Memorandum

TO: James Flockton
FROM: Ella Harrison
DATE: 28 March 2018
SUBJECT: North Byron FRMS&P –Hydrologic and Hydraulic Model Review
PROJECT NUMBER: 117098

1. INTRODUCTION

Byron Shire Council have engaged WMA Water to complete a Floodplain Risk Management Study and Plan (FRMS&P). The primary objective of this FRMS&P is to provide an improved understanding of the flood behaviour and impacts throughout the North Byron catchments in order to better inform the management of flood risk. As part of the initial stages of the study, WMA Water have undertaken a peer review of the hydrologic and hydraulic models developed in the North Byron Shire Flood Study (BMT WBM, 2016).

The purpose of this report is to outline the assessment of these models and determine their readiness for use within this FRMS&P. The review established that:

- The hydrologic model which has been developed using XP-RAFTS is fit-for-purpose and appropriately set up.
- The hydraulic model, developed using TUFLOW (version 2013-12AE-w64), is running and working well and meets standard quality criteria.
- Notwithstanding this, it is recommended the following updates are undertaken:
    - Incorporate latest topographic features and detail of missing structures into the hydraulic model configuration;
    - Incorporate the March 2017 event into model calibration and verification;
    - Further sensitivity tests of the form losses upstream of Mullumbimby;
    - Sensitivity tests on the initial losses for forested areas in design events.
    - Sensitivity tests on the manning's n values adopted in the hydrologic model.

2. BACKGROUND

The North Byron Shire Flood Study (herein referred to as the Flood Study) was completed by BMT WBM in April 2016. This Flood Study was commissioned in response to the Tweed-Byron Coastal Creeks Flood Study (BMT WBM, 2010) that recommended the development of a model to assess both the Brunswick River and Marshalls Creek catchments.

The following reports have also been considered background information as part of this review:

- Byron Shire Flood Review for Ex-Tropical Cyclone Debbie (BMT WBM, 2017)
- Hydrologic and Hydraulic Study at Bilinudgel (SMEC, 2005)

2.1. Study Area

The area of interest is located in northern New South Wales within the Byron Shire Local Government Area (LGA) and includes the towns of Mullumbimby, Brunswick Heads, Ocean Shores, New Brighton, South Golden Beach and Billinudgel. The study area includes Marshalls Creek catchment to the north, the Brunswick River catchment and the Simpsons Creek catchment to the south.

Marshalls Creek is a tributary to the Brunswick River and enters the Brunswick River just upstream of the mouth of Brunswick River at Brunswick Heads. Simpsons Creek flows into the Brunswick River just downstream of the Marshall Creek and Brunswick River confluence.

Figure 1 shows the hydrologic and hydraulic boundaries used within the Flood Study.

3. HYDROLOGIC MODEL REVIEW

The hydrologic model developed for the Flood Study was built using XP-RAFTS software. XP-RAFTS is a non-linear rainfall/runoff routing model and is widely used throughout Australia for both rural and urban catchments. The review looked at the catchment delineation, model setup and the appropriateness of adopted hydrologic parameters. The model was successfully run for the 12 hour and 24 hour storms for the 1% AEP and produced the same results as provided.

3.1. Catchment Delineation

The hydrologic study area consists of four catchments and are listed in Table 1.The delineation of the catchment and sub-catchment boundaries has been checked and is considered fit-for-purpose and appropriately defined. The sub catchment delineation is shown in Figure 2.

Table 1: Catchment areas

Catchment Name	Total Area (km^2)	Sub catchments
Brunswick River	112	47
Marshalls Creek	42	24
Yelgun Creek	11	13
Simpsons Creek	66	32

3.2. Model Input

The hydrologic model is built by delineating the catchment into sub catchments and connecting these using nodes and channel reaches to simulate creeks and rivers. XP-RAFTS requires geographical input data and hydrologic parameters for each sub catchment including the following:

- Slope (%)
- Area
- Fraction impervious
- Travel time between nodes
- Manning's n
- Storage Coefficient Multiplication Factor
- Initial Loss

- Continuing Loss

Terrain data and aerial data have been used to check the sub catchment slope, area and the fraction impervious. Appropriate values have been used for each sub catchment. The travel time between nodes was determined by assuming an average velocity. For a 1% catchment slope an average velocity of between 0.5m/s and 1m/s is considered normal. This approach was not adopted for all sub catchments. For the sub catchments in the Upper Main Arm area, the Muskingum-Cunge (defined in XP-RAFTS) method was adopted for the wide floodplain with significant potential storage, which is considered appropriate

Table 2 shows the adopted manning's n values to represent the roughness for each sub catchment. While these manning's n values are considered standard (ARR2016, Book 6, Chapter 2, Table 6.2.2), they are marginally lower than the recommended XP-RAFTS values, however are still considered to be appropriate roughness values. While, this is not thought to be an issue WMA Water recommend undertaking some sensitivity testing on these values.

