SC6.7 Flood hazard planning scheme policy

SC6.7.1 Introduction

Short Title -The planning scheme policy (PSP) may be cited as the Flood hazard PSP.

SC6.7.1.1 Purpose

The purpose of the planning scheme policy is to:

(1) provide background information on the derivation of the Flood hazard overlay identified as overlay maps OM-06.1 and OM-06.2; and

(2) provide applicants with additional information and guidance in meeting the requirements of the Flood hazard overlay code.

SC6.7.1.2 Legislative authority

This planning scheme policy is made under Chapter 2, Part 3 of the *Planning Act 2016.*

SC6.7.1.3 Relationship to the Townsville City Plan

This planning scheme policy is to be read in conjunction with the assessment provisions specified in the Townsville City Plan and applies to the whole of the local government planning scheme area. Flood hazard PSP specifically relates to the assessment of Flood hazard overlay code.

SC6.7.1.4 Terminology

Terms used in this planning scheme policy are defined in Schedule 1 – Definitions. A term used in the planning scheme policy which is not defined in Schedule 1 – Definitions, is to be interpreted in accordance with Part 1.3.1 Definitions.

SC6.7.2 Background information

SC6.7.2.1 Flood mapping

The flood hazard overlay maps show flood hazard derived from numerous sources and include:

(1) Detailed flood modelling studies identified in SC6.7.2.1.1 of this planning scheme policy; and

(2) Interim flood assessment overlay mapping completed by the Queensland Reconstruction Authority and amended for local constraints by Townsville City Council.

SC6.7.2.1.1 Flood modelling studies

Flood modelling studies are complex technical investigations requiring a detailed understanding of catchment hydrological processes and floodplain hydraulic controls. Computer simulations are used to quantify runoff from rainfall and evaluate flow patterns and flooding extents around floodplains. There are numerous flood modelling studies which have been completed for the Townsville local government area. Results from these flood modelling studies have been combined to provide the Flood overlay maps.

At the commencement date of the planning scheme, the flood modelling studies that have contributed to the Flood overlay maps are:

(1) Alligator and Whites Creek Flood Study (Alligatorcreek);

(2) Althaus Creek Flood Study - Baseline Flooding Assessment (AlthausCk);

(3) Townsville Flood Hazard Assessment Study (Arcadia, NellyBay and PicnicBay);

(4) Balgal Beach Infrastructure Master Planning Report (BalgalBeach);

(5) Black River Flood Study - Baseline Flooding Assessment (BlackRiver);

(6) Bluewater Creek Flood Study (Bluewater);

(7) Captains Creek Flood Study - Baseline Flooding Assessment (CaptainsCreek);

(8) Deeragun Flood Study - Baseline Flooding Assessment (Deeragun);

(9) Douglas/Annandale Flood Study - Baseline Flooding Assessment (DougAnnan);

(10) Gordon Creek Flood Study - Baseline Flooding Assessment (GordonCreek);

(11) Horseshoe Bay Flood Study - Baseline Flooding Assessment (HorseshoeBay);

(12) Little Bohle River Flood Study - Baseline Flooding Assessment (LittleBohle);

(13) Lousia Creek Flood Study - Baseline Flooding Assessment (LousiaCreek);

(14) Lower Bohle Flood Study - Baseline Flooding Assessment (LowerBohle);

(15) Townsville State Development Area - Flood Modelling (LowerStuart);

(16) Middle and Upper Bohle Flood Study - Baseline Flooding Assessment (MiddleBohle and Upper Bohle);

(17) North Ward Flood Study - Baseline Flooding Assessment (NorthWard);

