RUNOFF IN URBAN AREAS

Urban Catchment Modelling

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Session Outline

- Characteristics of Urban Modelling
- Selecting a Model
- Model Application

Why Model?

- Rapid calculation across large spatial and temporal domains
- Testing of multiple suites of parameters and inputs
- Better calibration to best represent the real world conditions
- Readily documented and reviewed
- Better assessments and design outcomes

Characteristics of Urban Modelling

- Impervious Cover
- Conveyance Systems
- Hydraulic Structures (including volume management facilities)

Also
- Complex landuse patterns (changes spatially and temporally)
- Data intensity
- Stakeholders

Impervious Cover

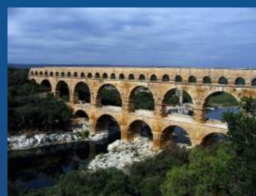
- Imp% is basic hydrologic model parameter
- Reduces infiltration and decreases lag
- Two types of impervious cover described in ARR
  - Directly connected
  - Indirectly connected
- Effective Impervious Area (EIA) as a proportion of Total Impervious Area (TIA)
- EIA/TIA between 50% and 70% (refer Book 5)
- TIA may be more suitable in some circumstances
- Importance of a quality Imp % estimate not the same in every application
- A well constructed model with adequate spatial scale should account for effective impervious area and connectivity effects

Conveyance Systems

- Artificial linings support steeper than natural slope resulting in decreased lag
- Alters flow characteristics
- Physical processes are explicitly modelled by most hydraulic models
- Requires detailed schematisation
- Conduit type, Cross-sectional dimensions, Length, Slope, Hydraulic parameters

Hydraulic Structures

- Localised Afflux
- Floodplain storage and hydrograph attenuation
- Tail water levels for upstream drainage
- Cross-catchment diversion of flow
- Bed scour and local stream morphology
- Blockage scenarios
- Model requires detailed physical description: dimensions, elevations etc



Selecting a Model

Selecting a Model - Common Urban Model Types

Hydrology
Rational Method
Time Area Method, Extended Rational Method
Runoff Routing
Continuous Simulation

Hydrology and Hydraulics
Hydrology coupled to 1D hydraulic model
Direct Rainfall ('Rain on Grid')
Runoff routing coupled to 2D hydraulic model

Hydraulics
One-dimensional hydraulic model
Two-dimensional hydraulic model
Pipe network models

Water Quality
Water quality models

Selecting a Model

Question 1: What capabilities do you need?

- Runoff generation and surface routing
- Channel and storage routing
- Structure hydraulics

Tables 9.6.1 and 9.6.2 assign a capability (limited, moderate, strong) to each type of model across these key areas.

Flood process	Limited Capability	Moderate Capability	Strong Capability
Runoff generation and surface routing	average intensity or burst Cursory treatment of infiltration losses Surface characteristics not fully represented	More complete storm Infiltration losses Surface characteristics partially represented	Full storm or rainfall sequence Infiltration losses Spatial distribution of rainfall Surface characteristics well represented (including surface wave speed)
Channel and storage routing	Channel characteristics not represented No explicit calculation of flood storage and its attenuation effects	Channel characteristics partially represented Storage behaviour partially represented including attenuation effects and spatial influences	Channel characteristics and flood wave speed well represented Storage behaviour well described including complex hydraulic behaviour and attenuation effects
Structure hydraulics	Basic hydraulic structures only Rating tables Manning's formula for open channels.	Small range of hydraulic structures Basic topographic representation	Wide range of hydraulic structures Resolves shallow water equations (1D or 2D or both)

