Peer review of Arcadia Flood Study

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Author	Richard Sharpe, Barry Rodgers
Reviewed By	Cathie Barton
Project Manager	Barry Rodgers

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1 Introduction

1.1 Background

Townsville City Council (TCC) is currently updating flood modelling and mapping within the LGA as part of the *Townsville Flood Modelling and Mapping Project* (the Project). BMT has been engaged to provide expert peer review for the Project to support achieving sound and defendable outcomes for TCC by:

- Ensuring the study follows latest industry standard techniques and best-practice;
- Instilling confidence in the study products and outputs;
- Identifying potential missed opportunities which might be rectified within this study, or flagged for future works.

The modelling and mapping for the *Townsville Flood Modelling and Mapping Project* has been commissioned under five separate contracts with each contract pertaining to a hydrological catchment (or group of catchments). These five contracts are as follows:

- Bohle River catchment
- Black River, Althaus and Bluewater Creeks
- Ross River and Surrounds
- Alligator Creek and Whites Creek.
- Magnetic Island and Balgal Beach (five separate studies):
  - Balgal Beach
  - Arcadia
  - Horseshoe Bay
  - Nelly Bay
  - Picnic Bay

This peer review report documents the review findings for the **Arcadia Flood Study** prepared by AECOM under the Magnetic Island and Balgal Beach contract.

1.2 Supplied Data

BMT has relied on information from the following sources in the completion of this review:

- Arcadia Flood Study Base-line Flooding Assessment Volumes 1 and 2, Revision A dated 8 October 2021 (AECOM, 2021).
- Request for Quotation: Townsville Recalibrated Flood Modelling and Mapping – Magnetic Island & Balgal Beach (TCC, 2019).

- Townsville Recalibrated Flood Modelling and Mapping Naming Convention Report (TCC, March 2020).
- Hydrologic Models:
  - AA_DES.xp
  - AA_DES_PMF.xp
  - Supporting GIS datasets
- Hydraulic Models:
  - TUFLOW model AA-_s1_-_s2_-_e1_-_s3__e2_.tcf

1.3 Peer Review Process

The peer review covers the following aspects:

- Technical review of the models for general configuration, parameters, calibration performance, model health etc;
- Assessment of conformance or otherwise to the Australian Rainfall and Runoff 2019 guideline (ARR2019);
- Assessment of the degree to which the deliverables provided to Council meet the stated aims in the respective project briefs and associated consultant proposals; and
- Commentary on the ability of the study outputs to be used for end purposes (i.e. application of the new flood models, flood maps and flood hazard maps for the planning, new development and rezoning purpose).

We have utilised a traffic light system to indicate how significant an issue might be. Each issue is allocated a colour (green, yellow or red) in accordance with Table 1.1. Where a potential issue has been identified, we have provided our recommendations on how to address or further investigate the issue.

At the end of each key review section, a summary table is provided of key review observations and recommendations along with an indication of the significance of the issue.

Table 1.1 Significance of Issue

Category	Category Description
Green	Checks have showed either no issues or issues are of a minor or cosmetic nature that don't have any bearing on model results
Yellow	An issue which is unlikely to be significant but does warrant further checking or justification.
Red	Potentially significant issue which may have implications on model results and further investigation is required

1.4 Limitations

In preparing this report, BMT has relied upon, and presumed accurate, information (or absence thereof) provided by AECOM. Except as otherwise stated in this report, BMT has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete, then it is possible that our observations and conclusions as expressed in this report may change. It is assumed that the results provided by AECOM correspond to the definitions in the control files provided for the model runs.

2 Modelling Overview

The Arcadia Flood Study uses a hydrologic XP-RAFTS model to convert rainfall to runoff. Runoff hydrographs are then extracted from the XP-RAFTS model and applied as inflows to a TUFLOW HPC hydraulic model. The TUFLOW HPC model also includes catchment area which is modelled with direct rainfall input. The direct rainfall is applied in combination with the XP-RAFTS derived inflows.

The TUFLOW model uses a 5m model grid and has been used to simulate design flood events with AEPs ranging from 50% (most frequent) to 0.05% (rarest). The Probable Maximum Flood (PMF) has also been assessed along with climate change scenarios for the 2% and 1% AEP events. The design hydrology is based on the Australian Rainfall and Runoff 2019 guideline (ARR2019) (Ball et al, 2019).

Model calibration was not undertaken as there are no water level gauges within the catchment. A verification of design flows has been performed against the Rational Method. A verification exercise has been performed on the hydraulic model by comparing modelled flood extents for the events of January/February 2019 and January 2020 against anecdotal data.

The remainder of this report sets out the key findings from our peer review.

3 Hydrologic Assessment

3.1 Background

As described in Section 2, the hydrologic modelling was undertaken using XP-RAFTS software. The XP-RAFTS model is a new model developed for the Arcadia Flood Study.

The peer review of the hydrologic modelling is limited to its overall suitability and defensibility of its implementation. The hydrologic review covers following aspects:

- High level checks on the appropriateness of the hydrologic modelling for the purposes of the flood study.
- Consistency checks that the hydrographs output from XP-RAFTS are applied at appropriate locations in the TUFLOW model and that all runoff is accounted for in the TUFLOW model.
- The application/implementation of ARR2019 methodology in deriving appropriate design hydrology.

3.2 Hydrologic Review

General Comments

When reviewing the catchment areas, it was noted that the GIS layer that was developed to digitise the subareas and construct the XP-RAFTS model contains digitising errors for two of the subareas (AA56 and AA41). This appears to be where the subarea has been digitised with two polygons, one of which (the erroneous part) is small and disconnected from the main polygon. The sum of the two parts has been inserted into XP-RAFTS. Therefore, the areas for these two subareas are slightly larger than they should be.

From inspection, it appears that the subarea delineation was undertaken using an automated process, which has created some unusually shaped (elongated) subareas. For example: AA54, AA48, AA25. While this is not ideal, this concern is not expected to cause a significant change to model results and no action is required.

Apart from these relatively minor inconsistencies in catchment area, the subareas are appropriate.

Impervious areas have been added to subareas AA1 to AA10. However, the developed area extends well beyond this selection of subareas. It is acknowledged that much of the runoff in the developed area is simulated using direct rainfall in the hydraulic model. However, there are still several subareas that span across developed areas where impervious areas have not been applied and direct rainfall is not used; a selection of these subareas is shown in Figure 3.1 below. This will result in an understatement of runoff from these subareas, albeit the differences are unlikely to be significant.

It seems that some subarea slopes are based on the slope of the stream channel rather than the slope of the local catchment, for example: AA49 and AA17. It is recommended that catchment slopes are used and that the way in which slopes have been calculated is documented in the report.

A simple stream lag has been used for stream routing through the catchment. This is generally only appropriate in small urban catchments. This is not a concern for most of the subareas, since local subarea runoff is replaced with direct rainfall within the hydraulic model. However, the catchment areas upstream of AA49 and AA40 comprise a significant proportion of the overall catchment and are applied as total catchment inflows in the hydraulic model. It is recommended that channel routing is used in the hydrologic model for subareas draining into AA49 and AA40.

It was noted that subarea AA5 drains directly to the coast and is not applied in the hydraulic model. Thus, this subarea is redundant in the flood study.

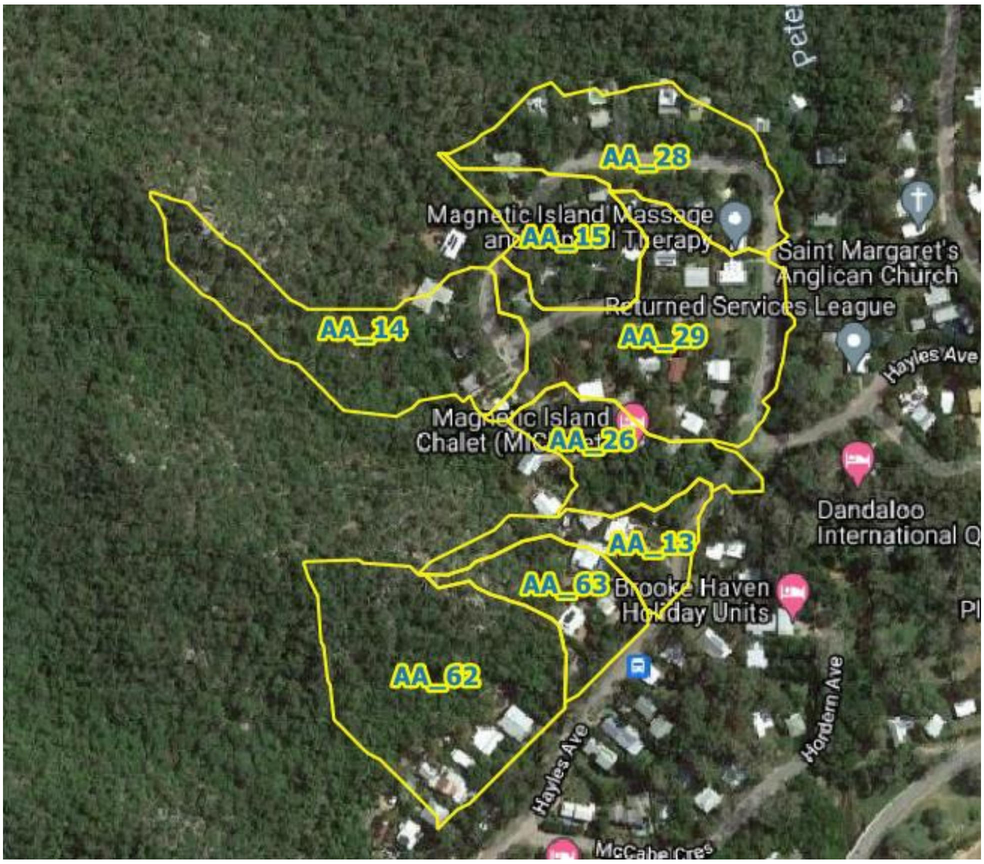


Figure 3.1 Subareas modelled with no impermeable area

Model Calibration/Verification

The hydrologic model was simulated for the historic events which occurred in January/February 2019 and January 2020. There are no stream gauges within the catchment and so the calibration has been assessed based on applying the hydrologic model derived flows within the hydraulic model and comparing results (peak flood levels and extents) to available anecdotal data. This is reviewed under Section 4.3.

As a comparison of modelled hydrologic flows against recorded (rated) flows could not be undertaken, AECOM has performed a verification of the hydrologic design flows against the Probabilistic Rational Method.

Use of the Probabilistic Rational Method was common under the ARR1987 guideline but current practice set out within ARR2019 no longer favours its use except at a localised lot scale[1]. This is

[1] ARR2019 advises that the Rational Method should only be applied within a catchment where more detailed analysis of rainfall runoff observations have defined its parameters (runoff coefficient and time of concentration).

primarily to do with the lack of scientific evidence underpinning for its runoff coefficient. It is noted however that the Queensland Urban Drainage Manual (QUDM) (IPWEAQ, 2017) still supports its use for urban catchments of less than 500 hectares or rural catchments of less than 25km^2 or as a checking tool for numerical models developed for small ungauged catchments.

BMT recognises that there is very limited historic data to calibrate/verify the model and therefore we consider that the use of the Rational Method as a tool to check for potential gross errors is acceptable.

AECOM has verified the hydrologic design event peak flows against the Rational Method at three nominated locations within the catchment. Generally the peak flow estimates compare reasonably well with no highlighted gross errors.

Overall, BMT is satisfied, given the limited data, that suitable verification has been performed.

3.3 Summary of Hydrologic Model Observations and Recommendations

Table 3.1 Hydrologic Model Development and Calibration Summary

ID	BMT Observation	BMT Recommendation
3.1	Subareas AA56 and AA41 are modelled with a larger area than the area they represent due to double accounting of some catchment area.	Observation only. Affected areas are minor so it is not considered warranted to update them.
3.2	Some subareas were identified outside of the direct rainfall extent which contain impermeable land uses not represented in the model	Observation only. Affected areas are minor so it is not considered warranted to update them.
3.3	Approach to extracting catchment slopes not documented. It appears that stream slope rather than catchment slope has been applied.	The way in which slopes have been calculated should be documented in the report.
3.4	Model uses simple catchment lagging and not routing. This is only recommended for small urban catchments	Recommended that channel routing is used in the hydrologic model for subareas draining into AA49 and AA40 which lie outside of the direct rainfall application.
3.5	Subarea AA5 drains directly to the coast and is not applied in the hydraulic model and so is redundant.	Observation only

4 Hydraulic Model Development and Calibration

4.1 Background

The hydraulic model is a new model developed using TUFLOW software. The TUFLOW model is predominantly 2D with nested 1D culvert elements. It uses TUFLOW HPC along with its Sub-Grid-Sampling (SGS) feature. The model was simulated using TUFLOW build 2020-10-AA-isp which was the latest version at the time of the assessment.

4.2 General Considerations

The supplied model files include a single TUFLOW control file (tcf) as follows:

AA-_s1_-_s2_-_e1_-_s3__e2_.tcf

TUFLOW's events and scenarios feature has been used allowing the same tcf to be used to simulate different design events, calibration events and sensitivity tests.

Naming Conventions

TCC has nominated a standardised hydraulic model naming convention to be used on models developed for the Project. The naming adopted by AECOM broadly meets the naming convention although does not conform exactly. For example, the AEP identified is larger than the requested 3 characters. A model run identifier is also not included which is important for ongoing model quality control practices.

The filename for the provided TUFLOW control file is: *AA-_s1_-_s2_-_e1_-_s3__e2_.tcf*. This filename does not use tilde characters to ascribe the event and scenario tags to the model output filenames. The filename should be: AA-~s1~-~s2~-~e1~-~s3~~e2~.tcf, which is what appears to have been used based on information in the supplied log files.

Whilst not strictly in accordance with the requested naming conventions, in BMT's opinion the adopted naming remains clear, logical and allows TCC to easily identify it as an Arcadia model (or result file). It is however recommended that a run ID is incorporated into the model name.

General Setup

The model folder structure is set up in accordance with TCC's requirements and follows TUFLOW's recommended folder structure approach. Default model settings are generally applied as recommended. In test simulations, BMT was able to initialise and run the design case model with the supplied model files. However, when attempting to run a blockage sensitivity scenario the supplied model issued an initialisation error associated with duplicate 1D network IDs. This is likely to do with the blockage layers (pipes and culverts) being read into the model (within the ecf file) after the unblocked layers. This could be resolved by incorporating the unblocked pipes and culverts into the same scenario block. It therefore appears as if the presented blockage simulation results were derived from a different (unsupplied ecf fle).

The extent of the model is appropriate to cover the main urban area of Arcadia. However, given the relatively small size of the model and the very quick simulation times, it would have been possible to include all upstream sub-catchments as local inflows into TUFLOW to limit the use of total inflows and limitations of hydrologic routing or lagging.

4.3 Hydraulic Model Development and Calibration

Topography

The base topography is based on a 1m DEM of 2019 LiDAR data, defined in the model using a 5m grid. Modifications are made in the form of breaklines to improve representation of the base topography around structures and to reinforce road crest elevations.

No issues were identified with the modelled topography.

Materials

Based on a visual inspection of the land use delineation against available aerial imagery, the mapped land uses are generally appropriate and mapped to a sufficient level of detail for the purposes of the assessment.

There is a land use layer surrounding the Arcadia Village Hotel labelled as *rough impervious surface* (material ID 105) with a Manning's *n* of 0.015. From aerial photography, this area looks grassed with some trees. Thus, the Manning's n seems too low.

Buildings within the direct rainfall area are specified using land use ID 610 and apply a depth varying roughness for sheet flow and concentrated flow. This is appropriate.

Land use category 205 is also labelled as buildings within the tmf but has a permeable rainfall loss values associated with it. Upon inspection, the buildings contained within category 205 are subsequently overwritten by buildings allocated to category 610 and the remaining area of 205 represents mostly permeable area. Therefore, the loss values are appropriate.

The materials layers are used to set the rainfall losses for the parts of the model to which direct rainfall is applied. This is discussed further in the section on External Boundaries.

Structures

No bridges are included in the modelled 2D domain. There are a small number of road crossings and these have been modelled as 1D nested culverts. The height contraction coefficient for rectangular culverts is set to 1.0. This is usually 0.6 for square edged and 0.8 for rounded edges.

A small number of pipes (12) have been included in the model as part of the stormwater drainage. Most of these pipes are associated with the drainage network near the Arcadia Village Hotel which then discharges through a culvert under Marine Parade and out to the ocean. Pipe 44952594 is only 2.7m long and is redundant in the model, which has a cell size of 5m.

TUFLOW can automatically create manholes at pipe junctions for energy loss calculations. AECOM has disabled this function and has digitised manhole locations. The default Engelund loss approach has been applied to these digitised manholes. The digitised manhole locations appear appropriate against the limited number of pipes included in the model.

External Boundaries

The model downstream boundary is configured as two water level vs time (type HT) boundaries snapped to the active code boundary.

Hydrologic model results are applied as 35 source area (type SA) inflows to the TUFLOW domain. Two of these inflows correspond to the same subarea (AA2) and so are labelled with the same ID.

The boundary condition database applies a 50% factor to the AA2 inflows. It is assumed the intention is to factor the flow by 50% and then apply that factored flow twice within the model. TUFLOW does not treat the boundary in this way. Instead the two SA polygons are treated as a single multi-part polygon. The inflow is then distributed to the lowest or wet cells across the multipart polygon. Under the current set up, only 50% of the subarea runoff from AA2 is being applied to the hydraulic model. This will lead to an understatement of flow in the model.

Checks have shown the allocation of the remaining total and local flows to the model is appropriate and accounts for the catchment flows.

Output Settings

A ‘Map Cutoff Depth’ of 0.1m has been applied within TUFLOW. The ‘Map Cutoff SGS’ approach is also set to ‘Exact’ which in effect is also a cut off depth as the elevation sampled exactly at each cell centre is used as the elevation below which the cells are shown as dry. Depth in the cell is measured from the cell minimum elevation as sampled by SGS. Therefore, whilst every cell receiving direct rainfall is wet, if the depth in the cell remains below the elevation sampled at the cell centre, the cell is mapped as being dry. The higher of these two cutoff depths is applied within the model.

The maximum velocity cutoff depth is set to zero (default value in TUFLOW is 0.1). This will track the maximum velocity irrespective of the depth of water and can potentially result in mapping showing high velocities for shallow depths. Overall this is considered a conservative approach but users should be aware that this setting is applied.

It is noted that TCC has requested that map outputs are post processed to exclude depths below 0.1m except where velocities exceed 0.8m/s. AECOM has not applied the additional velocity consideration for results filtering and state their rationale in Section 4.1. From a hydraulic output perspective, BMT is satisfied that suitable cut off criteria have been applied.

Model Calibration

The hydraulic model was verified to two historic events which occurred in January/February 2019 and January 2020. As discussed in Section 2, there were no stream gauges to assist with model calibration. The approach taken was therefore to simulate recorded rainfall and compare hydraulic model output against anecdotal data. The report states that recorded rainfall at Arcadia pluviograph for the two events was simulated but then later refers to use of the Nelly Bay gauge. This should be clarified.

The reporting on comparison of modelled results with anecdotal data is very limited and just states that reporting flooding issues were reflected in model results. It would be useful to include an example of where the model result accords with an anecdotal account of the flooding.

The report includes Figure 10 showing the January/February 2019 modelled results twice.

Overall BMT recognises that model calibration is very limited due to availability of data. BMT is satisfied that AECOM has attempted to verify the model to a satisfactory, albeit limited, standard using available data.

4.4 Summary of Hydraulic Model Observations and Recommendations

Table 4.1 Hydraulic Model Development and Calibration Summary

ID	BMT Observation	BMT Recommendation
4.1	Naming conventions are not in strict accordance with requested naming convention by TCC	For consideration by TCC. In BMT's opinion the adopted naming remains clear, logical and allows TCC to easily identify it is an Arcadia model. We do recommend that a run ID is incorporated into the model name.
4.2	The supplied tcf does not contain tildas in the name whereas the one used to simulate the models did.	Review supplied format of tcf name
4.3	The small size and of the model and the fast simulation times meant that it would have been feasible to include all upstream subareas as local TUFLOW inflows.	Observation only
4.4	Model would not initialise when attempting to run a blockage scenario	Review set up of ecf (see suggested fix in Section 5.2)
4.5	Land use ID 105 has a very low roughness (Manning's n of 0.015) but appears to represent grassed areas around Arcadia Village Hotel	Review this land use and its potential to impact on results.
4.6	The height contraction coefficient for rectangular culverts is set to 1.0. This is usually 0.6 for square edged and 0.8 for rounded edges	Review values used.
4.7	SA inflow 'AA2' only applies 50% of the intended flow	Review for potential impact on results. SA IDs should be allocated unique IDs and then referenced to the bc_dbase
4.8	Results filtering is not strictly in adherence with TCC requested filtering criteria as it omits the velocity component.	Cutoff depth applied appears reasonable but TCC to review against requirements.
4.9	The report states that recorded rainfall at Arcadia pluviograph for the two verification events was simulated but then later refers to use of the Nelly Bay gauge.	Update the report to clarify which gauge was used
4.10	Report includes Figure 10 twice	Remove duplicate Figure 10 from report

5 Determination of Design Floods

5.1 Overview

The approach to design flood estimation applied by AECOM uses approaches contained within the ARR2019 guideline. As no stream gauges exist within the catchment the approach relies upon design event simulation using the hydrologic and hydraulic models developed in the assessment.

The remainder of Section 5 sets out BMT's review of the design flood estimation including the design event selection process for model simulations.

5.2 Design Event Simulation

Design Parameters

A single IFD location appears to have been used to generate the direct rainfall. The longitude given for the IFDs in Table 7 is stated as 140.8626 degrees. However, the longitude should be around 146.8 degrees. The IFD data in this table also looks incorrect. For example, the rainfall depth for the 1% AEP 1.5-hour storm is listed as 126mm but should be 140mm (which is what was used in the model and verified by us in our review).

The critical duration of the PMF is stated as being 1.5 hours (Table 6). The supplied XP-RAFTS model also contains the 1.5 hour (90 minute) storm. Supplied PMF flood study results are for the 60 minute event. The XP-RAFTS model does not contain the 60 minute storm. It is therefore not possible to review the PMF hydrology component used for the final results.

Based on a review of the 90 minute PMF setup, a number of issues were noted as follows:

- The supplied hydrologic model appears to use an initial loss of 70mm and a continuing loss of 2.5mm/h for the PMF. No StormInjector files were supplied to see if this is overwritten
- The hydrologic model applies a PMP depth (90 minute duration) of approximately 533.5mm whereas the direct rainfall applies a PMP depth of 550mm.
- The PMF rainfall pattern within XP-RAFTS contains a lead in period of approximately 45 minutes with no rainfall applied whereas the PMP rainfall applied in TUFLOW commences near the start of the simulation. As the PMP should be simulated as a storm across the catchment, the two components should be made consistent

The 60 minute PMP rainfall applied within TUFLOW as direct rainfall appears to correspond to the 90 minute rainfall and temporal pattern. This should be checked as it is not correct.

The report states that an areal reduction factor (ARF) has been applied based on the 'East Coast North' region. BMT notes that an ARF of 1.0 has been applied in the modelling essentially meaning that no areal reduction in rainfall has been applied. It is likely that the ARF of 1.0 has resulted due to the 'East Coast North' region not extending across Magnetic Island. As such no ARF parameters are available for catchments on Magnetic Island. If an ARF was to be applied BMT recommends that the 'East Coast North' parameters are manually entered. However an ARF of 1.0 is a conservative approach and in BMTs opinion is suitable for the assessment. An ARF of 1.0 is also consistent with what has been applied in the direct rainfall.

An ensemble approach to temporal patterns has been applied as set out in ARR2019. Point temporal patterns have been applied as the catchment area is less than 75km^2.

With regards to rainfall losses the approach taken follows that given in ARR2019 whereby an initial storm loss is converted to an initial burst loss by accounting for pre-burst rainfall. For permeable areas an initial storm loss of 70mm is reported for both hydrology and hydraulic (direct rainfall) components of the modelling. The continuing loss is reported as being 2.5mm/h (1.0mm/h for the 0.05% AEP event) for permeable areas. These loss values differ from those specified in the ARR2019 datahub which lists a storm initial loss of 72mm and a continuing loss of 4mm/h. BMT notes that the adopted values better approximate the continuing loss values determined through model verification and agrees with their use.

The downstream boundary is specified as a constant level set at MHWS (1.1mAHD) for all design events. Use of MHWS is in accordance with the TCC Guideline.

Critical Duration / Event Selection

An ensemble approach to modelling rainfall temporal patterns has been applied in the design flood modelling. This is in accordance with ARR2019. The ensemble approach relies upon a representative average ensemble member being selected for a given AEP/Duration. This representative ensemble member may vary across the catchment being modelling and so its selection can be based on assumptions and judgement. BMT has reviewed the event selection process undertaken by AECOM and makes the following comments/observations.

- Identification of the critical durations and temporal patterns has been undertaken using the hydraulic model. This has involved running full ensembles (10 events) for each duration/AEP combination and analysing the flood levels in every grid cell. It results in a significant number of simulations but is feasible due to the rapid simulation times of the model (typically less than 5 minutes).

- The process results in a peak design flood elevation surface effectively based on a statistical analysis of results in keeping with the ARR2019 approach at every grid cell. For a given AEP, this process first identifies the median flood level for each duration in every grid cell and then generates a flood surface based on the maximum of the median flood levels. A drawback of the approach is that a flood surface for any given AEP may be composed of results from many hydraulic model simulations and can impact the usability of the model from a practical point of view. Given the rapid simulation times, running many hydraulic simulations is unlikely to be an issue. However, this can cause complications when using the model for impact assessments. It is recommended that TCC/AECOM provide supplementary guidance on how to select appropriate events for flood impact assessments to avoid a variety of approaches being applied by third parties.

- The report does not state, but it is assumed that, the process for deriving other gridded flood surfaces (velocity, hazard etc) is the same as that used for peak level (a max of the median approach). For a given location and for a given AEP, it is possible that different model simulations have generated the peak flood level and the peak of another output variable eg velocity. This can cause complications when using the model outputs for purposes beyond the flood study. It is recommended that the supplementary guidance referred to in the above point also includes selection of events for outputs other than peak level.

Sensitivity Analyses

Climate Change

A sensitivity assessment has been undertaken on climate change for both the 2% and 1% AEP in accordance with the RFQ. Relative Concentration Pathway 8.5 (RCP 8.5) has been used for the assessment which is also in accordance with the RFQ. Rainfall intensity has been increased by 15.4% and an allowance of 0.8m has been made for sea level rise (SLR).

The mapped results are in agreement with expectations and BMT has identified no issues.

Joint Probability Zone

AECOM has undertaken a pre-screening analysis in accordance with Book 6, Chapter 5 of ARR2019 for the consideration of riverine and oceanic flooding. This has been done for the 1% AEP and the 1% AEP with climate change.

Changes to rainfall and tidal boundary parameters (as per reporting) for the joint probability assessment scenarios were confirmed to be implemented correctly in modelling files, via alternative boundary conditions databases and TUFLOW logic. It is noted from the results that the defined storm tide level in the Townsville City Plan is greater than the fully dependent flood surfaces within the defined JPZ. Therefore existing planning provisions effectively already account for any uncertainty in choice of downstream boundary condition. BMT therefore agrees with AECOMs statement that a full design variable method is not warranted for Arcadia. Overall, the approach is consistent with ARR2019.

Structure Blockage

A blockage assessment has been undertaken which is in accordance with ARR2019. This assessment has been undertaken on modelled culverts and pipes with the critical blockage mechanism determined as being from sediment blockage rather than floating debris. The assessment is undertaken for both the 50% and the 1% AEP events.

The report notes that a blockage of 15% was derived. Based on the supplied model files a blockage of 60% has been applied for the 1% AEP and a blockage of 40% for the 50% AEP. The higher modelled blockages will provide a more precautionary assessment of blockage.

When attempting a test simulation of the blockage scenario, BMT found that the model would not initialise. It appears to be because for the blockage scenarios, the unblocked culvert GIS file is read by TUFLOW and then the blocked culvert GIS file is read. Thus, the culverts are read by the TUFLOW model twice. This causes an error, and the blocked scenarios don't run. A solution would be to use the logic shown below.

If Scenario == BS01
  Read blocked culverts
Else If Scenario == BS02
  Read blocked culverts
Else
  Read unblocked culverts
End If

BMT notes that in ARR2019 the 'design blockage' is the blockage condition that is most likely to occur for a given storm and that an 'all clear' (no blockage) scenario should be the sensitivity test. In the AECOM study, the sensitivity test is the one with the design blockage and the 'all clear' case has been adopted when producing the final flood surfaces. However, we understand the blockage scenario was specified as a sensitivity assessment in the RFQ.

In BMT's opinion, the blockage assessment has been undertaken in accordance with TCC's requested approach and blockage values are reasonable for the purposes of the sensitivity assessment. When using the results of the study to inform planning levels, the results of the blockage sensitivity test should be reviewed. Any areas where water levels are particularly sensitive to structure blockage should consider the water level under the blockage scenario for planning purposes.

Design Simulation Results

A comprehensive set of design results are included in a separate volume of the flood study report. Mapping includes flood level, depth, velocity, classified hazard (AIDR, 2017), and classified hazard in accordance with the TCC flood hazard overlay.

The labelling of the digital results generally conforms to TCC's requested naming conventions but is subject to the same comments as described in Section 4.2 on model naming conventions.

The results have also been analysed to provide information as follows:

- Counts of buildings within each AEP
- Water depth of main roads at selected crossings
- Commentary on what AEP inundates community buildings and infrastructure

5.3 Summary of Design Flood Estimation Recommendations

Table 5.1 Design Flood Estimation Summary

ID	BMT Observation	BMT Recommendation
5.1	The longitude given for the IFDs in Table 7 is stated as 140.8626 degrees. However, the longitude should be around 146.8 degrees. The IFD data in this table also looks incorrect and differs to what has been applied in the model	Update report to quote IFD data used in modelling.
5.2	The critical duration of the PMF is stated as being 1.5 hours (Table 6). The supplied XP-RAFTS model contains the 1.5 hour storm but the provided TUFLOW PMF result is for the 1 hour storm.	Clarify what duration has been modelled. If the 1 hour duration is modelled, the results should be included in the XP-RAFTS model.
5.3	The overall set up of the PMF should be checked due to the issues highlighted by BMT. In particular the 60 minute storm applied in TUFLOW appears to be the 90 minute storm.	Review BMT comments on PMF
5.4	An ARF of 1 (no reduction) is applied. The report states ARFs from the East Coast North region are applied but this is not the case.	Update report to state an ARF of 1.0 is applied.
5.5	Blockage sensitivity factors differ between report (15%) and modelled (40% and 60%).	Clarify in report what blockage factor has been applied.
5.6	The blockage scenario does not initialise in the supplied model. A suggested fix is contained in the text above.	Update model so blockage scenario does not error on model initialisation. See also recommendation 4.4.
5.7	The approach to simulate all ensembles and durations to generate a flood surface of a given AEP can complicate approaches taken for flood impact assessments.	TCC/AECOM provide supplementary guidance on how to select appropriate events for impact assessments, including selection of events for outputs other than peak level.

6 Other Considerations

6.1 RPEQ Signoff

The RFQ requests that the flood modelling study is completed by a suitably qualified and experienced Registered Professional Engineer of Queensland (RPEQ). As such the report should include signoff demonstrating RPEQ oversight.

6.2 Other Considerations Summary

Table 6.1 Summary of Other Considerations

ID	BMT Observation	BMT Recommendation
6.1	No RPEQ signoff included in report	Add RPEQ signoff

7 Conclusions

This peer review report has documented the review findings for the Arcadia Flood Study undertaken by AECOM as part of Townsville City Council's Townsville Flood Modelling and Mapping Project.

Overall the study was found to generally follow best-practice modelling approaches and techniques and conform with approaches within ARR2019.

Observations and recommendations have been made by BMT on key aspects of the study with a summary of these tabulated in each section of this report. For the majority of the design events, no significant issues were identified by BMT. There are some significant issues with how the PMF has been applied in the model and these should be checked. A number of further minor issues have been noted, the majority of which relate to requests for clarifications within the report.

8 References

AECOM (2021) Base-line Flooding Assessment – Arcadia Flood Study – Volume 1 and Volume 2 – Report (Revision A). Prepared for Townsville City Council, October 2021.

AIDR (2017) Managing the Floodplain: A Guide To Best Practice in Flood Risk Management in Australia, Handbook 7, third edition. Australian Institute of Disaster Resilience.

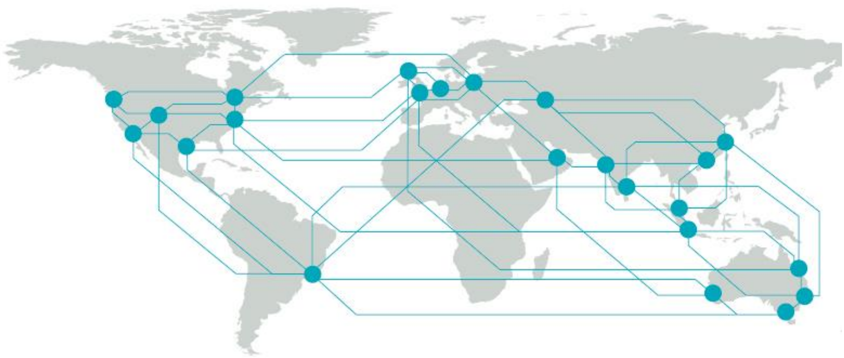
Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia.

IPWEAQ (2017). Queensland Urban Drainage Manual (QUDM), 4th Edition prepared by Institute of Public Works Engineering Australasia, Queensland Division, 2016.

TCC (undated) Request for Quotation: Townsville Recalibrated Flood Modelling and Mapping – Magnetic Island & Balgal Beach, RFQ002345.

TCC (2020) SC6.7.4 Attachment 1 - Guidelines for Preparation of Flood Studies and Reports, Townsville City Plan Version 2020/03.

BMT (OFFICIAL)



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Level 5
348 Edward Street
Brisbane
QLD 4000
Australia
+61 7 3831 6744

Registered in Australia
Registered no. 010 830 421
Registered office
Level 5, 348 Edward Street,
Brisbane QLD 4000 Australia

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