

Ensuring water availability with complete urban water modelling

Climate, water and health
HS7.3/CL3.7/NP1.4

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Presentation structure

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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)

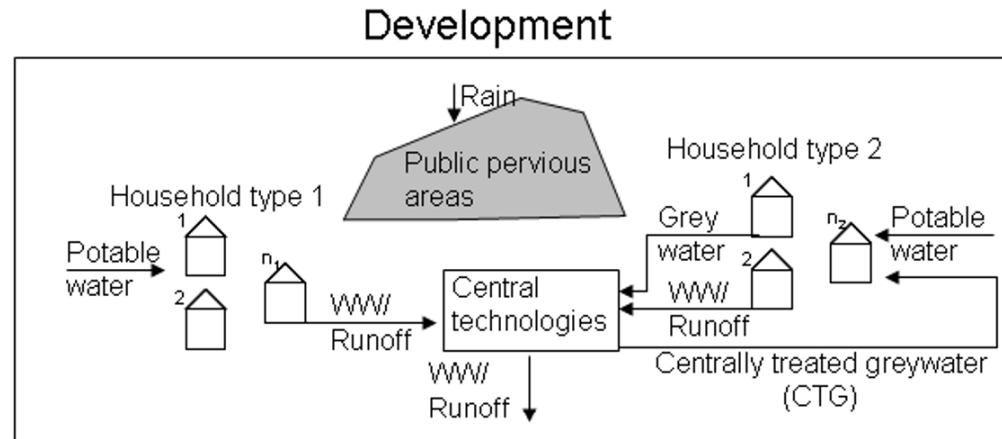
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UWOT simulates the urban water cycle by modelling individual water uses and technologies and aggregates their combined effects at development scale.

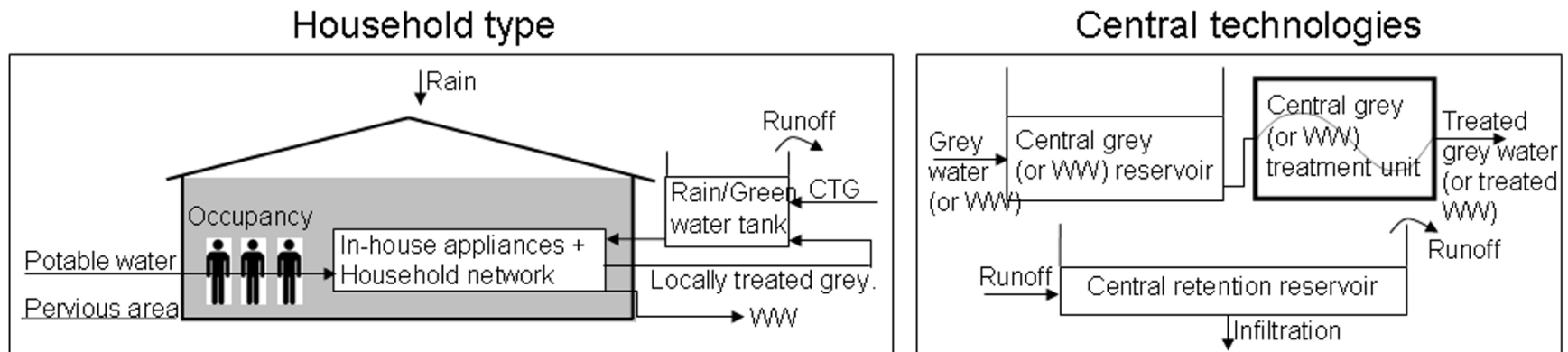
Description of UWOT (introduction)

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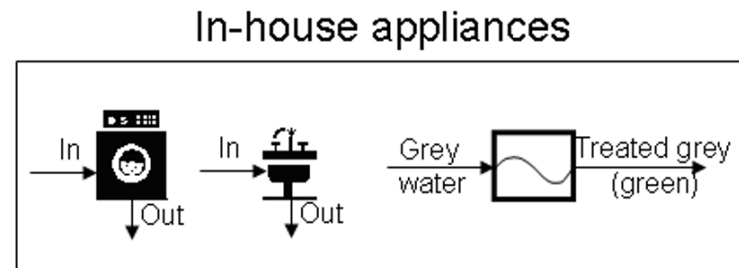
Higher level



Middle level



Lower level



Description of UWOT (introduction)

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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

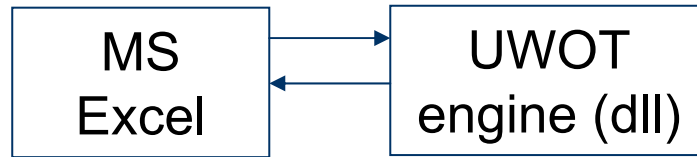
- Central treatment units
- Central SUDS

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	

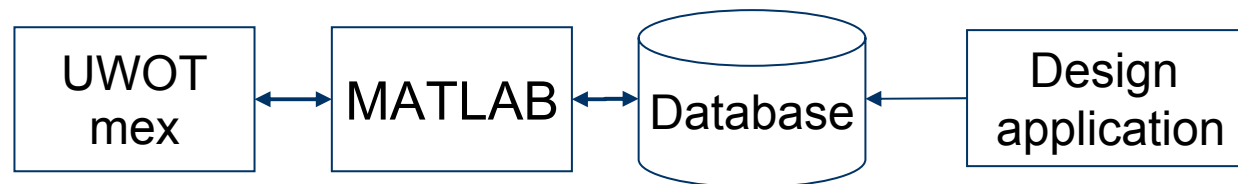
Description of UWOT (implementation)

Current version

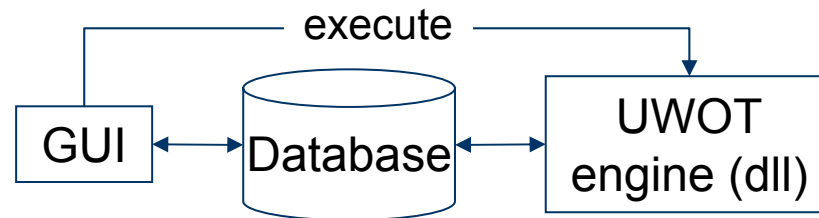


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New academic version



Future commercial version



Description of UWOT (assessment)