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Hydrology

Urban Model Type	Estimation Capabilities				Example Model Platforms (where relevant)
	Runoff Generation and Surface Routing	Channel and Storage Routing	Structure Hydraulics	Other specific capabilities or limitations	
Rational Method	Limited	None	None	Peak flow only – scalar quantity, single lumped catchment, requires 'Time of Concentration' assumption, only suitable for small catchments. It has best capabilities where there is no storage present.	RATHGL, PCdrain
Time Area Method, Extended Rational Method	Moderate	None	None	Suitable for small catchments only. Can be extended as a collection of linked sub-catchments.	ILSAX, DRAINS,
Runoff Routing	Strong	Moderate	Limited	Full event hydrograph, empirically derived lag parameters, non-linear routing capabilities. Structure hydraulics can be moderately capable for discrete structures but not for continuous conveyance networks.	RORB, RAFTS, WBNM, URBS, HEC-HMS
Continuous Simulation	Strong	Moderate	Limited	Continuous multi-year runoff sequence, comprehensive infiltration loss models. Limited capability for rare to very rare floods unless utilised with replicates of conditioned synthetic continuous rainfall (such as DRIP)	XP-RAFTS, MUSIC, PURRS, Systems Framework

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Hydrology and Hydraulics

Urban Model Type	Estimation Capabilities				Example Model Platforms (where relevant)
	Runoff Generation and Surface Routing	Channel and Storage Routing	Structure Hydraulics	Other specific capabilities or limitations	
Hydrology coupled to 1D hydraulic model	Moderate	Moderate	Strong	Not always emulating full capability of the underlying hydrologic model	DRAINS, Pcdrain, XP-SWMM
Direct Rainfall ('Rain on Grid')	Limited	Moderate	Strong	Does not require pre-defined flow paths. Sensitive to topographic data pre-processing and surface roughness assumptions. Not suitable for 'greenfield' subdivision drainage design.	TUFLOW, MIKE21, SOBEK, ANUGA
Runoff routing coupled to two-dimensional hydraulic model	Moderate	Strong	Strong	Requires pre-defined understanding of flow paths in order to establish initial model. Requires input and output procedure between two model software packages.	RAFTS with MIKE21, WBNM with TUFLOW, XP STORM with TUFLOW, DRAINS with TUFLOW

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Hydraulics

Urban Model Type	Estimation Capabilities				Example Model Platforms (where relevant)
	Runoff Generation and Surface Routing	Channel and Storage Routing	Structure Hydraulics	Other specific capabilities or limitations	
One-dimensional hydraulic model	None	Moderate	Strong	Simple channel or pipe behaviour only. Limited where complex flood storages exist.	HEC-RAS, MIKE11, SOBEK
Two-dimensional hydraulic model	None	Strong	Strong	Complex flow behaviour including breakout and diversion. Flow transitions and hydraulic jumps. Principally surface flow.	TUFLOW, SOBEK, ANUGA, MIKE21, HEC-RAS 2D, RMA, RiverFlow2D
Pipe network models	None	Moderate	Strong	Specialist models for underground drainage networks, storage routing performance best where flow is contained within the minor system.	SWMM, XP-STORM, DRAINS, PCdrain, MIKE URBAN

Selecting a Model

Question 2: What is your model's spatial scale?

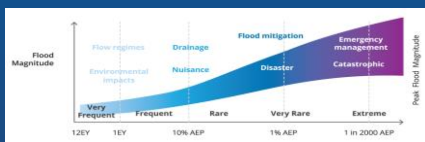
Lot	Site	Neighbourhood	Precinct
A small parcel of land with 1 or 2 buildings.	A large parcel of land with multiple buildings. Sometimes a small number of 'lots' combined.	Many parcels of land each with at least one building. Many 'lots' and potentially some multi-building complexes.	Hundreds of parcels of land each with at least one building. A large number of 'lots' and multi-building complexes combined. Several neighbourhoods.
e.g. single detached dwelling or duplex up to say 1,000m² in area	e.g. large townhouse complex covering an area up to say 1 hectare	e.g. a residential subdivision stage or a neighbourhood covering an area up to say 10 hectares	e.g. a small suburb covering an area of say 100 hectares

Number of flood generation processes increase with scale (Table 9.6.4)

More model capability required for larger catchments

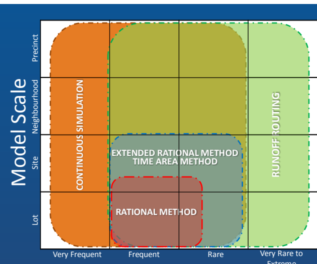
Selecting a Model

Question 3: What is your flood magnitude of interest?



