Supplementary data

S.1. Description of the model

The description of the model components are presented in Table S.1 according to the Overview, Design concepts, and Details, proposed by Grimm et al. (2010).

Table S.1: Description of the model according to the ODD protocol

ODD Element	Implementation in the model
Purpose	The purpose of the model is to simulate the decision-making process of the local government regarding the installation of public water sensitive urban design (WSUD) systems, i.e., ponds, raingardens and constructed wetlands.
Entities	The focus of the paper is on the decision-making of the local municipality or government, also known as city council. It is therefore the only agent in simulations.
Scales	The temporal and spatial scales are described in section 3.1. Simulations are run for the Kingston city case study and for the period 2005-2012.
Process overview and scheduling	The process overview and scheduling are reported in Figure 1.
Basic principles	It is assumed that stormwater treatment is the main water management objective of the council, as opposed to flood management or water savings. The council chooses the type and size of system to install based on a budget rule, location selection rules, providing in total 24 scenarios.
Emergence	The key results from the model are the cumulative treatment capacity and cumulative count of assets installed over the simulation period, as well as the spatial distribution of WSUD systems.
Adaptation	The council agent does not change its decision-making process during the simulation, nor is it given adaptive traits.
Objectives	The objective of the council agent is to achieve higher Total Nitrogen removal through the placement of WSUD systems.
Learning	The agent makes its decision based on the current year information and does not change its decision-making process over time.
Prediction	The agent does not predict the value of parameters for following years (e.g., rainfall) but it assumes that benefits and costs will remain the same for the service life of the systems when estimating the net present value of benefits and costs.

ODD Element	Implementation in the model
Sensing	Councils make decisions based on the catchment effective impervious area, which changes after the installation of a WSUD system. Therefore, the agent “senses” or adapts his decision to the new catchment effective impervious area.
Interaction	There is currently no interaction between the council agent and other potentially relevant agents, such as developers and households.
Stochasticity	For one location rule (i.e., **L1: Random selection**), parcels are ordered randomly by the agent. Stochasticity is also introduced through sampling, by selecting values from uniform distributions for the uncertain parameters shown in Table 3.
Collectives	There is no collective of agents.
Observation	The output data are collected in SQLite files with the SpatiaLite extension. The main model outputs are described in section 2.5 and displayed in Figure S.2.
Initialisation	Initialisation for the case study of Kingston city council is described in section 3.1.
Input data	Spatial input data are presented in Tables 2 and S.2, and the parameter range for uncertainty assessment is presented in Table 3.

S.2. Spatial layers and parameters

Figure S.2 shows the spatial representation of block- (500x500m) (Figure S.2a) and catchment-scale effective impervious area (EIA) (Figure S.2b). Catchment-scale EIA is measured as the sum of EIA of upstream blocks using flow paths and sub-catchment delimitations displayed in Figure S.2b. The translation of attributes from blocks to parcels is displayed in Figure S.2c, in this case showing the catchment-scale EIA of four blocks with their intersecting parcels.

