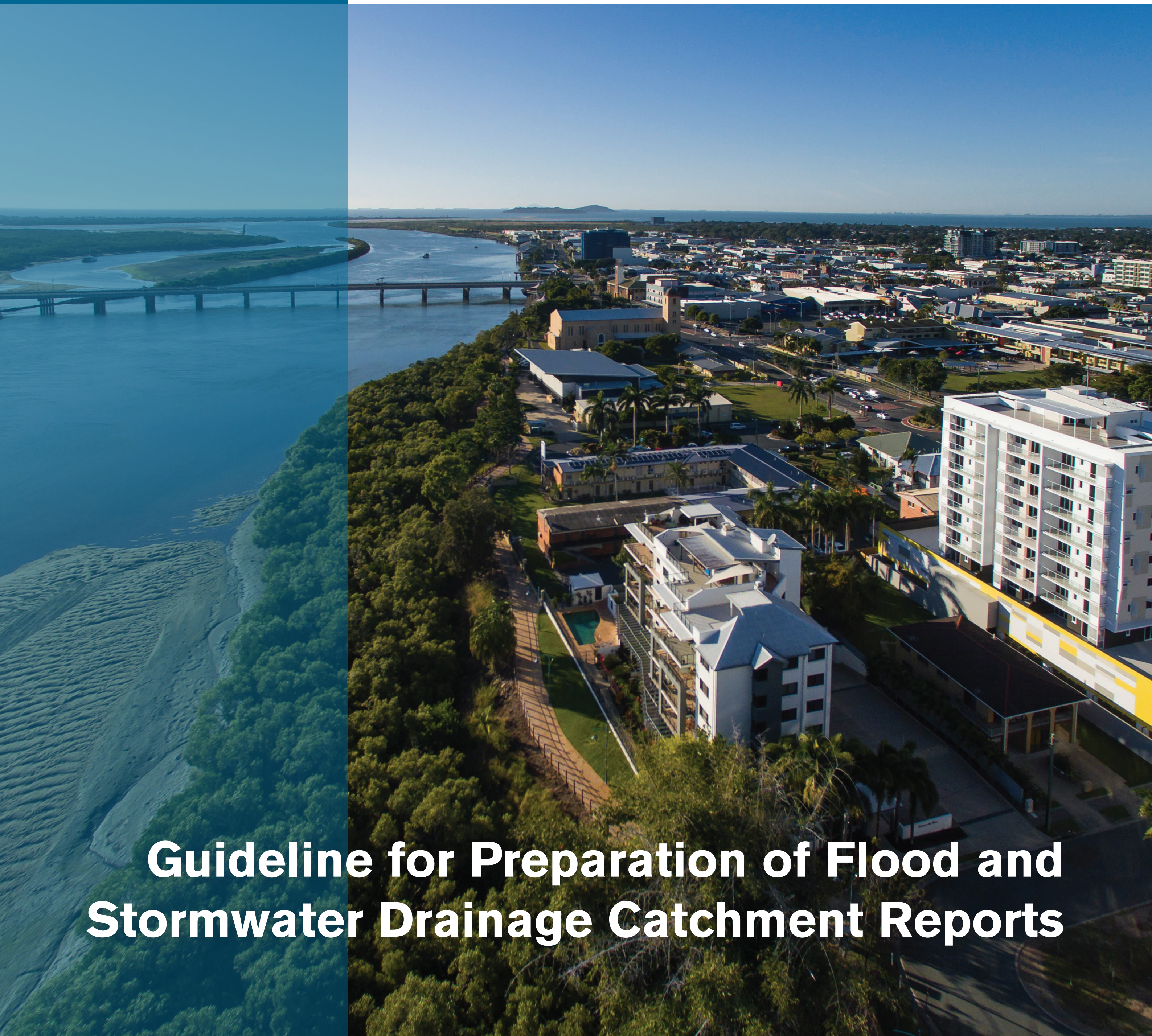

Guideline for Preparation of Flood and Stormwater Drainage Catchment Reports

Mackay REGIONAL COUNCIL

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Table of Contents

Foreword

These guidelines have been provided to allow technical professionals undertaking flood and stormwater drainage catchment studies within Mackay Regional Council quick reference to methodologies, parameters and presentation standards that Council expects. These guidelines do not remove the need for appropriate professional judgement to be used in the completion of these studies. Suitable, qualified and experienced technical professionals are still required to undertake these studies.

These guidelines contain references and summaries of information within the planning scheme, planning scheme policies, codes, standard specifications and industry standard technical documents and has had every effort made to ensure its accuracy at the time of publishing. It should be noted that it is the information within the Planning Scheme, Planning Scheme Policies and Codes that are enforceable and the information in this guideline is for information purposes only. The information has been provided for quick reference; however, it is up to the study practitioner to ensure the validity of any referenced information. Council will make every effort to update this document when it is aware of changes in the referenced material.

If there are any concerns with material provided within these guidelines, please contact the Council's Transport, Drainage and Infrastructure Planning Program.

