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MSc Water Management 2017-2019

TU Delft

THE INFLUENCE OF LOW IMPACT DEVELOPMENT ON RAINFALL-RUNOFF RELATIONSHIPS AT CATCHMENT SCALE

THE INFLUENCE OF LOW IMPACT DEVELOPMENT ON RAINFALL-RUNOFF RELATIONSHIPS AT CATCHMENT SCALE

- Introduction
- Modelling
- Scenarios
- Results
- Discussions
- Conclusions
- Recommendations

INTRODUCTION

- **Low Impact Development**
- Problem statement
- Research approach
- Study area
- Data

- **Conventional development** (**CD**: disturbance of nature)

→urban water problems

- **Low Impact Development** (mimic nature)

→solve water problems

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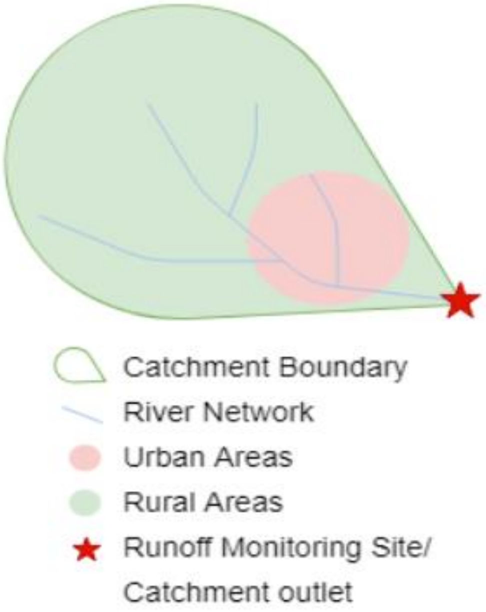

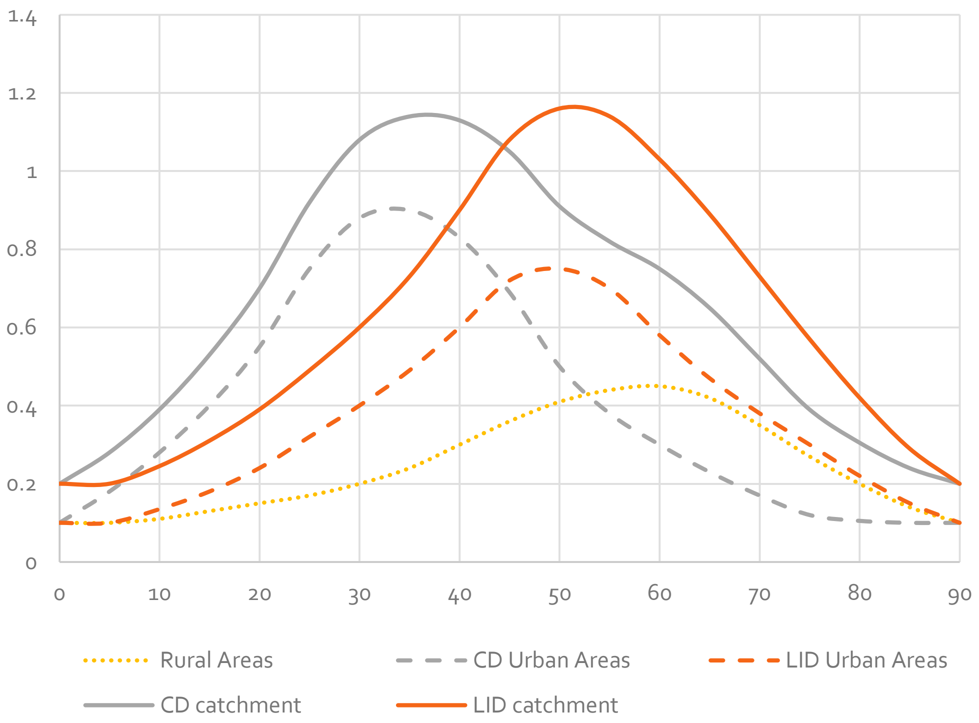

LID seems to decrease runoff

Flood risk: Delayed function of LID→ The approaching of urban and rural peak times → more stacking of urban and rural peaks and larger total peak

Trend of Urbanization

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Main Q: Explore **the impact of LID implementation** with regard to **peak runoff value** on the catchment scale

Q1: The different hydrologic characters of urban and rural areas;
Q2: The **urbanization** influence on rainfall-runoff relationship on catchment scale;
Q3: The **LID implementation** influence on rainfall-runoff relationship on catchment scale;
Q4: The problem caused by **the time approaching and stacking of peak flows** from urban and rural areas due to LID;

To deal with the prediction uncertainty, **scenario analysis** is used to give a reliable answer to the research question.

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This project will exploit **conceptual hydrological model with SUPERFLEX model framework** to simulate one real catchment under three different conditions.

1. Current CD situation
2. Urbanized CD situation under 3 urbanization scenarios (without LID practices)
3. Urbanized LID situation under 5 LID implementation scenarios

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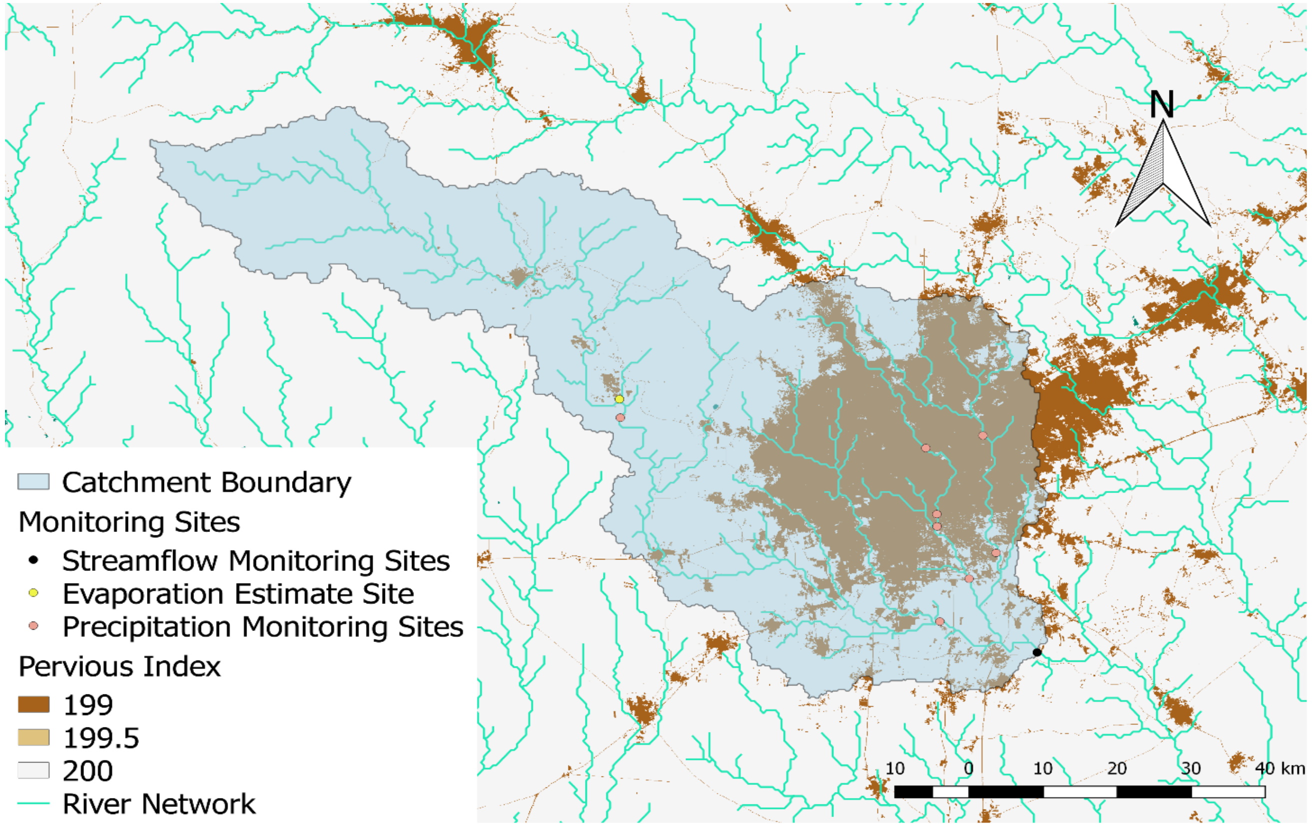

- Location: San Antonio city in Texas state, U.S. (29.424349; -98.491142)
- Area: 4544 km^2 (Rural, 73%; Urban 27%)
- Condition: The position of urban areas

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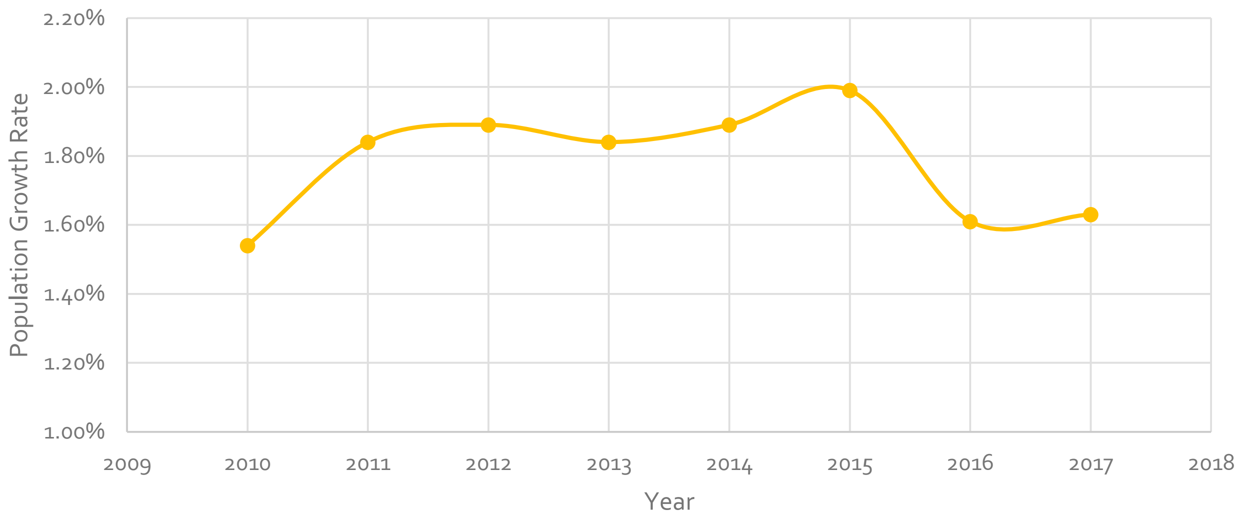

- Social condition: **the seventh most populous city** in the U.S. with 1.5 million residents (2017)
- Climate: transitional humid subtropical climate (Winters may pass **without any frozen precipitation** at all)
- Geology: moderately permeable deep clayey soils and marls
- <u>Urban water system: **separate** sewer and stormwater systems</u>

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Figure. The distribution area of Edwards Aquifer and the location of San Antonio City (Resources: Wikipedia)

- Geohydrology: prolific Edwards Aquifer provides the urban usage water for San Antonio City; **recharge project** in contribution zone (in north part of San Antonio City)

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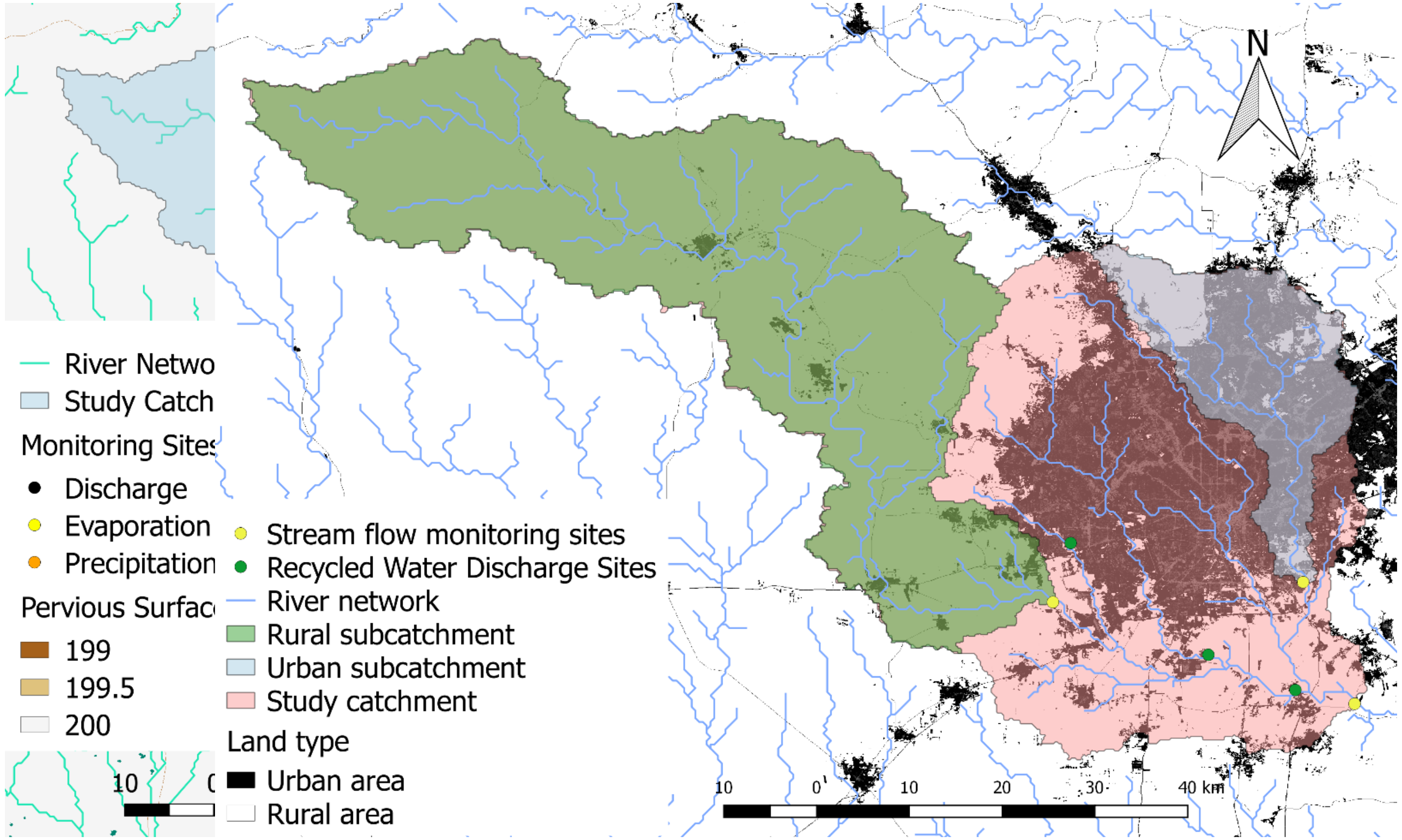