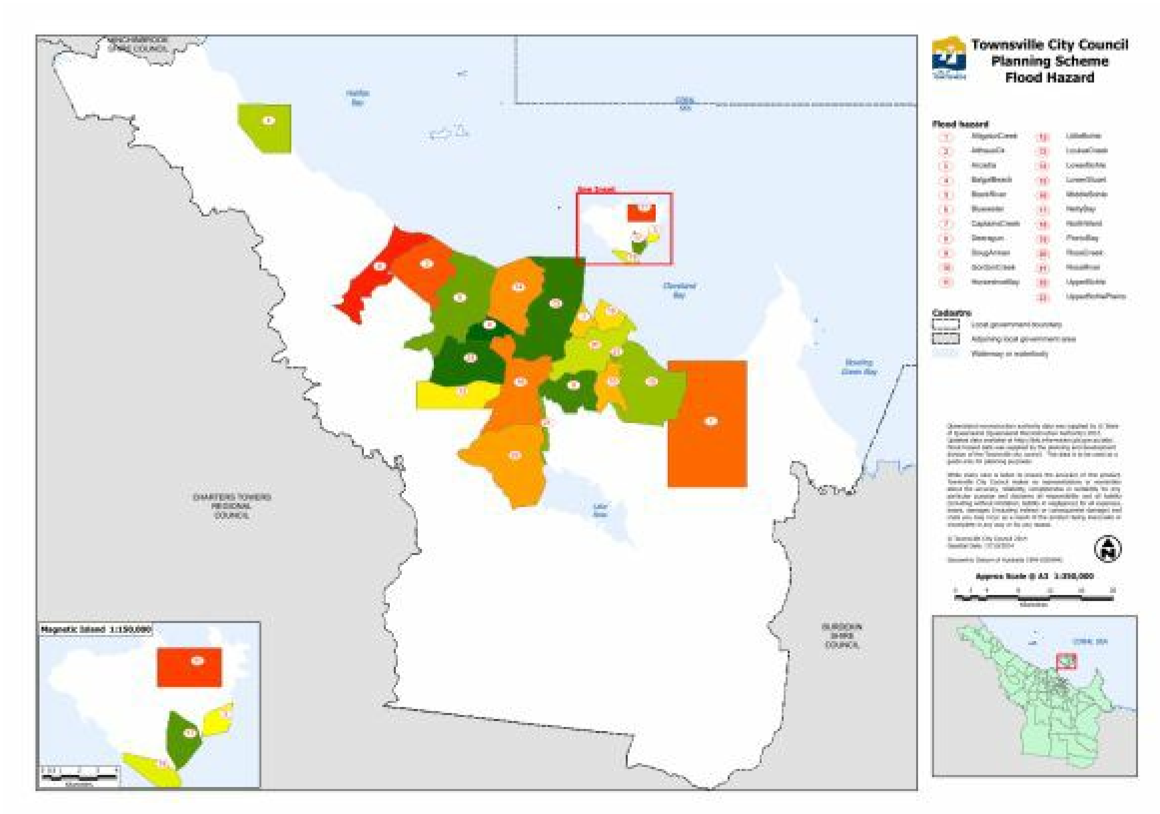
(18) Ross Creek Flood Study - Baseline Flooding Assessment (RossCreek);

(19) Ross River Flood Study - Baseline Flooding Assessment (RossRiver); and

(20) Upper Bohle Plains Flood Study - Baseline Flooding Assessment (UpperBohlePlains).

The area of applicability for each of the flood modelling studies identified in the aforementioned have been graphically presented on Figure SC6.7.1– Flood modelling study areas.

Flood modelling studies are under constant development due to the construction of infrastructure and the acquisition of new data. This information is available on Townsville City Council’s website and contains digital copies of the latest and current flood modelling studies.



Click here to view PDF high resolution map.

Figure SC6.7.1 - Flood modelling study areas

SC6.7.2.2 Flood hazards

The Flood hazard overlay maps OM-06.1 and OM-06.2 have the following flood hazard ratings identified:

(1) high flood hazard;

(2) medium flood hazard;

(3) low flood hazard; and

(4) medium flood hazard – further investigation.

SC6.7.2.2.1 High and medium flood hazard

Both the high flood hazard and the medium flood hazard areas mapped on the Flood hazard overlay maps OM-06.1 and OM-06.2 are based on the 1% AEP flood. A velocity-depth criterion is used to distinguish between high flood hazard and medium flood hazard areas. High flood hazard areas are characterised by faster flowing and/or deeper floodwaters.

Figure SC6.7.2 – Flood hazard categorisation on 1% AEP flood (below) - shows the velocity depth criteria for designating the high flood hazard and the medium flood hazard areas from the 1% AEP flood. Velocity and depth information for the 1% AEP flood has been determined from flood modelling studies (refer SC6.7.2.1.1).