Table 2: Manning's values

Ground cover	Manning's n
Urban	0.025
Rural	0.04
Forested	0.06

3.2.1. Storage Coefficient Multiplication Factor (B_X)

The Durrumbul Gauge is the only stream gauge in the area with a rating curve (see location in Figure 3) and thus is the only calibration gauge available for the hydrologic model. BMT WBM's calibration runs indicated that additional storage was required at this point. It is most likely due to the model inability to represent the wide floodplain with significant potential storage in the upper catchments.

Two distinct methods have been used to increase the storage:

- A local storage has been added at Williams Bridge upstream of the Main Arm Road Embankment in Main Arm (see location in Figure 3),
- A Storage Coefficient Multiplication Factor (Bx) of 1.5 instead of 1 was used to modify the calculated storage time delay in all sub-catchments except Marshalls Creek and Yelgun Creek catchments. This value of 1.5 has been chosen for calibration purposes. It is recommended the March 2017 event is used to verify the appropriateness of this parameter.

Those changes have helped to reach a better calibration for the simulated events (mainly January 2012, June 2005 and May 1987). Marshalls Creek and Yelgun Creek sub-catchments were modelled with a Bx factor of 1.0. This value was most likely adopted due to the lack of calibration data to show evidence of floodplain storage for these sub-catchments. Incorporating the March 2017 event will help verify and recalibrate these values.

3.2.2. Initial and Continuing Losses

The amount of rainfall that will result in runoff is highly dependent on the antecedent conditions and type of ground cover, particularly the infiltration capacity. These conditions are represented in a hydrologic model using initial and continuing loss parameters. Table 3 shows the initial and continuing loss parameters adopted during the calibration events.

ARR (Book5, Ch.3, Figures 5.3.18 and 5.3.19) discusses typical loss values seen throughout Australia and for Mullumbimby, recommended rural initial and continuing losses are 38mm and 2.5 mm/h. The continuing loss factor adopted for rural areas is higher than recommended by ARR (2016). It is recommended the March 2017 event is used to verify parameters.

The initial loss conditions adopted for the design events are low in comparison to the calibration events (see Table 4). It is common when calibrating a hydrologic model to an actual event to alter this value significantly. This accounts for the antecedent conditions within the catchment and can be used to better match the peak flow observed. The Flood Study notes that the design event initial losses were chosen deliberately to ensure an element of conservatism.

However, the forest initial loss adopted for the design event is significantly lower than the calibration loss (from 80 – 100 mm to 20mm) and the continuing losses are high. WMA Water suggests using a conservative value of 40mm instead of 20mm and a lower continuing loss and to check the impact of this change via a sensitivity test.

Table 3: Initial loss and continuing loss adopted for the calibration events

Ground cover	Initial Loss (mm)	Continuing Loss (mm/h)
Urban	0	1
Rural	30 (*May 1987*) 15 (*June 2005*) 5 (*Jan. 2012*)	4
Forested	100 (*June 2005, May 1987*) 80 (*Jan. 2012*)	6

Table 4: Initial loss and continuing loss adopted for the design events

Ground cover	Initial Loss (mm)	Continuing Loss (mm/hr)
Urban	0	1
Rural	5	4
Forested	20	6

3.3. Rainfall Sensitivity Assessment

The North Byron Flood Study was developed prior to the release of the 2016 ARR design rainfalls, as such the study used the 1987 Intensity-Frequency-Durations (IFDs). The 1987 ARR design rainfalls are expected to have an accuracy of +/- 30% and as such it is standard practice to compare the at-site rainfall data to the ARR IFDs.

The Flood Study estimated the 1% AEP event for eight storm durations for each gauge used in the rainfall frequency investigation. FLIKE, a widely used statistical program, was used for this statistical analysis and three statistical distributions were chosen; Lognormal, Log Pearson Type III and Generalised Extreme Value (GEV). Section 4.3 of the Flood Study discusses the results in detail and provides a comparison of the ARR 1987 IFDs against each gauge for the 1% AEP for three durations. The results highlighted where there was a +-10% discrepancy between the at-site gauge data and the 1987 ARR IFD.

These results show the ARR IFDs both over and underestimate the design rainfall when compared to the at-site gauge data. The report discusses the results from the gauges Main Arm, Huonbrook and Myocum in more detail. Main Arm and Myocum are within the catchment boundary and Huonbrook is the next closes to the Brunswick River catchment. While the Myocum gauge indicates the 1987 ARR IFD overestimates rainfall depths (17% - 55%), the results for Main Arm and Huonbrook show the 1987 ARR IFD are within +-30% and have no bias for over or underestimation.

The report concludes the rainfall frequency investigation does not provide justification to adopt a local correction factor and the 1987 ARR IFDs were used. Prior to the release of the 2016 IFDs, use of the 1987 ARR IFD was considered industry standard. While the assessment did show some differences between the at-site data and the 1987 IFD, there was no significant bias for over or underestimation. Given this, WMA Water concludes use of the 1987 ARR IFD to be defensible and fit-for-purpose.

4. HYDRAULIC MODEL REVIEW

The hydraulic model was built using the hydrodynamic package TUFLOW. TUFLOW is a widely used modelling package both nationally and internationally. The Flood Study model was configured using TUFLOW version 2013-12-AD TUFLOW_iDP_w64.exe and requires a multi domain license.

