TECHNICAL REPORT 03

Updated flooding and hydrology assessment

Appendix B Independent peer review

NARROMINE TO NARRABRI PROJECT

Narromine to Narrabri (N2N) Inland Rail - Hydrologic Review

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1 Introduction

JacobsGHD IR Joint Venture (JacobsGHD) is undertaking civil design of the Narromine to Narrabri (N2N) section of Inland Rail for the Australian Rail Track Corporation Ltd (ARTC).

It is understood that JacobsGHD completed a flood study as part of the Environmental Impact Statement (EIS) in support of the proposed project. BMT Commercial Australia (BMT) was initially engaged by JacobsGHD to conduct a review of their hydrology models used as the basis for the flood study at the 70% feasibility design stage of the project. The review was undertaken of calibrated hydrologic models and a subset of 10 smaller hydrologic models. Following the 70% feasibility design review, BMT were again engaged to review the hydrologic models developed for the 100% feasibility design, noting that models within only two catchments have changed between the two designs.

This report provides the methodology and outcomes of the review conducted by BMT. It should be noted as per BMT's proposal (agreed by JacobsGHD), that a subset of models has been selected for the review allowing the general project approach to model setup and parameterisation to be reviewed. As such, the review must not be taken as a comprehensive review of all the models supplied nor the total flood study or assessment.

2 Review Methodology

For the 70% feasibility design stage, JacobsGHD supplied eighty-four (84) hydrologic RORB models and one (1) hydrologic XP-RAFTS model for the purpose of this peer review. Supporting data for four flood frequency analyses and a subset of hydrological result files were also supplied. For the 100% feasibility design stage BMT understands the hydrology for two catchment models (Macquarie and Narromine) was updated. Hydrologic models for these two catchments were resupplied and reviewed. It is understood from JacobsGHD that no changes were made to the remaining hydrologic models between the 70% and 100% feasibility designs.

2.1 Review Elements

The hydrologic models supplied are all located within the Narromine to Narrabri study area.

The different components of the BMT review are set out in Table 2-1 along with a brief description of what the review has focussed on.

Table 2-1 Hydrologic Review Elements

Review Catchment/Item	Review Description
Castlereagh River	• RORB GIS layers only (catchments rely on FFA for peak flows)
Baradine Creek Coolbaggie Creek Bohena Creek	• RORB GIS Layers • RORB catchment files • RORB Parameter files • RORB Storm and Out files (Calibration and Design) • Calibration Results
Narromine (Backwater Cowal) comprising five (5) RORB models. Macquarie River	• RORB GIS Layers • RORB catchment files • RORB Parameter files • RORB Storm and Out files (Calibration and Design)
Ten (10) smaller RORB models	• Catchment sizes and Loss values used
Flood Frequency Analysis (FFA)	• FLIKE Inputs and Output files • Macquarie, Castlereagh, Baradine and Coolbaggie FFA files supplied
TUFLOW Inflows	• Comparison of TUFLOW inflows and RORB outputs

3 Review Outcomes

3.1 General RORB Comments

- For all of the calibrated RORB models, there are more than the recommended five subareas upstream of the key gauges used in the assessments. This allows for appropriate routing in the derivation of flow hydrographs at required locations.
- For all of the calibrated RORB models, the appropriate reach type (Type 1 – Natural Waterway) was used for all reaches. This represents how water will convey through the catchments appropriately. This is appropriate given the predominantly rural nature of all catchments.
- Nodes have been placed at the downstream end of subareas, and at all confluences of watercourses. The reporting nodes have also been positioned in the appropriate places for the study.

3.2 Individual Study Area Commentary

Table 3-1 to Table 3-5 present a summary of hydrologic model review findings for the five larger models. All five catchments were modelled using RORB software. For some catchments eg Castlereagh River, the RORB models were not supplied as the peak flows were derived using FFA techniques. Supporting files such as node and area locations were supplied and have been used to inform the reviews.

Table 3-1 Macquarie River RORB Model (MAC)

Review Item	Commentary
Subareas	• 31 subareas, this is considered sufficient to calibrate a RORB model • The range of subarea sizes is appropriate, with the largest subarea being approximately 6x the smallest
Reaches	• All reaches Type 1. Consistent with land use.
Storages	• There are no storages within the model. Lake Burrendong is a significant storage in the catchment with a significant portion of the catchment being upstream of this storage. • The inclusion of this will likely slow the flow down significantly, changing the shape of the hydrograph. However, it is understood that the storage effects have been modelled using a high kc value.
k_c	• Value of 262.71 seems very high and will have the effect of attenuating (reducing) the peak flow. It is understood from JacobsGHD that the high kc value was used to match the rising limb and peak flow rates to historic flood events and FFA respectively.
IL	• Varying losses, generally decreasing in rarer events
CL	• Consistent loss of 1.84 mm/h. This is acceptable.
Design Flows	• Match closely to FFA (within 5% for all events) and is acceptable for the study,

Table 3-2 Castlereagh River RORB Model (CAS)

Review Item	Commentary
Subareas	• 39 subareas, this is considered sufficient for RORB calibration • The range of subarea sizes is appropriate, with the largest subarea being approximately 6x the smallest
RORB Parameters	• Not applicable as the RORB model flows are scaled to match results from an FFA.

Table 3-3 Baradine Creek RORB Model (N2N7_1)

Review Item	Commentary
Subareas	• 25 subareas. 24 subareas used for calibration model, with Subarea ‘Y’ being added for design events. The range of subarea sizes is appropriate, with the largest subarea being approximately 5x the smallest
d_{av}	• Minor differences in value noted between design and calibration models. This is due to the additional subarea ‘Y’ for additional design reporting output.
k_c	• Value from calibration is 20 (x3 models), 25 and 31. The values appear reasonable and a good calibration is demonstrated. • Value adopted for design events is 20 which is reasonable based on values determined through calibration
IL	• Initial loss value adopted for design runs is 72.7mm. This comes from the November 1998 calibration event. It approximates the median of the three calibration events which is appropriate
CL	• Value of 2.9mm/h consistent between calibration and design events. • Consistent with ARR Losses from Datahub
ARF	• ARF value applied based on area (974.81km^2) is less than the total catchment size (1002.08km^2). However the catchment area to the key location of interest (C20 (node O1)) is 933.18km^2. This may have a slight effect on rainfall depths into the model in the design events but will most likely be minor
Calibration	• Only 3 of 5 calibration runs have results plotted (1997 and July 1998 events not available). It is understood from JacobsGHD that only the larger floods have been presented. • Calibration generally shows good match to the peak flows, as well as good rising and falling limbs. • Sept 1998 – Failure to match smaller peaks before and after the main peak suggests CL could be too high but as main peak matches well this is considered a minor issue and calibration is acceptable.

Table 3-4 Coolbaggie Creek RORB Model

Review Item	Commentary
Subareas	• 14 subareas. This is considered sufficient for RORB calibration • The range of subarea sizes is appropriate, with the largest subarea being approximately 4x the smallest
d_{av}	• The adopted design value of 40 matches 39.87 in calibration event outputs • No design runs provided to cross check against calibration. Discussions with JacobsGHD confirmed that this model was intended as a donor catchment model only for RORB parameter generation and ended up not being used at all. Therefore, no design runs are required.
k_c	• Value from calibration is 22 (x3 models) and 28 (x2 models). Seems reasonable and offer good matches in calibration figures. • No design kc (as model not used for design modelling) • It is understood a median value of 25 was adopted, no k_c value of 25 was used in the supplied calibration events. This should be investigated if the model is used to inform design flood modelling at any future stage of assessment.
IL	• Calibration ILs range from 20mm to 78.4mm • These differ slightly from adopted design values of 20mm to 73mm but are unlikely to result in any material change in model outcomes.
CL	• Calibration CLs range from 1.2mm/h to 1.6mm/h are consistent with adopted design values and with ARR 2019 estimated values
ARF	• Design runs not required and so no ARF values to assess
Calibration	• 4 out of 5 calibration runs have plotted results with the November 2010 event not shown. It is understood from JacobsGHD that only the larger floods have been presented. • Calibration demonstrates the model matches well to peak flows • Modelled hydrographs for the November 2000 and March 2012 events rise far later that observed, suggesting adopted IL for these events are possibly too high but the match to peak flows is considered satisfactory.

Table 3-5 Bohena Creek RORB Model

Review Item	Commentary
Subareas	• 25 subareas. This is considered sufficient for RORB calibration • The range of subarea sizes is appropriate, with the largest subarea being approximately 5x the smallest • Areas in RORB Shapefiles differ to those specified in the RORB 'catg' model file by a small margin. Likely to not affect results
d_{av}	• Adopted design value of 66 matches 66.06 in calibration event outputs and design outputs
k_c	• Value from calibration is 21 (x3 models), 22 and 25. Values seem reasonable and demonstrate a good calibration can be achieved • Design k_c is 21
IL	• Calibration ILs range from 27mm to 102mm • Design loss used is 39.7mm. The median value was 59mm so a loss of 39.7mm is conservative in this regard.
CL	• Calibration CLs range from 2.5mm/h to 3.5mm/h compared to the adopted design value of 2.5mm/h which is reasonable. • Consistent with ARR 2019 estimated values
ARF	• ARF value consistent with total area of the RORB model, and location of gauge at downstream end
Calibration	• 3 out of 5 calibration runs are plotted (2000 and 2004 events not included). It is understood from JacobsGHD that only the larger floods have been presented. • Calibrations demonstrate good matching to the peak flows, as well as a good match on rising and falling limbs.

3.3 Narromine (Backwater Cowal) RORB Models

BMT understands that following community feedback on the 70% feasibility design, more definition was required within the Narromine RORB model to map overland flow paths. The Narromine model was therefore broken up into five (5) RORB models for the 100% feasibility design. These models provide inflow hydrographs into the associated TUFLOW model that includes the Narromine catchments in the vicinity of the railway alignment.

3.3.1 Review Commentary

- Routed print locations are at the appropriate location for introduction of inflows into the TUFLOW model for each of the five RORB models which extend upstream of the model boundary.
- The range of the subarea sizes in each respective model is appropriate. The larger RORB models have proportionately larger subareas, with all models also having an acceptable minimum number of subareas required for routing.
- Reach types are consistently "Type 1 – Natural" throughout all RORB models. This is consistent with the land use and appropriate for the RORB models.
- Reach delineation is appropriate for all models, leading to appropriate values of the d_{av} parameter used in all RORB models.

- Multiple catchment areas have been used for calculations of the areal reduction factor (ARF) in RORB runs. These have been applied for each point upstream inflow into the TUFLOW model. This is an appropriate application of the ARF.
- The Initial Loss, Continuing Loss and k_c parameters for the five Narromine RORB models are shown in Table 3-6 below. This shows:
  - The Initial Loss values are consistent with using the Pre-Burst losses from Data Hub
  - The Continuing Loss values are consistent with the Data Hub losses for RORB models 3 to5.
  - The Continuing Loss values for RORB models 1 and 2 have been multiplied by a factor of 0.4 in accordance with NSW specific guidance on the Data Hub.
  - The k_c values seem appropriate for the catchment sizes.

Table 3-6 Narromine RORB Parameters

RORB Model	IL	CL	k_c	d_{av}
1	Varying IL based on Pre-burst losses	0.20	7.15	9.65
2		0.20	8.52	9.62
3		0.01	12.11	27.48
4		0.01	9.72	14.59
5		0.01	5.28	4.44

3.4 Smaller Catchment Reviews

In addition to the larger models reviewed in Section 3.2, a subset of smaller RORB models were also selected for a review. Ten models were selected for review from the approximate 80 models available. These reviews focused on ensuring the appropriate ARR 2019 data was used, and that rainfall loss values were appropriate. These reviewed models are listed below using the model identifier:

- D128980
- D17313
- D29411
- D32008
- D46230
- D57277
- D68620
- D79020
- D86480
- D98220.

3.4.1 Review commentary

- The way in which loss values were selected was initially unclear but later clarified by JacobsGHD who stated that for uncalibrated models a conservative approach was adopted by selecting the lower of the losses from neighbouring calibrated catchments or from the ARR2019 Data Hub. This appears to be a conservative approach and one which BMT deems to be appropriate. It is noted by BMT that the rainfall loss values in the smaller catchments seem to be significantly lower than those losses chosen for the design events in the calibrated catchments and those obtained from the DataHub. This will likely lead to conservative flow estimates.

- Where k_c values have been specified in models that route hydrographs to provide a point input to the hydraulic model i.e. not excess rainfall outputs, how the K_c value has been determined is not specified. Given that initial loss values are conservative then the model outputs are still likely to be conservative but future reporting should include a statement on how k_c values have been derived in these models.
- The application of the IFD and ARF data is consistent throughout all of the assessed RORB models and have been applied correctly.

3.5 Flood Frequency Analysis

A Flood Frequency Analysis (FFA) was provided for four catchments: Baradine Creek, Coolbaggie Creek, Macquarie River and Castlereagh River. The FFAs were undertaken using FLIKE software.

BMT has reviewed the supplied FLIKE software input and output files for the four catchments.