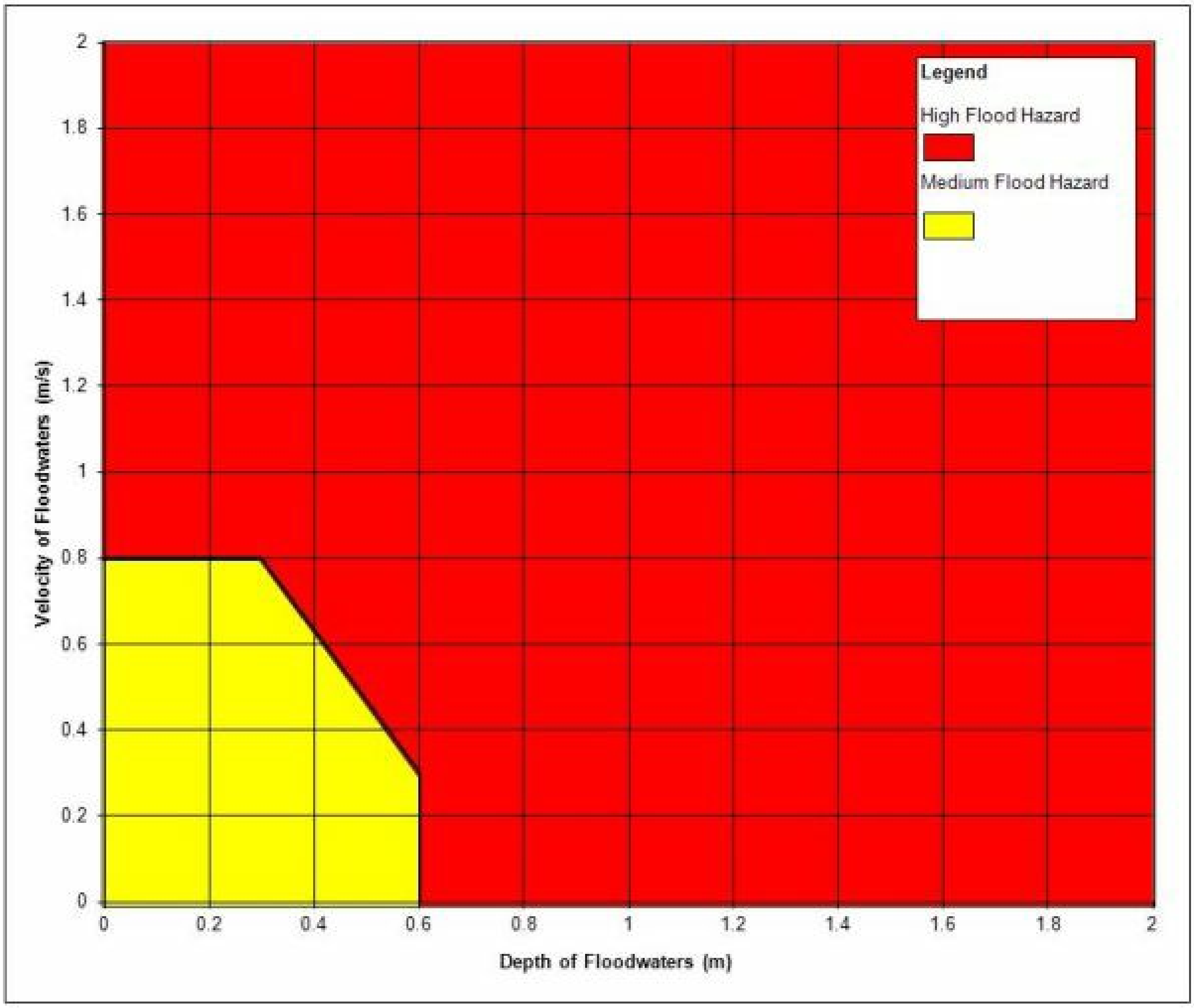


Figure SC6.7.2 - Flood hazard categorisation on 1% AEP flood

SC6.7.2.2.2 Low flood hazard

Areas of the floodplain outside the 1% AEP flood extent are still susceptible to flooding in rarer, more extreme flood events. Within the Flood hazard overlay maps OM-06.1 and OM-06.2, the low flood hazard area is identified as areas inundated by the probable maximum flood outside the combined extent of the high and medium flood hazard areas. The extent of the probable maximum flood has been determined from flood modelling studies (refer SC6.7.2.1.1).

SC6.7.2.2.3 Medium flood hazard - further investigation

Areas identified as medium flood hazard – further investigation on the Flood hazard overlay maps OM-06.1 and OM-06.2 are areas outside the extent of flood modelling studies and have been mapped by the Queensland

Reconstruction Authority. The Interim flood assessment overlay mapping produced by the Queensland Reconstruction Authority has been reviewed and amended by Townsville City Council to reflect local conditions. This information is less reliable than the other areas mapped on the flood hazard overlay maps OM-06.1and OM-06.2. Limited information is available on the flood characteristics in these areas as there is no information about flood depths, levels or velocities.

Within areas identified as medium flood hazard – further investigation, assessable development is likely to require further detailed flooding investigation, involving:

(1) development of a base-line flood study in accordance with Attachment 1 - Guidelines for preparation of flood studies and reports at a scale suitable to represent relevant floodplain process and site specific features;

(2) assessment of the potential impacts on flooding of the proposed development;

(3) identification of suitable measures to mitigate any adverse impacts on flooding; and

(4) demonstration of how the proposed development layout reduces the risk of flooding.

SC6.7.2.3 Defined flood level

Most development applications for which the Flood hazard overlay code is triggered will require details of the defined flood event (DFE). The DFE is the 1% AEP flood, which is spatially represented by the combined extent of the high flood hazard and the medium flood hazard areas mapped on the Flood hazard overlay maps OM-06.1 and OM-06.2.

For development which is accepted subject to requirements, it is most likely that existing information from flood modelling studies for the DFE will be adequate to address the acceptable outcomes of the Flood hazard overlay code. Information on the DFE derived from the flood modelling studies can be obtained from council's website.

SC6.7.3 Application requirements

This section provides information for a development application, guidance and advice for addressing assessment benchmarks.

SC6.7.3.1 Addressing assessment benchmarks

SC6.7.3.1.1

Development that is accepted subject to requirements and triggers the Flood hazard code only has to address the acceptable outcomes for performance outcomes 1 and 2 of the code.