References

DNR&W	Queensland Urban Drainage Manual
Austroads	Guide to Road Design - Part 5: Drainage - General and Hydrology Considerations
Austroads	Guide to Road Design - Part 5A: Drainage - Road Surface, Networks, Basin and Subsurface
Austroads	Guide to Road Design - Part 5B: Drainage - Open Channels, Culverts and Flood Ways
Brisbane City Central	Natural Channel Design Guidelines
QLD Reconstruction Authority	- Planning For Stronger, More Resilient Flood Plains. - increasing Queensland's Resilience to inland flooding in a changing climate: Final Report on the Inland Flooding Study
Queensland Government	State Planning Policy mandatory requirements; coastal hazard (Draft April 2013)
Engineers Australia	Project 2 - Spatial Platens Of Design Rainfall Project 10 - Appropriate Safety Criteria For Vehicle - Appropriate Safety Criteria For People Project 15 - Two Dimensional Simulation In Urban Area-Representation Of Building In 2D Numerical Flood Models Australian Rainfall and Runoff - A Guide To Flood Estimate, 2019
Mackay Regional Council	Engineering Design Guidelines - Stormwater Drainage Design
CSIRO (2001)	Climate Change Projections For Australia

Glossary

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall & Runoff (2019)
DEM	Digital Elevation Model
DFE	Defined Flood Event
DRAINS	Urban Hydrology and Hydraulics Software
HAT	Highest Astronomical Tide
HEC-RAS	Steady State One Dimensional Hydraulic Model
ISIS	Fully Dynamic One Dimensional Hydraulic Model
LIDAR	Light Detection and Ranging (Aerial Laser Survey)
MHWS	Mean High Water Springs
MIKE11	Fully Dynamic One Dimensional Hydraulic Model
MKE21	Fully Dynamic Two Dimensional Hydraulic Models
MIKE FLOOD	Fully Dynamic Coupled One & Two Dimensional Hydraulic Model
MLWS	Mean Low Water Springs
QUDM	Queensland Urban Drainage Manual
RAFRTS	Runoff Routing Software
RORB	Runoff Routing Software
SWMM	Fully Dynamic One Dimensional Hydraulic Model
TUFLOW	Fully Dynamic Coupled One & Two Dimensional Hydraulic Model
URBS	Runoff Routing Software
WBNM	Runoff Routing Software

1.0 Introduction

Flood studies

The object of carrying out flood studies is:

- the hydrological determination to calculate the likely volume of water that results from the storm under consideration;
- the hydraulic determination to calculate the inundation levels and flow velocities that will most likely occur from the flow of water determined in the hydrological determination; and
- subsequent modelling to determine development impacts for the proposed development along with evaluation of works to mitigate the impacts of development.
- To determine and map flood hazards to enable the development of mitigation options or appraise ways to manage risk.

Inundation level determination is required to satisfy appropriate Council Planning Scheme requirements.

An inundation study consists of the following parts:

- The **hydrological determination** to calculate the likely volume and distribution of water that results from the storm under consideration;
- The **hydraulic determinations** to calculate the inundation levels and flow velocities that will most likely occur from the flow of water determined in the hydrological determination; and
- Subsequent modelling to determine **development impacts** for the proposed development along with evaluation of works to mitigate the impacts of development.

Inundation studies will be accepted based on approved inundation estimation calculation procedures and observed historical records that can be quantified and related to an Annual Exceedance probability (AEP) by the use of the appropriate statistical flood frequency analysis procedures. It should be noted that the use of the historical records may allow for determination of inundation levels, however they are not suitable to quantify flooding impacts after significant changes in catchment behaviour.

For analysis purposes, a specific storm event is nominated as the benchmark event or standard to which Council requires immunity against inundation for a development. That event is called the Defined Flood Event (DFE). The current DFE used as a benchmark for inundation or stormwater investigation and development assessment is the 100 Year ARI., including climate change factors. This event is also referred to as the 1% Annual Exceedance Probability (AEP) event. It should be noted that floods other than the DFE will need to be modelled to fully assess the impact of development and catchment land use charges.

All flood studies undertaken should meet the Flood Investigation Level 3 standard identified in the "QRA - Planning for Stronger, More Resilient Flood Plain" documentation which includes LIDAR and topographic information of better than 0.3m vertical accuracy, and be based on the following technical documents:

1. Australian Rainfall and Runoff (AR&R); and
2. Queensland Urban Drainage Manual (QUDM).

In addition, the study should consider ranges of possible AEP events including 20%, 10%, 5%, 2%, 0.5%, 0.2% and the Probable Maximum Flood (PMF) event.

2.0 Catchment Land Use

Catchment land use is an important consideration for flood studies. The level of urbanisation within a catchment influences the volume of runoff and magnitude of peak discharges by:

- Increasing the impervious fraction of the catchment which, reduces the volume of infiltration and increase the total volume of runoff; and
- Decreasing the time to peak discharge due to construction of open drain and stormwater networks which concentrates flows and may increase the magnitude of peak discharges.
- Changing the distribution of flows due to obstructions in flow paths and changes to flow conditions

The strategy for how stormwater infrastructure caters for changes in catchment land use is the responsibility of Council's Strategic Planning Program.

The underlying principle of stormwater planning is that there should be no increase in flooding as a result of any works. Strategies for achieving the principle may include:

- Mitigation of flows at the individual development
- Catchment wide approach to mitigation of flows' and/or
- Allowance for additional flow capacity within flow paths.

The strategy for accommodating flows will depend on existing land-uses within the catchment and the environmental value of the watercourse. In preparing a flood study, **Council must be consulted to identify the proposed approach to flood mitigation within the catchment.** The flood study may require assessment beyond the planning horizon in the current planning scheme and make a determination of potential ultimate possible development or at least into the future for a period of 100 years, and possibly longer dependant of criticality of the infrastructure proposed.

Individual developers will be responsible for mitigating the impacts of developing their site, in a manner that aligns with the catchment strategy. However, at all points in time, the principle of no worsening of flood levels must be adopted. From time to time Council may request the developer construct additional works to accommodate the catchment strategy, in this instance the developer may be entitled to credits for infrastructure charges.

As a general principle, drains are an opportunity to have several functions including providing flood mitigation for an area, however for the rest of the time, they can be quite an effective open space for the community.

