Ensuring water availability with complete urban water modelling

Climate, water and health

HS7.3/CL3.7/NP1.4

Evangelos Rozos
Christos Makropoulos

National Technical University of Athens

Presentation structure

Urban Water Optioneering Tool (UWOT)

- Introduction
- Implementation
- Assessment
- Optimization

UWOT applications

- Water recycling in different climatic conditions
- Natural hydrosystem flow-pattern restoration
- Water scarcity in a small island
- Assessing health risk from water storage with RTI

Beyond the state-of-art

- Integration with other models

Description of UWOT (introduction)

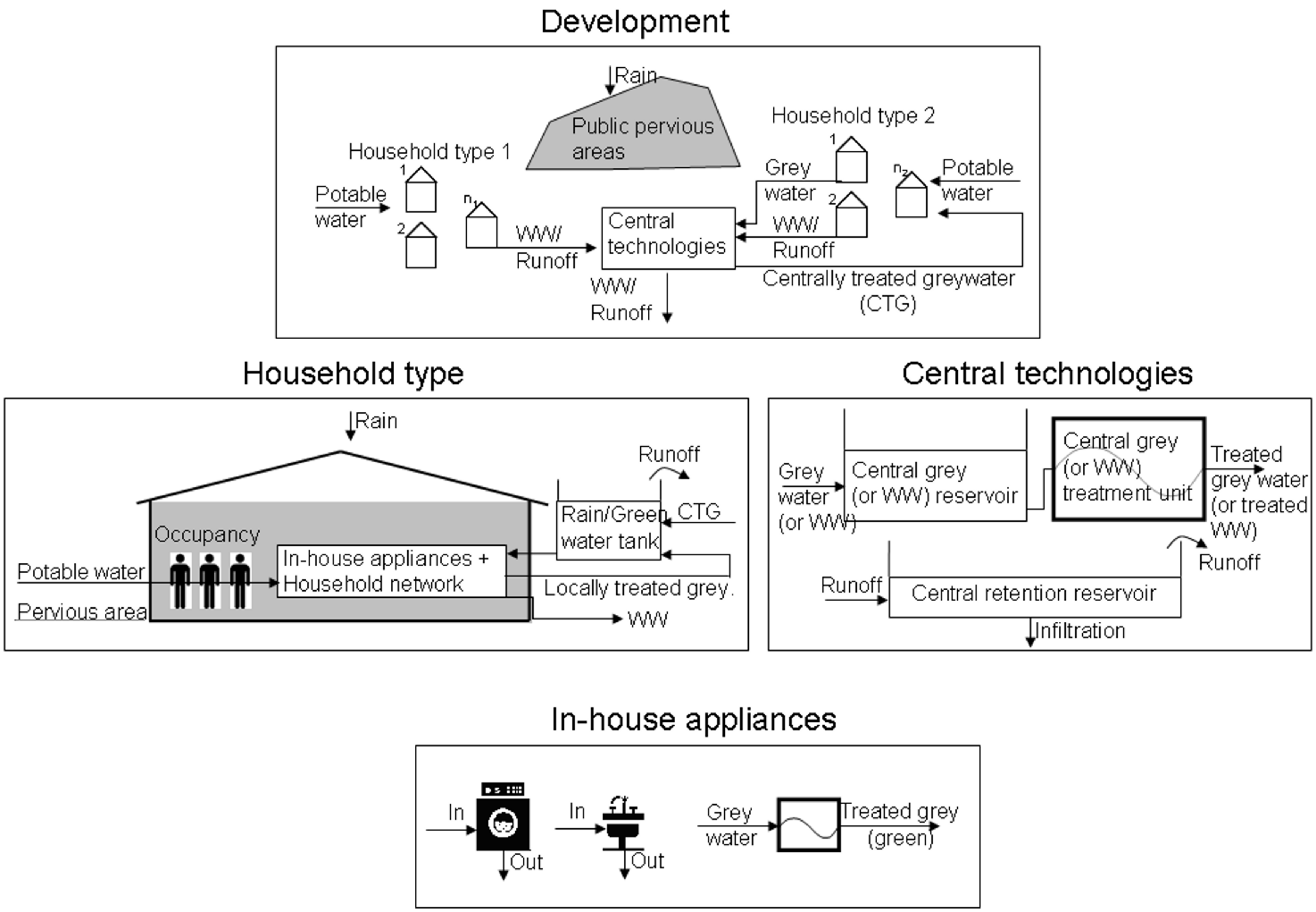
UWOT simulates the urban water cycle by modelling individual water uses and technologies and aggregates their combined effects at development scale.

Description of UWOT (introduction)

Higher level

Middle level

Lower level



Description of UWOT (introduction)

Appliances

1. Washing Machine
2. Toilet
3. Treatment
4. Shower
5. Bath
6. Hand-basin
7. Kitchen Sink
8. Dish Washer
9. Garden
10. Outside use
11. SUDS local

…

Central technologies

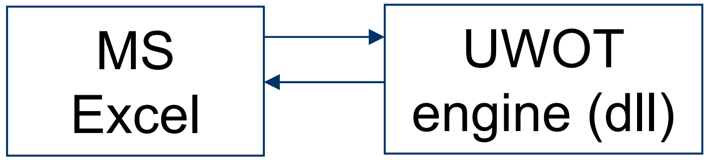
- Central treatment units
- Central SUDS

Technology library

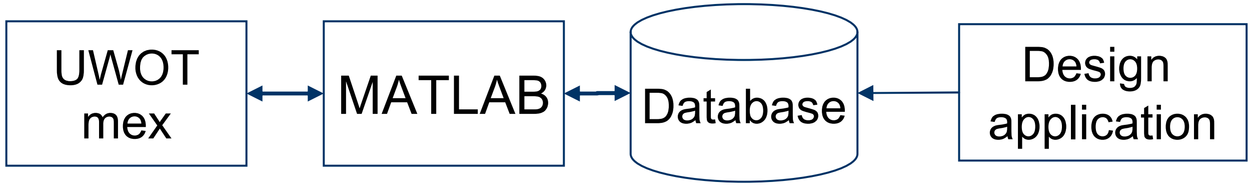
	Specification	Unit
Resources Utilisation	Water Usage	(l/use)
	Water Loss	(%)
	Energy Use	(kWh/use)
	Chemical Use	
	Land Use	(m^2)
Economic parameters	Willingness to pay	
	Capital Cost	(£)
	Operational Cost	(£/use)
Social parameters	Risks to human health	
	Acceptability	
	Public Awareness	
	Social Inclusion	
Technical parameters	Reliability	
	Durability	
Operational Parameters	Frequency of use	(uses/p/d)
	Input Quality (Worst)	
	Output Quality	

Description of UWOT (implementation)

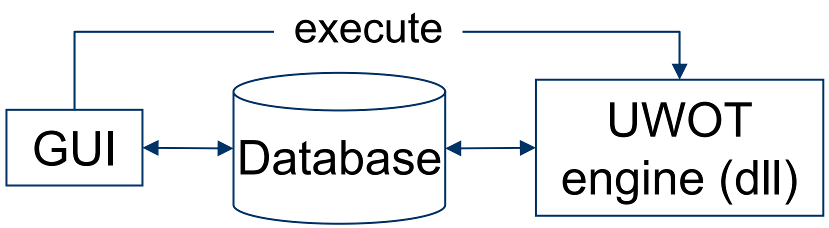
Current version



New academic version



Future commercial version



Description of UWOT (assessment)

UWOT assesses the sustainability of a development water cycle through the use of sustainability indicators.