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

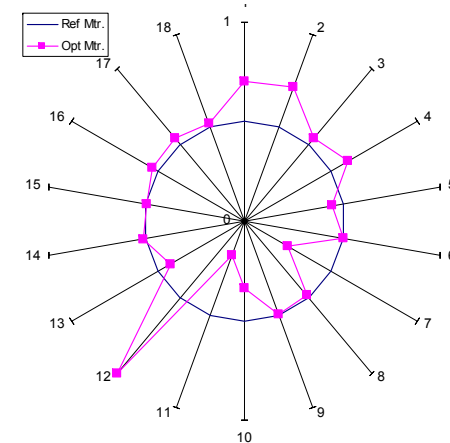
Indicator	Type	Aggregation method
Potable	Quantitative	Summation
Runoff	Quantitative	Summation
WW disch.	Quantitative	Summation
Energy	Quantitative	Summation
Landuse	Quantitative	Summation
Cap. cost	Quantitative	Summation
Op. cost	Quantitative	Summation
WW qual.	Qualitative	Mix
Chemical	Qualitative	Summation
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)

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

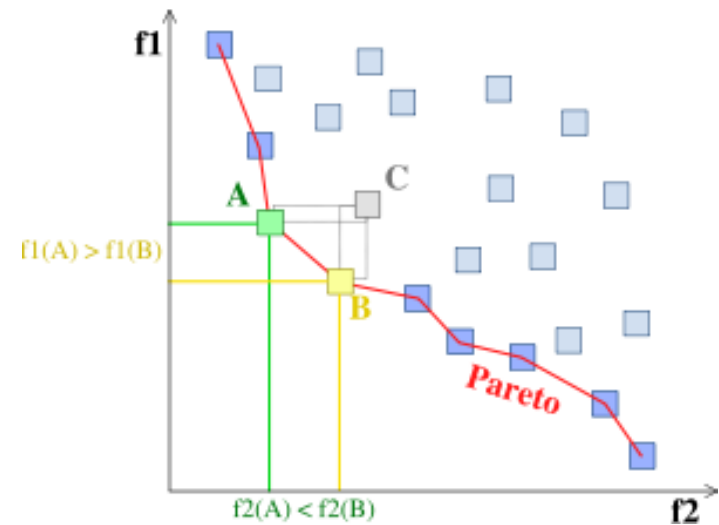
Where: \mathbf{x} is the decision variables vector,
 $\mathbf{w}=(w_1, w_2, \dots, w_n)$ is the preference vector and
 O_i is the standardize value of the i^{th} indicator.



Multi-objective optimization (MOGA)

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

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



Description of UWOT (GUI-current ver.)

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PRIORITY TABLE

Appliance	Washing Machine	Toilet	Treatment Shower Bath	HandBasin	KitchenSink	Dish Washer	Garden
Potable Water	2	2	99	2	2	1	2
Treated Grey water	1	99	99	1	1	1	99
Grey Water	99	1	1	99	99	99	99

HOUSEHOLD TECHNOLOGIES

Appliances	Household	1	2	3	4	5	6
Washing Machine		5					
Toilet		2					
Treatment		0					
Shower		2					
Bath		1					
Handbasin		1					
Kitchen Sink		2					
Dish Washer		1					
Garden		2					
Outside use		1					
SUDS local		0					

HOUSEHOLD DATA

Occupancy	4
Number of Houses	1000
Total Impervious Area (m2)	160
Total Pervious Area (m2)	520
Total Rain Harvesting Area (m2)	160

HOUSEHOLD SWITCHES

Greywater Recycling	2
Rainwater Recycling	1

HOUSEHOLD CAPACITIES

Grey Tank Capacity (L)	0
Green Tank Cap. (L)	7000
Green Buffer (L)	300
Grey Tank ini condition (L)	0
Green Tank ini condition (L)	100
Grey Tank Quality	4
Green Tank Quality	3

CENTRAL TECHNOLOGIES SPEC.

Rain Harvesting Area (m2)	100000
Total Impervious Area (m2)	260000
Total Pervious Area (m2)	300000
Harv. Rain Tank Cap. (L)	0
Grey Tank Cap. (L)	0
WW Tank Cap. (L)	0
Service Reservoir Cap. (L)	1000000
SUDS Capacity (L)	2300000

CENTRAL TECHNOLOGIES

SUDS central	4
Rain Treatment	0
Grey Treatment	6
WW Treatment	0

RAINFALL-RUNOFF MODULE

Number of sets	8704
Evaporation (L, H)	0.1
Spill after yield %	0

ECONOMY

Max runoff (m3/sec)	1.13
Mean waste (m3/10)	2.81
Water dried (m3)	49.66
Op. Cost (M\$)	0.04
Energy (MWh)	296.72
Cap. Cost (M\$)	9.13

BUDGET

Rain input (m3)	1000244.00
Potable input (m3)	25197.02
Dev. Output (m3)	67160.18
Infiltration (m3)	124252.20
Losses (m3)	7750.91
Evaporation (m3)	12549.60

Observed-simulated runoff

Consumed water volume per water type

Abx err (m3) 8.7

Preferred water type per appliance

Central reservoirs and public areas

At most 6 different household types

Appliances id

Central technologies id

Properties of the household types

Rainfall-runoff module parameters

Recycling scheme

Consumed water volume per water type

Observed-simulated runoff

Household tanks capacities

GUI

GANetXL optimization add-in

GANetXL 2006 Configuration Wizard

Genetic Algorithm Excel Link Options

Chromosome Objectives Constraints Simulation Write Back

Please enter the range or single cell where objective functions are stored, press the Update button and select the type of the objective.

Objectives Range: G2:G7 (e.g. A1 or C2:F5) Update

Cell	Objective Type	Objective Name
G2	Minimize	Potable
G3	Minimize	Energy
G4	Minimize	Capcost
G5	Minimize	Opcost
G6	Maximize	RTI_Grn
G7	Maximize	RTI_Gre

Each of an appli funct **max**

Hint: colour mouse desir

Description of UWOT (GUI-new ver.)