3.5.1 General Comments

The rating curves which underpin the FFA analyses appear to rely on the flow to level gaugings undertaken by Water NSW. Further clarification was sought by BMT from JacobsGHD as to how the accuracy of each rating curve used was considered noting that, in general, rating curves from government agencies tend to be less accurate for larger flows once discharge engages the floodplain. JacobsGHD confirmed that flow gauging data and cross sections at the gauges were reviewed. In the case of the Namoi River/Narrabri Creek and Bohena Creek (N2N1 TUFLOW model), the adopted rating curves were compared against TUFLOW model results to verify rating curves which is a best practice approach. JacobsGHD stated that this was not possible for Baradine Creek as the gauge had not been surveyed to Australian Height Datum and was discontinued.

Quality checks of the data only appear to be undertaken for large data gaps. It is not clear the degree to which any sanity checks may have been performed to ensure the maximum flow for each year is the actual maximum flow and not an artificial spike (as water level gauges can fail during large events). Commentary should also be made if the ‘water year’ has been used to calculate the annual maximum flow series, although this is not likely to have any notable bearing on outcomes.

The Grubbs Beck test for outliers has been performed for the FFA, however no further sensitivities appear to be undertaken.

The FFA derived peak flows for Baradine Creek and Coolbaggie Creek are notably lower than the corresponding flows from the RORB models for events rarer than the 1 in 10 AEP. It would be of value to understand some of the reasons behind these large differences. However, based on discussions with JacobsGHD, the larger RORB flows have been adopted for use on these catchments which is a conservative approach and therefore acceptable.

3.5.2 Baradine Creek FFA

It is understood from discussions from JacobsGHD that the peak flows from the Baradine Creek FFA were not adopted for design purposes, with higher peak flows from RORB modelling used instead. The gauge on Baradine Creek was also discontinued. The comments summarised below regarding the Baradine Creek FFA are included for completeness but will not affect design flood modelling and no further action is required unless the FFA is used for future purposes.

- There are 28 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.
- The peak flows from 2002 and 2006 were not included in the analysis. The reasons for the exclusion are not stated. If it is simply that the flows are very low, it is recommended that these years are still included but as censored data so that they do not unduly influence the fit of the distribution for floods at the rare tail end.
- The peak flow from 1981 was included in the analysis, however recorded flows commenced in this year and as such 1981 only has a partial record of flows in that year. Given the full year is not available, this should be removed to maintain consistency with the rest of the FFAs but it is not likely to have a notable effect on outcomes.

3.5.3 Coolbaggie Creek FFA

It is understood from discussions from JacobsGHD that the peak flows from the Coolbaggie Creek FFA were not adopted for design purposes, with higher peak flows from RORB modelling used instead. The comments below regarding the Coolbaggie Creek FFA are included for completeness but will not affect design flood modelling and no further action is required unless the FFA is used for future purposes.

- There are 38 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.
- The peak flow from 1980 has been removed from the analysis. It is assumed that this was due to the record beginning in November 1980, therefore a full year of data was not available. This is appropriate.
- 19 of the 38 years have been censored in the censored assessment. This is a significant proportion and the reasons behind this should be further explored if the FFA is to be used for future purposes.

3.5.4 Castlereagh River FFA

It is understood that the Castlereagh River FFA is relied upon to obtain peak design flow estimates which the RORB model flows are then scaled to. The FFA “without” censoring was provided for review. The findings from the review are as follows:

- There are 33 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.

- The peak flows from 1968 and 2004 were removed due to the records not being full years of recorded data. This is appropriate.
- Peak flows in 2001 and 2002 were removed. Very small flows were recorded in these two years, all less than $2m^3/s$, with some missing data from the record in both years. It is assumed that the years were excluded on the basis of the missing data and are therefore 'incomplete years' which is recommended practice.
- Clarification was sought regarding by how much the RORB flows differed from the FFA derived peak flows. The response from JacobsGHD was that a scaling factor of approximately 1 was used, suggesting that the peak flow estimates from both approaches were in agreement. A comparison was also provided between the peak FFA flows derived in this assessment verses peak FFA flows derived from a previous flood study prepared by Lyall and Associates in 1996. Generally, the peak flows were in agreement with those from the 1996 study and are slightly higher.

3.5.5 Macquarie River FFA

It is understood that the Macquarie River FFA is relied upon to obtain peak design flow estimates which the RORB model flows are then scaled to. The FFA "with" censoring was provided for review. The findings from the review are as follows:

- There are 32 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.
- The peak flow from 2018 was removed from the analysis. It is assumed that this was due to the records not being complete at the time of the data collection.
- The peak flow from 1986 was included in the analysis, even though records started in June 1986. Given the full year is not available, this should be removed from the analysis to maintain consistency with the rest of the FFAs but is unlikely to result in any change in outcomes.
- Clarification was sought regarding by how much the RORB flows differed from the FFA derived peak flows. The response from JacobsGHD was that a scaling factor of approximately 1 was used, suggesting that the peak flow estimates from both approaches were in agreement. A comparison was also provided between the peak FFA flows derived in this assessment verses peak FFA flows derived from a previous flood study prepared by Lyall and Associates in 2013. Generally, the peak flows were in agreement with those from the 2013 study and are slightly higher.

3.5.6 Regional Flood Frequency Estimate (RFFE)

Regional Flood Frequency Estimates have been undertaken for the larger catchments at the gauges. From discussions with JacobsGHD, an RFFE has also been undertaken for smaller catchments and compared against RORB flows for validation.

The RFFE is a high level tool that can provide a sense check on peak flow estimates. It often contains large uncertainty bounds but these can be refined through assessing and refining the gauges used within a 'region of influence' to inform the RFFE.

It is not clear whether the gauges within the respective regions of influence for each assessed subject site have been further analysed. From discussions with JacobsGHD the sparsity of gauges in the assessed catchments results large regions of influence which are difficult to refine.

It is understood the RFFE peak flow estimates have not been relied upon to factor RORB flows and as such the use of this technique as a sense check on peak flows is considered appropriate.

3.5.7 Other methods flow estimation methods

For smaller catchments, it is understood that conservative parameters such as the lower bound on initial losses have typically been adopted. This is considered acceptable given the overall uncertainty of peak flow estimation in areas where there is a lack of gauged data.

Other techniques that could potentially be applied when validating the smaller catchments include the probabilistic rational method (where applicable), quartile regression technique, or reconcile results with another hydrologic model package such as WBNM. Such techniques would also include a significant degree of uncertainty but may provide an additional validation of peak flows.

3.6 Baseflow

Due to their geographic location, baseflow is not expected to have any influence on peak flood modelling results in the catchments under consideration. It is noted however that during model calibration, baseflow has been separated from the recorded hydrographs for calibration of the RORB model. From discussions with JacobsGHD it is understood that the baseflow was found to be almost negligible. It was confirmed with JacobsGHD that baseflow was not then added back into the hydraulic model for water level calibration. Given that the baseflow was assessed by JacobsGHD as being negligible this is not considered to be an issue.

3.7 TUFLOW Input Hydrographs

The hydrographs from the review subset of 10 hydrologic models were reviewed and compared to the inflow hydrographs in the TUFLOW models (as these should be the same). BMT has the following comments:

- In all cases the hydrographs used for inputs into the TUFLOW models match the outputs from the hydrology models.
- For each of the ten catchments respective TUFLOW models, a single inflow is applied which is the routed total flow from the respective catchment hydrologic model.
- The inflow location for the Bohena Creek model ("C-2" in N2N1) is 12km upstream of the printout location for the routed hydrograph. This effectively double routes the flow along this 12km length but is unlikely to result in any significant impact on results.
- Inflows into the TUFLOW models for catchments D29411, D32008, D68620, D79020 and D86480 are effectively rain on grid inputs as they utilise TUFLOW's '2d_sa ALL' command. This distributes the inflow hydrograph across all grid cells within the defined boundary (which covers the whole

catchment area). These input hydrographs have already been routed within the RORB models. It is BMT's understanding that this would lead to routing having occurred twice for these catchments, likely leading to a reduction in peak flows at the downstream end of these catchments. This issue was raised with JacobsGHD who confirmed that it affected a limited number of subcatchments. It was noted by JacobsGHD that the issue affects both calculations for the existing scenario, before Inland Rail, and the operational scenario, after Inland Rail. It was also confirmed that the catchments in question are predominantly rural with a low risk of changes significantly affecting the number of buildings impacted from the existing case to the operational scenario. JacobsGHD has stated that this will be investigated and addressed further as part of the detailed design.

4 Conclusions

BMT has undertaken a review of hydrologic models and the modelling approach for the Narromine to Narrabri (N2N) study. The review identified minor issues that are not anticipated to have a significant impact on the overall model outcomes. The overall approach is a conservative one which is best practice, particularly in those catchments with little or no gauged data.

Overall the models are deemed have been appropriately set up except for one identified issue which affects a limited number of subcatchments where routed flows are being distributed evenly across catchments. JacobsGHD were made aware of this issue and have identified a low risk of changes significantly affecting the number of buildings impacted. It is understood that this will be investigated and addressed as part of the detailed design.

BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

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It is understood that JacobsGHD completed a flood study as part of the Environmental Impact Statement (EIS) in support of the proposed project. BMT Commercial Australia (BMT) was initially engaged by JacobsGHD to conduct a review of their TUFLOW models used as the basis for the flood study at the 70% feasibility design stage of the project. Following the 70% feasibility design review, BMT were again engaged to review the TUFLOW models developed for the 100% feasibility design, noting that only two of fourteen models have changed between the two designs.

This report provides the methodology and outcomes of the review conducted by BMT. It should be noted as per BMT's proposal (agreed by JacobsGHD), the scope of the review is a verification of the basic model elements, and as such must not be taken as a comprehensive review of the models nor the flood study or assessment.

2 Methodology and Review Outcomes

2.1 General

JacobsGHD supplied several TUFLOW models that include various scenarios for the study area. These scenarios were Existing, Design (Operational), Construction and Sensitivity (Manning's 'n' and blockage).

BMT reviewed only the Design scenario for each study area as this is the primary model that contains the proposed design elements including the underlying base conditions.

2.2 Study Areas

The study area stretches from Narromine to Narrabri. Figure 2-1 identifies the study areas covered by the review. Table 2-1 lists the study areas, the design scenario and Tuflow log file(tlf) reviewed.

Table 2-1 Study Areas and Model Files Checked

Study Area	Tuflow log file and Design Scenario checked
NFMv7*	N2N_NFMv7_des21_0100yr_240hr_REV09_10m.tlf
N2N14	N2N_N2N14_DES15_0100yr_CRT_REV04.tlf
N2N13	N2N_N2N13_DES15_0100yr_CRT_REV04.tlf
N11N12	N2N_N2N11N12_des16_0100yr_CRT_REV04.tlf
N2N10	N2N_N2N10_des16_0100yr_CRT_REV04.tlf
N2N9	-N2N_N2N9_des18_0100yrCC_CRT_REV04.tlf
N2N8	N2N8_025_01PCT______D.tlf
N2N7	N2N7_014_01PCT______D__.tlf
N2N6	N2N6_023_01PCT______D.tlf
N2N5	N2N5_025_01PCT______D.tlf
N2N4	N2N4_014_01PCT______D.tlf
N2N23	N2N23_009_01PCT______D__.tlf
N2N1	N2N1_023_01PCT______D.tlf
Narrabri*	Narrabri_014_01PCT______D.tlf

*Only NFMv7 and Narrabri models were supplied for the 100% feasibility design. BMT understands from JacobsGHD that all other models incurred no changes between the 70% feasibility design and the 100% feasibility design.

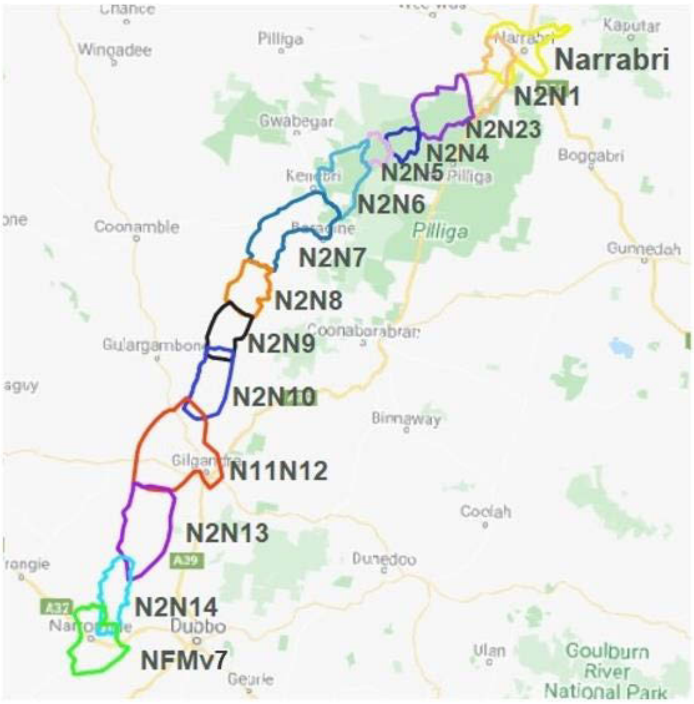

Figure 2-1 Locality Map of Study Areas

2.3 Review Elements

As per BMT's scope of works defined in the proposal, the review was conducted based on the basic elements of the TUFLOW models that are summarised in Table 2-2.