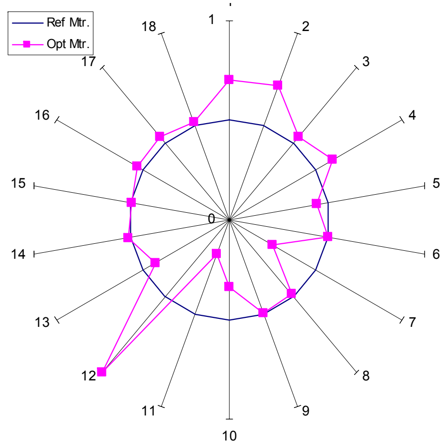
Indicator	**Type**	**Aggregation method**
Potable	Quantitative	Summation
Runoff	Quantitative	Summation
WW disch.	Quantitative	Summation
Energy	Quantitative	Summation
Landuse	Quantitative	Summation
Cap. cost	Quantitative	Summation
Op. cost	Quantitative	Summation
WW qual.	Qualitative	Mix
Chemical	Qualitative	Summation
RTI	Qualitative	-
Will. To pay	Qualitative	Summation
Acceptabl.	Qualitative	Summation
Publ. awarn.	Qualitative	Summation
Social incl.	Qualitative	Summation
Reliability	Qualitative	Summation
Durability	Qualitative	Summation
Flexibility	Qualitative	Summation

Description of UWOT (optimization)

Single objective optimization (SOGA)

$\min \sum w_i O_i(\mathbf{x})$

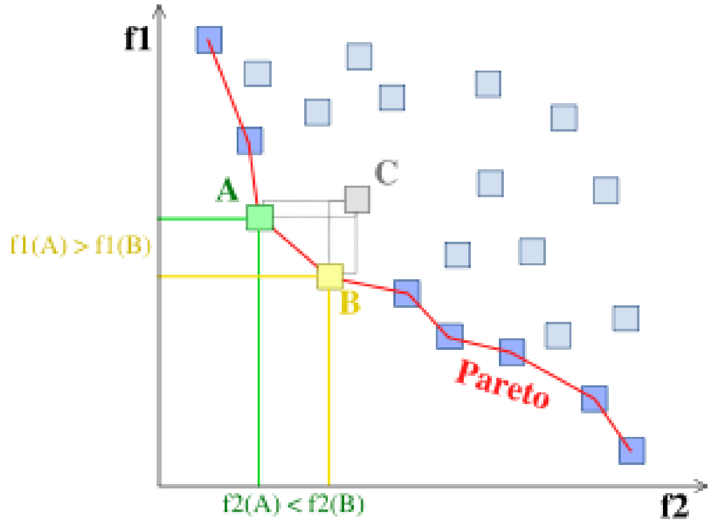
Where: **x** is the decision variables vector, **w**=$(w_1, w_2, \ldots, w_n)$ is the preference vector and O_i is the standardize value of the i^{th} indicator.



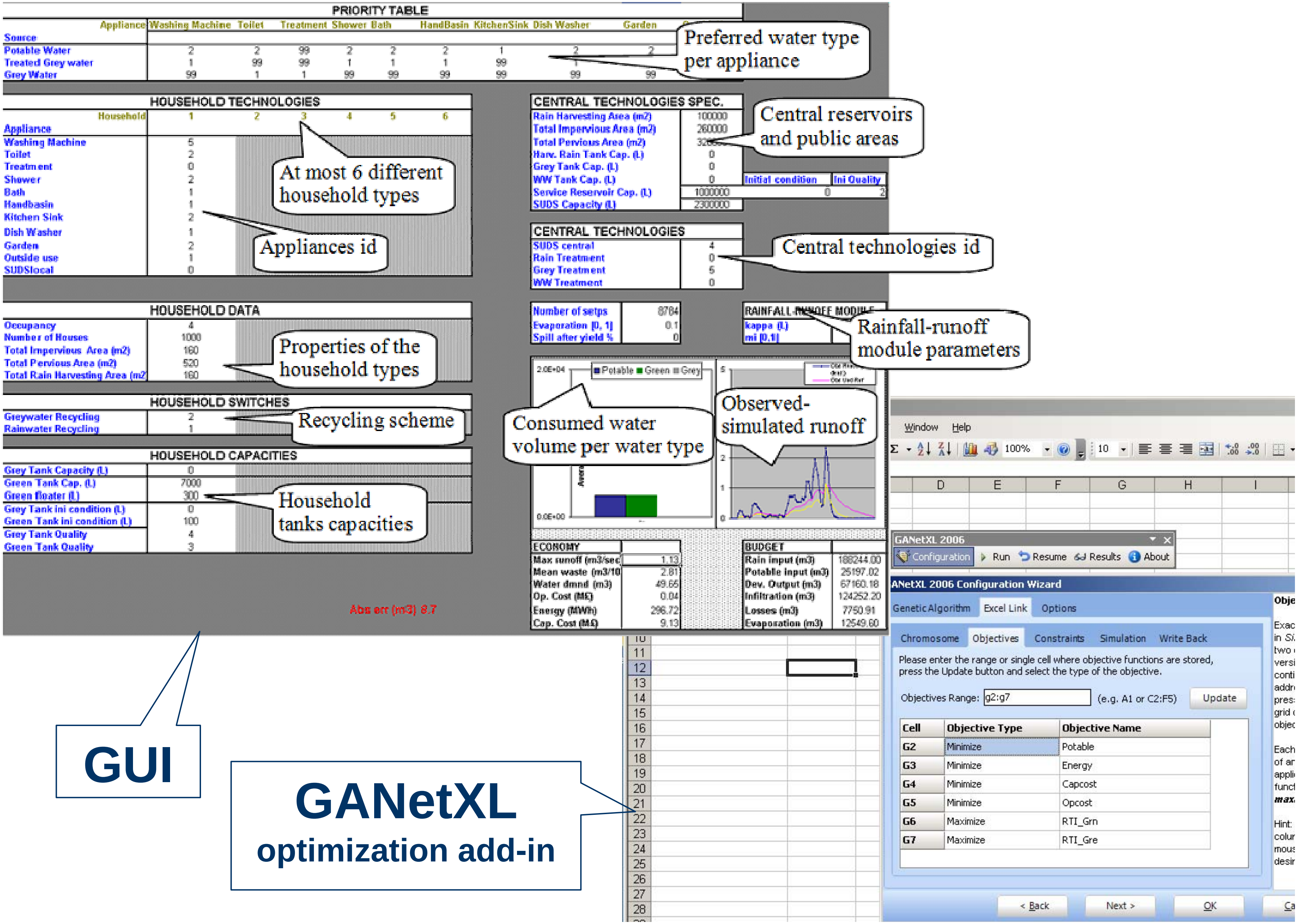
Multi-objective optimization (MOGA)