3.0 Catchment and Sub-Catchment Drainage Studies

In general catchment and sub-catchment drainage studies shall encompass the general requirements of the Engineering Design Guidelines, however, shall consider performance of the overland and underground drainage system over a range of possible AEP events, including

generation of minimum building floor levels for critical infrastructure, to ascertain performance of the proposed overland and underground systems in containing surcharge flows to public areas and to provide input to hazard analysis.

Design AEP for infrastructure shall be based on land use categories with varying minor system design requirements as specified in the Engineering Design Guidelines - Stormwater Drainage. Major system criteria generally shall be the 1% AEP event where a surcharge path shall be modelled and identified to contain the flow within public lands where it cannot be contained in underground infrastructure or open channels to depth and velocities specified in QUDM.

4.0 Hydrological Determination

4.1 General

The hydrological process that are used for determining the design flows is to be representative of the proposed land uses. The hydrological model calibrated against historical events is only applicable to determine flows for land use similar at the time of the storm event under calibration.

The choice of hydrologic method must be appropriate to the type of catchment and the required degree of accuracy. Simplified hydrologic methods such as the Rational Method should not be used whenever a full design hydrograph is required for flood mapping or to assess flood storage issues. Instead the more reliable runoff-routing techniques presented in Australian Rainfall and Runoff (ARR) Book 5 should be adopted. Chapter 4 of the Queensland Urban Drainage Manual (QUDM) provides details guidance on the selection of an appropriate hydrologic method.

4.2 Hydrologic Method

The hydrologic method adopted for the required analysis should be appropriate to the type of catchment and the design problem being assessed. Designers should be aware of the limitations, for each of the methods.

Approach	When Appropriate	Notes
Rational Method	▪ Regular catchment; ▪ 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; ▪ Time of concentration is likely to be less than 30 minutes.	An appropriate method for calculation the time of concentration is essential to applying the Rational Method. Where applicable, it is recommended that a more robust method recommended in ARR Book 5 is adopted to replace Rational Method.
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	▪ Rural catchments; ▪ Larger flood events where overbank flows are developed; ▪ Rainfall can be assumed to be uniform across the catchment; ▪ Synthetic Unit Hydrograph Procedure has limited practical application in development assessment.

Approach	When Appropriate	Notes
Non-Linear Runoff-Routing Models (RORB, RAFTS, BNM, URBS)	▪ Rural and Urban catchments (Rural only for RORB and all others should be used with caution in urban areas); ▪ Storage or timing issues are relevant.	Council uses RAFTS and has a preference for RAFTS as a non-linear runoff-routing model ▪ Rural and Urban catchments (Rural only for RORB and all others should be used with caution in urban areas); ▪ Storage or timing issues are relevant. **Non-linear Runoff Routing Models are appropriate for drainage design or impact assessment at master planning stage, particularly for areas comprising both rural and urban land uses.**
Time Area Runoff-Routing Models (DRAINS, ILSAX)	▪ Urban catchments with significant underground pipe network; ▪ Storage or timing issues are relevant	▪ Urban catchments with significant under ground 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 areas only urban land uses.**
Direct rain on grid application in hydraulic model (MIKE FLOOD, TUFLOW)	▪ Flatter areas to prevent instabilities forming from flows down steep surfaces; ▪ Study area needs to be small enough so that the model grid cell is not too large. ▪ 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.**

Any hydrologic method using emerging technologies needs to clearly demonstrate:

- The approach and the principles it employees;
- Assumptions and limitations; and
- Appropriate calibration or verification

4.3 Catchment Parameters

Discussion on catchment parameters is required in particular;

- Overall catchment area and sub-catchment areas;
- (sub-)catchment roughness and how the roughness or retardance was developed (may include a photographic record);
- Fraction impervious and how values have been derived including reference to what date values represent;
- Rainfall losses; and
- (sub-) catchment slopes and how these have be derived

All information used to define catchment parameters should be clearly referenced. A site assessment in the selection of some parameters is essential.

Catchment Roughness

Catchment roughness or surface accounts for the influence of vegetation and surface rouges on the generation of flows from sub-catchments. Ideally values should be determined from calibration of the hydrological model to stream gauging. Values should be in the ranges presented below:

Surface retardance values are also provided in the Engineering Design Guideline - Stormwater Drainage Design for individual surface types. Note that a sub catchment may consist of numerous surface types that need to be accounted for in the specification of the catchment.

