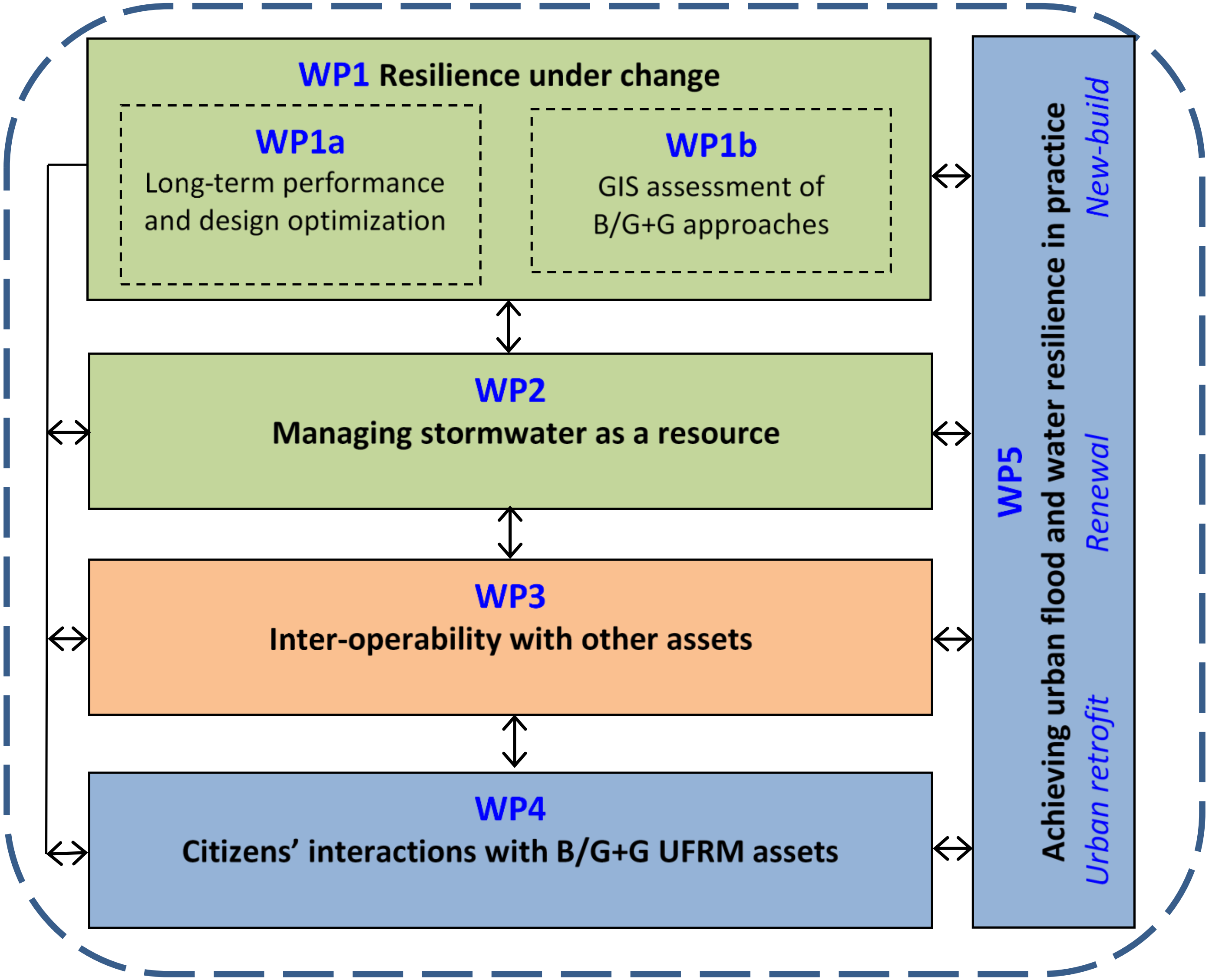

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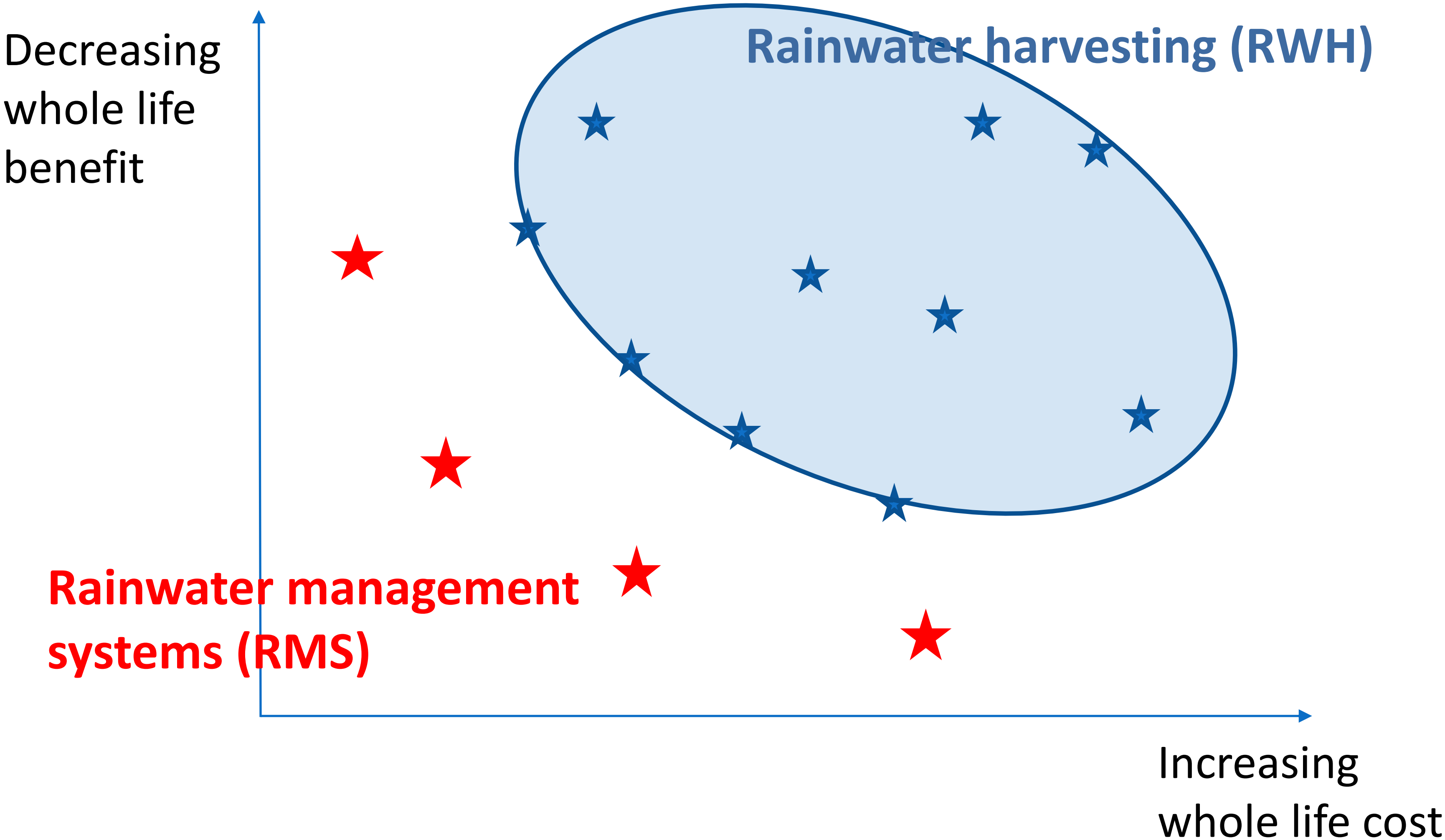
Summary

- Rainwater management systems (RMS)
- Conventional systems
- Low energy
- Passive control
- Active control
- RMS performance case studies
- Conclusions

RWH to RMS?



Melville-Shreeve, P., Ward, S., and Butler, D. 2017. Dual-purpose rainwater harvesting system design. In S.,Charlesworth and C., Booth. Sustainable Surface Water Management: A Handbook for SUDS.