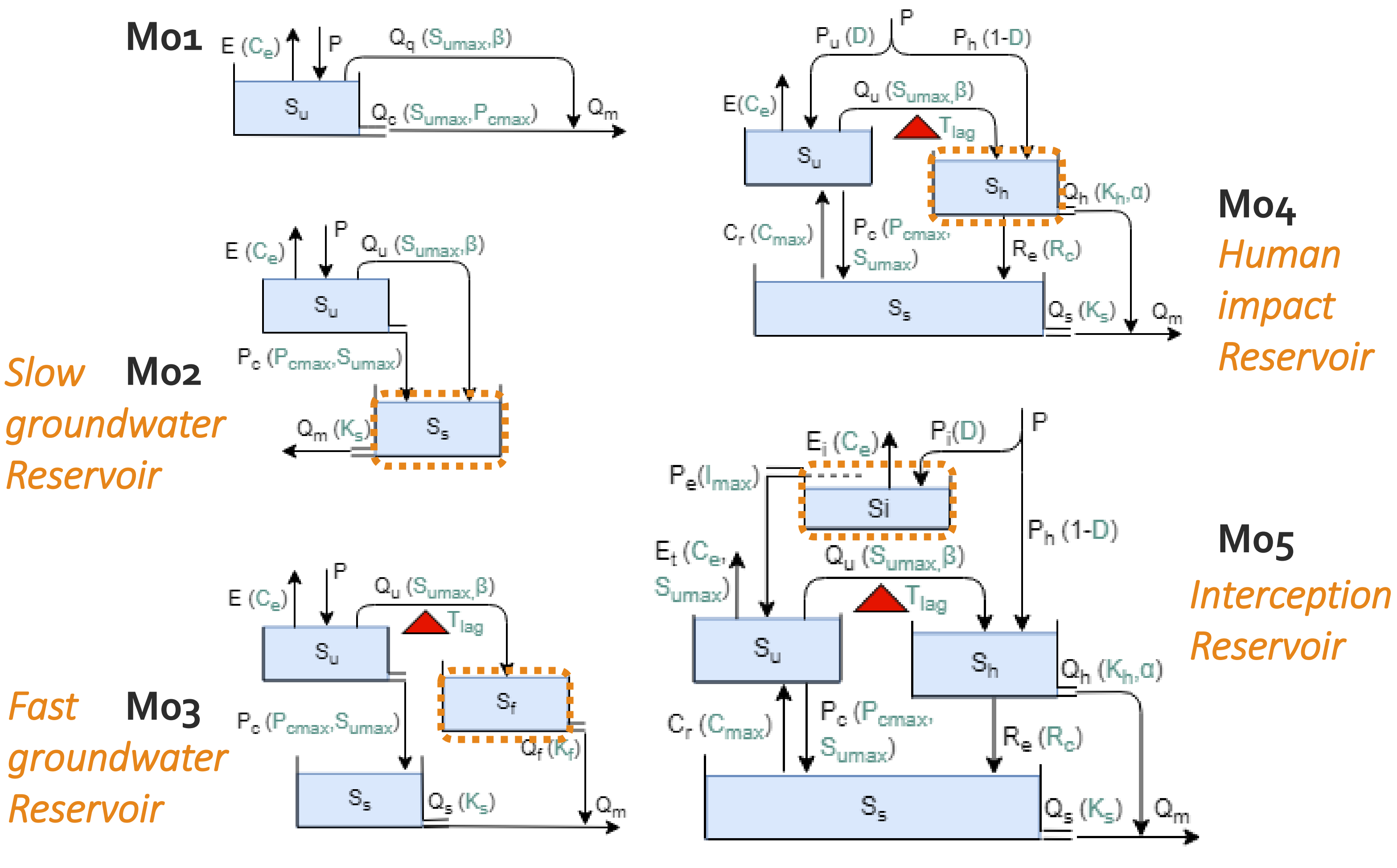
- <u>Type: Precipitation; Discharge; Evaporation</u>
- Available period: 2017-04-12 to 2018-12-02 (600 days)
- Time scale: 30 minutes (The number of data = 28800)
- Resources: USGS website

THE INFLUENCE OF LOW IMPACT DEVELOPMENT ON RAINFALL-RUNOFF RELATIONSHIPS AT CATCHMENT SCALE

MODELLING

- **Lumped models for rural and urban sub-catchments**
- Semi-distributed model for study catchment
- The expression of LID practices in model

a. Urban lumped model development (for urban sub-catchment)



MODELLING

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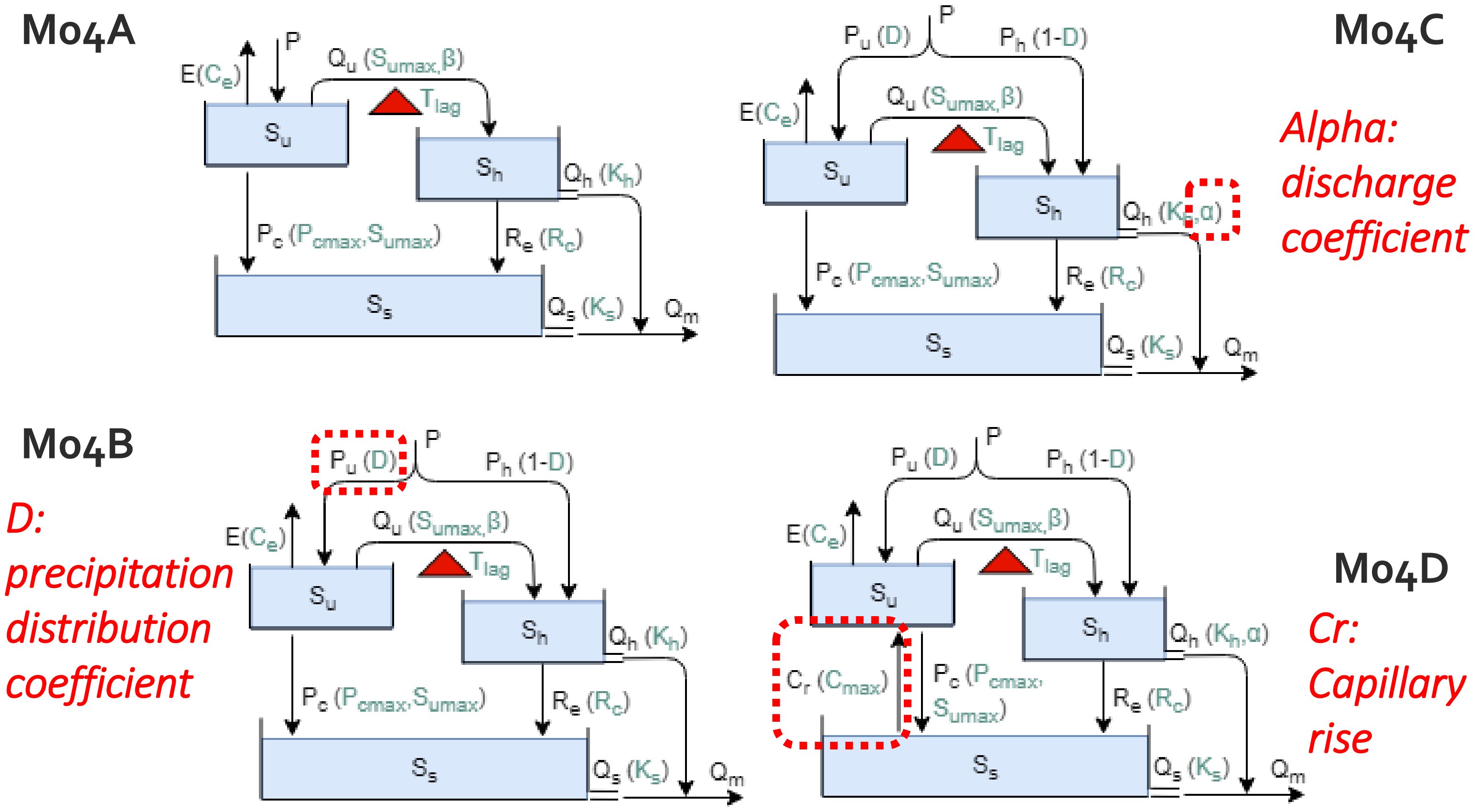
a. Urban lumped model development (M04 as example)



MODELLING

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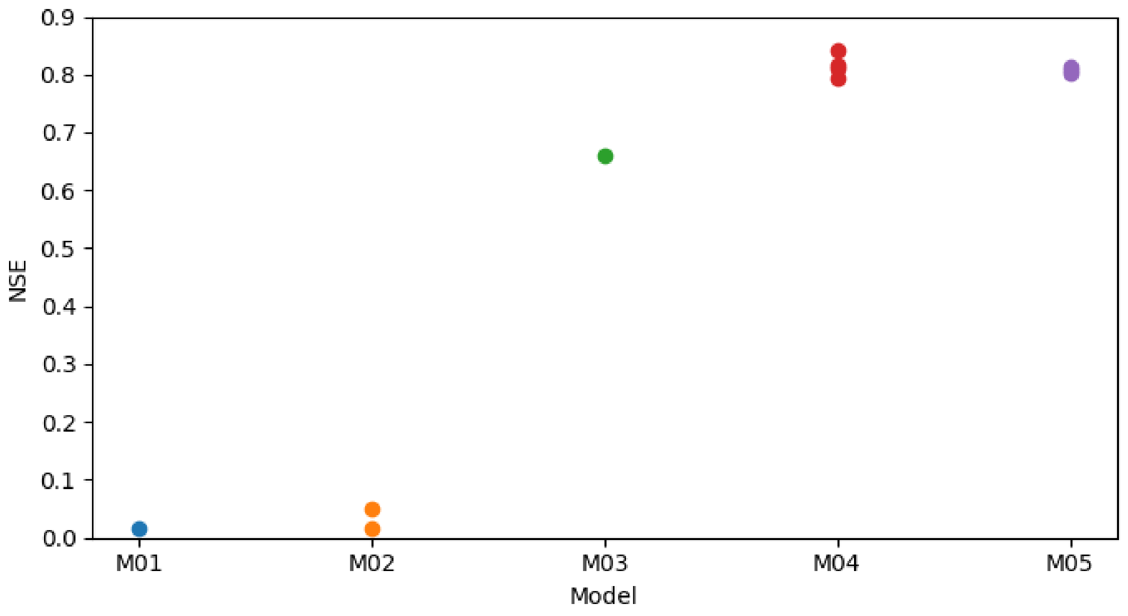
b. Urban lumped model result



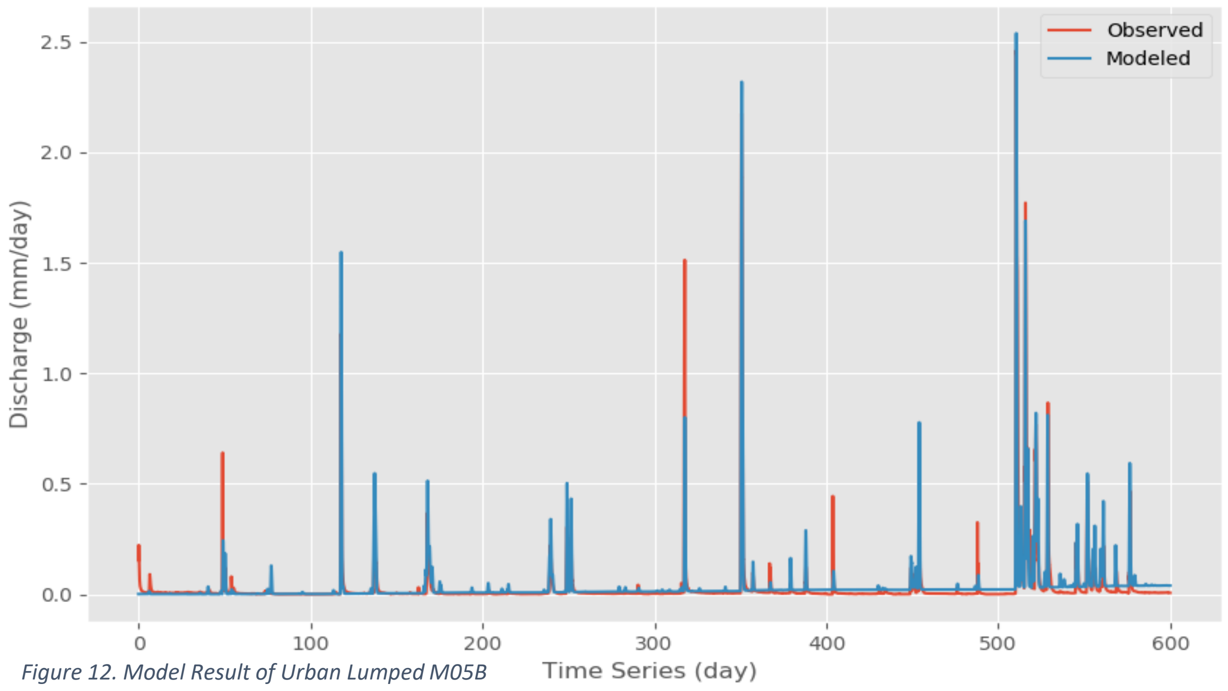


Figure 12. Model Result of Urban Lumped M05B

MODELLING

- **Lumped models for rural and urban sub-catchments**
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c. Model components selection: dominant; effective and efficient

By comparing 5 generations of model structure:

- ✓ "Unsaturated Reservoir-Slow groundwater Reservoir-Human impact Reservoir" three buckets as basic model framework;
- ✓ Although Interception Reservoir does not have positive effect on the NSE, the model performance on peak runoff simulation is improved.

By comparing different model structures of one generation:

- ✓ Capillary rise (Cr);
- ✓ Discharge exponent (α);
- ✓ Precipitation distribution factor (D);

MODELLING

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d. Parameter calibration of lumped model

- Determine initial parameter intervals in semi-distributed model

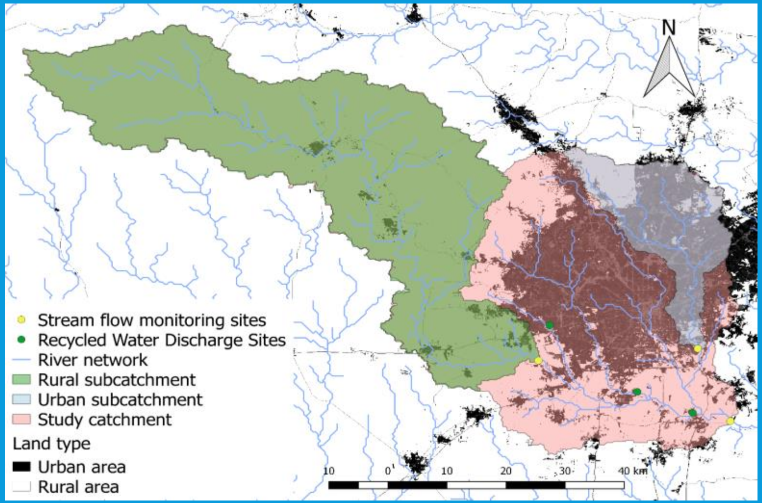
✓ parameter intervals, rather than specific parameter value;

Table 4. Calibrated parameter intervals of rural and urban lumped models

Para. range		Imax [mm]	D [-]	Ce [-]	Sumax [mm]	Pmax [mm/d]	Cmax [mm/d]
Rural	Min	-	0.97	1	150	0	0
	Max	-	1	3	250	5	1
Urban	Min	0	0.985	0.5	30	0	0
	Max	5	1	3	375	5	1
Para. range		beta [-]	Kr/Kh [1/mm*d]	Kf/Rc [1/mm*d]	Ks [1/mm*d]	alpha [-]	Tlag [-]
Rural	Min	5	0	0	0	1	41
	Max	10	1	1	0.006	10	101
Urban	Min	0.5	0	1	0	1	21
	Max	5	0.5	15	0.0002	2	85