Not all hydrologic models capable across range of flood magnitudes

Question 2 and 3 lead to Figure 9.6.1



Not all hydrologic models are capable across range of flood magnitudes AND model scales

Selecting a Model

Question 4: What hydraulic model is suitable?

- Is flow behaviour 1D or 2D
- Proportion of flow underground
- Importance of storage

Selecting a Model

Other factors:

- simplest model, capable of the necessary calculations
- availability of sufficient input data
- parameter research
- output data capabilities
- cost
- user familiarity with the model

Model Application

Model Application - Rainfall

- Design rainfall depths from BOM
- Temporal patterns, ARF, climate change factors, pre-burst from ARR Datahub

Input	ARR 1987	Pre Update	ARR 2016
IFD	Paper maps	BoM web page	Updated BoM web page. Book 2 Chapter 2 Design Rainfall.
ARF	Figure 2.7 from US data	FORGE work (except NSW)	New equations derived using Australian data. Book 2 Chapter 4: Areal Reduction Factors.
Temporal patterns	Single temporal pattern of design burst rainfall based on average variability method (AVM)	AVM, filtered for embedded burst	Ensemble of real storms. Book 2 Chapter 5: Temporal Patterns.
Spatial pattern	Centroid	Spatially distributed IFD	Spatially distributed IFD
Climate change			Factors available from the Datahub Book 1 Chapter 6: Climate change considerations
Losses	State based advice, sometimes based on data	Calibrated in the hydrologic Model.	Calibrated losses. Uncalibrated models use losses available from the datahub. Book 5 Chapter 3: Losses.
Pre burst	Allegedly incorporated into advice	mixed	Estimates provided on Datahub. Use 60 minute pre-burst rainfall with burst rainfall ensembles of durations less than 60 minutes

Model Application - Losses

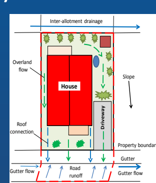
- ‘Initial Loss/Continuing Loss’ Loss model recommended
- For urban catchments apply the following hierarchy:
  1) Locally derived data
  2) Regional losses as per Book 5 Ch 3.5 i.e. for:

Effective Impervious Area	IL = 1 to 2mm	CLR = 0mm/hr
Indirectly connected Area	IL = 60% to 80% of rural losses	CLR = 1 to 3 mm/hr (for South East)
Pervious Area	IL = Rural loss (from data hub)	CLR = Rural loss (from data hub)

- Datahub provides storm loss. Burst Loss = Storm Loss – Preburst

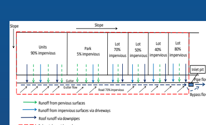
Model Application - Property Runoff

- Basic ‘building block’ of most urban models.
- Limited number of flood generation processes
- Physical definition should be sufficient to allow local effects to be determined
- Deemed to comply and Rational Method solutions can be considered for property drainage on simple sites e.g. AS/NZS 3500.3
- Continuous simulation may become important for volume harvesting and water quality design (resolve joint probability problems)



Model Application - Sub-catchment runoff

- Second ‘building block’ for urban models
- Landuse complexity, storage effects, variations in rainfall temporal patterns and pre-burst rainfall become more important
- Runoff routing or continuous simulation models more relevant (volume or joint probability)
- May be some opportunity for simplified definition of catchment



Model Application – Inlet to Outlet

- Third 'building block'
- Multiple sub-catchment flows accumulate at junctions.
- Some simplification of catchment necessary.
- Coupled 1D or 2D hydrology and hydraulic models suggested.
- Ensemble of patterns in hydrology with at least one pattern taken through to hydraulic model.
- Refer 'Brownfields' case study

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Urban Catchment Modelling Summary

- Models have become necessary tools in modern practice
- Urban modelling has a number of special characteristics (impervious cover, conveyance systems and structures)
- To select a model identify:
  - Capabilities required
  - Model spatial scale
  - Flood magnitudes of interest
- When applying models consider the amount of physical simplification that is suitable for each model building block

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Thankyou

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