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The image displays the MATLAB 7.10.0 (R2010a) interface. The Variable Editor shows two structures: 'Globals' and 'Outs'. The 'Globals' structure contains fields for simulation parameters, and the 'Outs' structure contains simulation results. The Command Window shows the execution of the `mxUWOT` function and the plotting of the results. A plot titled 'Figure 1' shows rainfall (mm) as a bar chart and stored water (L) as a line graph over time.

Globals: a structure with everything UWOT needs to run

Field	Value	Min	Max
t	0	0	0
dt	0.0069	0.0069	0.0069
SPecs	<2761x9 do...>	0	10000...
COMpnts	<66x5 doubl...>	0	90000...
NEtConne...	<76x5 doubl...>	1	140
Rainfall	<1x4 struct>		
Houses	<1x4 struct>		
Occup	<1x4 struct>		
Demnd	<1x4 struct>		
ngroups	4	4	4

Simulation results into a structure

Field	Value	Min	Max
Logs	<1x6 struct>		
WatLev	<1x6 struct>		
NrgPot	<1x4 struct>		
InfPot	<1x4 struct>		
LkgPot	<1x4 struct>		
EvaPot	<1x4 struct>		
CapPot	<1x4 struct>		
OprPot	<1x4 struct>		

UWOT is a function

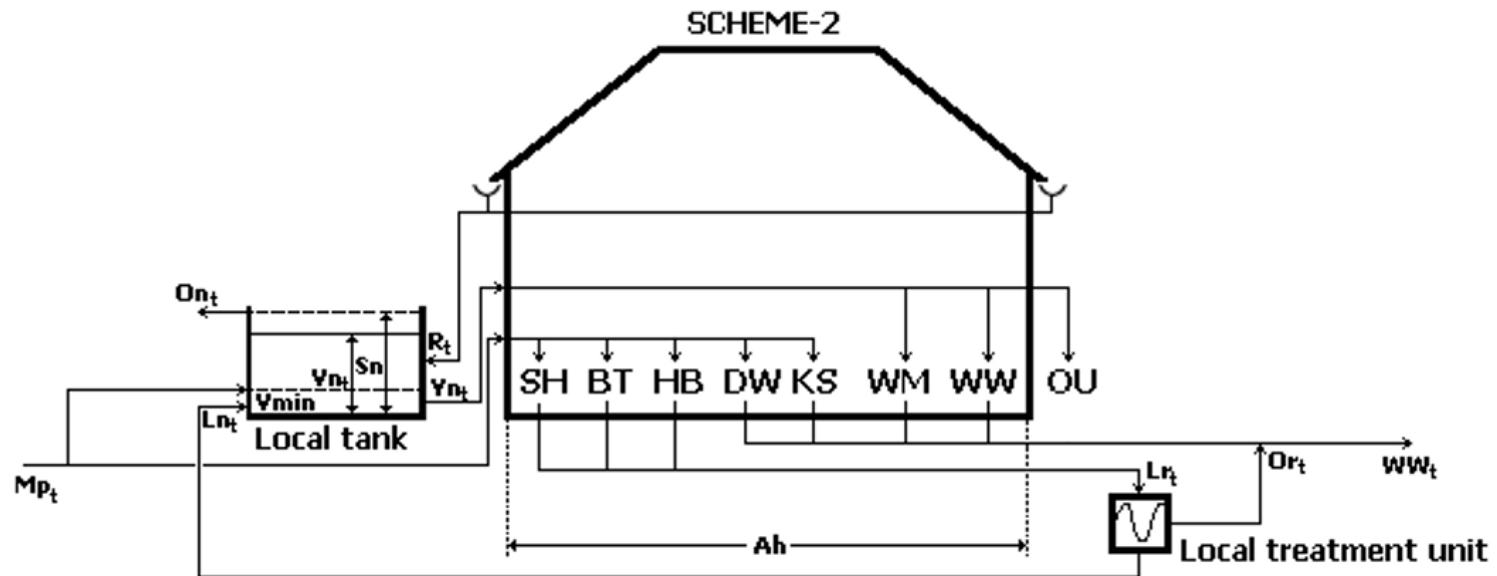
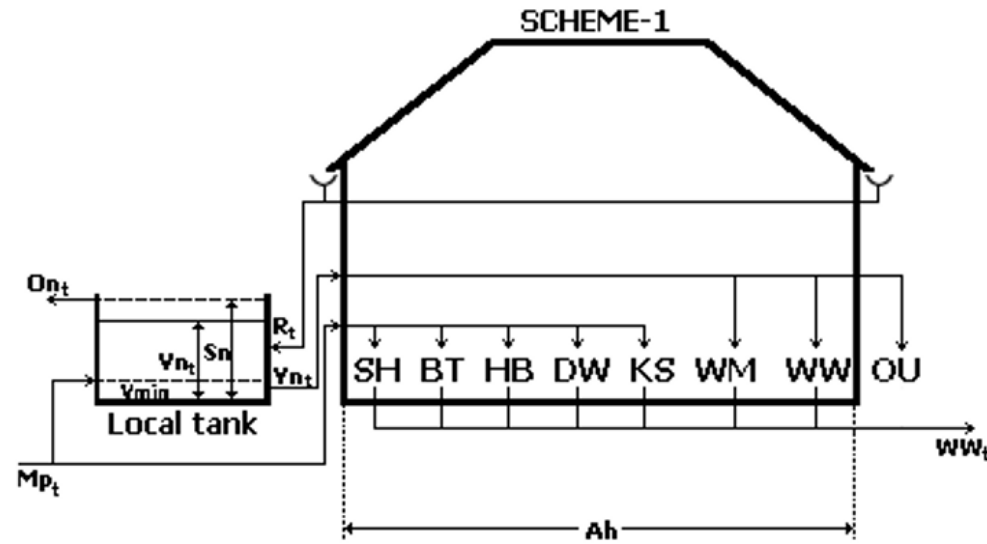
```
>> Outs=mxUWOT(Globals, 8784);  
>>  
>> [AX,H1,H2] = plotyy([1:8784],Rainfall,[1:8784],Outs.Wa  
>> set(get(AX(2),'Ylabel'),'String','Stored water (L)')  
>> set(get(AX(1),'Ylabel'),'String','10" rainfall (mm)')  
fx >>
```

Figure 1: A plot showing rainfall (mm) on the left y-axis (0 to 5) and stored water (L) on the right y-axis (0 to 100) over time (0 to 9000). The rainfall is shown as a bar chart, and the stored water is shown as a line graph.

