BUNDABERG
REGIONAL COUNCIL

Building Australia's best
regional community

Stormwater Management Guidelines

Part 1 – Stormwater Quantity Assessment

Revision 3 – July 2023

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Revision History

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Preface

Background to the Guidelines

These guidelines were developed by AECOM Australia Pty Ltd (AECOM) on behalf of Bundaberg Regional Council (Council). During the guideline development, a number of Council staff and external consultancies were consulted.

Purpose of the Guidelines

These Stormwater Management Guidelines have been prepared to assist developers and practitioners by providing further guidance to support Council's Planning Scheme and Planning Scheme Policy for Development Works (Section SC6.3.5). The current requirements as set out in the Planning Scheme Policy for Development Works continue to have effect and in the event of any inconsistency override these guidelines. Application of these guidelines will promote a consistent approach to stormwater management studies, mapping and reporting throughout the Bundaberg region.

Intended Users of the Guide

The guidelines are primarily intended to assist private developers and their engineering consultants when preparing a Stormwater Management Report, and by Council's officers when interpreting outputs. It is anticipated that all users have some technical background, preferably in flood and stormwater management.

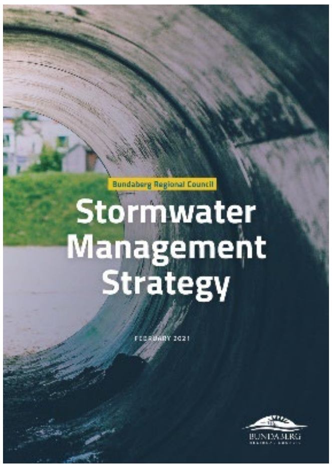
1.0 Introduction

1.1 Background

Bundaberg Regional Council (Council) provides and maintains stormwater drainage infrastructure (such as roadway kerb and channel, pits, pipes and open drains) on public land to collect and convey stormwater to creeks and rivers.

Council assesses development within the Local Government Area (LGA), including impacts to stormwater infrastructure, flooding impacts, changes to water quality as well as proposed mitigation works. Council is focused on ensuring development does not cause an actionable nuisance, while considering potential flooding impacts at the whole-of-catchment level. Assessment of stormwater quantity and quality impacts from development are to consider local and whole-of-catchment influences.

1.1.1 Bundaberg Regional Council Stormwater Management Strategy



The Bundaberg Regional Council Stormwater Management Strategy, February 2021, aims to manage Council's stormwater network in a sustainable and holistic way. It sets the direction for managing the many aspects of stormwater in the region including the environmental health of our waterways, social amenity, pollution control, affordability, minimising impacts of a changing climate and catering for future growth.

The Strategy establishes a logical, justified approach to Council's long-term management of natural and built stormwater assets to minimise impact on Council's forward operations and risk to life, property, community well-being, the environment, and the economy. It also demonstrates Council's desire to become an integrated, water sensitive city.

Further details on the Strategy can be found at https://www.bundaberg.qld.gov.au/water-services/stormwater-drainage/2.

1.2 Introduction

These guidelines seek to establish a standardised approach which facilitates greater consistency for stormwater management reports throughout the Bundaberg region, including assessment of Stormwater Quantity and Stormwater Quality. These guidelines comprise two sections:

- **Part 1: Stormwater Quantity Assessment (this document)** – Provides guidance on stormwater management and modelling for quantity assessments.
- **Part 2: Stormwater Quality Assessment** – Provides guidance on stormwater management and modelling for quality assessments.

It should be noted that these guidelines are considered to be a dynamic document which will continue to be updated as stormwater management practices and the needs of Council evolve. Whilst every effort has been made to develop a clear and consistent document, it remains the responsibility of the Developer / Consultant to identify any key deficiencies and seek clarification from Council officers as required.

1.3 Purpose of this Document

These guidelines are intended to improve consistency and efficiency for modelling, designing, and assessing stormwater features associated with development in the Bundaberg region.

Guidance on hydrologic and hydraulic modelling is provided, including appropriate ranges for modelling parameters, along with requirements for assessment of development impacts, assessment of mitigation solutions, reporting and mapping.

The guidelines are **not** intended to provide:

- Fundamental understanding of stormwater runoff, hydrology and hydraulics.
- Mandated modelling software or approaches.
- One-size-fits-all modelling parameters.
- Flood impact mitigation solutions.
- Water quality improvement solutions.
- Confirmation of acceptable levels of flood impact.

1.4 Flood Mechanisms

The Bundaberg region is affected by a range of flooding mechanisms which can occur in isolation or combination. Selection of the appropriate flood mechanism(s) for assessment is the responsibility of the Registered Professional Engineer Queensland (RPEQ). However, where the RPEQ is unsure of the relevant flood mechanisms, they should contact Council for confirmation prior to commencement.

Flood mechanisms affecting the Bundaberg LGA include:

- Riverine Flooding.
- Creek Flooding.
- Overland Flooding.
- Storm Tide Inundation.
- Groundwater Flooding.

1.5 Document Structure

Part 1 (this document) of the Stormwater Management Guidelines is structured as follows:

- Section 2.0 - Definitions relevant to stormwater modelling and development assessments.
- Section 3.0 - General stormwater design considerations
- Section 4.0 - Data available within the region and associated processes.
- Section 5.0 - Considerations for hydrologic modelling approaches and parameters.
- Section 6.0 - Considerations for hydraulic modelling - approaches and parameters.
- Section 7.0 - A quality checklist for modelling activities.
- Section 8.0 - Impact assessment requirements for varying applications.

- Section 9.0 - Documentation requirements for impact assessment reports.
- Section 10.0 - Processes for delivery and handover.
- Section 11.0 - References used within this guideline.

2.0 Definitions

2.1 Strategic Vision

Council's vision for stormwater management in the region is as follows:

As an organisation Council aspires to lead regional practice of:

- **Sustainable, holistic management of all catchments.**
- **Reduce risk and improve public safety for future stormwater flooding.**
- **Connecting informed communities with our catchments and waterway assets.**

We will be recognised as a Council that proactively implements appropriate practice that demonstrates care for the community and our catchments.

(Bundaberg Regional Council Stormwater Management Strategy, 2021)

2.2 Relevant Literature

The planning and design of developments within the Bundaberg Regional Council local government area must be undertaken in accordance with the current edition of the following key reference documents, unless specifically outlined in this chapter or other Council references dictate otherwise:

- Queensland Government – at the time of writing this document the series was as listed below:
  - State Planning Policy - state interest guideline Water quality,
  - Environmental Protection (Water) Policy 2009 – Burrum, Gregory, Isis, Cherwell and Elliott Rivers environmental values and water quality objectives – Basin 137 at https://www.ehp.qld.gov.au/water/policy/pdf/documents/burrum-river-ev-2010.pdf, and Plan WQ1371 at https://www.ehp.qld.gov.au/water/policy/pdf/plans/burrum-river-ev-plan-2010.pdf.
- IPWEA – Queensland Urban Drainage Manual Fourth Edition, 2016
- Environment Protection Agency's (EPA) – Guideline – EPA Best Practice Urban Stormwater Management – Erosion and Sediment Control http://www.derm.qld.gov.au/register/p02301aa.pdf
- Engineers Australia – Australian Rainfall and Runoff (ARR) – 1987 and 2019,
- Bundaberg Regional Council – Improving Dwelling Resilience to Flood Induced Scour, Guidelines for Dwellings Constructed within a Flood Hazard Area, 2013
- EDAW – Ecological Engineering Practice Area – Urban Stormwater – Queensland best practice environmental management guidelines 2009
- The following Australian Standards:
  - AS1554 Structural Steel Welding
  - AS1597 Precast Reinforced Concrete Box Culverts
  - AS3725 Design for Installation of Buried Concrete Pipes
  - AS 4058 Precast Concrete Pipes
  - AS4139 Fibre Reinforced Pipes

- AS4671 Steel Reinforcing Materials

- Austroads – Waterway Design – A Guide to the Hydraulic Design of Bridges, Culverts and Floodways
- Austroads – Guide to Pavement Technology – at the time of writing this document, part relating to development was AGPT10-09 - Part 10: Subsurface Drainage
- Australian Institute for Disaster Resilience – Managing the floodplain – a guide to best practice in flood risk management in Australia – Handbook 7 - Floodplain Management in Australia: Best Practice Principles and Guidelines
- John Argue – Storm Drainage Design in Small Urban Catchments – A handbook for Australian Practice – Special Report 34 Australian Road Research Board
- International Erosion Control Association – Best Practice Erosion and Sediment Control
- Lewis Rossman – Stormwater management model User's Manual Version 5 – United States Environmental Protection Agency
- Bundaberg Regional Council Standard Drawings at https://www.bundaberg.qld.gov.au/development-infrastructure-and-charges.

2.3 Design Storm Events

2.3.1 Design Event Terminology

Figure 1.2.1 of Australian Rainfall and Runoff 2019 (ARR19), replicated in Table 1 below, outlines design event terminology (preferred terminology highlighted). Council's preference is to use Annual Exceedance Probability (AEP) percentage (%), as shown in the red box below.

Table 1 ARR Preferred Terminology

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

2.3.2 Bundaberg Region Major Design Storm

The Major Design Storm (or Defined Flood Event, DFE) is defined as:

- **Burnett River** – 2013 Burnett River Flood Event.
- **All other flooding mechanisms** – 1% AEP plus Climate Change. Refer sections 5.9 and 6.6 below for Climate Change requirements for hydrologic and hydraulic modelling respectively.

2.3.3 Bundaberg Region Minor Design Storm

Table 2 below provides the minor design storms for developments within the Bundaberg Regional Council local government area.

Table 2 Design storms for minor drainage systems

Development Category (QUDM)	Council Planning Scheme – Zone	Design Storm AEP
Central business and commercial	Principal centre zone, Major centre zone, district centre zone, Local centre zone, Neighborhood centre zone, Specialised centre zone	10% AEP
Industrial	Industry zone, High impact industry zone	10% AEP
Urban residential high density	High density residential zone	10% AEP
Urban residential low density	Medium density residential zone, Low density residential zone, Emerging community zone, Limited development zone, Community facilities zone	18% AEP
Rural Residential	Rural residential zone, Sport and recreation zone	39% AEP
Open space – parks, etc.	Rural zone, Open space zone, Environmental management and conservation zone	63% AEP
Roadway Criteria		**Design Storm AEP**
Major Road (i.e., Arterial, Sub-arterial, Trunk Collector (Suburban), Industrial Collector, Principal Rural Road)	Table Drain/Kerb & Channel	10% AEP (1)
	Cross Drainage (Culverts)	2% AEP (2,3)
All other Roads	Kerb and Channel	Use relevant Development Category above
	Cross Drainage (if Rural Culverts(4))	10% AEP (3)

Notes—
1. The design storm for Major Road overrides the Development Category design storm
2. Designer must ensure that the 1% AEP backwater does not enter properties upstream. In addition, the downstream face of the causeway embankment may need protection where overtopping is likely to occurs and d*v checks must still be below maximum levels
3. May change if the Roadway is deemed to be part of Council's emergency evacuation route
4. Rural cross drainage requirement may be reduced to 39% AEP where risk level is medium in 2% AEP flood event as defined in SCARM 73.

2.4 Freeboard

The Developer / Applicant should confirm the adopted freeboard within the Stormwater Management Report.

2.4.1 Urban (including industrial and commercial)

- The minimum freeboard provided in QUDM is to be adopted, however, where an existing situation has a freeboard greater than the value given in QUDM the existing freeboard must be maintained, unless specifically approved by Council.

2.5 Flow Depth and Width

- The flow depth and width limitations given in QUDM are adopted. However, the lower value of 0.4 m^2/s must be adopted for all lateral drainage conditions or where loss of life situation occurs for longitudinal drainage conditions.

2.6 Overland Flow Paths

Council defines overland flow paths as the following:

- where a piped drainage system exists, the path-of-travel of the floodwaters which exceed the capacity of the underground drainage system, or
- where no piped drainage system (or the outlet to the system) or other form of defined watercourse exists, the path taken by surface runoff from higher parts of the catchment. This does not include a watercourse or gully with well-defined banks.

Overland flow paths must have velocity and depth product not greater than 0.4 m^2/s in high risk areas and 0.6 m^2/s elsewhere. Concerning overland flow paths and development:

- Any proposed development, especially those involving filling, needs to take account of existing or created overland flow paths and make due provision in the design. Overland flow paths must be clearly indicated on the drawings and supported by calculations, cross sections and plan layouts shown on the approved engineering drawings with due consideration of freeboard.
- Developments within or adjacent to any defined overland flow paths must satisfactorily demonstrate compliance with all the flood immunity freeboard and trafficability (especially depth and velocity product issues and emergency evacuation routes) requirements set out in this document.
- In residential subdivisions, overland flow paths must be located in roadways, parks (in a combined park and drainage reserve) or pathways.
- No overland flow paths will be permitted through urban allotments – unless specifically approved by Council. Where an overland flow path is approved, such paths must be covered by an easement with the preferred tenure i.e., easement or reserve, to be determined by Council.
- In site developments such as apartment buildings or townhouses where the sites are filled to provide suitable falls to the roadway, the Developer must pay particular attention to the preservation of existing overland flow paths, the obstruction of which may cause flooding or ponding of stormwater on adjoining properties.
- Where overland flow paths are to be located through commercial/industrial development, such paths must be located along and through the car park/driveways and must be covered by an easement.

2.7 Lawful Points of Discharge

Lawful points of discharge (LPOD) has no prescribed legal meaning but is used to "*assess whether all applicable regulatory and other legal requirements have been met to allow stormwater to discharge in a particular location*." (QUDM 2016). Due diligence assessment must be undertaken along with the LPOD test, in accordance with Section 3.9.1 of QUDM 2016 which states:

> The criteria for determining the lawful point of discharge are:

(i) Will the proposed development alter the site's stormwater discharge characteristics in a manner that may substantially damage a third-party property? Note:

(The issue of whether or not there is an actionable nuisance does not depend on what is demonstrated at the time the works are proposed. The issue is what in fact occurs. This is consistent with it being the developer's responsibility to not cause nuisance, rather than the regulator's responsibility to assess and condition works to prevent a nuisance.)

- If not, then no further steps are required to obtain tenure for a lawful point of discharge (assuming any previous circumstances and changes were lawful).
- If there is a reasonable risk of such damage, then consider issue (ii) or (iii).