	ARR Project 15	ARR Book 7	Eng Design Guidelines	QUDM (Horton n)	Suggested 1D Range	Suggested 2D Range
Condition	Manning's 'n'					
Undeveloped	0.2-0.5					
Residential - High Density	0.1-0.2					0.02-0.5
Residential - Low Density					0.06-0.15	0.1-0.2
Residential - Rural Residential	0.2-0.5					0.08-0.15
Industrial Commercial						0.2-0.5
Open Pervious , Bare Stand				0.01-0.016		0.025-0.035
Open Pervious , Gravel				0.012-0.03		0.025-0.035
Open Pervious , Earth				0.012-0.033		0.025-0.035
Open Pervious Areas , Sparse Vegetation (grassed)		0.025-0.035		0.053-0.13		0.03-0.05
Open Pervious Areas Minimal Vegetation (Grassed)	0.03-0.05	0.03-0.05		0.1-0.2		0.03-0.055
Open Pervious Areas, Moderate Vegetation (Shrubs)	0.05-0.07	0.040-0.080				0.05-0.07
Open Pervious Areas, Thick Vegetation (Trees)	0.07-0.12	0.07-0.2				0.07-0.12
Open Pervious Areas, Sugarcane					0.08-0.15	0.1-0.2
Waterways / Channels - Minimal Vegetation	0.02-0.04	0.016-0.020	0.022-0.028		0.022-0.028	0.02--0.04
Waterways / Channels - Short To Long Grass		0.025-0.033	0.033-0.043		0.033-0.043	
Waterways / Channels - Vegetated	0.04-0.1	0.050-0.150				0.04-0.1
Concrete Lined Channels	0.015-0.02					0.015-0.02
Concrete Lined Channels (Trowel Finish)			0.014		0.014	
Concrete Lined Channels (Formed Finish)			0.016		0.016	
Open Channel / Pipes - Concrete Pipe / Box Section			0.013	0.11-0.013	0.013	
Open Channel / Pipes - PVC					0.01	
Open Channel / Pipes - Sprayed Concrete			0.018		0.018	
Open Channel / Pipes - Bitumen Seal			0.018		0.018	
Open Channel / Pipes - Bricks / Pavers			0.015		0.015	
Open Channel / Pipes - Pitchers Or Deressed Stone In Mortar			0.016		0.016	
Open Channel / Pipes - Rubble Masonry Or Random Stone In Mortar	0.035-0.050		0.028		0.028	
Open Channel / Pipes - Rock Lining / Rip Rap	0.025-0.040		0.028		0.028	
Open Channel / Pipes - Corrugated Metal			0.027		0.027	
Open Channel / Pipes - Rock Cut			0.038		0.038	
Paved Roads/ Car Parks / Driveways	0.02-0.03			0.15	0.015-0.018(AC) 0.018-0.020(CHIP SEAL) 0.015 (CONC) 0.025-0.035 (Composite)	0.02-0.03
Roads, Buildings, Gardens, Fences Combined	0.06-0.1					0.06-0.1
Building, Gardens, Fences Combined	0.08-0.3					0.08-0.3
Buildings (Within Flooded Areas)	0.1-0.5					0.1-0.5
Buildings (Outside Flooded Areas In Direct Rainfall Models)	0.015-0.02					0.015-0.02
Gardens / Lawns	0.03-0.1			0.19-0.48		0.03-0.1
Fences	Variable					Variable
Lakes (No Emergent Vegetation)	0.015-0.35					0.015-0.35
Wetlands	0.05-0.08					0.05-0.08
Estuaries/Oceans	0.02-0.04					0.02-0.04

Rainfall Losses

Rainfall loses account for rainfall which does not contribute to stormwater runoff because of infiltration and storage in surface depressions. Rainfall losses can vary from event to event and depend on antecedent rainfall conditions. Loss values for historical floods should be determined from calibration with loss values within the range of values as follows:

Surface Type	Loss Values
Pervious	Median initial loss 15 - 35 mm Median continuing loss - 2.5mm/h Initial loss 0 - 140 mm Continuing loss 0 mm/h
Impervious	Initial loss 1 mm Continuing Loss 0mm/h

It should also be noted that loss values will vary between design storms of different frequencies. Guidance on appropriate loss values for different AEP storms can be obtained by matching peak discharges with peak flows determined from flood frequency assessment.

Sub-catchment Slope

Sub-catchment slope can be derived from, topographic maps or survey. Slopes applied should be representative of the sub-catchment and the modeller should ensure:

- The appropriate slope schematisation is applied when assigning values (equal area slope, vectored slope); and
- Limitation of slope within the hydrological calculation method
  (i.e. Laurensen's method - minimum slope 0.3 - 0.5%, maximum slope 15%).

4.4 Intensities

Design Intensity-Frequency Duration (IFD) Rainfall - IFD relationships shall be derived from Bureau of Meteorology's Design Rainfall data System or the ARR Data Hub as described in Book 2 of ARR for the particular catchment under consideration.

The Local Government Association of Queensland (LGAQ) and the Queensland Government have undertaken a study (QLD GOVT, 2010), to establish a framework to provide Queensland local governments with advice on how to account for climate change in assessing flood risk. The study recommends a 'climate change factor' be included into flood studies in the form of a 5% increase in rainfall per degree of global warming. For the purposes of applying the climate change factor, the study outlines the following temperature increases and planning horizons:

- 2° Celsius by 2050;
- 3° Celsius by 2070; and
- 4° Celsius by 2100

These increases in temperature equate to a 10% increase in rainfall depth by 2050 and 15% increase in rainfall depth 2070 and a 20% increase in rainfall depth by 2100 (Qld Gov., 2010). In addition, to the temperature rise and generated increased rainfall, climate change has the potential to increase sea levels. A sea level rise of 0.8 is expected by 2100.

Spatial Weighting

Design rainfall depths for the various AEP events should be estimated for a range of storm durations. The Areal Reduction Factor (ARF) to be applied depends on the duration of event and catchment area and the ARF recommended for each combination in ARR Book 2, Chapter 4, should be applied.

4.5 Partial Area Effects

If rational methods are being used then these should always be checked to ensure that flows of greater magnitude are not apparent for partial catchment areas with faster runoff characteristics. These partial areas should be checked with the higher intensities relating to the shorts times of concentration.

Likewise, when using hydrograph techniques (such as runoff routing or Rain on Grid procedures), a range of storms of different duration for the same ARI should be checked to ensure that the worst event for the ARI is calculated and adopted. It should be noted that a range of storm durations may be required to evaluate sites that cover longer reaches of watercourses or numerous watercourses. It should be noted that a range of storm durations and temporal patters, recommended in Book 2, Chapter 5 may be required to evaluate sites that cover longer reaches of watercourses or numerous watercourses and to calculate relevant critical durations for the design storm event.

4.6 Calibration and Verification of Hydrological Models

Calibration of results based on observed inundation events is desired. There are many pluviograph stations located within and adjacent to the City. Information from these is generally available from the Bureau of Meteorology or Department of Environment and Resource Management. Records from stream gauging stations will be required to match hydrologic calculation and are generally available from Department of Environment and Resource Management.