Performance outcome 1 Development in medium and high hazard areas is designed and located to minimise susceptibility to and potential impacts of flooding.

Other than in the medium hazard - further investigation, council will be able to make available the height of the flood level for any particular location, upon request, where flood modelling studies have been undertaken (refer SC6.7.2.1.1).

In some areas, storm tide hazard areas will also co-exist with flood hazard areas. In these instances, the floor levels and other design responses will need to be sufficient to comply with both the Coastal environment overlay code, the Flood hazard overlay code and the *Building Regulation 2006*. Typically, floor levels will need to be based on the highest of either the defined flood level or the defined storm-tide level as depicted in Figure SC6.7.3.1.1.1-Floor control levels for both flooding and storm tide (below).

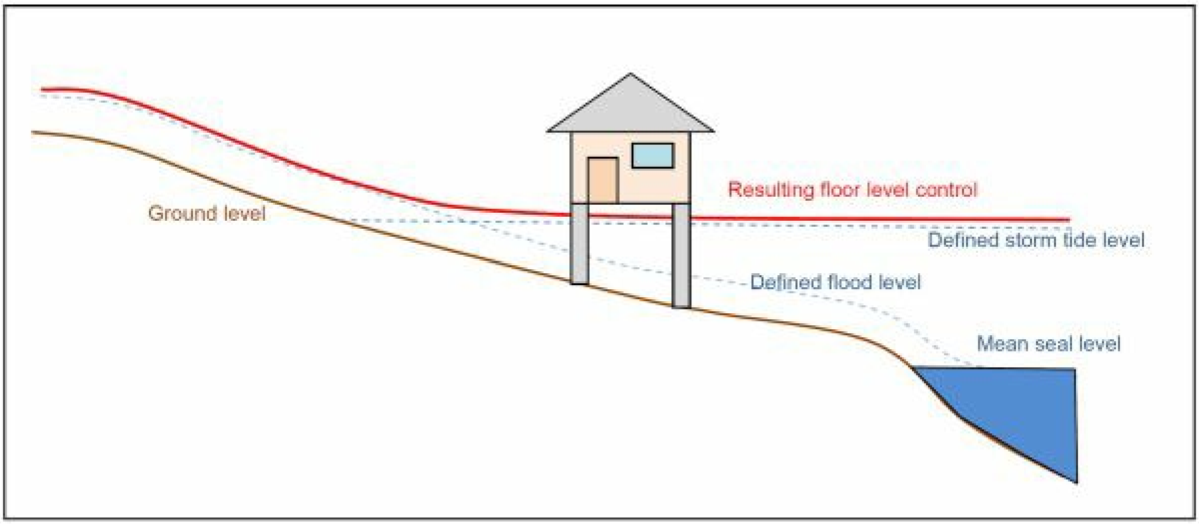


Figure SC6.7.3.1.1.1 - Floor control levels for both flooding and storm tide

Performance outcome 2
Development in high hazard areas does not significantly impede the flow of flood waters through the site or worsen flood flows external to the site.

The delineation of the high flood hazard areas on Flood hazard overlay maps OM-06.1 and OM-06.2 allows for clear identification of areas where performance outcomes 2 is applied.

Performance outcome 3
Development does not intensify use in high hazard areas, in order to avoid risks to people and property.

The delineation of the high flood hazard areas within Flood hazard overlay maps OM-06.1 and OM-06.2 allows for identification of areas where performance outcome 3 applies. Where flood flows are potentially altered by the development, a flood study will likely be required and the revised extent of the high flood hazard area will need to be mapped.

Performance outcome 4
Siting and layout of development maintains the safety of people and property in medium hazard areas.

Other than in the medium hazard – further investigation, council will be able to make available the height of the flood level for any particular location, upon request, where flood modelling studies have been undertaken (refer to SC6.7.2.1.1).

Alternatively, council's online flood mapping service can be used to obtain the height of flood levels for any particular locations.

Where flood flows are potentially altered by the development, a flood study will likely be required and the revised extent of the medium flood hazard area will need to be mapped.

Performance outcome 5
Signage is provided within high and medium flood hazard areas to alert residents and visitors to the flood hazard.

Signage will need to clearly state the nature of the flood hazard, with regards to inundation depths and flow velocities. Signage should also be able to function during a flood event and be practically visible.

Performance outcome 6
Development within high and medium flood hazard areas ensures any changes to the depth, duration, velocity of flood waters are contained within the site.

A flood modelling study, completed by a suitably qualified and experienced Registered Professional Engineer of Queensland (RPEQ), in accordance with Attachment 1 - *Guidelines for Preparation of Flood Studies and Reports*, will likely be required.