$\min [O_1(\mathbf{x}), O_2(\mathbf{x}), .. O_n(\mathbf{x})]$

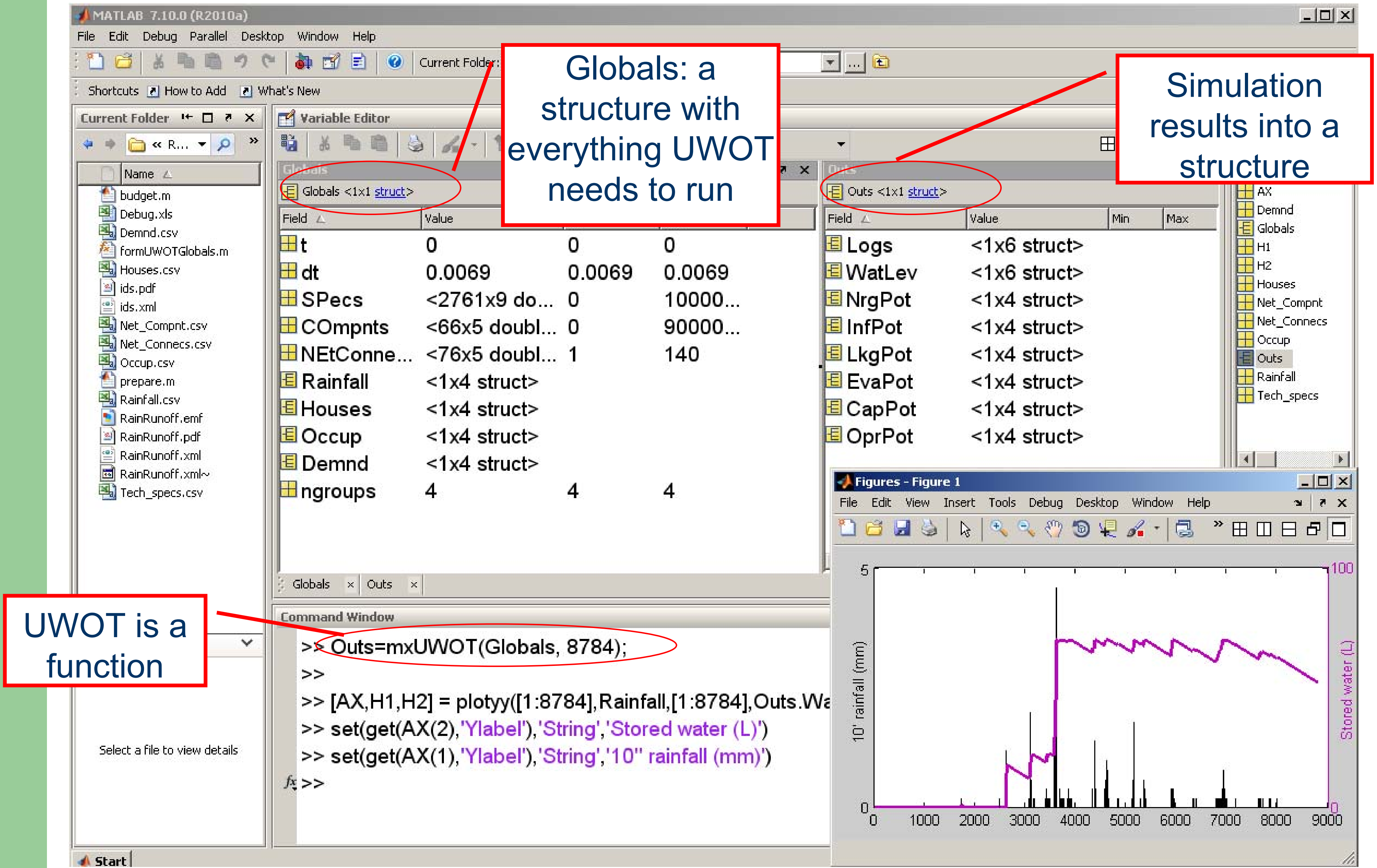
The solution to the above problem is a set of Pareto points.



Description of UWOT (GUI-current ver.)



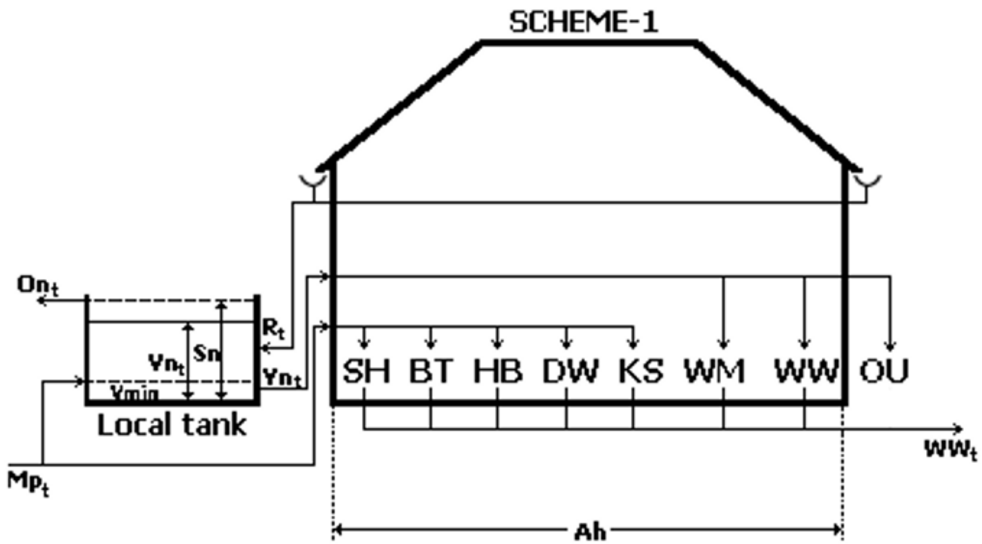
Description of UWOT (GUI-new ver.)