Table 2-2 Basic Elements of Model Review

Model Element	Description
1	Checking for unusual commands with tcf/ecf/tgc/tbc
2	Log file checking for warnings/errors, mass error and negative depths
3	Model extent check against flood extent
4	Material roughness (values and distribution)
5	1D-2D connections
6	Inflow application
7	Bridge losses
8	Culvert losses
9	Grid Size
10	Downstream boundary application
11	Railway design elements checks (DEM and relevant structures)
12	Visual inspection of 2D outflow hydrographs
13*	Visual comparison that modelled results agree with those presented in the Flooding and Hydrology Assessment Technical Report 3

*Review Element 13 was undertaken for the Narrabri and NFMv7 only following their supply to BMT for the 100% feasibility design stage

3 Review Outcomes

3.1 Summary of General Comments

- The proposed bridges were modelled as a Layered Flow Constriction Shape File (lfcsh). The form loss values adopted for the lfcsh are generally in accordance with typical values that are appropriate for the initial assessment. BMT understands that for the proposed Macquarie River and Narrabri viaducts a detailed assessment of form loss values was undertaken at the 100% feasibility design. For the detailed assessment of the remaining bridge structures it is suggested to calculate the final values based on pier configuration, dimension and alignment or model calibration in accordance with industry best practice. The accurate estimation of the above-stated form loss factors can have an impact on the afflux and hence flood impact for the downstream and upstream areas.
- The depth and blockage attributes of Layer 3 of the lfcsh were specified but no form loss was adopted. Whilst this is appropriate where there is no overtopping, the form loss coefficient factor is relevant where overtopping occurs. Hence, it is recommended to apply form loss coefficient for those bridge where overtopping is predicted to occur.
- Some of the bridges were modelled as a 1D structure combined with a HW type (elevation versus width) cross section table. A review of the HW table showed that no small value of width (typically 0.001) was defined at or past the top elevation. This means that if the water surface elevation overtops the top, the width would be artificially extended upwards based on the top width. A check was made at one bridge location and it was found that the PMF flood level did not reach the top of the HW table, so the cross-section definition is appropriate in this case. It is suggested to check all the bridge locations to confirm the validity of the assumption.
- In the case of “2d_SA ALL” inflow applications, the hydrologic sub-catchments were adopted as the SA polygons. The ‘SA All’ approach distributes flows to all cells equally within the SA polygon (i.e. the flows would be routed in the hydraulic model across the entire SA polygon). It was found in BMT’s concurrent review of the associated hydrology models, that these inflows are also routed hydrologically leading to routing having occurred twice for affected catchments. It is understood that JacobsGHD will investigate this issue further as part of the detailed design.
- The Manning’s n values adopted for some sections of the proposed railway line(formation) appear to be high. It appears that the underlying existing roughness were adopted. Whilst this may not have any significant impact where the railway formation is not overtopped, it is recommended to adopt representative values where there is overtopping and cross drainage structures. Note that this issue was amended for both the NFMv7 and Narrabri 100% feasibility design models.
- Whilst the 1D(culvert) entry and exit losses were appropriately specified for the Design scenario, the losses were not completely specified for the existing 1D structures. Whilst these factors are not required to be specified for 1D pipes forming a series of stormwater network (losses are built in), for culverts/pipes directly connected to the 2D domain the losses are required to be specified to derive accurate hydraulic characteristics.

3.2 Common Commentary

Table 3-1 provides commentary that are generally applicable for all the study areas.

Table 3-1 Common Commentary for All Study Areas

Element	Comments or recommendations
1	-No unusual commands were found.
2	-No unusual warnings or errors were found.
3	-Based on the 1:2000 AEP design flood inundation extent, the model extent appears to have adequate coverage.
4	- The Manning's n values are generally considered to be representative of the surface roughness of the study area
5	-The 1D-2D connections are generally in accordance with industry practice.
6	-A combination of 2d_SA, 2d_SA ALL and 2d_bc inflows were adopted that are appropriate for the study
7	-The Form loss coefficient K values adopted for Layer 1 and Layer 2 are as per typical values.
8	-The design cross-drainage structures utilised appropriate entry loss (0.4) and exit loss (1.0) that are generally in accordance with industry practice
9	-Given the extent of the model area and proposed design, a 10m grid size is considered to be appropriate.
10	-A combined HQ and HT downstream boundaries were adopted that are appropriate for the study. -The locations and extents appear to be are a reasonable distance from the area interest and adequate to allow for the transfer/exit of flow from the system
11	-The proposed design surface of the railway was found to have been incorporated into the model. -Several 1D cross-drainage structures were found to have been incorporated with the design with appropriate entry loss (0.5) and exit loss (1.0). -For the proposed bridges, whilst the blockage and form loss attributes were specified for Layer 3, no attribute (zero value) was specified for the depth of this Layer. This needs to be checked.
12	-The 2D outflow hydrographs were found to smooth
13	-For NFMv7 and Narrabri models, mapped outputs agree with model results for instances checked.

3.3 Individual Study Areas Commentary

The following tables present a summary of commentary for each study area.

Table 3-2 NFMv7 Commentary

Element	NFMv3-Comments or recommendations
4	-The main channel of Macquarie River appears to be clear of vegetation. The Manning's n value of 0.065 applied for this part of the river appears to be high. It is suggested to consider a lower n value.
5	-At some 1D structure locations, bed levels were lowered by as much as 2.7m to match the 1D node invert level. Check if these are real.
6	- It was noted that no inflows were applied within the site to the north of Mitchell Highway. This assumption needs to be confirmed to ensure the total flows have not been underestimated. -For a limited number of 2D_SA polygons (8 out of 56), the inflow applied to those polygons has been scaled (increased) using a multiplier factor in the TUFLOW boundary condition database. It appears as though this has been done to compensate for upstream catchment area that is not represented in TUFLOW. There are two issues identified with this approach (termed Type 1 and 2) with the affecting issue dependent on the model set up. These are summarised in Table 3-3 for the 8 affected SA polygons. Whilst the Type 1 issue is expected to have a larger effect on flows than the Type 2 issue, for both Type 1 and Type 2 issues the consequences are likely to have only a minor effect on model results. This is because the erroneous additional area modelled to be contributing flow is small relative to the total contributing catchment area. The affected sub catchments are also at the upstream extent of the respective TUFLOW models and so are located some distance from the railway alignment. It is recommended that the model set up is revised at the next opportunity to update the model as part of the design process.
11	-The proposed bridges and culverts were updated from the 70% feasibility design to include a 10% blockage in layer three of the flow constriction. This was checked and confirmed in this review., whilst the blockage and form loss attributes were specified for Layer 3, no attribute (zero value) was specified for the depth of this Layer. This needs to be checked. -BMT understands that form loss values for the Macquarie River viaduct were updated from the 70% feasibility design. The values have been checked and appear to be within an acceptable range for a structure of this nature. -BMT understands that culverts comprising 13 cells or more have been represented in the 2D domain for the 100% feasibility design. Whilst this is appropriate, BMT has noted two minor issues with the model set up: • A handrail layer (2d_zsh_handrail_v1_L.shp) is included at culvert locations where the culvert is now represented in 2D. This layer adds a value of 0.8m to the cell elevations. This layer is no longer required due to use of layered flow constrictions. Model results are not affected as the handrail layer is later overwritten by elevations contained in the layered flow constriction layer. However it is recommended that this layer is removed at the next opportunity to avoid confusion. • The z-shape layer (2d_zsh_NFM_Smooth_atCulvertAsBrdg_R.shp) applied at culvert locations is assumed to have the intent of lowering cell values to match the invert level of the culvert. This layer is not functioning as intended as the elevation value is ignored by TUFLOW. Instead the elevations around the perimeter used to interpolate values across the polygon. For the elevation to be applied, the 'No Merge' flag needs to be applied to the 'shape options' attribute of the layer. This flag can be included with 'min' to have the desired effect. The implications of this

Element	NFMv3-Comments or recommendations
	are likely to be minor as the layered flow constriction sets the invert level at the structure. The 2D cells within the general vicinity of the culvert which were intended to be lowered will not be lowered to the specified elevation. This may have an influence on modelled conveyance to and from the culverts but is unlikely to have any notable affect for the flood events considered in the assessment.
13	-A sample of model results for the 1% AEP event were visually cross checked against those shown in the Flooding and Hydrology Assessment Technical Report 3 (Appendix H). The checks showed the model results and mapping to be in agreement.

Table 3-3 NFMv7 SA Inflow Commentary

Type	Affected SA Polygons	Description of Issue	Consequence	Recommended Approach
1	1R, 1Z, 3N, 4O, 4X	Scaling factor increases inflow to account for missing catchment area but this is already accounted for as TUFLOW uses RORB flow with no adjustment for area	Overstates local catchment peak flow and volume	Remove scaling factor as area already accounted for using SA approach.
2	1O, 4T, 4H	Scaling factor increases inflow to account for separate upstream sub-area.	Potentially overstates peak flow due to lack of upstream routing	Remove scaling factor and apply upstream sub-area as additional inflow at upstream boundary of TUFLOW model

Table 3-4 N2N14 Commentary

Element	N2N14-Comments or recommendations
4	-The n value 0.03 used for road corridor appears to be higher than the value adopted for the paved road (0.02). It recommended to adopt 0.02 for the road corridor as well.

Table 3-5 N2N13 Commentary

Element	N2N13-Comments or recommendations
4	-Some vegetated areas of the main floodway and floodplain adopted lower Manning’s n value (0.045 to 0.05) which are lower than typical values that would be appropriate for vegetated surfaces (0.08 to 0.1). -The n value 0.03 used for road corridor appears to be higher than the value adopted for the paved road (0.02). It recommended to adopt 0.02 for the road corridor as well.
6	-Inflows were applied 2d_sa layers within the floodplain and main waterway which are considered to be appropriate for the study area.
7	-No attributes were defined for Layer 3. This assumption needs be checked to ensure the highest flood level will not overtop the road.

Table 3-6 N11N12 Commentary

Element	N11N12-Comments or recommendations
4	- Manning’s n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour
6	-The 2d_SA inflow at the upstream part of Castlereagh River should be checked to ensure that the runoff from the downstream catchment areas were represented in the model area.
11	-Some of the proposed bridges adopted zero blockage for Layer 1 (suggesting no piers), but a nominal form loss factor of 0.04 was applied for Layer 1 (typically if there are no piers in the waterway a form loss of zero should be adopted).

Table 3-7 N2N10 Commentary

Element	N2N10-Comments or recommendations
4	- Manning’s n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour

Table 3-8 N2N9 Commentary

Element	N2N9-Comments or recommendations
4	- Manning’s n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour
6	- A river inflow was applied as a 2d_bc polyline directly on the grid cells, i.e. the polyline was not snapped to the edge of the active model area(2d_Code). Whilst this does not affect the outcome, the typical practice is to snap or digitise the line along edge of the Code.

Table 3-9 N2N8 to Narrabri Commentary

Element	N2N8-Comments or recommendations
4	-The Manning’s n values adopted for some sections of railway in the 70% feasibility design (0.065 and 0.1) were deemed too high. These have now been amended in the 100% feasibility design to 0.045, which is reasonable.
11	-The following changes were made to the design going from the 70% to the 100% feasibility design: • Manning’s n roughness values for the railway updated (see #4 above) • FLC values for the Narrabri viaduct updated • A 10% blockage adopted for handrails at bridges BMT has checked and confirmed that the above stated changes were appropriately incorporated into the model.
13	-A sample of model results for the 1% AEP event were visually cross checked against those shown in the Flooding and Hydrology Assessment Technical Report 3. The checks showed the model results and mapping to be in agreement.

Table 3-10 N2N7 Commentary

Element	N2N7-Comments or recommendations
7	-A high percentage blockage (25%) was adopted for a bridge within Layer 1; this needs to be confirmed to ensure the adopted value is realistic.

4 Conclusions

BMT completed a verification of the basic elements of the TUFLOW models of the Narromine to Narrabri (N2N) study area developed by JacobsGHD. The review identified minor issues that are not anticipated to have a significant impact on the overall model outcome. Overall, the models are deemed to have been appropriately set up and the basic model outputs were found to be sensible.

It is however noted that the scope of the review is a verification of the basic model elements, and as such must not be taken as a comprehensive review of the models nor the flood study or assessment.

BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

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N2N Responses to BMT-WBM Independent Hydraulic Model Review (23 November 2020)

Element	BMT Review Comments	JGHD Response
	Summary of General Comments	
	The proposed bridges were modelled as a Layered Flow Constriction Shape File (lfcsh). The form loss values adopted for the lfcsh are generally in accordance with typical values that are appropriate for the initial assessment. BMT understands that for the proposed Macquarie River and Narrabri viaducts a detailed assessment of form loss values was undertaken at the 100% feasibility design. For the detailed assessment of the remaining bridge structures it is suggested to calculate the final values based on pier configuration, dimension and alignment or model calibration in accordance with industry best practice. The accurate estimation of the above-stated form loss factors can have an impact on the afflux and hence flood impact for the downstream and upstream areas.	A generic approach has been adopted in combination with blockage due to piers for the majority of the new bridges excluding the proposed Macquarie River and Narrabri viaducts. Hence, generally a conservative approach has been adopted in the estimation of energy losses at the majority of new bridges for the proposal. The adopted generic approach will be updated based on the detailed information on bridge piers, skewness, scour protection etc. at the detailed design stage to minimise the potential impacts to buildings, rail lines, roads and watercourses during construction and operation of the proposal.
	The depth and blockage attributes of Layer 3 of the lfcsh were specified but no form loss was adopted. Whilst this is appropriate where there is no overtopping, the form loss coefficient factor is relevant where overtopping occurs. Hence, it is recommended to apply form loss coefficient for those bridge where overtopping is predicted to occur.	A loss coefficient of 1.56 has been adopted for bridge deck and parapet for the majority of bridges. Soffits of the bridges are located above the one per cent AEP flood event and hence modelled flood levels below bridge decks are not influenced by the adopted loss coefficient. Form loss coefficients for layer three (ie. hand rails) are expected to be negligible as hand rails are most likely to be washed away during flood events which result in overtopping of the rail formation.
	Some of the bridges were modelled as a 1D structure combined with a HW type (elevation versus width) cross section table. A review of the HW table showed that no small value of width (typically 0.001) was defined at or past the top elevation. This means that if the water surface elevation overtops the top, the width would be artificially extended upwards based on the top width. A check was made at one bridge location and it was found that the PMF flood level did not reach the top of the HW table, so the cross-section definition is appropriate in this case. It is suggested to check all the bridge locations to confirm the validity of the assumption.	The adopted maximum height of box culverts is three metres. A plank bridge has been selected to replace a culvert higher than three metres. Single span plank bridges have been represented as 1D structures and soffit levels of all plank bridges are located below the one per cent AEP flood levels. The HW table will be updated to define a small width (typically 0.001) at bridge soffit at the detailed design stage.
	In the case of “2d_SA ALL” inflow applications, the hydrologic sub-catchments were adopted as the SA polygons. The ‘SA All’ approach distributes flows to all cells equally within the SA polygon (i.e. the flows would be routed in the hydraulic model across the entire SA polygon). It was found in BMT’s concurrent review of the associated hydrology models, that these inflows are also routed hydrologically leading to routing having occurred twice for affected catchments. It is understood	This approach was adopted by JacobsGHD at the Reference Design stage. Models will be refined and updated as part of the detailed design.

Element	BMT Review Comments	JGHD Response
	that JacobsGHD will investigate this issue further as part of the detailed design.	
	The Manning's n values adopted for some sections of the proposed railway line(formation) appear to be high. It appears that the underlying existing roughness were adopted. Whilst this may not have any significant impact where the railway formation is not overtopped, it is recommended to adopt representative values where there is overtopping and cross drainage structures. Note that this issue was amended for both the NFMv7 and Narrabri 100% feasibility design models.	The rail formation is not overtopped in the one per cent AEP event with climate change and hence the adopted roughness values will not impact on adopted flooding impacts up to and including the one per cent AEP event with climate change. The adopted high Manning's n values for the rail formation in other TUFLOW models will be updated during detailed design.
	Whilst the 1D(culvert) entry and exit losses were appropriately specified for the Design scenario, the losses were not completely specified for the existing 1D structures. Whilst these factors are not required to be specified for 1D pipes forming a series of stormwater network (losses are built in), for culverts/pipes directly connected to the 2D domain the losses are required to be specified to derive accurate hydraulic characteristics.	The rail formation is generally located away from the existing transverse drainage structures and consequently, flood behaviour along the rail formation are generally not influenced by the existing drainage structures.
	Common Commentary for All Study Areas	
1	No unusual commands were found.	Noted
2	No unusual warnings or errors were found.	Noted
3	Based on the 1:2000 AEP design flood inundation extent, the model extent appears to have adequate coverage.	Noted
4	The Manning's n values are generally considered to be representative of the surface roughness of the study area	Noted
5	The 1D-2D connections are generally in accordance with industry practice.	Noted
6	A combination of 2d_SA, 2d_SA ALL and 2d_bc inflows were adopted that are appropriate for the study	Noted
7	The Form loss coefficient K values adopted for Layer 1 and Layer 2 are as per typical values.	Noted
8	The design cross-drainage structures utilised appropriate entry loss (0.4) and exit loss (1.0) that are generally in accordance with industry practice	Noted
9	Given the extent of the model area and proposed design, a 10m grid size is considered to be appropriate.	Noted
10	A combined HQ and HT downstream boundaries were adopted that are appropriate for the study.	Noted

Element	BMT Review Comments	JGHD Response
	The locations and extents appear to be are a reasonable distance from the area interest and adequate to allow for the transfer/exit of flow from the system	Noted
11	The proposed design surface of the railway was found to have been incorporated into the model.	Noted
	Several 1D cross-drainage structures were found to have been incorporated with the design with appropriate entry loss (0.5) and exit loss (1.0).	Noted
	For the proposed bridges, whilst the blockage and form loss attributes were specified for Layer 3, no attribute (zero value) was specified for the depth of this Layer. This needs to be checked.	Soffits of the proposed bridges are located above the one per cent AEP flood levels and hence modelled flood levels below bridge decks are not influenced by the adopted loss coefficient. Form loss coefficients for layer three (ie. hand rails) are expected to be negligible as hand rails are most likely to be washed away during major flood events which result in overtopping of the rail formation.
12	The 2D outflow hydrographs were found to smooth	Noted.
13	For NFMv7 and Narrabri models, mapped outputs agree with model results for instances checked.	Noted.
	NFMv7 Commentary	
4	The main channel of Macquarie River appears to be clear of vegetation. The Manning's n value of 0.065 applied for this part of the river appears to be high. It is suggested to consider a lower n value	The Macquarie River is a regulated river and landowners are not generally permitted to clear floating debris and remove snags from the river. The floating debris and snags have the potential to impede flood flow resulting in higher energy losses. The adopted Manning's n values for the main channel of the Macquarie River are in agreement with previous flood studies (Bewsher, 1998; Lyall, 2009, and Lyall, 2013) for Narromine.
5	At some 1D structure locations, bed levels were lowered by as much as 2.7m to match the 1D node invert level. Check if these are real.	The subject 1D structures are defined in the model to represent the existing pits and pipes stormwater network in the township of Narromine. These structures were included in the TUFLOW model provided by Narromine Shire Council. The subject 1D structures are located away from the proposal and the structures are unlikely to influence the flooding assessment undertaken for the proposal.
6	It was noted that no inflows were applied within the site to the north of Mitchell Highway. This assumption needs to be confirmed to ensure the total flows have not been underestimated.	The Macquarie River has a catchment area of approximately 25,900 square kilometres. The catchment area located north of Mitchell Highway is only a few square kilometres which will have negligible influence on the adopted inflows for the Macquarie River.
	For a limited number of 2D_SA polygons (8 out of 56), the inflow applied to those polygons has been scaled (increased) using a multiplier factor in the TUFLOW boundary condition database. It	Catchment areas for the identified eight 2D_SA polygons vary between 1.0 to 8.7 square kilometres and the average size of the contributing catchment area is 4.0 square kilometres. Scaling up of

Element	BMT Review Comments	JGHD Response
	appears as though this has been done to compensate for upstream catchment area that is not represented in TUFLOW. There are two issues identified with this approach (termed Type 1 and 2) with the affecting issue dependent on the model set up. These are summarised in Table 3-3 for the 8 affected SA polygons	inflows for the eight catchments provide conservative peak flows at the rail formation. Hence, no scaling factors will be used at the detailed design stage.
	Whilst the Type 1 issue is expected to have a larger effect on flows than the Type 2 issue, for both Type 1 and Type 2 issues the consequences are likely to have only a minor effect on model results. This is because the erroneous additional area modelled to be contributing flow is small relative to the total contributing catchment area. The affected sub catchments are also at the upstream extent of the respective TUFLOW models and so are located some distance from the railway alignment. It is recommended that the model set up is revised at the next opportunity to update the model as part of the design process	No scaling factors will be used at the detailed design stage for the eight 2D_SA polygons.
11	For the proposed bridges, whilst the blockage and form loss attributes were specified for Layer 3, no attribute (zero value) was specified for the depth of this Layer. This needs to be checked.	Soffits of the proposed bridges are located above the one per cent AEP flood event and hence modelled flood levels below bridge decks are not influenced by the adopted loss coefficient. Appropriate form loss coefficients for Layer three will be applied in the detailed design.
	BMT understands that form loss values for the Macquarie River viaduct were updated from the 70% design. The values have been checked and appear to be within an acceptable range for a structure of this nature.	Noted
	BMT understands that culverts comprising 13 cells or more have been represented in the 2D domain for the 100% design. Whilst this is appropriate, BMT has noted two minor issues with the model set up:	Noted
	• A handrail layer (2d_zsh_handrail_v1_L.shp) is included at culvert locations where the culvert is now represented in 2D. This layer adds a value of 0.8m to the cell elevations. This layer is no longer required due to use of layered flow constrictions. Model results are not affected as the handrail layer is later overwritten by elevations contained in the layered flow constriction layer. However it is recommended that this layer is removed at the next opportunity to avoid confusion.	The handrail layer (2d_zsh_handrail_v1_L.shp) will be excluded from the model set up at the detailed
	• The z-shape layer (2d_zsh_NFM_Smooth_atCulvertAsBrdg_R.shp) applied at culvert locations is assumed to have the intent of lowering cell values to match the invert level of the culvert. This layer is not functioning as intended as the elevation value is ignored by TUFLOW. Instead the elevations around the perimeter used to interpolate values across the polygon. For the elevation to be	Noted. The TUFLOW model will be updated at the detailed design stage to resolve the minor issue.

Element	BMT Review Comments				JGHD Response
	applied, the 'No Merge' flag needs to be applied to the 'shape options' attribute of the layer. This flag can be included with 'min' to have the desired effect. The implications of this are likely to be minor as the layered flow constriction sets the invert level at the structure. The 2D cells within the general vicinity of the culvert which were intended to be lowered will not be lowered to the specified elevation. This may have an influence on modelled conveyance to and from the culverts but is unlikely to have any notable affect for the flood events considered in the assessment.				
	NFMv7 SA Inflow Commentary				
Type	Affected SA Polygons	Description of Issue	Consequence	Recommended Approach	
1	1R, 1Z, 3N, 4O, 4X	Scaling factor increases inflow to account for missing catchment area but this is already accounted for as TUFLOW uses RORB flow with no adjustment for area	Overstates local catchment peak flow and volume	Remove scaling factor as area already accounted for using SA approach.	Agreed. No scaling factors will be used at the detailed design stage for the identified 2D_SA polygons.
2	1O, 4T, 4H	Scaling factor increases inflow to account for separate upstream sub-area.	Potentially overstates peak flow due to lack of upstream routing	Remove scaling factor and apply upstream sub-area as additional inflow at upstream boundary of TUFLOW model	Agreed. No scaling factors will be used at the detailed design stage for the identified 2D_SA polygons.
	N2N14 Commentary				

Element	BMT Review Comments	JGHD Response
4	The n value 0.03 used for road corridor appears to be higher than the value adopted for the paved road (0.02). It recommended to adopt 0.02 for the road corridor as well	The difference between the adopted Manning's n value for road and the typical Manning's n value for road is small and the small difference is unlikely to impact on flooding assessment undertaken for the proposal.
	N2N13 Commentary	
4	Some vegetated areas of the main floodway and floodplain adopted lower Manning's n value (0.045 to 0.05) which are lower than typical values that would be appropriate for vegetated surfaces (0.08 to 0.1).	Agreed. further refinement in detailed design stage is recommended. Given that the proposal is located on hillside in this area and the majority of the new cross drainage works being bridge structures with more than 5 – 8 metre clearance, the adopted lower Manning's n values would have no impact on the design.
	The n value 0.03 used for road corridor appears to be higher than the value adopted for the paved road (0.02). It recommended to adopt 0.02 for the road corridor as well	The difference between the adopted Manning's n value for road and the typical Manning's n value for road is small and the small difference is unlikely to impact on flooding assessment undertaken for the proposal.
6	Inflows were applied 2d_sa layers within the floodplain and main waterway which are considered to be appropriate for the study area.	Noted
7	No attributes were defined for Layer 3. This assumption needs be checked to ensure the highest flood level will not overtop the road.	Soffits of the proposed bridges are located above the one per cent AEP flood levels and hence modelled flood levels below bridge decks are not influenced by the adopted loss coefficient. Appropriate form loss coefficients for Layer three will be applied in the detailed design
	N11N12 Commentary	
4	Manning's n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour	The rail formation is not overtopped in the one per cent AEP event with climate change and hence the adopted roughness values will not impact on flood behaviour up to and including the one per cent AEP event with climate change.
6	The 2d_SA inflow at the upstream part of Castlereagh River should be checked to ensure that the runoff from the downstream catchment areas were represented in the model area.	The Castlereagh River has a catchment area of approximately 6,630 square kilometres at the proposal. The catchment area located downstream of the proposal is very small in comparison to the catchment area of the Castlereagh River located upstream of the proposal and hence rainfall runoff generated from the smaller catchment located downstream of the proposal has been ignored.
11	Some of the proposed bridges adopted zero blockage for Layer 1 (suggesting no piers), but a nominal form loss factor of 0.04 was applied for Layer 1 (typically if there are no piers in the waterway a form loss of zero should be adopted).	A review of the model confirms that blockage factors have been adopted for all bridges included in the proposal.
	N2N10 Commentary	