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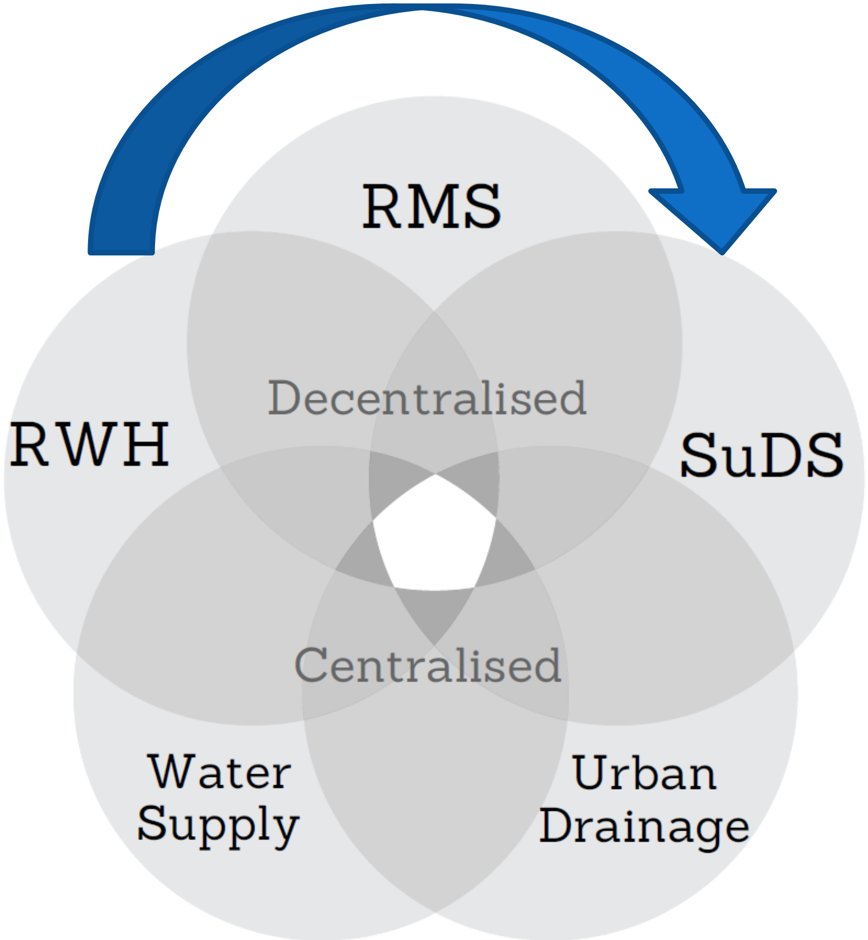
Rainwater Management Systems (RMS)

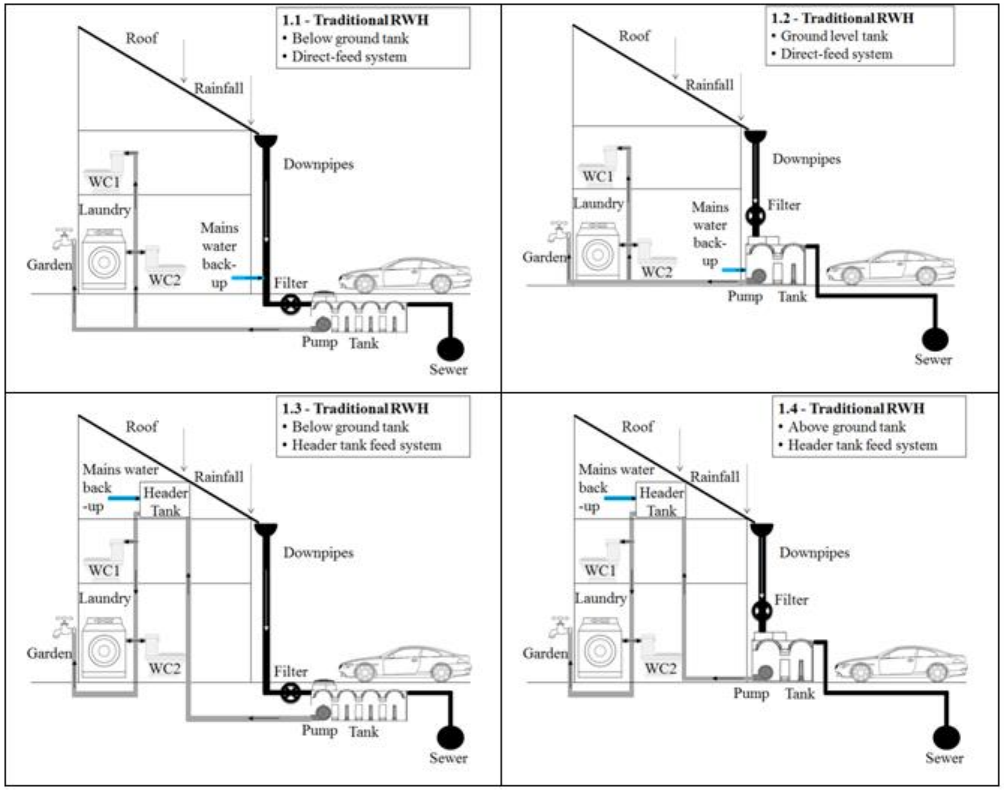
- **RWH** – single function, single benefit.
- **RMS** – multi-function and/or multi-benefit:
  - Reduced water demand
  - Reduced energy (embodied and operational)
  - Reduced stormwater discharges
  - Increased resilience and sustainability



Conventional RWH systems

RESILIENCE

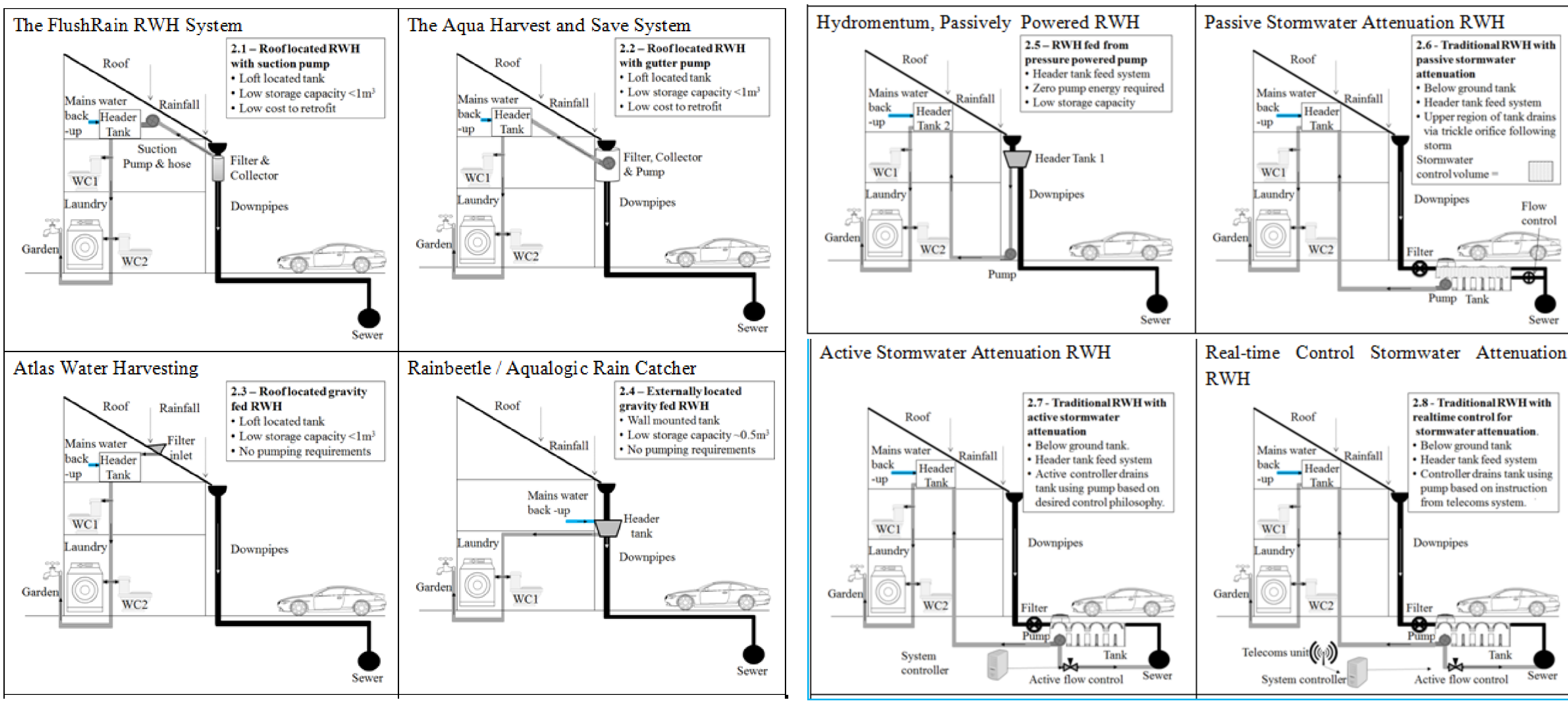
- Flexible XXX
- Duplicated XXX
- Interconnected X
- Dispersed XXX
- Diverse X
- Multi-function X