Figure 4 shows the hydraulic model boundary and the domain configurations. The hydraulic model covers 52 km^2 in total. The default 2D domain was represented with a 12.5m grid with a north-south grid orientation. For the areas of South Golden Beach and Brunswick Heads a 5m grid with no rotation was adopted. Mullumbimby was also represented using a 5m grid size, however a 19.5 degree grid rotation was applied. This rotation digitises the grid perpendicular to the dominant flow and is handled properly by TUFLOW.

There are two different TUFLOW simulation control files available to run *NBFS_~e1~_166.tcf* and *NBFS_~e1~_168_ext.tcf.* The former is used for all design events except for the PMF which used the second file. The reason for the separate files is due to the downstream boundary conditions. The coastal dunes are only overtopped in the PMF event, and therefore for this event, a wider downstream boundary condition is required than in all other design events. This is a relatively common practice.

WMA Water were able to successfully run the model for the 1% AEP events and results were consistent with the 2016 BMT WBM report.

4.1. Boundary Conditions

4.1.1. Tidal Conditions

Figure 5 shows the inflow and downstream boundaries included in the Flood Study model. The downstream boundary has been setup up as a water level versus time boundary to represent the tidal conditions. This tidal condition is variable and the timing of the peak of the tide has been aligned to coincide with the peak of the flood. Table 5 describes the corresponding peak tidal conditions for each AEP and climate change conditions. Byron Shire Councils policy on Climate Change Strategic Planning discusses the adopted 2050 and 2100 and are 0.4m and 0.9m respectively.

Table 5: Tidal downstream boundary condition

AEP	Peak Water Level (mAHD)
20%	0.8
10%	1.5
5%	2.2
2%	2.48
1%	2.6
5% CC2050	2.4
1% CC2050	2.6
5% CC2100	2.9
1% CC2100	3.1

4.1.2. Inflow Boundaries

The inflow polygons have been represented as 2d_sa layer which applies to flow directly onto the lowest cells first and then distributing between wet cells within the defined polygons. These have been correctly identified as either local or total inflows depending on their location.

The TUFLOW boundary condition database (bc_dbase) contains hydrographs for the 12 hour and 24 hour storm durations for all AEPs and climate change scenarios.

All inflow files have been provided for the 12 hour and 24 hour storm durations.

4.1.3. 1D and 2D Boundaries

Marshalls Creek, Brunswick River and Simpsons Creek are modelled in 1D by cross sections when the 2D domain grid size is set to 12.5m (see Figure 4).

Marshalls Creek hydraulic roughness is set to 0.03 (upstream) and 0.024 (downstream). Brunswick River and Simpsons Creek Hydraulic Roughness is set to 0.02. These are standard values for sandy bed rivers.

4.2. Review of Recent Developments

Figure 6 shows the ground and terrain data used in the hydraulic model.

4.2.1. Orchid Place (Mullumbimby)

Orchid Place roughness is defined as an urban place. The recent development topography has not been included in the model.
It is recommended this information is incorporated into the model. Byron Shire Council will request and provide a survey of the area.

4.2.2. Shara Boulevard/Brunswick Valley Sportsfield (Billinudgel)

The roughness need to be updated to match the new development (from n = 0.045 to n = 0.025). Byron Shire Council has sent the latest development drawings to WMA Water and it is recommended these added to the model topography.

4.2.3. Tallow Wood Estate (Mullumbimby)

The model includes the Stage 3 development terrain data. Byron Shire Council has sent the Stage 4 development drawings to WMA Water including the Tuckeroo Avenue box culvert dimensions. It is recommended the model is updated to incorporate this information.

4.2.4. Miram Place/Rajah Road (Ocean Shores)

The model includes an older development terrain data. Byron Shire Council has sent the Stage 4 development drawings for Miram Place in Ocean Shores to WMA Water. It is recommended this information is incorporated into the model.

4.3. Bend loss

Bend loss are defined only for the Brunswick River. Values upstream of Mullumbimby are between 1.0 and 1.75 and between 2.0 and 3.0 downstream. These values are high considering the river morphology does not change significantly in these areas. These values can have a significant impact on flood level in Mullumbimby, and given the development pressures in this area, it is recommended the March 2017 event is used to verify these parameters.

4.4. Review of Hydraulic Structures

4.4.1. Model Structures

Review of structures included within the Flood Study identified the following missing structures:

- Tuckeroo Avenue Culverts (Mullumbimby),
- Orana Road Culvert and Waterlily Park survey (Ocean Shores),
- Terrara Court Culvert (Ocean Shores),
- Golf Course Bridge (Ocean Shores).
- Narooma Drive Culvert (Ocean Shores)

Bonanza Drive drainage plan have been provided by Byron Shire Council, however as the road is not flooded until the PMF event, the road drainage would not have any significant impact on the flood behaviour. This structure will still be included for completeness.

It is recommended the other structures are incorporated into the model build.