UWOT application 1

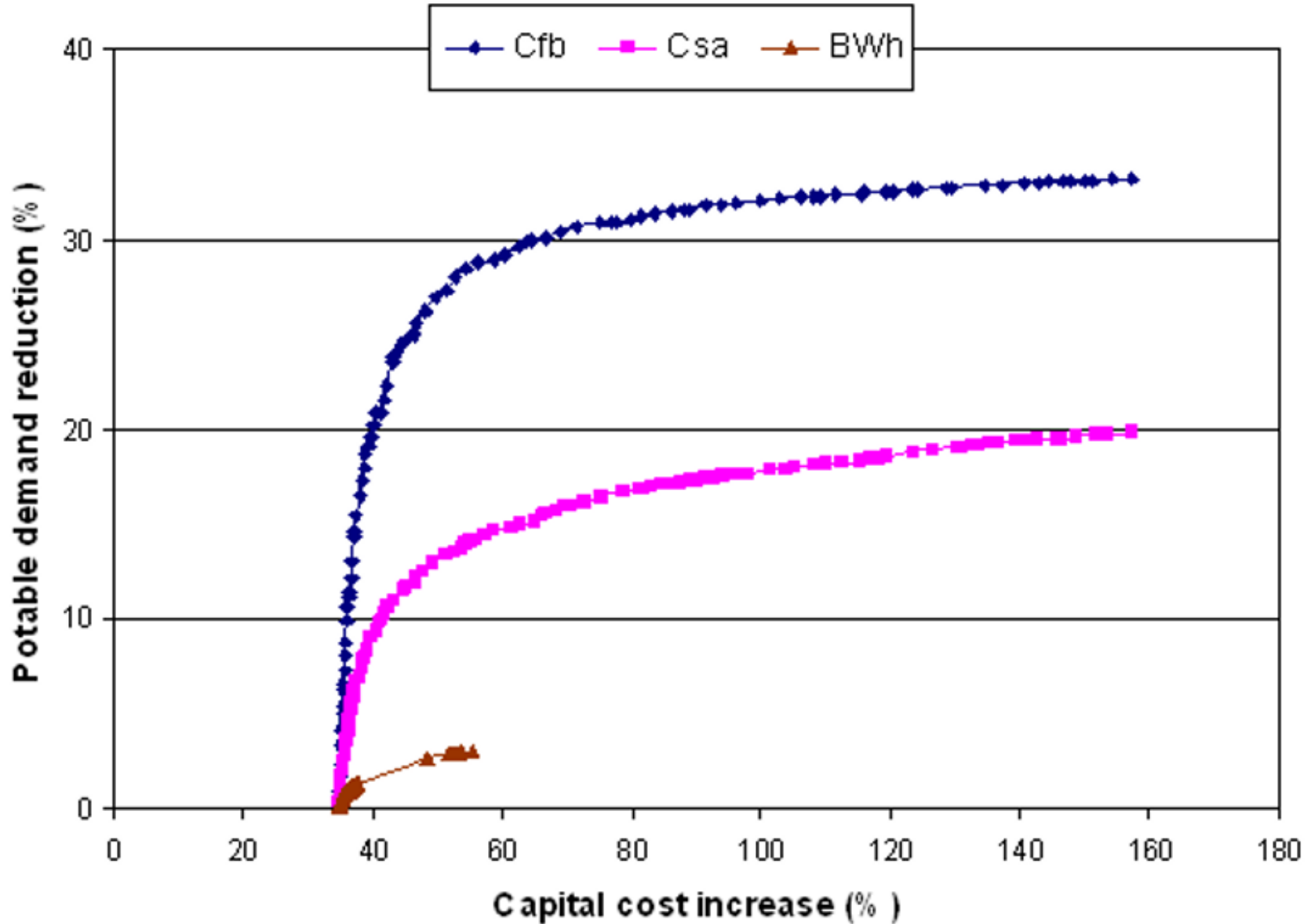
Two water recycling schemes are optimized under three different climatic conditions: humid (Cfb), Mediteranean (Csa) and arid (BWh).

UWOT application 1 (recycling schemes)

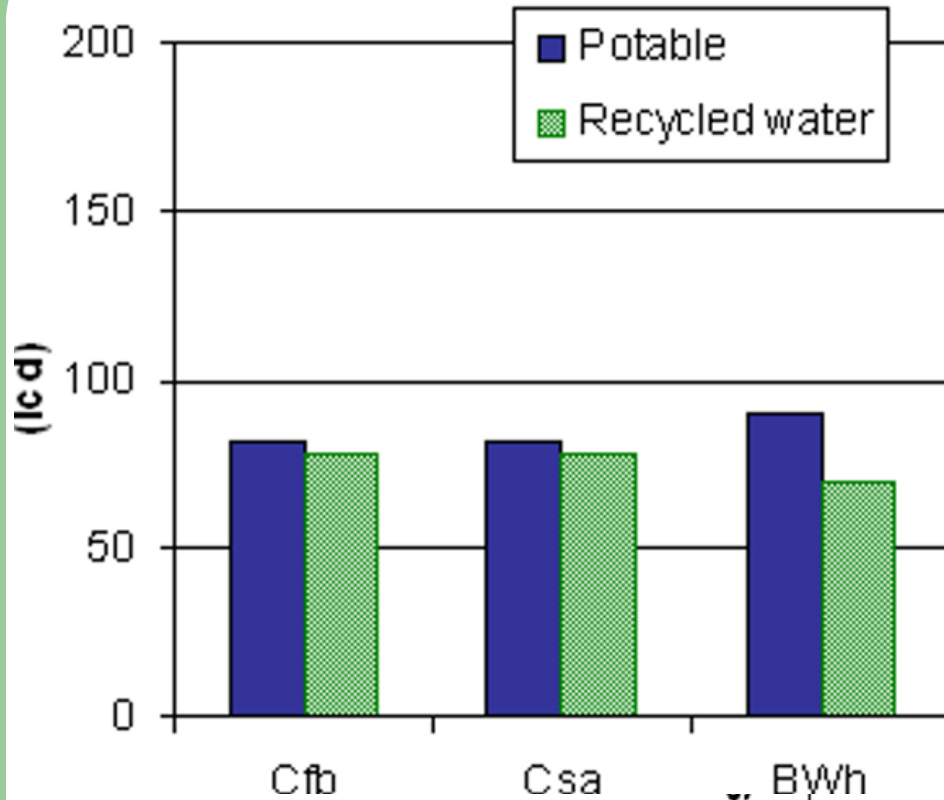


UWOT application 1 (Results)