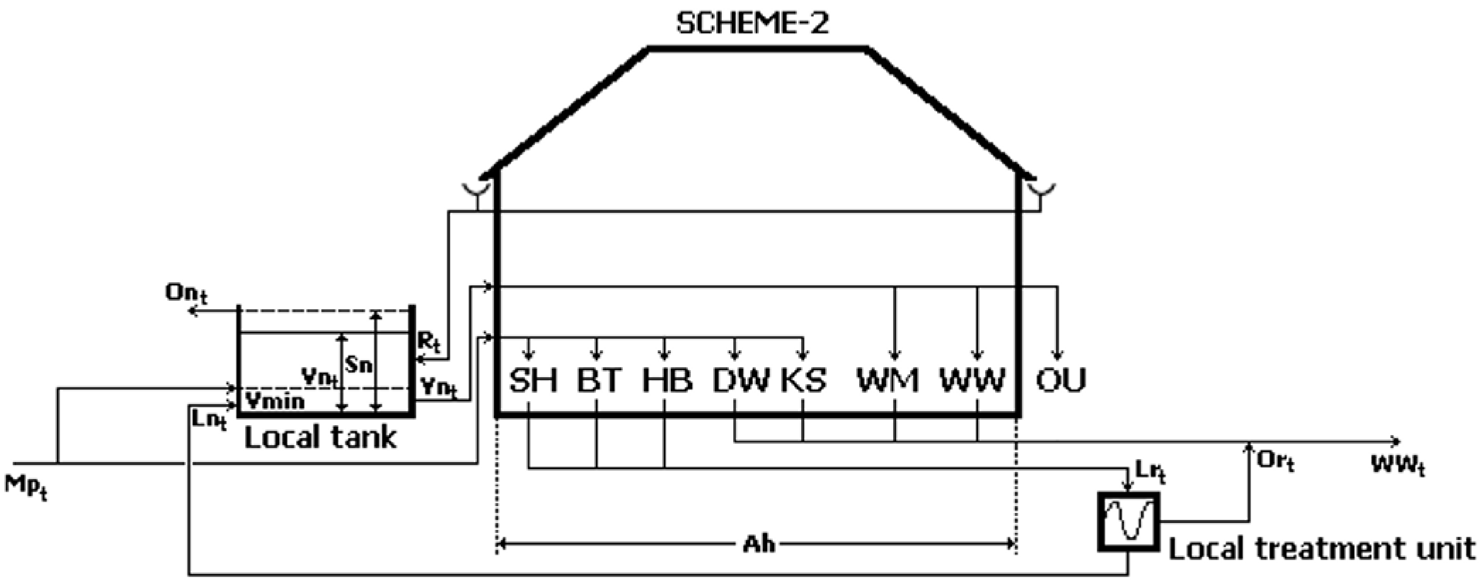


UWOT application 1

Two water recycling schemes are optimized under three different climatic conditions: humid (Cfb), Mediteranean (Csa) and arid (BWh).

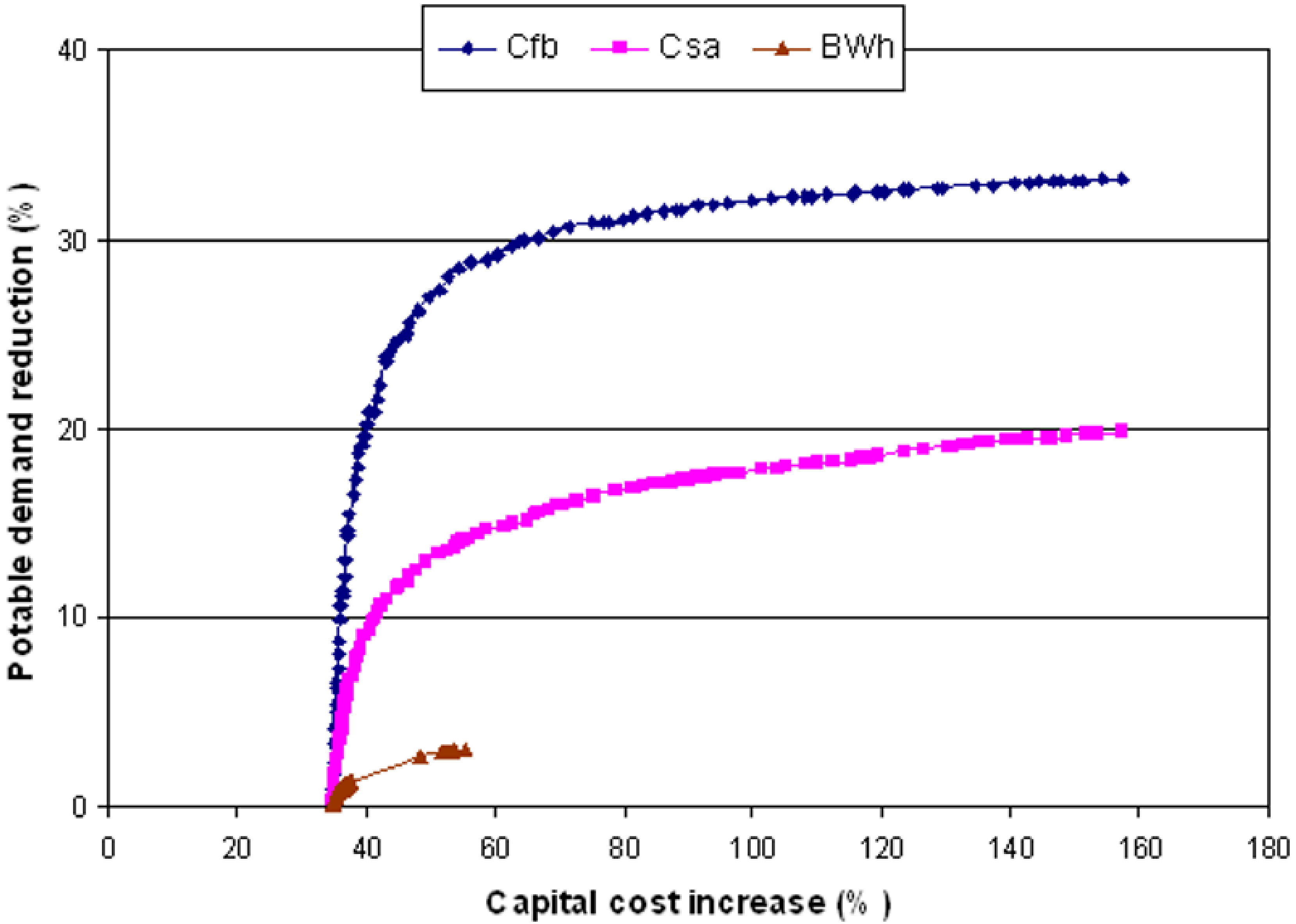
UWOT application 1 (recycling schemes)



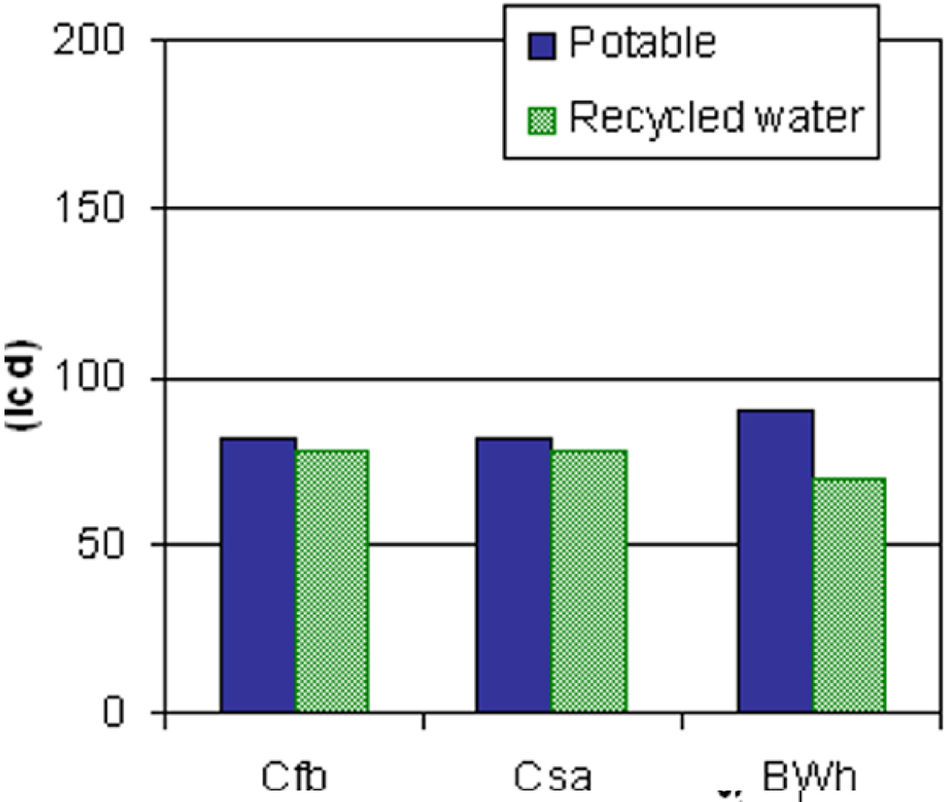


UWOT application 1 (Results)