As a minimum, evaluating the impacts on floods up to the defined flood event will require a flood modelling study to evaluate the minor drainage system capacity event and the defined flood event for the catchment-wide critical duration and the site-specific critical duration. In addition, certain areas of the Townsville Local Government area will require evaluation of other frequency floods to assess adverse impacts on flooding. Attachment 2 – *Adverse Flooding Impacts Assessment – Additional Design Floods for Assessment* outlines areas where impact assessment and flood mitigation works will need to consider additional design floods to the minimum requirements.

To confirm adverse impacts on flood levels/depths, flow velocities and time of inundation are contained to the site; a pre- and post-development scenario will need to be assessed. Where possible, council requires the base-line flood modelling study that was used for deriving the flood hazard overlay to be used for evaluating development impacts. The RPEQ undertaking the impact study will need to determine if there is a need to update the base-line flood modelling with site specific survey/detail to adequately describe the hydrologic or hydraulic controls.

Performance outcome 7
Development within high and medium flood hazard does not directly, indirectly or cumulatively worsen flood characteristics outside the development site, having regard to: (a) increased scour and erosion; or (b) loss of flood storage; or (c) loss of or changes to flow paths; or (d) flow acceleration or retardation; or (e) reduction in flood warning times.

To adequately assess the impacts of development on flooding regimes may require a hydrological and hydraulic assessment to be carried out by a suitably qualified and experienced hydrologist or engineer in accordance with Attachment 1 - *Guidelines for Preparation of Flood Studies and Reports.*

As a minimum, evaluating the impacts on floods up to the defined flood event will require a flood modelling study to evaluate the minor drainage system capacity event and the defined flood event for the catchment-wide critical duration and the site-specific critical duration. In addition, certain areas of the Townsville Local Government area will require evaluation of other frequency floods to assess adverse impacts on flooding. Attachment 2 – *Adverse Flooding Impacts Assessment – Additional Design Floods for Assessment* outlines areas where impact assessment and flood mitigation works will need to consider additional design floods to the minimum requirements.

To evaluate the potential for worsening flooding outside the development site; a pre- and postdevelopment scenario will need to be assessed. Where possible, council requires the baseline flood modelling study that was used for deriving the flood hazard overlay to be used for evaluating development impacts. The RPEQ undertaking the impact study will need to:

(a) determine if there is a need to update the base-line flood modelling with site specific survey/detail to adequately describe the hydrologic or hydraulic controls; and

(b) undertake analysis to adequately assess the potential for directly, indirectly or cumulatively impacting on flooding.

Figure SC6.7.1 – Flood modelling study areas of this PSP identifies which flood study has derived the flood hazard overlay in given areas.

Performance outcome 8
Facilities with a role in emergency management and vulnerable community services are able to function effectively during and immediately after flood events.

It is appropriate to have a higher level of flood immunity for critical community infrastructure. Table 8.2.6.3(b) within the Flood hazard overlay code outlines the required immunity for critical community infrastructure with a role in emergency management. The identified flood immunities within Table 8.2.6.3(b) should be used for setting flood levels as well as designing building services associated with the facility.

Performance outcome 9
Public safety and the environment are not adversely affected by the detrimental impacts of flooding on hazardous materials manufactured or stored in bulk.

The delineation of the low, medium and high flood hazard areas are shown the Flood hazard overlay maps OM-06.1 and OM-06.2 and allows for clear identification of areas where performance outcome 9 is applied.

Other than in the medium hazard – further investigation, council will be able to make available the height of the flood level for any particular location, upon request, where flood modelling studies have been undertaken (refer to SC6.7.2.1.1).

Alternatively, council’s online flood mapping service can be used to obtain the height of flood levels for any particular locations.

SC6.7.4 Attachment 1 - Guidelines for preparation of flood studies and reports

Abbreviations

AEP	Annual exceedance probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff (1998)
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
MIKE21	Fully Dynamic Two Dimensional Hydraulic Model
MIKE FLOOD	Fully Dynamic Coupled One & Two Dimensional Hydraulic Model
MLWS	Mean Low Water Springs
QUDM	Queensland Urban Drainage Manual
RAFTS	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

SC6.7.4.1 Introduction

A flood study consists of the following parts:

(1) the hydrological determination to calculate the likely volume of water that results from the storm under consideration;

(2) 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

(3) subsequent modelling to determine development impacts for the proposed development along with evaluation of works to mitigate the impacts of development.

Flood studies will be accepted based on approved inundation estimation calculation procedures and on observed historical records that can be quantified and related to an Average Recurrence Interval (ARI) by the use of the appropriate statistical flood frequency analysis procedure. It should be noted, use of historical records may allow for determination of inundation levels, however, will not be able to quantify the impacts on flooding of a development.

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).

This guideline provides guidance on the appropriate use of given methods as well as some guidance on parameter values within the Townsville Local Government Area. There are numerous industry technical documents that detail the methods that should be consulted when completing flood studies including:

(1) Australian Rainfall and Runoff (AR&R); and

(2) Queensland Urban Drainage Manual (QUDM).