5. RECOMMENDATIONS

Following the hydrologic and hydraulic model review, we recommend the following amendments to the model:

- Incorporate the following recent developments into the model's topography:
  - Shara Boulevard/Brunswick Valley Sportsfield (Billinudgel)
  - Tallow Wood Estate (Mullumbimby)
  - Miram Place (Ocean Shores)
- Incorporate the following structures:
  - Tuckeroo Avenue Culverts (Mullumbimby)
  - Orana Road Culvert and Waterlily Park survey (Ocean Shores)
  - Terrara Court Culvert (Ocean Shores)
  - Golf Course Bridge (Ocean Shores)
  - Narooma Drive Culvert
  - Bonanza Drive
- Run the March 2017 event (Ex-Tropical Cyclone Debbie).
  - Calibration of the Hydrological Model for this event through rainfall data and Durrumbul Stream Gauge
  - Calibration of the Hydraulic Model for this event through flood marks and rivers level data
- Perform a sensitivity test of the forested Initial Loss value to assess its impact on flows and volumes.
- Perform a sensitivity test on the manning's n values adopted in the hydrologic model.
- Perform a sensitivity test of the hydraulic losses upstream of Mullumbimby to assess their impact on flood level particularly at Tallow Wood Estate.
- Update both Hydrologic and Hydraulic model based on calibration results and run the design events.

List of Figures

Reference

North Byron Shire Flood Study (BMT WBM, 2016)

Byron Shire Flood Review for Ex-Tropical Cyclone Debbie (BMT WBM, 2017)

Tweed-Byron Coastal Creeks Flood Study (BMT WBM, 2010)