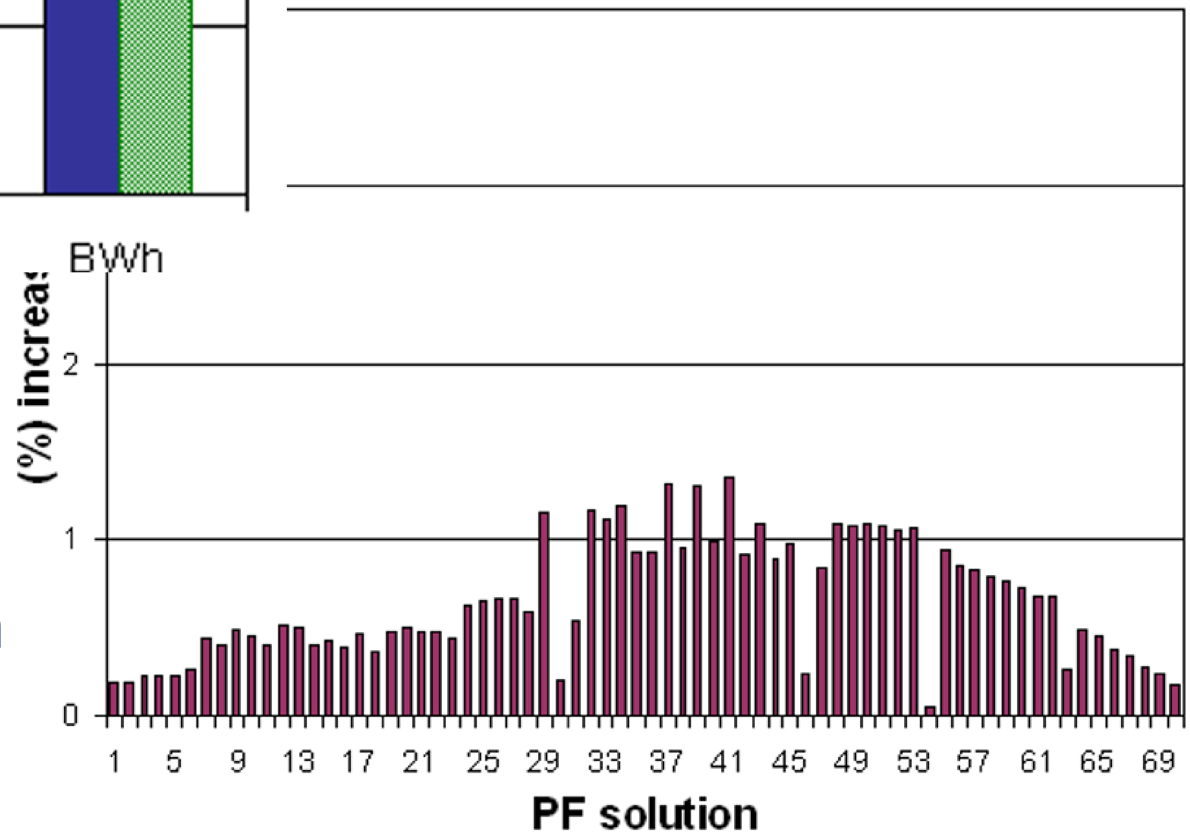
Pareto front of scheme 1



UWOT application 1 (Results)



Scheme 2 solutions with min potable demand



Scheme 2, 20% reduction of rainfall

UWOT application 2

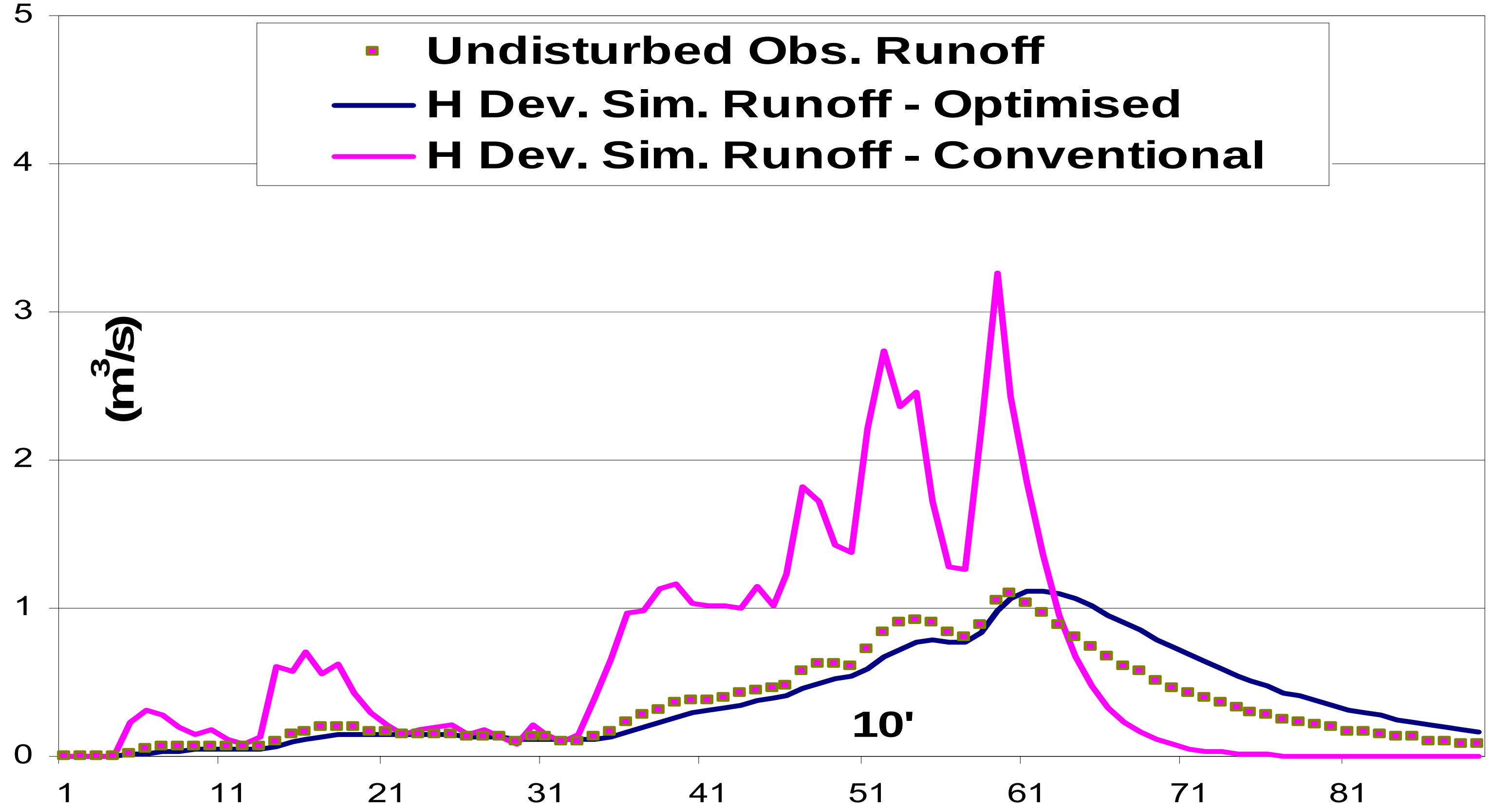
The runoff from two hypothetical developments, one with high (H) and one with low (L) urban density is investigated with UWOT.