Pareto front of scheme 1



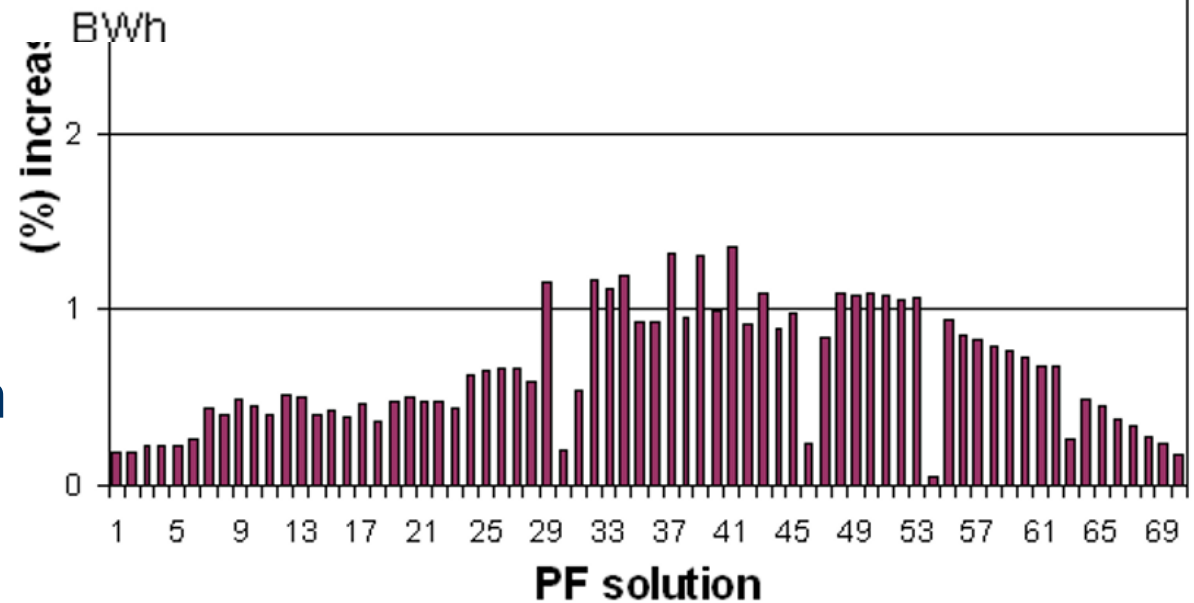
UWOT application 1 (Results)



Scheme 2 solutions with min potable demand

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Scheme 2, 20% reduction of rainfall



UWOT application 2

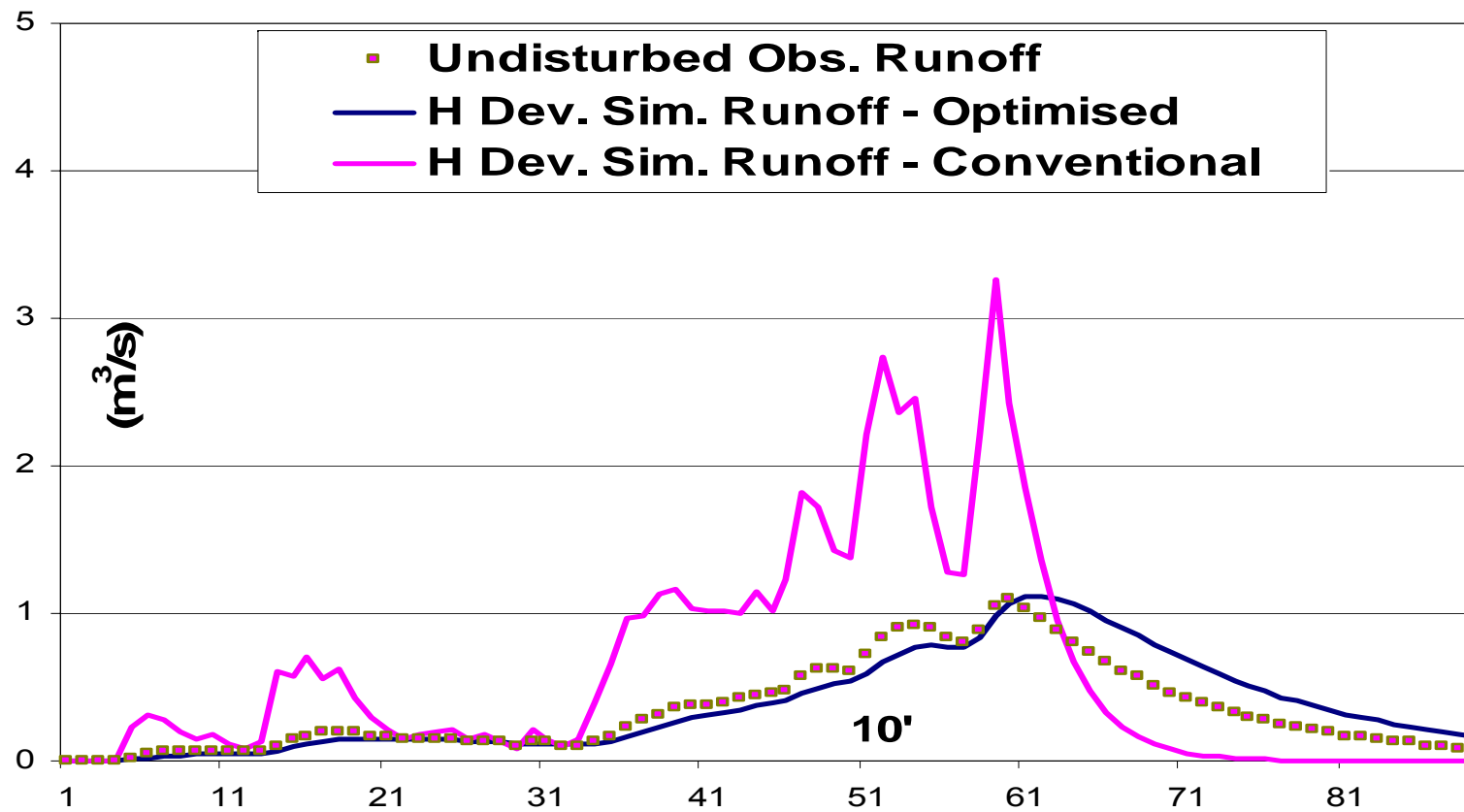
The runoff from two hypothetical developments, one with high (H) and one with low (L) urban density is investigated with UWOT.