SUSTAINABILITY

- Affordable X
- Equitable XXX
- Non-polluting X
- Low energy X
- Reusable XX
- Simple XXX

An explosion of new system configurations



Melville-Shreeve, P., Ward, S., and Butler, D. Rainwater Harvesting Typologies for UK Houses: A Multi Criteria Analysis of System Configurations. Water. Water 2016, 8(4), 129; doi:10.3390/w8040129.

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Storage tanks & configurations

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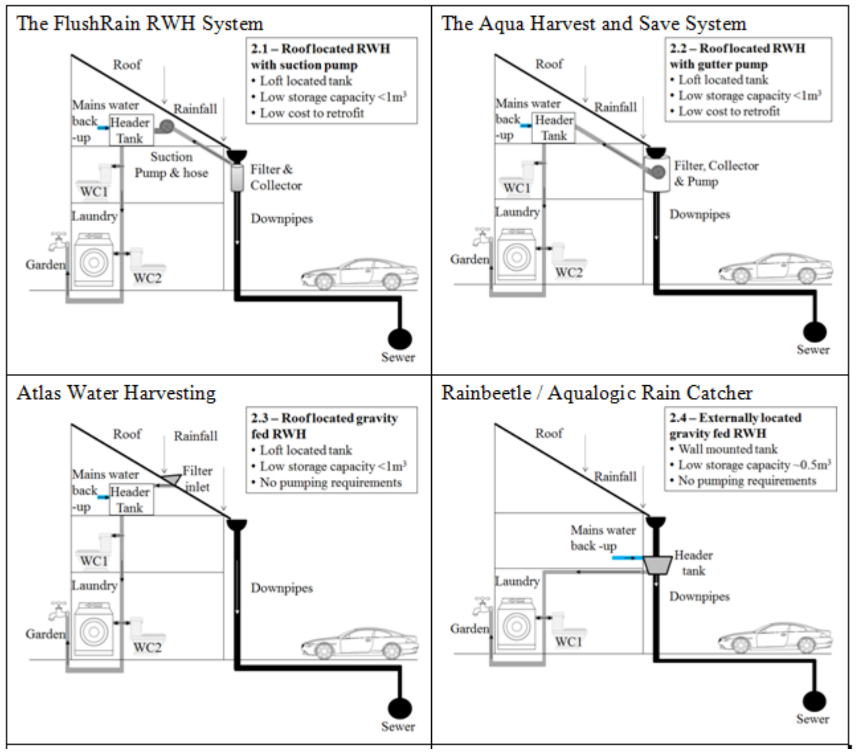
Low energy RMS

RESILIENCE

- Flexible XXX
- Duplicated XXX
- Interconnected X
- Dispersed XXX
- Diverse X
- Multi-function X



SUSTAINABILITY

- Affordable XX
- Equitable XXX
- Non-polluting X
- Low energy XXX
- Reusable XX
- Simple XXX

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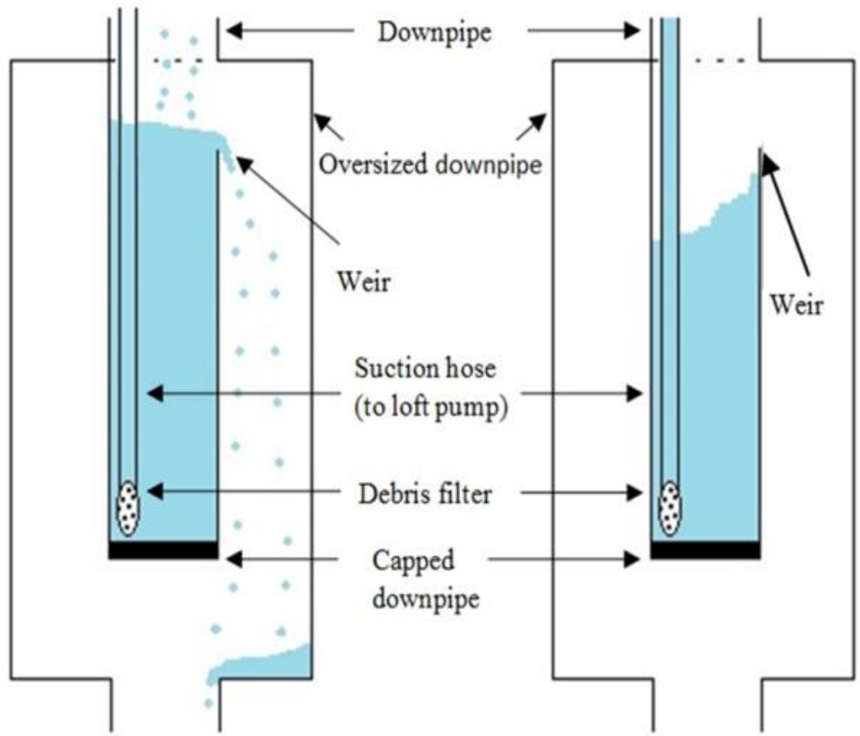
Low energy RMS

A) Chamber connected to downpipe

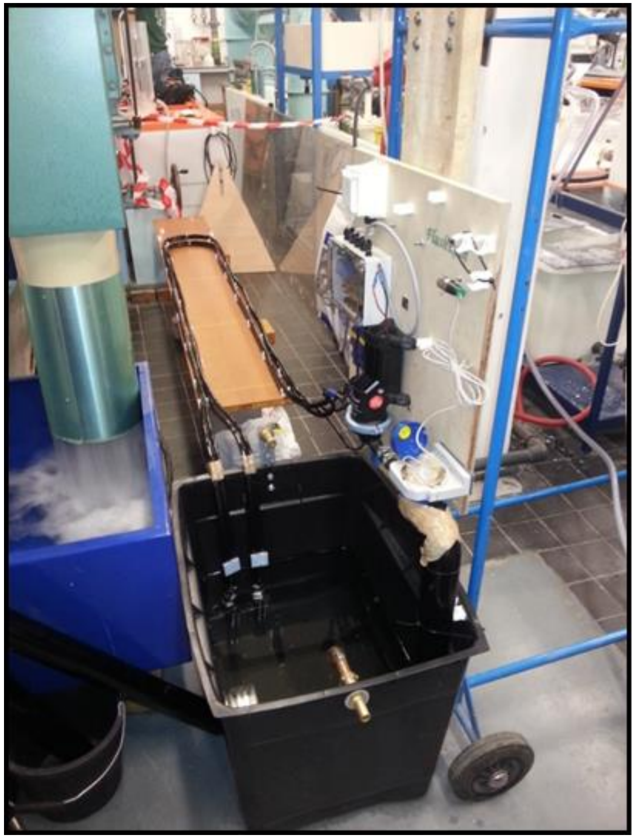


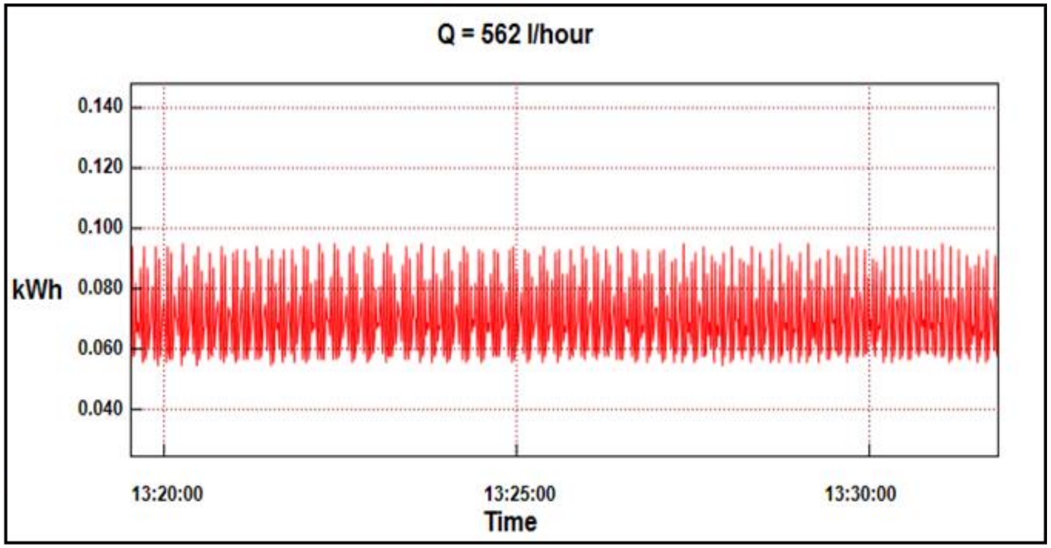
B) Illustration of chamber discharging to downpipe

