Urban Developer: Technical Overview

Technical Report

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Urban Developer Technical Overview

Urban Developer is an integrated urban water management (IUWM) modelling tool designed to meet the needs of water professionals facing the challenges of integrated water cycle service planning, management and assessment activities.

Urban Developer v1 provides the ability to simulate all three urban water cycle service networks (water supply, stormwater, wastewater), at scales ranging from the sub allotment through to large clusters, or small subdivisions.

Why a new model?

To date, no single model offers the ability to undertake the integrated modelling required to assess the performance of integrated urban water management options across the entire urban water cycle (Barry and Coombes, 2006). An extensive review of existing models, undertaken by eWater (Breen *et al*., 2006) further highlights an industry need for models capable of dealing with the urban water cycle in a holistic manner.

"There appears to be a lack of IUWM models which strike a balance between the scope and detail of integrated system representation. At one end of the spectrum are models… which represent the system in a high degree of detail but provide little run-time feedback between the separate water streams. At the other end of the spectrum is the handful of IUWM models which lack the detail to progress beyond volumetrically based feasibility analysis into more detailed design which would require greater accuracy of peak flow rates and water quality." (Breen *et al.* 2006, p.6).

What type of model is Urban Developer?

Urban Developer adopts a water balance methodology for simulating the movement of water around the urban water cycle. Water balance modelling is based on the application of the principle of continuity (conservation of mass) to the movement of water through each element of a system. Put simply the water balance methodology implies that matter (water in this case) can neither be created nor destroyed and all inflows, outflows and changes in storage must be accounted for.

The hydrological and hydraulic routing models offered in Urban Developer draw on many industry accepted methodologies; however, in some cases it has been necessary to create new methodologies and algorithms for the simulation of modelled processes.

Key features

Urban Developer provides:

- An easy-to-use node-link modelling environment that includes representation of all three urban water cycle service networks : water supply, stormwater, and wastewater;
- Simulation of sub-daily demand and end-use to improve insights into the operation and interactions of water cycle service systems in integrated management frameworks;
- The capability to model using continuous rainfall and climate data as well as supporting AR&R Design Rainfall based assessment of stormwater system components;
- The ability to simulate at temporal and spatial scales commensurate with state and local government planning and approval metrics. For example Urban Developer can support the estimation of peak discharge and the evaluation of measures to achieve mandated peak discharge reduction targets;
- The ability to group service network elements into subnetworks, reducing the visual complexity of models and allowing the Urban Developer software to be more easily applied at a range of scales; and
- Reduced network and computational complexity by using styles: "sets" of configuration parameters that can be re-used and applied to multiple node models.

Uses for Urban Developer

Urban Developer can be used to support a range of planning, management and design activities in the urban water sector. In particular Urban Developer has been designed to represent multiple water cycle service systems and/or their interactions. It can be equally applied to greenfield or redevelopment projects and can be used to assess the benefits of retrofitting existing developments. The following, are some examples of the types of modelling exercises Urban Developer is designed to support:

- The flood frequency analysis of small urban catchments, including the assessment of changes to the hydrological flow regime of urban creeks and streams;
- The reliability analysis and sizing of rainwater storage tanks for domestic, commercial, or industrial applications;
- Surface water peak discharge analyses for pre and post-development scenarios to support Development Application requirements, e.g. analysis of number of run-off days, peak flow reduction targets and onsite retention/detention requirements, etc.;
- Assessing lot and cluster based potable water supply reduction target by facilitating the scenario based comparison of alternative supply strategies;

- Assessing decentralised collection, treatment and supply strategies such as stormwater or greywater harvesting and sewer mining
- Demand management modelling; and
- Upscaling of the impacts of decentralised management strategies, such as rainwater tanks, to regional scale models (e.g. Source IMS), via network time series outputs.

Modelling Components

Simulation engine

Urban Developer operates across a range of temporal scales, using times steps varying from sub minute, through to daily. Urban Developer has the capability to run both **continuous rainfall** as well as **ARR design rainfall** simulations. This functionality is invaluble for assessing the numerous design and development consent metrics required for the comprehensive assessment of water cycle service delivery.

Urban Developer utilises an **adaptive time-stepping simulation engine**. This gives Urban Developer the ability to match its simulation time step to the response time of the systems it is representing. This feature helps to reduce computational model runtimes for complex systems. For example during rainfall events Urban Developer will adopt a fine time step in order to capture the dynamics of the rapidly responding stormwater system but will then switch to a longer, more appropriate, time steps in dry periods where system dynamics are more stable.