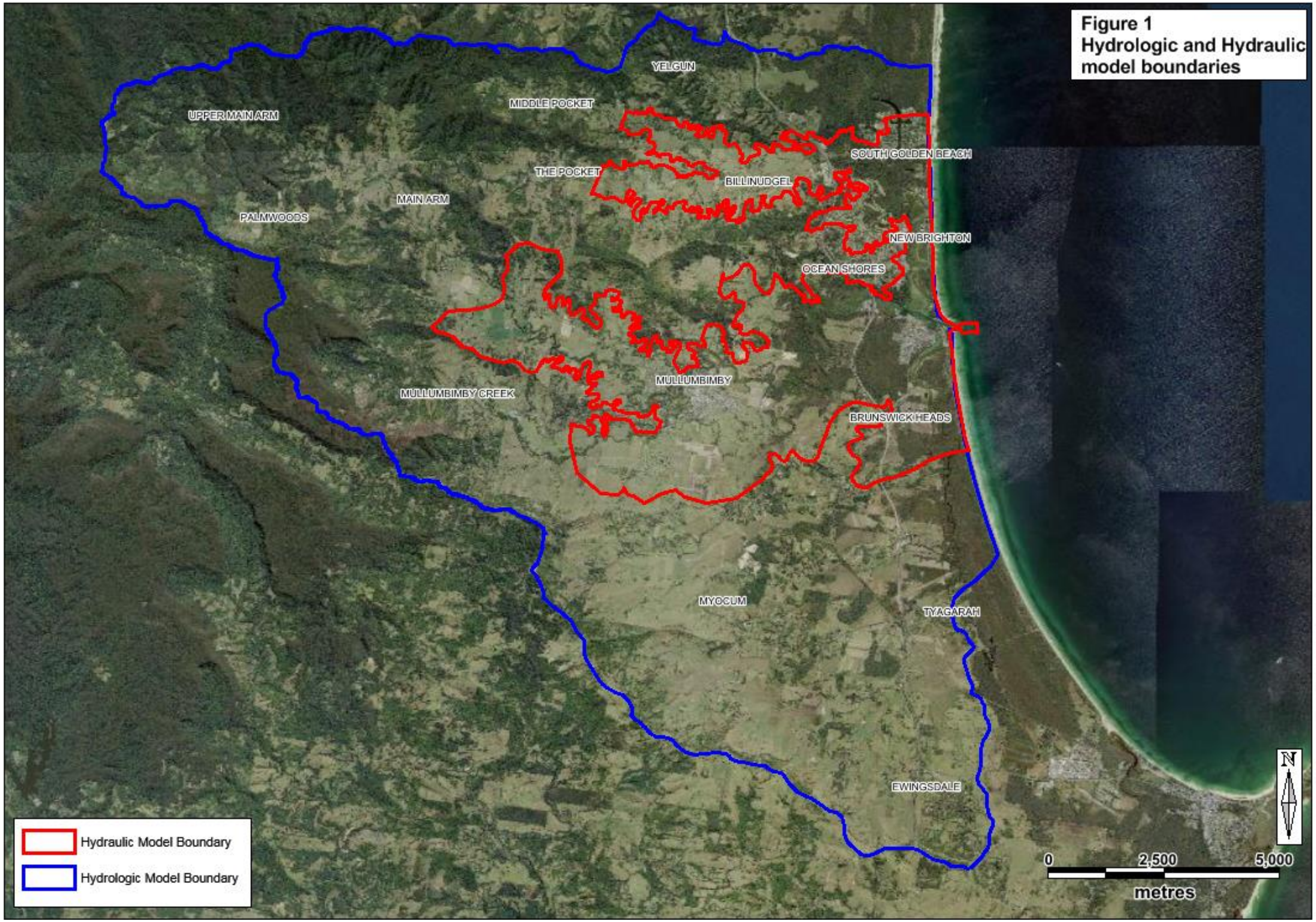

Figure 1: Hydrologic and Hydraulic Model Boundaries

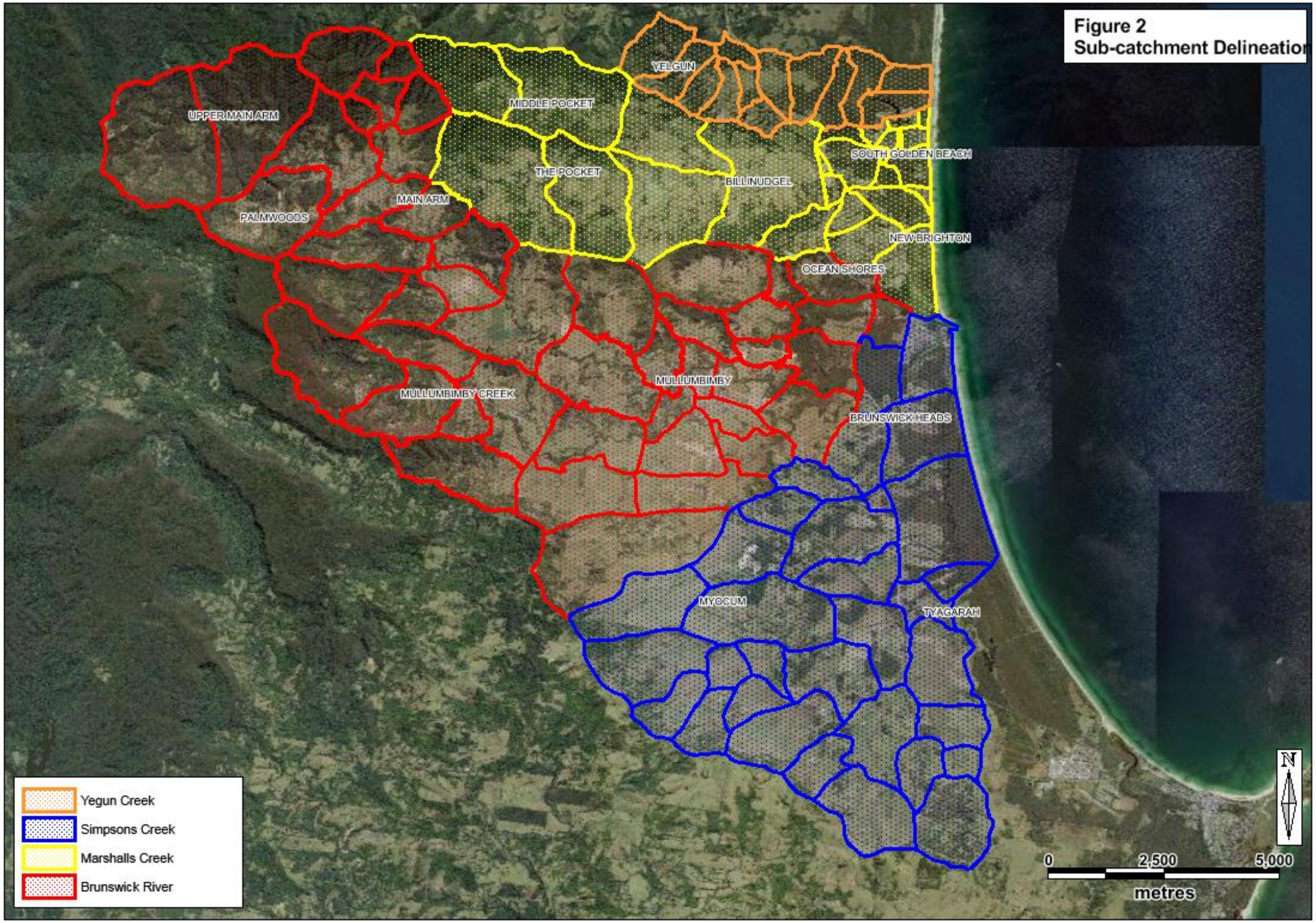