(ii) Is the location of the discharge from the development site under the lawful control of the local government or other statutory authority from whom permission to discharge has been received? This will include a park, watercourse, drainage or road reserve, stormwater registered drainage easement, or land held by local government (including freehold land).

Note: The regulatory authority (in its capacity as land holder) is likely to require information about the potential impact of the site's stormwater discharge characteristics on the discharge site and on third party properties (particularly those downstream of the proposed discharge point) before it will consent to the discharge entering its land.

- If so, then no further steps are required to obtain tenure for a lawful point of discharge.
- If not, then consider issue (iii). A landowner or regulator may require that the developer obtain an authority to discharge as described in (iii) in order for the stormwater to ultimately flow to a location described in (ii).

(iii) An authority to discharge over affected properties will be necessary. In descending order of certainty, an authority may be in the form of:

- Dedication of a drainage reserve or park
- A registered easement for stormwater discharge/works
- Written discharge approval

Note: Council may not accept a written approval from a current landowner because a subsequent purchaser will not be bound by the previous owner's letter or contract.

2.7.1 Outlets – point of discharge – under control of Council

The Developer/Applicant should not assume that drainage channels, overland flow paths, drainage outlets, energy dissipaters or stormwater detention basins will automatically be permitted in public space (newly created Council asset or existing Council asset).

Prior to the design of any stormwater discharge facility into Council controlled land, the Developer/Applicant should consult with the Council to ensure that Stormwater outlets in any public space (existing or newly created Council asset) are addressed at the development approval (conceptual design) stage.

2.8 Easements

- The extent of an easement is determined by the necessity to obviate an actionable nuisance. Hence, this issue needs to be determined early in the development process. Accordingly, it is beneficial to have a pre-submission meeting to determine the likelihood of a nuisance issue, and address other concerns raised in the due diligence assessment.

- Generally, where an easement is required over downstream properties, Council will require the Developer/Applicant to obtain an in-principle agreement from affected property owners. The in-principle agreement would note the characteristics of the flow, the proposed solution, and the necessity for registration of easement(s) (prior to submission of the operational works approval).
- Council has a standard instrument of easement for use by developers for Drainage (pipes) and Open Cut Drainage (open drains); a copy of the instrument can be made available upon request.

2.9 No Actionable Nuisance

The Queensland Law Handbook (2016) defines nuisance as follows:

- An actionable public nuisance is an unreasonable interference with the public's right to property. It includes conduct that interferes with public health, safety, peace or convenience.
- An actionable private nuisance is the unlawful interference with a person's use or enjoyment of their own land or of a right connected with that land.

To be able to take legal action in relation to nuisance, the interference needs to be substantial and unreasonable. Adverse impacts (or interference) can be caused by changes to:

- Flow path direction (diversion).
- Limiting future land use or productivity.
- Peak discharges.
- Flood levels.
- Flow velocities.
- Frequency of flooding.
- Duration of flooding.
- Water quality.
- Erosion or sedimentation.

Council appreciates that *it is generally impractical to completely mitigate increases in runoff volume caused by urbanisation*. For Development Assessment within the LGA:

1. A due diligence assessment and LPOD test must be undertaken in accordance with Section 3.9.1 of QUDM 2016 (refer Section 7.0).
2. No Actionable Nuisance must be established in accordance with QUDM, statutory and common law requirements. Potential damage and nuisance should be clearly quantified and documented in accordance with documentation guidance presented in Section 7.0. Adverse effects must consider current and ultimate land uses within the study area.

2.10 Registered Professional Engineer Queensland Responsibilities

The Registered Professional Engineer Queensland (RPEQ) for the development is ultimately responsible for determining the appropriate hydrologic and hydraulic modelling methodology, reporting and mapping requirements, impact mitigation measures (if required), determination of lawful point of discharge and confirmation of 'no actionable nuisance'.

Where referenced in PSPDW SC6.3.5 the RPEQ is to ensure these guidelines are followed, which will provide Council with consistent hydrologic and hydraulic assessment approach, reporting structure and content, and mapping.

3.0 General Stormwater Design Requirements

3.1 Major Drainage System

The design of a major drainage system without an overland flow path is strongly discouraged and should only be adopted where overland flow is either impractical or unacceptable. In such circumstances, justification and prior approval with Council will be required. Consideration should be given to the performance objectives of major drainage system design as follows:

- Operation of the drainage system during the major design storm event does not cause unacceptable safety risks,
- To the maximum degree possible, the principles of Water Sensitive Urban Design (WSUD) are appropriately integrated into the planning and design of major drainage paths,
- The drainage system appropriately integrates into the natural and built environment,
- Major overland flow paths are retained along their natural alignment and are not significantly encroached upon wherever possible.

3.2 Preservation of Natural Waterways

Consideration must be given to the preservation and enhancement of existing natural waterways/channels, particularly in the following circumstances:

- waterways identified as important within a Waterway Corridor Plan, Catchment Management Plan, or similar strategic plan (such as Council's Stormwater Management Strategy, Saltwater Creek Master Plan, Washpool Creek Master Plan),
- waterways recognised as fish passage corridors or covered under MSES overlays,
- natural waterways with well-defined bed and banks, and their associated floodways.

3.3 Rehabilitation of Modified Waterways

Urban planners and stormwater designers must avoid land use planning and design decisions that remove opportunities for the rehabilitation of natural waterways that have been channelised as part of historical urban development. Urban planning and design should encourage the rehabilitation of these 'low-value' waterways back to stable waterways that are consistent with the long-term hydrologic and desirable ecological conditions of the catchment.

The past channelisation of an urban waterway does not prevent the future rehabilitation of that waterway and return of ecological values to the urban area.

Moving forward, urban creeks must be considered as more than concrete channels. Urban creeks offer significant potential for both Council and the community due to aspects such as social and environmental benefits, hazard reduction and increasing sustainability over time.

Urban creeks must be elevated beyond a stormwater infrastructure improvement or engineering undertaking.

Creek naturalisation and rehabilitation projects are rich in opportunities to deliver an integrated public open space to the City of Bundaberg (and broader region) which balances its technical stormwater and drainage functions whilst also delivering significant water quality, ecological and environmental improvement to the immediate and wider context. As active and connected systems, urban creeks will become pleasant places to walk, play, explore and live nearby.

3.3.1 Belle Eden Park Waterway Naturalisation

Council has recently completed the Belle Eden Park Waterway Naturalisation project. The project involved the restoration of a man-made drain back to a natural state with the inclusion of park facilities to activate the area. A key objective of the project was to create a sustainable and resilient stormwater asset that provides multiple functions and benefits, including stormwater conveyance and quality functions, carbon sequestration, urban cooling, ecological and social benefits.

This project represents and is an example of Council's strategic intent for sustainable stormwater management in the Bundaberg region including:

- that the purpose of stormwater assets should be more than just for the conveyance of stormwater,
- that for improved stormwater asset sustainability and resilience, nature-based solutions are the preferred solution when compared to traditional hard infrastructure solutions (e.g. concrete-lined drains).

Further details on the project can be found at https://www.ourbundabergregion.com.au/belle-eden-park-waterway-naturalisation.

Figure 1 – Belle Eden Park Waterway Naturalisation – Before (Left) | After (Right)

3.4 Pipe Considerations

3.4.1 Standard Alignment

The standard alignment for stormwater drainage lines is given in Council Standard Drawing R1050 – Public Utilities Typical Service Conduit Alignment.

3.4.2 Standard Requirements

Pipes used may be either reinforced concrete or fibre reinforced concrete type and have the following properties:

- Minimum subsurface pipe sizes:
  - Low flow pipes 300mm diameter (unless inter-allotment drainage);
  - Other 300mm diameter – refer QUDM - Minimum pipe sizes;

- Between manholes – 375mm diameter;

- Minimum culvert dimension of 450mm wherever possible (noting cover may dictate otherwise)
- Minimum desirable grades refer QUDM;
- Minimum Class 3 within roadways,
- Minimum clear cover shall be 600mm to subgrade in all instances, unless approved otherwise by a Council development engineer;

3.4.3 Start Hydraulic Grade Line (HGL)

- Start HGL will be, the maximum of 150mm below the invert of the kerb and channel (when entering an existing pit) otherwise, in accordance with QUDM.

3.5 Access Chambers

- Manhole or access chamber spacing shall be in accordance with Section 7.6 of QUDM.
- Where a pre-cast gully pit is provided as an access chamber the chamber shall be constructed to the invert of the pipe.
- Combined access chamber/gully pits shall only be used up to a pipe size of 600mm diameter.
- Chambers may be pre-cast or cast-insitu concrete boxes or circular. Chambers may only be used for inter-allotment drainage below 300mm diameter. Minimum dimensions of the pits are provided in Table 3. For inter-allotment drainage pits, junctions or changes in direction for pipes over 300mm refer standard drawings for further details.

Table 3 Inter-allotment chamber pit dimensions

Minimum Depth to Invert	Boxes – Internal Dimensions (mm)	Circular FRC or RCP Systems – Internal Diameter (mm)
< 900 mm	600*600(1)	600 mm
> 900 mm	600*900(1)	750 mm

Note—(1) Minimum wall thickness 100 mm all cast insitu boxes

- Lids to cast-insitu manholes shall be light duty in allotments, gardens etc., and heavy duty elsewhere. Close fitting cast iron galvanised steel or concrete infill type (Gatic Light Duty, Polycrete Broadstel or similar) of approximately the same internal dimensions as the manhole.
- Lids to FRC and RCP manholes shall be the manufacturers' proprietary concrete or concrete infill type.
- Lids must match finished surface ground slope and level.

3.6 Pipe Junctions – Instead of Access Chambers

Council's preference for new connections into existing subsurface pipe networks is via a standard access chamber for ease of future maintenance. If this is impractical and prior approval is provided by Council, branch pipe connections may be permitted subject to the following:

- Maximum incoming branch size 150 mm dia. on 450 – 900 mm dia. mains,
- Maximum incoming branch size 300 mm dia. on 900 – 1500 mm dia. mains,

- Intercept angle is to be not less than 45 degrees in the direction of flow and always in the direction of flow.

3.7 Stormwater Inlets

- Stormwater inlets are to be designed with an allowance for an appropriate level of blockage in accordance with QUDM.
- Council has approved the use of lip in line (with grate) drainage pits unless the pit is located in or near a bus crossing, refer Standard Drawings for further pit details.

3.8 Floodways and Open Channels

Floodways and open channels should generally be designed in accordance with section 9 of QUDM. Unless specifically approved otherwise, Council requires open channels and floodways to be designed in accordance with the following:

- Side slopes not greater than 1 in 6 unless approved by Council,
- Landscaping and tree planting to facilitate minimal visual impact of the open drain.
- An open channel with critical or supercritical conditions is not acceptable. The velocity should be limited to less than 90% critical velocity in the major storm event (or Froude less than 0.8). The maximum velocity allowed in an unlined channel is set out in QUDM for earth and vegetated channels.
- Must have velocity and depth product not greater than 0.4 m2/s in high risk areas and 0.6 m2/s elsewhere.
- Channel velocity checks should assume that downstream undersized drainage structures, such as culverts, will be upgraded to current design standards at some time in the future. The afflux caused by any roadway crossing over a watercourse should not affect the adjoining properties. This should be discussed with Council prior to lodgement of a development application.
- Council's preference and strategic intent is that development retains existing natural waterways and rehabilitates modified waterways in the first instance. Any proposed open channel **should be vegetated** (e.g. with native groundcovers, shrubs and trees) and consistent with natural channel design principles and designed by a suitably qualified professional. Council will generally **not accept constructed channels with hard linings**.

3.9 Emergency Evacuation Routes

At least one identified emergency exit route must be designed to the following considerations - derived in accordance with SCARM 73 (CSIRO 2000):

- Medium Level Hazard – Adjusted Hazard Estimate for the 1% AEP event,
- Low Level Hazard – Adjusted Hazard Estimate for the 2% AEP event.

Wherever possible, emergency exit routes should be designed such that evacuees are directed towards a location of higher immunity.

3.10 Detention Basins

- It should be noted that ad hoc detention basins in public land are not a preferred drainage solution and may not be used without the prior approval of Council.
- Detention basins shall be designed in accordance with Section 5 of QUDM and to criteria nominated by Development Approval.
- Other conditions pertaining to the design and construction of detention basins are given as follows:
  - Basins must be visually and physically integrated into the parkland. Landscape plans are to be supplied as part of the operational works approval,
  - All batter slopes less than 1(V):6(H),
  - Provision of 0.5% crossfall to detention basin floor,
  - Provision of appropriate signage and depth markers,
  - Provision of safety grilles on outlets,
  - All outlet structures shall be designed to allow egress by small children.
- Major detention systems, as determined by Council, on private land (on-site stormwater detention basin) will only be permitted in developments pertaining to material change of use such as Community Titles Scheme, commercial and industrial developments where such a basin is covered by an appropriate easement and maintenance plan.
- The detailed design submission must be prepared and certified by an RPEQ suitably qualified in the field of drainage/hydraulic investigations. The following information must be included in the submission:
  - Calculations for storage – major basins must be undertaken by an approved program using the documented runoff routing method described in this guideline,
  - Where WSUD components are proposed the water depth must be limited to under 500 mm with maximum extended detention depth of not greater than 300 mm,
  - Calculations verifying that the flow paths/floodways, drainage systems and any overflow weirs have sufficient capacity – to cater for the design storm event,
  - Design plans and engineering plans.
- Underground detention facilities are not a preferred drainage solution and may not be used without the prior approval of Council. However, in the event that an underground detention storage system is required, the design should address a number of public health, maintenance and pollution issues. The storage should be self-cleaning, well ventilated, not cause accumulation of noxious gas, and facilitate easy maintenance and inspection. The design should incorporate the following requirements:
  - The base has a suitable fall to the outlet (minimum grade 0.7%) and is appropriately shaped to prevent permanent ponding;
  - Provision of a minimum 600 mm x 1000 mm maintenance access opening. The lifting weight of the grated lid should not exceed 20 kg;
  - Installation of step irons to storage pits greater than 1.2 m depth;

- Where the storage is not sufficiently deep (< 1.2 m), access grates should be placed at the extremities of the tank and at intervals not exceeding 3 m. This should allow any point in the tank to be flushed or reached with a broom or similar implement, without the need to enter the tank;
- The minimum clearance height for accessible tanks is 1.2 m. Tanks less than 0.75 m high must be precast to avoid difficulties with removing formwork;
- To enable visual observation of the entire base of the storage pit, at least 30% of the roof surface area should be grated. Grates should be a minimum of 600 mm wide by 1000 mm long, and arranged in a continuous lengths along the storage pit. Both the access point and the grated areas should be secured to prevent public access.