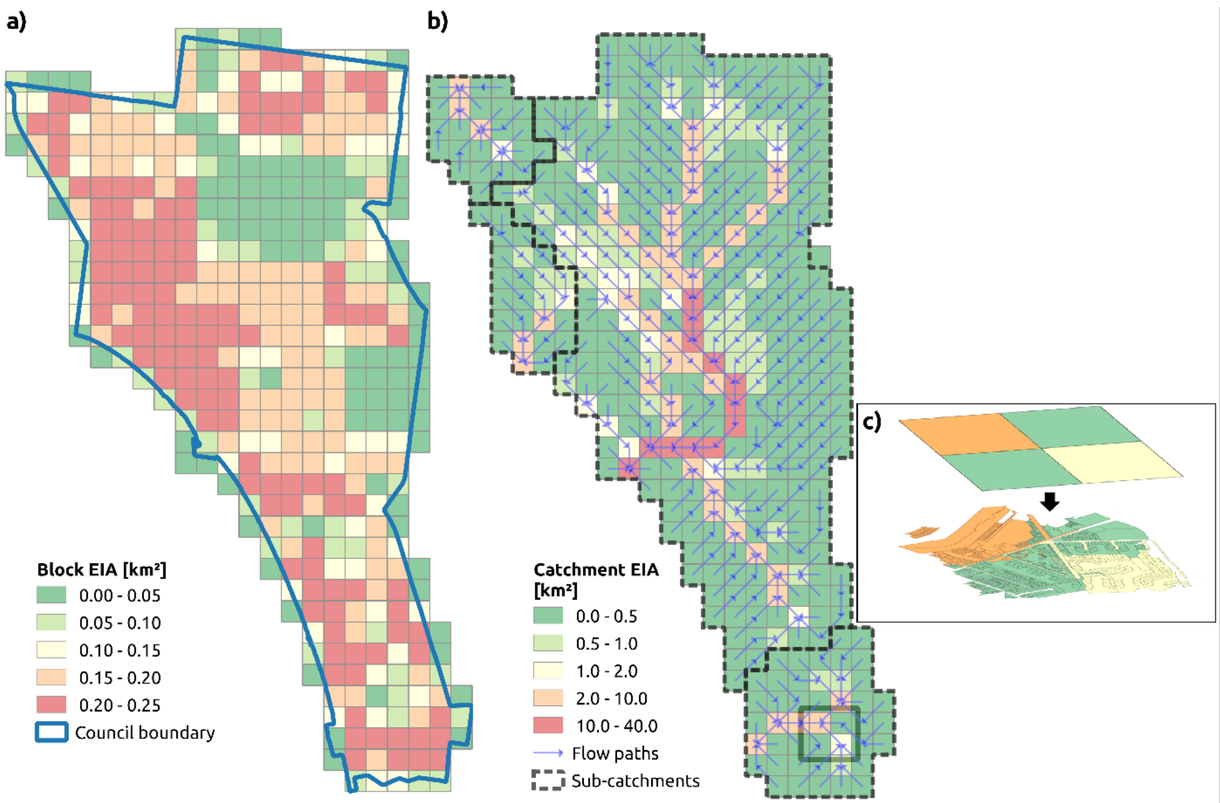

Figure S.2: Spatial representation of block- (**a**) and catchment-scale EIA (**b**). Block attributes are written on the parcel layer, with the example of catchment-scale EIA (**c**).

Table S.2 shows the parameters used in the DynaMind simulation (for a list of parameters for UrbanBEATS simulations, please refer to Bach et al. (2018)). Parameters are grouped by parcel, block, flow and council layers. Input parameters in the model are distinguished from variables, i.e., created and updated during the simulations. The table also indicates which parameters are directly used for the different decision rules.

The main output variables used to evaluate the performance of the model are $TREAT_y$ and $COUNT_{w,y}$ from the council layer.

Table S.2: Model parameters and spatial layers.