C) Illustration of chamber being pumped empty

Melville-Shreeve, P., Horstman, C., Ward, S., Memon, F. A. & Butler, D. 2016. A Laboratory Study into a Novel, Retrofittable RWHS. British Journal of Environment and Climate Chang,. 6(2): 128-137, DOI: 10.9734/BJECC/2016/23724.

Low energy RMS – lab testing





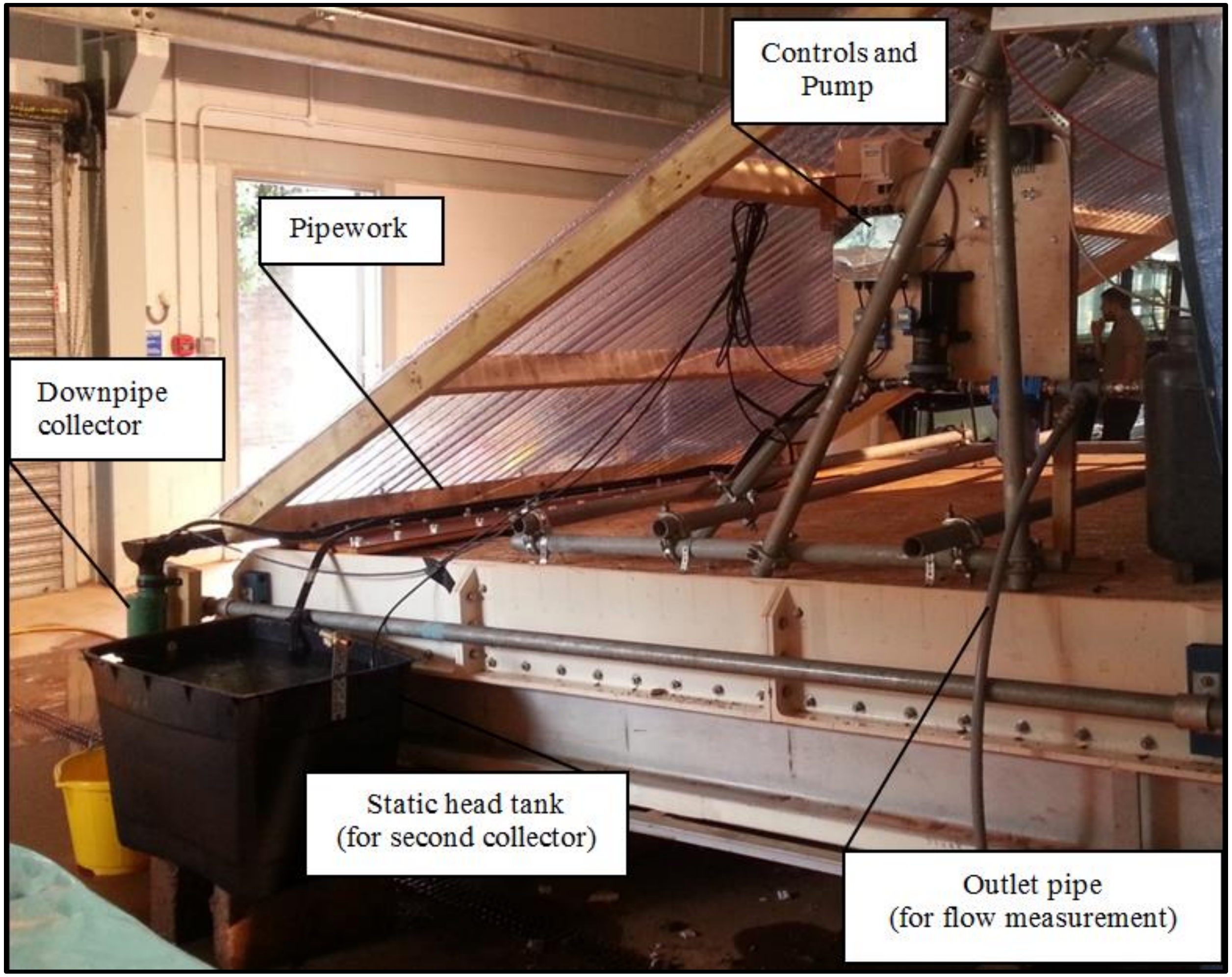
Laboratory energy use:
0.12-0.18 kWh/m³

Water supply power consumption

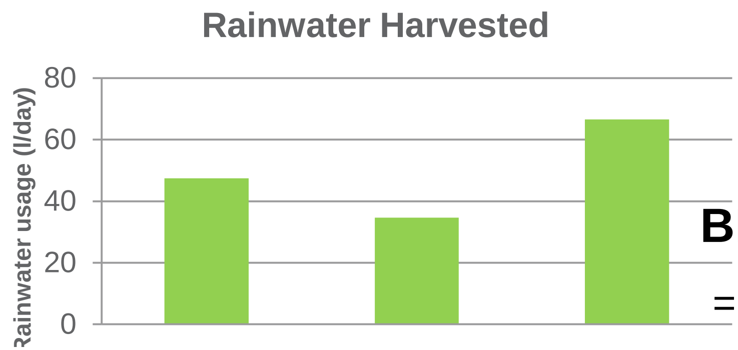
System	Consumption (kWh/m³)	Ref
This study	0.12 – 0.18	
Commercial RWH	0.54	1
Market Leader RWH	0.68	1
Municipal supply	0.60	1
Median of 10 RWH studies	1.40	2
Global desalination	3.60	2

[1] Ward S., Butler D. & Memon F.A. (2012), Benchmarking energy consumption and CO2 emissions from rainwater-harvesting systems: an improved method by proxy. *Water and Environment Journal*, 26: 184 –190. [2] Vieira et al.(2014). Energy intensity of rainwater harvesting systems. Renewable and Sustainable Energy Reviews 34, 225 –242.