The households of these developments implement a rainwater harvesting scheme (like scheme 1 presented previously).

The aim is to **restore the rainfall-response** to the pre-urbanization form and to minimize the potable water demand.

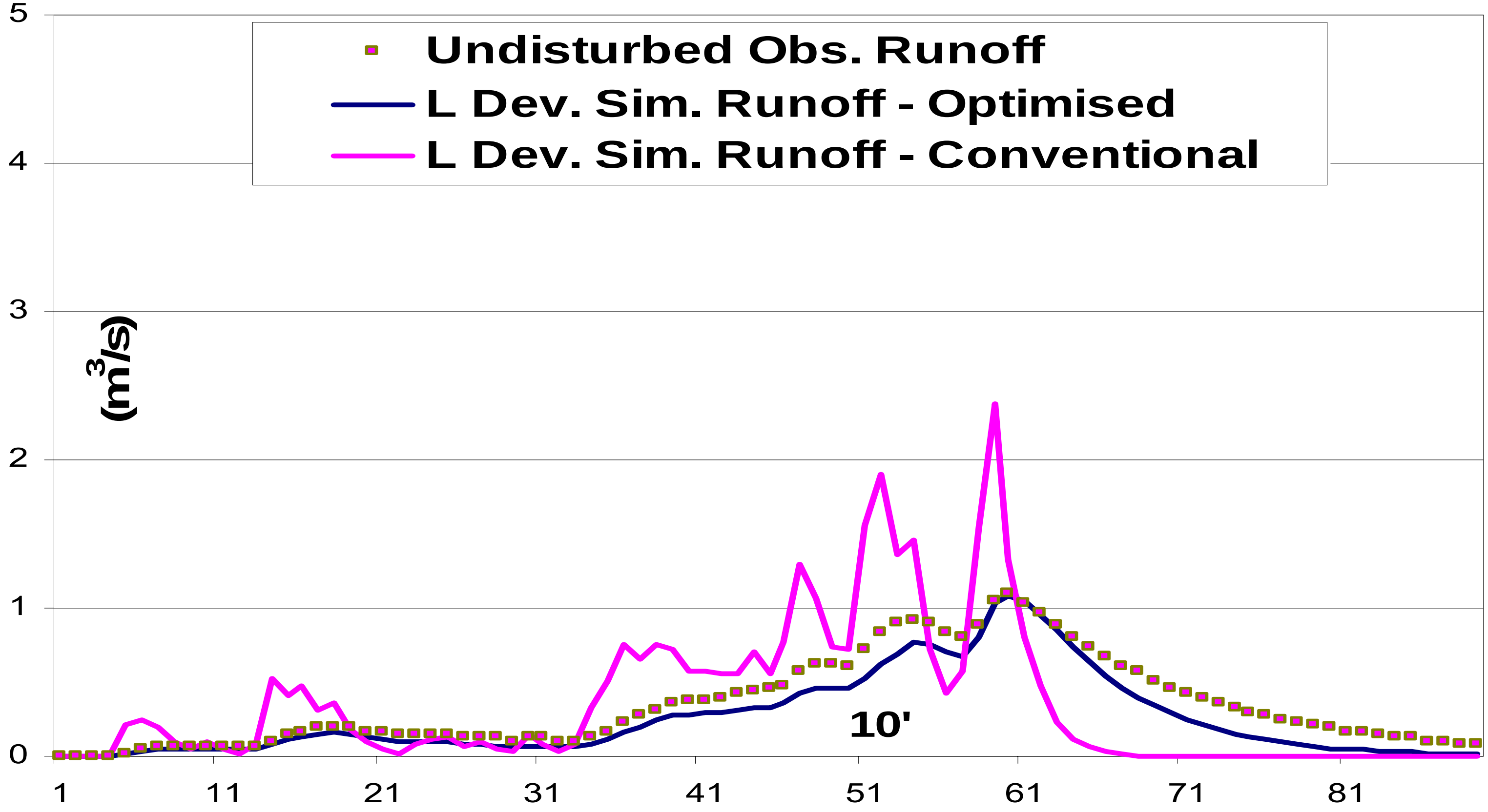
UWOT application 2 (Results)

	Conventional development H	Optimized development H
Maximum runoff (m^3/s)	3.26	1.12
Potable water demand (m^3/d)	1116	834



UWOT application 2 (Results)

	Conventional development L	Optimized development L
Maximum runoff (m^3/s)	2.38	1.09
Potable water demand (m^3/d)	563	413