Spatial layer	***Parameter name***	***Symbol***	***Unit***	***Type***	***Decision rules***		
					B	**L**	**S**
parcel	Annualised renewal cost of WSUD system *w* of area *a*	$RC_{a,w}$	AU$	Variable			
parcel	Area converted to a WSUD of type *w* on parcel *p*	$a_{p,w}$	m^2	Variable			
parcel	Effective impervious area of block *b* that overlays parcel *p*	$EIA_{b,p}$	m^2	Input			
parcel	Building area on parcel *p*	Bld_area_p	m^2	Input			
parcel	Catchment effective impervious area of block *b* that overlays parcel *p*	$Cat\_EIA_{b,p}$	m^2	Input			
parcel	Construction cost of WSUD system *w* of area *a*	$CC_{a,w}$	AU$	Variable			
parcel	Decommissioning cost of WSUD system *w* of area *a*	$DC_{a,w}$	AU$	Variable			
parcel	Economic value of TN removal benefit for parcel *p* provided by WSUD system *w* at year *y*	$B_{p,w,y}$	AU$	Variable			
parcel	Impervious catchment area treated by WSUD system *w* for a given parcel *p*	$A_{p,w}$	m^2	Variable			**S1, S3, S4**
parcel	Land use	-	-	Input			
parcel	Maintenance cost of WSUD system *w* of area *a*	$MC_{a,w}$	AU$	Variable			
parcel	Net present benefit of TN removal for parcel *p* provided by WSUD system *w* at year *y* [AU$]	$NPB_{p,w,y}$	AU$	Variable			**S3**
parcel	Net present costs of WSUD system w of area a	$NPC_{a,w}$	AU$	Variable			**S3, S4**
parcel	Rainfall	$P_{p,y}$	m	Input			
parcel	Randomly generated number for ordering parcels for location rule **L1: Random selection**	Rd_p	-	Input		**L1**	
parcel	Runoff	$R_{p,y}$	m	Variable			
parcel	Runoff coefficient for each parcel *p*	Rv_p	%	Variable			
parcel	Impervious fraction	Ia	%	Input			
parcel	Suitability of WSUD system *w* for parcel *p*	$S_{w,p}$	-	Input		**L2**	**S1, S2**
parcel	Total nitrogen removed by a WSUD system *w* on parcel *p* at year *y*	$TN_{p,w,y}$	kg	Variable			
parcel	Extent of catchment effective impervious area that has been treated on parcel *p*	$treated_p$	m^2	Variable			
parcel	Zoning	-	-	Input			
block	Block effective impervious area on block *b*	EIA_b	m^2	Input			
block	Catchment effective impervious area on block *b*	Cat_EIA_b	m^2	Input			
block	Suitability of WSUD system *w on block* b	$S_{b,w}$	-	Input			
block	Extent of catchment effective impervious area that has been treated on block *b*	$treated_b$	m^2	Variable			
flow	Block-scale effective impervious area for flow path *f*	EIA_f	m^2	Input			
flow	Catchment effective impervious area for flow path *f*	Cat_EIA_f	m^2	Input			
council	Adjustment factor to account for different hydrologic regions across Melbourne for WSUD system *w*	AF_w	-	Input			
council	Count of WSUD system *w* at year *y*	$COUNT_{w,y}$		Variable			
council	Current year	y	year	Input			
council	Discount factor at year *n* of the lifespan of WSUD system *w*	$d_{n,w}$	-	Variable			
council	Discount rate	r	%	Input			
council	Fraction of annual rainfall events that produces runoff	F	%	Input			
council	Lifespan of WSUD system *w*	t_w	year	Input			
council	Allocation for capital works in annual Kingston budget at year *y*	$allocation_y$	AU$	Input	**B1**		
council	Aggregated construction cost of actual systems installed at year *y*	Sum_cc_y	AU$	Input	**B2**		
council	Aggregated net present cost of actual systems installed at year *y*	Sum_npc_y	AU$	Input	**B3**		
council	Targeted removal of TN	TNR	%	Input			
council	TN concentration from runoff	C	kg/m^3	Input			
council	Aggregated treatment capacity	$TREAT_y$	m^2	Variable			
council	Annualised stormwater offset rate at year y	O_y	AU$	Input			

S.3. Annual rainfall and rain stations

Figure S.3 shows the location of the two rain stations in the case study area. Each parcel is assumed to receive the same annual rainfall as the closest rain station and rainfall is updated annually.

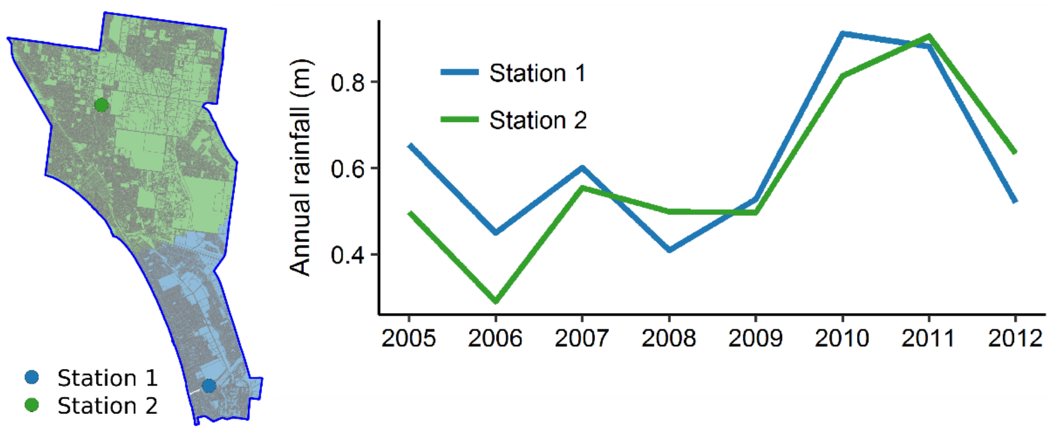

Figure S.3: Location of the two rain stations and associated parcels, with their annual rainfall for the simulation period.