If observed data is not available to assist in the study, then it is suggested that the estimation of discharge flows from several methods will be considered with greater confidence in the result than the estimation of flows from one method alone.

4.7 Calibration and Verification of Hydrological Models

When undertaking an assessment of the potential for development impacts on flooding, the development must be appropriately accounted for in the hydrological assessment including:

1. Changes to imperviousness and expected rainfall losses;
2. Changes to catchment layouts or extents;
3. Changes to catchment roughness;
4. Changes to slopes; and
5. A re-evaluation for the potential for partial-area effects.

4.8 Preparation of Reports

The method chosen should be adequately referenced and values derived should be sustained by defining procedures used in their derivation. Where parameters are chosen or assumed, references and reasons should be supplied. The preferred method of setting out the hydrology is to describe in the text of the report the method to be used, and then to set the calculation out in a clear and concise table with sufficient date to enable quick verification of the results. The time of concentration or critical duration storm from the hydrological assessment should be clearly identified for areas relevant to the site.

Where computer methods for calculation of flows are used, the text of the report should describe the method that is utilised by the computer programme. Parameters that have been chosen should be referenced with reason stated for any assumptions. A figure should be used to clearly demonstrate the layout of the model. Output from software should be tailored to produce concise tabular results to enable quick verification of the results. Where recognised computer programmes are utilised, Council will require the electronic data files to be in acceptable format.

Where insufficient data is supplied then delays will occur while studies are returned to enable the additional data to be provided.

4.9 Catchment Maps

Most hydrological techniques will require a catchment analysis and stream slope analysis. The catchment analysis should be presented on as a large-scale map (smallest reduction ratio) as possible. The following scales for catchment sizes are recommended for sue, when maps are available:

Scale	Catchment Area
1:1000	Up to 0.5 sq. kms (50 ha)
1:2000	Up to 1.0 sq. kms (100 ha)
1:5000	Up to 1.5 sq. kms (150 ha)
1:10000	Up to 50 sq. kms (5000 ha)
1:25000	Limited to 300 sq. kms per sheet

5.0 Hydraulic Determination

5.1 General

The hydraulic determination involves the calculation of flood levels and velocities for the flood flows from the hydrological determination. Book 6 of the Australian Rainfall and Runoff 2019 and the Queensland Urban Drainage Manual sets out the aspects of hydraulic calculations that be utilised to determine water levels and flow through hydraulic structures for determined discharges.

Unless the channel consists of long lengths of uniform section and uniform flow, the Manning's equation cannot be used in its simple form. This equation describes flow in a uniform channel at non-varying steady state flow conditions.

Book 6 of the Australian Rainfall and Runoff describes the calculating flows through open channels, hydraulic structures and the interaction with coastal and other boundary condition.. The method for hydraulic determination will be dependent on the hydraulic controls of the study area. In general, it is appreciated that these methods will use computer applications.

5.2 Hydraulic Method

The hydraulic method adopted for the required analysis should be appropriate to the hydraulic control of the study area and the design problem being assessed. Designers should be aware of the limitation, for each of the methods.

Approach	When Appropriate	Notes
Steady State - One-Dimensional (HEC-RAS)	▪ Storage or timing issues are not relevant; and ▪ Flows are one-dimensional, largely within a watercourse and the immediate overbank area.	Generally, only suitable for channel type hydraulic analysis.
Fully Dynamic - One-Dimensional (MIKE11, ISI, SWMM)	▪ Storage or timing issues are relevant; ▪ Flows are one-dimensional, largely within a watercourse and the immediate overbank area.	Suitable for smaller one-dimensional watercourses. Provides stability advantages over 2D models for steeper areas. Council uses TUFLOW and has a preference for TUFLOW.
Fully Dynamic - Two-Dimensional (MIKE21, TUFLOW, HEC-RAS)	▪ Storage or timing issues are relevant; ▪ Flows are two-dimensional	Flood maps are generally direct output from models. Council uses TUFLOW and has a preference for TUFLOW.
Fully Dynamic - Couple One and Two Dimensional (MIKE FLOOD, TUFLOW, HEC-RAS)	▪ Storage or timing issues are relevant; ▪ Flows are combinations of one and two-dimensional; ▪ Large areas need to be represented in combination with fine detail	Council uses TUFLOW and has preference for TUFLOW.

5.3 Topographic Data

Topographic data used for the hydraulic determination will be dependent on hydraulic method:

- One-dimensional models employee cross-sections along branches to represent the study are topography; and
- Two-dimensional models employ digital elevation models to represent the study area topography.

The accuracy of the topographic data governs the accuracy of the hydraulic determination. The accuracy of the topographic data should be clearly stated.

Cross Sections

Cross sections are required at representative locations along a stream reach and at locations where changes occur in discharge, slope, shape, or roughness, and at bridges, culverts` or control structures such as weirs. Where abrupt changes occur, several cross sections should be used to describe the change in shape regardless of the distance between sections.

Cross section spacing is also a function of stream size, slope, and uniformity of cross section shape. For one dimensional models, the cross sections should be enough so that the water surface is contained within the extent of the cross-sections. The accuracy of the hydraulic modelling will be dependent upon the spacing of cross sections and the accuracy of the cross-section.

Digital Elevation Models

Digital elevation models used for two-dimensional models should use a grid spacing fine enough to resolve watercourses within the study area. As a general rule, a watercourse should be represented by a minimum of 5 grid-cells perpendicular to the direction of flow. Coupled models can be used as an alternative to maintain the resolution within the water course. The flow interaction across 1D-2D interface should be realistically depicted in case of a coupled model.

The digital elevation model should be orientated to minimise disturbance of flows by the grid cell orientation. Aligning grid cells with streets (often part of the major drainage system) helps to achieve an appropriate orientation.