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.

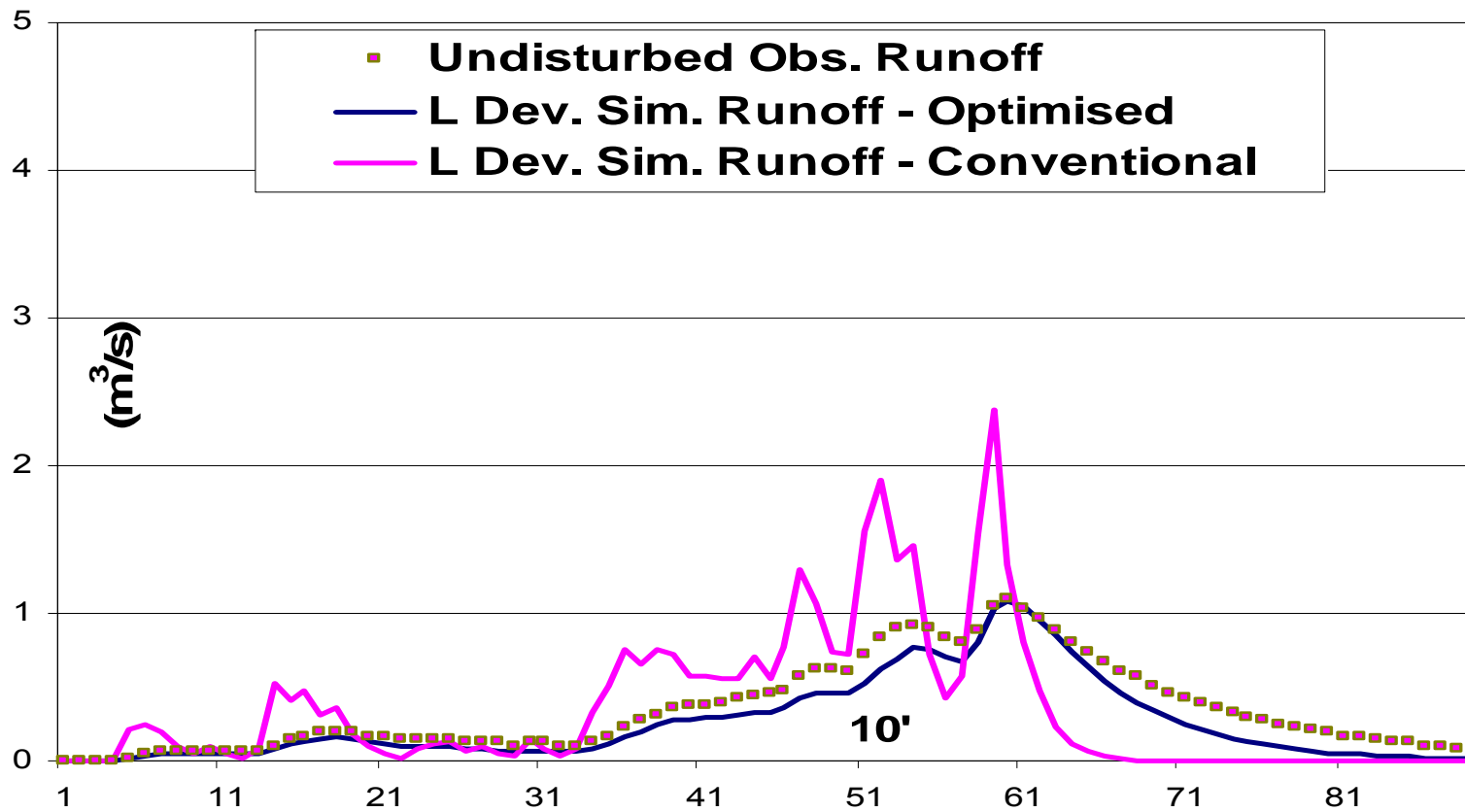
UWOT application 2 (Results)