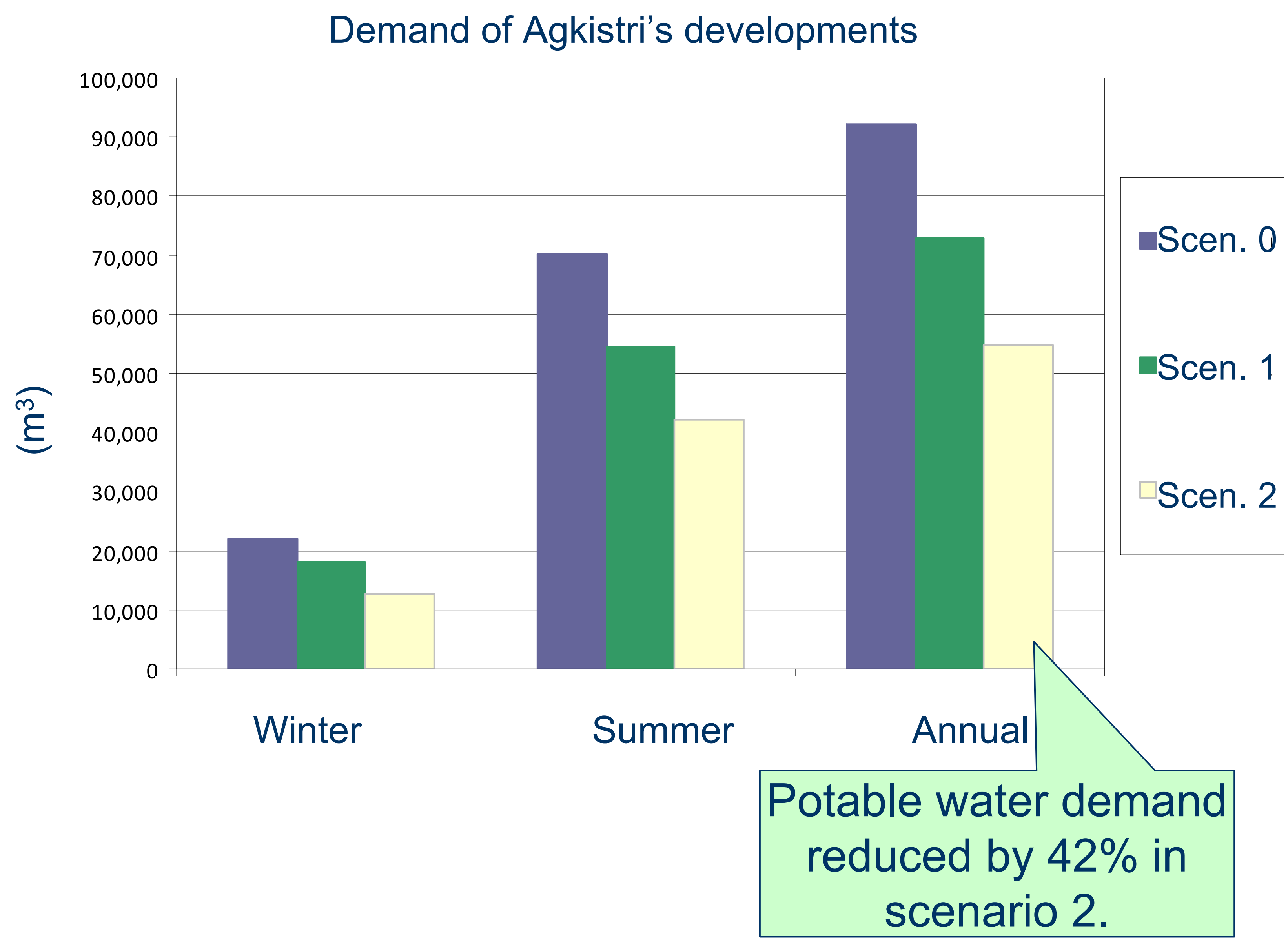


UWOT application 3

Retro-fit solutions for potable water demand reduction in a small, water scarce island in Greece (Agkistri) was examined.

UWOT assessed the benefits of replacing conventional water appliances with low consumption ones (scenario 1) as well as the benefits of implementing greywater recycling (scenario 2).

UWOT application 3 (Results)



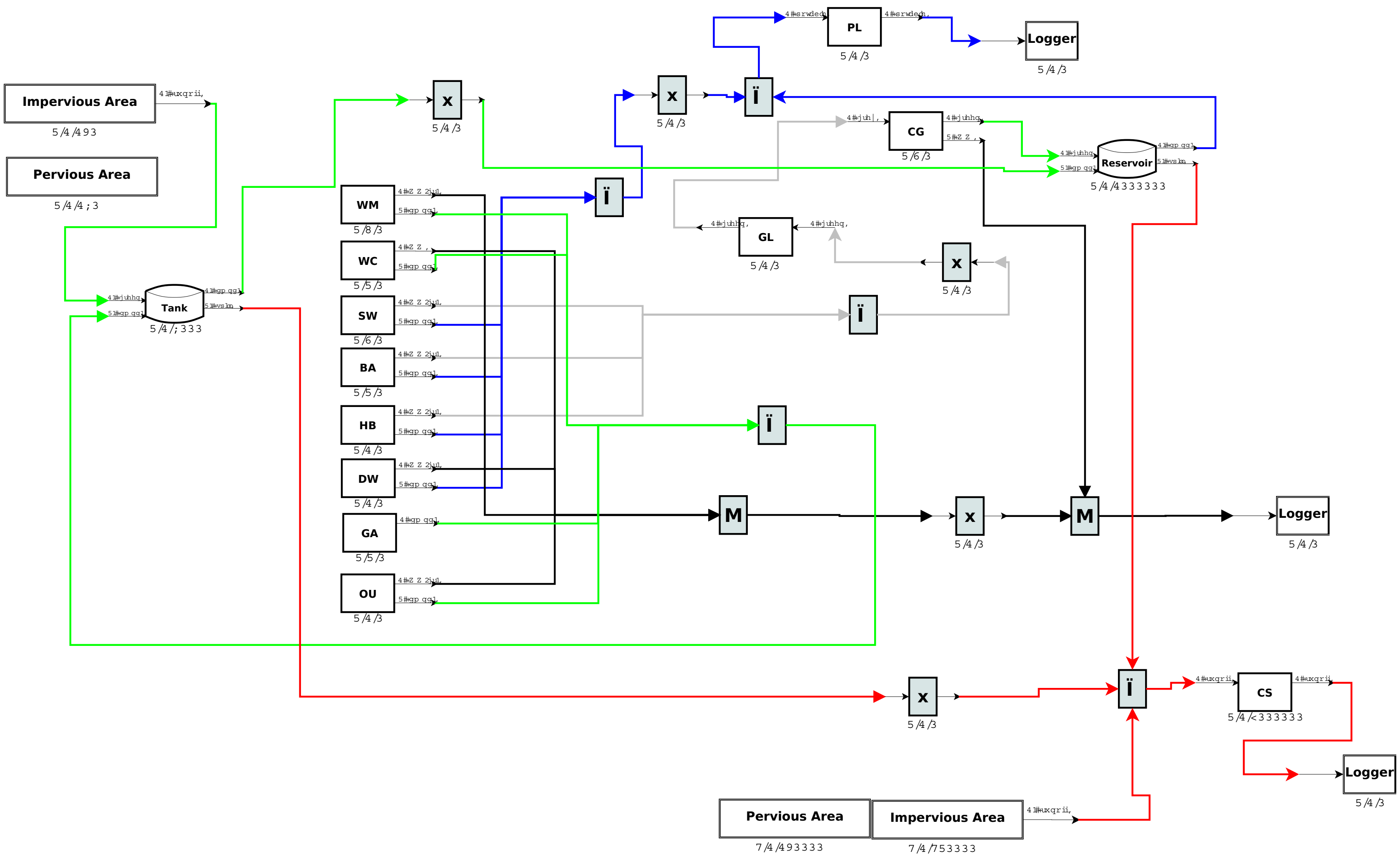
UWOT application 4 (Results)

The probability of the Residence Time (RT) to be less than 2 days may be used as a hazard index for the water quality degradation due to prolonged storage. The RT changes continuously along with the water level fluctuation. For this reason a probabilistic approach is recommended.