S.4. Convergence of mean treatment capacity

Figure S.4 shows the convergence of mean treatment capacity at year 2012 as a function of the number of model runs. We assumed that 500 simulations for each model variation was sufficient to achieve the convergence of model results.

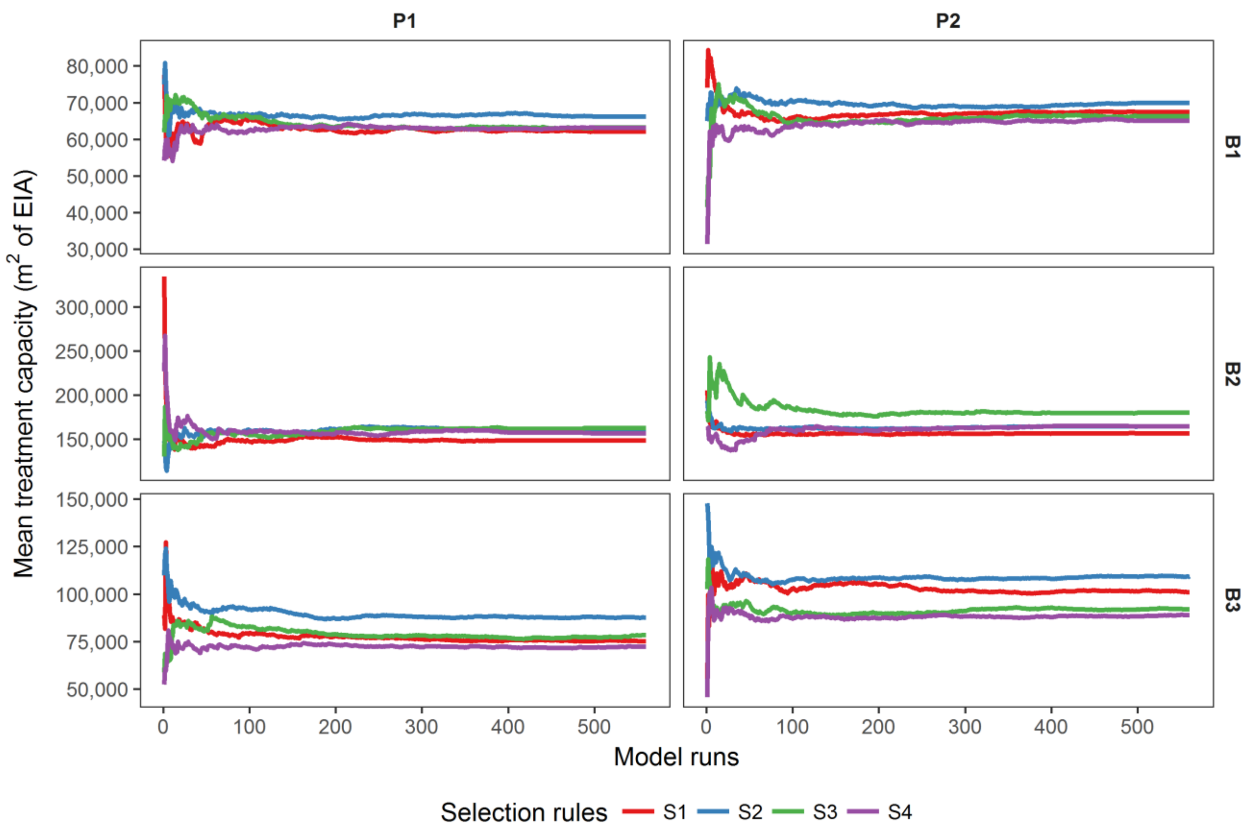

Figure S.4: Convergence of the mean treatment capacity at year 2012 as a function of the number of model runs.

S.5. Location and density of WSUD assets

The estimated two-dimensional kernel density of modelled systems is compared to the location of actual assets for all type/size and location selection rules and for budget measure **B2: installation costs** in Figure S.5.