Digital elevation models are often captured from aerial surveying methods such as LiDAR or Photogrammetry. These methods can lose accuracy in areas of dense vegetation. It should be clearly demonstrated what steps (including ground survey) have been taken to improve the accuracy in areas potentially obscured by vegetation. To accurately represent flow interaction with buildings structure in a 2D model, the elevation within building footprint is to be adjusted above the flood levels.

5.4 Roughness Values

Based on the procedure developed by Cowan (1956), stream roughness values are a combination of influences from:

- Bed material
- Surface irregularities;
- Variations in channel cross-section;
- Obstructions;
- Vegetation and flow conditions; and
- Meandering

Different methods for hydraulic determination such as fully dynamic and fully dynamic two-dimensional modelling will account for some of these influences within the underlying digital elevation model or solution scheme of the model.

Where possible, roughness values should be determined from calibration. Often calibration will not be possible and sensitivity analysis to variations in roughness should be undertaken.

In the case of a one-dimensional model, roughness should be appropriately defined across the cross-sections based on the land-use. In the case of a two-dimensional model, roughness should be appropriately defined using a grid to represent the study area based on the land-use. Adjustment of grid configuration and spacing or depth varying roughness is recommended to better depict the roughness distribution when dealing with channelized flow paths.

When representing development, roughness values should only be changed to reflect the change in land-use resulting from the development. These changes need to be clearly identified and justified. In assigning roughness values within new drainage channels or areas impacted by flooding, there should be consideration given to the way regrowth can occur within these areas. Areas below Highest Astronomical Tide (HAT) are likely to have mangrove regrowth occur. In areas further upstream regrowth by tea-tree is likely to occur and can create a significant impediment to flows. Also, most flood events within Mackay occur towards the end of the wet season (January to March), when earlier rain has enabled grass in drains to grow with minimal ability to mow. Roughness values within drainage corridors for development assessment should be adopted towards the higher end of the range of values to account for growth, which may have minimal maintenance.

5.5 Bridges and Culverts

Book 6 of ARR provides useful information and references for the determination of afflux levels and water profiles at bridges and other structures.

Head losses across major drainage structures assessed within fully dynamic models should be verified by hand-calculations or assessment with a steady state model.

5.6 Tailwater Conditions

Tailwater conditions for hydraulic models will be depending on the location of the downstream extent of the model. Tailwater conditions may be one of the following:

- Sea levels for a coastal boundary;
- A gauged rating curve;
- Food levels from the same ARI flood based on a previously accepted flood study; or
- Flood levels calculate from simplified means in the absence of other information (e.g. normal depth or critical depth).

In using flood levels calculated from simplified mean the method of calculation should be justified and sensitivity to input parameters should be evaluated. The downstream boundary should be located so that the boundary conditions do not influence results at the study site. Ensuring the boundary is sufficiently far enough downstream from the study site will reduce the impact on results at the site.

Requirements for a couple of specific boundary conditions are discussed below.

Coastal Boundaries

When calibrating hydraulic models, tailwater conditions should be based on observed sea levels for the event. Sea levels are monitored at the Mackay port, with the information available through the Bureau of Meteorology.

Predicted Tide Planes For Mackay Outer Harbour		
	Predicted Tide Level (M AHD)	Probability Of Exceedance (%)
Highest Astronomical Tide (HAT)	3.64	0
Mean High Water Springs (MHWS)	2.35	5
Mean High Water Neaps (MHWN)	1.12	26
Mean Low Water Neaps (MLWN)	-0.98	74
Mean Low Water Springs (MLWS)	-2.20	97
Lowest Astronomical Tide (LAT)	-2.94	100

To maintain the probability of the assessed flood event for design purposed, the tailwater condition adopted should not have frequency of occurring any less than once a year. A fixed tailwater condition equal to the height of the Mean High-Water Springs (MHWS) tide should be adopted. For storm events greater than 24 hours, a representative tidally varying water surface level between MHWS and Mean Low Water Springs (MLWS) can be adopted.

As part of understanding the risk associated with sea level ride due to climate change, a sensitivity assessment in tailwater condition should be undertaken. The official projections of global sea rise from 1990 to 2100 are in the ranger from 0.09 to 0.88 m (IPCC 2001' CSIRO 2001) as summarised below:

Range	Sea Level Rise (m)
Minimum	0.09
Central	0.48
Maximum	0.88

However, for Queensland 0.8m sea level rise has been adapted as the progressive sea level rise from 1990 levels to 2100 (State Planning Policy mandatory requirements: coastal hazard)

Advice

Where development in an existing urban area is expected to be replace frequently due to a short design life, this should be factored into any requirement for the development to address coastal hazard risks. The assessment of risk from coastal hazards could consider the opportunity to modify the design when it is due for future replacement. This allows risk to be reassessed and dealt with at the replacement stage. Table 1 provides typical design life of common urban development components and table 2 provides sea level rise to be considered for the development assessment.

Table 1: Typical design life of development in existing urban areas.

Type of Development	Design Life
▪ Commercial buildings ▪ Industrial buildings ▪ Short-term tourist accommodation ▪ Residential dwellings including multi-storey unit blocks of 10 dwellings or less	40 Years
▪ Multi-storey residential buildings of more than 10 dwellings ▪ Reconfiguration of a lot for urban purposes that involves the provision of new public infrastructure such as roads, water connections or sewage connections ▪ Permanent community infrastructure such as sewage treatment plants	90 + Years

Table 2: Projected sea level rise for the year of the end of design life as per table 1.