SC6.7.4.2 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:

(1) increasing the impervious fraction of the catchment which reduces the volume of infiltration and increases the total volume of runoff; and

(2) decreasing the time to peak discharge due to construction of open drains and stormwater networks which

concentrates flows and may increase the magnitude of peak discharges.

Strategies to avoid and increase in flooding as a result of any works may include:

(1) mitigation of flows at the individual development;

(2) catchment wide approach to mitigation of flows; or

(3) 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 50 years, and even possibly 100 years.

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.

SC6.7.4.3 Hydrological determination

SC6.7.4.3.1 General

The hydrological process that is to be used for determining the design flows for the hydraulic modelling is to be cognisant of the proposed land uses. When calibration is being undertaken based on historical events, then the model being calibrated is to be based on the land use 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 publications such as Australian Rainfall & Runoff (ARR) should be adopted. Chapter 4 of the Queensland Urban Drainage Manual (QUDM) provides detailed guidance on the selection of an appropriate hydrologic method.

SC6.7.4.3.2 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	Applicability	Notes
Rational method	• Regular shaped catchment; • Homogenous catchments (generally uniform land use within the catchment); • Storage or timing issues are not relevant; • Rural catchments smaller than 25km^2; • Urban catchments smaller than 5km^2; • Time of concentration is likely to be less than 30 minutes; • **Rational method should only be used for drainage design as it is not appropriate for impact assessment at master planning stage.**	An appropriate method for calculating the time of concentration is essential to applying the rational method.
Synthetic unit hydrograph procedure	• 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.**	Use of synthetic unit hydrograph procedures is not preferred and should preferably be undertaken by an experienced hydrologist with an extensive knowledge of the catchment.

Non-linear runoff-routing models (RORB, RAFTS, WBNM, 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. • **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.**	Council uses RAFTS and requires any flood studies completed within the Townsville LGA to be completed using RAFTS. Models should be generally developed by suitably experienced practitioners, with appropriate verification / calibration of the models.
Time area runoff-routing models (DRAINS, ILSAX)	• 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 areas only urban land uses.**	Models should be generally developed by suitably experienced practitioners, with appropriate verification / calibration of the models.
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.**	Although these methods are a component of hydraulic determination, they supplement the need for hydrologic determination and are gaining wider acceptance within the industry. Models should be generally developed by suitably experienced practitioners, with appropriate verification / calibration of the models.

Any hydrologic method using emerging technologies needs to clearly demonstrate:

(1) The approach and the principles it employs;

(2) Assumptions and limitations; and

(3) Appropriate calibration or verification.

SC6.7.4.3.3 Catchment parameters

Discussion on catchment parameters is required in particular:

(1) Overall catchment area and sub-catchment areas;

(2) (Sub-) catchment roughness and how the roughness or retardance was developed (may include a photographic record);

(3) Fraction impervious and how values have been derived including reference to what date values represent;

(4) Rainfall losses; and

(5) (Sub-) catchment slopes and how these have been 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 retardance accounts for the influence of vegetation and surface roughness 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:

Catchment land use	Roughness coefficient (n*)
Urban impervious areas	0.010-0.030
Bare soil	0.010-0.050
Sparse vegetation	0.050-0.130
Heavily vegetated areas	0.080-0.200

Note that a sub-catchment may consist of numerous surface types that need to be accounted for in the specification of the catchment roughness.

Rainfall Losses

Rainfall losses 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 – 2.5 mm/h Initial loss 0 – 140 mm Continuing loss 0.1 to 8 mm/h
Impervious	Initial loss 1mm Continuing Loss 0 mm/h

It should also be noted that loss values can vary between design storms of different frequencies. Guidance on appropriate loss values for different ARI 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:

(1) The appropriate slope schematisation is applied when assigning values (equal area slope, vectored slope,); and

(2) Limitations of slope within the hydrological calculation method (i.e. Laurensen's method – minimum slope 0.3-0.5%, maximum slope 15%).

SC6.7.4.3.4 Rainfall intensities

Design Intensity-Frequency-Duration (IFD) Rainfall - IFD relationships shall be derived in accordance with the methodologies outlined in Australian Rainfall & Runoff, for the particular catchment under consideration. Input parameters shall be shown in the calculations submitted to council.

SC6.7.4.3.5 Partial area effects

If the Rational Method is being used, then there should always be checks 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 shorter 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.

SC6.7.4.3.6 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 relevant Queensland Government department(s). Records from stream gauging stations will be required to match to hydrologic calculations and are generally available from the relevant Queensland Government department(s).

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.

SC6.7.4.3.7 Assessment of development impacts

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.

SC6.7.4.3.8 Preparation of reports

Reporting requirements

The method chosen should be adequately referenced and values derived should be substantiated 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 calculations out in a clear and concise table with sufficient data 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 reasons 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 may require the electronic data files to be provided in acceptable format.