Figure 2: Sub-catchments division

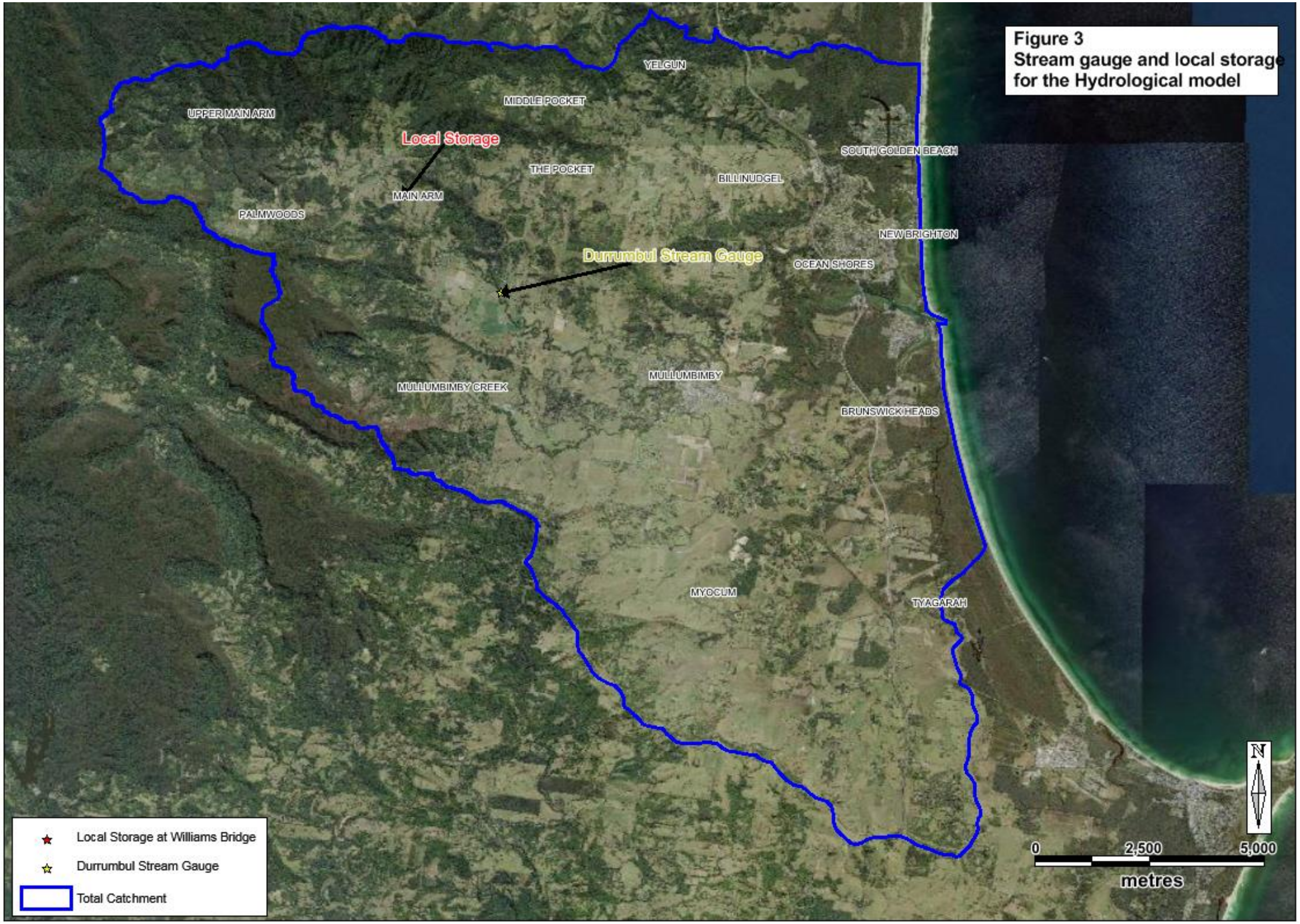

Figure 3: Stream Gauge and Local Storage