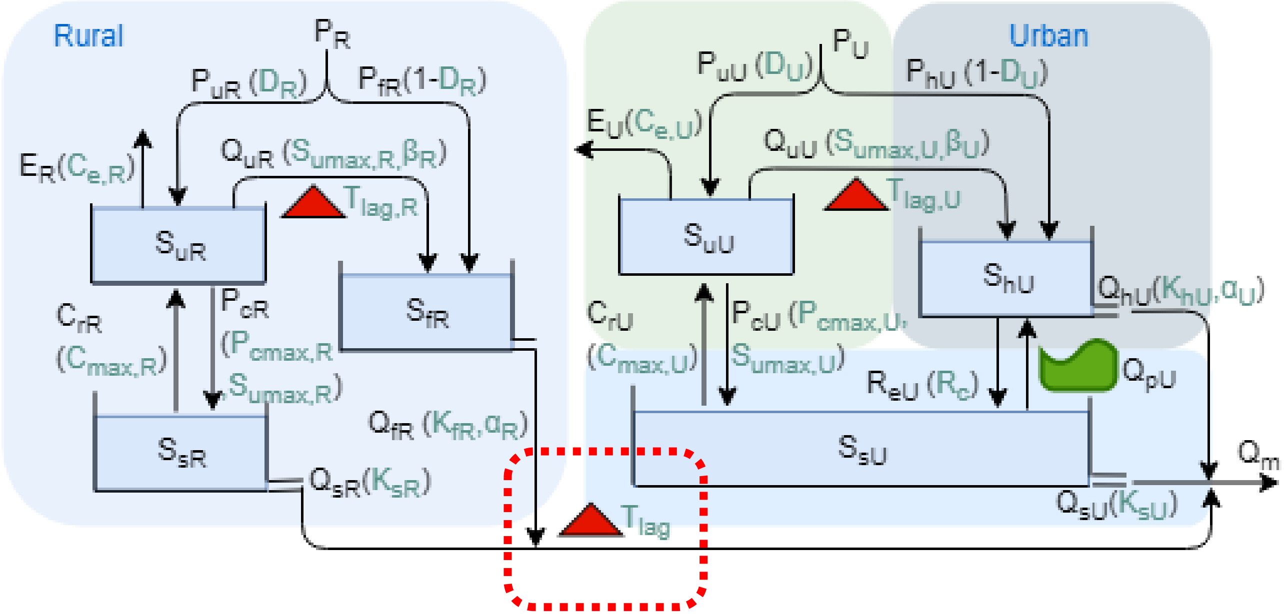
MODELLING

- Lumped models for rural and urban sub-catchments
- **Semi-distributed model for study catchment**
- The expression of LID practices in model



a. Key elements in semi-distributed model

- Time lag for rural area, since the position of rural area (Initial interval: 1.25 - 10 hours)
- Human activity module for urban area
- Constraints on parameter limitation



MODELLING

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- **Semi-distributed model for study catchment**
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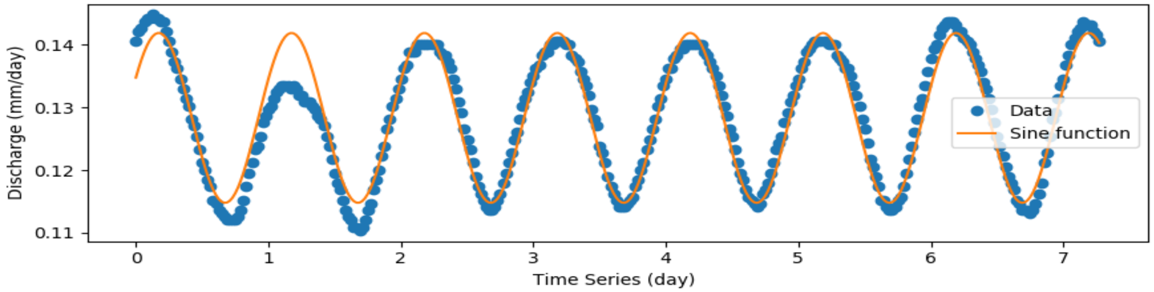

Figure 16. The calibration result of water pumping process

a. Key elements in semi-distributed model

- Time lag for rural area (Initial interval: 1.25 - 10 hours)
- Human activity module for urban grey areas (impervious areas)
- Constraints on parameter limitation

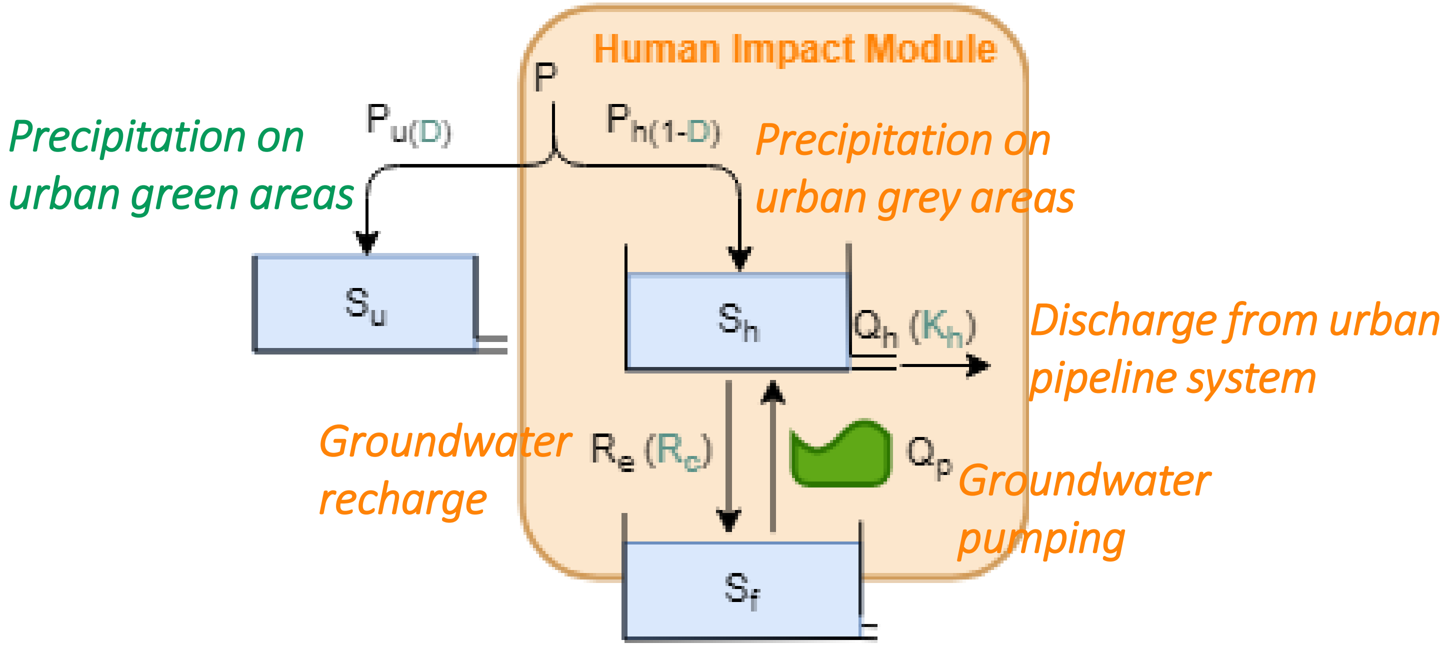

Figure 17. Schematic figure of designed Human Impact Module

MODELLING

- Lumped models for rural and urban sub-catchments
- **Semi-distributed model for study catchment**
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a. Key elements in semi-distributed model

- Time lag for rural area (Initial interval: 1.25 - 10 hours)
- Human activity module for urban area
- <u>Constraints to avoid unrealistic combination of parameters</u>

1. $P_{max,R} > P_{max,U}$ (The maximum percolation velocity)
2. $S_{umax,R} > S_{umax,U}$ (The maximum unsaturated storage depth)

Table 4. Calibrated parameter intervals of rural and urban lumped models

Para. range		Imax [mm]	D [-]	Ce [-]	Sumax [mm]	Pmax [mm/d]	Cmax [mm/d]
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Rural	Min	5	0	0	0	1	41
	Max	10	1	1	0.006	10	101
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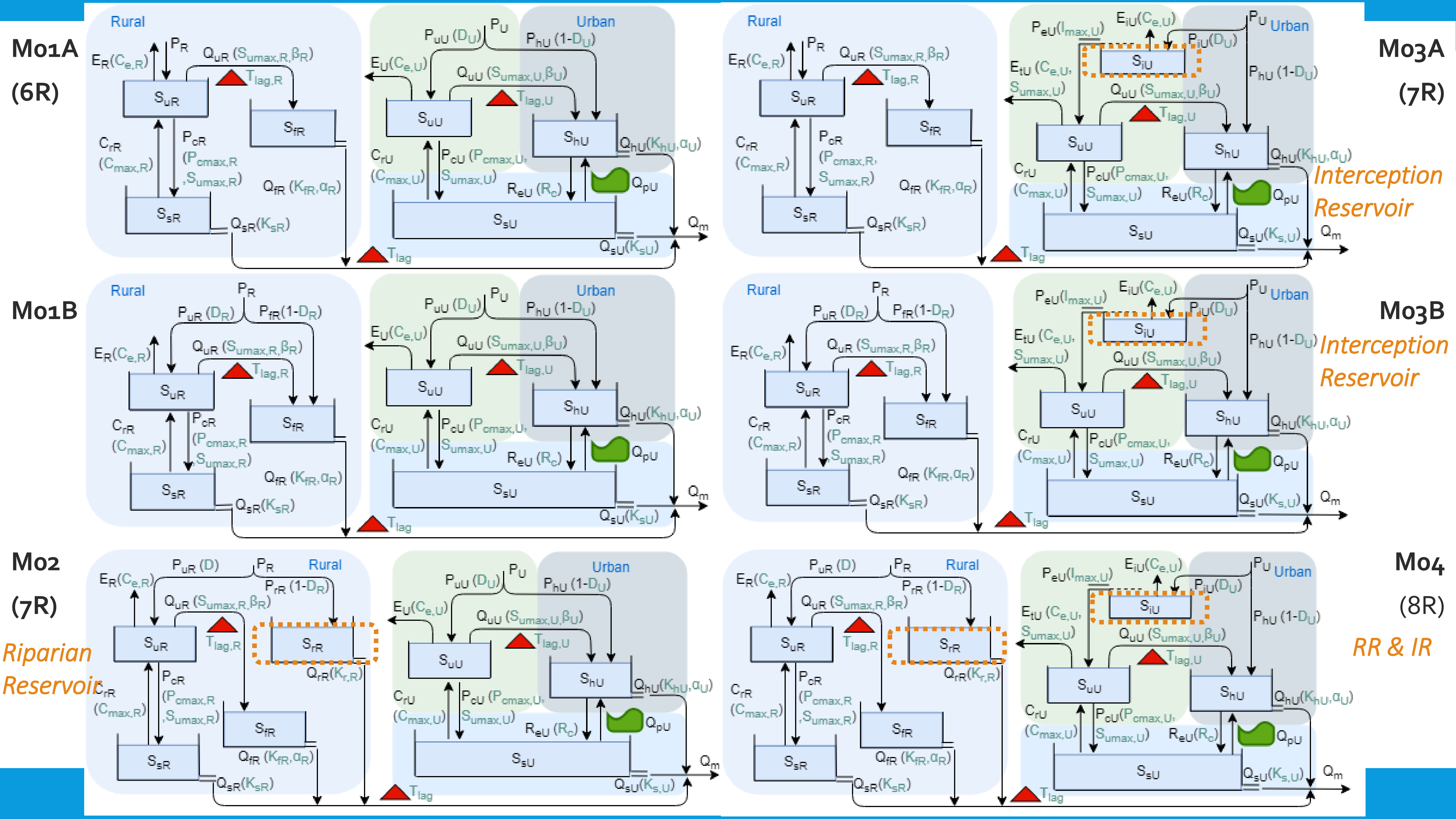
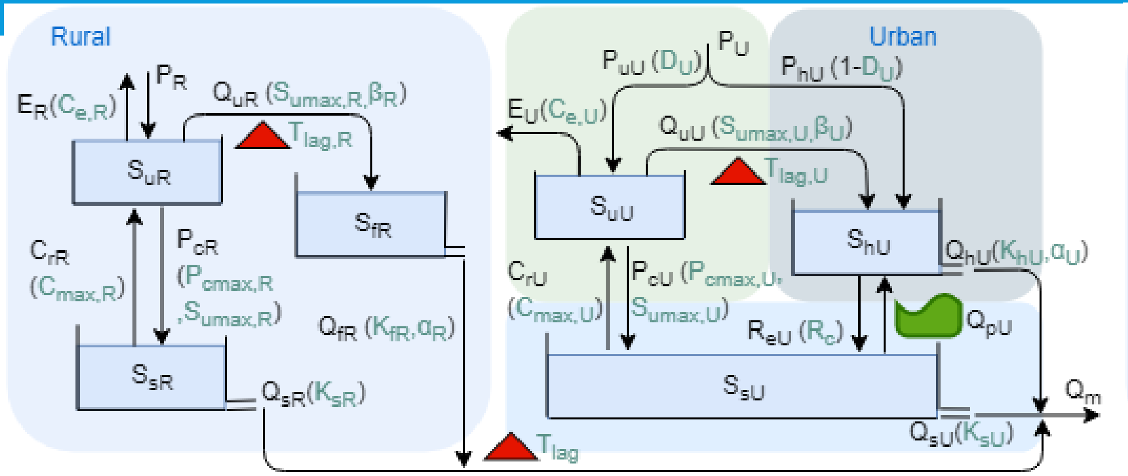
	Max	5	0.5	15	0.0002	2	85

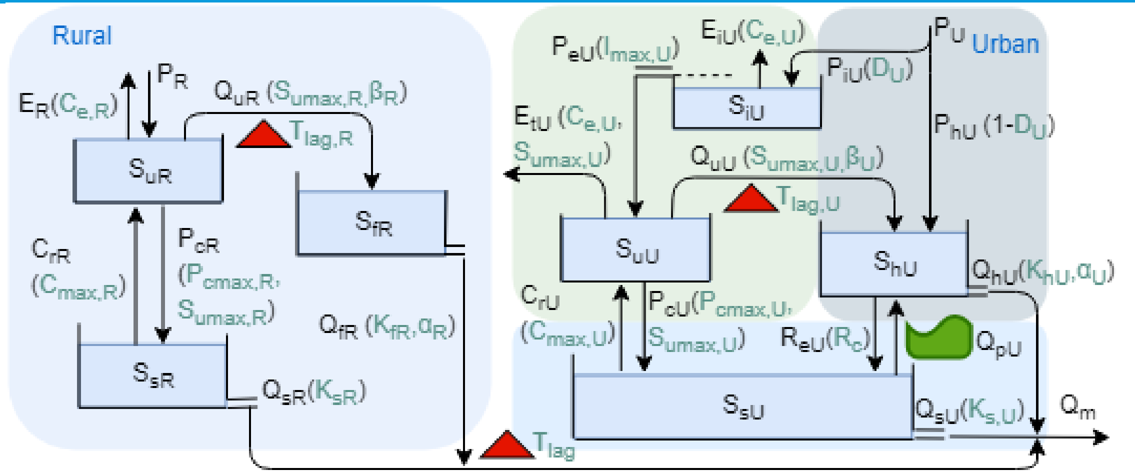


M01A
(6R)
M01B
M02
(7R)
M03A
(7R)
M03B
M04
(8R)
Rural
Urban
Interception Reservoir
Interception Reservoir
Riparian Reservoir
RR & IR
P_R
E_R(C_e,R)
Q_uR (S_umax,R, β_R)
T_lag,R
S_uR
S_fR
C_rR (C_max,R)
P_cR (P_cmax,R ,S_umax,R)
Q_fR (K_fR, α_R)
S_sR
Q_sR(K_sR)
P_uR (D_R)
P_fR(1-D_R)
P_uR (D)
P_rR (1-D_R)
S_rR
Q_rR(K_r,R)
P_U
P_uU (D_U)
P_hU (1-D_U)
E_U(C_e,U)
Q_uU (S_umax,U, β_U)
T_lag,U
S_uU
S_hU
Q_hU(K_hU, α_U)
C_rU (C_max,U)
P_cU (P_cmax,U, S_umax,U)
R_eU (R_c)
Q_pU
S_sU
Q_sU(K_sU)
Q_sU(K_s,U)
Q_m
T_lag
P_eU(I_max,U)
E_iU(C_e,U)
P_iU(D_U)
S_iU
E_tU (C_e,U, S_umax,U)