Low energy RMS – lab testing

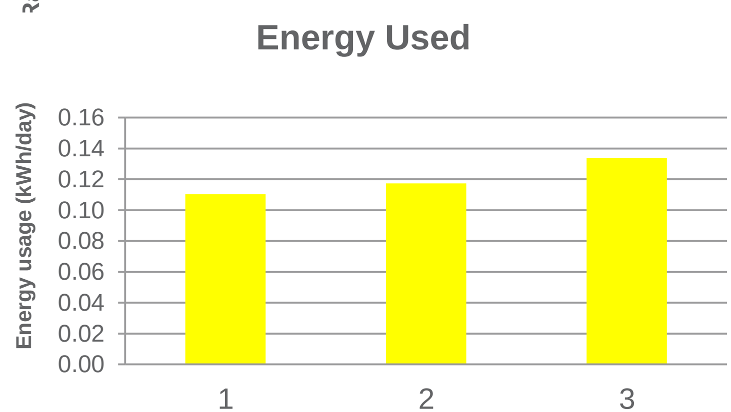


Low energy RMS – field trials



BENEFITS

= £120/year



COSTS

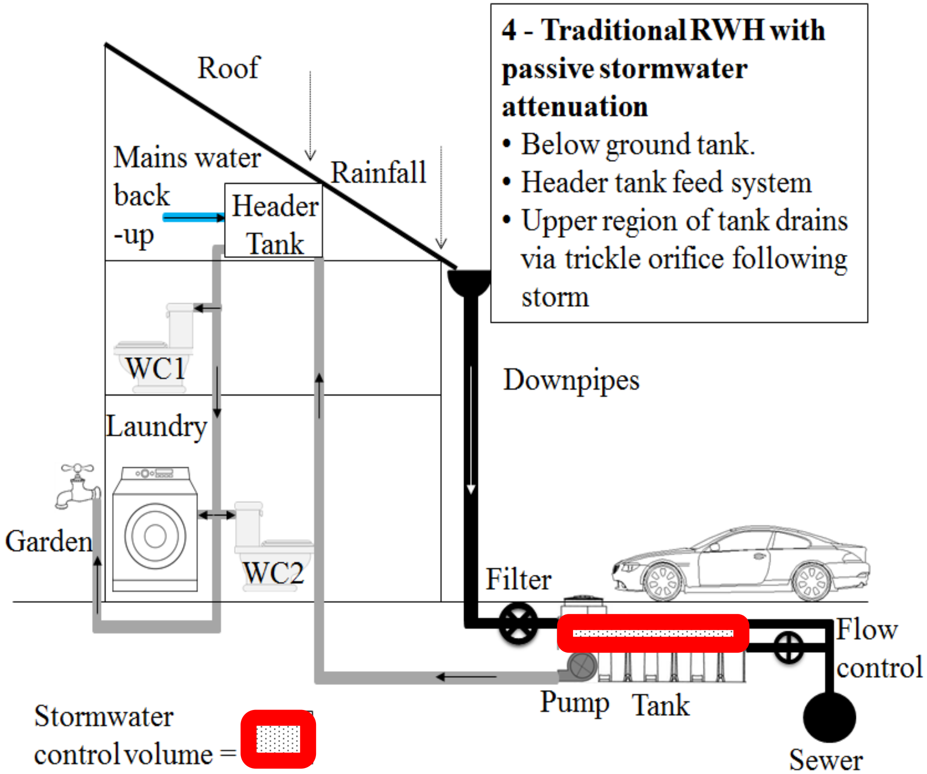
= £6/year

0.5m^3 RWH tank supplying 10-20m^3/annum

Water-saving & runoff control RMS

RESILIENCE

- Flexible XXX
- Duplicated XXX
- Interconnected X
- Dispersed XXX
- Diverse XX
- Multi-function XX



SUSTAINABILITY

- Affordable X
- Equitable XXX
- Non-polluting XX
- Low energy XX
- Reusable XX
- Simple XX

Passive control RMS

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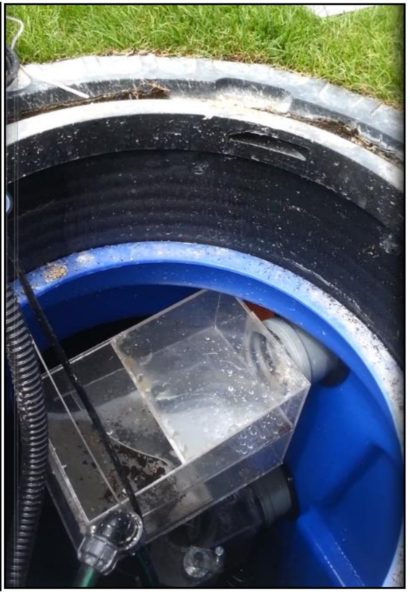
Passive control RMS



2.5m^3 RWH tank supplying 30-60m^3/annum.
PLUS >2.5m^3 of stormwater attenuation (source control)

Melville-Shreeve, P., Ward, S., and Butler, D. Design and Analysis of a Dual Purpose Rainwater Harvesting System: A Pilot Study. International Conference on Urban Drainage, 2017. Prague.