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

Catchment maps

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

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

Maps should be well presented with catchments contained upon one sheet where possible. Standard sized sheets should be used. Sub-catchments should be boldly defined and the contours should be clearly defined to enable easy verification of the catchments in relation to the contours. Where sub-catchments are not consistent with the contour information then reasons should be stated in the text and clearly labelled on the map. Good drafting standards should be maintained in the presentation of these maps.

SC6.7.4.4 Hydraulic determination

SC6.7.4.4.1 General

The hydraulic determination involves the calculation of flood levels and velocities for the flood flows from the hydrological determination. Australian Rainfall and Runoff and the Queensland Urban Drainage Manual set out aspects of hydraulic calculations that can be utilised to determine the water levels for design discharges.

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

Australian Rainfall and Runoff describes methods for flood level determination in gradually varied flow conditions. 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.

SC6.7.4.4.2 Hydraulic method

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

Approach	Applicability	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 small site scale hydraulic determination.
Fully dynamic – one-dimensional (MIKE11, ISIS, SWMM)	• Storage or timing issues are relevant; • Flows are one-dimensional, largely within a watercourse and the immediate overbank area.	Suitable for smaller onedimensional watercourses. Provides stability advantages over 2D models for steeper areas. Council uses MIKE11 and requires any flood studies completed within Townsville using a fully dynamic – onedimensional model, to use MIKE11.
Fully dynamic – two dimensional (MIKE21, TUFLOW)	• Storage or timing issues are relevant; • Flows are two-dimensional,	Flood maps are generally direct output from models. Council uses MIKE21 and requires any flood studies completed within Townsville using a fully dynamic – two-dimensional model, to use MIKE21.
Fully dynamic–coupled one & two dimensional (MIKE FLOOD, TUFLOW)	• Storage or timing issues are relevant; • Flows are combination of one and two- dimensional; • Large areas need to be represented in combination with fine detail	Council uses MIKE FLOOD and requires any flood studies completed within Townsville using a fully dynamic – one & two-dimensional model, to use MIKE FLOOD.

SC6.7.4.4.3 Topographic data

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

(1) One-dimensional models employ cross-sections along branches to represent the study area topography; and

(2) 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 wide 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 survey.

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 across the width of the watercourse. Coupled models can be used as an alternative to maintain the resolution within the watercourse.

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.

SC6.7.4.4.4 Roughness values

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

(1) Bed material;

(2) Surface irregularities;

(3) Variations in channel cross-section;

(4) Obstructions;

(5) Vegetation and flow conditions; and

(6) Meandering.

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

Suggested ranges for roughness values based on the hydraulic method are provided below:

Land use	Roughness values (Manning's n)		
	1D Steady state	1D fully dynamic	2D fully dynamic
Natural watercourse	0.03-0.08	0.025-0.06	0.02-0.05
Riparian corridor	0.15-0.2	0.08-0.16	0.06-0.12
Open grassland	0.04-0.08	0.035-0.06	0.03-0.05
Low density vegetation	0.06-0.12	0.045-0.08	0.04-0.06
Medium density vegetation	0.08-0.18	0.06-0.1	0.05-0.08
High density vegetation	0.1-0.25	0.08-0.15	0.06-0.12
Roads	0.03-0.06	0.025-0.05	0.02-0.04
Open channels	0.03-0.05	0.025-0.05	0.02-0.04
Rural residential	0.06-0.1	0.05-0.08	0.04-0.07
Urban residential	0.06-0.15	0.05-0.12	0.04-0.1
Parks	0.04-0.18	0.035-0.1	0.03-0.08

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.

SC6.7.4.4.5 Bridges and culverts

Australian Rainfall and Runoff and Queensland Urban Drainage Manual provide 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.

SC6.7.4.4.6 Tailwater conditions

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

(1) Sea levels for a coastal boundary;

(2) A gauged rating curve;

(3) Flood levels from the same ARI flood based on a previously accepted flood study; or

(4) Flood levels calculated from simplified means in the absence of other information (e.g. normal depth or critical depth).

In using flood levels calculated from simplified means, 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 some 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 Townsville port, with the information available through the Bureau of Meteorology.

To maintain the probability of the assessed flood event for design purposes, the tailwater condition adopted should not have a 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.

Backwater effects in tributaries from larger streams

Where a smaller stream discharges 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 levels 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 fully 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.

SC6.7.4.4.7 Impact of climate change

The impacts of climate change on flooding are likely to manifest from increased sea levels and changes in extreme event rainfall intensities. As part of understanding the risk associated with climate change, a sensitivity assessment should be undertaken as part of a flood study. The sensitivity should account for the latest projections in sea-level rise and increased rainfall intensities, specific to the area from leading authorities including relevant Queensland Government department(s), Australian Rainfall and Runoff, Commonwealth Scientific and Industrial Research Organisation, Bureau of Meteorology or Intergovernmental Panel on Climate Change. At the time of preparing this PSP appropriate values were:

Parameter	Value
Sea level rise to 2100	0.88m
Extreme rainfall Intensities to 2100	+15%

The DFE should be assessed in combination with the maximum sea-level rise applied to the MHWS level and the increase in rainfall intensities to evaluate the additional risk associated with climate change. The results from the climate change sensitivity should be assessed with commentary provided about:

(1) Areas where the floor level freeboard above the DFE would be exceeded;

(2) Any new flow paths that are formed; and

(3) What is the AEP of the climate change DFE relative to existing conditions.