Climate data requirements

Urban Developer is driven by rainfall time series data. Version 1 supports a number of common file formats, including Comma Separated Value (.csv) files.

Urban Developer can also model the effects of evapotranspiration on catchment rainfall runoff process and users can input daily potential evapotranspiration time series, again common file formats including CSV are supported.

In addition to rainfall and evaporation, modellers wishing to utilise the Behavioural End-use Stochastic Simulator (BESS) model (Thyer et al., 2011) will be required to provide daily maximum temperature data for their site.

Water quality

Urban Developer v1.1 does not include representation of water quality for any of the system models. Future releases will include the ability to simulate surface water as well as track water quality indicators for supply and waste streams.

Urban Developer Models

Node Icon	Node Name	Summary
	**Agricultural Catchment**	An *agricultural catchment* node models areas of agricultural or "non-urban" use within an urban or peri-urban area.
	**Alternative Supply**	An *alternative supply* node represents any water supply stream in the model, such as bore water, snow melt, or others. An alternative supply node has no configurable parameters.
	**Forest Catchment**	A *forest catchment* node models forested and/or vegetated areas outside urban or peri-urban areas.
	**Gutter Entry Pit**	A *gutter entry pit* node links surface and piped flows, and is often where changes in stormwater pipe size, slope and direction occur. Entry pits are categorised into two broad classes: on-grade and sag entry pits. They receive flow from contributing pervious and impervious surface areas and/or pipe and channel flows from upstream.
	**Impervious Area**	An *impervious area* node is used to model catchment areas of zero infiltration, such as roads, driveways, parking lots, and other concreted or paved surfaces.
	**Junction**	A *junction* is a point where outflows or runoff from two or more other nodes converge and are aggregated.
	**Mains Water Supply**	A *mains water supply* node represents the primary water supply system and is used to track mains water usage throughout the model. A mains water supply node has no configurable parameters.
	**Pervious Area**	A *pervious area* node models areas within the catchment that allow infiltration and seepage to groundwater.

Node Icon	Node Name	Summary
	**Receiving Node**	A *receiving* node is intended to be the most downstream node in a network, or part of a network, and is used for tracking purposes.
	**Retention / Detention Tank**	A *retention or detention tank* (or infiltration trench) is a structure designed to capture runoff from rainwater tanks, pervious and impervious surfaces, and both store it temporarily and allow infiltration into the subsoil.
	**Roof Catchment**	A *roof* node represents a physical roof catchment surface, and is similar to an impervious area node.
	**Subnetwork**	A *subnetwork* is a characterisation of a group or cluster of dwellings, water uses or general water demands, as a discrete unit.
	**Tank**	A *tank* is a type of storage used in domestic and industrial settings to store water from runoff or mains supply, and to release it in a controlled manner.
	**Urban Catchment**	An urban catchment node represents a defined area of urban land use that drains hydrologically to a single outlet.
	**User-defined Source**	A *user-defined source* node can be used to represent any type of catchment that is not specifically urban, forested or agricultural.
	**Wastewater Connection**	A *wastewater connection* node is an optional end-point of the wastewater aspect of a modelled system.
	**Water use**	A *water use* node represents urban water demand and water consumption behaviour.

Key Urban Developer v1 node models

Urban Developer's **Water Use**  node is the core of its integrated water cycle modelling capabilities. The Water Use model not only lets users represent consumptive demand but also facilitates the simulation of end use behaviour and the rules based prioritisation of available supply to meet specific demands. Waste discharge streams for each end use can also be chosen so as to track water movement or model re-use of the different streams of wastewater throughout the network.

Urban Developer offers users two methods for simulating demand and water use behaviour:

- an **average daily** model, which uses monthly varying, average daily consumption figures for indoor and outdoor use. The model disaggregates the daily demand data to a sub-daily time-step by using a user-defined non-dimensionalised diurnal pattern.
- the **Behavioural end-use stochastic simulator (BESS)**. The BESS model supports both the deterministic and stochastic definition of model inputs, enabling users to define distributions of key model parameters that are sampled at model run time.

Through its incorporation of demand and end use simulation Urban Developer enables users to model:

- stormwater and rainwater harvesting for domestic, commercial and industrial potable and non-potable use;
- the effects of alternative supply strategies such as third pipe systems on the urban water balance;
- simulate the effects of model end-uses strategies for systems that maximise the yield of domestic water storages; and
- potable water supply savings targets required for development approval.

Roof , **Impervious**  and **Pervious**  catchment nodes can be linked to model detailed catchment systems. They use a time-area kinematic wave surface routing model to simulate runoff.