M01A

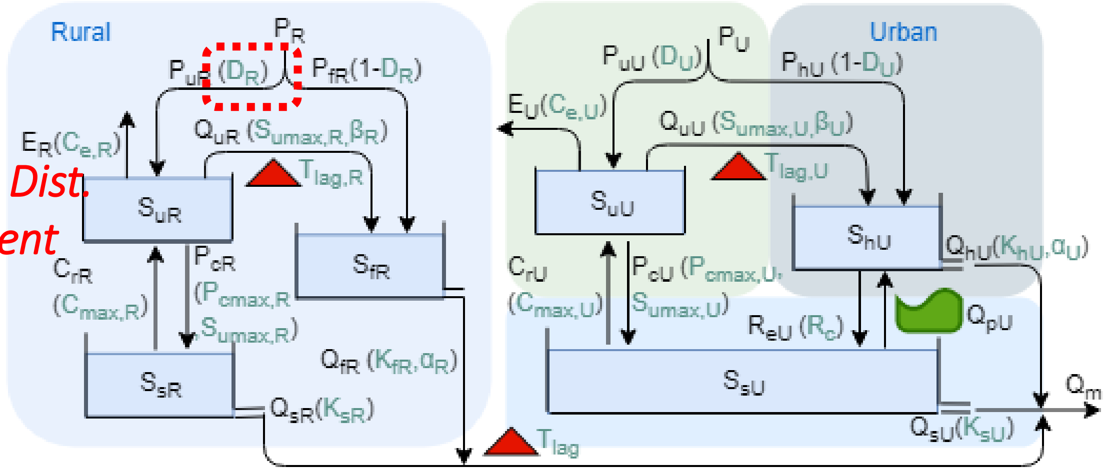


M03A



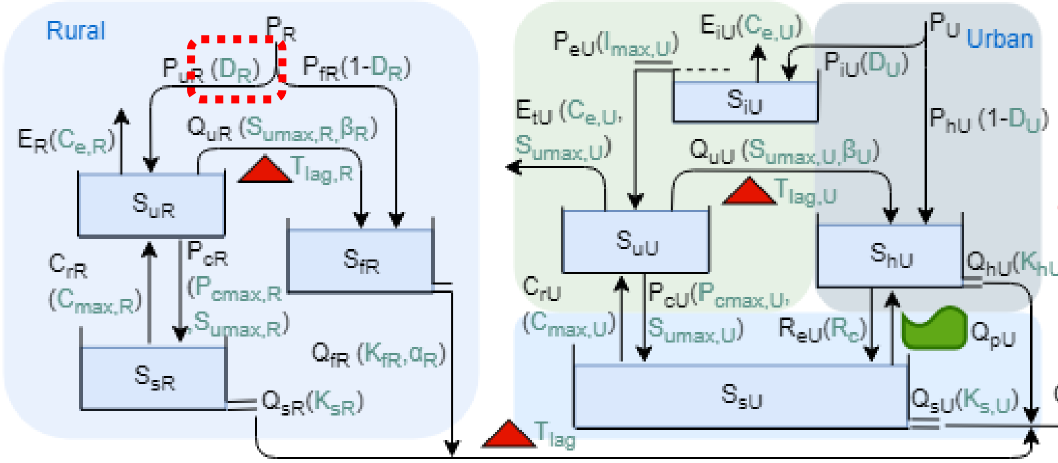
M01B

D-Prec. Dist. coefficient

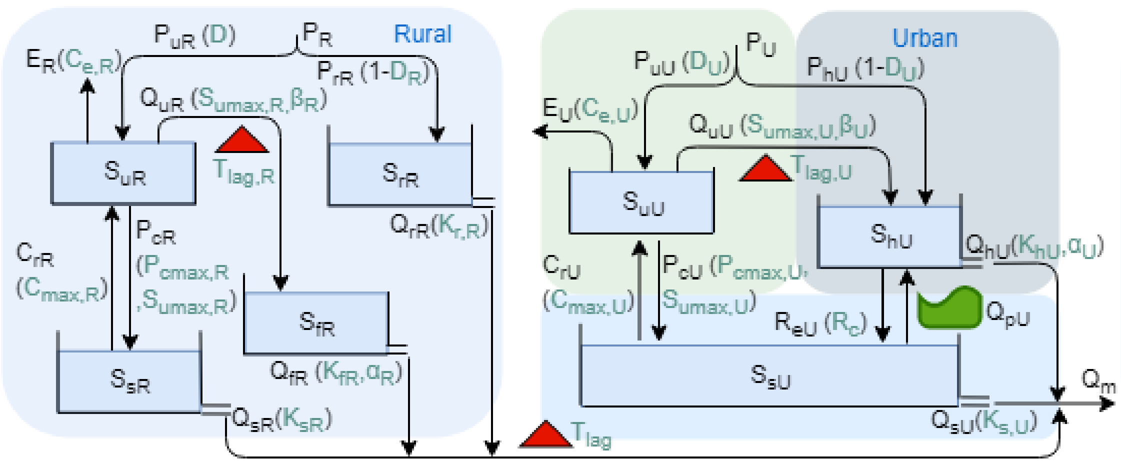


M03B

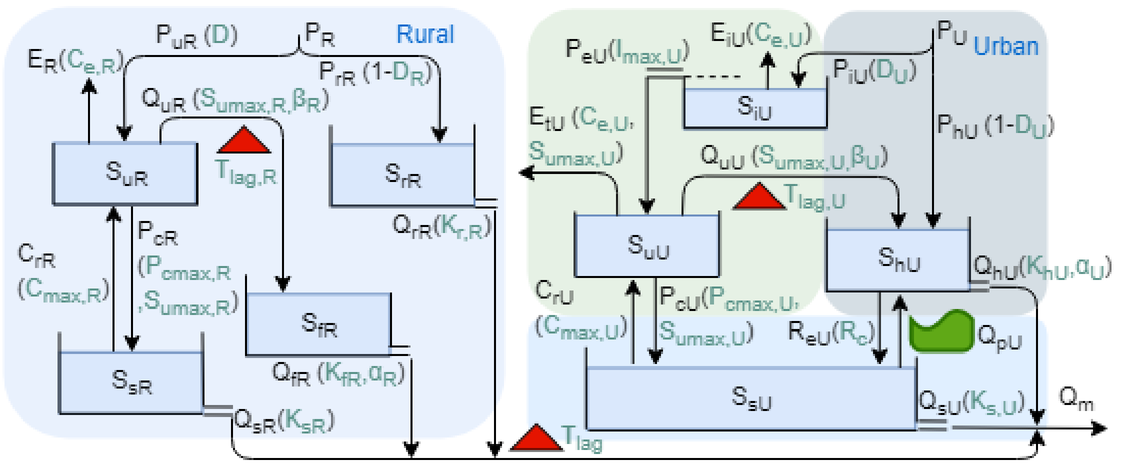
D-Prec. Dist. coefficient



M02



M04



MODELLING

- Lumped models for rural and urban sub-catchments
- **Semi-distributed model for study catchment**
- The expression of LID practices in model

c. Selection of Semi-distributed model

- The selection of model structure
- The determination of propriate parameter set

Table 6. The model performance of 12 semi-distributed models

	Accuracy index					Precision index
Model Num.	*The R^2 of calibration*	Optimal verified R^2	*The NSE of calibration*	Optimal verified NSE	Mean of verified NSE	Variance of verified NSE
M01A	*0.882*	0.865	*0.723*	0.735	0.117	0.399
M01B	***0.897***	**0.873**	***0.673***	**0.748**	**0.297**	**0.240**
M02	*0.863*	0.871	*0.712*	0.749	0.155	0.424
M03A	*0.902*	0.850	*0.721*	0.706	-0.056	0.758
M03B	*0.815*	0.855	*0.656*	0.730	0.039	0.587
M04	*0.878*	0.883	*0.714*	0.744	0.036	0.606

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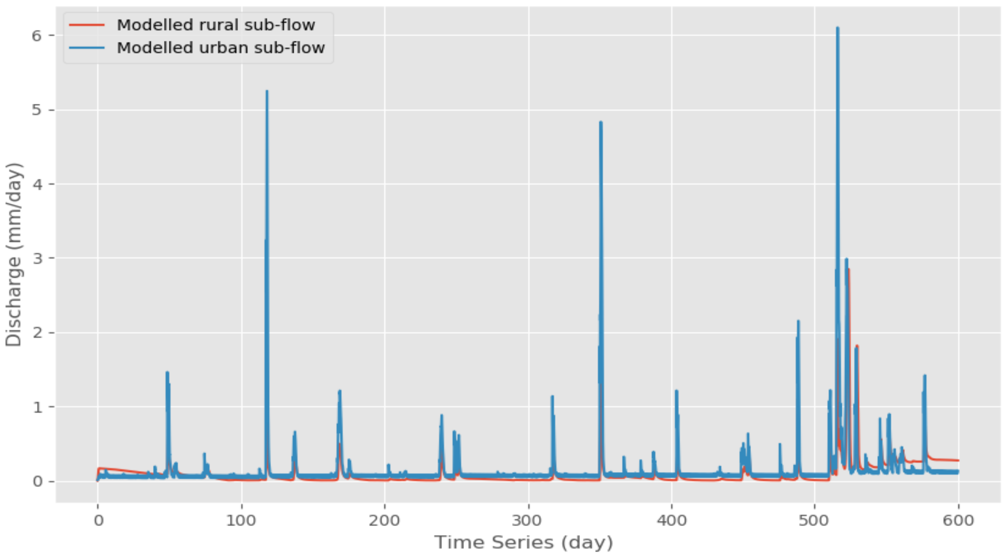
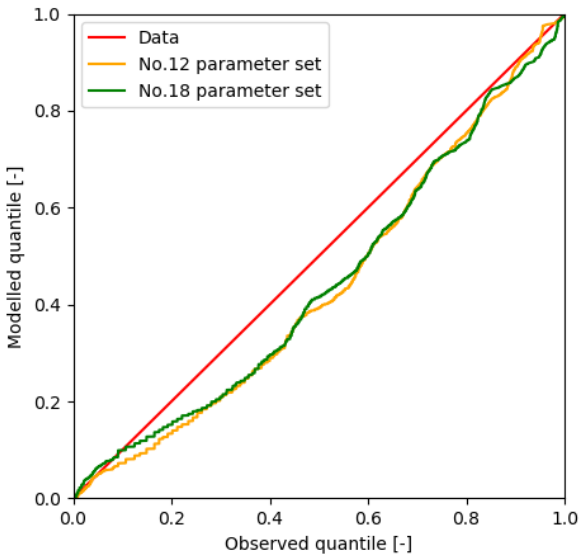
- <u>The determination of propriate parameter set:</u>

  1. The performance on sub-flows and basin peak runoff
  2. Distribution analysis (QQ plots)





MODELLING

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d. The final selection of rainfall-runoff semi-distributed model for current condition

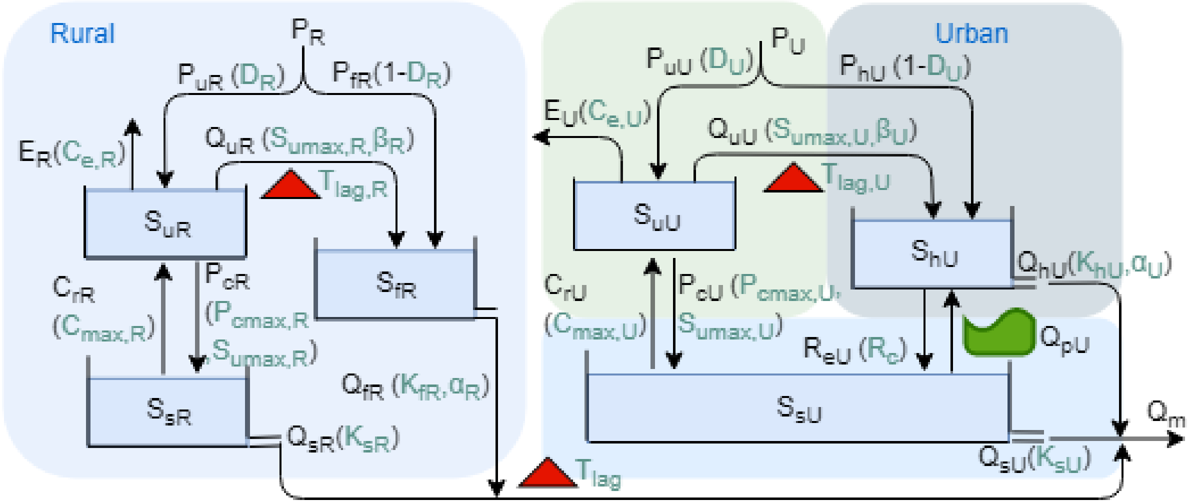

Table 7. Parameter values in current model

Para.	D	Ce	Sumax	Pcmax	Cmax	Rc
Unit	[-]	[-]	[mm]	[mm/d]	[mm/d]	[1/d]
Rural	0.983	2.70	186	4.94	0.70	-
Urban	0.830	1.08	51.1	4.79	0.99	1.47
Para.	beta	Kf/Kh	Ks	alpha	Tlag	Tlag for rural sub-flow
Unit	[-]	[1/d]	[1/d]	[-]	[-]	[-]
Rural	6.49	0.875	0.0036	8.04	83.7	39.5
Urban	1.60	0.510	0.0017	1.45	83.9	-

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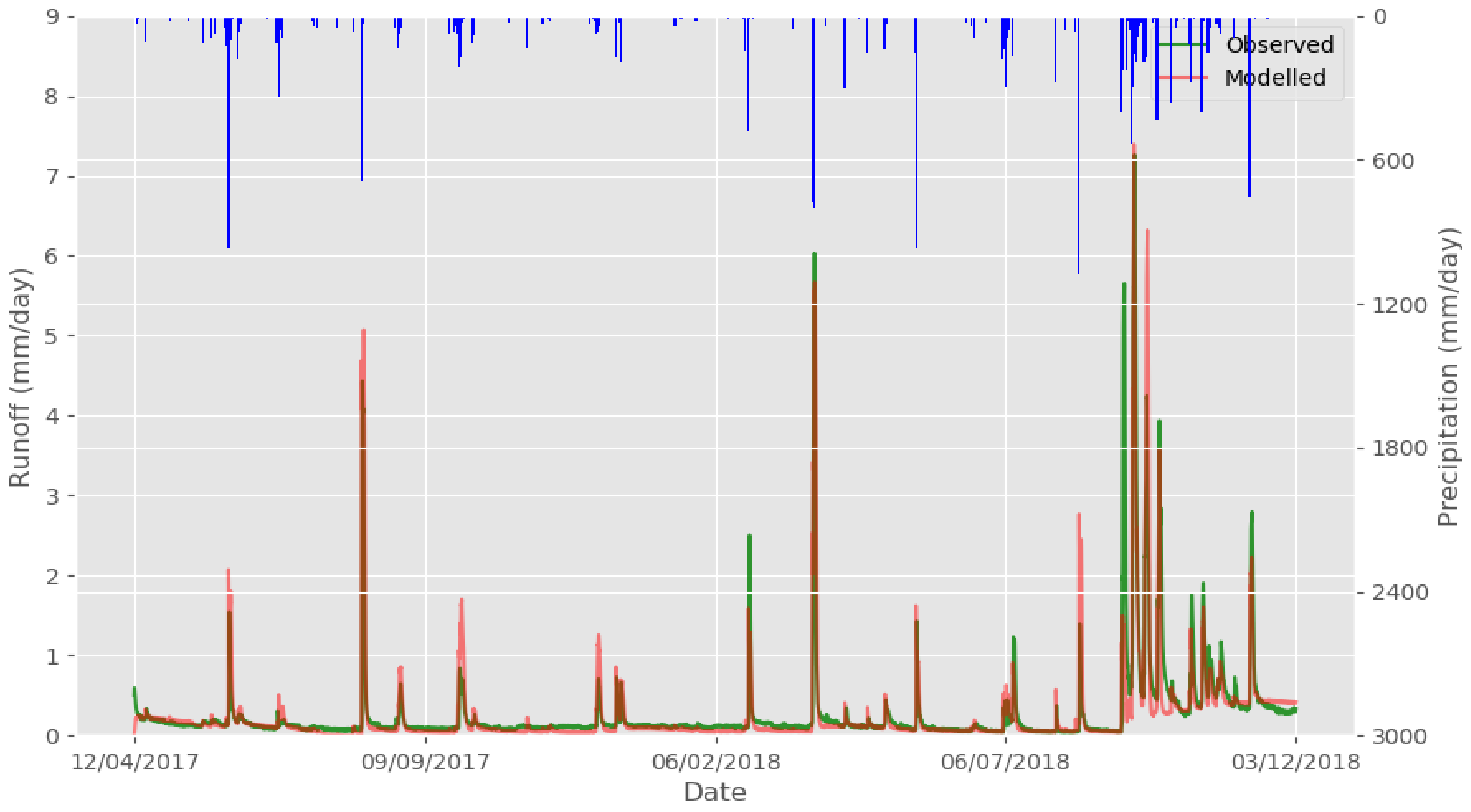