Element	BMT Review Comments	JGHD Response
4	Manning's n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour	The rail formation is not overtopped in the one per cent AEP event with climate change and hence the adopted roughness values will not impact on flood behaviour up to and including the one per cent AEP event with climate change.
	N2N9 Commentary	
4	Manning's n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour	The rail formation is not overtopped in the one per cent AEP event with climate change and hence the adopted roughness values will not impact on flood behaviour up to and including the one per cent AEP event with climate change.
6	A river inflow was applied as a 2d_bc polyline directly on the grid cells, i.e. the polyline was not snapped to the edge of the active model area(2d_Code). Whilst this does not affect the outcome, the typical practice is to snap or digitise the line along edge of the Code.	Noted. The inflow for the river will be defined along the edge of the 2d_Code in the detailed design.
	N2N8 to Narrabri Commentary	
4	The Manning's n values adopted for some sections of railway in the 70% feasibility design (0.065 and 0.1) were deemed too high. These have now been amended in the 100% feasibility design to 0.045, which is reasonable.	The rail formation is not overtopped in the one per cent AEP event with climate change and hence the adopted roughness values will not impact on flood behaviour up to and including the one per cent AEP event with climate change. The adopted high Manning's n values for the rail formation will be updated as part of the detailed design.
11	The following changes were made to the design going from the 70% to the 100% design: • Manning's n roughness values for the railway updated (see #4 above) • FLC values for the Narrabri viaduct updated • A 10% blockage adopted for handrails at bridges BMT has checked and confirmed that the above stated changes were appropriately incorporated into the model.	Noted
13	A sample of model results for the 1% AEP event were visually cross checked against those shown in the Flooding and Hydrology Assessment Technical Report 3. The checks showed the model results and mapping to be in agreement.	Noted
	N2N7 Commentary	
7	A high percentage blockage (25%) was adopted for a bridge within Layer 1; this needs to be confirmed to ensure the adopted value is realistic.	The adopted 25 per cent blockage accounts for blockage due to piers, abutments and skew of the bridge. The adopted blockage and bridge loss coefficients will be updated at the detailed design stage.

N2N Responses to BMT-WBM Independent Hydrology Review **(23 November 2020)**

Review Item	BMT Review Comments	JGHD Response
	Summary of General Comments on RORB Models	
	For all of the calibrated RORB models, there are more than the recommended five subareas upstream of the key gauges used in the assessments. This allows for appropriate routing in the derivation of flow hydrographs at required locations.	Noted
	For all of the calibrated RORB models, the appropriate reach type (Type 1 – Natural Waterway) was used for all reaches. This represents how water will convey through the catchments appropriately. This is appropriate given the predominantly rural nature of all catchments.	Noted
	Nodes have been placed at the downstream end of subareas, and at all confluences of watercourses. The reporting nodes have also been positioned in the appropriate places for the study.	Noted
	Commentary for Macquarie River RORB Model (MAC)	
Subareas:	• 31 subareas, this is considered sufficient to calibrate a RORB model • The range of subarea sizes is appropriate, with the largest subarea being approximately 6x the smallest	Noted
Reaches:	All reaches Type 1. Consistent with land use.	Noted
Storages	• There are no storages within the model. Lake Burrendong is a significant storage in the catchment with a significant portion of the catchment being upstream of this storage. • The inclusion of this will likely slow the flow down significantly, changing the shape of the hydrograph. However, it is understood that the storage effects have been modelled using a high kc value.	Noted Noted
Kc:	• Value of 262.71 seems very high and will have the effect of attenuating (reducing) the peak flow. It is understood from JacobsGHD that the high kc value was used to match the rising limb and peak flow rates to historic flood events and FFA respectively.	Noted
IL	• Varying losses, generally decreasing in rarer events	Noted
CL	• Consistent loss of 1.84 mm/h. This is acceptable.	Noted
Design Flows	Match closely to FFA (within 5% for all events) and is acceptable for the study,	Noted

Review Item	BMT Review Comments	JGHD Response
	Commentary for Castlereagh River RORB Model (CAS)	
Subareas:	• 39 subareas, this is considered sufficient for RORB calibration • The range of subarea sizes is appropriate, with the largest subarea being approximately 6x the smallest	Noted
RORB Parameters:	Not applicable as the RORB model flows are scaled to match results from an FFA.	Noted. A RORB model for the Castlereagh River will be developed during detailed design to follow the same approach adopted both for the Macquarie River and the Namoi River.
	Commentary for Baradine Creek RORB Model (N2N7_1)	
Subareas:	• 25 subareas. 24 subareas used for calibration model, with Subarea 'Y' being added for design events. The range of subarea sizes is appropriate, with the largest subarea being approximately 5x the smallest	Noted
d_{av}:	• Minor differences in value noted between design and calibration models. This is due to the additional subarea 'Y' for additional design reporting output.	Noted
Kc:	• Value from calibration is 20 (x3 models), 25 and 31. The values appear reasonable and a good calibration is demonstrated. • Value adopted for design events is 20 which is reasonable based on values determined through calibration	Noted
IL	• Initial loss value adopted for design runs is 72.7mm. This comes from the November 1998 calibration event. It approximates the median of the three calibration events which is appropriate	Noted
CL:	• Value of 2.9mm/h consistent between calibration and design events. • Consistent with ARR Losses from Datahub	Noted
ARF:	• value applied based on area (974.81km^2) is less than the total catchment size (1002.08km^2). However the catchment area to the key location of interest (C20 (node O1)) is 933.18 km^2. This may have a slight effect on rainfall depths into the model in the design events but will most likely be minor	The adopted ARF is based on the catchment area, 974.81km^2 , at the rail formation.
Calibration:	• Only 3 of 5 calibration runs have results plotted (1997 and July 1998 events not available). It is understood from JacobsGHD that only the larger floods have been presented. • Calibration generally shows good match to the peak flows, as well as good rising and falling limbs. • Sept 1998 – Failure to match smaller peaks before and after the main peak suggests CL could be too high but as main peak	Noted. Noted The available sub-daily rain gauge (064046) used to define the temporal distribution of rainfall is located outside the modelled catchment. This is considered one of the key reasons for failure to match smaller peaks before and after the main peak.

Review Item	BMT Review Comments	JGHD Response
	matches well this is considered a minor issue and calibration is acceptable.	
	Commentary for Coolbaggie Creek RORB Model	
Subareas:	• 14 subareas. This is considered sufficient for RORB calibration • The range of subarea sizes is appropriate, with the largest subarea being approximately 4x the smallest	Noted
d_{av}:	• The adopted design value of 40 matches 39.87 in calibration event outputs • No design runs provided to cross check against calibration. Discussions with JacobsGHD confirmed that this model was intended as a donor catchment model only for RORB parameter generation and ended up not being used at all. Therefore, no design runs are required.	Noted
Kc:	• Value from calibration is 22 (x3 models) and 28 (x2 models). Seems reasonable and offer good matches in calibration figures. • No design kc (as model not used for design modelling). • It is understood a median value of 25 was adopted, no kc value of 25 was used in the supplied calibration events. This should be investigated if the model is used to inform design flood modelling at any future stage of assessment.	Noted Noted. The proposal does not cross the catchment areas of Coolbaggie Creek and as such, flood modelling for design flood events was not undertaken.
IL	• Calibration ILs range from 20 mm to 78.4 mm • These differ slightly from reported values of 20 mm to 73 mm but are unlikely to result in any material change in model outcomes.	Noted
CL	• Calibration CLs range from 1.2 mm/h to 1.6 mm/h are consistent with reported values and with ARR 2019 estimated values	Noted
ARF	• Design runs not required and so no ARF values to assess	Noted
Calibration	• 4 out of 5 calibration runs have plotted results with the November 2010 event not shown. It is understood from JacobsGHD that only the larger floods have been presented. • Calibration demonstrates the model matches well to peak flows • Modelled hydrographs for the November 2000 and March 2012 events rise far later that observed, suggesting adopted IL for these events are possibly too high but the match to peak flows is considered satisfactory.	Noted
	Commentary for Bohena Creek RORB Model	
Subareas	• 25 subareas. This is considered sufficient for RORB calibration	Noted

Review Item	BMT Review Comments	JGHD Response
	• The range of subarea sizes is appropriate, with the largest subarea being approximately 5x the smallest • Areas in RORB Shapefiles differ to those specified in the RORB 'catg' model file by a small margin. Likely to not affect results	
d_{av}	• Adopted design value of 66 matches 66.06 in calibration event outputs and design outputs	Noted
Kc	• Value from calibration is 21 (x3 models), 22 and 25. Values seem reasonable and demonstrate a good calibration can be achieved • Design kc is 21	Noted
IL	• Calibration ILs range from 27mm to 102mm • Design loss used is 39.7mm. The median value was 59mm so a loss of 39.7mm is conservative in this regard.	Noted The adopted rainfall loss (39.7 mm) is the median rainfall loss based on calibration results for three major flood events
CL	• Calibration CLs range from 2.5mm/h to 3.5mm/h compared to the adopted design value of 2.5mm/h which is reasonable. • Consistent with ARR 2019 estimated values	Noted
ARF	• ARF value consistent with total area of the RORB model, and location of gauge at downstream end	Noted
Calibration	• 3 out of 5 calibration runs are plotted (2000 and 2004 events not included). It is understood from JacobsGHD that only the larger floods have been presented. • Calibrations demonstrate good matching to the peak flows, as well as a good match on rising and falling limbs.	Noted. Adopted median rainfall losses and RORB model parameter values were selected for design flood events based on calibration results for three major flood events.
	Commentary on Narromine (Backwater Cowal) RORB Models	
	• BMT understands that following community feedback on the 70% feasibility design, more definition was required within the Narromine RORB model to map overland flow paths. The Narromine model was therefore broken up into five (5) RORB models for the 100% feasibility design. These models provide inflow hydrographs into the associated TUFLOW model that includes the Narromine catchments in the vicinity of the railway alignment.	Noted
	• Routed print locations are at the appropriate location for introduction of inflows into the TUFLOW model for each of the five RORB models which extend upstream of the model boundary.	Noted
	• The range of the subarea sizes in each respective model is appropriate. The larger RORB models have proportionately larger	Noted

Review Item	BMT Review Comments	JGHD Response
	subareas, with all models also having an acceptable minimum number of subareas required for routing.	
	• Reach types are consistently "Type 1 – Natural" throughout all RORB models. This is consistent with the land use and appropriate for the RORB models	Noted
	• Reach delineation is appropriate for all models, leading to appropriate values of the dav parameter used in all RORB models.	Noted
	• Multiple catchment areas have been used for calculations of the areal reduction factor (ARF) in RORB runs. These have been applied for each point upstream inflow into the TUFLOW model. This is an appropriate application of the ARF.	Noted
	• The Initial Loss, Continuing Loss and kc parameters for the five Narromine RORB models are shown in Table 3-6 below. This shows: • ○ The Initial Loss values are consistent with using the Pre-Burst losses from Data Hub • ○ The Continuing Loss values are consistent with the Data Hub losses for RORB models 3 to5 • ○ The Continuing Loss values for RORB models 1 and 2 have been multiplied by a factor of 0.4 in accordance with NSW specific guidance on the Data Hub. • ○ The kc values seem appropriate for the catchment sizes.	Noted. Noted Noted Noted Noted
	• The low loss values may result in peak flow values that are conservative (high) but this is considered a precautionary approach.	Agreed. The adopted rainfall losses for design flood events are conservative. In the absence of recorded stream gauge data and feedback provided by local landowners, a precautionary approach is justified.
	Smaller catchment reviews – 3.4.1 Review commentary	
	• The way in which loss values were selected was initially unclear but later clarified by JacobsGHD who stated that for uncalibrated models a conservative approach was adopted by selecting the lower of the losses from neighbouring calibrated catchments or from the ARR2019 Data Hub.	Noted.
	• This appears to be a conservative approach and one which BMT deems to be appropriate. It is noted by BMT that the rainfall loss values in the smaller catchments seem to be significantly lower than those losses chosen for the design events in the calibrated catchments and those obtained from the DataHub. This will likely	Noted

Review Item	BMT Review Comments	JGHD Response
	lead to conservative flow estimates.	
	• Where kc values have been specified in models that route hydrographs to provide a point input to the hydraulic model i.e. not excess rainfall outputs, how the Kc value has been determined is not specified. Given that initial loss values are conservative then the model outputs are still likely to be conservative but future reporting should include a statement on how kc values have been derived in these models.	Based on calibration and verification results, and in consideration of recommendations in ARR 2019, the RORB hydrology models were parameterised as follows: • Calibrated models –median values of Kc from calibration results • Uncalibrated models – RORB model parameter values were based on ARR 2019 (ie. $\mathbf{K_c = 1.18\ A^{0.46}}$, where, A is the catchment area in square kilometres)
	• The application of the IFD and ARF data is consistent throughout all of the assessed RORB models and have been applied correctly.	Noted
	3.4 Flood Frequency Analysis	
	The rating curves which underpin the FFA analyses appear to rely on the flow to level gaugings undertaken by Water NSW. Further clarification was sought by BMT from JacobsGHD as to how the accuracy of each rating curve used was considered noting that, in general, rating curves from government agencies tend to be less accurate for larger flows once discharge engages the floodplain. JacobsGHD confirmed that flow gauging data and cross sections at the gauges were reviewed. In the case of the Namoi River/Narrabri Creek and Bohena Creek (N2N1 TUFLOW model), the adopted rating curves were compared against TUFLOW model results to verify rating curves which is a best practice approach. JacobsGHD stated that this was not possible for Baradine Creek as the gauge had not been surveyed to Australian Height Datum and was discontinued.	Noted
	Quality checks of the data only appear to be undertaken for large data gaps. It is not clear the degree to which any sanity checks may have been performed to ensure the maximum flow for each year is the actual maximum flow and not an artificial spike (as water level gauges can fail during large events). Commentary should also be made if the 'water year' has been used to calculate the annual maximum flow series, although this is not likely to have any notable bearing on outcomes.	Noted. "Water year" is based on calendar year. There is a reasonable agreement between the FFA results and the other available independent FFA estimates and as such, further sensitivities were not warranted as part of the Feasibility Design.