Active control RMS

RESILIENCE

Flexible XXX

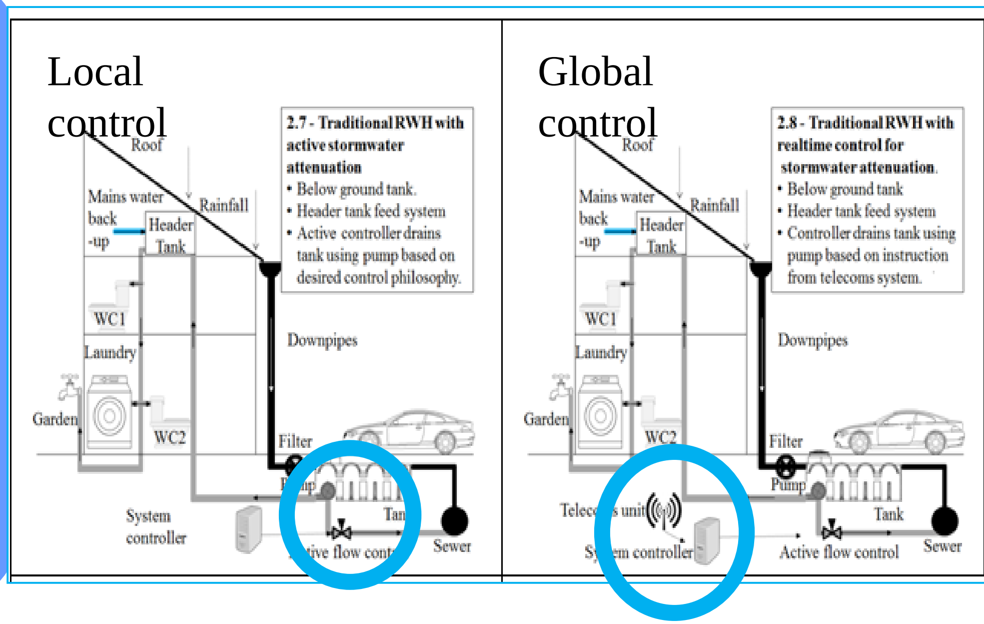
Duplicated XXX

Interconnected XXX

Dispersed XXX

Diverse XXX

Multi-function XXX



SUSTAINABILITY

Affordable X

Equitable XXX

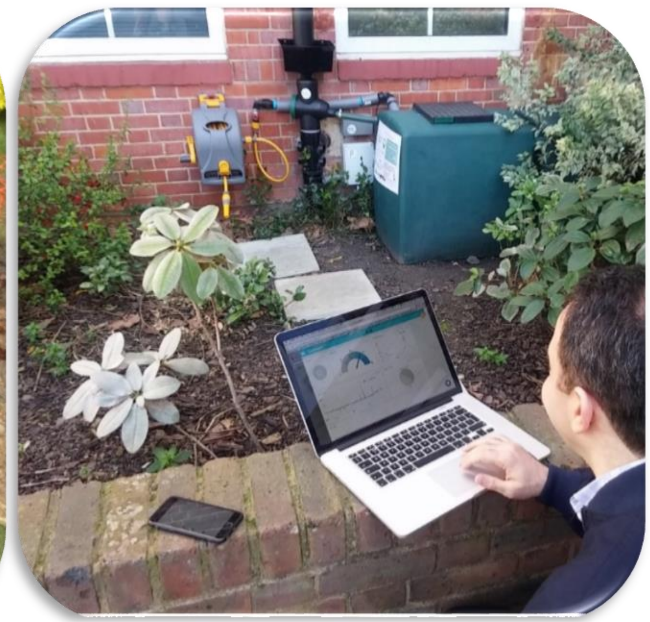
Non-polluting XXX

Low energy XX

Reusable XX

Simple X

Active control RMS

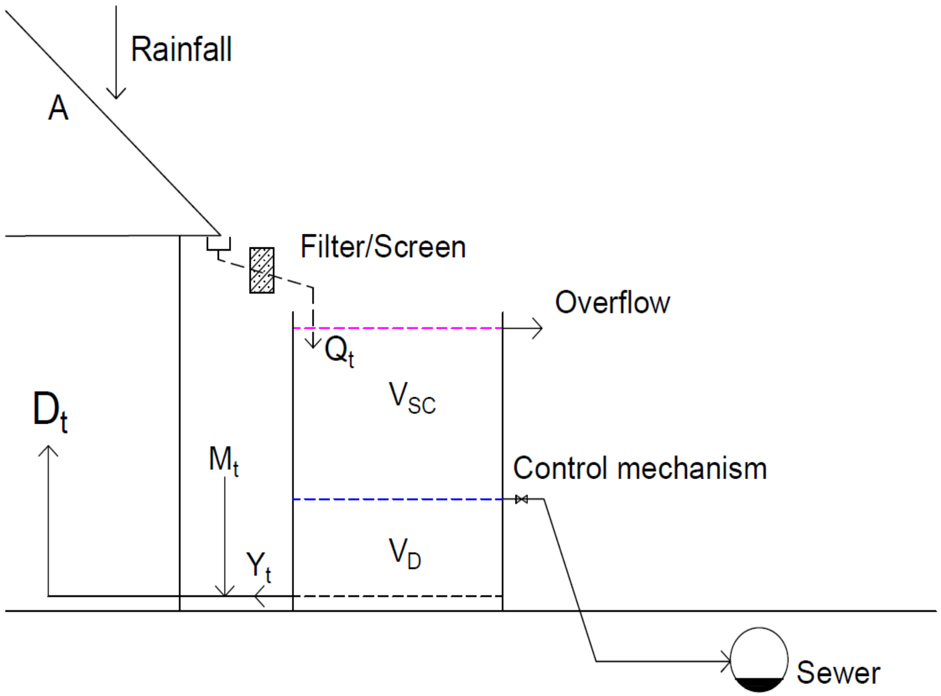


Rezaei, H., Melville-Shreeve, P. & Butler, D. 2017. Smart Rainwater Management Systems Powered by the Internet of Things: a UK Case Study, CCWI17 – Computing & Control for the Water Industry, Sheffield, 5th-7th September.

How well do these RMS systems perform?

- Dwelling located in **Newcastle**, UK
- One year evaluation:
  - Rainfall: Environment Agency (2012)
  - Non-potable water demand = 50 L/day per person (150L/day total)
- Dwelling:
  - Roof area + 100 m^2 (0.9 runoff coefficient)
  - Occupancy = 3 persons
- Storage tank volume = 3000 L
- Design based on three cases

Model set-up



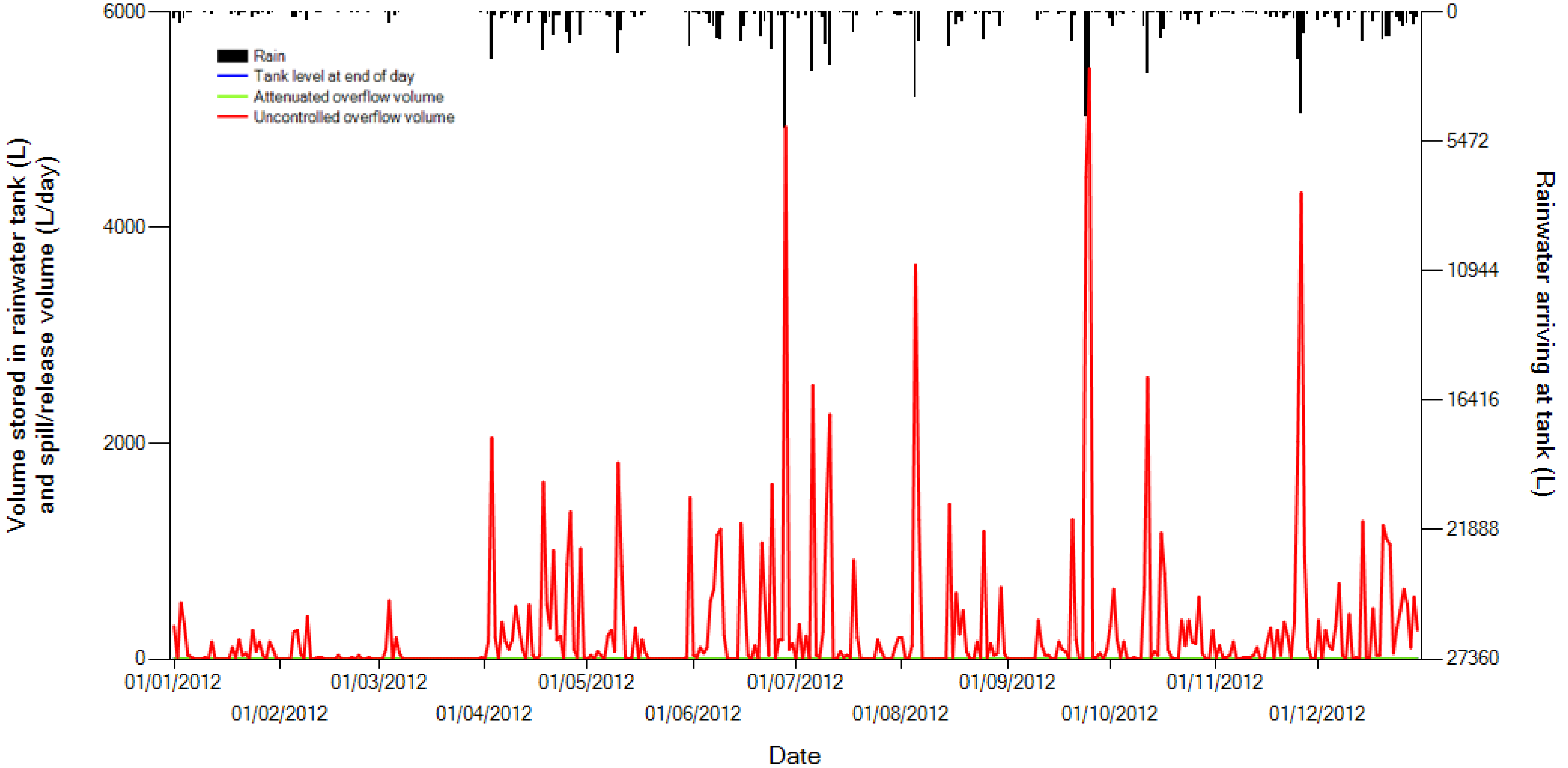
Three cases considered:

1. **Standard [1]:** water supply plus indirect stormwater management – single 'oversized' tank ($V= V_D+V_{SC}$)
2. **Passive [2]:** Water supply plus direct, passive stormwater management – two tanks (or tank compartments), 50/50 split ($V_D=V_{SC}$).
3. **Active [3]:** Water supply plus direct, active stormwater management – one tank designed to be operated actively (V).

Rainwet model: daily supply-demand balance of rainfall, water demand and overflow discharges based on "yield after spillage" (Fewkes and Butler, 2000).

Fewkes, A & Butler, D., 2000. Simulating the performance of rainwater collection and reuse systems using behavioural models, Building Services Engineering Research & Technology, 21, 2, 99-106.