3.11 Scour protection

3.11.1 General

All outlets shall be designed to incorporate adequate scour protection or energy dissipation systems in accordance with QUDM.

3.11.2 Energy Dissipaters

Ad hoc energy dissipaters in public land are not a preferred drainage solution and may not be used without the prior approval of Council. If approved by Council, energy dissipaters shall be designed in accordance with QUDM.

3.12 Hand Calculation Documentation

- Calculations for rational method pipe design are to be presented in accordance with QUDM. Care must be taken to ensure that partial area effects are determined in the programs and that the dynamic values are calculated in accordance with QUDM.
- All calculations are to be accompanied with catchment plans and other manual calculations sufficient to facilitate checking and approval of plans for minor and major storms.
- The design hydraulic grade line is to be shown on the pipe longitudinal sections and where the pipes are flowing part full, the grade line shall be adjusted to the upstream obvert of the part full pipe.

3.13 Drainage Reserves and Easements

The minimum widths of drainage reserves and easements are presented in Table 4 (drainage reserve and easement considerations).

Table 4 Drainage reserve and easement considerations

Description	Title	Minimum Widths
Inter-allotment drainage	Easement	Minimum 3.0 m, where pipe is > 300 mm and if shared with sewerage will increase to minimum 3.5 m
Road drainage piped through private property without an overland flow path	Easement	The greater of - 3.0 m or pipe(s) width plus 1.0 m either side

Description	Title	Minimum Widths
Overland flow path – either with or without underground drainage component	Reserve or Easement	The greater of – 5.0 m or sufficient drain width to contain the major design event plus freeboard plus a minimum of 2.5 m for linear access roads

3.14 Inter-allotment Drainage

Inter-allotment drainage is not to be used except in the following instances:

- Inter-allotment drainage must be provided to allotments that cannot be drained directly to an adjacent drainage reserve (including road corridors).

Inter-allotment drainage systems must be designed to cater for major design event flows unless specifically approved otherwise by Council's development engineer.

4.0 Data

4.1 Overview

Reliable data is imperative for stormwater modelling within the Bundaberg region. This section seeks to present Council's available datasets as well as data managed by other organisations.

4.2 Regional Datasets

Council manages the following regional databases which are relevant to stormwater modelling, design, and assessments:

- Baseline Hydrologic and Hydraulic Models related to specific study areas (refer Table 5).
- Current Flood Hazard area overlays.
- Survey and Bathymetric data (Kolan River, Burnett River, Burrum River, Elliott River)
- Stormwater Features (pits, pipes, culverts and the like).
- Regional Building Footprint and Floor Level Database.
- Riverine Flooding Calibration Database.
- Creek and Overland Flooding Calibration Datasets.
- Fraction Impervious Database (within the Bundaberg city and coastal urban catchment areas only).

4.3 Flood Studies and Flood Model Data

4.3.1 Flood Models for Development Assessment

Council has commissioned various flood studies and can supply flood models (other than the Burnett River Flood model) that inform Council's current flood hazard areas (declared by Council resolution). These models are detailed in Table 5 below and in Council's Flood Hazard Area Resolution 1/2021.

Any flood studies or models developed by Council not listed in Table 5 below (that do not inform Council's current flood hazard area resolution) are not currently available and are not adopted or supported for development purposes (i.e., for the Building Act and the Planning Scheme). This includes the recent Bundaberg Citywide Overland Flow Path Study and Coastal Drainage Study which have been developed to inform Council's Stormwater Management Strategy.

This advice does not preclude Developers / Applicants from using Council's adopted models or undertaking their own modelling (where necessary) to support a development application.

Table 5 Adopted Flood Studies and Baseline Hydraulic Models Informing Council's Current Flood Hazard Areas

Title	Author	Date	Model Type
Palmer and O'Connell Creek Drainage Study	GHD	1997	1d HEC-RAS, Lumped Hydrology
Apple Tree Creek Flood Study	Cardno	2004	1d HEC-RAS, Lumped Hydrology
Saltwater Creek Flood Study	Cardno	2010	1d/2d XPSWMM, Lumped Hydrology
Bundaberg Creek Flood Study	Cardno	2013	1d/2d XPSWMM, Lumped Hydrology
Burnett River Flood Study	GHD	2013	1d/2d TUFLOW, Lumped Hydrology

Title	Author	Date	Model Type
Kolan River and Gin Gin Creek	GHD	2014	1d/2d TUFLOW, Lumped Hydrology
Baffle Creek Flood Study	O2	2014	Not available
Bundaberg Coastal Small Streams	BMT	2014	1d/2d XPSWMM, Lumped Hydrology
Burrum, Cherwell, Isis, Gregory River Flood Study	GHD	2015	1d/2d XPSWMM, Lumped Hydrology
McCoys Creek Flood Study	GHD	2015	1d/2d XPSWMM, Lumped Hydrology
Non-urban Creeks and Overland Flow Path Flood Study	BMT	2019	2d TUFLOW, Lumped Hydrology & Rain-on-Grid

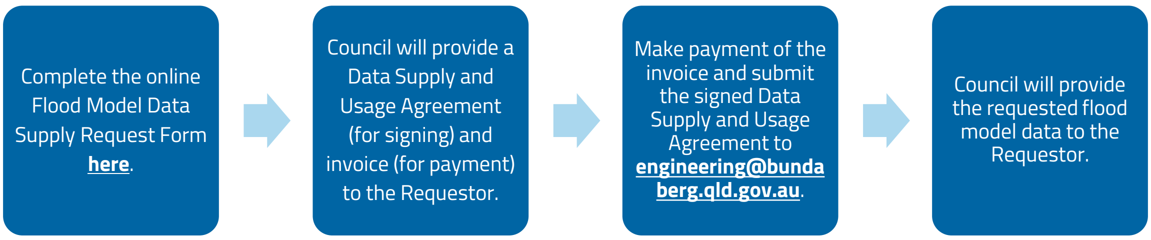
4.3.2 Changes to Adopted Baseline Flood Models

Any changes made to Council's adopted baseline hydrologic and / or hydraulic models will require approval by Council. The RPEQ is to demonstrate that the baseline updates have not fundamentally changed the adopted model calibration and validation. Where notable changes are evident, model re-calibration and / or re-validation will be required. This process and associated results shall be documented in the Stormwater Management Report.

4.3.3 Flood Model Data Supply Process

From 1 July 2023, a fee will apply for the provision of flood model data which will apply to each individual development using the data.

The process for obtaining flood model data from Council is as follows:



New flood studies are commissioned regularly by Council and will become available once approved / endorsed by Council. The Developer/Applicant should check for the availability of new flood studies prior to undertaking any modelling works.

Note, Council is not positioned to provide information regarding downstream boundary conditions (such as tailwater levels). Where possible, a calibrated, catchment-scale model should be used to inform boundary conditions. Where a calibrated, catchment-scale model doesn't already exist, the model should be extended to capture the catchment area influencing the downstream flood behaviour.

4.4 Calibration Datasets

Council can provide access to the following calibration datasets:

Table 6 Calibration Datasets

Catchment(s)	Dataset Description
Burnett River	FFA, historic rainfall (daily and pluviographic), dam storage levels, stream gauge records and recorded peak flood heights for Jan 1942, Feb 1971, Dec 2010, Jan 2011 and Jan 2013 events.
Gregory River Isis River Burrum River	FFA, historic rainfall (daily and pluviographic) and stream gauge records for Feb 2008, Dec 2010 and Jan 2013 events.
Kolan River Gin Gin Creek	FFA, historic rainfall (daily and pluviographic), dam storage levels, stream gauge records and recorded peak flood heights for Mar 2010, Dec 2012 and Jan 2013 events.
Saltwater Creek	FFA, historic rainfall (daily and pluviographic) and recorded peak flood heights for Oct 2017 events. Stream gauge records for Feb 1992 event.
Washpool Creek	FFA, historic rainfall (daily and pluviographic), stream gauge records and recorded peak flood heights for Oct 2017 event.
Bundaberg Creek McCoys Creek Palmer Creek O'Connell Creek	Historic rainfall (daily and pluviographic) and recorded peak flood heights for Oct 2017 event.

4.5 Other Sources of Data

Other data that may be required to undertake flood studies is available from the following sources:

Table 7 Other Datasets

Source	Description	Notes
Bundaberg Regional Council Interactive Mapping https://www.bundaberg.qld.gov.au/interactive-mapping-system	Online Interactive Mapping	-
Australian Rainfall and Runoff (ARR) Data Hub https://data.arr-software.org/	Hydrologic Parameters, Design Storms.	Parameters should not be adopted without review – the RPEQ should provide justification in the Stormwater Management Report.
Regional Flood Frequency Estimation (RFFE) Model https://rffe.arr-software.org/	High-level flood quantile estimation (e.g. 1% AEP flow)	Should be used with care for validation purposes only.
Bureau of Meteorology (BOM) http://www.bom.gov.au/climate/data/	Climate data (e.g. rainfall records), Gauge data	-
Water Monitoring Information Portal (WMIP) https://water-monitoring.information.qld.gov.au/		-
Marine Safety Queensland (MSQ) https://www.msq.qld.gov.au/Tides/Open-data	Tidal definitions (e.g. MHWS), historic and predicted tidal levels	-
Queensland Department of Transport and Main Roads (TMR)	Infrastructure details associated with major transport corridors.	-
Queensland Rail and/or Aurizon		-
QLD Globe / QSpatial http://qldspatial.information.qld.gov.au/catalogue/	State-managed datasets.	-
ELVIS - Elevation and Depth - Foundation Spatial Data Website, https://elevation.fsdf.org.au/	Open source LiDAR and LAS datasets.	Does not have all available LiDAR.
Shuttle Radar Topography Mission (NASA) https://elevation.fsdf.org.au/	Low-resolution topographic data (2009).	Not suitable for design. Recommend using hydrologically corrected version if required.
Copernicus GLO-30 (ESA) https://spacedata.copernicus.eu/web/cscda/dataset-details?articleId=394198	Low-resolution topographic data (2019).	Not suitable for design.
QImagery website – Queensland Government online aerial photograph library, https://qimagery.information.qld.gov.au/	Georeferenced historic imagery.	Georeferencing quality may vary.
Nearmap website, https://www.nearmap.com/au/en	High-resolution, recent aerial imagery.	Subscription required.

4.6 Topographic Data

Ground levels within the catchment (topography) are to be taken from the most accurate source possible, which may include survey, LiDAR, bathymetry and SRTM data. Table 8 provides a summary of topographic data sources and their corresponding quality.

Table 8 Terrain Data Assessment Guide

Terrain Data	High Quality	Medium Quality	Poor Quality
Aerial Survey	LiDAR coverage of entire study area and reporting catchment	LiDAR coverage of study area	SRTM data ESA data (more precise than SRTM)
Bathymetry	Bathymetric survey undertaken within the previous 5 years	Previous historic bathymetric survey	No data
Structures	Survey data of all major waterway crossings (riverine studies) and/or pit/pipe structures for overland studies	Survey data of major waterway crossings	Some survey data for major waterway crossings

4.7 Review of Data Adequacy

All data must be reviewed for suitability, accuracy and data gaps. Where data gaps exist, assumptions and limitations are to be documented by the Developer / Applicant. Typical examples include:

- Reviewing LiDAR accuracy within vegetation extents, particularly riparian corridors. Survey may be required for key overland flow paths.
- Comparing LiDAR precision to PSMs within the area of interest.
- Reviewing stormwater network long sections to ensure inverts and gradients are logical.
- Comparing ARR Data Hub losses against previous studies / regional parameter ranges.
- If a baseline model exists, review of the baseline model layers (such as roughness delineation) within the area of interest, particularly within overland flow paths. Recent, high-resolution aerial imagery should ideally be used alongside a site visit.
- Reviewing completeness of building footprints database against recent, high-resolution aerial imagery.
  - Where buildings are found to be missing, the Developer / Applicant is to add the building footprint to the database.
  - Floor levels of newly added buildings are to be assumed (with assumptions documented) or surveyed.

In all cases, a site visit for the area of interest is **strongly recommended**.

4.7.1 Assumptions

Where data is missing from a GIS database or is not available for a specific area, all reasonable steps must be taken to complete the data (e.g. via survey). Following this, if data gaps still exist, the following assumptions are deemed acceptable to Council:

- Minimum cover over stormwater pipes of 450mm.

- Stormwater pipe size equals that of the downstream pipe.
- Access chamber is circular in shape and 1,050mm in diameter.
- Minimum fall through an access chamber of 20mm.
- Where inlet data or invert level data does not exist:
  - Where pipe size stays the same:
    - U/S invert level is calculated using minimum fall through access chamber.
    - D/S invert level is calculated from grade matching U/S pipe grade (allowing for minimum cover).
  - At changes in pipe size, obvert levels match.

It is the responsibility of the RPEQ to justify all assumptions made.

4.8 Accuracy of the Data Supplied

Council will take care to ensure that the information supplied is accurate, however, the accuracy of the information cannot be guaranteed. If the information supplied, or any part of it, is used, the Developer / Applicant must satisfy themselves as to the completeness, adequacy, accuracy and content of the information and shall make their own interpretations, deductions or conclusions and shall accept full responsibility thereof.

4.9 Continuous Improvement Initiative

Council is actively working to bridge gaps and develop confidence across asset databases. This recurring initiative is in place to promote a future single point of reference for stormwater data which is live and up to date with the best available information.

To assist the Continuous Improvement Initiative, Council strongly encourages Developers / Applicants to share erroneous data or updates to stormwater models / databases by emailing engineering@bundaberg.qld.gov.au.

Through this process, future modelling and assessments can have increased confidence in database integrity and completeness.

5.0 Hydrologic Modelling

5.1 Overview

This section relates to the development of new hydrologic models and outlines Council's requirements for hydrologic assessments, provides guidance on appropriate hydrologic modelling methodology and sets out acceptable modelling parameters. Where possible, guidance has been provided on model parameter values or ranges suitable for use in the Bundaberg Region. Note that model naming conventions are covered in Section 6.3.