Review Item	BMT Review Comments	JGHD Response
	The Grubbs Beck test for outliers has been performed for the FFA, however no further sensitivities appear to be undertaken. The FFA derived peak flows for Baradine Creek and Coolbaggie Creek are notably lower than the corresponding flows from the RORB models for events rarer than the 1 in 10 AEP. It would be of value to understand some of the reasons behind these large differences. However, based on discussions with JacobsGHD, the larger RORB flows have been adopted for use on these catchments which is a conservative approach and therefore acceptable.	Noted. The gauging station for Baradine Creek is a discontinued gauge and the gauge zero is not connected to the Australian Height Datum. In addition, JacobsGHD was unable to locate the gauge or the bench mark for the gauge. Hence the RORB simulated peak flows and the FFA estimates were not reconciled and the hydrographs simulated by the RORB model for Baradine Creek were adopted. The proposal does not cross the catchment areas of Coolbaggie Creek and as such, RORB estimated peak flows were not reconciled with the FFA estimates.
	Baradine Creek FFA	
	It is understood from discussions from JacobsGHD that the peak flows from the Baradine Creek FFA were not adopted for design purposes, with higher peak flows from RORB modelling used instead. The gauge on Baradine Creek was also discontinued. The comments summarised below regarding the Baradine Creek FFA are included for completeness but will not affect design flood modelling and no further action is required unless the FFA is used for future purposes.	Noted
	• There are 28 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.	Noted
	• The peak flows from 2002 and 2006 were not included in the analysis. The reasons for the exclusion are not stated. If it is simply that the flows are very low, it is recommended that these years are still included but as censored data so that they do not unduly influence the fit of the distribution for floods at the rare tail end.	Noted
	• The peak flow from 1981 was included in the analysis, however recorded flows commenced in this year and as such 1981 only has a partial record of flows in that year. Given the full year is not available, this should be removed to maintain consistency with the rest of the FFAs but it is not likely to have a notable effect on outcomes.	Noted. To be reviewed as part of detailed design.
	Coolbaggie Creek FFA	

Review Item	BMT Review Comments	JGHD Response
	It is understood from discussions from JacobsGHD that the peak flows from the Coolbaggie Creek FFA were not adopted for design purposes, with higher peak flows from RORB modelling used instead. The comments below regarding the Coolbaggie Creek FFA are included for completeness but will not affect design flood modelling and no further action is required unless the FFA is used for future purposes.	Noted
	• There are 38 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.	Noted
	• The peak flow from 1980 has been removed from the analysis. It is assumed that this was due to the record beginning in November 1980, therefore a full year of data was not available. This is appropriate.	Noted
	• 19 of the 38 years have been censored in the censored assessment. This is a significant proportion and the reasons behind this should be further explored if the FFA is to be used for future purposes.	Noted
	Castlereagh River FFA	
	It is understood that the Castlereagh River FFA is relied upon to obtain peak design flow estimates which the RORB model flows are then scaled to. The FFA “without” censoring was provided for review. The findings from the review are as follows:	Noted
	• There are 33 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.	Noted
	• The peak flows from 1968 and 2004 were removed due to the records not being full years of recorded data. This is appropriate.	Noted
	• Peak flows in 2001 and 2002 were removed. Very small flows were recorded in these two years, all less than 2m3/s, with some missing data from the record in both years. It is assumed that the years were excluded on the basis of the missing data and are therefore ‘incomplete years’ which is recommended practice.	Noted

Review Item	BMT Review Comments	JGHD Response
	• Clarification was sought regarding by how much the RORB flows differed from the FFA derived peak flows. The response from JacobsGHD was that a scaling factor of approximately 1 was used, suggesting that the peak flow estimates from both approaches were in agreement. A comparison was also provided between the peak FFA flows derived in this assessment verses peak FFA flows derived from a previous flood study prepared by Lyall and Associates in 1996. Generally, the peak flows were in agreement with those from the 1996 study and are slightly higher.	Peak FFA flows adopted by Lyall & Associates (Gilgandra Floodplain Management Study (1996)) were derived on the basis of recorded peak stages at the discontinued Gilgandra gauge for the periods 1909-1924, 1944-1978 and 1985-1992, and details on peak gauge heights associated with a number of historic floods, including 1874 and 1890.
	Macquarie River FFA	
	It is understood that the Macquarie River FFA is relied upon to obtain peak design flow estimates which the RORB model flows are then scaled to. The FFA “with” censoring was provided for review. The findings from the review are as follows:	Noted
	• There are 32 years of data in the analysis, more than the minimum recommendation of 10 years to utilise an annual maximum series approach but there will be a large degree of uncertainty when results are extrapolated out to larger flood events such as the 1 in 100 AEP. Due to this uncertainty, other techniques (RORB and RFFE) have also been applied for comparative purposes which is in accordance with best practice.	Noted
	• The peak flow from 2018 was removed from the analysis. It is assumed that this was due to the records not being complete at the time of the data collection.	Noted. The data for the full calendar year was not available at the time of undertaking the analysis.
	• The peak flow from 1986 was included in the analysis, even though records started in June 1986. Given the full year is not available, this should be removed from the analysis to maintain consistency with the rest of the FFAs but is unlikely to result in any change in outcomes.	The upstream gauge, Macquarie River at Dubbo, shows that peak flows occurred during August and September 1986 and hence the peak flow for 1986 was included in the FFA.
	• Clarification was sought regarding by how much the RORB flows differed from the FFA derived peak flows. The response from JacobsGHD was that a scaling factor of approximately 1 was used, suggesting that the peak flow estimates from both approaches were in agreement. A comparison was also provided between the peak FFA flows derived in this assessment verses peak FFA flows derived from a previous flood study prepared by Lyall and Associates in 2013. Generally, the peak flows were in agreement with those from the 2013 study and are slightly higher.	Noted.
	Regional Flood Frequency Estimate (RFFE)	

Review Item	BMT Review Comments	JGHD Response
17	Regional Flood Frequency Estimates have been undertaken for the larger catchments at the gauges. The RFFE is a high level tool that can provide a sense check on peak flow estimates. It often contains large uncertainty bounds but these can be refined through assessing and refining the gauges used within a 'region of influence' to inform the RFFE. It is not clear whether the gauges within the respective regions of influence for each assessed subject site have been further analysed. From discussions with JacobsGHD the sparsity of gauges in the assessed catchments results large regions of influence which are difficult to refine. It is understood the RFFE peak flow estimates have not been relied upon to factor RORB flows and as such the use of this technique as a sense check on peak flows is considered appropriate.	Noted
	Other methods flow estimation methods	
18	For smaller catchments, it is understood that conservative parameters such as the lower bound on initial losses have typically been adopted. This is considered acceptable given the overall uncertainty of peak flow estimation in areas where there is a lack of gauged data. Other techniques that could potentially be applied when validating the smaller catchments include the probabilistic rational method (where applicable), quartile regression technique, or reconcile results with another hydrologic model package such as WBNM. Such techniques would also include a significant degree of uncertainty but may provide an additional validation of peak flows.	Noted RFFE was used to validate the RORB estimated peak flows in this study. If necessary, other methods would be considered during detailed design for further validation of the RORB estimated peak flows for smaller catchments.
	Baseflow	
	Due to their geographic location, baseflow is not expected to have any influence on peak flood modelling results in the catchments under consideration. It is noted however that during model calibration, baseflow has been separated from the recorded hydrographs for calibration of the RORB model. From discussions with JacobsGHD it is understood that the baseflow was found to be almost negligible. It was confirmed with JacobsGHD that baseflow was not then added back into the hydraulic model for water level calibration. Given that the baseflow was assessed by JacobsGHD as being negligible this is not considered to be an issue.	Noted
	TUFLOW Input Hydrographs	

Review Item	BMT Review Comments	JGHD Response
	The hydrographs from the review subset of 10 hydrologic models were reviewed and compared to the inflow hydrographs in the TUFLOW models (as these should be the same). BMT have the following comments:	
	• In all cases the hydrographs used for inputs into the TUFLOW models match the outputs from the hydrology models.	Noted
	• For each of the ten catchments respective TUFLOW models, a single inflow is applied which is the routed total flow from the respective catchment hydrologic model.	Noted
	• The inflow location for the Bohena Creek model ("C-2" in N2N1) is 12km upstream of the printout location for the routed hydrograph. This effectively double routes the flow along this 12km length but is unlikely to result in any significant impact on results	Noted
	• Inflows into the TUFLOW models for catchments D29411, D32008, D68620, D79020 and D86480 are effectively rain on grid inputs as they utilise TUFLOW's '2d_sa ALL' command. This distributes the inflow hydrograph across all grid cells within the defined boundary (which covers the whole catchment area). These input hydrographs have already been routed within the RORB models. It is BMT's understanding that this would lead to routing having occurred twice for these catchments, likely leading to a reduction in peak flows at the downstream end of these catchments. This issue was raised with JacobsGHD who confirmed that it affected a limited number of subcatchments. It was noted by JacobsGHD that the issue affects both calculations for the existing scenario, before Inland Rail, and the operational scenario, after Inland Rail. It was also confirmed that the catchments in question are predominantly rural with a low risk of changes significantly affecting the number of buildings impacted from the existing case to the operational scenario. JacobsGHD has stated that this will be investigated and addressed further as part of the detailed design.	Noted. Relevant TUFLOW models will be updated during detailed design.
	Conclusions	
	BMT has undertaken a review of hydrologic models and the modelling approach for the Narromine to Narrabri (N2N) study. The review identified minor issues that are not anticipated to have a significant impact on the overall model outcomes. The overall approach is a conservative one which is best practice, particularly in those catchments with little or no gauged data.	Noted
	Overall the models are deemed have been appropriately set up except for one identified issue which affects a limited number of	Noted. To be addressed during detailed design.