No water demand met, 100% discharge to sewer



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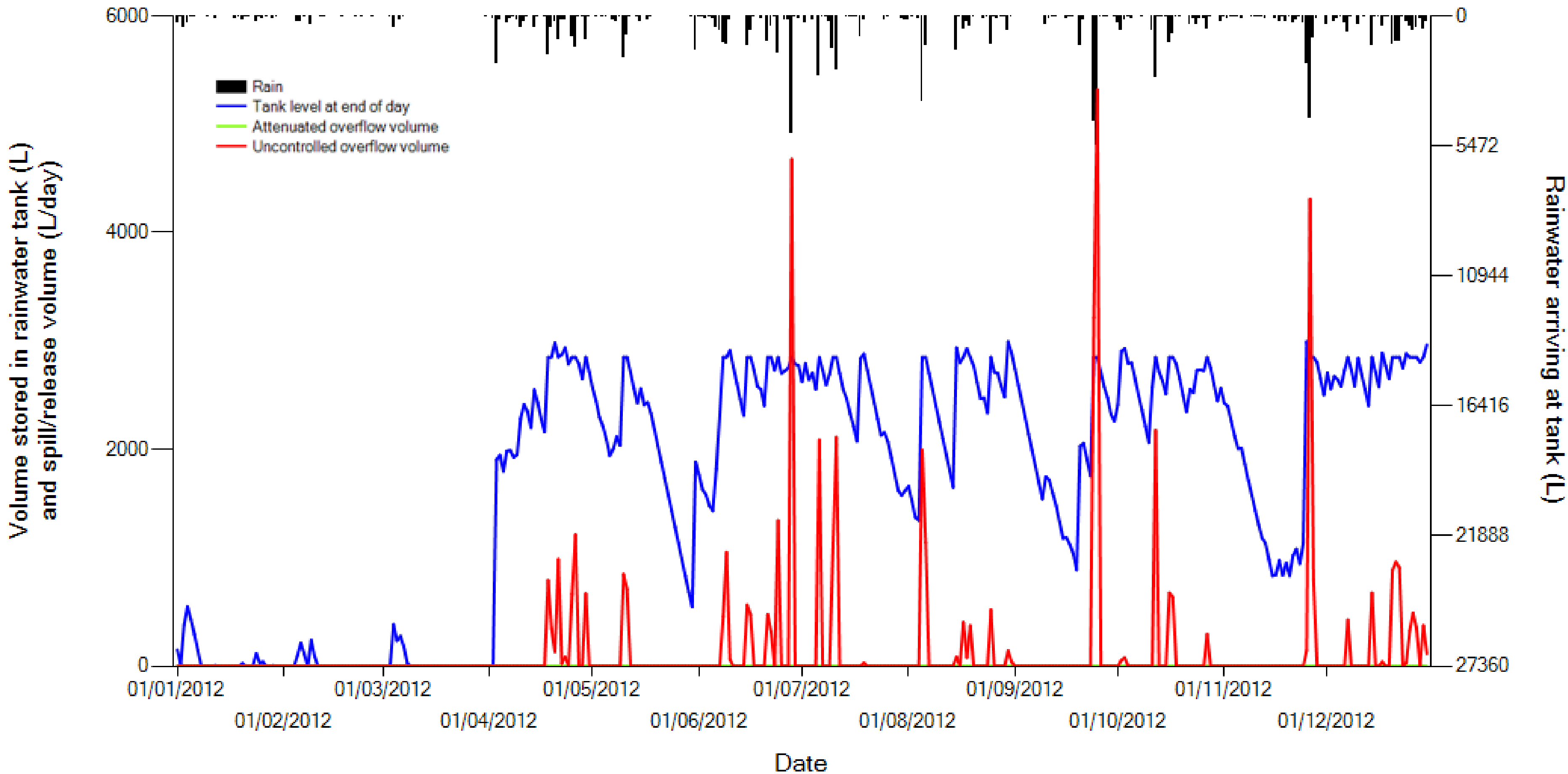
Water supply plus indirect stormwater management: Type 1



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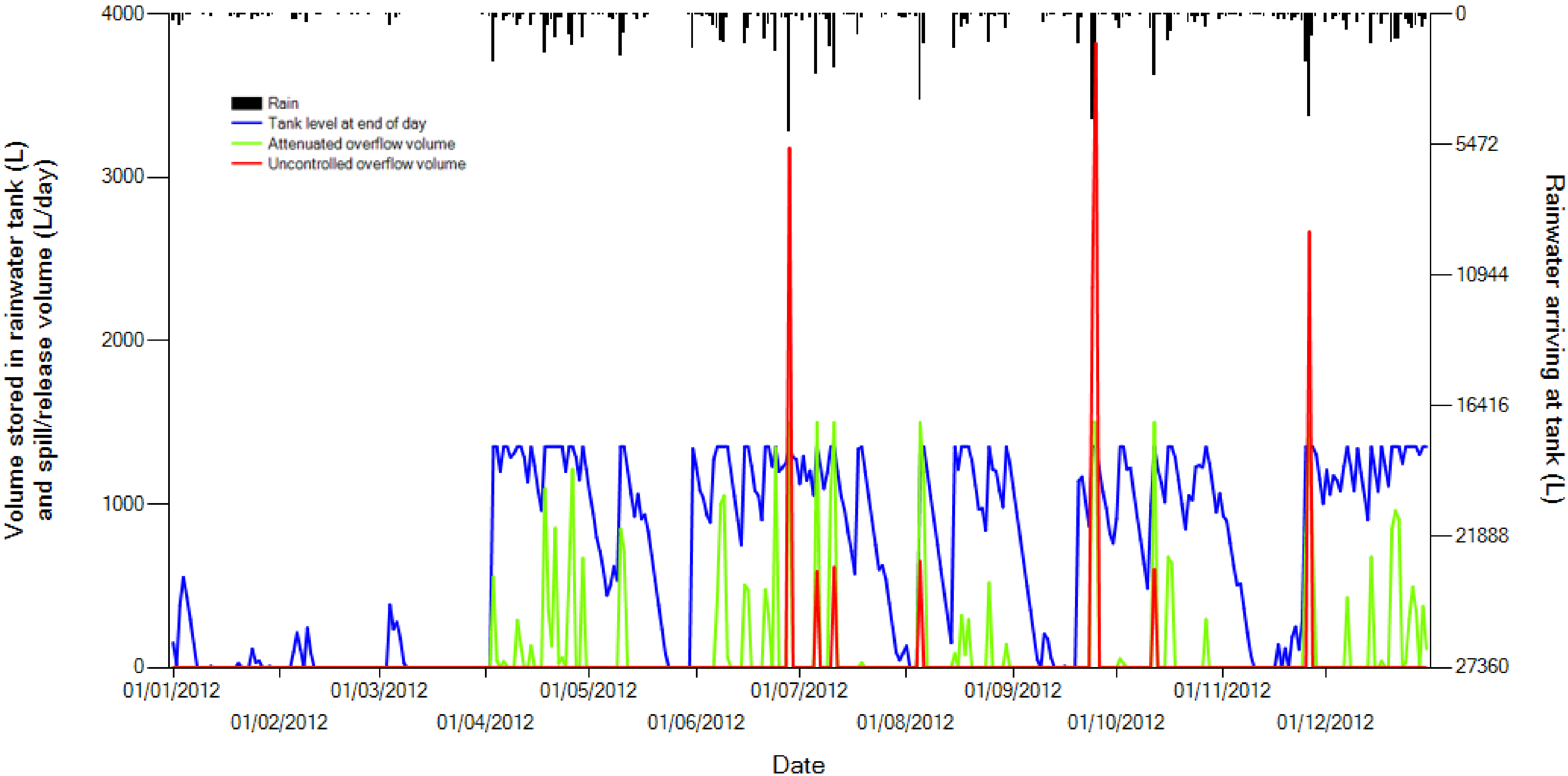
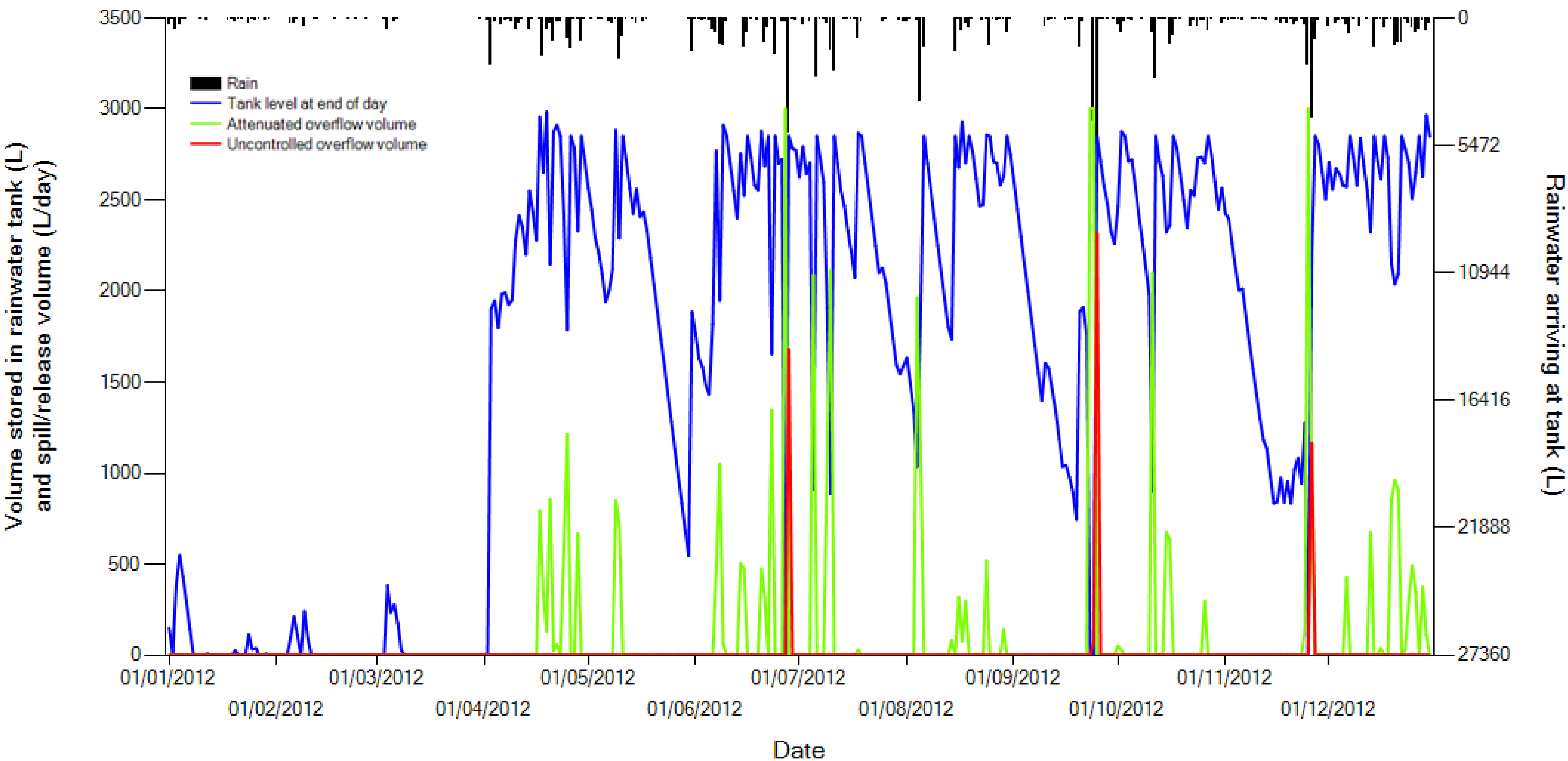
Water supply plus direct, passive stormwater management: Type 2