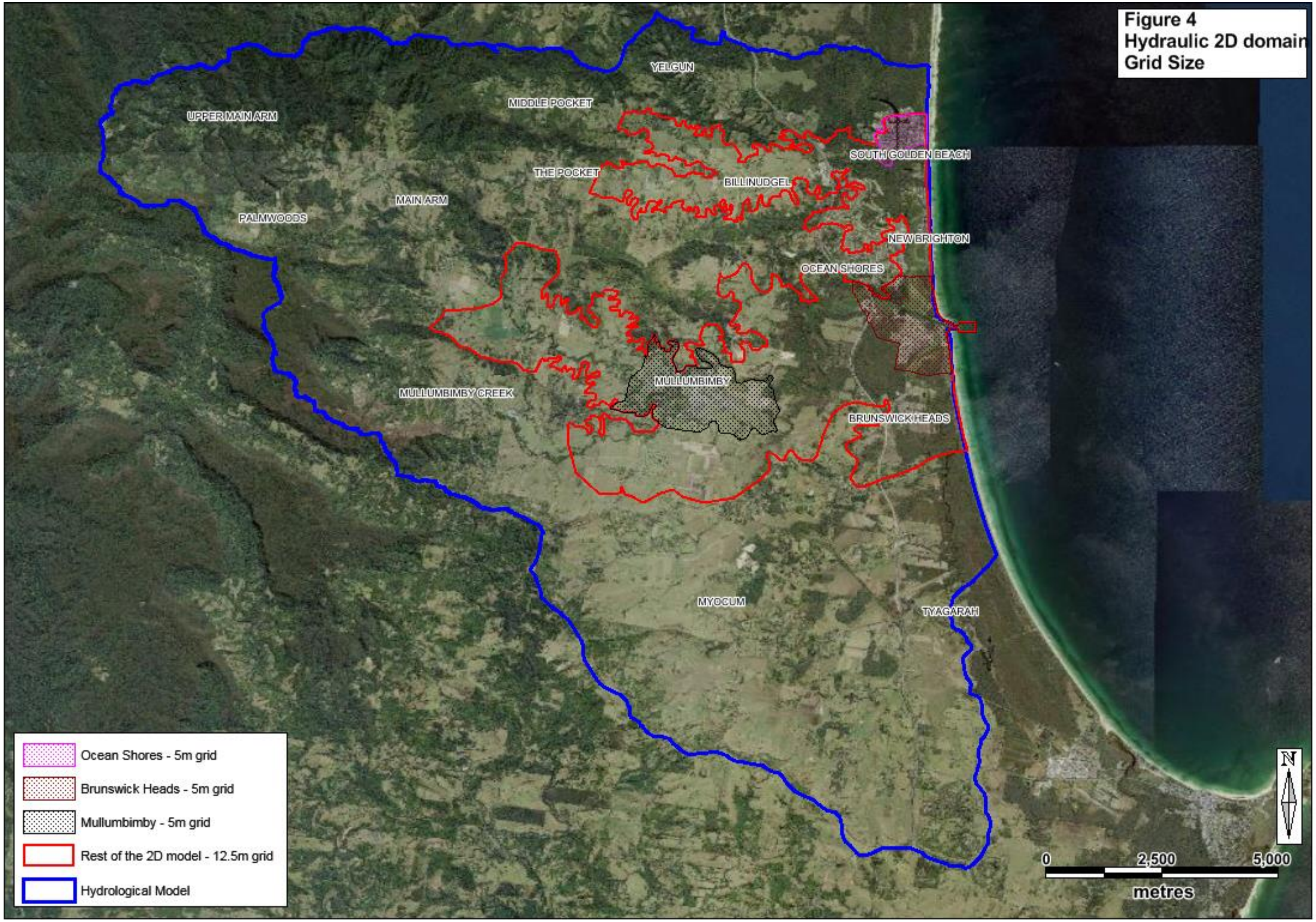

Figure 4: 2D Domain Grid Size

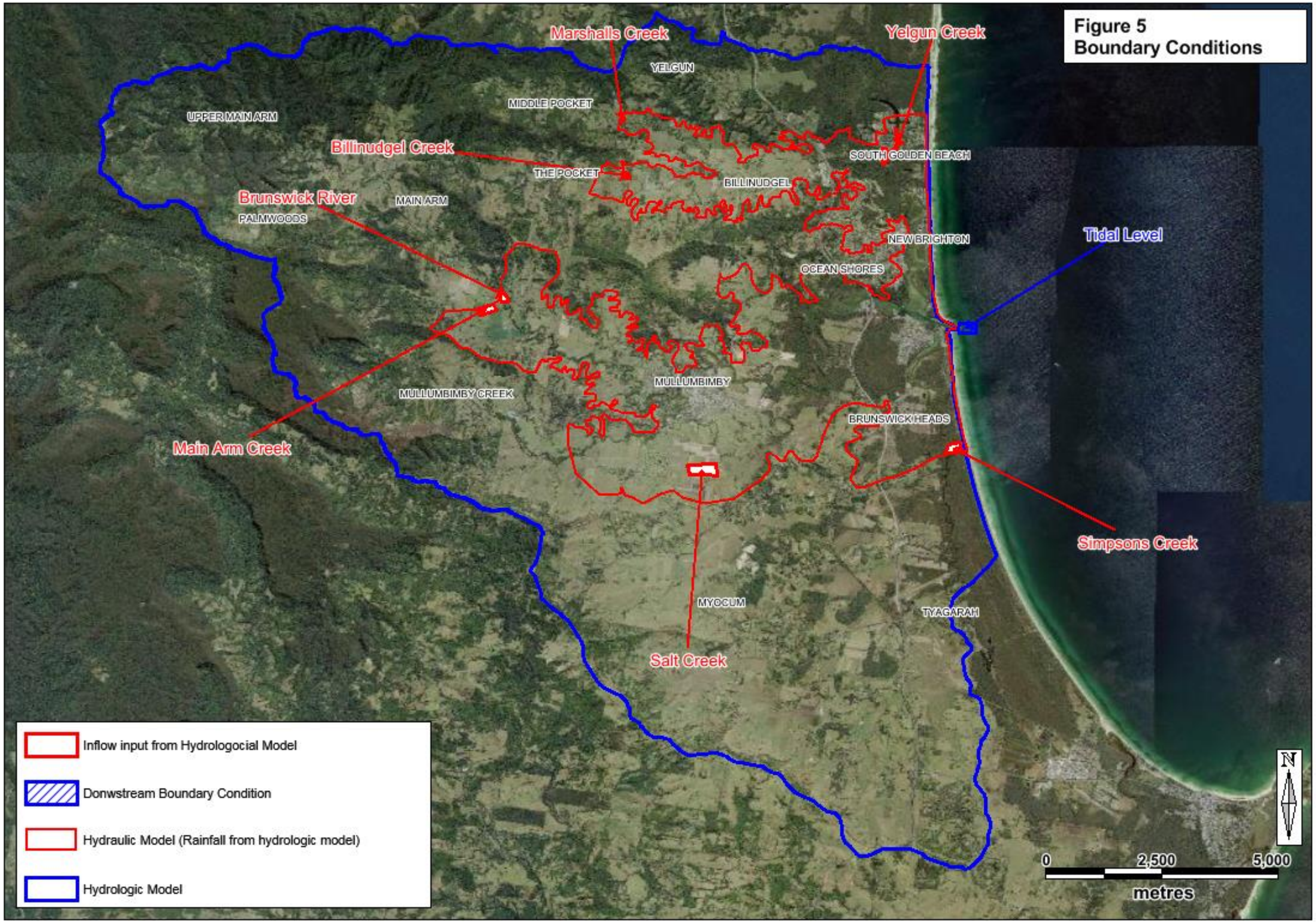