Review Item	BMT Review Comments	JGHD Response
	subcatchments where routed flows are being distributed evenly across catchments. JacobsGHD were made aware of this issue and have identified a low risk of changes significantly affecting the number of buildings impacted. It is understood that this will be investigated and addressed as part of the detailed design.	Noted. Relevant TUFLOW models will be updated during detailed design

Model	BMT original comments	BMT subsequent comment	Recommended Action
N2N9	Manning’s n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour.	Manning's n along the railway has been reduced to 0.04, which seems reasonable. It is noted that this comment is very minor as water does not flow along the railway, only across it briefly.	Nil
	A river inflow was applied as a 2d_bc polyline directly on the grid cells, i.e. the polyline was not snapped to the edge of the active model area(2d_Code). Whilst this does not affect the outcome, the typical practice is to snap or digitise the line along edge of the Code.	The river inflows are still not snapped to the edge of the model extent. However, they are close (within 30-50 m). Thus, it is not expected that the additional storage available between the boundary and model extent will noticeably affect model results. It would be prudent to correct this prior to any future model reruns.	Fix when convenient
N2N10	Manning’s n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour.	Manning's n along the railway has been reduced to 0.04, which seems reasonable. It is noted that this comment is very minor as water does not flow along the railway, only across it briefly.	Nil
N2N11_12	Manning’s n values adopted for the proposed railway (0.045 to 0.05) appear be slightly higher than typical values, but these are not expected to have a significant impact on the flooding behaviour.	Manning's n along the railway has been reduced to 0.04, which seems reasonable. It is noted that this comment is very minor as water does not flow along the railway, only across it briefly.	Nil
	The 2d_SA inflow at the upstream part of Castlereagh River should be checked to ensure that the runoff from the downstream catchment areas were represented in the model area.	Catchment runoff on the Castlereagh River downstream of the railway is still not included in the model. It is noted that the downstream catchment area (22 km^2) is very small compared to the upstream catchment area (6,700 km^2). Thus, it is unlikely to make a substantial difference to the results. Nevertheless, the missing catchment flows should be included for completeness.	Fix
	Some of the proposed bridges adopted zero blockage for Layer 1 (suggesting no piers), but a nominal form loss factor of 0.04 was applied for Layer 1 (typically if there are no piers in the waterway a form loss of zero should be adopted).	Blockages have now been added to the model.	Nil

Model	BMT original comments	BMT subsequent comment	Recommended Action
N2N13	Some vegetated areas of the main floodway and floodplain adopted lower Manning's n value (0.045 to 0.05) which are lower than typical values that would be appropriate for vegetated surfaces (0.08 to 0.1).	This comment does not appear to be addressed. Most of the floodplain and channel is covered by land use categories with an ID of 4 or 6. These IDs are categorised as 'grazing' and 'non-irrigated cropping' and assigned a Manning's n of 0.05 and 0.045. However, substantial sections of floodplain and channel, that have been given a Manning's n of 0.045 or 0.05, appear forested according to current Google imagery.	Fix
	No attributes were defined for Layer 3. This assumption needs be checked to ensure the highest flood level will not overtop the road.	Depths of zero are still used for Layer 3, which represents flow through guardrails over the top of the bridge. The approach that has been adopted is suitable if there are no guardrails on the railway bridges.	Check
N2N14	The n value 0.03 used for road corridor appears to be higher than the value adopted for the paved road (0.02). It recommended to adopt 0.02 for the road corridor as well.	It is normal for a road corridor to have a higher Manning's n than the paved road because the road verge may be short grass/gravel. Therefore, no change is needed. We note that the transport corridor layer is still being used with a Manning's n of 0.03 and that this is suitable.	Nil
Narromine (NFM)	The main channel of Macquarie River appears to be clear of vegetation. The Manning's n value of 0.065 applied for this part of the river appears to be high. It is suggested to consider a lower n value.	The Manning's n in the low-flow channel is still 0.065, This is too rough for a sandy bed.	Fix
	At some 1D structure locations, bed levels were lowered by as much as 2.7m to match the 1D node invert level. Check if these are real.	We have checked the model terrain surrounding boundary cells and there are no large holes/depressions of concern. It is noted that some upstream and downstream boundaries either side of embankments are close, and there are at least two culverts (543.766 & 316315) that are not functioning correctly because the boundaries are adjoining.	Fix when convenient
	It was noted that no inflows were applied within the site to the north of Mitchell Highway. This assumption needs to be confirmed to ensure the total flows have not been underestimated.	TUFLOW simulation results of the 1% AEP event for short durations capture the peak local runoff from the five RORB models but do not capture the peak level of the Macquarie River.	Check
	For a limited number of 2D_SA polygons (8 out of 56), the inflow applied to those polygons has been scaled (increased) using a multiplier factor in the TUFLOW boundary condition database. It appears as though this has been done to compensate for upstream catchment area that is not represented in TUFLOW. There are two issues identified with this approach (termed Type 1 and 2) with the affecting issue dependent on the model set up. These are:	1. Scaling factors for sub-catchments 1R, 1Z, 3N, 4O and 4X have been changed to 1.0. 2. The scaling factor for sub-area 1O has been changed to 1.0, but we did not observe an additional inflow to account for upstream flow from sub-area 'V'. The	1. Nil 2. Fix

Model	BMT original comments	BMT subsequent comment	Recommended Action
	1. Scaling factor increases inflow to account for missing catchment area but this is already accounted for as TUFLOW uses RORB flow with no adjustment for area (SA polygons ID: 1R, 1Z, 3N, 4O, 4X). These scaling factors should be removed. 2. Scaling factor increases inflow to account for separate upstream sub-area (SA polygon ID: 1O, 4T, 4H). These scaling factors should be removed, and additional inflows added to account for upstream flow.	scaling factors for sub-catchments 4T and 4H have not been adjusted. The applied scaling accounts for the upstream catchment area but will apply flow in a more concentrated way as it has not been routed. As such results will likely be conservative estimates.	
	The proposed bridges and culverts were updated from the 70% feasibility design to include a 10% blockage in layer three of the flow constriction. This was checked and confirmed in this review., whilst the blockage and form loss attributes were specified for Layer 3, no attribute (zero value) was specified for the depth of this Layer. This needs to be checked.	A zero depth is still applied for Layer 3. However, this is suitable if the railway bridges have no guardrails.	Check
	BMT understands that culverts comprising 13 cells or more have been represented in the 2D domain for the 100% feasibility design. Whilst this is appropriate, BMT has noted two minor issues with the model set up: 1. A handrail layer (2d_zsh_handrail_v1_L.shp) is included at culvert locations where the culvert is now represented in 2D. This layer adds a value of 0.8m to the cell elevations. This layer is no longer required due to use of layered flow constrictions. Model results are not affected as the handrail layer is later overwritten by elevations contained in the layered flow constriction layer. However it is recommended that this layer is removed at the next opportunity to avoid confusion. 2. The z-shape layer (2d_zsh_NFM_Smooth_atCulvertAsBrdg_R.shp) applied at culvert locations is assumed to have the intent of lowering cell values to match the invert level of the culvert. This layer is not functioning as intended as the elevation value is ignored by TUFLOW. Instead the elevations around the perimeter used to interpolate values across the polygon. For the elevation to be applied, the 'No Merge' flag needs to be applied to the 'shape options' attribute of the layer. This flag can be included with 'min' to have the desired effect. The	1. The offending file has been removed from the model. 2. This layer has been used to cut through the embankment to simulate culverts as open spans. The 'MIN' flag has been used and the layer appears to have the desired effect on the model's terrain.	Nil

Model	BMT original comments	BMT subsequent comment	Recommended Action
	implications of this are likely to be minor as the layered flow constriction sets the invert level at the structure. The 2D cells within the general vicinity of the culvert which were intended to be lowered will not be lowered to the specified elevation. This may have an influence on modelled conveyance to and from the culverts but is unlikely to have any notable affect for the flood events considered in the assessment.		

N2N Responses to BMT-WBM Subsequent Independent Review of Updated N2N9, N2N10, N2N11_12, N2N13, N2N14, Narromine TUFLOW Models (18 January 2022)

Element	BMT Subsequent Review Comments	JGHD Response
N2N9	Manning's n along the railway has been reduced to 0.04, which seems reasonable. It is noted that this comment is very minor as water does not flow along the railway, only across it briefly.	Noted
	The river inflows are still not snapped to the edge of the model extent. However, they are close (within 30-50 m). Thus, it is not expected that the additional storage available between the boundary and model extent will noticeably affect model results. It would be prudent to correct this prior to any future model reruns.	The river inflow will be snapped to the edge of the model extent during next stage of the design.
N2N10	Manning's n along the railway has been reduced to 0.04, which seems reasonable. It is noted that this comment is very minor as water does not flow along the railway, only across it briefly.	Noted
N2N11_12	Manning's n along the railway has been reduced to 0.04, which seems reasonable. It is noted that this comment is very minor as water does not flow along the railway, only across it briefly.	Noted
	Catchment runoff on the Castlereagh River downstream of the railway is still not included in the model. It is noted that the downstream catchment area (22 km^2) is very small compared to the upstream catchment area (6,700 km^2). Thus, it is unlikely to make a substantial difference to the results. Nevertheless, the missing catchment flows should be included for completeness.	The missing catchment flows will be included in the next stage of the design.
	Blockages have now been added to the model.	Noted
N2N13	This comment does not appear to be addressed. Most of the floodplain and channel is covered by land use categories with an ID of 4 or 6. These IDs are categorised as 'grazing' and 'non-irrigated cropping' and assigned a Manning's n of 0.05 and 0.045. However, substantial sections of floodplain and channel, that have been given a Manning's n of 0.045 or 0.05, appear forested according to current Google imagery.	Land use categories will be updated in the next stage of the design.
	Depths of zero are still used for Layer 3, which represents flow through guardrails over the top of the bridge. The approach that has been adopted is suitable if there are no guardrails on the railway bridges.	It is assumed that guardrails on the railway bridges would collapse during rare and extreme flood events.
N2N14	It is normal for a road corridor to have a higher Manning's n than the paved road because the road verge may be short grass/gravel. Therefore, no change is needed. We note that the transport corridor layer is still being used with a Manning's n of 0.03 and that this is suitable.	Noted

Element	BMT Subsequent Review Comments	JGHD Response
	The Manning's n in the low-flow channel is still 0.065, This is too rough for a sandy bed.	The Manning's n value of 0.065 for the low-flow channel is based on calibration results.
	We have checked the model terrain surrounding boundary cells and there are no large holes/depressions of concern. It is noted that some upstream and downstream boundaries either side of embankments are close, and there are at least two culverts (543.766 & 316315) that are not functioning correctly because the boundaries are adjoining.	The two culverts will be updated during the next stage of the design.
	TUFLOW simulation results of the 1% AEP event for short durations capture the peak local runoff from the five RORB models but do not capture the peak level of the Macquarie River.	TUFLOW model results for the 1% AEP event are based on six model runs which include five short duration runs to capture peak runoff from the five RORB models and one long duration run to capture the peak level of the Macquarie River.
Narromine (NFM)	• Scaling factors for sub-catchments 1R, 1Z, 3N, 4O and 4X have been changed to 1.0. • The scaling factor for sub-area 1O has been changed to 1.0, but we did not observe an additional inflow to account for upstream flow from sub-area 'V'. The scaling factors for sub-catchments 4T and 4H have not been adjusted. The applied scaling accounts for the upstream catchment area but will apply flow in a more concentrated way as it has not been routed. As such results will likely be conservative estimates.	• Noted • Noted. The scaling factor for sub-area '1O' will be increased to account for upstream inflow from sub-area 'V'.
	A zero depth is still applied for Layer 3. However, this is suitable if the railway bridges have no guardrails.	It is assumed that guardrails on the railway bridges would collapse during rare and extreme flood events.
	• The offending file has been removed from the model. • This layer has been used to cut through the embankment to simulate culverts as open spans. The 'MIN' flag has been used and the layer appears to have the desired effect on the model's terrain.	• Noted • Noted

BMT Commercial Australia Pty Ltd
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Australia

ABN: 54 010 830 421

Our ref: L.N21291.002_CalibrationReport.docx

9 December 2021

GHD
Level 3 GHD Tower
Newcastle NSW 2300

Attention: Richard Hackett

Dear Richard

RE: NARROMINE TO NARRABRI CALIBRATION REPORT REVIEW

BMT Commercial Australia has been engaged by Jacobs and GHD IR Joint Venture (JacobsGHD) to conduct an independent review of the Hydrology and Hydraulics Model Calibration Report used to support the feasibility design of the Narromine to Narrabri (N2N) project. The full reference for the report that has been reviewed is:

> JacobsGHD (2021). *ARTC Inland Rail Narromine to Narrabri (N2N) Hydrology and Hydraulics Model Calibration Report, Revision 3*. Report No: 2-0001-250-IHY-00-RP-0002.docx, Issued on: 27/07/2021.

This document will herein be known as “the report”.

The purpose of this letter is to review the report to determine the adequacy of reporting on the methodology and results for the calibration of the hydrologic and hydraulic models for N2N project.

General comments

A review of the layout of the N2N Calibration Report has found that the report is well-written and discusses the subject matter comprehensively. The report is generally consistent with what could reasonably be expected of a model calibration report. However, the structure of the report is somewhat confusing and there are some inconsistencies in terminology. Therefore, the following recommendations are made to aid readability:

- The data available for a study is usually discussed before, or at the start of, a methodology. In this case, the section documenting the available data is included after the calibration methodology. It is recommended that Section 4 (*Available data*) is moved to become Section 3.

- Section 3 is titled *Calibration methodology*. However, some of the subsections are not specifically part of the calibration. It is recommended that Section 3 be titled *Methodology*.

- It is recommended that more attention is paid to consistency of terminology. Specifically:

  - Section 3.5 is titled *Configuration of hydrology models* and Section 3.12 is titled *Formulation of hydraulic models*. It is recommended that one term is used consistently (configuration or formulation).

  - Section 5 is titled *Calibration of hydrology models*, and Section 6 is titled *Validation of hydraulic models*. Be consistent with the titles for Sections 5 and 6 since both sections discuss both calibration (to historic events) and validation (checking design events against other methods).

- More care is needed with the use of the terms: *validation* and *verification*. Subsection 6.5 is titled *Verification of models*. This should be changed to *validation* to be consistent with the remainder of the report.