MODELLING

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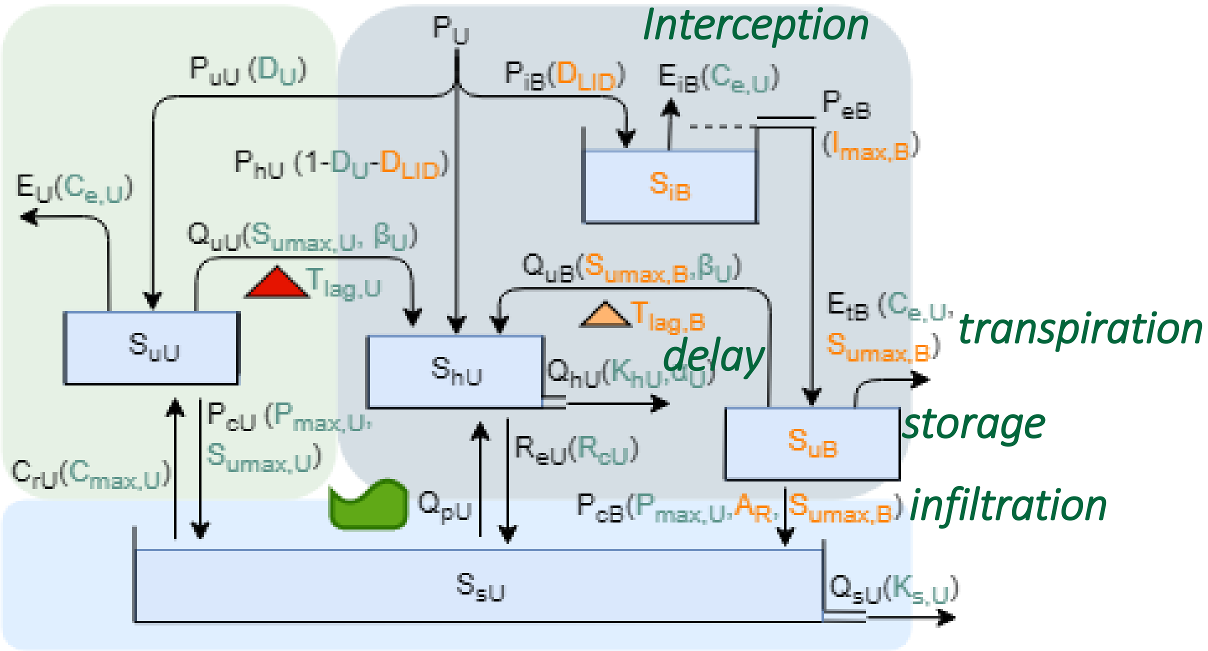
- **The expression of LID practices in model**

a. Qualitative hydrologic routes of four representative LID practices (Bioretention cells as example)

Table 9. The hydrologic functions of four representative LID practises

	Interception	Transpiration	Infiltration	Storage	Delay
Bioretention	++	++	++	++	++
Vegetated swales	+	+	++	+	++
Green roof	++	++	-	-	+
Permeable Pavement	++	-	++	+	++

Symbols: ++ major function; + accessory function; - insignificant function;



MODELLING

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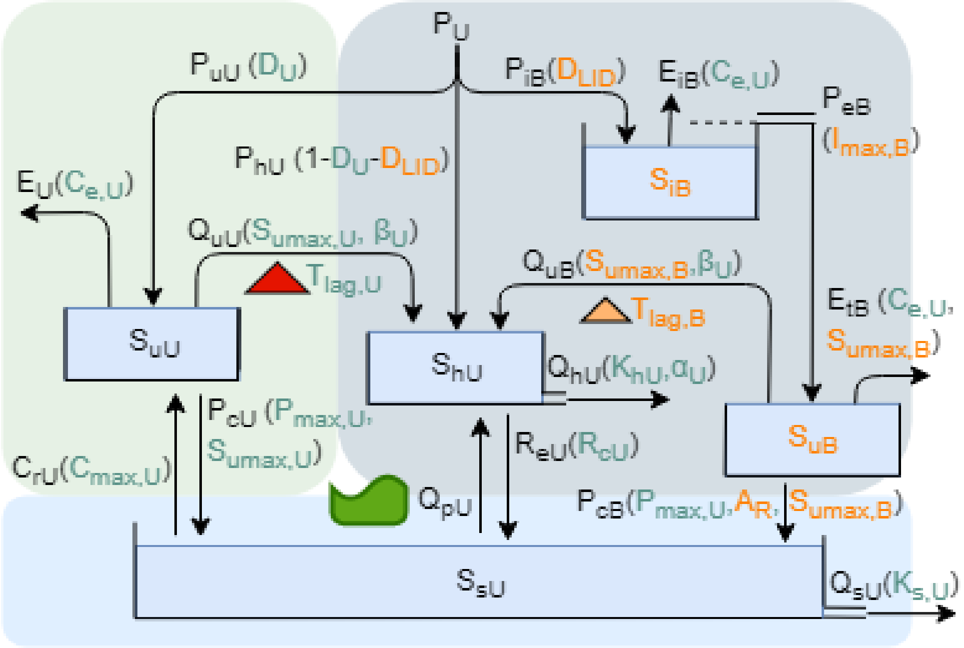
- **The expression of LID practices in model**

b. Quantitative parameters estimation

1. Precipitation distribution factor (D_{LID});
2. The ratio of drainage area to construction area (A_R);
3. The maximum interception depth ($I_{max,B}$): 3.5 mm
- 0.6 to 4.6 mm, <u>field tests</u> in Maryland, U.S. (Li et al , 2009);
4. The maximum water storage depth in soil layer (S_{umax}): 300 mm
- <u>"SARA LID Guidance Manual"</u> recommends 0.6 - 1.2 m soil media depth;
- <u>Empirical</u> soil porosity as 0.35 for moderately permeable local soil;
5. Time lag coefficient of bioretention cells (T_{lagB}): 3h
-according to a <u>field test</u> result, peak flow could be delayed by 3 hours by bioretention cells (Hunt., 2008);



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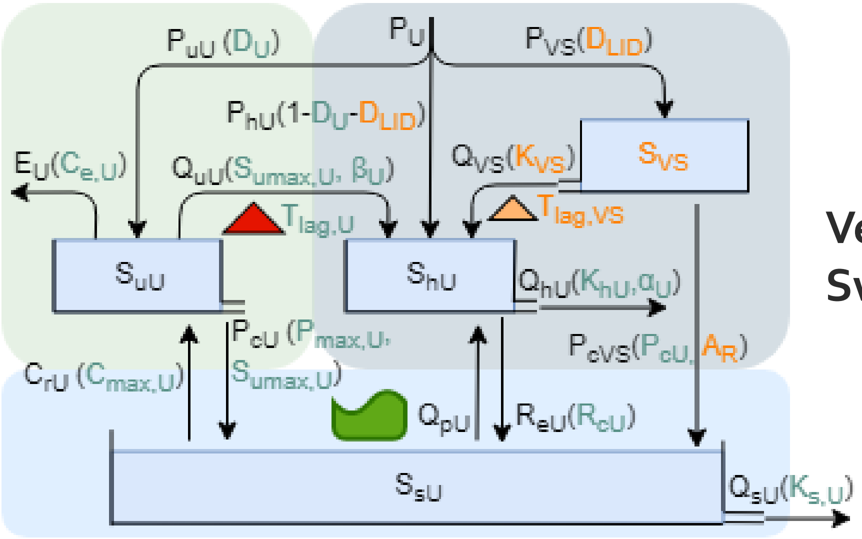
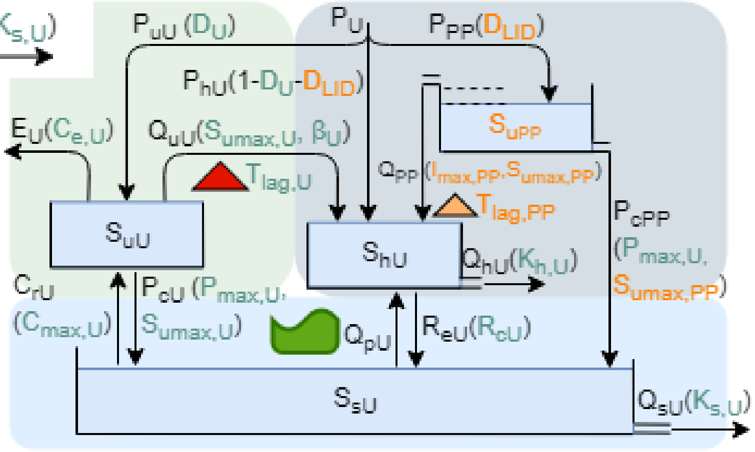
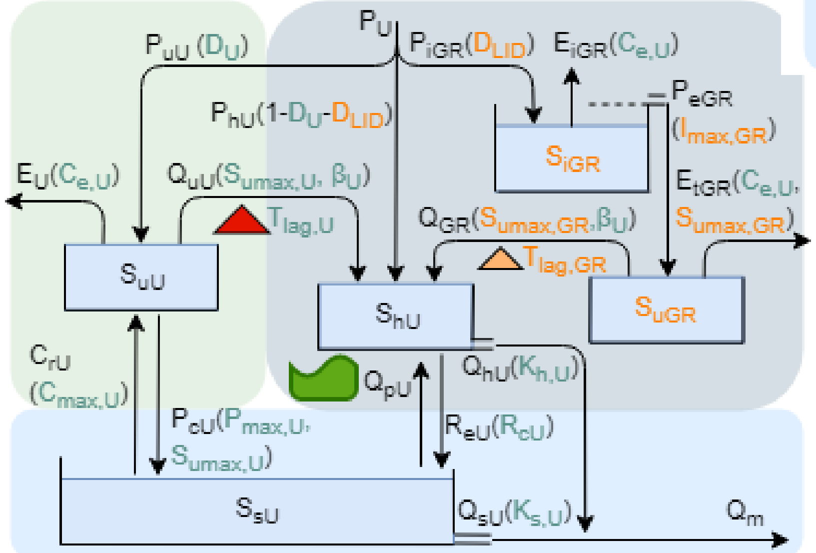


Vegetated Swales

Pervious pavements





Green Roofs

MODELLING

The expression of LID practices in model: the parameter estimation results of four LID practices

Table 10. The comparison of physical processes and their parameter expression in model

Physical Meaning	Prec. dist. factor [-]	Drainage area / Construction area [-]	Max intercept. Capacity [mm]	Max. storage capacity [mm]	Time lag of peak runoff [h]	Discharge coefficient [-]
Urban green area	0.779	1	-	51	-	-
Bioretention cell	D_B	$A_{R,B} \geq 1$	3.5	300	3	-
Vegetated swale	D_{VS}	$A_{R,VS} \geq 1$	-	-	2.5	0.34
Green roof	D_{GR}	1	3.1	42	0.5	-
Permeable Pavement	D_{PP}	1	4	120	2.5	-
Parameters	D [-]	A_R [-]	Imax [mm]	Sumax [mm]	Tlag [-]	K [-]
Urban green area	0.779	-	-	51	-	-
Bioretention cell	D_B	$A_{R,B} \geq 1$	$3.5/A_R*D_B$	$300/A_R*D_B$	13	-
Vegetated swale	D_{VS}	$A_{R,VS} \geq 1$	-	-	11	0.34
Green roof	D_{GR}	-	$3.1*D_{GR}$	$42*D_{GR}$	3	-
Permeable Pavement	D_{PP}	-	$4*D_{PP}$	$120*D_{PP}$	11	-

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SCENARIOS

- **Urban development scenarios**
- LID implementation scenarios

a. Scenarios design of urban development

- **Population Forecast: 2.4 million in 2040**
- **Urban development strategy: Higher density, less expansion;** since the former unconstrained outward urban expansion has led to disinvestment in the urban core areas and high cost of infrastructure and utility service

Table 11. Urban development scenarios between 2017 and 2040

Scenarios	New residents follows infill development [%]	Total residents in current urban areas (million)	New residents follows sprawl development [%]	New residents in urban expansion areas (million)
Current (2017)	-	1.5	-	-
A (2040)	100	2.4	0	0
B (2040)	70	2.13	30	0.27
C (2040)	50	1.95	50	0.45

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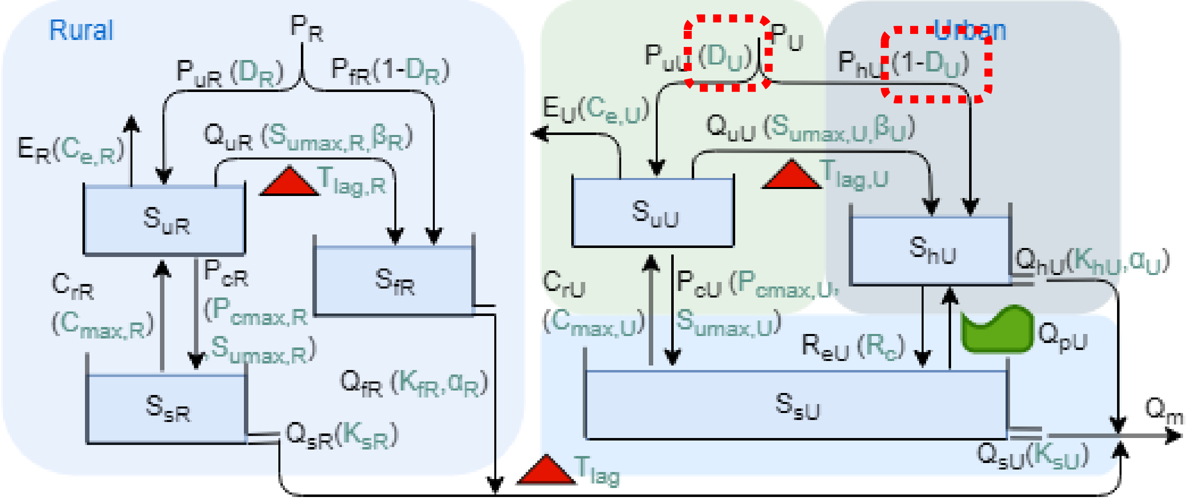
- **Urban development scenarios**
- LID implementation scenarios



b. The expression of urban development scenarios in model

- <u>The distribution of rural and urban areas;</u>
- <u>The distribution of urban green and grey areas (D);</u>

Two assumptions:

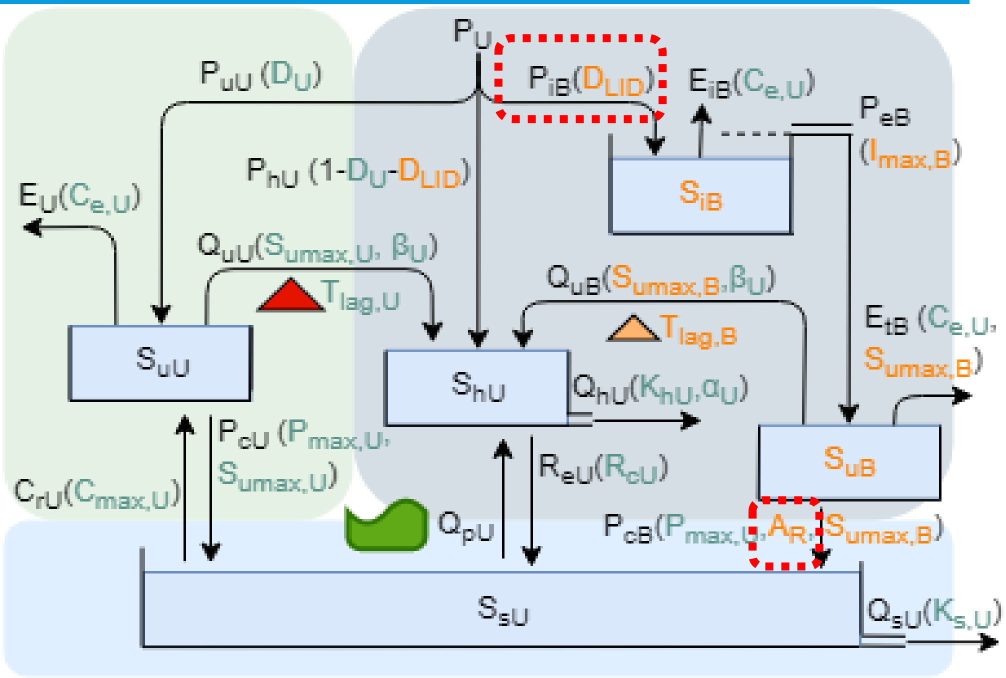
1. Uniform construction degree;
2. More infill urban development, less per capita urban grey areas: 3 estimate ratios for the compaction degree of living space (0.85, 0.9, 1)

Table 11. Urban development scenarios between 2017 and 2040

Scenarios	New residents follows infill development [%]	Total residents in current urban areas (million)	New residents follows sprawl development [%]	New residents in urban expansion areas (million)
Current (2017)	-	1.5	-	-
A (2040)	100	2.4	0	0
B (2040)	70	2.13	30	0.27
C (2040)	50	1.95	50	0.45

SCENARIOS

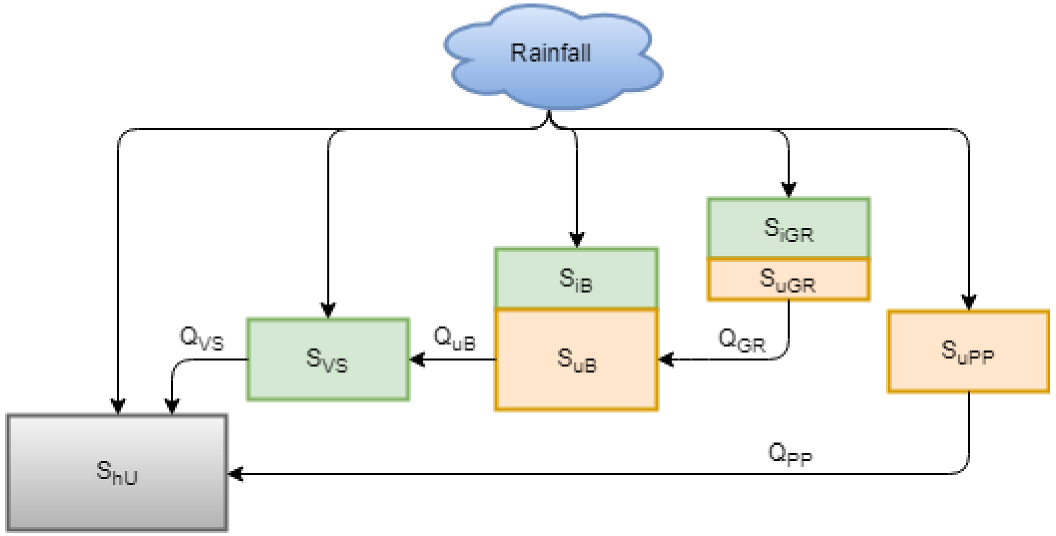
- Urban development scenarios
- **LID implementation scenarios**



Five scenarios are formulated and tested based on the urban development scenario C (half infill and half sprawl strategy).

1. Bioretention: 15% (precipitation on urban grey areas);
2. Vegetated Swales: 15%;
3. Green roofs: 15%;
4. Pervious pavement: 15%;
5. Mixed LID scenario: Bioretention cells 15% (A_R = 1.5); Vegetated swales 15% (A_R = 3); green roofs 5%; permeable pavements 15%; Cascade connection among LID practices;

A_R: the ratio of drainage areas and construction areas



THE INFLUENCE OF LOW IMPACT DEVELOPMENT ON RAINFALL-RUNOFF RELATIONSHIPS AT CATCHMENT SCALE

RESULTS

- **Q1: The different rainfall-runoff relationship of urban and rural areas**
- Q2: Urbanization influences
- Q3: LID implementation influences
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

a. The parameters calibration result of rural and urban lumped models

Table 13. The comparison of parameter intervals in rural and urban lumped models

Para. range		Ce [-]	Sumax [mm]	Pmax [mm/d]	Cmax [mm/d]	Ks [1/mm*d]	Tlag [-]
Rural	Min	1	150	0	0	0	41
	Max	3	250	5	1	0.006	101
Urban	Min	0.5	30	0	0	0	21
	Max	3	375	5	1	0.0002	85

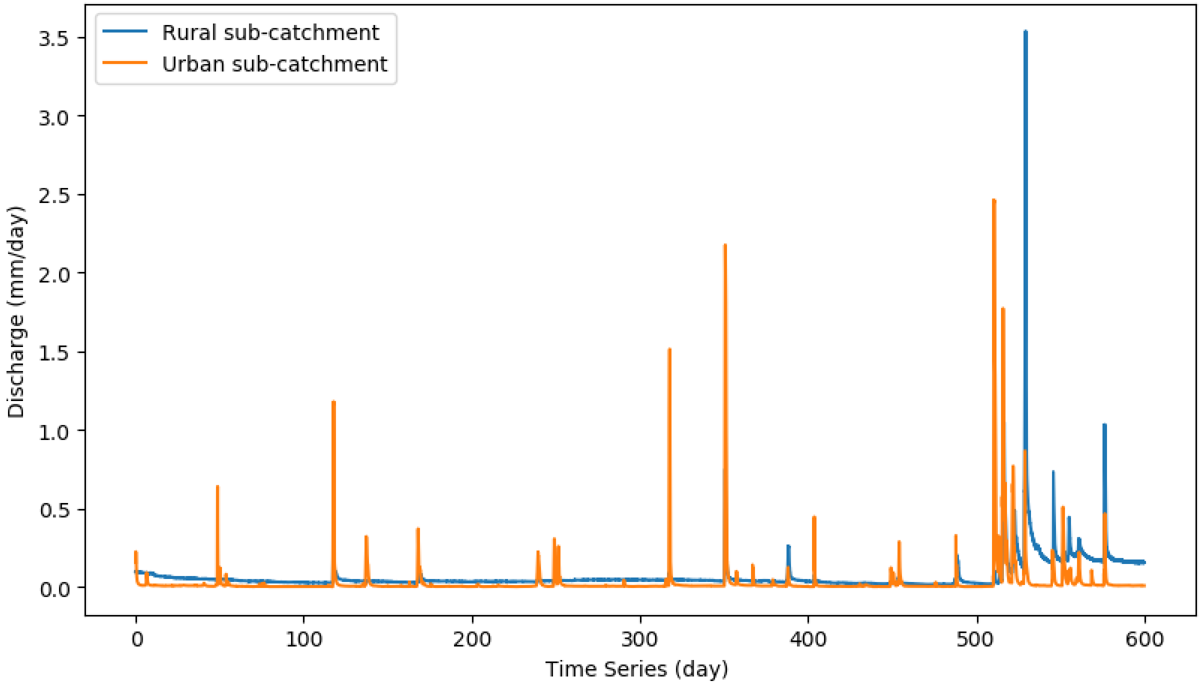
Evaporation correction coefficient *Maximum unsaturated storage* *Slow groundwater flow coefficient* *Time lag coefficient*

	Evaporation	Water storage	Runoff delay	Groundwater flow
Rural	+	+	+	+
Urban	-	-	-	-

Symbols: + strong; - weak;

RESULTS

- **Q1: The different rainfall-runoff relationship of urban and rural areas**
- Q2: Urbanization influences
- Q3: LID implementation influences
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation



b. The comparison of rainfall-runoff relationship of urban and rural areas

In general, the runoff from rural areas performs more moderate than it from urban areas.

Urban: varies between extreme flood and extreme drought;

Rural: the peak flows seldom happen in dry seasons, but in flood season, the magnitude of peaks may be great.

(And the presence of peak runoff is always accompanied with the increase of base flow caused by large groundwater stock.)

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- **Q2: Urbanization influences**
- Q3: LID implementation influences
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

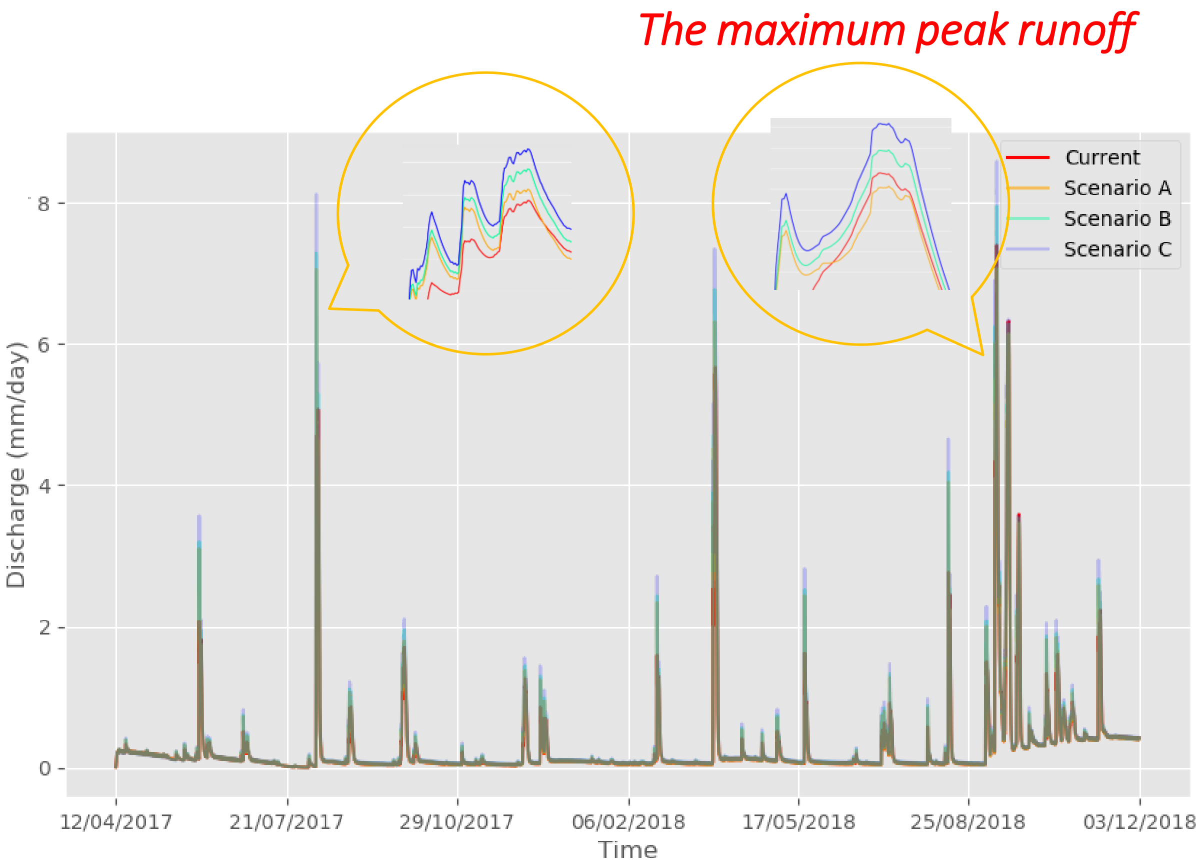


Figure 32. The total basin runoffs of the three urban developed scenarios

Table 14. The statistical analysis of modelled runoff results for three urban development scenarios

	Current	Scenario A	Scenario B	Scenario C
Total runoff volume in research period [mm]	159.6	163.9	173.5	182.5
Increase proportion of the total runoff [-]	-	2.7%	8.7%	14.3%
The maximum peak runoff [mm/d]	7.40	7.08	7.95	8.59
Increase proportion of the maximum peak runoff [-]	-	-4.3%	7.5%	16.1%

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- **Q2: Urbanization influences**
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- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

❖ *The decrease of extreme peak flow in Scenario A*

Scenario A: has larger urban grey areas and less urban green areas

Small to medium peaks: only generate from urban grey areas, increase;

Extreme large peaks in flood season: mainly generate from large area of urban green surface (and rural areas), decrease;

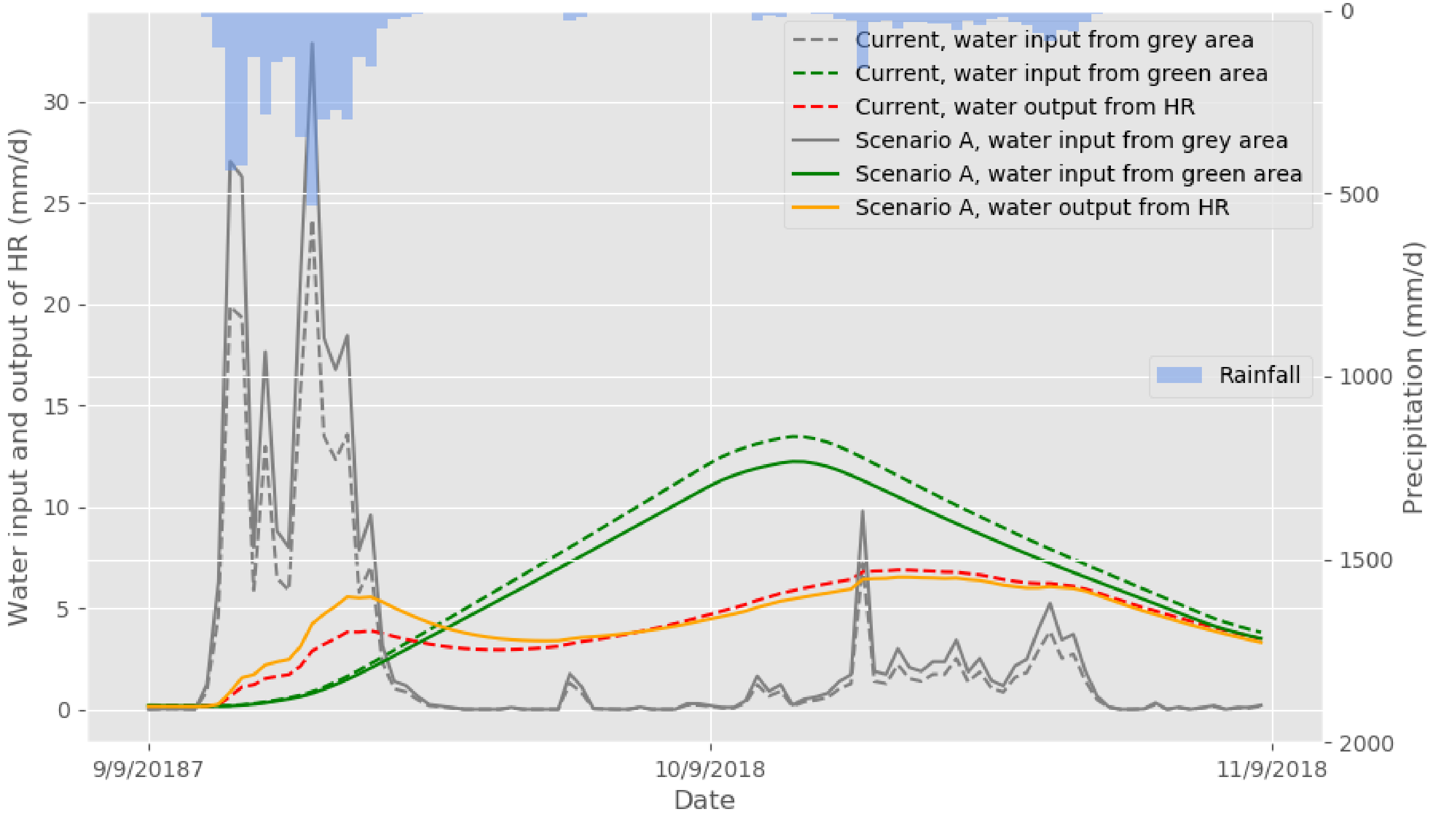

Figure 34. The water input and output of urban drainage system (HR) in current situation and urban development scenario A

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- Q2: Urbanization influences
- **Q3: LID implementation influences**
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

a. Less effective on basin peak runoff reduction in flood season

Reason 1. LID practices influence urban grey areas; however peaks in flood season are generated from rural and urban green areas.