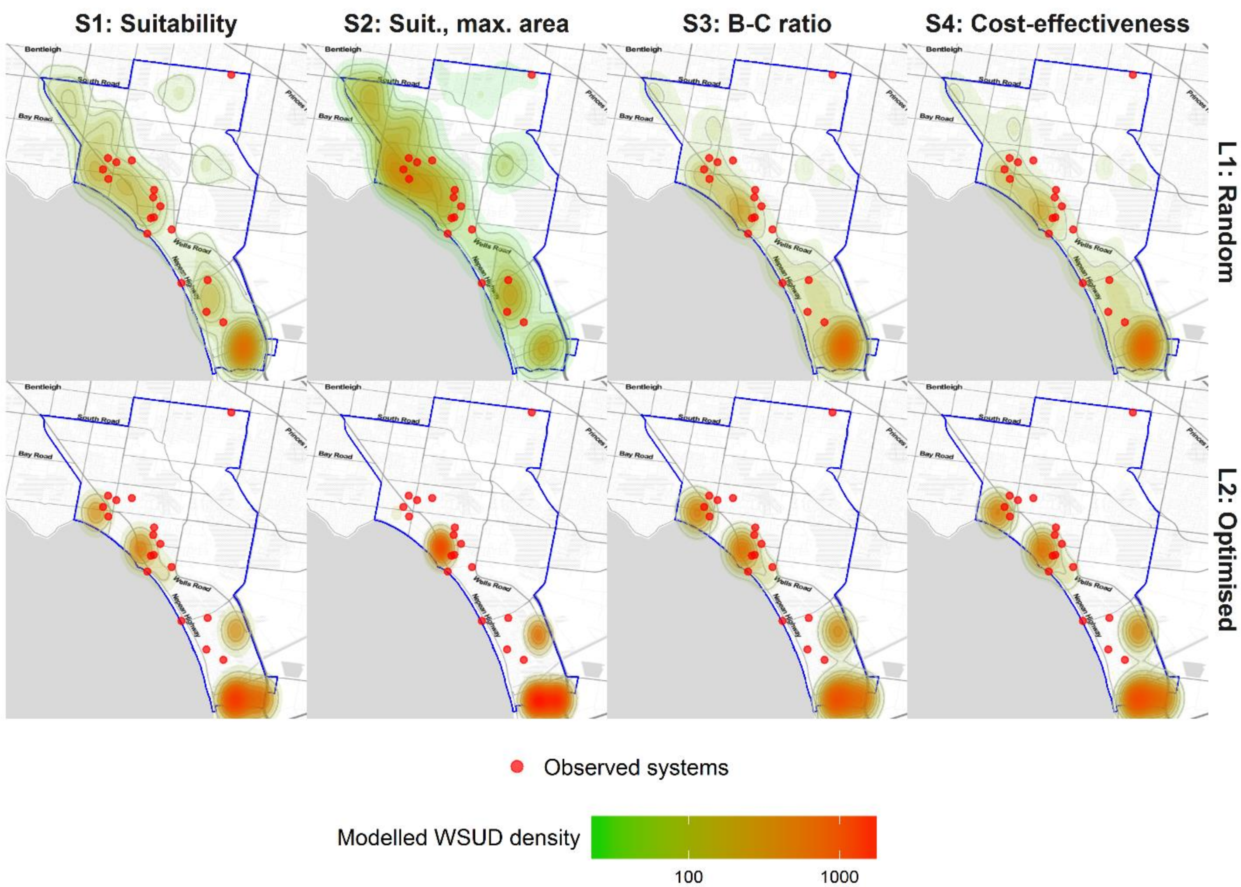

*Figure S.5: Location of systems for all selection and location rules for **B2: Installation costs** budget scenario.*

S.6. Interpolated treatment capacity

Figure S.6 presents the interpolated treatment capacity from modelled systems using the inverse distance weighting method. This interpolated treatment capacity is compared with the treatment capacity of actual assets for all type/size and location selection rules and for budget measure **B2: installation costs**.