- There are a variety of methods used: calibration to historic events and validation against previous models, flood frequency analysis, and ratings curves. It is difficult to follow what methods are being used where. The report would benefit from a summary table or flow chart that summarises the methods used, and which methods were applied to which hydrology and hydraulic models. In the summary, it would be useful to list the models that were not calibrated to show the context and extent of the calibration relative to the broader study area.

- References within text to Figures and Sections should be utilised more.

Specific comments

The findings from the review are summarised by report section in Table 1.1. The comments are typically of a minor nature and relate to assisting a technical reader in understanding the approach followed and the results achieved. If no comment is provided against a section, then that section is considered satisfactory.

Table 1.1 List of specific comments

Section	Comment
1.3	It would be useful here to remind the reader that the purpose of this work is to simulate existing flood behaviour across the study area only. Inclusion of the proposed works in the models and assessment of the influence of the proposed works on flood behaviour will be addressed separately.
3.4	It is recommended that the report tabulates the historic events selected for calibrating each model. It is also recommended that the report detail how significant each event is – comparing the event size to the FFA would assist with an understanding of the event magnitude.
3-5	A figure of the extents of the hydrology models would be useful here. This comment could be addressed by referring the reader to Figure 4.3.
3.6	This subsection should explain, tabulate and/or illustrate which rainfall gauges were used for which event and which model. The report states that the nearest rainfall gauges were used to define temporal patterns. However, it is not explained how this was this done; e.g. using a method like inverse distance weighting or Theissen's polygons? (See also comment for 4.4)
3.7	The explanation and methodology of the baseflow separation is adequate. It is recommended that the exponential decay function that was used to model the baseflow recession curve is reported and an example is shown using one of the streamflow records to demonstrate how the method was applied.
3.9	To assist the reader, models that have been calibrated should be listed. This comment is related to the comment for 3.4, above. Reference could be made to Table 6-1, which shows which TUFLOW models were calibrated.
3.10	Reference should be made to the Section where the reader can find the results. Here, it is stated that the rising limb and falling limb and time to peak are assessed. However, these factors are not discussed in the results (see comment for Section 5.4 below).
3.11	Section 3.11 launches straight into the fact that design event runs were undertaken, then FFA and RFFE, without explaining why or how these analyses will be used. It is recommended that a few introductory paragraphs are included explaining that the FFA and RFFE analyses were

Section	Comment
	undertaken for comparison with design event results from the hydrology models to validate the models. To assist the reader, models that have been validated should be listed.
3.12	Very little information is provided on the method used to simulate bridges. This will be a key component of the analysis when simulating the proposed design, and more information should be provided on the methods and assumptions regarding form loss coefficients and blockage factors (if used). It may be useful to include the extent of the TUFLOW models on the figures showing structure locations (Figure 4-2).
4.2	It should be made clear where previously developed models have been relied upon. It is recommended that a table is included that summarises which pre-existing models have been used and how (used directly, updated, or converted to RORB/TUFLOW). Alternatively, include this information in Table 3-1 and refer the reader to the table.
4.4	Further clarification on rainfall data used should be provided. For example, which models used what rainfall data? What data was eliminated and why? How was rainfall data distributed for calibration? (See also comment for 3.6)
4.5	The reader should be referred to Section 5.1 for the discussion on which stream gauges were used for calibration.
Figure 4.3	Suggest that catchments are labelled, and key rivers are marked on and labelled
5.1	It is recommended that a table is included that lists the two stream gauges that were used for calibration along with the relevant hydrology model and noting which hydraulic model they fall in.
5.4	It would be useful to include comparisons of the timing of the peaks and Nash–Sutcliffe model efficiency coefficients.
5.5	It appears that of the calibrated IL for the three events, the central (or 'in between') IL was adopted for the design event simulations. Often, the average IL is adopted, e.g. see https://data.arr-software.org/nsw_specific. Regardless, it seems that the method used to select the IL has not been discussed in the report. A total of four at-site FFA were undertaken. Yet design flows from the hydrology models were only compared at one location (Baradine Creek, Figure 5-6). It is not clear why the reconciliation was not done at the other three gauges where an FFA was done. If this was because a spatially uniform storm derived from ARR 2019 is too simplistic for the three large catchments upstream of the proposed alignment and, therefore, results from the RORB models are much less accurate than the FFA and should be disregarded, this should be stated in the report.
6.1	It would be useful to include the floods that the models have been calibrated to in Table 6-1.
Appendix B	The plots show recorded hydrographs. Is the recorded hydrograph the 'adjusted' recorded hydrograph with baseflow removed? If so, this should be stated (if the adjustment was significant).

Please contact the undersigned should you wish to clarify or discuss the content of this letter further.

Yours Sincerely,

BMT

Barry Rodgers
Principal

BMT

Richard Sharpe
Principal Engineer

N2N Responses to BMT-WBM Hydrology and Hydraulic Models Calibration Report (2-0001-250-IHY-00-RP-0002, Rev 3) Review (18/01/2022)

Element	BMT Review Comments	JGHD Response
General Comments	A review of the layout of the N2N Calibration Report has found that the report is well-written and discusses the subject matter comprehensively. The report is generally consistent with what could reasonably be expected of a model calibration report. However, the structure of the report is somewhat confusing and there are some inconsistencies in terminology. Therefore, the following recommendations are made to aid readability:	Noted. Recommendations made on the structure of the report will be considered in defining the structure of the Flood Design Verification Report.
	• The data available for a study is usually discussed before, or at the start of, a methodology. In this case, the section documenting the available data is included after the calibration methodology. It is recommended that Section 4 (Available data) is moved to become Section 3.	• Noted
	• Section 3 is titled Calibration methodology. However, some of the subsections are not specifically part of the calibration. It is recommended that Section 3 be titled Methodology.	• Noted
	• It is recommended that more attention is paid to consistency of terminology. Specifically:	• Noted
	○ Section 3.5 is titled Configuration of hydrology models and Section 3.12 is titled Formulation of hydraulic models. It is recommended that one term is used consistently (configuration or formulation).	○ Either configuration or formulation will be used consistently throughout the Flood Design Verification Report
	○ Section 5 is titled Calibration of hydrology models, and Section 6 is titled Validation of hydraulic models. Be consistent with the titles for Sections 5 and 6 since both sections discuss both calibration (to historic events) and validation (checking design events against other methods).	○ Consistent section headings will be used in the Flood Design Verification Report
	○ More care is needed with the use of the terms: validation and verification. Subsection 6.5 is titled Verification of models. This should be changed to validation to be consistent with the remainder of the report.	○ Noted
	• There are a variety of methods used: calibration to historic events and validation against previous models, flood frequency analysis, and ratings curves. It is difficult to follow what methods are being used where. The report would benefit from a summary table or flow chart that summarises the methods used, and which methods were applied to which hydrology and hydraulic models. In the summary, it would be useful to list the	• If necessary, a flow chart will be included in the Flood Design Verification Report to summarise calibration, verification and validation of both hydrology and hydraulic models.

Element	BMT Review Comments	JGHD Response
	models that were not calibrated to show the context and extent of the calibration relative to the broader study area. • References within text to Figures and Sections should be utilised more.	• Noted
1.3	It would be useful here to remind the reader that the purpose of this work is to simulate existing flood behaviour across the study area only. Inclusion of the proposed works in the models and assessment of the influence of the proposed works on flood behaviour will be addressed separately.	Noted
3.4	It is recommended that the report tabulates the historic events selected for calibrating each model. It is also recommended that the report detail how significant each event is – comparing the event size to the FFA would assist with an understanding of the event magnitude.	If necessary, a table will be included in the Flood Design Verification Report for each calibrated RORB model showing year, peak flow and approximate AEP for each calibration flood event.
3.5	A figure of the extents of the hydrology models would be useful here. This comment could be addressed by referring the reader to Figure 4.3.	Noted
3.6	This subsection should explain, tabulate and/or illustrate which rainfall gauges were used for which event and which model. The report states that the nearest rainfall gauges were used to define temporal patterns. However, it is not explained how this was this done; e.g. using a method like inverse distance weighting or Theisen's polygons? (See also comment for 4.4)	A table will be included in the Flood Design Verification Report to identify which rainfall gauges were used for each calibration flood event for each RORB model. In addition, a map will be included in the report showing rain gauges which were assigned to each sub-area for each calibrated RORB model.
3.7	The explanation and methodology of the baseflow separation is adequate. It is recommended that the exponential decay function that was used to model the baseflow recession curve is reported and an example is shown using one of the streamflow records to demonstrate how the method was applied.	An example of baseflow separation for one flood event will be included in the Flood Design Verification Report.
3.9	To assist the reader, models that have been calibrated should be listed. This comment is related to the comment for 3.4, above. Reference could be made to Table 6-1, which shows which TUFLOW models were calibrated.	A list of calibrated models will be included in the Flood Design Verification Report.
3.10	Reference should be made to the Section where the reader can find the results. Here, it is stated that the rising limb and falling limb and time to peak are assessed. However, these factors are not discussed in the results (see comment for Section 5.4 below).	A comparison between modelled and observed flow hydrographs for each calibration event is included in Appendix B. The visual comparison shows good agreement between observed and modelled rising limb, falling time and to peak.
3.11	Section 3.11 launches straight into the fact that design event runs were undertaken, then FFA and RFFE, without explaining why or how these analyses will be used. It is recommended that a few introductory paragraphs are included explaining that the FFA and RFFE analyses were undertaken for comparison with design event results from the	Further details on validation of each hydrology model will be included in the Flood Design Verification Report.

Element	BMT Review Comments	JGHD Response
	hydrology models to validate the models. To assist the reader, models that have been validated should be listed.	
3.12	Very little information is provided on the method used to simulate bridges. This will be a key component of the analysis when simulating the proposed design, and more information should be provided on the methods and assumptions regarding form loss coefficients and blockage factors (if used). It may be useful to include the extent of the TUFLOW models on the figures showing structure locations (Figure 4-2).	Detailed information on adopted form loss coefficients and blockage factors for all new bridges will be included in the Flood Design Verification Report.
4.2	It should be made clear where previously developed models have been relied upon. It is recommended that a table is included that summarises which pre-existing models have been used and how (used directly, updated, or converted to RORB/TUFLOW). Alternatively, include this information in Table 3-1 and refer the reader to the table.	An updated table will be included in the Flood Design Verification Report to identify the original source of each hydrology and hydraulic model.
4.4	Further clarification on rainfall data used should be provided. For example, which models used what rainfall data? What data was eliminated and why? How was rainfall data distributed for calibration? (See also comment for 3.6)	Further details on the gauges used for each calibration event will be included in the Flood Design Verification Report.
4.5	The reader should be referred to Section 5.1 for the discussion on which stream gauges were used for calibration.	Noted.
Figure 4.3	Suggest that catchments are labelled, and key rivers are marked on and labelled.	Catchments will be labelled, and key rivers will be marked on and labelled in the Flood Design Verification Report.
5.1	It is recommended that a table is included that lists the two stream gauges that were used for calibration along with the relevant hydrology model and noting which hydraulic model they fall in.	A table will be included in the Flood Design Verification Report for the two stream gauges that were used for calibration.
5.4	It would be useful to include comparisons of the timing of the peaks and Nash–Sutcliffe model efficiency coefficients.	The Nash–Sutcliffe efficiency is typically used to assess efficiency of conceptual continuous rainfall runoff models. The benefit of using the Nash–Sutcliffe efficiency to assess calibration results for event based rainfall runoff model will be considered in the Flood Design Verification Report.
5.5	It appears that of the calibrated IL for the three events, the central (or 'in between') IL was adopted for the design event simulations. Often, the average IL is adopted, e.g. see https://data.arr-software.org/nsw_specific. Regardless, it seems that the method used to select the IL has not been discussed in the report. A total of four at-site FFA were undertaken. Yet design flows from the hydrology models were only compared at one location (Baradine Creek, Figure 5-6). It is not clear why the reconciliation was not done at the other three gauges where an FFA was done. If this was because a	Details of selection of IL will be included in the Flood Design Verification Report and a sensitivity analysis will be undertaken using the average IL based on the three calibration events. The RORB model for Baradine Creek was used to simulate inflow hydrographs for the full range of flood events. Adopted peak flows for the three major rivers (i.e., Macquarie, Castlereagh and Namoi rivers) for large and rare flood events are based on the FFA

Element	BMT Review Comments	JGHD Response
	spatially uniform storm derived from ARR 2019 is too simplistic for the three large catchments upstream of the proposed alignment and, therefore, results from the RORB models are much less accurate than the FFA and should be disregarded, this should be stated in the report.	analysis of recorded peak flows. RORB models developed for the three major rivers were used to simulate the shape of the inflow hydrographs for the full range of flood events.
6.1	It would be useful to include the floods that the models have been calibrated to in Table 6-1.	Calibration events will be identified in the Flood Design Verification Report.
Appendix B	The plots show recorded hydrographs. Is the recorded hydrograph the 'adjusted' recorded hydrograph with baseflow removed? If so, this should be stated (if the adjustment was significant).	The recorded hydrograph is the 'adjusted' recorded hydrograph with baseflow removed. Updated figures will be included in the Flood Design Verification Report.