5.2 Australian Rainfall and Runoff

Council is currently working towards adoption of ARR19 across all catchments. For new models, Council requires design hydrology to be in accordance with ARR19 guidance and data (together with information in this guideline). Where an existing model has been agreed for use in a development assessment, the previously adopted design hydrology (whether ARR87 or ARR19) is to be maintained. Wherever possible, ARR19 inputs and guidance should be adopted.

Council is currently working with industry to develop new, catchment-scale baseline models which adopt ARR19 design hydrology. These models are intended to be maintained as digital assets which will be updated over time with significant development, new datasets and changes in the catchment. Table 5 will be updated as these models are published and made available for development assessments in the region.

5.3 Design Event Approach

Table 9 Rainfall-Based Procedures (Adapted from ARR19 Book 1 Chapter 3)

Method	Applicability	Advantages	Limitations
Simple Event	• Suitable for preliminary estimates. • Limited justification with currently available computing resources.	• Familiar to most practitioners • Easy to implement	• Unable to quantify bounds of uncertainty (e.g. change in flood behaviour due to temporal pattern shape) • Difficult to demonstrate that probability - neutrality is achieved
Ensemble (Temporal Patterns) Event	• Well suited to accommodating single source of hydrologic variability in simple catchments • Temporal pattern datasets readily available. **Preferred approach for new, ARR19 Models**	• Simple means of minimising probability bias • Modest investment, making application practical • Provides easy transition for practitioners familiar with design event method • Process can be automated (e.g. StormInjector)	• Not suited to considering multiple sources of hydrologic variability or other joint probability influences • Difficult to determine if probability bias remains in the estimates
Monte Carlo event	• Non-dimensional loss distributions and temporal pattern ensembles are readily available.	• Rigorous means of deriving probability estimates for range of factors considered • Readily extended to consider multiple sources	• Requires specialist skills • Dependent on availability of software • For more complex applications care needs to

Method	Applicability	Advantages	Limitations
	• Suitable for high-risk, complex applications, particularly those with joint probability. **Preferred approach for complex applications, such as dam failure assessments.**	of variability and additional joint probability factors (anthropogenic and natural)	be taken to ensure correlations between dependent factors are appropriately considered
Continuous Simulation	• Most applicable for very frequent / frequent events • Useful for hindcasting stream flows for sites with short periods of record • Model parameters not easily transposed to ungauged locations	• Well suited to assessing flood risk in complex systems that are sensitive to flood volume	• Difficult to parameterise model to correctly reproduce the frequency of flood exceedance in manner that adequately captures shape of observed hydrographs

5.4 Modelling Approach

Consultants are encouraged to discuss their planned hydrological approach with Council prior to commencement.

Table 10 Hydrologic Model Approach

Approach	Preferred Software	Application	Notes
Flood Frequency Analysis	FLIKE	• Use where 15-years or more data available. Minimum 30-years recommended for determination of 1% AEP. • Peak-over-Threshold Series for >10% AEPs. • Annual Maxima Series for ≤10% AEPs.	• Range of fitting methods (e.g. GEV, LPIII) must be tested for best fit. • Where possible, incorporate historic flood data. • Incorporate Multiple Grubbs-Beck test. • Can be used to validate other methods. • Sensitive to changing land use, urbanisation, upstream regulation, and non-stationary climate.
Rain-on-Grid / Direct Rainfall	TUFLOW	• Flatter areas (<5%). Not suitable for steep catchments. • Handles complex interaction between flow path cross-connectivity. • Automatically defines overland flow paths and surface-subsurface connections. • Grid cell size needs to be appropriate for use case. A resolution convergence assessment should be used to defend cell selection size. • Storage or timing issues are relevant.	• Rain on Grid approach is appropriate for drainage design or impact assessment at master planning stage and can represent areas comprising both rural and urban land uses. • Must use high-resolution topographic data (support by survey where required), precise land use data and depth-varying roughness. • **Should be calibrated/validated wherever possible.**
Non – Linear	XPRAFTS	• Rural and Urban catchments (Rural only for RORB and all others should be used with caution in urban areas).	• Non-linear Runoff Routing Models are appropriate for drainage design or impact assessment at master planning

Approach	Preferred Software	Application	Notes
Runoff – Routing		• Storage or timing issues are relevant. • Can be highly sensitive to parameters and **should be validated against other methods**. • Application for urban catchments can be complex (storage, surface-subsurface linkages, cross-connectivity in rarer events) and should be used with caution.	stage, particularly for areas comprising both rural and urban land uses. • Can be used to refine ensemble of storms for hydraulic modelling.
Time Area Runoff – Routing Models	12D DRAINAGE	• Urban catchments with significant underground pipe network. • Storage or timing issues are relevant.	• Time Area Runoff Routing Models are appropriate for drainage design or impact assessment at master planning stage, particularly for urban areas.
Rational Method	-	• Regularly shaped catchments. • Homogenous catchments (generally uniform land-use within the catchment). • Storage or timing issues are not relevant. • Rural catchments smaller than 25 km^2. • Urban catchments smaller than 5km^2 with no flow detention facilities.	• An appropriate method for calculation the time of concentration is essential to applying the Rational Method. • Should only be used for the simplest of applications (refer to Section 5.5).
Synthetic Unit Hydrograph Procedure	-	• Rural catchments. • Larger flood event (~50 Year ARI) where over bank flows are developed. • Rainfall can be assumed to be uniform across the catchment	• Limited practical application in development assessment.

5.5 Rational Method

Rational method may be used in simple applications.

5.5.1 Time of concentration

Use of standard inlet times for urban catchments is recommended because of the uncertainty related to the calculation of time of overland flow. The standard inlet times depicted in Table 4.6.2 QUDM may be used with the addition of kerb, pipe and channel flow times determined in accord with Section 4.6.6 of QUDM. Where detailed overland flow in urban areas can be justified, sheet flow times are to be determined using Friend's Equation. For sheet flow lengths outside the limitations of the Friend's Equation and for rural catchments, the time of concentration shall be calculated using the Bransby-Williams or modified Friend's Equation (refer QUDM 4.6.11).

5.6 Model Parameters

5.6.1 Catchment Delineation and Slope

The following requirements apply to the delineation of catchment and sub-catchment areas:

- The entire upstream catchment must be identified, and runoff taken into account.
- Catchment boundaries must align with adjoining catchment boundaries.
- Council drainage systems should be considered when delineating sub-catchments (where relevant).
- Catchment and sub-catchment size must be appropriate for the hydrologic methodology adopted.
- Catchment and sub-catchment slope are to be representative and the modeller is to ensure the appropriate slope schematisation is applied when assigning values (equal area slope, vectored slope).
- Modelling should adopt a semi-distributed approach (i.e. not lumped).
- Sub-catchment characteristics should be homogenous with shape factor as close to 1.0 as possible (shape factors less than 0.5 or greater than 1.5 should be avoided).
- When undertaking developed case scenario hydrologic modelling, the sub-catchment slope adopted must be reflective of the post-developed site characteristics. Unless approved by Council, at a minimum, the following applies:
  - For urban and rural residential development classes, the developed case scenario sub-catchment slope for the development site must be modelled as 0.50% at a minimum. [1]
  - For commercial and industrial development classes, the developed case scenario sub-catchment slope for the development site must be modelled as 0.25% at a minimum. [2]

5.6.2 Channel Routing Method

Where links are created between sub-catchments in a hydrological model, the preferred method of channel routing is the Muskingum-Cunge method. Where an automatic calculation of K and X is adopted, typical cross-section and long-section information can be applied for XPRAFTS to estimate each parameter. Where a direct method of entry in XPRAFTS is used, the channel routing X factor must be between 0.0 and 0.5, where:

- Values less than 0.2 are only acceptable for significant out of bank flows and storages which must be justified for each application.
- Values of 0.2 to 0.3 are typical for natural flow paths with some storage and out of bank flows.
- Values towards 0.5 represents an equal weighting between inflows and outflows and minimal attenuation of flow.

K value shall be determined using the formula below, adopting a representative velocity which should be estimated using Manning's Equation. Special attention to the typical hydraulic roughness characteristics that inform manning's n should be taken. Where an alternative channel routing approach is utilised, justification and calculations must be provided to Council for approval.

$$K(hrs) = \frac{Reach\ Length\ (m)}{3600 \times Representative\ Velocity\ (\frac{m}{s})}$$

[1] PSPDW SC6.3.10.1(a) – The minimum fall on residential or rural residential allotments must be 1 in 200 to the street or other approved stormwater lawful point of discharge.

[2] PSPDW SC6.3.10.1(b) – The minimum fall on commercial or industrial allotments must be 1 in 400 to the street or other approved stormwater lawful point of discharge.

5.6.3 Fraction Impervious

Baseline fraction impervious (FI) is to be determined based on current land use activities / characteristics. Council's fraction impervious database can be used to assist in determining baseline FI within the Bundaberg city and coastal urban catchment areas only.

Unless approved by Council, developed case FI for the development site must be in alignment with the development class as per Table 11.

Table 11 Fraction Impervious by Development Class (Adapted from QUDM Table 4.5.1 and Informed from Analysis of Council's Fraction Impervious Database)

Development Class	Average Allotment Size	Fraction Impervious
Open Space (including Parks)	-	0%
Rural residential (4,000-10,000m^2)	4,000-10,000m^2	20%
Rural residential (2,000-4,000m^2)	2,000-4,000m^2	40%
Urban residential - Low density (>1,000m^2)	>1,000m^2	50%
Urban residential - Low density (600-1,000m^2)	600-1,000m^2	60%
Urban residential - Low density (<600m^2)	<600m^2	70%
Urban residential - Medium density	-	80%
Urban residential - High density	-	90%
Commercial / Industrial	-	90%
Central Business District	-	100%
Road Corridor	-	90%

The Developer / Applicant should ensure that the fraction impervious is included in the Stormwater Management Report in table format detailing the fraction impervious for each zone within a sub-catchment as well as the overall fraction impervious for the sub-catchment.

5.6.4 Rainfall Losses

The allowance for infiltration and storage of rainfall within surface depressions is referred to as rainfall losses and are expressed as either initial loss or continuing loss. Rainfall losses vary between pervious and impervious surfaces and may vary from event to event, within the ranges shown in Table 13.

Adopted rainfall losses for runoff routing models should be informed through model calibration and validation wherever possible. Where this is not possible, adopted rainfall losses should be based on calibrated regional flood models (preferred), otherwise values from the ARR Data Hub may be used (least preferred).

Table 12 Regional Calibrated Hydrologic Model Rainfall Losses - Bundaberg City & Coastal Urban Areas

Surface Type	Initial Loss	Continuing Loss
Pervious	25 mm	1.5 mm/h
Impervious	1 mm	0 mm/h

Should a rainfall Continuing Loss outside the range shown in Table 13 be proposed, approval by Council is required. Hydraulic conductivity testing may be required at locations agreeable with Council which represent typical conditions, and to a suitable depth. It is not considered appropriate to increase Initial Loss beyond the 140mm upper limit. Rather, highly pervious soils should only change Continuing Loss values.

Table 13 Rainfall Loss Ranges

Surface Type	Initial Loss	Continuing Loss
Pervious	Range: 0 - 140 mm Median: 15 - 35 mm (preferred)	Range: 0.0 - 3.5 mm/h Median: 2.5 mm/h (preferred)
Impervious	Initial loss: 0 - 1 mm	Continuing loss: 0 mm/h

5.6.4.1 Groundwater Considerations

For areas with known groundwater issues, coastal localities, or where the developable topography is below 5mAHD, a sensitivity test must be included which considers high groundwater conditions. Wherever possible, nearby groundwater gauges (which can be accessed at the https://water-monitoring.information.qld.gov.au/) should be reviewed for the highest groundwater level on record. If the maximum recorded level exceeds any portion of the developable area, rainfall losses (initial and continuing) should be set to 0mm and 0mm/hr respectively as a sensitivity test to consider high ground water conditions. The predicted flood behaviour modelled within this sensitivity assessment should be used to inform design decisions such as:

- Adopted freeboard for habitable floor levels.
- Siting and usage of in-ground assets, such as pools or septic systems.
- Accessibility and provision of an emergency exit route.
- Drainage infrastructure constrains, such as pooling water in open channels.
- Water quality treatment measures, such as bioretention basins – refer to Stormwater Management Guidelines (Part 2).

5.6.5 Ground Roughness

Ground roughness accounts for the influence land use and surface features have on the flood behaviour.

5.6.5.1 Baseline Hydrologic Roughness

Wherever possible, baseline values should be determined from calibration of the hydrological model to stream gauging. In lieu of calibration data, some form of validation must be undertaken, to demonstrate the reliability of the baseline hydrologic model, as per section 5.10.

5.6.5.2 Developed Case Hydrologic Roughness

When undertaking developed case scenario hydrologic modelling, the roughness parameters adopted for pervious and impervious surfaces of the development site may be as per Table 14 below. However, some form of validation must be undertaken, to demonstrate the reliability of the developed case hydrologic model, as per section 5.10.

Table 14 Developed Case Hydrologic Roughness Parameters

Surface Type	Roughness "n" Value
Pervious	0.040
Impervious	0.015

5.7 Critical Duration Selection

Assessment of stormwater quantity is to be based on the critical duration (or durations) within the study area, for each of the design events noted in Section 8.2. The following is noted:

- There may be multiple critical durations across the study area. All predominant critical durations are to be assessed.
- The critical duration may change between design events. The critical duration for each design event is to be assessed for that specific design event.
- Critical duration may change between Baseline and Developed Case. If so, each of the Baseline and Developed Case critical durations are to be assessed for both cases.
- A range of durations are to be assessed to identify the critical duration.
- In complex or storage driven catchments, the Developer / Applicant should confirm the critical duration within the hydraulic model (not just the hydrologic model).
- Where a new hydrologic model is being created, the methodology for selection of critical duration outlined in ARR19 is to be adopted.
- Selection of the critical duration is to be demonstrated graphically (e.g. map of critical duration, critical duration histogram to show predominant durations).

5.8 Temporal Pattern Selection

5.8.1 ARR87 Models

Temporal pattern will be as per the selected design event due to the 'Simple Event' approach used in ARR87 (refer Table 9).

5.8.2 ARR19 Models

Where a new flood model is required, the 10 ensemble temporal patterns from ARR19 are to be analysed. These ensemble temporal patterns have been chosen to represent the variability in observed patterns.