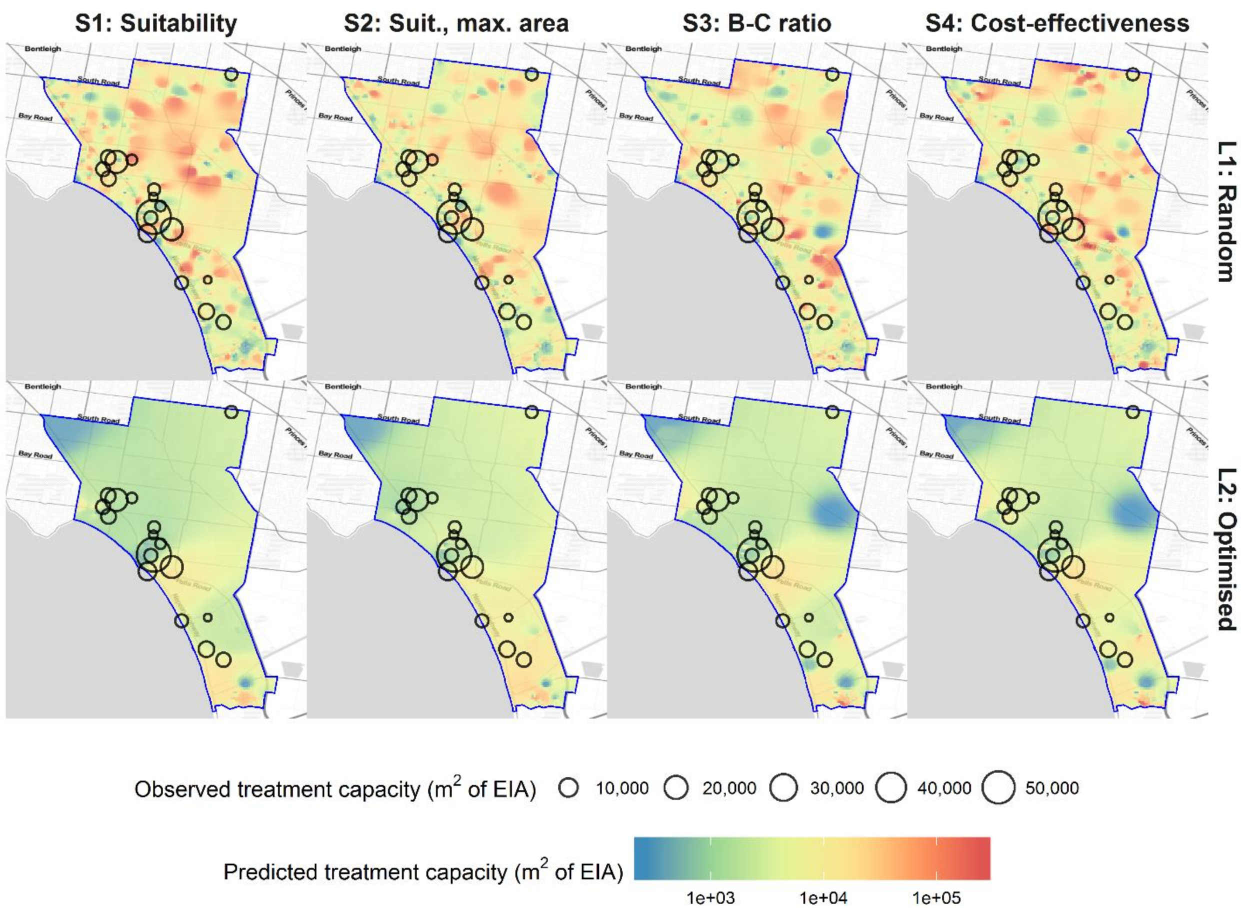

Figure S.6: Interpolated treatment capacity for all selection and location rules with budget measure ***B2: Installation costs*** *and an inverse distance power of 5.*

S.7. Cross-validation of interpolation

Table S.7 shows the leave-one-out cross-validation results for the selection of the inverse distance power (IDP) for the inverse distance weighting interpolation of stormwater treatment capacity. A power of 5 resulted in lower error and was used in Figures 6b and S.6.

Table S.7: Nash-Sutcliffe coefficient of model efficiency (NSE) and root-mean-square error (RMSE) for three power factors used for the calibration.

IDP	NSE	RMSE
1	0.998	579.693
2	0.998	525.547
5	0.999	445.695

References

Bach P. M., Deletic A., Urich C. and McCarthy D. T., 2018. Modelling characteristics of the urban form to support water systems planning. *Environmental Modelling & Software* 104, 249-269.

Grimm V., Berger U., DeAngelis D. L., Polhill J. G., Giske J. and Railsback S. F., 2010. The ODD protocol: A review and first update. *Ecological Modelling* 221(23), 2760-2768.