SC6.7.4.4.8 Determination of impacts of development

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

(1) Increasing the impervious fraction, reducing amount of infiltration and generating a larger volume of runoff;

(2) Providing more efficient conveyance of flows through the site so that flows are concentrated faster at the downstream end of the site producing larger peak flows; and

(3) Removing floodplain storage due to filling 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 developed state to determine increased amounts of flow and flood levels. The pre-developed state should represent the state of development within the catchment and floodplain immediately prior to time of construction of the proposed works.

Adverse impacts on flooding may preclude development unless appropriate flood mitigation measures are proposed as part of the development. As a result of developments:

(1) Flood levels should not increase beyond the accuracy of the method of hydraulic determination (generally 0.01 m) either upstream, downstream or adjacent to the site;

(2) There should be no significant change in flow patterns so that new flow paths on adjacent land are formed; and

(3) Any 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:

(1) Clear identification of the land parcels impacted;

(2) Development applications (material change of use, reconfiguration of a lot or operational works) - as required; and

(3) Identification of maintenance measures including responsibilities and funding sources.

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

Hydraulic modelling of development

When representing development typically the hydraulic model is updated by:

(1) Changing the topography (cross-sections/DEM) to represent the development;

(2) Updating inflows to represent changes in hydrological response; and

(3) Updating roughness to represent the 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 Townsville 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 regrowth, which may have minimal maintenance.

Freeboard for existing areas

Within some existing urban areas, design criteria have changed over time and have resulted in freeboard to existing buildings being less than is required in new development. To ensure the freeboard for existing areas is maintained, there should be no adverse impacts on flooding for all events floods up to the DFE. As a minimum, the assessment should demonstrate that there are no adverse impacts on flooding for the minor system drainage capacity AEP and the DFE.

SC6.7.4.5 General matters

SC6.7.4.5.1 Presentation of reports

As stated in the previous sections all reports and tabulations are to be printed on A4-sized sheets, and drawings presented on standard size sheets prepared using good drafting standards. The expected content of the reports is as discussed in SC6.7.4.2, SC6.7.4.3 and SC6.7.4.4 above. In summary the contents of a study report must include:

Hydrology section

(1) catchment Map - large as possible;

(2) report on procedure (brief), including hydrologic method, catchment characteristics, assumptions and discussions on results including critical duration /time of concentration as detailed in SC6.7.4.3 above; and

(3) calculations and model results - tabulated where possible and attached in appendix if significant in volume.

Hydraulics section

(1) report on procedure including hydraulic method, stream/floodplain characteristics and assumptions as detailed in SC6.7.4.4 above;

(2) model Results – Clearly presented as maps and tabulated values;

(3) stream Flood profile and bed profile of the study area;

(4) 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);

(5) a plan containing the proposed works showing any filling and excavation associated with development; and

(6) model results updated on the basis of including the development with the revised flood extents and impacts on flooding.

General

(1) discussion on sensitivity analysis for critical parameters (e.g. roughness, infiltration etc.);

(2) discussion on accuracy of inundation mapping and the resulting required flood line;

(3) recommendations as to methods of flood mitigation within the site;

(4) recommendations as to method of flood mitigation beyond the site together with development approvals,

construction proposal and funding proposals; and

(5) 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 in 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.

SC6.7.4.5.2 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 where the results have been calibrated using observed levels and measured rainfalls will be recognised as providing a more representative result for the study area.

The hydrologic and hydraulic methods adopted should be suitable for purpose as indicated in SC6.7.4.3.2 and SC6.7.4.4.2. Townsville City Council requires that any flood studies completed within the Townsville Local Government Area uses software that is run internally which includes:

(1) Non-linear Routing – XP-RAFTS;

(2) 1D Steady State – HEC-RAS;

(3) 1D Fully Dynamic – MIKE11;

(4) 2D Fully Dynamic – MIKE21; and

(5) Coupled 1D/2D Fully Dynamic – MIKE FLOOD.

SC6.7.4.5.3 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 practices adopted are those developed by the engineering profession through initiative and ingenuity and ratified through the professions recognised body "The Institution of Engineers, Australia" currently trading as "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 acknowledged by any authorised third party user.

Submitted as part of a development application

Submitted as part of a Development Application and adopted as supporting the application only

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.

SC6.7.4 Attachment 2 - Adverse Flooding Impacts Assessment - Additional Design Floods for Asessment

Location	Design flood event
Ross River - Downstream *Within the immediate area around Ross River downstream of Ross River Dam and the lower Ross River Floodplain.*	0.2 % AEP
Ross River Upstream *Upstream of Ross River Dam*	0.5 % AEP