The RT Index (RTI) is estimated numerically in UWOT with the formula:

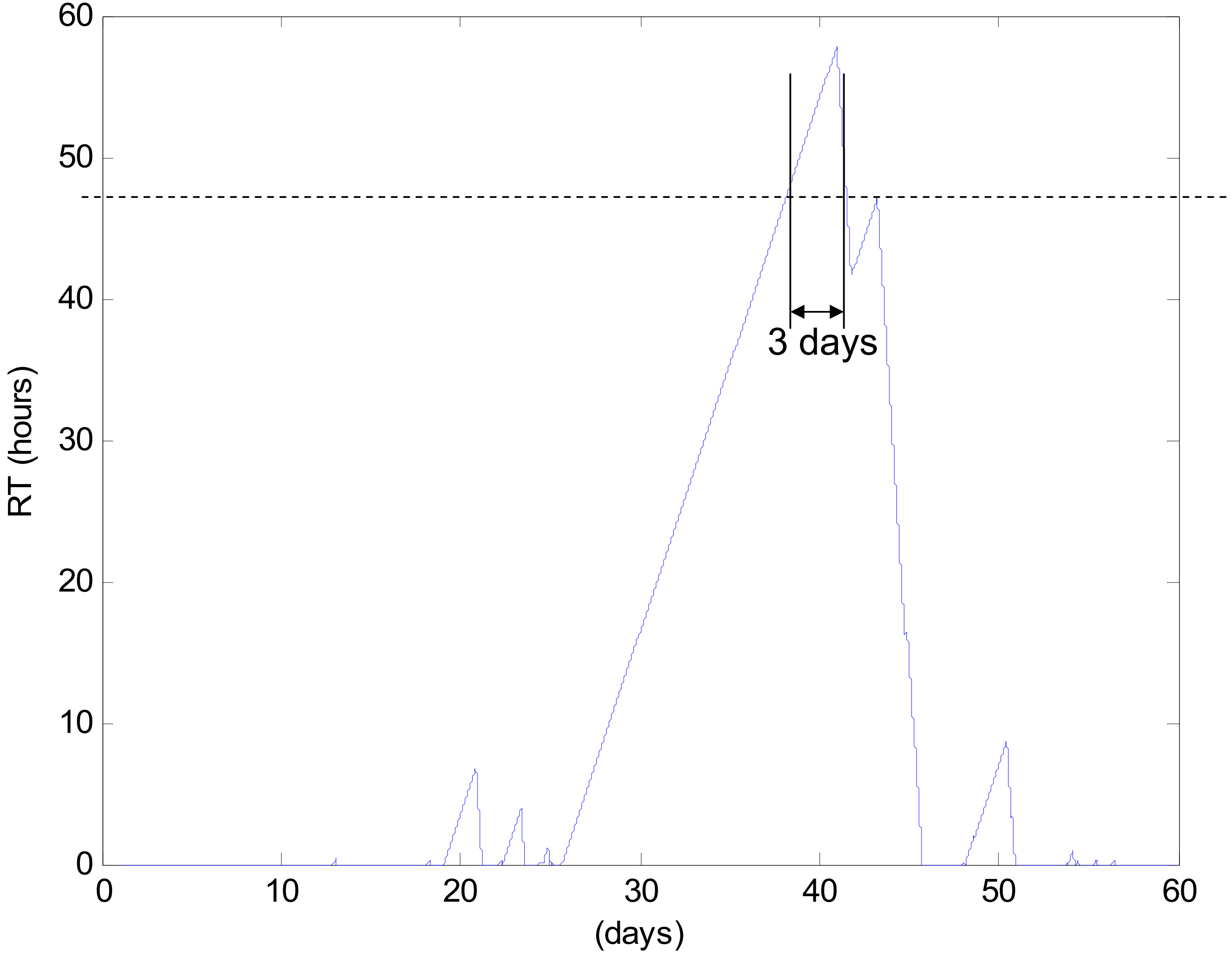
$$\mathrm{RTI} = \frac{\text{Number of days with RT<2}}{\text{Number of days of simulation}}$$

UWOT application 4 (Results)



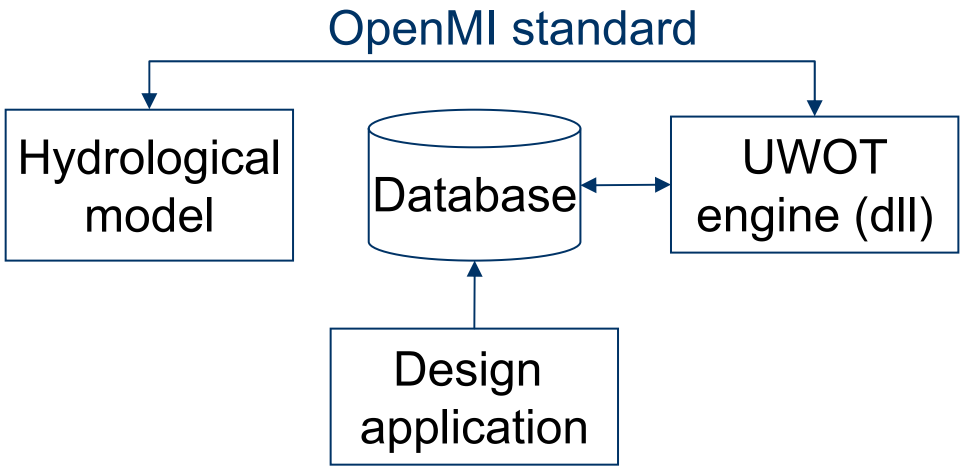
UWOT application 4 (Results)

The Residence Time (RT) of the central reservoir is (60-3)/60=0.95.



Beyond the state-of-art (integration)

UWOT will be linked with a hydrological model to provide.



Sustainable (green) urban growth. UWOT will be integrated with a land-use model based on cellular automata to study the interactions between urbanization and the urban water infrastructure.

References

- Bicik, J., Morley, M.S. & Savic, D.A. (2008): A Rapid Optimization Prototyping Tool For Spreadsheet-Based Models, Proceedings of the 10th Annual Water Distribution Systems Analysis Conference (WDSA2008), Kruger National Park, South Africa, pp 472-482.
- Liu, S., D. Butler, F.A. Memon, C. Makropoulos, L. Avery, B. Jefferson (2010): Impacts of residence time during storage on potential of water saving for grey water recycling system, Water Research, Volume 44, Issue 1, Pages 267-277
- Makropoulos, C. K., Natsis, K., Liu, S., Mittas, K., and Butler, D. (2008). “Decision support for sustainable option selection in integrated urban water management.” Environ. Modell. Software, 23(12), 1448–1460.
- Makropoulos, C.K., Morley, M., Memon, F.A., Butler, D., Savic, D. and Ashley, R. (2006). A Decision Support Framework for Sustainable Urban Water Planning and Management in New Urban Areas, Water Science & Technology, 54, 6-7, pp. 451-458.
- Rozos, E., C. Makropoulos, and D. Butler, Design robustness of local water-recycling schemes, Journal of Water Resources Planning and Management - ASCE, 136 (5), 531–538, doi:/10.1061/(ASCE)WR.19, 2010.
- Rozos, E., and C. Makropoulos, Assessing the combined benefits of water recycling technologies by modelling the total urban water cycle, International Precipitation Conference (IPC10), Coimbra, Portugal, 2010.