	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



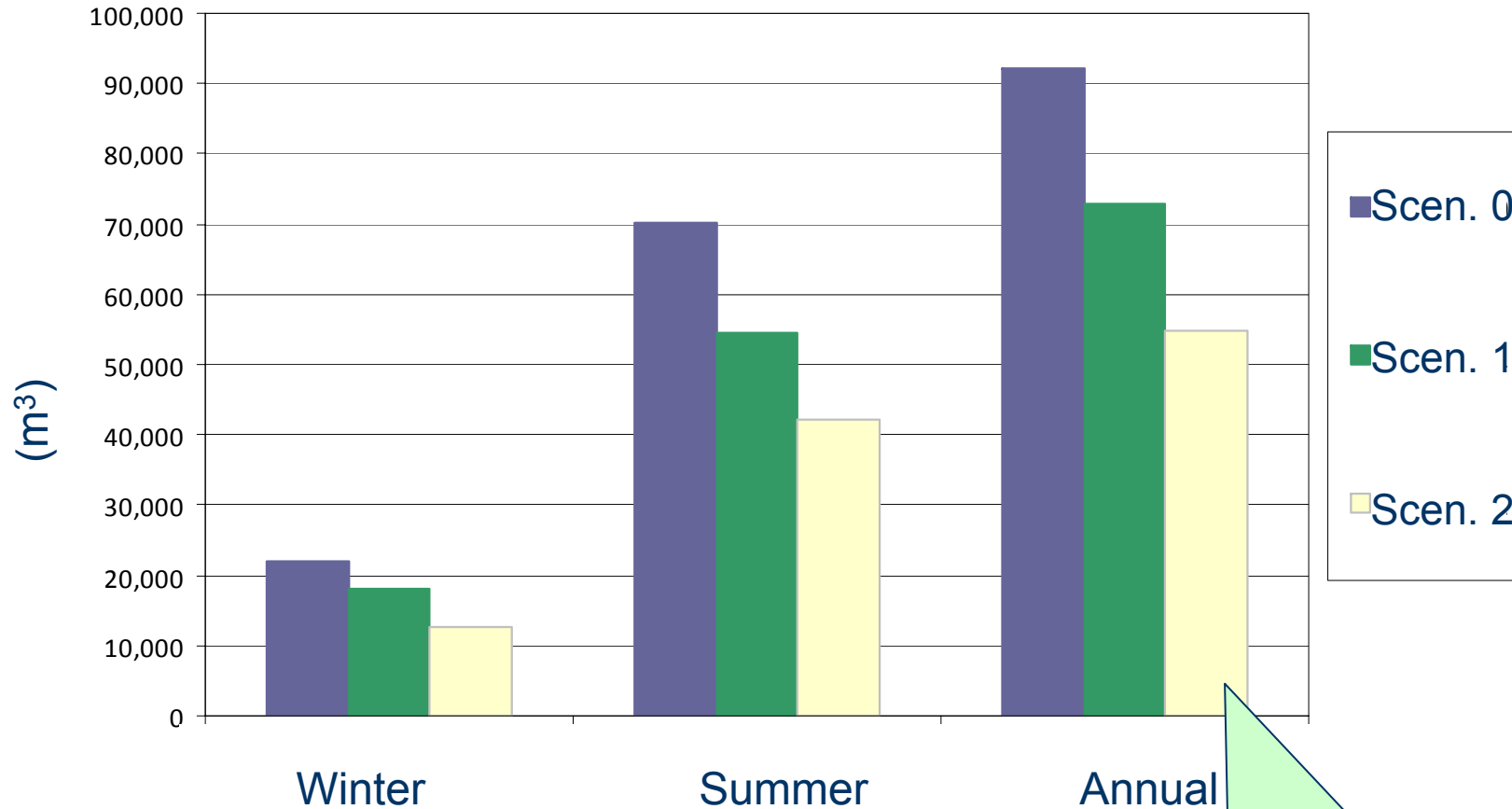
UWOT application 3

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)

Demand of Agkistri's developments



Potable water demand reduced by 42% in scenario 2.

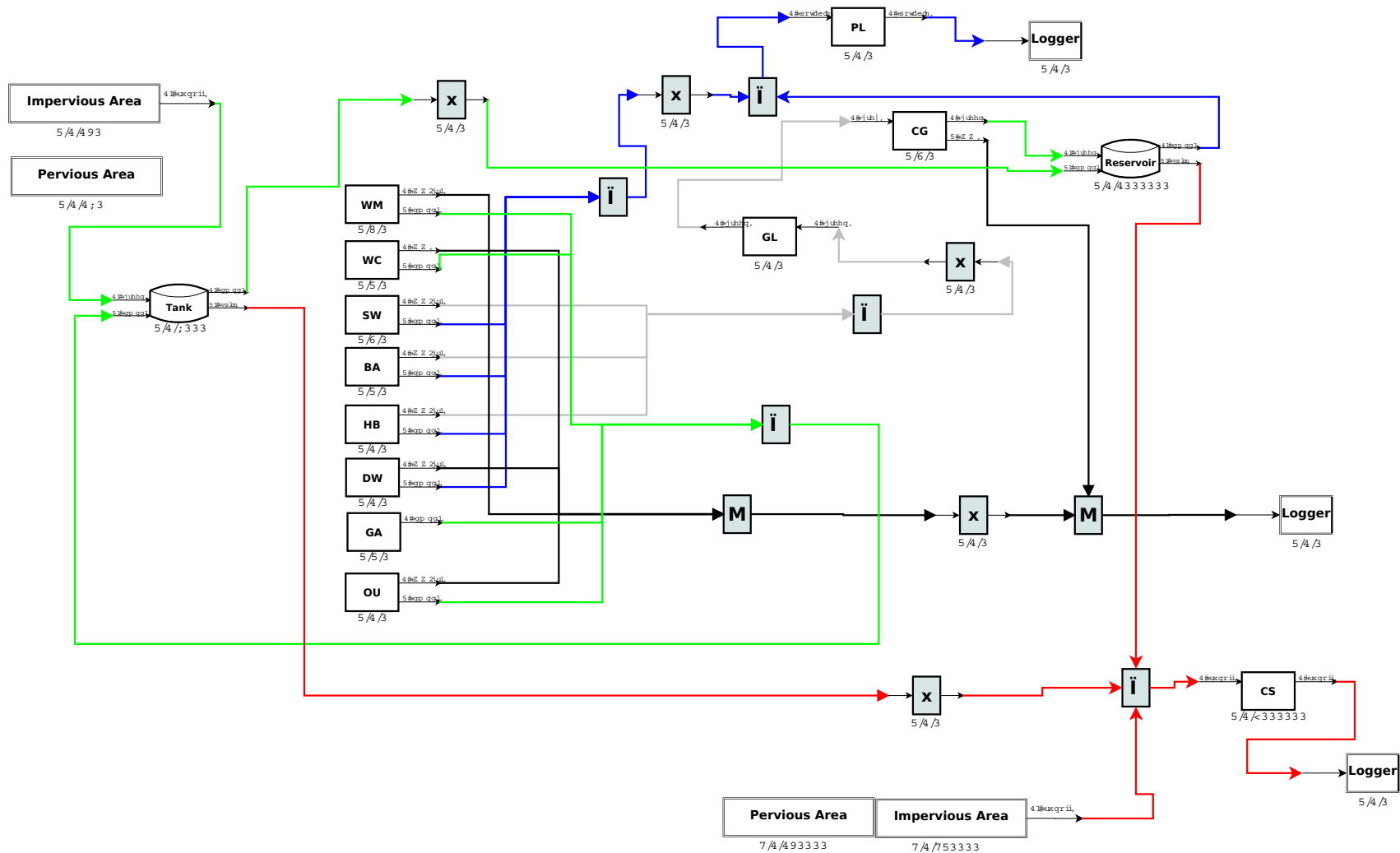
UWOT application 4 (Results)