The surface water and soil water balance model implemented in the pervious catchment node combines kinematic wave surface flow routing along with a two-zone soil water storage model to represent the root and sub-surface soil zones for pervious surfaces. While able to track groundwater losses, Urban Developer does not presently consider processes, such as surface groundwater interactions or base flow.

The Holtan soil infiltration model (Holtan, 1961; Holtan et al., 1975) has been adopted for use in the soil moisture balance because of its relative simplicity and the wide availability of data sets to parameterise the model. Future releases will expand on the available catchment models.

MUSIC Catchment nodes     can be linked to other Urban Developer models to generate runoff from large areas, such as new sub-division sites or suburbs. At this stage, only water quantity functionality of the MUSIC Catchment nodes is available and is limited to long-term continuous simulation runs using historical or synthetic rainfall data. This later limitation is due to the disaggregated daily runoff model structure underlying the MUSIC rainfall runoff model.

Urban Developer v1 includes detailed representation of storage **Tanks** . The tank node model can be used to simulate distributed storage within a catchment. Tanks can be connected to receive inflows from catchments as well as other nodes or can be used to store harvested grey or blackwater for supplying domestic demand.

The tank model includes representation of detention storage and also facilitates the bypass and collection of first flush inflows.

The **Retention** / **Detention Tank** model  provides temporary storage of water before it is discharge or infiltrated into the underlying soil. Runoff from surfaces, such as roofs or overflow from structures such as rainwater tanks, can now be directed to a retention or detention device.

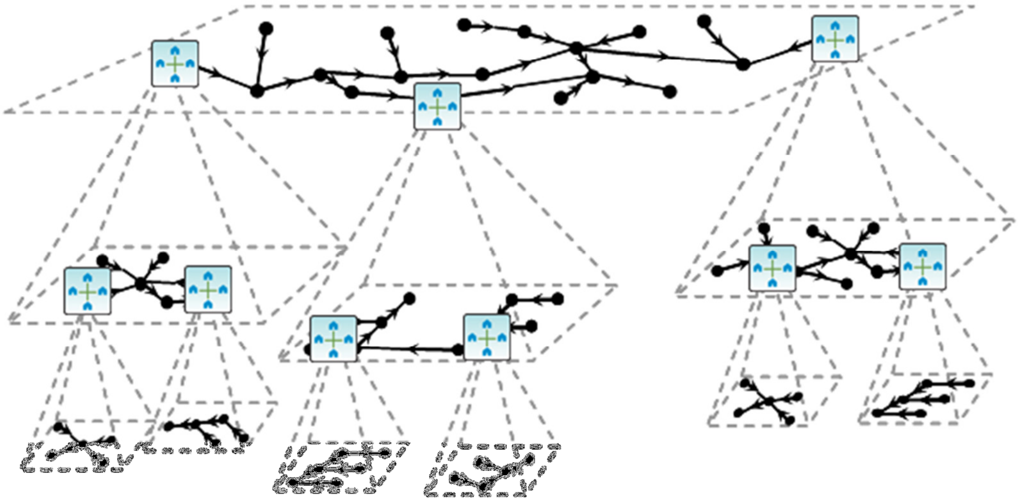
Gutter Entry Pit  models can be used to link surface and piped flows, particularly useful for where changes in stormwater pipe size, slope and direction occur. Entry pits are categorised into two broad classes: on-grade and sag entry pits. They receive flow from contributing pervious and impervious surface areas and/or pipe and channel flows from upstream.

Urban Developer supports the integration of scales with **Subnetworks** .

While it is possible to represent and explore multiple scales through the use of a number of different modelling packages, the processes of transferring data and results between models can often best be described as problematic (Rauch et al., 1998).

Instead of opting for the transformation of results between scales Urban Developer explicitly deals with the issue of scale by linking grouping models at each scale through the adoption of hierarchical subnetworks.

For example, a group of nodes such as a Roof, Tank and Water Use node can be created inside a subnetwork to represent a single allotment. This grouping can then be re-used to quickly build up clusters of houses, and even subdivision-scale models.



Put simply, Urban Developer's subnetwork node allows the user to group a number of nodes together, such as a number of dwellings into an allotment cluster (e.g. a block of flats), a "development" (e.g. several streets in a new sub-division). The user can set up subnetwork nodes, one inside the other, up to three levels (or layers).

The inclusion of multiple scales in this manner offers significant opportunity and flexibility to explore integrated urban water cycle management strategies across a range of spatial scales not currently facilitated within a single framework and this is seen as an important and valuable step forward in model capability.

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