Water supply plus direct, active stormwater management: Type 3



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No red = no spills

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Newcastle results

RMS performance	Newcastle (2012)					
Type	1	2	3			
Total rainfall (mm)		1085				
Demand met (%)	**82.9**	**78.3**	**82.9**			
Demand met (m^3)	45.44	42.89	45.44			
Stormwater discharge reduction (%)	**49.5**	**85.2**	**94.6**			
Stormwater discharge reduction (m^3)	48.26	83.05	92.23			
Stormwater discharge reduction of max daily event (%)	**2.8**	**30.2**	**57.7**			
Stormwater discharge reduction of maximum daily event (m^3)	0.16	1.66	3.16			

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Newcastle & Exeter results

RMS performance	Newcastle (2012)			Exeter (2017)		
Type	1	2	3	1	2	3
Total rainfall (mm)	1085			1039		
Demand met (%)	**82.9**	**78.3**	**82.9**	**97.6**	**93.3**	**97.6**
Demand met (m^3)	45.44	42.89	45.44	53.5	51.1	53.5
Stormwater discharge reduction (%)	**49.5**	**85.2**	**94.6**	**59.2**	**99.5**	**100**
Stormwater discharge reduction (m^3)	48.26	83.05	92.23	55.4	93.1	93.5
Stormwater discharge reduction of max daily event (%)	**2.8**	**30.2**	**57.7**	**7.9**	**84.6**	**100**
Stormwater discharge reduction of maximum daily event (m^3)	0.16	1.66	3.16	0.2	1.7	2.0

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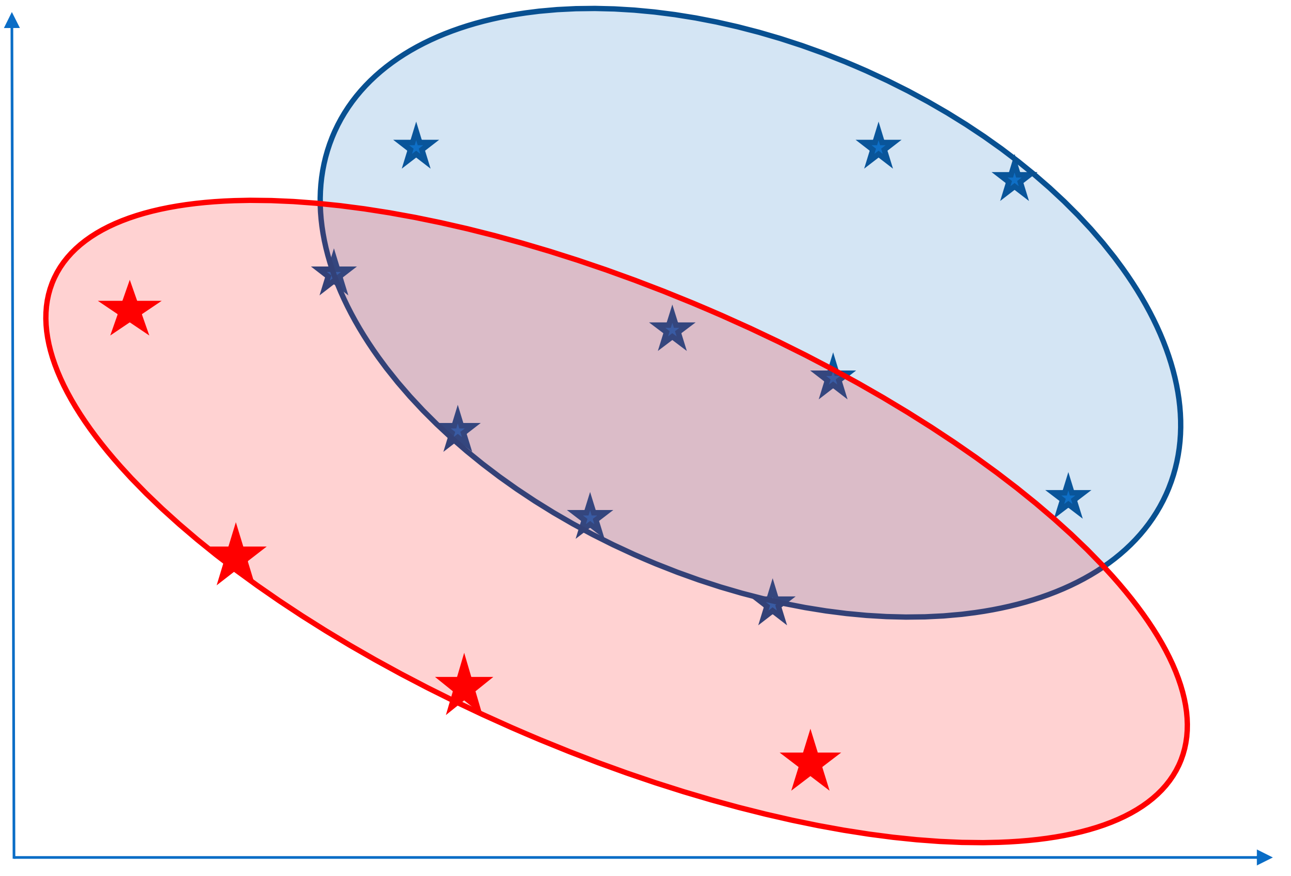
RWH to RMS

Decreasing whole life benefit



Increasing whole life cost

Conclusions

- **All** RMS systems deliver water saving benefits **AND** stormwater benefits to varying degrees.
- Where **supply is high relative to demand (e.g. Exeter)**, tanks are likely to be emptied less frequently so water supply **yield is higher.**
- Where **supply is low relative to demand (e.g. Newcastle)**, tanks are likely to be emptied more frequently so water supply **yield is lower**, but this provides greater potential for **stormwater control**.
- **Passive** and particularly **active** control provides improved performance, w.r.t. **stormwater** management, especially **peak flows.**
- Other benefits can be achieved by design & operation optimisation: **pollution control** (CSO reduction), **climate change adaptation** (variable tank splits), **resilience enhancement** (supply failure) and reduction in **urban heat island** effects.
- **Multi-functional, multi-benefit systems** are the future as exemplified by rainwater management systems.

Acknowledgement

The research in this presentation is being conducted as part of the Urban Flood Resilience Research Consortium with supported from: