Peer Review of Alligator and Whites Creek Flood Modelling and Mapping

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Synopsis: **Peer Review of Alligator and Whites Creek flood modelling and mapping as part of Townsville City Council's Flood Modelling and Mapping Project.**

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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 four separate contracts with each contract pertaining to a hydrological catchment (or group of catchments). These four areas are modelled as separate domains by different consultants:

- Bohle River catchment
- Black River, Althaus and Bluewater Creeks
- Ross River and Surrounds
- Alligator Creek and Whites Creek.

This peer review report documents the review findings for the modelling contract undertaken for the **Alligator Creek and Whites Creek** catchments by Northern Consulting Engineers (NCE).

1.2 Supplied Data

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

- Townsville Recalibrated Flood Modelling and Mapping – Alligator Creek Report (NCE, June 2020)
- Request for Quotation: Townsville Recalibrated Flood Modelling and Mapping- Alligator Creek (TCC, October 2019)
- Townsville Recalibrated Flood Modelling and Mapping Naming Convention Report (TCC, March 2020)
- TUFLOW hydraulic model:
  - All model input files;
  - Peak result grids:
    - Calibration events;
    - Design events (processed for critical duration envelope);
    - Sensitivity scenario events (including afflux);

  - Critical duration analysis grids;
- Previous study result grids;
- XP-RAFTS hydrologic model;
  - All model files;
  - Storm Injector file and metadata;
  - Results outputs;
  - GIS Catchment layer; and
- DRAFT Review of Hydrological Methods for the Townsville Region, Phase 4 - AR&R 2019 Hydrologic Model Updates (AECOM, January 2020).

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;
- Commentary on differences in flood levels from previous assessments (which were developed based on the ARR1987 and the MIKE FLOOD modelling tool in 10m grid resolution); 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.

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 NCE. 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 NCE correspond to the definitions in the control files provided for the model runs.

2 Modelling Overview

A hydrologic model was prepared for TCC under a separate commission to NCEs contract as part of the 'Review of Hydrological Methods for the Townsville Region' project (AECOM, 2020). This hydrologic model was developed using XP-RAFTS software.

This hydrologic model was updated by NCE and then formed the basis of the hydraulic modelling inflows used by NCE. The updates made to the hydrologic model by NCE were of a relatively minor nature and involved splitting a limited number of subcatchments to provide greater resolution in areas of interest. This is reported as being at the request of TCC for the purpose of better accommodating the application of direct rainfall and to apply flows to individual watercourses in areas outside of direct rainfall extents.

A hydraulic model was developed by NCE using TUFLOW HPC software. This model used inflow hydrographs derived from the hydrologic XP-RAFTS model. For numerous sub-catchments within the hydraulic model extent (where they included urban areas), local XP-RAFTS inflows were replaced with direct rainfall inputs. It is assumed that this was to provide more detailed capture of overland flow paths within these areas.

3 Hydrologic Assessment

3.1 Background

As described in Section 2, the development of the hydrologic model used in the assessment (AECOM 2020), was undertaken separately to the modelling prepared by NCE and is separate to the contract which is subject to this peer review. NCE utilised the supplied hydrologic model, incorporating minor updates and resimulating to generate inputs for the hydraulic model. It is recognised that the hydrologic models and results provided to NCE were intended to be fit for purpose, and that a contract variation was granted for the minor updates. As such, NCE's reporting on the hydrologic model generally refers back to the AECOM report with documentation typically limited to the updates made by NCE. Whilst a review of AECOMs modelling is outside the scope of the peer review, the context of the AECOM modelling has been taken into consideration along with how it has been utilised by NCE. Our hydrologic modelling review is therefore limited to assessing the overall approach to design event modelling and consistency with ARR2019.

3.2 Design Event Hydrology (ARR2019)

Table 3-1 Hydrologic Model

ID	BMT Observation	BMT Recommendation
3.2.1.1	**Software Versions**: The AECOM "AR&R 2019 Hydrologic Model Updates Review of Hydrological Methods for the Townsville Region" report states XP-RAFTS version 2018.1 and Storm Injector 1.2.2.0 were used. The NCE report does not state the versions used for the updated model but the provided Storm Injector metadata file confirms the same version were utilised by NCE: *** CSS Ensemble Storm Injector (v1.2.2.0) Project *** C:\Program Files (x86)\Innovyze\xprafts2018.1.2\raftsEngW.exe	Suggest updating report to state the versions of RAFTS and Storm Injector used.
3.2.1.2	**XP-RAFTS configuration:** First subcatchment has been used for the 0% impervious portion of subcatchment, and the second subcatchment used for 100% impervious portion, as recommended by XP-RAFTS. Areas were compared between XP-RAFTS subcatchment and GIS layers. The total catchment area appears consistent, but several subcatchment areas were found to differ by up to about 20%.	As noted by NCE, the provided hydrologic model has subcatchment areas that do not match the GIS catchment delineation. Further investigation is recommended.
3.2.1.3	**IFD locations:** Storm Injector is configured to apply one IFD location for all subcatchments. This will not capture any spatial variability in IFDs across the catchment but could still be appropriate if it represents a suitable catchment average.	NCE reporting would benefit from a summary of applied ARR2019 hydrologic parameters, and documentation of the

ID	BMT Observation	BMT Recommendation
	It is understood that this is as per the configuration supplied by AECOM.	appropriateness of a single IFD location.
3.2.1.4	**Areal reduction:** Storm Injector is configured to apply ARR2019 areal reduction factors relevant to the selected IFD location, as documented in AECOM's "AR&R 2019 Hydrologic Model Updates Review of Hydrological Methods for the Townsville Region" .	Appropriate NCE reporting would benefit from a summary of applied ARR2019 hydrologic parameters.
3.2.1.5	**Temporal patterns:** Storm Injector is configured to apply ARR2019 ensemble point temporal patterns (with smoothing applied to remove embedded bursts), relevant to the selected IFD location, as documented in AECOM's "AR&R 2019 Hydrologic Model Updates Review of Hydrological Methods for the Townsville Region"	Appropriate NCE reporting would benefit from a summary of applied ARR2019 hydrologic parameters.
3.2.1.6	**Bx:** A Bx storage factor of 1 has been applied for design events, as documented in AECOM's "AR&R 2019 Hydrologic Model Updates Review of Hydrological Methods for the Townsville Region"	Appropriate NCE reporting would benefit from a summary of applied hydrologic model parameters.
3.2.1.7	**Losses and Pre-burst Excess:** The ARR2019 Data Hub initial and continuing losses have been overwritten with those selected from calibration, as documented in AECOM's "AR&R 2019 Hydrologic Model Updates Review of Hydrological Methods for the Townsville Region". Burst excess has been applied to the storm.	Appropriate NCE reporting would benefit from a summary of applied hydrologic model parameters.
3.2.1.8	**XP-RAFTS model directory structure:** The model directory structure for adopted for GIS hydraulic model outputs is sensible and generally conforms with the information in the Naming Convention document.	Appropriate.

ID	BMT Observation	BMT Recommendation
3.2.1.9	**XP-RAFTS results:** Following review by NCE as part of their verification of the direct rainfall approach, they noted discrepancies in the hydrologic inputs and have recommended review of the hydrologic model. Based on the information presented by NCE in their direct rainfall verification, BMT support this recommendation, as the results of the hydrologic modelling underpin the hydraulic modelling outcomes.	Recommend that the hydrology modelling is reviewed, noting a similar recommendation made by NCE.

4 Hydraulic Assessment

The following sections provide commentary and recommendations following peer review of the TUFLOW hydraulic model configuration and modelling approach.

4.1 General considerations

Table 4-1 Hydraulic Model – General considerations

ID	BMT Observation	BMT Recommendation
4.1.1.1	**Executable version:** Simulations were confirmed to have been undertaken with TUFLOW Build 2018-03-AE (reported by NCE as the latest version available at the time the project was commenced). This is consistent with the study RFQ, which requested the latest version.	Appropriate.
4.1.1.2	**Executable Precision**: Simulations were confirmed to have been undertaken with the single precision (iSP) version of the TUFLOW Build. This is appropriate for use with direct rainfall modelling when simulating with the HPC Solver.	Appropriate.
4.1.1.3	**Control file structure:** A single TCF has been configured to contain all relevant scenarios and events. The configuration of logic blocks and the use of automatic variables has been reviewed, and is confirmed to be appropriately defined and utilised, effectively organising model inputs and outputs. This is considered good practice, and is recommended.	Appropriate
4.1.1.4	**Events simulated:** Design, sensitivity and calibration events modelled and mapped as specified in the study RFQ.	Appropriate.
4.1.1.5	**Critical duration - Approach:** The hydrology model has been used to select a single representative temporal pattern per duration for application to the entire model, based on an assessment of three separate locations. The hydraulic model has then been used to select the critical duration/temporal pattern combinations that produce the peak flood levels across the study area, based on the 1% AEP event. NCE's report Section 6.2 (critical duration assessment) quotes ARR2019 to justify selection of a single representative mean temporal pattern. It is BMTs understanding that the ARR approach for	The simplified approach is considered appropriate. It is recommended to include temporal pattern hydrograph plots and box plots to make the selection clearer, and demonstrate the spread of results.

ID	BMT Observation	BMT Recommendation
	selection of a mean temporal pattern relates to a specific location of interest. For a flood study such as this, the entire area could be considered of interest. NCE has selected three separate locations to assess, and have selected a single temporal pattern per duration to represent all three. NCE's adopted approach is considered a simplification of the usually adopted process of running (in this case) up to three separate critical temporal patterns (one for each of the three locations of interest). Justification of the simplified approach is provided by comparing flows for: • The adopted representative temporal pattern as used in the study • The critical (based on mean flow) temporal pattern at each location If the adopted representative temporal pattern produced flows that were within 5% of those from the critical temporal pattern for a given location, then the adopted representative temporal patterns were considered acceptable for use. BMT is satisfied with the approach undertaken noting that the flows were within 5%.	To verify that the hydrologic modelled flows and hydraulic modelled flows are in general agreement (and could be expected that a critical temporal pattern assessment would give similar results in the hydrologic and hydraulic models), it is recommended that peak flows from the hydraulic and hydrologic models are compared at the three nominated locations. Note that if there is a wider issue with the hydrologic model (as flagged in NCE's direct rainfall verification) then this issue may not be apparent from this comparison as the hydrologic flow hydrographs are used as input to the hydraulic model, in addition to areas of direct rainfall.
4.1.1.6	**Critical duration – documentation:** Noted that NCE's Report Table 6.1 And Appendix D references 50% as selected as a representative AEP, but later text and maps reference 20%.	Minor text amendment required.
4.1.1.7	**Critical duration - Confirmation of selection**: The processed 1% AEP critical duration map was inspected and critical duration/temporal pattern combinations were confirmed to have been appropriately selected based on the spatial results. It is noted that the spatial mapping of critical durations run for the PMF indicate that the 6 hour was not critical in any significant area - simulating this duration for the other scenarios may have been unnecessary.	Appropriate.
4.1.1.8	**Naming convention - TCF and raw outputs:** TCC's Naming Convention document was reviewed and compared to the model TCF filename (and hence raw results output filename) configuration. Identifiers specified by TCC were generally appropriately assigned by NCE, however minor differences in the configuration of model filenames were identified:	Identifiers were generally assigned appropriately and are clear, and filenaming does not impact results. However, it is expected that TCC will require consistency across other studies by other consultants.

ID	BMT Observation	BMT Recommendation
	• a single scenario has been simulated for each of the climate change and joint probability scenarios (CC, JP and JPCC), however these have not been attached an '01' iteration ID as specified in the RFQ. If there is not expected to be more than a single time horizon/type of each of these scenarios than this may be acceptable. • the format of the TCF filename, and hence the output raw results, has been configured by NCE with underscores and not hyphens as appears to be specified in Section 2.5 of the Naming Convention. This may only be significant should the format differ from other consultant's studies, and TCC wish to ensure consistency. the format of the TCF filename, and hence the raw output results, has been configured by NCE with an underscore between the ""EEE"" event and ""FFF"" ""GGGG"" duration/temporal pattern identifiers. Section 2.5 of the Naming Convention specifies no character between the event and duration identifiers. However, it is noted that in post-processing and enveloping results of critical storms for each design event, the ""FFF""""GGGG"" identifier is necessarily removed anyway.	TCC to review if the filenaming of models and results is acceptable, and appropriately consistent with other consultants' studies as required.
4.1.1.9	**Naming convention - post-processed outputs:** It is good practice for post-processed results filenames to reflect the raw results filenames as much as practically possible (with consideration, for example, to appropriate naming when enveloping results) for clarity on simulation source. The post-processed results' filenames were confirmed to be consistent with the TCF and raw output filename configuration (after accounting for enveloping results of critical storms for each design event, e.g. the "FFF""GGGG" identifier is necessarily removed).	If changes are deemed to be required to model file names, then post-processed results' filenames will need to be equivalently updated.
4.1.1.10	**Naming Convention – inputs:** Filename structure for model inputs appears generally consistent with that specified in TCC's Naming Convention document. However minor differences were identified: • with the order of information; and • with the use of underscores instead of hyphens. All inputs are currently assigned an iteration "001" identifier consistent with the TCF iteration. Some filenames additionally include the "ZZZ" scenario identifier as appropriate. Hydrology output files have been appropriately renamed for application to TULFOW with the equivalent identifiers in the filenames that allow effective use of event and scenario logic.	Appropriate. There are minor differences, however these do not affect the outcome of results, and are unlikely to cause issues if there is any inconsistency in approach with other consultants' studies.
4.1.1.11	**Naming Convention - Model directory structure:** The Naming Convention document does not comprehensively describe the folder structure required to categorise all outputs.	Appropriate

ID	BMT Observation	BMT Recommendation
	The hydraulic model folder structure conforms with that recommended by TUFLOW, and accepted as best practice. The model directory structure adopted for GIS hydraulic model outputs is sensible and generally conforms with the information in the Naming Convention document.	

4.2 Model Structure

4.2.1 TUFLOW Control File (TCF)

Table 4-2 Hydraulic Model – TUFLOW Control File

ID	BMT Observation	BMT Recommendation
4.2.1.1	**Solution Scheme:** Simulations were configured with the TUFLOW HPC Solver, as specified in the study RFQ. GPU hardware has been appropriately set for the most efficient application of the HPC Solver.	Appropriate.
4.2.1.2	**Projection**: The model is correctly configured in projection GDA94 MGA Zone 55.	Appropriate.
4.2.1.3	**Cell wet dry depth**: Appropriately set to 0.0002 m, as recommended for direct rainfall modelling. This is also recommended where steep flow occurs.	Appropriate.
4.2.1.4	**Start Time**: Set to 0 hours for all scenarios. BMT do not have access to the raw tidal and rainfall data for calibration events. It is assumed that these inputs were appropriately converted from real-world time for the simulation periods specified in reporting, and that results were appropriately converted back for comparison against the actual recorded gauge data.	Appropriate, assuming calibration data has been correctly converted for the relevant period.
4.2.1.5	**Timestep:** The initial timestep is set. HPC uses adaptive timestepping thereafter by default.	Appropriate.
4.2.1.6	**Map Output Types**: • Map output data types for maximum gridded datasets have been specified consistent with the study RFQ. • Hazard results were mapped as per TCC's flood hazard criteria, following post-processing from TUFLOW's Z4 output (confirmed in accordance with email correspondence between NCE and TCC). Temporal data (XMDF format) is written only for water level, velocity and depth.	Appropriate. It is noted that output type ZAEM1 (food hazard category as outlined by Australian Emergency Management Institute in 2014) was not specified, however is a commonly required

ID	BMT Observation	BMT Recommendation
	• Minimum timestep (dt) has been additionally specified, appropriate for allowing assessment of HPC stability.	output, and its inclusion should be considered for any future simulations.
4.2.1.7	**Map Output Format**: Map output format does not appear to have been specified in the study RFQ. XMDF and FLT formats have been selected for temporal and maximum gridded results, respectively. These are standard and considered acceptable.	Appropriate.
4.2.1.8	**Map Output Intervals**: Values selected are reasonable given the length of simulation. Temporal output is appropriately turned off for gridded datasets - only maximums are output.	Appropriate.
4.2.1.9	**Matrix Blockage**: Event and structure size dependent blockage has been assigned to culvert/pipe elements (consistent with ARR2019) utilising TUFLOW Matrix Blockage functionality. The approach to derive design blockage values is generally in accordance with ARR2019 and is considered appropriate. The Reduced Area Method of blockage has been specified, this is appropriate. The TUFLOW Matrix Blockage has been confirmed to be configured correctly, consistent with the values reported upon. Adopted matrix blockage values, as reported on, were cross checked against ARR2019 Table 6.6.6, and confirmed to be correct except for the value for Large culverts in Rare events - however this value is not utilised in the modelling (all culverts are small or medium). This will not affect any results. Overrides for the blockage sensitivity scenarios (to force 0% or 50% blockage for all events) were also confirmed to be configured correctly.	Appropriate. Update report Table 6.5 blockage value from 0% to 10% for Large culverts in Rare events.
4.2.1.10	**Plot Outputs:** A limited number of plot output (2d_po) reporting lines (flow) and points (water level) have been included in the model. They appropriately capture the water level and flow at the two gauged sites on Whites Creek and Alligator Creek. The orientation and location are reasonable, and the 2d_po flow lines are mostly of sufficient length to capture the entire flow width up to the 0.05% AEP. The 2d_po at Alligator Creek gauge does not extend entirely across the flowpath in the 0.2% and 0.05% AEP events, however the missing section appears to likely be backflow, and the current 2d_po would capture the majority of flow conveyance. This could be extended, however it is likely to have minimal impact on the peak flow rate results reported for these events. 2d_po lines do not appropriately capture flow rates for the PMF.	Generally appropriate. The extent of the 2d_po line at the Alligator Creek gauge could be reviewed to ensure it is sufficiently capturing flow. Flow rates at 2d_po lines should not be used for the PMF. The inclusion of additional reporting 2d_po lines and points could be considered for future simulations, to ensure data is available at more

ID	BMT Observation	BMT Recommendation
		points of interest, and to aid in model review and quality assurance.
4.2.1.11	**Checkfiles**: The output of checkfiles is appropriately configured, with some types of larger file size excluded. As checkfiles can be easily reproduced later if required, this is reasonable.	Appropriate. Additional organisational functionality (scenario/event logic) could be added in future to reduce the repetition of some checkfiles that would not change with design even simulations (e.g. geometry checkfiles).
4.2.1.12	**Initial Water Levels**: Confirmed that the initial water levels (IWLs) called for each scenario from the TCF correctly match the downstream boundary static value or initial timeseries value called from the relevant bc_dbase, and are as per reporting, except for March 2018 calibration event. This event is set to an IWL of -1.05m, whereas the downstream boundary timeseries begins at -0.05m. A disparity such as this may cause stability issues at the beginning of the simulation, as the boundary pushes water into the model. However, HPC's adaptive time-stepping will generally cope with a situation such as this, though simulation time may be affected if this configuration causes the model's controlling timestep. Due to the low elevations and minimal extent of model that this would affect, this is not expected to affect the results of the calibration at the gauge locations, nor the mapped extents of the calibration results. It is noted that no bathymetry or creek topographic modifications have been included in the model, so bed elevations of some downstream creeks and estuaries are set to a "ground" elevation higher than some of the IWL scenarios.	Mostly appropriate, however the March 2018 event IWL does not match the start of the downstream boundary timeseries. Correcting this is not expected to have an impact on the peak flood levels.

ID	BMT Observation	BMT Recommendation
4.2.1.13	**Set Variable iteration == 001**: It is noted that a variable is set for 'iteration', which is used to automatically organise model outputs to folders. However, this is decoupled from the actual model version/iteration which is 'hardcoded' into the TCF file name. This is not currently an issue as the 'iteration' variable is appropriately set to "001" to match the TCF filename, however it is flagged that this may not be a clear update that is required by any future users of the model. It appears that the only consequence of a user failing to appropriately update the set 'iteration' variable along with any future TCF filename iterations would be for checks and results to be written to an incorrectly named folder.	No consequence to current modelling.
4.2.1.14	**CSV Time == Hours**: The timeseries output units are set to hours. It is noted that this is the default in the absence of this specific command anyway.	Appropriate.
4.2.1.15	**XFs**: XF files are used by default.	Appropriate.
4.2.1.16	**Map Output Cutoff Depth**: Direct rainfall modelling requires filtering of results to remove shallow depths to produce a more usable product. The automatic Map Output Cutoff Depth command has not been used to directly filter results prior to output by TUFLOW. This is consistent with the study RFQ which identifies filtering the direct rainfall results through post-processing by applying Council's own depth and velocity dependent filtering criteria.	Appropriate.

4.2.2 TUFLOW Event File (TEF)

Table 4-3 Hydraulic Model – TUFLOW Event File

ID	BMT Observation	BMT Recommendation
4.2.2.1	**Structure**: Definition blocks set up correctly and neatly.	Appropriate.
4.2.2.2	**End Time**: The same end time is set for all temporal patterns (TPs) for a given duration. Appropriate results files (e.g. PO CSVs and t_maxh) were not available to BMT to confirm that simulations had been run for a sufficient length of time to capture peak flow throughout the model, or if durations were being simulated for an excessive period.	Configured appropriately. NCE to ensure that end times have been set to capture peak flows.
4.2.2.3	**BC Event Source**: The text for each BC Event Source was confirmed to match the relevant event definition block it is within.	Appropriate.
4.2.2.4	**Blockage**: Blockage event groups (Blockage ARI) necessary for the application of Matrix Blockage functionality (see TCF Section 4.2.1). The relevant Blockage ARI was confirmed to have been assigned correctly for each event definition.	Appropriate.

4.2.3 TUFLOW Geometry File (TGC)

Table 4-4 Hydraulic Model – TUFLOW Geometry File

ID	BMT Observation	BMT Recommendation
4.2.3.1	**Code and orientation**: The domain extent and orientation are reasonable in relation to active code area - there is not significant redundant area included that may impact on memory requirements. The active code extent is generally appropriate, with the upstream subcatchments trimmed to only capture the downstream end where the source area and external QT inflows are applied. The entire subcatchments are included in the active code extent where direct rainfall is applied. However, the extents of the code boundary along the east and west sides of the downstream areas cause 'glasswalling' of water, as shown in Figure 4-1 below this table. The sides of the active code here are not connected to open boundary cells. It is recognised that these areas of glasswalling are limited to the tidal/estuary zones, well downstream of the area of interest, and that assumptions such as this are likely necessary. The eastern downstream area is one of particular uncertainty, due to the likely interactions with Crocodile Creek that would occur in reality, which has been excluded from consideration in this modelling. There is minor area of glasswalling in events larger than the 0.5% AEP at subcatchment KM-1-DS. This is not expected to have a significant impact on results.	Glasswalling at downstream area of active code boundary. Reporting would benefit from additional detail/explanation on the model configuration in this area. It should be confirmed in the report that such areas are not specific areas of interest and that results should be treated with caution near to these affected boundaries.
4.2.3.2	**Cell Size**: The model has a 5m grid resolution, which is consistent with the study RFQ, and is considered appropriate for fit-for-purpose model.	Appropriate.
4.2.3.3	**Hydraulic Roughness:** Three GIS delineation layers have been defined. These were confirmed to be appropriately layered. Gaps in the delineation correspond to road corridors, and these areas are appropriately infilled with the default Mat ID of 1. It is noted that the ocean area is also undefined, and will hence have the Roads Mat ID of 1 applied to it. Considering the value for this ID is 0.03, this is a reasonable, however it is preferential for the areas to be clearly delineated from each other. The DEM_M (land use check file) was confirmed to contain all 10 Mat IDs specified in the TMF. Inspection of the DEM_M and input files confirmed that delineation of hydraulic roughness categories appears appropriate, and suitable Mat IDs have been appropriately assigned to those delineated areas. Delineation of categories is generally quite coarse (i.e. lumped definitions based on broad land use categories), however this is considered suitable for study objectives. It is noted that this layer also defines the spatial distribution of material-dependent losses via the	Appropriate for catchment scale. Delineation of hydraulic roughness categories could be further refined if used for localised assessments.

ID	BMT Observation	BMT Recommendation
	Materials CSV definition file (see TMF Section 4.2.4 for further discussion), applied for 2d_rf direct rainfall areas.	
4.2.3.4	**Base Topography**: Three base LiDAR topographic datasets are used in the model. These appear to be layered and clipped appropriately relative to capture date. Reporting does not clearly document the metadata for the datasets, including resolution (confirmed as 1m from inspecting datasets), nor the available extent of each LiDAR source. The 2018/2019 LiDAR data has been used to represent the Elliot Springs subdivision, however it is unclear if this data may cover a wider area where it should have been used in preference to the 2016 LiDAR. If this were the case, it is unclear from reporting if the 2016 LiDAR was comparable to the 2018/2019 LiDAR elsewhere, or if there was other justification for limiting its extent of application or comparison provided. The clipped extents of the 2018/2019 LiDAR included in the model was confirmed to merge well with the underlying 2016 LiDAR. However, the join between the 2016 and 2009 LiDAR datasets in the downstream extent of the model did not show good agreeance, as demonstrated in Figure 4-2, below this table. The 2009 LiDAR is generally higher across the floodplain areas, and the watercourse channels are generally lower (likely due to the data capture at different tide levels). This may create a minor damming effect at low water levels. The LiDAR also has poor triangulation across the channels in the downstream area, and as it picks up the tidal level at the time of capture, many creeks are represented with topography that is higher than set IWLs and boundary conditions. It is recognised that these areas are still likely controlled by the downstream boundary conditions and don't affect the main area of interest up Alligator and Whites creeks (as evident from the results of the Joint Probability assessment). For the climate change and joint probability scenarios, the initial water level is set at an elevation that submerges these poorly merged areas.	Generally appropriate. Reporting would benefit from specifying metadata for the input LiDAR datasets, including resolution, and clarification of the available data extents and choices in clipping them. Topographic edits could be made to merge the different datasets together more smoothly and eliminate triangulation issues in the LiDAR, particularly in the creek channels but ultimately this is unlikely to affect project outcomes given the downstream location. Similar to the glasswalling comment for ID 4.2.3.1, a general limitation should be given on the accuracy of results in this downstream area. This would also apply to smaller modelled events where limitations of having no bathymetry would have a greater influence.
4.2.3.5	**Default Elevations**: A default elevation of -1m has been applied to the model. This infills areas where there are null values in the base LiDAR datasets, including at the ocean and a number of locations along channels near the ocean. Although this makes the channel uneven, these areas are submerged by the ocean boundary condition and initial water levels anyway.	Appropriate.
4.2.3.6	**Fill embankments**: Where the LiDAR incorrectly filtered out embankments, TUFLOW 2d_zsh terrain modifiers have been used to infill the embankments. Whilst we have confirmed that such embankments have been infilled, we can only assume they represent the correct levels.	Appropriate.

ID	BMT Observation	BMT Recommendation
4.2.3.7	**Enforce crests**: Major road and rail crests have been enforced with TUFLOW 2d_zsh terrain modifiers. It was confirmed in checkfiles that the major flow-controlling routes across the floodplain have been enforced.	Appropriate.
4.2.3.8	**Watercourse channels**: It is common for the bed of drainage paths/watercourses to be enforced with TUFLOW "gully" 2d_zsh terrain modifiers, particularly where the model resolution is insufficient to effectively capture the watercourse inverts, unrealistically obstructing the free drainage of runoff. Enforcement of bed elevations has not been included in this model.	Consider enforcing minor watercourse bed elevations with topographic modifications. This would have a greater impact in the area of direct rainfall application, and on smaller events.
4.2.3.9	**Bathymetry**: The model does not include any representation of bathymetry. It is recognised that this data may not exist. However, it is noted that the different base LiDAR topography datasets pick up different tidal water levels (due to time of capture) in the downstream sections (with some sudden step changes) and there is uneven triangulation across the downstream extents of Alligator Creek and the estuaries. Some areas of creek channels are set to a higher "ground" elevation than some of the initial water levels set for different scenarios.	Reporting would benefit from discussion on the necessity (or lack thereof) for inclusion of data or assumptions about bathymetry. The impact of not including bathymetry is unknown but is potentially not significant for larger events that are largely out of bank. It may have a greater impact on smaller events however.
4.2.3.10	**Bridges**: Bridges have been included as TUFLOW layered flow constriction elements (2d_lfcsh) and have been generally configured appropriately. Reporting does not provided any detail on supplied datasets (e.g. as-constructed drawings) nor summaries of the values adopted for blockage and constriction factors in each layer of the element. A generic FLC value for the bridge deck of 0.8 has been specified. A value of 1.56 is typically used, however this is unlikely to result in any changes to modelling outcomes. TUFLOW also recommends that the FLC values calculated for the sub-structure (in accordance with Hydraulics of Bridge Waterways) already accounts for the blockage provided by the piers, and hence additional blockage factor is not required to account for this as it may over-represent losses. This may lead to slightly conservative results but given the head losses for two key structures were validated with a HEC-RAS 1D model the approach is considered satisfactory.	Reporting would benefit from a brief discussion as to how sub-structure bridge form losses were derived or assumed. It is usual practice to calculate these in accordance with industry standard publications such as “Hydraulic Design of Waterway Structures” (Austroads, 2019). It is noted that the values appear within the expected range.
4.2.3.11	**Initial water level of dams:** The model area includes numerous farm dams. Water levels have not been set for any dams, so the LiDAR level picked up from the water surface will be enforced as a “ground” level. A conservative approach would be to assume these dams are at full supply level (set	Reporting would benefit from discussion on the necessity (or lack thereof) for including a conservative

ID	BMT Observation	BMT Recommendation
	with GIS IWL functionality) and not contributing to additional storage and detention of runoff from the catchment, however it is recognised this data may not be available. The base LiDAR topography picks up approximate water levels in the dams at the time of capture.	dam "full supply" assumption. It is not expected that this has a significant impact on results, however there would likely be a greater impact in smaller events.

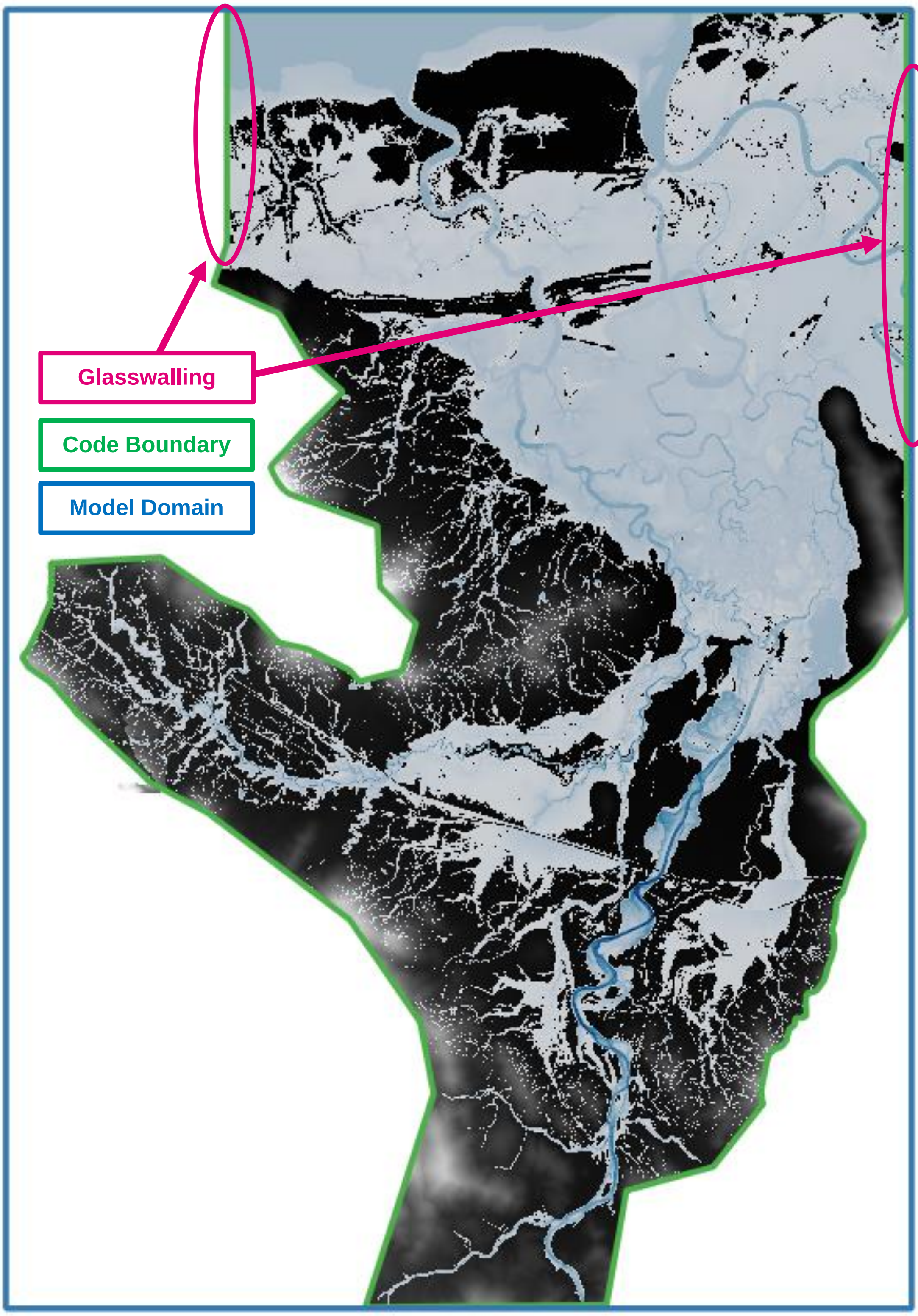

Figure 4-1 Glasswalling in downstream area (1% AEP event)

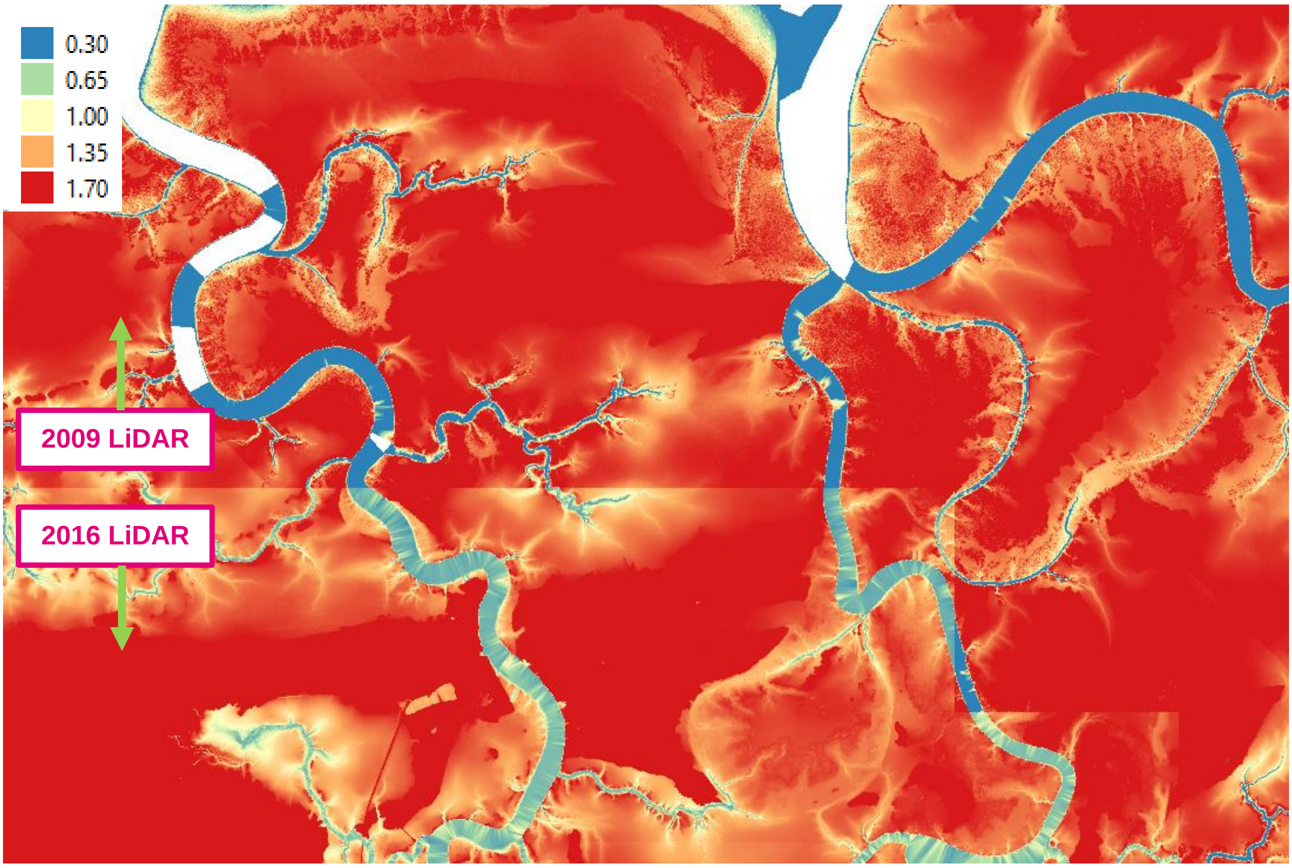

Figure 4-2 Incongruent elevations between boundary of 2009 and 2016 LiDAR datasets

4.2.4 TUFLOW Materials File (Materials*.csv)

Table 4-5 Hydraulic Model – TUFLOW Materials File

ID	BMT Observation	BMT Recommendation
1.1.1.1	The scenario-dependent Materials definition CSV was confirmed to contain values as per reporting for the default scenario. These values are within the standard range of Manning's n roughness values, and are considered appropriate. A sufficient range of values has been defined to sufficiently define the hydraulic characteristics for the model. It was confirmed that the Materials definition CSVs for the RS01 and RS02 sensitivity scenarios correctly increased and decreased the Mannings roughness values by 30% (as per reporting), respectively, compared to the default definitions for all other scenarios (design and calibration). The GIS spatial delineation of landuse (specified in TGC) and this Materials definition CSV also defines material-dependent rainfall losses through TUFLOW variables. These losses apply to parts of the model where direct rainfall has been used in place of hydrologic model inputs. Rainfall losses appear to be configured appropriately and assigned appropriate values but their derivation and method of application should be reported on.	Reporting would benefit from additional explanation of how losses have been adopted, applied and scaled.

4.2.5 TUFLOW Read File (TRD)

Table 4-6 TUFLOW Read File

ID	BMT Observation	BMT Recommendation
4.2.5.1	A separate control file has been created to set the event and duration dependant initial and continuing rainfall loss variables. These variables are then implemented on a materials-dependant basis in the Materials CSV for areas where direct rainfall is applied. See Materials CSV Section 0 for more comments. No discussion or summary of applied losses has been included in the reporting, therefore it is not clear if the values set are appropriate. Losses appear to have been proportionally reduced based on increased imperviousness, noting that ARF reduced median burst losses appear to be removed from the Initial Loss after scaling. This could	Reporting would benefit from additional explanation of how losses have been adopted, applied and scaled. The structure of the losses TRD control file is not as clear as it could be, and would benefit from improvement, to reduce the risk of misinterpretation by future users. However, the functionality appears to be correct.

ID	BMT Observation	BMT Recommendation
	be reported upon and confirmed. The losses TRD is formatted poorly, with the first "If Event == PMF" needing to be appropriately indented as a sub-logic block below the "Else" of the "If Scenario == CAL" block. Scenarios and Events cannot be combined as part of the same If/Else logic blocks (e.g. If **Scenario** XX, Else If **Event** YY, End If), though they can be configured within each other. Although the current formatting results in the correct functionality, confirmed in .tlf log files, the structure may be confusing to future users.	

4.2.6 TUFLOW Boundary File (TBC)

Table 4-7 Hydraulic Model – TUFLOW Boundary File

ID	BMT Observation	BMT Recommendation
4.2.6.1	**Downstream boundary**: The downstream boundary is configured as a 2d_bc HT type (level vs time), digitised snapped to the northern side of the active code boundary. There are no open boundary cells along the east and west sides of the code boundary in the downstream area. The "glass walling" of flows in these areas is discussed further in the TGC Code Section 4.2.3. The boundary element is correctly linked to relevant source data in the scenario-dependent bc_dbases (see Section 4.2.8 for further discussion).	Glasswalling at downstream area of active code boundary. Reporting would benefit from additional detail/explanation on the model configuration in this area, and the reliability/applicability of results in the downstream areas that may be impacted by these boundary/code assumptions, and at Crocodile Creek.
4.2.6.2	**External Inflows**: The external boundaries are configured as a 2d_bc QT type(flow vs time), digitised snapped to the active code boundary. The boundary elements are correctly linked to source data for the relevant catchment ID in the scenario-dependent bc_dbase (see Section 4.2.8 for further discussion), and to "Total flow" .tot XP-RAFTS outputs.	Appropriate.
4.2.6.3	**Source-Area Inflows**: The 2d_sa source area inflows are generally being applied near the downstream end of each subcatchment, which is considered appropriate. The boundary elements are correctly linked to source data for the relevant catchment ID in the scenario-dependent bc_dbase (see Section 4.2.8 for further discussion), and to "Local flow" .loc XP-RAFTS outputs.	Appropriate.

ID	BMT Observation	BMT Recommendation
4.2.6.4	**Direct Rainfall Inflows**: The direct rainfall inflows are applied as two separate 2d_rf polygons. The areas of application are assumed to have been agreed with TCC to appropriately cover "urban" areas, as requested in the RFQ. Rainfall inputs have been confirmed to be correctly linked to event and duration dependent hyetograph CSVs in the scenario-dependent bc_dbases. The hyetographs were confirmed to be configured with 0 values at first and last timesteps as recommended by TUFLOW. Reporting does not document the methodology of applying the direct rainfall boundaries, nor the relevant ARR2019 parameters. It therefore cannot be completely confirmed that the input hyetographs are correct. It appears that the same or similar data for the IFD location used in the hydrologic modelling has been used. Input hyetographs were spot checked and confirmed to have an appropriate total rainfall with areal reduction factor applied (though did not match the hydrologic model inputs exactly). The hyetographs for the two 2d_rf polygon sources were identical for design events, and differed based on gauged data for calibration which allows for a spatial rainfall pattern in the calibration. Currently, the 2d_rf polygon extents appear to use the XP-RAFTS subcatchment delineation. However, it is recommended that the 2d_rf polygons are aligned with more accurate topographic boundaries derived from LiDAR data (or be inset from the subcatchment boundaries), to ensure that they do not inadvertently extend into neighbouring catchments. Where the boundaries are not configured exactly along the crest of a subcatchment (in accordance with the base LiDAR topography), the 2d_rf polygon is sometimes being applied over model cells that drain into the neighbouring catchment. This is evident in all subcatchments bordering the 2d_rf area. These adjacent (non-direct rainfall) subcatchments then result in rainfall runoff trickling into the subcatchment and showing as a flow path in the resultant mapping, see example in Figure 4-3, below this table. These flows will not be representative of design flows and could be misinterpreted in the mapping. It is recommended that instances of this are either fixed by adjusting the model boundaries or appropriately caveated in the report/mapped figures.	Reporting requires additional detail/explanation on the application methodology and parameterisation of the direct rainfall, particularly in relation to ARR2019 compliance. Direct rainfall 2d_rf polygons should be aligned with more accurate lidar data (or inset from the top of catchment) to prevent minor spillage into neighbouring subcatchments. If left as is, appropriate caveats should be included in the mapping/reports.
4.2.6.5	**SX (1D-2D connection):** All 1d SX connections utilise the Z flag to lower 2D boundary cell elevations to sit below the 1d channel invert levels. The TLF log file/messages layer identifies numerous WARNING 2118 (where the cell elevation is lowered by more	Generally appropriate. Review WARNING 2118 messages and confirm

ID	BMT Observation	BMT Recommendation
	than 0.3m). Spot checking of these locations shows many that are around, or higher than, 1m. Confirmed that the appropriate number of boundary cells were selected for the total structure widths of elements, and that the number of boundary cells was consistent at the upstream and downstream ends of the structure. The location of boundary cells selected was generally appropriate.	that the Z flag, in combination with the positioning of the boundary cells, has not excessively lowered topography creating any unacceptable holes, or breaks in embankment crests.

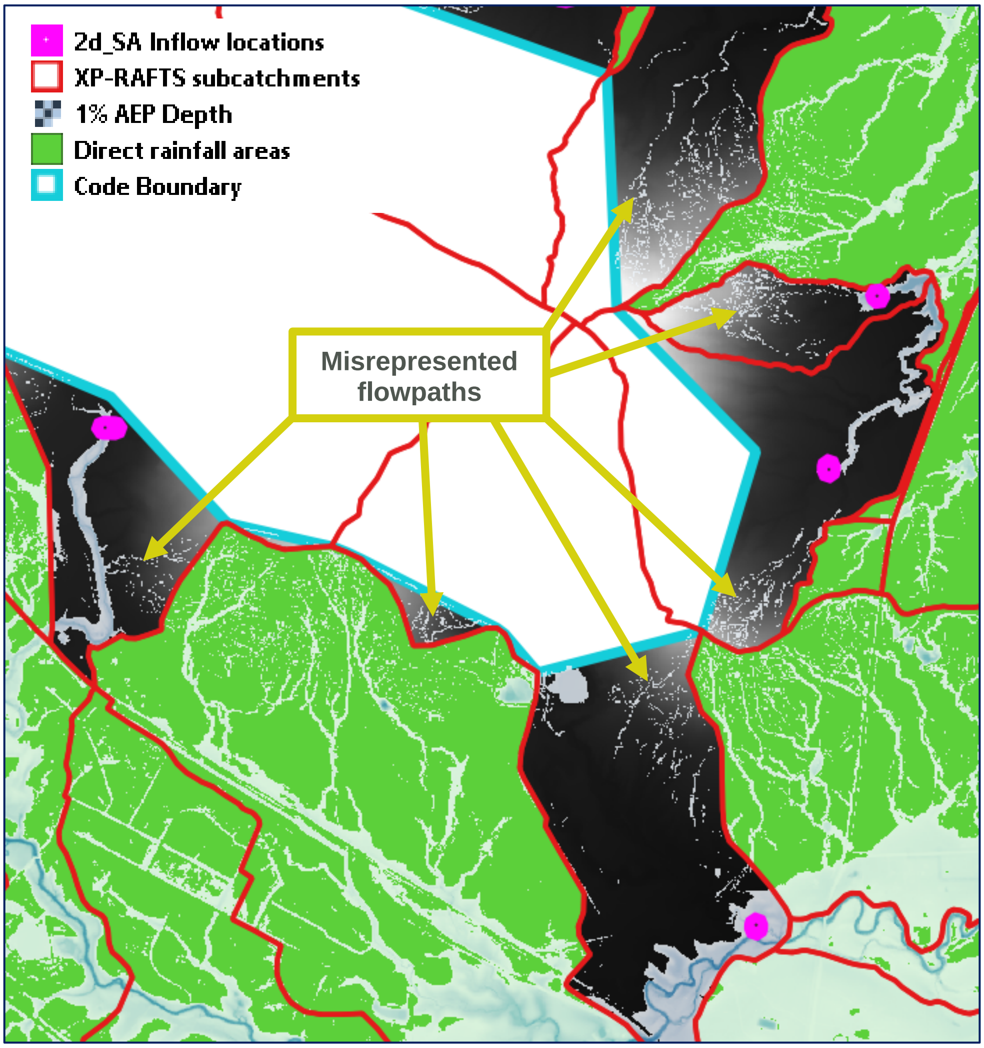

Figure 4-3 Example of direct rainfall causing mispresented flowpaths in neighbouring source-area-represented catchments

4.2.7 ESTRY Control File (ECF)

Table 4-8 Hydraulic Model – ESTRY Control File

ID	BMT Observation	BMT Recommendation
4.2.7.1	**Timestep**: The initial timestep is set. HPC uses adaptive timestepping thereafter by default.	Appropriate.
4.2.7.2	**Pipe Locations**: It is assumed that IDs, dimension data and spatial locations of culvert/pipe elements has been correctly assigned to TUFLOW as per the supplied network data - review of the base dataset is outside of BMT's scope. Cross drainage elements appear to have been appropriately and consistently included where embankments cross watercourses.	Appropriate.
4.2.7.3	**Pipe Mannings Roughness:** NCE reporting identifies that a Manning's N roughness of 0.013 has been applied to all culverts. Assuming concrete pipes/culverts, then this value is typical and industry-accepted. However, a number of circular culverts (IDs start with "QR_") have a value of 0.024 applied, which is somewhat high assuming these are concrete, which would typically be in the range of 0.012-0.015.	Confirm intended values of Manning's N roughness applied. To ensure consistency, update inputs or update reporting Should the values for the inconsistent pipes be lowered, this is not expected to have a significant impact on results.
4.2.7.4	**Pipe Lengths**: It is assumed that dimension data has been correctly assigned to TUFLOW as per the supplied network data - review of the base dataset is outside of BMT's scope. Checkfiles were inspected for any unusually short or long elements, none were found to be inappropriate.	Appropriate.
4.2.7.5	**Pipe Diameters**: NCE reporting identifies that "culverts with an equivalent diameter greater than or equal to 600 mm were included in the model. Multi barrel smaller culverts were included if the total cross-sectional area of the culvert group was greater than or equal to that of a single 600 mm pipe." This is a reasonable assumption given the scale of modelling and purpose. Confirmed that included culverts/pipes were consistent with this approach. Checkfiles were inspected for any diameters and number of barrels that resulted in a total structure width that was excessive. The elements with the largest total width were manually inspected and confirmed to be appropriate for the surrounding topography, and were confirmed to have sufficient boundary cells connected.	Appropriate.

ID	BMT Observation	BMT Recommendation
4.2.7.6	**Pipe Loss Coefficients**: Recommended TUFLOW values for entry and exit loss and height and width contraction coefficients have generally been correctly applied to circular and rectangular culverts/pipes, except for several of circular culverts (IDs start with "ES_") which are missing the recommended loss coefficients.	Generally appropriate. The recommended loss coefficients should be applied where missing for several circular culverts, however this is not expected to make a significant impact to results.
4.2.7.7	**Pipe Gradients**: Confirmed no adverse gradients for individual 1d_nwk elements. For the elements with the highest gradient, it was confirmed that this appeared appropriate with the surrounding topography.	Appropriate.
4.2.7.8	**Pipe Blockage**: Confirmed that that correct Matrix Blockage class was assigned based on culvert width or diameter. Checkfiles from different event groups were spot checked, and it was confirmed that the appropriate percentage blockage was applied, and widths/diameters were reduced accordingly.	Appropriate.
4.2.7.9	**Pits and pit inlet database**: It is assumed that IDs, dimension data and spatial locations of pit elements has been correctly assigned to TUFLOW as per the supplied network data - review of the base dataset is outside of BMTs scope. Pits appear to be appropriately configured.	Appropriate.

4.2.8 Boundary Condition Database (bc_dbase.csv)

Table 4-9 Hydraulic Model – Boundary Condition Database

ID	BMT Observation	BMT Recommendation
4.2.8.1	**Scenarios**: Several bc_dbases are configured to be called from the TCF, dependent on a given scenario. Each bc_dbase was confirmed to correctly contain the relevant links/data values for that specific scenario. Confirmed that the boundary source 'name' called the corresponding data column of the same name from the loc and tot XP-RAFTS input files. Confirmed that the boundary source 'name' was consistent across all relevant scenario bc_dbases.	Appropriate. Improvement can be made with the use of ts1 groups/file types for the hydrologic inputs, drastically reducing the number of required lines in the bc_dbase. Updates would be required in the 2d_sa and 2d_Rf GIS layers in combination with this.

ID	BMT Observation	BMT Recommendation
	Each bc_dbase is configured correctly, however it is noted that the use of .ts1 groups is generally beneficial for reducing input file sizes and supporting neater bc_dbases.	
4.2.8.2	**Downstream Boundary**: Confirmed that the appropriate data value (design events) and source (calibration events) for each scenario, as specified in reporting, is correctly linked to the downstream boundary. BMT do not have access to the raw tidal data for calibration events to confirm the appropriate elevations and period of data has been applied.	Appropriate.
4.2.8.3	**Inflows**: Confirmed that the appropriate input files are correctly linked in each scenario's bc_dbase. The names for external 2d_bc QT boundaries correctly link to .tot files, and 2d_SA boundaries to .loc files. BMT do not have access to the raw rainfall data for calibration events to confirm the appropriate values and period of data has been applied .	Appropriate.

4.3 Model Calibration

Table 4-10 Hydraulic Model – Calibration

ID	BMT Observation	BMT Recommendation
4.3.1.1	Calibration scenarios were confirmed to have been appropriately configured in the modelling files. The results and NCE's evaluation were reviewed and the hydraulic model calibration is considered acceptable.	Appropriate.

4.4 Sensitivity Analyses

Table 4-11 Hydraulic Model – Sensitivity analyses

ID	BMT Observation	BMT Recommendation
4.4.1.1	**Climate Change**: Changes to rainfall and tidal boundary parameters (as per reporting) were confirmed to have been implemented in modelling files appropriately, via alternative boundary conditions databases and TCF logic. Approach is consistent with ARR2019.	Appropriate.

ID	BMT Observation	BMT Recommendation
4.4.1.2	**Roughness**: It was confirmed that the materials definitions CSVs for the RS01 and RS02 sensitivity scenarios correctly increased and decreased the values by 30% (as per reporting), respectively, compared to the default definitions for all other scenarios (design and calibration).	Appropriate.
4.4.1.3	**Blockage**: Overrides for the blockage sensitivity scenarios (to force 0% or 50% blockage for all events) were confirmed to be configured correctly in the TCF.	Appropriate.
4.4.1.4	**Joint Probability**: 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 TCF logic. Approach is consistent with ARR2019.	Appropriate.

4.5 Results

Limited checks have been undertaken, with checks mostly focusing that peak flood levels increase with increasing flood rarity, model extent is sufficient to contain results i.e. no glass walling and no anomalous results.

Table 4-12 Hydraulic Model – Results

ID	BMT Observation	BMT Recommendation
4.5.1.1	**Types**: Mapping of results has generally been undertaken as per the RFQ. However, the RFQ does specify mapping of storage/conveyance/flood fringe zones which does not appear to be available.	Appropriate.
4.5.1.2	**Filtering**: Reporting specifies that TCC's filtering criteria has been applied to the raw results (as per RFQ), which "excludes flooding in areas where the depth of flow is less than 100 mm unless the velocity is greater than 0.8 m/s"	Appropriate.
4.5.1.3	**Gridded Outputs - General:** The gridded map outputs for peak depths, velocities and water surface elevation were inspected for the 1% AEP event for any abnormalities. Results generally appear reasonable. Depth results indicate some flow accumulation in farm dams and behind minor road embankments, however this is considered a reasonable limitation based on the scope of the project. Review of the results in conjunction with the modelling elements confirm major cross drainage structures have been appropriately included.	Appropriate.

ID	BMT Observation	BMT Recommendation
4.5.1.4	**Gridded Outputs - Glass walling**: As discussed in the TGC Code and Downstream boundary sections, glass walling occurs along the east and west sides of the code boundary in the downstream, where no open boundaries exist.	Glasswalling at downstream area of active code boundary. Reporting would benefit from additional detail/explanation on the model configuration in this area. It should be confirmed in the report that such areas are not specific areas of interest and that results should be treated with caution near to these affected boundaries.
4.5.1.5	**Gridded Outputs - Unintended mapped flowpaths**: As discussed in the TBC 2d_rf direct rainfall Section 4.2.6.	Recommendation as per ID 4.2.6.4
4.5.1.6	**Messages log file**: TUFLOW messages log files were spot checked for a variety of event magnitudes and scenarios for any errors, warnings or checks. No major warnings were found but it is recommended that 2D boundary cells for culverts are reviewed where they have been automatically lowered using the 'Z' flag.	Generally appropriate but recommended that automatically lowered 2D culvert boundary cells are reviewed.
4.5.1.7	**Stability**: Stability checks have been limited to checking peak water level grids. These were spot checked around culverts 1D-2D connections: flood surfaces appeared stable, with no unexpected localised peaks that may indicate an instability in the solution. TUFLOW TLF and hpc.dt.csv log files were spot checked for a variety of event magnitudes and scenarios for stability issues. HPC Repeated Timesteps summarised in the TLF can indicate stability issues if the number is excessive. In the inspected TLFs, the number of HPC HCN Repeated Timesteps were considered acceptable (a relatively small number is generally not of concern as repeating timesteps is intended to maintain stability), and no HPC NaN Repeated Timesteps were logged. In the inspected dt.csv log files, the minimum timesteps and the control numbers over time were plotted. The minimum timestep did not reduce to an excessively small value, which is acceptable. The value of the minimum timestep and the control numbers did show some oscillation (normally smoothly changing values is a good indicator of stability), however the oscillation was generally	Generally appropriate based on the information reviewed.

ID	BMT Observation	BMT Recommendation
	within a small range and could be a result of the large model area triggering differing hydraulic conditions that are causing similar minimum controlling timesteps at the same time.	

5 Analyses

A number of analyses and verifications were undertaken by NCE to support the validity of the model development and study results. BMT has provided additional peer review commentary on these analyses.

5.1 Direct Rainfall Verification

Table 5-1 Direct rainfall verification

ID	BMT Observation	BMT Recommendation
5.1.1.1	The verification assessment documented in Appendix F of NCE's report flagged issues with storm injector flows being significantly lower than those resulting from a direct rainfall model (and those from a modified XP-RAFTS model). The issue was flagged but reasons for the large differences were not identified. The differences are of concern if Storm Injector derived flows are used for hydraulic model inflows - these flows also underpin the critical duration and critical temporal pattern assessments.	BMT concurs with NCEs recommendation in S.11.2 that a review of the hydrology inputs should be undertaken to ensure that all parameters are suitable. Evidence of the flow discrepancy from the NCE report (Appendix F) should be used to inform the review and the reasons for differences should be better understood.

5.2 Comparison to Previous Assessments

Table 5-2 Comparison to previous assessments

ID	BMT Observation	BMT Recommendation
5.2.1.1	The modelling methodology undertaken by NCE and AECOM is based on the ARR2019 guideline. The analysis provided by NCE on the differences in model results between the previous flood study (based on the ARR1987 guideline) and the current work is considered to provide appropriate justification for the differences in peak flood levels (generally lowered) compared to the previous 2008 flood study. The difference in design rainfall depths between ARR1987 and ARR2019 documented by NCE would be a significant factor in the differing flood study peak levels.	The differences in design flood levels between the 2008 study and the present study appear to result from use of the ARR2019 guideline. However, similar to other recommendations, it is recommended that the hydrology is reviewed to ensure there are no

ID	BMT Observation	BMT Recommendation
	However, it is noted that potential issues were flagged by NCE with the hydrologic model inputs. BMT support their recommendation for this to be investigated further, as this may also be a contributing factor.	issues impacting on the assessment.

5.3 Flood Frequency Analysis

Table 5-3 Flood frequency analysis

ID	BMT Observation	BMT Recommendation
5.3.1.1	The peak flows derived by FFA (at Allendale) appear to show good agreement to the design peak flows in the hydraulic model. However, it is not stated what rating curve was used to derive the Annual Maximum flow series for the FFA. Section 7.8 shows a fairly significant discrepancy in peak flow estimates (for flows >200m^3/s) depending on if the DNRM rating is used or one informed by the hydraulic modelling. The DNRM rating may therefore potentially understate flows and if this DNRM rated flow series is used in the FFA then the FFA flows may also be understated. An amended FFA may then show higher flows than design flows from the hydraulic model.	The rating used in the FFA should be confirmed and if the DNRM rating (which is described in Section 7.8 as being based on erroneous extrapolated data) is used then the implications of this should be investigated. (For example, the FFA should be revisited using the recommended rating curve and resulting FFA flows compared with modelled design peak flows.)

6 Conclusions

This peer review report has documented the review findings for the modelling contract undertaken by Northern Consulting Engineers (NCE) for the **Alligator Creek and Whites Creek** catchments, as part of Townsville City Council's Townsville Flood Modelling and Mapping Project.

The hydraulic modelling (including application of hydrologic modelling inputs derived by AECOM) was found to generally follow best-practice modelling approaches and techniques, conform with ARR2019 and be fit-for-purpose, however a number of moderate and more significant issues were found that should undergo further investigation.

Numerous recommendations have been made to provide further justification and/or documentation on elements of the modelling undertaken, however these are not expected to result in any notable changes to modelling outcomes.

Three issues of greater potential significance were identified that should be further investigated, or addressed:

- A review of the hydrology inputs should be undertaken as per NCEs recommendation in S.11.2 to ensure that all parameters are suitable, as they underpin all subsequent assessment and modelling. Evidence of the flow discrepancy from the NCE report's Appendix F should be used to inform the review and the reasons for differences should be better understood.
- Currently, the configuration of direct rainfall 2d_rf polygons results in mapped flowpaths that are not representative of design flows in the upper reaches of adjacent (non-direct rainfall) subcatchments. The direct rainfall polygons should be aligned with more accurate LiDAR data (or inset from the top of catchment) to prevent minor spillage into neighbouring subcatchments. If left as is, appropriate caveats should be included in the mapping/reports.
- The rating curve used to derive the Flood Frequency Analysis peak flows at Allendale should be confirmed. If the DNRM rating (which is described in Section 7.8 as being based on erroneous extrapolated data) was used then the implications of this should be investigated. (For example, the FFA should be revisited using the recommended rating curve and resulting FFA flows compared with modelled design peak flows.) This is particularly important as the FFA is an independent check on peak flows from the hydrology model which has been identified as showing some discrepancies.

7 References

AECOM (2020) DRAFT Review of Hydrological Methods for the Townsville Region, Phase 4 - AR&R 2019 Hydrologic Model Updates. Prepared for Townsville City Council, January 2020.

Austroads (2019) Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures June 2019.

NCE (2020) Townsville Recalibrated Flood Modelling and Mapping – Alligator Creek Report. Prepared for Townsville City Council, June 2020.

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