Year of end of design life	Projected sea level rise
Year 2050	0.3 meters
Year 2060	0.4 meters
Year 2070	0.5 meters
Year 2080	0.6 meters
Year 2090	0.7 meters
Year 2100	0.8 meters

Additional information that may assist local government

- Declared erosion prone area plans help by EHP available on the EHP website.
- Property scale coastal hazard area maps for individual lot-on-plan descriptions, available on the EHP website.
- Natural Hazard Risk Assessment Guideline: Coastal Hazards Areas, EHP Queensland Government (2012).

The DFE should be assessed in combination with the maximum sea level rise applied to the MHWS level to evaluate the additional risk associated with climate change; the impacts of the sea level rise should be clearly discussed with any loss of freeboard identified.

Backwater Effects in Tributaries from Larger Streams

Where a smaller stream discharged into a larger stream, it will be most probable that the larger stream will experience more severe flooding for storms of longer duration and hence lesser intensity for the same average recurrence interval. The tributary is to be checked for a storm of the same duration and intensity as that causing the peak flow in the larger stream.

The hydraulic assessment should assess the flooding for both the storm duration critical for the larger stream and the local tributary. Flood level in the area will be based on the highest flood level determined from both storm durations. Peak velocities in the area will be based on the fastest velocity determined from both storm durations regardless of whether the storm duration that generates the fastest velocities produced the highest flood levels. It is acknowledged that runoff routing models combined with full dynamic hydraulic models will adequately account for these processes.

Estuary boundaries

Sometimes downstream boundary conditions for hydraulic models will be required in reaches of watercourses that are influenced by tides but are not located at the coastline. In this instance, it is inappropriate to use neither a tidal water level boundary condition nor a rating curve boundary condition alone. The downstream boundary condition must account for both the tidal conditions and the ability for water levels to be elevated due to flood flows. Typically, this would involve the development of a rating curve with flows below MHWS set to zero and flows above MHWS to be calculated based on an appropriate water surface slope.

5.7 Freeboard for Existing Areas

Within some existing urban areas, a design criterion has changed over-time and has resulted in freeboard to existing buildings being less than is required in new development. To ensure the freeboard for existing areas is maintained, flooding for all standard ARI floods up to the DFE must be examined as a minimum. The assessment should demonstrate that there is no increase in flooding in any ARI flood.

5.8 Freeboard for New Development

In general, development (particularly residential) is preferred to occur in areas outside inundation zones to provide a sense of security and amenity for the public. However, not all people want to live in these inundation free "safer" areas. Lifestyle choices include living outside the 'standard' urban inundation free locations. These other lifestyle areas include:

- Living close to watercourses;
- Living on larger lot sizes in non-urban areas;
- Living in urban and non-urban areas developed within a previous inundation zone;
- Living in coastal townships or coastal residential areas;
- Living in areas where stormwater flow paths or outlets are limited or restricted;
- Living in areas where discharge of stormwater is against the natural topography;
- Living within naturally perched watercourse systems

Council can choose to approve development outside inundation zones (which provides the greatest overall protection to the community) or can choose to approve development within an inundation zone subject to certain parameters and/or acceptable solutions. These parameters will be determined on a case by case basis but are likely to include:

- Ensuring floor levels are suitably far above the DFE;
- Providing a level of flood immunity for access routes to properties;
- Ensuring flood level are not increased as a result of the development; and
- Ensuring development does not affect the integrity of watercourses.

The current planning scheme has a uniform for approach to freeboard and minimum floor levels across the Local Government Area. Minimum lot levels are applied at low lying areas, close to the coast where inundation of lots is more likely from storm tide than flooding. Elsewhere, floor levels are dictated by a freeboard above the DFE.

Values from the planning scheme are:

RL 5.40 m AHD for Mackay and Environs,
RL 5.30 m AHD for Ball Bay/ Halliday Bay/ Seaforth,
RL 5.00 m AHD for Midge Point, or
RL 5.30m AHD for Sarina.

NOTE: THE MINIMUM LEVEL IS TO BE RAISED A FURTHER 0.60m WHEN THE PROPERTY IS LOCATED WITHIN 100M OF THE FORESHORE.
A review of the levels will be required after completion of a Coastal Hazard Adaption Strategy.

5.9 Determination of Impacts of Development

Developments have potential to cause significant adverse impacts of flooding due to:

- Increasing the impervious fraction, reducing amount of infiltration and generating a larger volume of runoff;
- Providing more efficient conveyance of flood through the site so that flows are concentrated faster at the downstream end of the site producing larger peak flows; and
- Removing floodplain storage due to filing which reduces the natural flow attenuation of the floodplain and increases flood levels.

It will be necessary to carry out studies of the catchment in the pre-developed state (base case) and the development state to determine increased amounts of flow and flood levels. The pre-developed state should represent the state of development within the catchment and flood plain immediately prior to time of construction of the proposed works.

In some cases, the adverse impacts on flooding may preclude development unless appropriate flood mitigation measure within and beyond the subject site are proposed as art of the development. As a result of developments:

- Flood levels should not increase beyond the accuracy of the method of hydraulic determination (generally 0.01m) either upstream, downstream or adjacent to the site;
- There should be no significant change in flow patterns so that new flow paths on adjacent changes in flow velocities should be shown to have minimal impact on erosion potential.

Mitigation works such as levees or detention basins involving embankments; need to be shown to have a safe overtopping failure. Such works should be modelled for the Probable Maximum Flood (PMF) to demonstrate safe passage of these flows without catastrophic failure of embankments.

Any mitigation measures recommended beyond the subject site will need to undergo the development assessment process including:

- Clear identification of the land parcels impacted;
- Development applications (material change of use, reconfiguration of a lot and/or operational works) - as required; and
- Identification of maintenance requirements including responsibilities and funding sources.

Mitigation measures should generally be on the subject site unless prior discussions have been entered into with Council and there is an agreement for works outside of the subject site.