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:

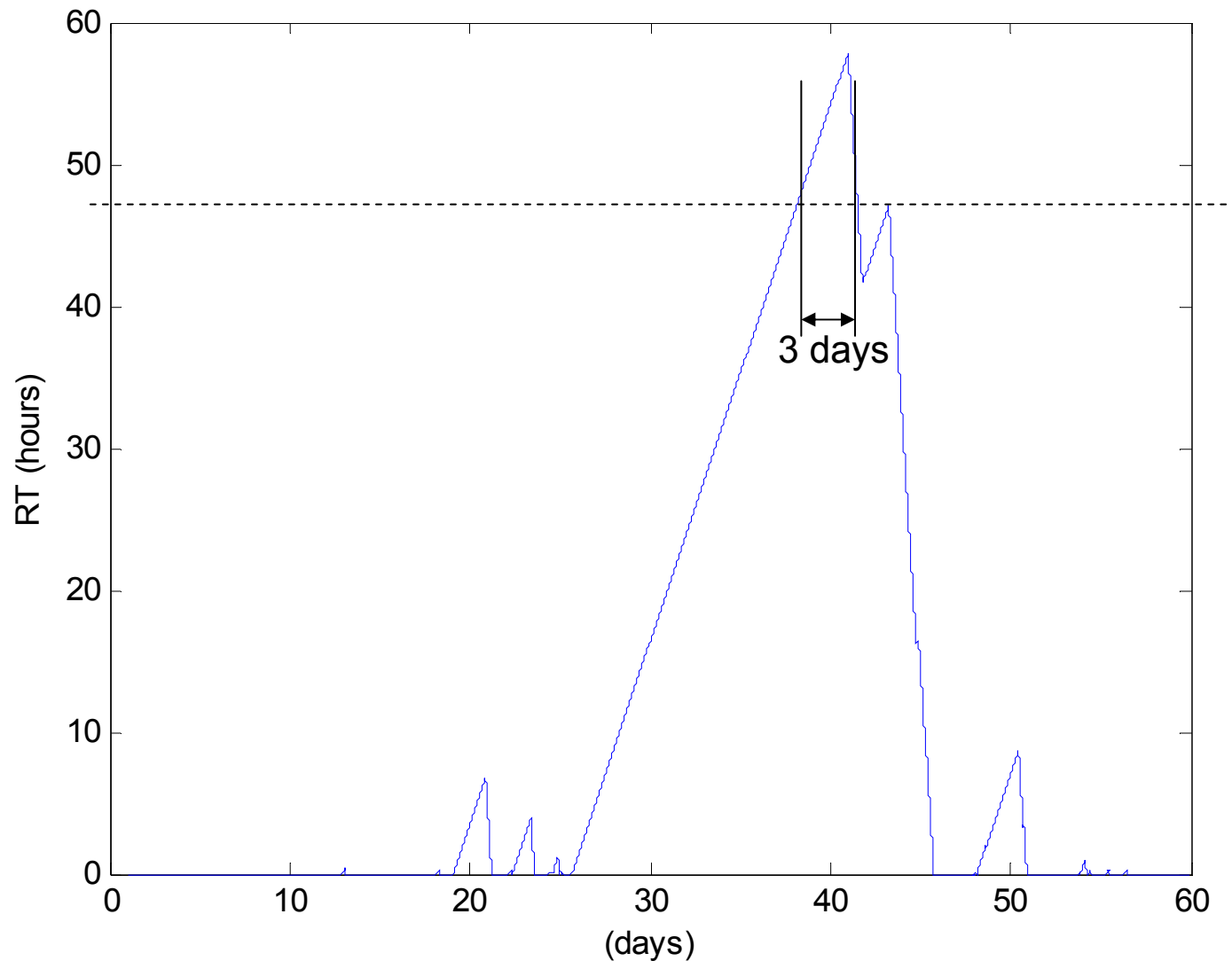
$$RTI = \frac{\text{Number of days with } RT < 2}{\text{Number of days of simulation}}$$

UWOT application 4 (Results)



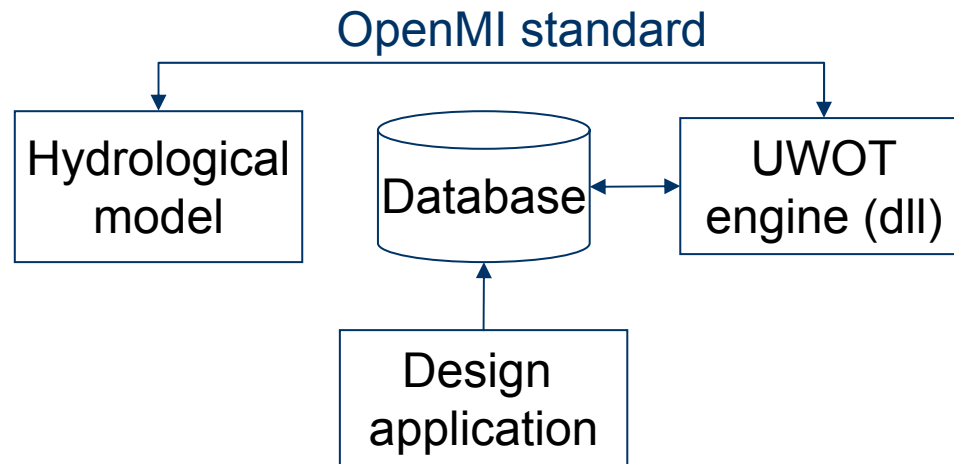
UWOT application 4 (Results)

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

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