For analyses using hydrologic modelling, the full ensemble of temporal patterns should be adopted in accordance with the method prescribed in ARR. Critically, temporal patterns with embedded bursts must be either smoothed or removed (which is automated in some software packages).

For hydraulic modelling, a representative temporal pattern is considered appropriate for a single location of interest. This should be demonstrated using a map which shows the median temporal patterns across the model extent. The representative temporal pattern must be re-checked for the developed case, as it may vary with catchment changes and the nature of design (e.g. detention basins).

Sections 5.8.2.1 to 5.8.2.5 below explain the method to be used for selecting a representative temporal pattern.

5.8.2.1 Temporal Pattern Metric

The metric to be used for selecting a representative temporal pattern should consider the nature of the catchment and the development, as well as any mitigation infrastructure proposed. Options include time to peak (e.g. emergency management), volume (e.g. storage-driven catchments) or peak flow (most other applications).

5.8.2.2 Temporal Pattern Selection

The temporal pattern first exceeding the median (the 6^{th} highest flow out of 10 ensemble temporal patterns or median if odd number of patterns) should be used.

5.8.2.3 Embedded Bursts

Section 5.9.4 (Book 2) of ARR requires that consideration be given to filtering out (or excluding) embedded bursts of a lower (i.e., rarer) AEP in temporal patterns. Embedded bursts occur when the rainfall accumulated over a subset (the 'burst') of a storm's temporal pattern has a depth that exceeds the IFD value for the burst's duration for the same AEP. This means that the burst has a lower (rarer) AEP than the design hyetograph.

Embedded bursts should be detected using appropriate software (such as Storm Injector v1.1.6 or later) and smoothed to remove embedded bursts. Smoothing is achieved by adjusting non-zero timesteps in the temporal pattern closer to the mean as outlined by Scorah, Hill, Lang & Nathan (HWRS 2016).

5.8.2.4 Pre-burst

The application of storm pre-burst must be included by distributing pre-burst rainfall depth equally over a defined number of time steps (prior to the storm burst). The number of timesteps required is to be determined such that the pre-burst intensity is not greater than the burst intensity. Pre-burst rainfall depth and distribution is to be documented in the Stormwater Management Report.

5.8.2.5 Areal Reduction Factors

Areal reduction factors are to be applied in accordance with Chapter 4 (Book 2) of ARR and documented in the Stormwater Management Report.

5.9 Climate Change

For all flooding mechanisms except Burnett River flooding, Council's defined flood event (DFE) includes the impacts of Climate Change and is to be assessed for all development, as noted within the Council Planning Scheme Policy for Development Works (2015).

Climate Change is to be calculated based on a Representative Concentration Pathway (RCP) of 8.5. Climate Change is therefore to be applied to the 1% AEP event as an increase in rainfall intensity of 19.7%.

5.10 Hydrologic Calibration and Validation

All hydrologic models should have some form of calibration and validation (where possible), to demonstrate the reliability of the model to estimate discharges within the study area. Council's order of preference is:

- Flood Frequency Analysis (FFA), where the catchment is gauged, and an adequate period of record is available (nominally 15 years or greater).
- Validation of flows via:
  - An alternate hydrologic method to that adopted for the study (preferred).
  - Regional Flood Frequency Estimation (RFFE) and/or Rational Method check.
  - Check against rational method and/or discharge per hectare catchment area.

It may be necessary to employ more than one method to validate model performance. It is noted that validation is not to include adjustments to model setup or model parameters. Baseline setup of existing calibrated / validated models are not to be adjusted unless approved by Council.

6.0 Hydraulic Modelling

6.1 Overview

This section relates to the development of new hydraulic models and outlines Council's requirements for hydraulic assessments, provides guidance on appropriate hydraulic modelling methodology and sets out acceptable modelling parameters. Where possible guidance has been provided on model parameter values or ranges suitable for use in the Bundaberg Region.

6.2 Model Methodology

The purpose of hydraulic modelling is to estimate flooding characteristics (i.e. flood levels, depths, extents, velocities, hazard etc), for the flooding mechanism/s impacting the study area, based on the flows determined in the hydrological assessment.

Hydraulic assessments are to be undertaken in accordance with ARR19 guidance and data (together with information in this guideline). Where an existing model has been agreed for use in a development assessment, the previously adopted design hydrology (whether ARR87 or ARR19) is to be maintained. Wherever possible, ARR19 inputs and guidance should be adopted.

The modelling process must be capable of accurately determining flows within the study area, whether it be an urban area, rural area or a floodplain. Table 15 provides a summary of potential hydraulic approaches and where they may be suitable for application.

The following general points are also made:

- Two-dimensional (2d) hydraulic models are required in all but the simplest applications. To be considered a simple application, the development must have:
  - Small defined upstream catchment, with minimal change in Land Use;
  - A single, well-defined flowpath; and
  - Minimal storage within the upstream catchment.
- Model resolution must be sufficient to represent hydraulic controls within the study area.
- If the critical temporal patterns differ between Baseline and Developed Case, both critical temporal patterns are to be assessed for both the cases (refer Section 4.7 for temporal pattern selection).
- Blockage of new drainage structures must be assessed in accordance with the methodology outlined in ARR19.

Table 15 Hydraulic Approach Summary

Model Type	Preferred Software	Selection	Notes
Steady State – 1d	**HEC-RAS**	▪ Storage or timing issues are not relevant; and ▪ Flows are 1d, largely within a watercourse and the immediate overbank area.	Generally, only suitable for channel type hydraulic analysis.
Fully Dynamic – 1d	**TUFLOW**	▪ Storage or timing issues are relevant; and ▪ Flows are one-dimensional (1d), largely within a watercourse and the immediate overbank area.	Suitable for smaller 1d watercourses. Provides stability advantages over 2d models for steeper areas.
Fully Dynamic – 2d	**TUFLOW**	▪ Storage or timing issues are relevant; and ▪ Flows are 2d.	Flood maps are generally a direct output from models.
Fully Dynamic – Couple 1d/2d	**TUFLOW**	▪ Storage or timing issues are relevant; and ▪ Flows are combinations of 1d or 2d; and ▪ Large areas need to be represented in combination with fine detail.	This is the preferred methodology, unless it can be demonstrated an alternative is appropriate.
Internal sub-division Stormwater Network Design – 1d	**12D Model Drainage Analysis**	▪ Sizing of simple stormwater networks and road flow widths as per QUDM.	Uses a Rational Method peak flow determination and Manning's pipe flow.

6.3 Naming Convention

Table 16 presents Council's mandatory naming convention, denoted *AAA_B_CC_DDDD_EEEEmin_FFFF_G*.

Table 16 Mandatory Naming Convention

Identifier	Description
AAA	2 or 3 letter model identifier (for example): • BA – Bargara Regional Model • BR – Burnett River • BOM – Bundaberg Overland Model • CH – Childers Regional Model • EH – Elliott Heads Regional Model • GG – Gin Gin Regional Model • MPB – Moore Park Beach Regional Model • WGT – Woodgate Regional Model
B	Single letter case identifier: • E – Existing Case • D – Developed Case • M – Mitigation Case • S – Sensitivity Analysis
CC	Run ID/Revision number (e.g. 01)
DDDD	4-digit AEP of modelled event in percentage: • 63p2 – 63.2% AEP (1 EY) • 39p4 – 39.4% AEP (2-year ARI) • 18p1 – 18.1% AEP (5-year ARI) • 10p0 – 9.5% AEP (10-year ARI) • 5p00 – 5% AEP (20-year ARI) • 2p00 – 2% AEP (50-year ARI) • 1p00 – 1% AEP (100-year ARI) • 1pCC – 1% AEP + Climate Change (DFE) • 0p50 – 0.5% AEP (200-year ARI) • _PMF – Probable Maximum Flood
(EEEE)min	3- or 4-digit duration of modelled event in minutes (e.g. 010min, 120min, 1440min etc)
FFFF	Temporal pattern identifier (if applicable)
G	Results data type contained in GIS file: • A – afflux • A_wd – wet/dry information associated with afflux plots • D – depth • H – water surface level • V – velocity • Z0 – Hazard (D x V) • ZAEM1 – Hazard (ARR19) Add **_Max** for GIS output producing maximum of multiple durations (if applicable)

For example, the Bundaberg Overland Model existing case simulated for the 1% AEP plus Climate Change (DFE) 120-minute storm with temporal pattern 5105 would be ***BOM_E01_1pCC_120min_5105***.

6.4 Model Parameters

6.4.1 Model Extent

The hydraulic model is to cover either:

- The full catchment extent; or
- The full extent of the study area, including any hydraulic impacts in events up to and including the DFE (as defined in Section 2.3).

6.4.2 Minimum Grid Size

Where two-dimensional hydraulic modelling is utilised, the grid is to be sized to provide sufficient resolution to assess impacts of the proposed development. A resolution convergence assessment is recommended to identify the optimum grid size to balance model resolution with simulation time.

If using a TUFLOW hydraulic model, the TUFLOW Wiki provides guidance on grid size at the following link: https://wiki.tuflow.com/index.php?title=TUFLOW_2D_Cell_Size_Selection

The following grid size ranges are generally acceptable within the Bundaberg region:

- Flow in channels – preferrable to provide a minimum of 5 grid cells laterally across the channel.
- Urban areas – grid size of 4m or less.
- Semi-Rural areas – grid size between 3m and 10m.
- Rural and floodplain areas – grid size between 5m and 15m.

Grid sizes larger than those noted above may be used if it can be demonstrated model results are not significantly impacted by the reduced resolution. Ultimately this is a decision for the RPEQ.

6.4.3 Quadtree (TUFLOW Models Only)

Quadtree refinement allows for recursive division of square TUFLOW cells into four smaller squares. This provides the ability to increase the grid resolution of the model in urban areas, complex and critical flowpaths, while elsewhere a larger grid cell size can be applied. Quadtree therefore has the potential to speed up computational times whilst maintaining resolution of model outputs in key areas. The Developer / Applicant should however be aware of the following limitations:

- Quadtree requires additional licencing within TUFLOW.
- There may be a need to update Baseline mesh once development within a catchment comes online.

6.4.4 Sub-Grid Sampling (TUFLOW Models Only)

When applying Quadtree and / or Sub-Grid Sampling (SGS) within TUFLOW hydraulic models, the following preferences are noted:

- Crests and embankments of significance **must be** manually stamped in to prevent 'leaking' across embankments.
- Channel inverts **should not be** manually stamped in unless being used to fix tinning issues in the base topography.
- Careful consideration of map output flags is to be applied when using SGS. The TUFLOW manual provides guidance on options for SGS map outputs. Council's preferred SGS map output flag is:
  - Map Cutoff SGS == Exact
  - SGS Map Extent Trim == All

6.4.5 Boundary Conditions (Inflows and Outflows)

Boundary conditions set the flows entering a model (inflows) and the flows exiting the model (outflows). Both external and internal boundaries may be required, where:

- External boundaries allow flows to enter and exit the model along the external edges of the model domain.
- Within the model domain, Internal boundaries define the interface between wet cells and dry cells.

For each design event, inflows must be based on a single temporal pattern applied model wide. It is not acceptable to apply different temporal patterns at different inflow locations. If a common temporal pattern cannot be established, or if the critical temporal pattern changes between Baseline and Developed Case, it may be necessary to complete multiple hydraulic simulations for a specific critical duration.

Council is not positioned to provide boundary conditions beyond supply of available models shown in Table 5.

6.4.5.1 Tailwater Conditions

The downstream extent of the hydraulic model will determine the tailwater conditions to be applied, which may include the following:

- Sea level, for a coastal downstream boundary (refer Section 6.4.5.2).
- Levels based on a previous flood study, for the corresponding AEP event.
  - Requires the previous study to have been accepted by Council and remains current.
- In the absence of any other information, levels calculated from simplified means (i.e. critical depth or normal depth).

The downstream boundary should be located sufficiently far enough downstream from the study site, to reduce the impact of the downstream boundary on results at the site.

6.4.5.2 Coastal Boundaries

Where the downstream boundary is coastal or within a tidal area, the following boundary conditions apply:

- When undertaking historic event simulations for calibration or validation purposes, observed sea levels should be used for tailwater conditions.

- When undertaking design event simulations, a fixed height equal to Mean High Water Springs (MHWS) tide should be applied.
- When undertaking design event simulations that include Climate Change, a fixed height equal to Mean High Water Springs (MHWS) tide plus 0.8m should be applied.

Sea levels for the Bundaberg Region are monitored at Burnett Heads, with the information available through Marine Safety Queensland (MSQ). As sea levels are continually being reviewed, the latest data is to be obtained from MSQ at the time of the study and documented in the Stormwater Management Report.

6.4.5.3 Estuarine Boundaries

Where the downstream boundary is located within a tidally influenced watercourse, but not within a coastal area, tidal conditions and elevated tailwater conditions due to flood flows are to be accounted for. This would typically be achieved using a rating curve, as follows:

- Where tailwater levels are below MHWS, flows are set to zero.
- Once tailwater levels reach MHWS, flows are calculated based on water surface slope.

6.4.6 Topographic Data

The accuracy of the hydraulic model is directly influenced by the topographic data used, the accuracy of which should be clearly stated. Depending on the hydraulic methodology applied, the following topographic data is recommended:

- 1d models – Cross-sections along branches within the study area.
- 2d models – Digital elevation model (DEM) based on the most accurate and most current topographic data within the study area. The DEM is to be built up from the following data, where available:
  - Base topography – LiDAR.
  - Ground survey.
  - Bathymetric survey for rivers, creeks, lakes, dams, basins and the like.
  - 'Stamped in' ridges.
  - 'Stamped in' gullies, except for where SGS is being applied.

When undertaking 2d hydraulic modelling, the following are to be 'stamped in' to ensure these key hydraulic controls are adequately represented within the model topography:

- ridges such as road crests.
- gullies such as open channels and natural flow paths, except for where SGS is applied.

For developed case scenario modelling, the topography must be amended to reflect the post-developed site characteristics.

6.4.7 Hydraulic Roughness

Baseline hydraulic roughness parameters should be informed based on current land use activities / characteristics and wherever possible, determined from calibration. In lieu of calibration data, some form of validation must be undertaken, to demonstrate the reliability of the baseline hydraulic model, as per section 6.5.