Figure 5: Boundary Conditions

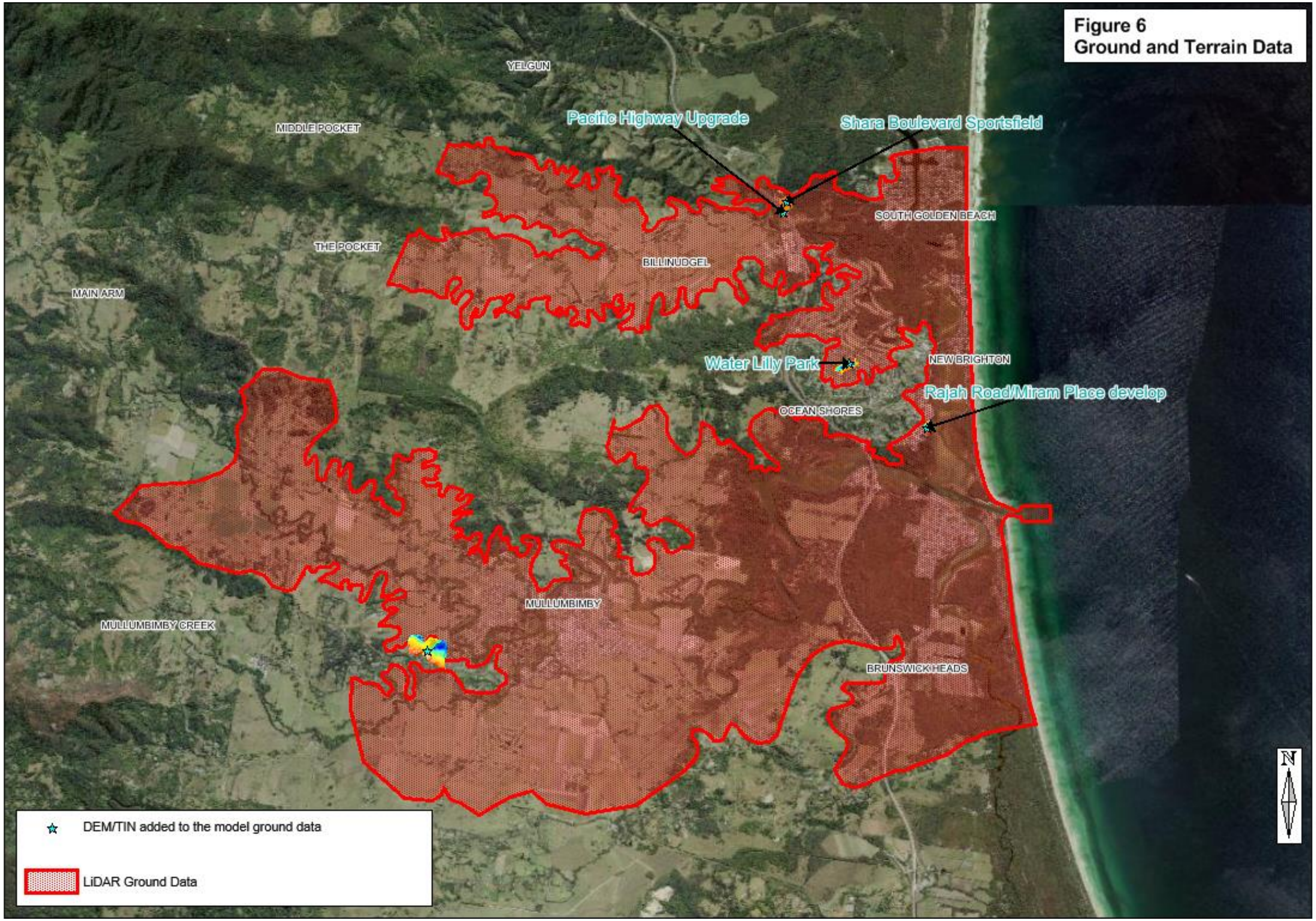

Figure 6: Ground and Terrain Data