6.0 Hazard Analysis

As part of the outputs from flood, catchment and sub-catchment studies shall be a requirement for generation of hazard and risk mapping in accordance with classification specified Australian Rainfall and Runoff Book 6 Chapter 7. In addition, vulnerability and tolerability scoring shall be also be supplied and mapped based on the same documentation.

For flood studies possible risk treatment options shall be developed and cost estimates provided as part of the finalised report.

7.0 General Matters

7.1 Presentation of Reports

As stated in the previous sections all reports, and tabulation are to be printed on A4 size sheets and drawing presented on standard size sheets prepared using good drafting standards. The expected content of the report is as discussed in Section 2, 3 and 4 above. In the summary the contents of a study report must include:

Hydrology Section

- Catchment Map - larges as possible;
- Report on procedure (brief), including hydrologic method, catchment characteristics, assumptions, and discussions on results including critical duration / time of concentration as detailed in Section 4.0 above; and
- Calculations and/or model results - tabulated where possible and attached in appendix if significant in volume.

Hydraulic Section

- Report on procedure including hydraulic method, stream/floodplain characteristics and assumptions as detailed in Section 5.0 above;
- Modes results - clearly presented as map and tabulated values;
- Steam flood profile and bed profile of the study are
- Drawings/figures of topographic data used for the model (Digital Elevation Model map or plan of cross-section locations and cross-sections with X and Z coordinates included);
- A plan containing the proposed works showing any filing and excavation associated with development; and
- Model results updated based on including the development with the revised flood extents and impacts on flooding.

General

- Discussion on sensitivity analysis for critical parameters (e.g. roughness, infiltration etc...)
- Discussion on accuracy of inundation mapping and the resulting required flood line (e.g. 50 year ARI),
- Recommendations as to methods of flood mitigation within the site
- Recommendations as to methods of flood mitigation beyond the site together with development approvals, constructions proposal and funding proposals
- Electronic data for both the hydrology and hydraulics in an agreed format (modelling platforms and GIS)

Drawings should be bound into the report where sizes are A3 or A4. Larger drawings are to be appropriately folded and inserted in a pocket in the back cover.

Recognition by the consultant, that the assignment of data to Council, and use of the studies by Council, for its sole use is a mandatory requirement before a study is commissioned and/or the results of any study will be accepted by Council.

All studies, reports, and submissions forwarded to council shall be prepared by, or at least certified, by a Registered Professional Engineer Queensland (RPEQ) who is registered I the specific area of engineering in which the study or report has been prepared. E.g. an RPEQ (Structural) shall not certify a stormwater report.

7.2 Time Required for Checking Studies

As inundation studies are generally comprehensive and complex in nature it is necessary to allow sufficient time for checking and approval by Council staff. A minimum lead time of four week is required for this purpose and the designers should plan their development programmes accordingly. Designers should ensure that all necessary information is required for checking of calculations is presented to avoid unnecessary delays while studies are returned to have the necessary additional information appended to the report.

Council will require request that model files used for the study are provided for the review. Models provided which are not in the preferred software listed in Section 5.4 will attract longer periods of time for the review.

7.3 As-Constructed Information

Inundation studies are normally carried out assuming design ground surface level for channels and over bank areas. Where "As Constructed" information shows sufficient change o the designed surface level and chainage elements, then the inundation study may need to be updated to provide for the changes during construction.

7.4 Preference of Computer Models

It is acknowledged that where no modelling has been undertaken, then any modelling will provide a more accurate estimation of inundation levels than collated levels from observed inundation events.

Modelling studies and hydraulic methods adopted should be suitable for purpose as indicated in Section 4.2 & 5.2. Mackay Regional Council prefers software that is run internally which includes:

- Non-linear Routing - XP-RAFTS;
- 1D Steady State - HEC-RAS;
- 1D Fully Dynamic - TUFLOW;
- 2D Fully Dynamic - TUFLOW; and
- Couple 1D/2D Fully Dynamic - TUFLOW

7.5 Copyright of Reports, Studies and Drawings

Prepared Directly for Council

It is acknowledged that intellectual capacity has been demonstrated in the preparation of the report. However, the report is prepared and based on accepted engineering fundamentals and principles. In addition, the practises adopted are those developed by the engineering profession through initiate and ingenuity and ratified through the professions recognised body "Engineers Australia".

All reports and studies (including drawings, tables, model files etc...) prepared for Council under direct commission will become the sole copyright of Council, and those reports will be used by Council in a manner that will provide the optimum benefit to the community, all reports adopted by Council will also be available for public and professional perusal on Council's website.

In any reference to the report the author of the report will be acknowledged by Council and should be acknowledge by any authorised third party user.

Submitted As Part of a Development Application

When a technical report or study is submitted to council as part of a development application, this report/study, along with all components of the submission, can be made available to the public as part of the notification stage. The report can be provided to anyone seeking the report during this stage and following the approval. Use of the report for any third-party use will be at the complete risk of the third party. It should be noted that it will be only the approved report including any council requested amendments, which should be referred to in future.

Submitted as part of a Development Application and adopted by council as a benchmark report for future development or other purposes

From time to time, reports etc. submitted as part of a development application, or supporting an application, could provide a wider 'regional' significance and importance than just the development site for which they were prepared. Council may choose to open discussions with the developer to determine if obtaining all supporting digital and electronic data along with software input/output files would allow the option of adopting the report as a 'base-line' report for council. The decision as to whether a report has wider regional significance will be Council's alone.

Once these reports have been adopted by council as a 'base-line' report, the report assumes the status as if the report was prepared by or for council, and the copyright previously assigned by the author is released and the copyright provided to council. Council can use the report to achieve optimal outcomes for the wider community.