Reason 2. Intensive rainfalls take up most space of LID practices and exhaust the water retention capacity.

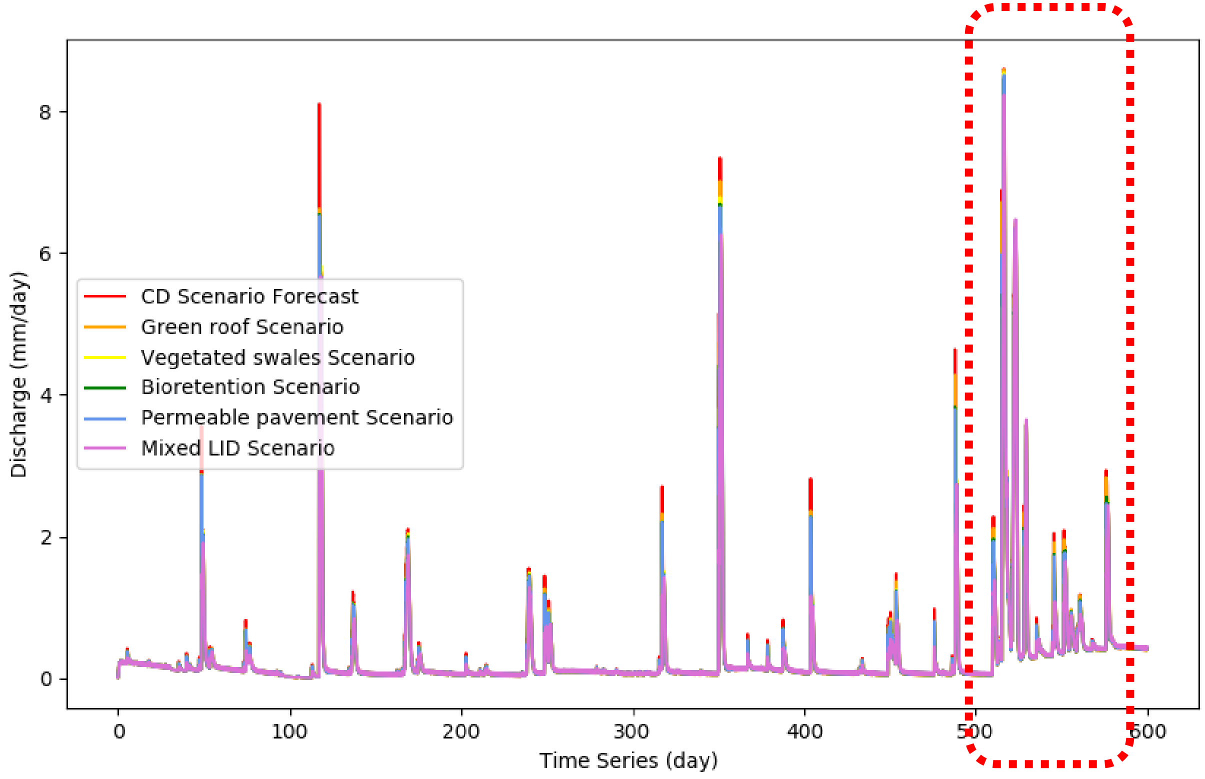

Figure 35. The total basin runoff of five LID scenarios and the CD scenario

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- Q2: Urbanization influences
- **Q3: LID implementation influences**
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

b. LID practices have more significant effect on the first vertex

The first peak vertex mainly generates from urban grey areas;

The second vertex mainly generates from large areas of urban green surface or rural areas, which are not the "domain" of LID.

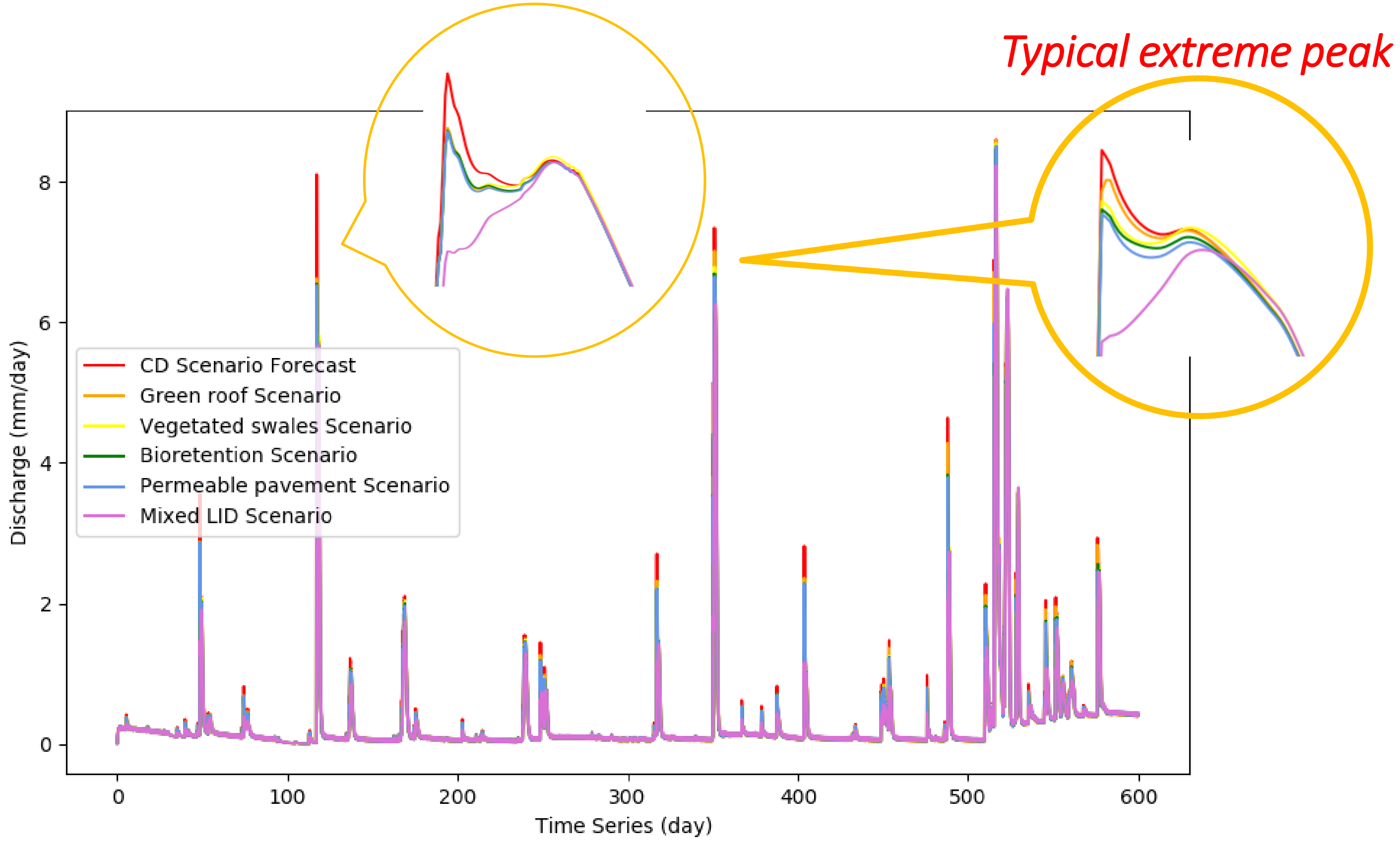

Figure 35. The total basin runoff of five LID scenarios and the CD scenario

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- Q2: Urbanization influences
- **Q3: LID implementation influences**
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

c. The comparison of 4 LID practices

(the first 4 scenarios with single LID practices)

- Bioretention cells, pervious pavements: forceful runoff volume and peak runoff reduction ability;
- Vegetated Swales: weak runoff volume reduction ability;
- Green Roofs: weak peak runoff reduction ability, lose function in flood seasons, since small water retention capacity.

Table 15. The statistical analysis of modelled runoff results for 5 LID scenarios

Table 51. Specific runoff retention amount of 4 single LID scenarios in model results in 600 research days

		Prec.	Evap.	Infill.	Overflow	Storage
Bioretention	Amount (mm)	437	94.1	238.2	69.8	35.2
cell	Ratio	100%	21.5%	54.5%	16.0%	8.1%
Green roof	Amount (mm)	437	187.9	-	160.1	88.6
	Ratio	100%	43.0%	-	36.8%	20.3%
Vegetated	Amount (mm)	437	-	109.8	327.5	0
swale	Ratio	100%	-	25.1%	74.9%	0
Pervious	Amount (mm)	437	-	383	37.8	16.1
pavement	Ratio	100%	-	87.7%	8.6%	3.7%

Symbols: - the processes not in model structure (do not indicate non-exist process, but are neglected compared to other major functions)

peak runoff [mm/d]

Decrease proportion of the second vertex [-]	-	0.2%	-0.2%	1.4%	2.2%	3.5%

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
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- **Q3: LID implementation influences**
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

d. More water input and less construction areas for bioretention cells (Mixed scenario & Bioretention scenario)

- The ratio of overflow kept the same
- Infiltration decreases: less construction areas ;
- Evaporation (Interception and transpiration): better developed.

Great runoff reduction potential, especially evaporation;

Table 54. Performance comparison of bioretention cells in mixed LID scenario and single bioretention scenario

Scenarios		Prec.	Inflow	Evap.	Infil.	Overflow	Storage
Mixed Scenario	Amount (mm)	437	59.9	257	133.3	82.0	24.9
	Ratio	87.9%	12.1%	51.7%	26.8%	16.5%	5.0%
Single scenario	Amount (mm)	437	-	94.1	238.2	69.8	35.2
	Ratio	100%	-	21.5%	54.5%	16.0%	8.1%

	Drainage area (of urban grey area)	Construction area (of urban grey area)	Water input (mm)
Mixed scenario	15%	10%	497
Bioretention scenario	15%	15%	437

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- Q2: Urbanization influences
- **Q3: LID implementation influences**
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

e. Mixed LID scenario (based on urban development scenario C)

- Most peaks (generating from urban grey areas) are controlled well.
- Extreme large peaks in flood season (also generating from rural and urban green areas): the peak reduction ability was restrained significantly; But larger extent of infill urban development strategy (like scenario A) could be used to solve this problem;

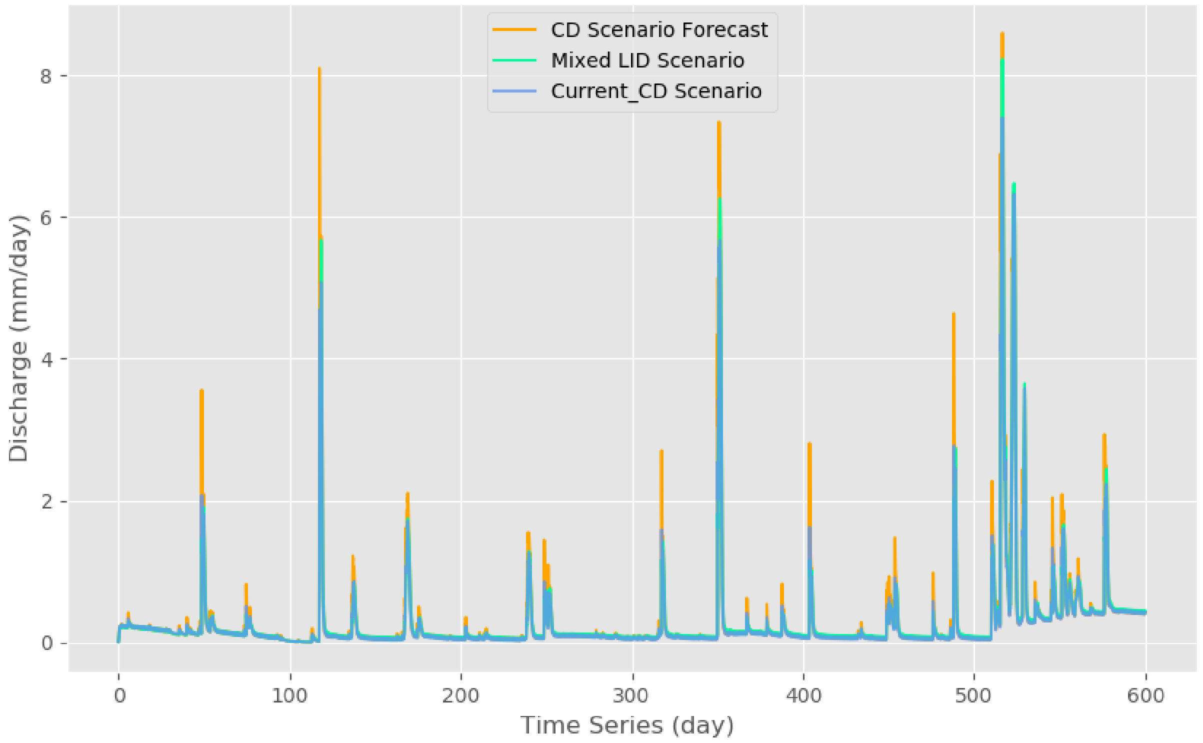


Table 55. Model results of the total basin runoff in mixed LID scenario, the current CD scenario and the CD scenario in 2040

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- Q2: Urbanization influences
- Q3: LID implementation influences
- **Q4: The time approaching and stacking of urban and rural peaks due to LID implementation**

a. Four scenarios with single LID practice

Time lags between LID and CD urban peaks: 0.5 - 2.5 hours;