6.4.8 Hydraulic Structures

Hydraulic structures that are likely to influence flows within the study area are to be included within the hydraulic model. These may include road crests, gullies, culverts, bridges (road, rail, driveway, pedestrian etc), pit and pipe drainage systems, open channels, safety barriers and the like.

6.4.8.1 Culverts, Pit and Pipe Drainage Systems

Council maintains a GIS database which contains information on existing culverts, pits and pipes within the Council owned drainage system. Key drainage infrastructure is to be included in the hydraulic model, with details such as size and invert levels confirmed on site (as required).

Should there be State Controlled roads within the study area, the Department of Transport and Main Roads is to be contacted to obtain detail of drainage infrastructure within the State-controlled road corridor. Alternatively, infrastructure within state-controlled road corridors can be picked up during detailed survey.

6.4.8.2 2d Hydraulic Structures

Where a 2d hydraulic model is being used, the following are to be modelled as 2d structures:

- driveway and footpath crossings of drains and watercourses.
- Road and rail bridges.
- unstable culverts (when modelled as a 1d structure).

When using a 2d Layered Flow Constriction Shape (LFCSH) within TUFLOW, Council's preferred methodology for application of losses is the PORTION method. The following guidance is provided when selecting the most appropriate method for modelling LFCSH to accurately apply the calculated Form Loss Coefficients (FLC):

- **LFCSH Line Thin** (i.e. no width specified) – most appropriate for not overly wide bridges and non-perpendicular flow.
    - Applies FLC to a single cell side.
    - Total FLC does not need to be divided by the number of cell sides.
    - Total FLC is therefore applied to the bridge.
- **LFCSH Line Thick / Wide** (i.e. width specified) – again most appropriate for perpendicular flow, however better suited to consistent soffit level across the bridge.
    - Applies FLC to the number of cell side intersected by the line width.
    - TUFLOW tries to calculate how many cell sides will be affected based on the line width and divides the FLC value accordingly.
    - However, it needs to be checked that the FLC has been applied to the correct amount of cell sides, which is quite sensitive to digitization and adopted line width.
    - Either line width or LFC value may need to be adjusted if the LFC values do not add up to the intended total value.
    - Risk that the FLC is not applied to the correct number of cell sides, and therefore loss is either under or over estimated.

- **LFCSH Region –** most appropriate for perpendicular flow, where bridge soffit level may change across the bridge width (i.e. super-elevation).
    - Applies FLC to the number of cell side contained within the region.
    - Total FLC therefore needs to be divided by the number of cell sides times the grid size (unless you use a negative value).
    - Risk that the FLC is not applied to the correct number of cell sides, and therefore loss is either under or over estimated.

An alternative method, such as HEC-RAS, is to be used to validate the 2d structure head loss across bridges. Comparison of head loss across the structure between the alternative method and the 2d model is to be documented within the assessment report (refer Section 9.1).

6.4.8.3 Safety Barriers

Where safety barriers are present, they are to be included in the hydraulic model as 2d structures, with the following blockage factors:

- 100% fully blocked for concrete barriers and
- 100% fully blocked for Safety barriers with motorcyclist injury countermeasures.
- For guardrail, 100% blocked from underside of the cross member to top of the barrier, with a calculated blockage factor from pavement to underside of the first cross-member.

6.5 Hydraulic Model Calibration and Validation

All hydraulic models are to have some form of calibration and/or validation (where possible), to demonstrate the reliability of the model to represent flow conditions within the study area, as follows:

- For study areas with recorded data from multiple historic events:
    - Calibration to the most recent major flood event, ideally with the largest number of reliable recorded flood levels.
    - Validation to a historic event of different magnitude, preferably a minor or frequent flood event with reliable data.
- For study areas with recorded data from a single historic event:
    - Calibration to the single recorded flood event.
    - Validation of frequent flood event estimated levels against local knowledge, where available.
- For study areas with no historic event data:
    - Validation of modelled design event hydrographs (flows, volume and shape) against an alternative hydrologic model (**preferred**), such as comparing direct rainfall to XP-RAFTS hydrographs.
    - Validation of flows against Regional Flood Frequency Estimation (RFFE) and/or Rational Method check.
    - Validation of frequent flood event estimated levels against local knowledge, where available.

It is noted that validation is not to include adjustments to existing calibrated / validated model setup or parameters. Baseline setup of existing calibrated / validated models are not to be adjusted without approval from Council.

6.5.1 Hydraulic Model Calibration and Validation Performance

Calibration and validation performance are to be assessed using the following criteria:

- Where data is surveyed and considered reliable:
    - Within tolerance, ±150mm.
    - Outside tolerance but acceptable, ±300mm.
    - Outside tolerance, > ±300mm.
- Where data is anecdotal or collected from debris marks and the like:
    - Within tolerance, ±300mm.
    - Outside tolerance but acceptable, ±500mm.
    - Outside tolerance, > ±500mm.

Where modelling is related to riverine or creek flooding, the hydraulic grade of the watercourse is to be compared to recorded flood levels along the reach and presented within the Stormwater Management Report. Hydraulic model calibration and validation performance is to be mapped as shown in Section 9.3.4.

6.6 Climate Change

Refer Section 5.9 for details of Climate Change application to hydrologic modelling. Climate Change is to be applied to hydraulic modelling as follows:

- Increase added to the 1% AEP event.
- For rain-on-grid models and lumped hydrograph models – Apply increase in rainfall to RCP 8.5 year 2090 (19.7% increase).
- Coastal Boundaries – an increase in sea level of 0.8m (as adopted in Queensland as the progressive sea level rise from 1990 levels to 2100 levels – State Planning Policy mandatory requirements: coastal hazard).

7.0 Modelling Quality Assurance

7.1 Overview

This section provides guidance for 'good practice' and 'sense checks' within the hydrologic and hydraulic Quality Assurance (QA) process, which aim to promote defensible modelling throughout the region.

7.2 Model Logs

A model log is to be set up for each model developed, containing the following information at a minimum (as relevant to the type of model):

- Software used and version.
- Model ID or Build.
- Date finished.
- Events simulated, including durations and temporal patterns (where applicable).
- Model description.
- Names of key input files.
- Adopted model parameters (mainly for hydrologic models).

Other relevant information and details should be included (as required).

7.3 Quality Assurance Checks

The checklist provided in Table 17 must be completed and included as an Appendix to the Stormwater Management Report for the purposes of hydrologic and hydraulic modelling quality assurance.

Additional checks should also be undertaken for the following simulation parameters to gauge model health:

- Model grid size is not 3x smaller than the maximum modelled depth.
- Simulation mass error is within +-1%,
- For adaptive timestep models (such as TUFLOW HPC), timesteps do not repeat more than five times in a row.
- For adaptive timestep models (such as TUFLOW HPC), dt values are not more than 25x smaller than the model grid size.

Table 17 Quality Assurance Checklist

Modelling Aspect to be Reviewed	Yes	No	N/A	Comments
Data Appropriateness				
Is the topographic data of sufficient accuracy to delineate catchment/s and identify flows paths?				
Are previous models being used? If so, has sufficient review been undertaken to ensure suitability.				
Is there sufficient information on structures such as culverts, bridges, pit/pipe systems?				
Has all available calibration and validation data been sourced and used in the study?				
Have data gaps and assumptions been adequately documented?				
HOLD POINT – RPEQ review and acceptance recommended prior to undertaking hydrologic modelling				
Hydrologic Modelling				
Has ARR19 methodology been adopted (where an existing ARR87 study does not exist)?				
Has an appropriate hydrologic methodology been adopted?				
Where a runoff routing method has been used, are catchments appropriately delineated?				
Has the correct IFD data been applied?				
Are areal reduction factors required? If so, have they been applied?				
Has the model been calibrated? If not, has there been some other means of verifying the results?				
Has the Developed Case model been correctly updated to include the proposed development?				
Do model results seem reasonable? Are results consistent with previous studies (if applicable)?				
In determining differences between Baseline and Developed results are we comparing like with like?				
Have all assumptions and inputs been documented?				
Has a model log been kept?				
HOLD POINT – RPEQ review and acceptance recommended prior to undertaking hydraulic modelling				

Modelling Aspect to be Reviewed	Yes	No	N/A	Comments
Hydraulic Modelling				
Has an appropriate hydraulic methodology been adopted?				
Do the model extents cover the area of interest?				
Are model extents sufficient to minimise the impact of boundary conditions on the area of interest?				
Does the grid size allow for sufficient detail (refer Section 6.4.2)?				
Are boundary conditions appropriate: • Are all inflows into the model accounted for? • Have ocean boundaries been based on the latest information? • Have downstream water levels been set at appropriate levels? • Are source points/internal inflows placed at the right locations? • Are the source points linked to the correct hydrographs (where applicable)? • Were input hydrographs extracted from other models correctly (where applicable)? • Are the initial conditions appropriate?				
Has all critical infrastructure been represented / included and input into the model correctly?				
Have bridges (where required) been modelled appropriately: • Have bridge data / drawings been documented adequately? • Are bridges modelled appropriately using 2d_lfcsh? • Have bridge obvert / depth levels been double checked against drawings (check datum)? • Have critical bridges been checked using an alternate 1d scheme (i.e. HEC-RAS)? • Have bridge structure blockage and form loss values been applied correctly? • Are bridge widths applied to ensure losses are modelled over the correct number of cells?				

Modelling Aspect to be Reviewed	Yes	No	N/A	Comments
Hydraulic Modelling (continued)				
Stability and Checks (apply where relevant to modelling methodology): • Have 1d/2d boundary conditions been checked? • Have subsurface network long sections been visually inspected for errors in invert data? • Have 2d_lfcsh check files carried through the correct parameters? • Do zpt and zsh check file extents match the extents of topographic modifiers? • Have model warnings been inspected and addressed where necessary? • Have negative depths and repeated timesteps been inspected and addressed? • Have the DEM_Z and DEM_M check files been reviewed to confirm model setup? • Does the model run with acceptable stability and efficiency (>90% if HPC TUFLOW model)? • Are there any changes required to improve stability in the area of interest?				
Has the model been calibrated? If not, has there been some other means of verifying the results?				
Has the Developed Case model been correctly updated to include the proposed development?				
Do model results seem reasonable? Are results consistent with previous studies (if applicable)?				
In determining differences between Baseline and Developed results are we comparing like with like?				
Have all assumptions and inputs been documented?				
Has a model log been kept?				

8.0 Impact Assessment

8.1 Purpose

The impact assessment component of a Stormwater Management Report is to:

- assess the potential impacts of the development on flood hazard, including Council's Flood Hazard Area;
- assess the potential impacts of flood hazard on the development;
- recommend strategies to be incorporated into the proposed development to satisfy the outcomes of the Council Flood Hazard Overlay Code; and
- describe and evaluate the impact of the proposed mitigation strategies on the existing and likely future use of land and buildings in proximity to the proposed development.

Assessment of development impacts is to be undertaken for a range of AEP events (refer Section 8.2). The purpose of the impact assessment is to identify potential changes in flood characteristics as a result of the development, including changes to flood levels, extents, depths, velocity, hazard, timing and impacts to key infrastructure and buildings.

8.1.1 Design Considerations

The developer/applicant must take the following design considerations into account for all development, in relation to flood impacts:

- Where detention basins are proposed, peak flood levels may become runoff volume driven and critical storm duration/s may change. It must be demonstrated that the critical duration has been established for all AEP events for both Baseline and Developed Case conditions.
- Where kerb inlets, field inlets or culverts are proposed, calculation of inlet capacity must demonstrate the system can receive and discharge the design event flows.
  - Appropriate allowance for blockage of inlets must be included as outlined in Section 5.2.

8.2 Design Events

A range of design events is to be assessed for all developments, including at a minimum the 39% AEP, 10% AEP, 1% AEP and 1% AEP + Climate Change (DFE).

8.3 Impacts to be Assessed

Table 18 summarises the impacts to be assessed **at a minimum**. Each impact is discussed in further below.

Table 18 Impacts to be Assessed

Consideration	Potential Impact	Reference
Are there any changes in flood behaviour?	Change in Peak Water Surface Level (PWSL)	Section 8.3.1
	Change in Peak Depth Averaged Velocity (PDAV)	Section 8.3.2
	Change in Peak Flood Hazard	Section 8.3.3
Are there buildings within the impacted area?	Change in Above Floor Flooding	Section 8.3.4
Are there crops, roads or private properties within the impacted area (i.e. increased TOS)?	Change in Time of Submergence (TOS)	Section 8.3.5
Is the cumulative impact of development likely to cause or increase adverse impacts of flooding?	Cumulative Impacts	Section 8.3.6

8.3.1 Change in Peak Water Surface Level (PWSL)

For each AEP event assessed, peak water levels of all critical durations (in either Baseline or Developed Case) must be enveloped into a single composite peak water level (peak of peaks) for that specific AEP event. The change in PWSL for each AEP event is determined by the difference in composite peak water levels between Developed Case and Baseline.

8.3.2 Change in Peak Depth Averaged Velocity (PDAV)

For each AEP event assessed, peak velocities of all critical durations (in either Baseline or Developed Case) must be enveloped into a single composite peak velocity (peak of peaks) for that specific AEP event. The change in PDAV for each AEP event is determined by the difference in composite peak velocities between Developed Case and Baseline.

8.3.3 Change in Peak Flood Hazard

For each AEP event assessed, peak flood hazard of all critical durations (in either Baseline or Developed Case) must be enveloped into a single composite peak flood hazard (peak of peaks) for that specific AEP event, and classified as shown in Table 19, Table 20 and Figure 2.

Table 19 ARR19 Hazard Classification Descriptions

Category	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.

H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 20 ARR19 Hazard Classification Limits

Hazard Vulnerability Classification	Classification Limit (D and V in combination) (m^2/s)	Limiting Still Water Depth (D) (m)	Limiting Velocity (V) (m/s)
H1	D*V ≤ 0.3	0.3	2.0
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V > 4.0	-	-

The change in peak flood hazard is to identify areas where flood hazard classification has increased as a result of the development. These locations are to be presented in the report, along with a discussion on the increased flood hazard posed by the development (if any).