(Time lags between rural peaks and CD urban peaks: 6.5 - 15.5 hours;)

delay ability < reduction ability, most basin peak runoffs decrease

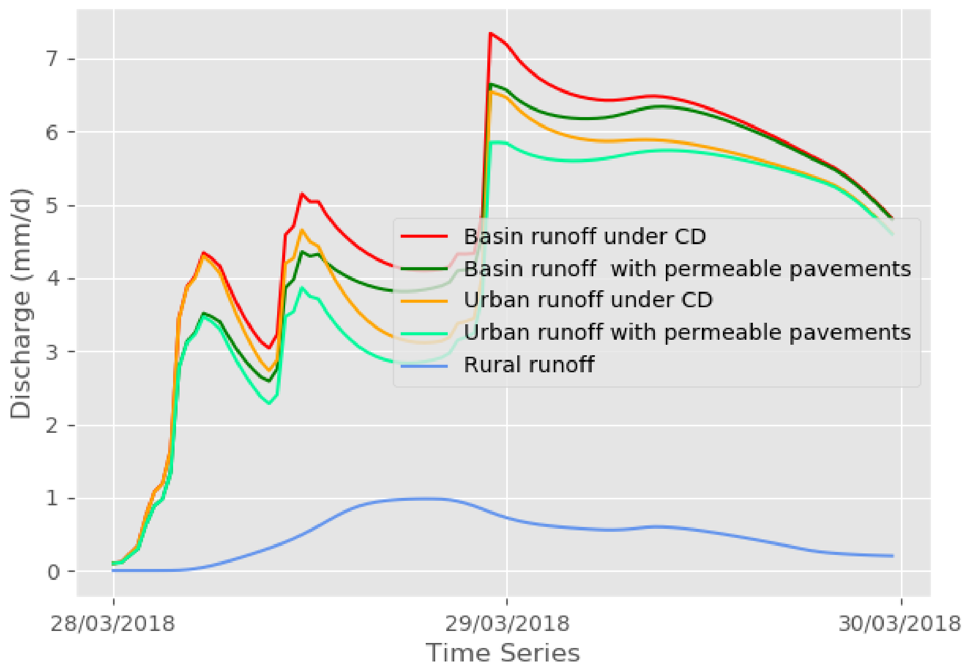


Table 55. Model results of the total basin runoff in mixed LID scenario, the current CD scenario and the CD scenario in 2040

RESULTS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- Q2: Urbanization influences
- Q3: LID implementation influences
- **Q4: The time approaching and stacking of urban and rural peaks due to LID implementation**

b. The mixed LID practices scenario

Time lags between LID and CD urban peaks: 0.5 - 6.5 hours;

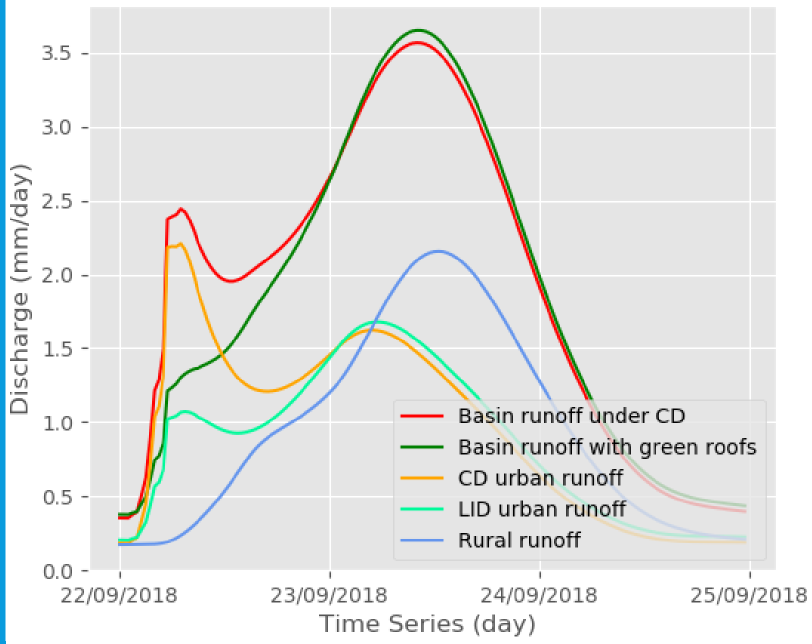
(Dry season: reduction ability > delay ability, basin peaks decrease)

<u>Flood season: reduction ability < delay ability, basin peaks increase</u>

Urban runoff (L): increased by 0.06 mm/d, from 1.62 to 1.68 mm/d;

Total basin runoff (L): increased by 0.08 mm/d, from 3.57 to 3.65 mm/d;

Total basin runoff (R): increased by 0.12 mm/d, from 6.35 to 6.47 mm/d.



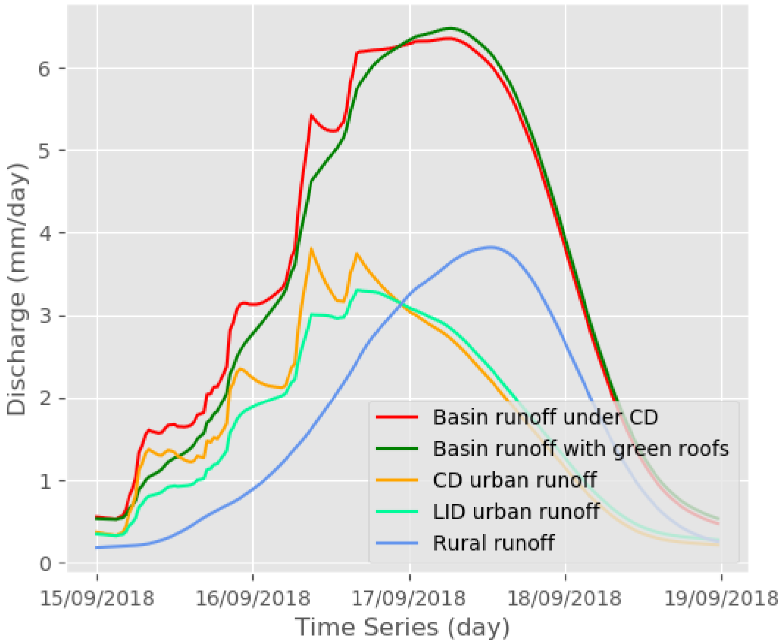


Figure 40. The peak runoffs from rural, urban, and basin areas in mixed LID practices scenario and CD scenario

THE INFLUENCE OF LOW IMPACT DEVELOPMENT ON RAINFALL-RUNOFF RELATIONSHIPS AT CATCHMENT SCALE

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DISCUSSIONS

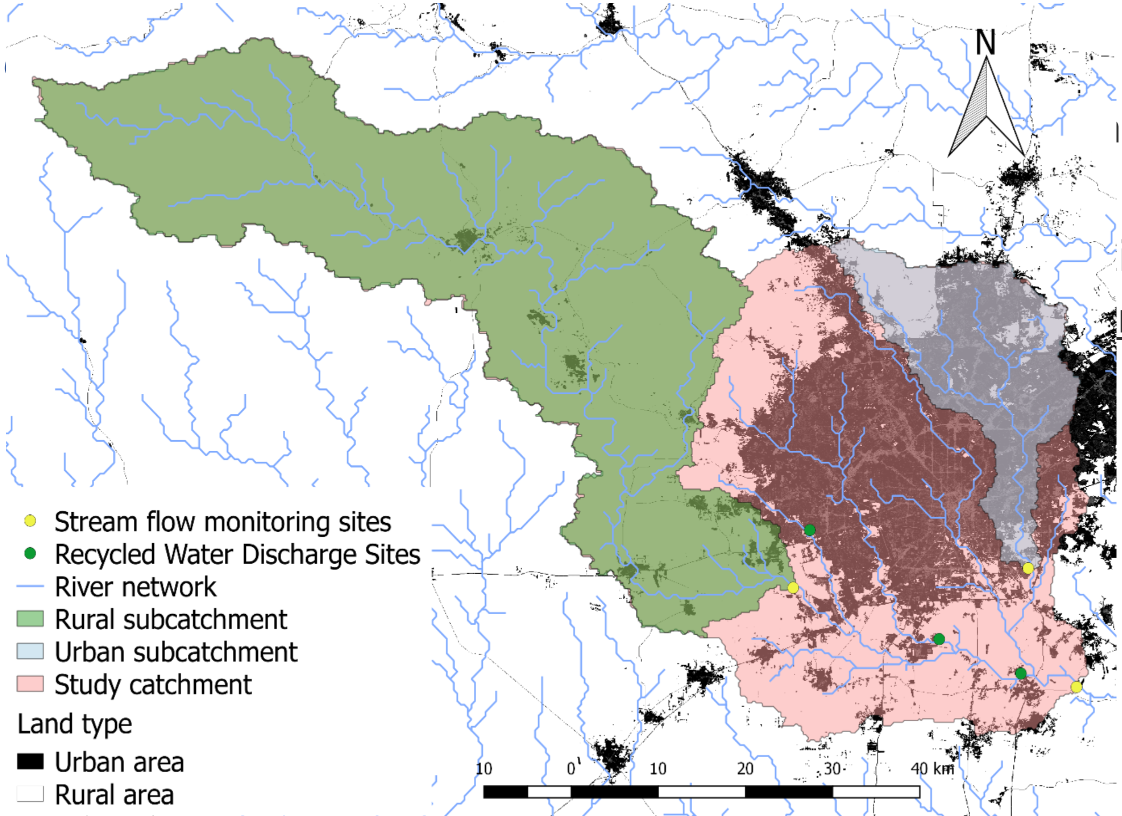
- **Model uncertainty**
- Scenario limitation
- The comparability of research results and literatures about LID

a. Low complexity of model structure

- Overlook the heterogeneity within the rural or urban areas;
- Reliability and accuracy of the mathematical expressions of many artificial water processes (such as urban stormwater drainage, water pumping, and groundwater recharge) are arguable;

b. The model components inheritance from lumped to semi-distributed model

- Some information may be lost;



as 12-cm soil

ices, lack of daily

neglected.

DISCUSSIONS

- Model uncertainty
- **Scenario limitation**
- The comparability of research results and literatures about LID

a. The limitation of urban development scenarios

- Population forecast: 0.9 million new residents between 2017 and 2040;
- Uniform construction degree;
- 3 estimate ratios for the compaction degree of living space (0.85, 0.9, 1).

b. The limitation of LID implementation scenarios

- Uniform LID implementation;
- Optimistic design: 50% of the precipitation on urban impervious surface is collected, and cascade connections for mixed LID scenarios.

DISCUSSIONS

- Model uncertainty
- Scenario limitation
- **The comparability of research results and literatures about LID**

a. The comparability of model result

The reduction of total runoff volume	Literatures (Resources)	This research
Bioretention cells	**48% - 97%** (Chapman and Horner, 2010; DeBusk and Wynn, 2011)	**84%**
Green roofs	**23% - 100%** (VanWoert, 2005; Hathaway, 2008; Carpenter and Kaluvakolanu, 2011)	**63%**
Permeable pavements	**50% - 93%** (Rushton, 2001; Hunt, 2002; Dreelin, 2006)	**91%**
Vegetated swales	**85%** for small storms; **35% - 66%** for large storms (Hunt, 2010)	**25%** for all the storms in total

b. Analysis comparability

- Ineffective runoff reduction performance (total volume) of <u>vegetated swales</u> is ascribed to its <u>fast rainwater transportation and short residence time</u> (Huang, 2018).
- <u>Permeable pavement</u> is the most hydrologically effective LID practice among the four test LID practices (Ahiablame, 2012).
- Compared to single LID practices, <u>the mixed of various LID practices</u> should be promoted with better robustness (Qin, 2013; Askarizadeh, 2015; Fang, 2017; Huang, 2018).

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CONCLUSIONS

- **Q1: The different rainfall-runoff relationship of urban and rural areas**
- **Q2: Urbanization influences**
- Q3: LID implementation influences
- Q4: The time approaching and stacking of urban and rural peaks due to LID implementation

Since the specific conditions of study catchment, some quantitative conclusions of this research are limited in a restrained region.

Q1 :

- Urban: varies between extreme flood and extreme drought;
- Rural: more moderate, but in flood season peak runoffs may be large.

Q2 :

- The infill urban development strategy is more helpful on runoff reduction than sprawl urban development strategy.
- For the scenario C (half-infill and half-sprawl), the total runoff volume would rise by 14% compared to current situation. And for scenarios B (70%-infill and 30%-sprawl), the total runoff would rise by 9% in. As for scenario A (full infill development), this growth rate is only 3%.
- For scenario C and scenario B, the peak runoff of a typical extreme peak increased by 16% and 8% than current situation, however scenario A even decreased the peak runoff by 4%.

CONCLUSIONS

- Q1: The different rainfall-runoff relationship of urban and rural areas
- Q2: Urbanization influences
- **Q3: LID implementation influences**
- **Q4: The time approaching and stacking of urban and rural peaks due to LID implementation**

Q3 :

- LID practices are less effective on peak runoff reduction in flood season than dry season;
- Bioretention cells and pervious pavements have forceful runoff reduction ability; The runoff volume reduction ability of vegetated swales is weak; Green Roofs performed worst on peak runoff reduction;
- More water input and less construction areas could better develop the evaporation ability of bioretention cells;

Q4:

- For four scenarios with single LID practice (15%), the peak delay is not significant, and therefore there is no obvious increase on basin peaks.
- For the mixed LID scenarios (50%), the delayed urban runoff brings larger stack of rural and urban peaks and increases two basin peak runoffs in flood season from 3.57 to 3.65 mm/d and from 6.35 to 6.47 mm/d.

THE INFLUENCE OF LOW IMPACT DEVELOPMENT ON RAINFALL-RUNOFF RELATIONSHIPS AT CATCHMENT SCALE

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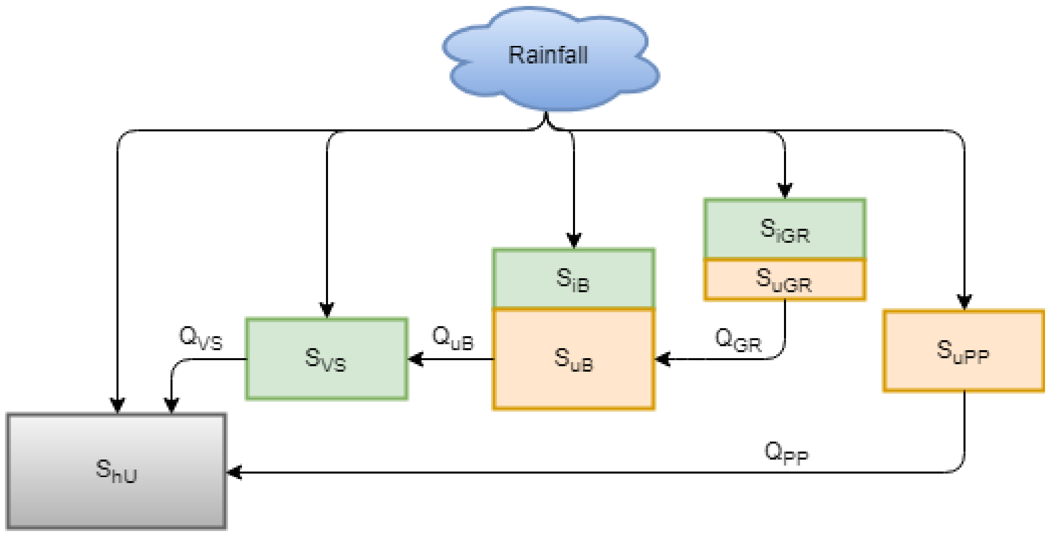
RECOMMENDATIONS

- **Recommendations for the suitable LID implementation**
- **Recommendations and suggestions for future research**

- The combination of various LID practices rather than single LID; and cascade connections among different LID practices
- The infill development strategy is more helpful on runoff reduction than sprawl development strategy,
- When making urban development and LID implementation plans, the time difference between the peak runoffs from the sub-areas (rural areas, urban grey and green areas; bare, grass, bush and tree areas) could be design by adjusting the area and position of sub-areas. Therefore, the basin peak runoffs could be controlled.
- Future research could exploit distributed models to further explore the influence of heterogeneous urban condition (caused by urban drainage system, regional water police, partial construction degree and etc).



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THANK YOU FOR YOUR LISTENING!