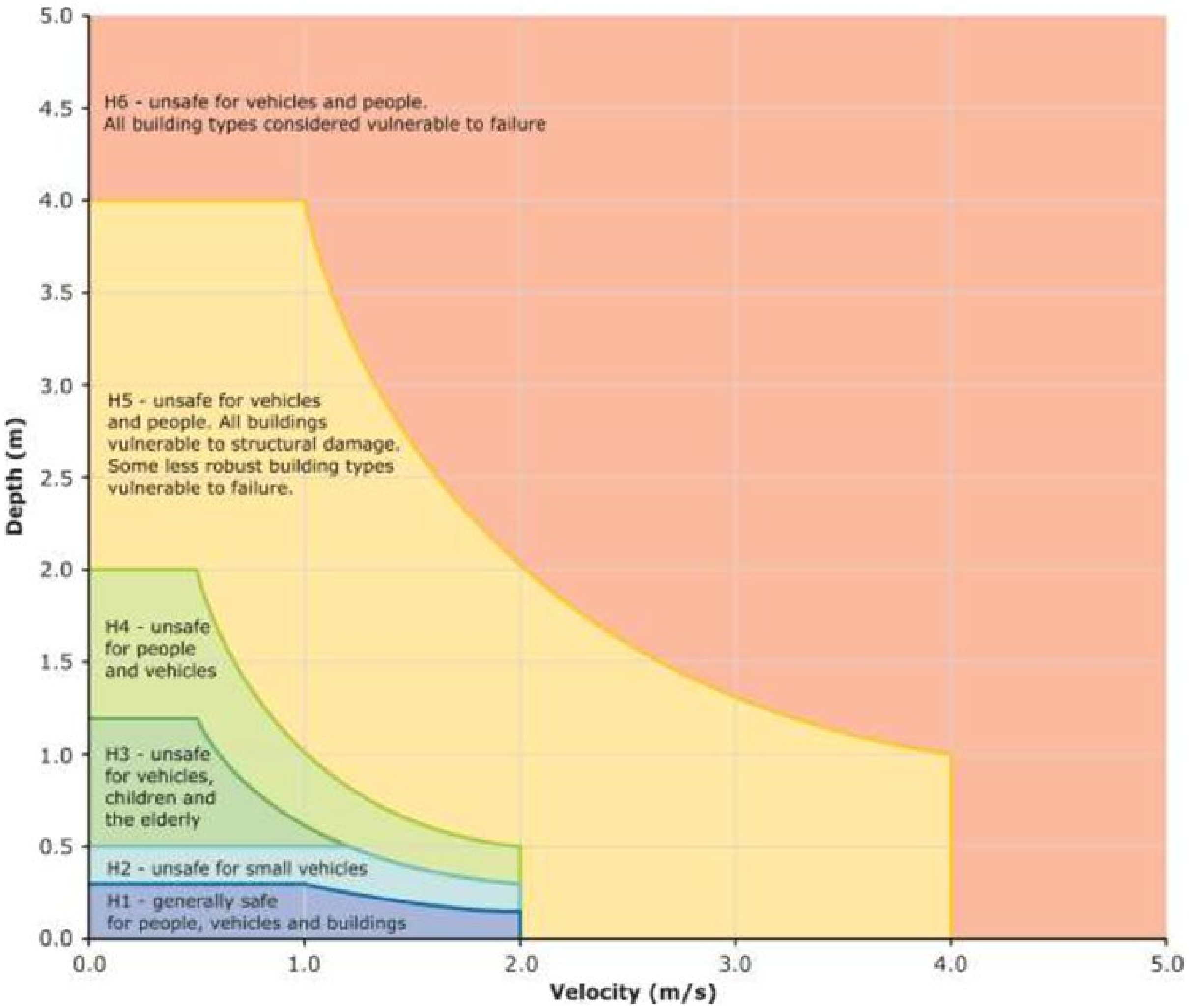


Figure 2 Hazard Vulnerability Classifications (Graphical)

8.3.4 Change in Above Floor Flooding

Any changes to existing building inundation within the study area are to be displayed on the Difference in PWSL maps, in accordance with the building impact categories summarised in Table 21 and Figure 3.

Table 21 Change in Over Floor Flooding – Categories (Tabular)

Category	Description
1	**Category 1 – No Change / Building Not Flooded in Baseline or Developed Case**
2	**Category 2 – Building inundated above floor level in Baseline, but not inundated above floor level in the Developed Case**
3	**Category 3 – Building inundated above floor level in Baseline and receives a flood depth decrease in the Developed Case**
4	**Category 4 – Building inundated above floor level in Baseline and receives a flood depth increase in the Developed Case**
5	**Category 5 – Building not inundated above floor level in Baseline, but is inundated above floor level in the Developed Case**

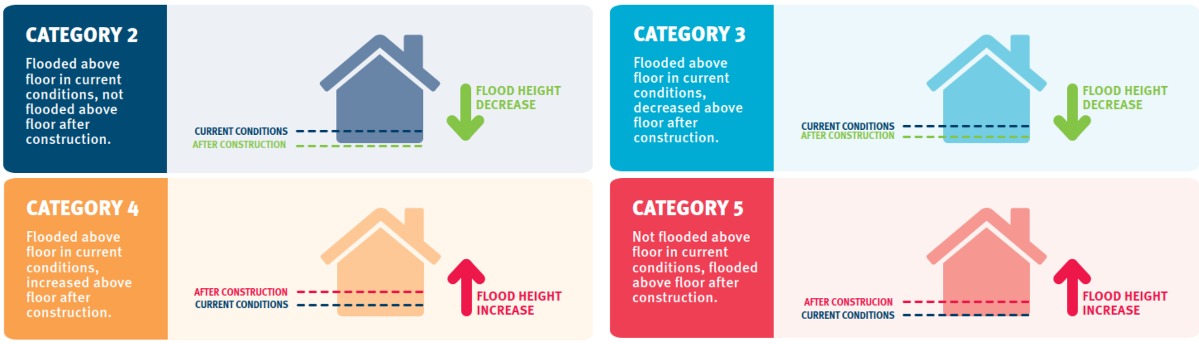


Figure 3 Change in Over Floor Flooding - Categories (Graphical)

8.3.5 Change in Time of Submergence (TOS)

If applicable, Time of Submergence (TOS) is to be assessed at the following key locations within the study area, for both the Baseline and Developed Case:

- Impacted private properties.
- Impacted crops, ensuring the TOS remains below 24-hours in accordance with advice from the Department of Agriculture and Fisheries (DAF). Note, this may require consideration of which storm duration results in the critical TOS:

  > Waterlogged soils are deficient in oxygen because the oxygen between soil particles is replaced by water. Oxygen is essential for healthy root growth insufficient oxygen in soils over time causes cell, root and eventually plant death. Tree crops are able to survive without oxygen to the roots for longer than most vegetables and flowers. The longer soils remain saturated, the more likely root death will occur. Usually, as long as water drains within 24 hours, the impact on plant health is minimal. (DAF, 2016).

- Impacted key roads, as deemed necessary between the RPEQ and Council.

Changes in TOS as a result of the development are to be presented in the Stormwater Management Report.

8.3.6 Cumulative Impacts

Cumulative Impacts should be considered and discussed within the Stormwater Management Report. The proposed stormwater management philosophy for a given development should consider the cumulative impacts, should other present and reasonably foreseeable future development occur within the catchment, with the same proposed stormwater management philosophy.

Simply, if the proposed stormwater management philosophy for the individual development was applied throughout the catchment, what would the impacts be?

For stormwater, cumulative impacts are caused by the aggregate of incremental changes within the catchment and can result from individually minor, but collectively significant, actions taking place over a period of time. Minor increases in runoff or filling within a floodplain from individual developments are common occurrences that can cause cumulative impacts within a catchment.

An example of how incremental increases in runoff from individual development occurrences can cause cumulative impacts is given below.

8.3.6.1 Example of Cumulative Impacts (Incremental Increases in Runoff)

A local catchment is made up of multiple properties comprised of single unit dwellings. The area is zoned as "high density residential" to provide for future higher order residential uses (such as multi-dwelling unit complexes).

Baseline stormwater modelling predicts that the peak baseline runoff in a 1% AEP plus climate change event is $1.25m^3/s$.

A single property within the local catchment develops to a high density residential standard (multiple residential units), causing a relatively small increase in runoff (+25L/s). Whilst there is an increase in runoff within the local catchment (+2%), it has been demonstrated that the impacts are minor and do not cause an actionable nuisance, and therefore, mitigation measures (such as on-site detention) are deemed to not be required.

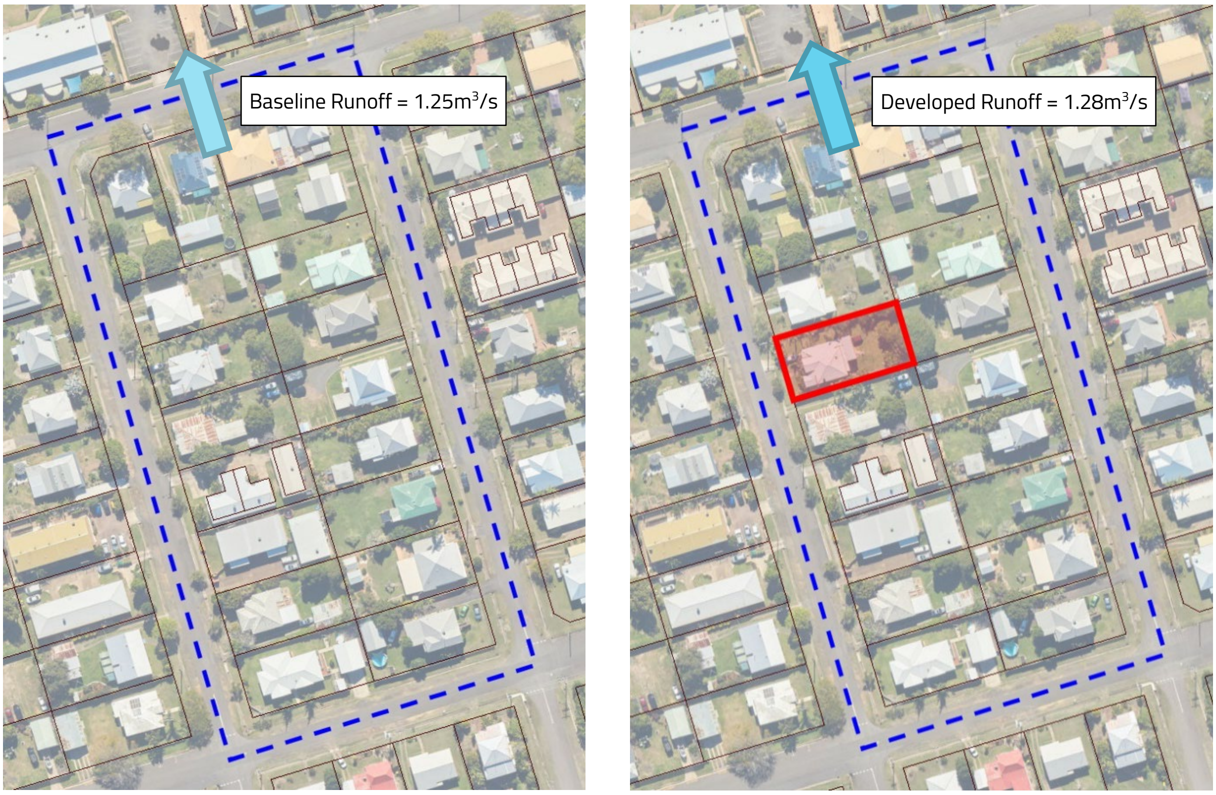


Figure 4 Example Scenario – Incremental Change in Local Runoff (Minor Impact)

Over a period of time, each individual property develops in the same manner, to a high density standard (multiple residential units), individually causing a relatively small increases in runoff (+25L/s) which when assessed individually, are deemed not to require mitigation measures (such as on-site detention).

However, when considering the cumulative runoff from each individual development, the peak runoff from the local catchment is now 1.7m^3/s, representing a 36% increase in runoff when compared to the pre-developed baseline condition. The cumulative increase in runoff is deemed to cause an actionable nuisance.

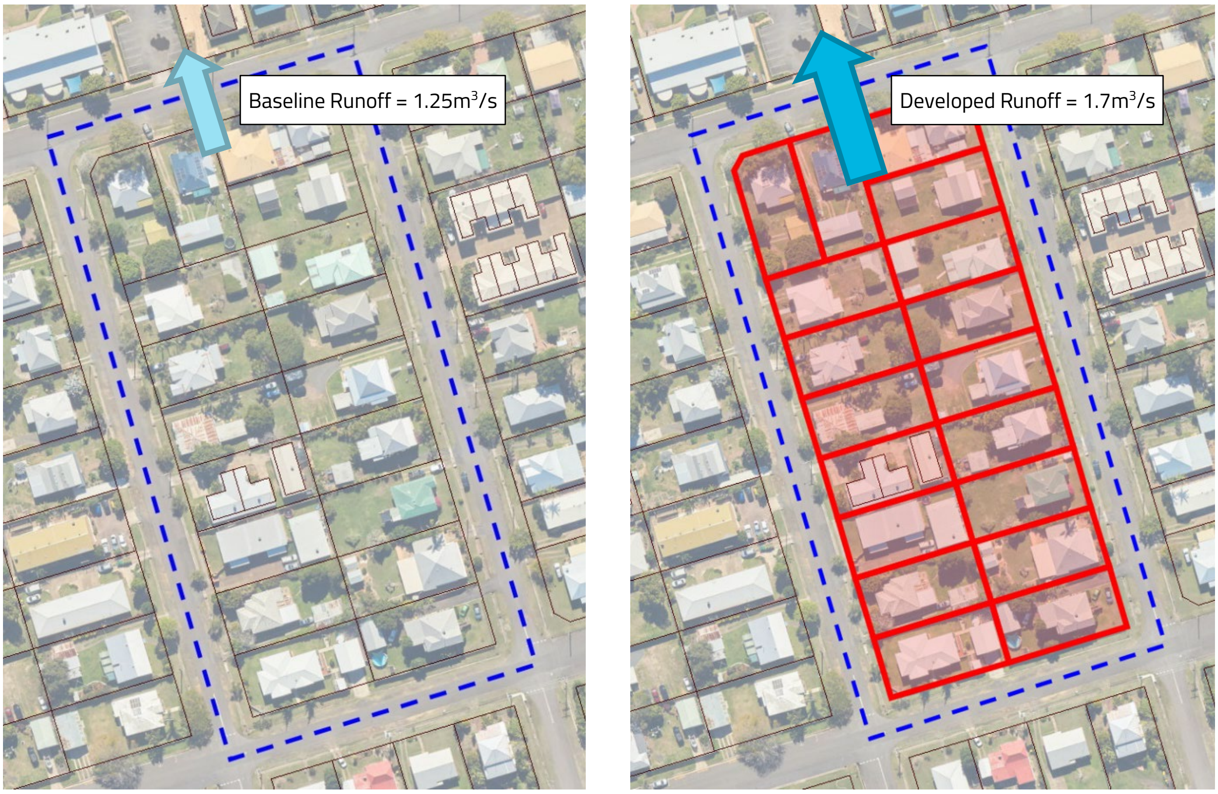


Figure 5 Example Scenario – Aggregate of Incremental Change in Local Runoff (Major Impact)

8.3.7 Sensitivity Analysis

If applicable, at a minimum, the following scenarios should be sensitivity tested for the 1% AEP plus Climate Change event:

- Highest Astronomical Tide (HAT) + 0.8m

9.0 Documentation

9.1 Overview

A Stormwater Management Report (also referred to as a Flood Hazard Mitigation Report in Council's Planning Scheme, where a development is within the adopted Flood Hazard Area) should address the following:

- water quality outcomes (refer to Part 2 of the Guidelines – Stormwater Quality Assessment);
- impacts on adjacent properties both upstream and downstream;
- preferred areas and non-preferred areas on site for various activities, based on the probability of inundation and the volume and velocity of flows;
- the use of flood resistant materials and construction techniques able to withstand relevant hydraulic and debris loads where appropriate;
- the location and height of means of ingress and egress,
- the location and height of buildings, particularly habitable floor areas;
- structural design, including the design of footings and foundations to take account of static and dynamic loads (including debris loads and any reduced bearing capacity owing to submerged soils);
- the location and design of plant and equipment, including electrical fittings;
- access requirements for maintenance of proposed infrastructure;
- the storage of materials which are likely to cause environmental harm if released as a result of inundation or stormwater flows;
- the appropriate treatment of water supply, sanitation systems and other relevant infrastructure;
- relevant management practices, including flood warning and evacuation measures;
- details of any easements or reserves required for stormwater design; and
- details of detention/retention storages.
- due diligence and confirmation of LPOD test outcomes.

The level of detail required for a particular development application should be determined in consultation with Council's development assessment officers.

9.2 Reporting

Stormwater Management Reports (Quantity) are to be clear and concise, RPEQ certified, and generally in alignment with the following structure (which is provided as a guide):

Table 22 Stormwater Management Report (Quantity) Preferred Structure

Section	Description
1	**Executive Summary**
2	**Introduction**
	• Project Background, Study Objectives, Locality and Description • Proposed Development Site, Development Class and Freeboard Adopted. • Confirmation of the Lawful Point of Discharge • Assumptions, Limitations and Exclusions
3	**Data Compilation and Review**
	• Aerial Imagery • Site Visit • Topographic Data • Land Use Data • Historical Data (if applicable) • Design Storm Event Data • Tidal Data • Stormwater Network Data • Building Floor Height Data • Previous Studies and Reports (if applicable)
4	**Hydrologic Assessment**

	• Modelling Software
	• Methodology
	• Model Development
	• Catchment
	  - Sub-catchment Delineation and Slope
	  - Fraction Impervious
	  - Roughness
	  - Losses
	  - Sub-catchment Parameters Summary
	• Historical Storm Event Modelling (if applicable)
	• Design Storm Event Modelling
	  - Design Storm Events and Durations
	  - Burst Rainfall
	  - Pre-burst Rainfall
	  - Temporal Patterns
	  - Areal Reduction Factors
	  - Climate Change

Section	Description
	• Results - Critical Durations and Temporal Patterns - Hydrograph Outputs - Summary • Calibration and Validation - Methodology - Summary • Discussion
5	**Hydraulic Assessment**
5.1	**Baseline Assessment**
	• Modelling Software • Methodology • Model Development • Historical Storm Event Modelling (if applicable) - Boundary Conditions - Roughness • Design Storm Event Modelling - Boundary Conditions - Roughness • Results - Flood Mapping - Hydrograph Outputs - Summary • Calibration and Validation - Methodology - Summary • Discussion • Model Health
5.2	**Developed Case Assessment**
	• Methodology • Model Development • Proposed Management Strategy (Detailed) • Design Storm Event Modelling - Boundary Conditions - Roughness - Topography • Results (Unmitigated Scenario) - Flood Mapping - Hydrograph Outputs - Summary • Results (Mitigated Scenario)

Section	Description
	- Flood Mapping - Hydrograph Outputs - Summary • Calibration and Validation - Methodology - Summary • Cumulative Impacts • Sensitivity Analysis • Discussion • Model Health
6	**Other Design Considerations**
7	**Confirmation of No Actionable Nuisance**
8	**Conclusions and Recommendations**
9	**References**

9.2.1 Technical Appendices

Where it will make the main report more succinct, it is preferable for technical information and data to be attached to the report as appendices. This may include technical details on hydrologic and hydraulic modelling methodology, with only a summary table provided in the main body of the report.

9.3 Mapping

Detailed GIS mapping is essential to assess the impacts of the development and confirm adequacy of any impact mitigation works. This section details the minimum mapping requirements and provides guidance on mapping types, colour palettes and mapping scales. This section relates to mapping of 2d hydraulic modelling results. Where 1d hydraulic modelling has been undertaken, mapping is to be provided where possible.

9.3.1 Post Processing of Results

For direct rainfall models, the following post processing of maximum grid results is required:

- Removal of flooded areas where:
  - Peak flood depth is less than 100mm; and
  - Peak flood depth-velocity product is less than 0.05m^2/s.
- Removal of flooded areas less than 250m^2.

9.3.2 Map Types

The following minimum mapping is recommended for all assessments:

- Catchment extent and topography.
- Baseline Calibration and Validation Performance.
- Baseline Peak Flood Extents, including all AEP events assessed.

- Baseline PWSL, for all AEP events assessed.
- Baseline Peak Flood Depth, for all AEP events assessed.
- Baseline PDAV (including direction arrows), for all AEP events assessed.
- Baseline Peak Flood Hazard, for all AEP events assessed.
- Developed Case Peak Flood Extents, including all AEP events assessed.
- Developed Case PWSL, for all AEP events assessed.
- Developed Case Peak Flood Depth, for all AEP events assessed.
- Developed Case PDAV (including direction arrows), for all AEP events assessed.
- Developed Case Peak Flood Hazard, for all AEP events assessed.
- Developed Case Difference in PWSL, for all AEP events assessed.
    - Include Building Impact Categorisation.
- Developed Case Difference in PDAV, for all AEP events assessed.
- Developed Case Change in TOS.
- Sensitivity Analysis, Developed Case Peak Flood Depth, for 1% AEP plus Climate Change event.
- Sensitivity Analysis, Developed Case PWSL, for 1% AEP plus Climate Change event.
- Sensitivity Analysis, Developed Case Difference in PWSL, for 1% AEP plus Climate Change event.

9.3.3 Mapping Transparency

Mapping should include the latest aerial imagery and adopt appropriate transparency of modelling results, to ensure underlying features are visible. Generally, a transparency between 30-50% should be adopted for flood results but needs to be tested to ensure both the results and underlying features are clearly distinguishable.

9.3.4 Calibration and Validation Performance

Calibration and validation is to be mapped as colour coded points, to show the spatial distribution of model performance, in accordance with the criteria set out in Section 6.5. An example is provided in Figure 6.

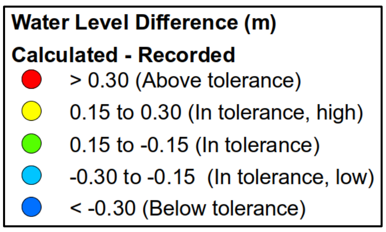


Figure 6 Model Calibration / Validation Legend

9.3.5 Peak Flood Extents

Peak flood extents are to be displayed as polygons/regions, using the colour palette provided in Table 23.

Table 23 Peak Flood Depth Palette

Design Event	Polygon Fill Colour (Red, Green, Blue)			Polygon Outline
	Red (R)	Green (G)	Blue (B)	
39% AEP (2 year ARI)	191	191	191	Black
10% AEP (10 year ARI)	255	255	208	Black
5% AEP (20 year ARI)	255	208	208	Black
1% AEP (100 year ARI)	92	170	233	Black
1% AEP + Climate Change (DFE)	0	0	128	Black
0.2% AEP (500 year ARI)	112	48	160	Black
PMF	0	0	0	Black

9.3.6 Peak Water Surface Level

PWSL is to be displayed as polygons/regions at set increments, with colour palette selected to clearly display changes in flood levels. PWSL contours are to be provided as black polylines at 0.1m or 0.2m increments.

9.3.7 Peak Flood Depth

Peak Flood Depth is to be displayed as polygons/regions at set increments, as detailed in Table 24.

Table 24 Peak Flood Depth Palette

Depth Band (m)	Polygon Fill Colour (Red, Green, Blue)			Polygon Outline
	Red (R)	Green (G)	Blue (B)	
0.0 - 0.3m	124	183	111	Black
0.3 - 0.6m	148	197	129	Black
0.6 - 0.9m	173	212	148	Black
0.9 - 1.2m	200	227	169	Black
1.2 - 1.5m	226	240	190	Black
1.5 - 1.8m	255	255	213	Black
1.8 - 2.1m	249	221	183	Black
2.1 - 2.4m	243	191	159	Black
2.4 - 2.7m	233	162	136	Black
2.7 - 3.0m	223	135	118	Black
> 3.0m	210	102	102	Black

9.3.8 Peak Depth Averaged Velocity

PDAV is to be displayed as polygons/regions at set increments, as detailed in Table 25. Black arrows indicating flow direction are to be displayed, distribution to provide the highest detail without compromising map clarity.

Table 25 Peak Depth Averaged Velocity Palette

PDAV Band (m/s)	Polygon Fill Colour (Red, Green, Blue)			Polygon Outline
	Red (R)	Green (G)	Blue (B)	
0.00 - 0.25m/s	33	102	172	Black
0.25 – 0.50m/s	103	169	207	Black
0.50 – 1.00m/s	209	229	240	Black
1.00 – 1.50m/s	253	219	199	Black
1.50 – 2.00m/s	239	138	98	Black
>2.00m/s	174	24	43	Black

9.3.9 Peak Flood Hazard

Peak Flood Hazard is to be displayed in accordance with ARR19 classifications, as shown in Table 26.

Table 26 ARR19 Hazard Classification Palette

Hazard Vulnerability Classification	Polygon Fill Colour (Red, Green, Blue)			Polygon Outline
	Red (R)	Green (G)	Blue (B)	
H1	143	170	255	Black
H2	189	231	255	Black
H3	117	213	142	Black
H4	194	229	155	Black
H5	255	255	147	Black
H6	255	176	137	Black

9.3.10 Difference in Peak Water Surface Level

The Difference in PWSL is to be displayed as polygons/regions at set intervals, as outlined in Table 27. Two bands are provided, dependent on the quantum of impacts expected.

Table 27 Difference in Peak Water Surface Elevation Palette

Difference Band (m)		Polygon Fill Colour (Red, Green, Blue)			Polygon Outline
High Range	Low Range	Red (R)	Green (G)	Blue (B)	
< -0.50	< -0.20	0	0	160	Black
-0.30 to -0.225	-0.20 to -0.15	0	0	255	Black
-0.225 to -0.15	-0.15 to -0.10	81	98	255	Black
-0.15 to -0.075	-0.10 to -0.05	133	173	241	Black

Difference Band (m)		Polygon Fill Colour (Red, Green, Blue)			Polygon Outline
High Range	Low Range	Red (R)	Green (G)	Blue (B)	
-0.075 to -0.01	-0.05 to -0.01	187	220	224	Black
-0.01 to 0.01	-0.01 to 0.01	217	217	217	Black
0.01 to 0.075	0.01 to 0.05	255	220	208	Black
0.075 to 0.15	0.05 to 0.10	255	150	150	Black
0.15 to 0.225	0.10 to 0.15	255	70	70	Black
0.255 to 0.30	0.15 to 0.20	255	0	0	Black
> 0.30	> 0.20	128	0	0	Black
Was Wet Now Dry		0	255	0	None
Was Dry Now Wet		255	0	255	None

Difference in PWSE mapping is to include building impacts (refer Section 8.3.4), where buildings are located within the impacted area.

9.3.11 Difference in Peak Depth Averaged Velocity

The Difference in PWSL is to be displayed as polygons/regions at set intervals, as outlined in Table 28.

Table 28 Difference in Peak Depth Averaged Velocity Palette

Difference Band (m/s)	Polygon Fill Colour (Red, Green, Blue)			Polygon Outline
	Red (R)	Green (G)	Blue (B)	
< -0.50	0	0	160	Black
-0.50 to -0.40	0	0	255	Black
-0.40 to -0.30	81	98	255	Black
-0.30 to -0.20	133	173	241	Black
-0.20 to -0.10	187	220	224	Black
-0.10 to 0.10	217	217	217	Black
0.10 to 0.20	255	220	208	Black
0.20 to 0.30	255	150	150	Black
0.30 to 0.40	255	70	70	Black
0.40 to 0.50	255	0	0	Black
> 0.50	128	0	0	Black
Was Wet Now Dry	0	255	0	None
Was Dry Now Wet	255	0	255	None

9.3.12 Mapping Scale

The extent and scale of all mapping is to be such that adequate detail is provided, and key elements are easy to read. The following is a guide on appropriate mapping scales:

- Catchment maps – up to 1:25,000
- Study area maps – up to 1:15,000

10.0 Delivery Handover

Upon completion of the assessment, the developer/applicant is to provide Council with the following documentation:

- Technical report/s and associated GIS mapping.
- Where changes have been made to Council's GIS database, copies of updated files.
- Copy of hydrologic model and associated calculations / data.
  - Must include background GIS files, such as sub-catchments, links and nodes.
  - Must include a summary of setup parameters and settings where ARR19 is applied externally through Storm Injector or similar software packages.
  - Must include outputs in .ts1 or .csv formats.
- Copy of hydraulic model and associated calculations / data.
  - Must include model setup files in .shp format for vectors, .12da for tins and .dem, .flt or .asc formats for rasters.
  - Must include model all 1d (such as .csv) and 2d result (such as .xmdf) files, with maximum value rasters in .flt, .asc or .tif formats.

11.0 References

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