NOTICE OF MEETING

BYRON SHIRE FLOODPLAIN RISK MANAGEMENT COMMITTEE MEETING

A Byron Shire Floodplain Risk Management Committee Meeting of Byron Shire Council will be held as follows:

Venue	**Conference Room, Station Street, Mullumbimby**
Date	**Tuesday, 19 February 2019**
Time	**2.00pm**

Phil Holloway Director
Director Infrastructure Services

I2019/196
Distributed 12/02/19

CONFLICT OF INTERESTS

What is a "Conflict of Interests" - A conflict of interests can be of two types:

Pecuniary - an interest that a person has in a matter because of a reasonable likelihood or expectation of appreciable financial gain or loss to the person or another person with whom the person is associated.

Non-pecuniary – a private or personal interest that a Council official has that does not amount to a pecuniary interest as defined in the Local Government Act (eg. A friendship, membership of an association, society or trade union or involvement or interest in an activity and may include an interest of a financial nature).

Remoteness – a person does not have a pecuniary interest in a matter if the interest is so remote or insignificant that it could not reasonably be regarded as likely to influence any decision the person might make in relation to a matter or if the interest is of a kind specified in Section 448 of the Local Government Act.

Who has a Pecuniary Interest? - a person has a pecuniary interest in a matter if the pecuniary interest is the interest of the person, or another person with whom the person is associated (see below).

Relatives, Partners - a person is taken to have a pecuniary interest in a matter if:

- The person's spouse or de facto partner or a relative of the person has a pecuniary interest in the matter, or
- The person, or a nominee, partners or employer of the person, is a member of a company or other body that has a pecuniary interest in the matter.

N.B. "Relative", in relation to a person means any of the following:

(a) the parent, grandparent, brother, sister, uncle, aunt, nephew, niece, lineal descends or adopted child of the person or of the person's spouse;

(b) the spouse or de facto partners of the person or of a person referred to in paragraph (a)

No Interest in the Matter - however, a person is not taken to have a pecuniary interest in a matter:

- If the person is unaware of the relevant pecuniary interest of the spouse, de facto partner, relative or company or other body, or
- Just because the person is a member of, or is employed by, the Council.
- Just because the person is a member of, or a delegate of the Council to, a company or other body that has a pecuniary interest in the matter provided that the person has no beneficial interest in any shares of the company or body.

Disclosure and participation in meetings

- A Councillor or a member of a Council Committee who has a pecuniary interest in any matter with which the Council is concerned and who is present at a meeting of the Council or Committee at which the matter is being considered must disclose the nature of the interest to the meeting as soon as practicable.
- The Councillor or member must not be present at, or in sight of, the meeting of the Council or Committee:
  (a) at any time during which the matter is being considered or discussed by the Council or Committee, or
  (b) at any time during which the Council or Committee is voting on any question in relation to the matter.

No Knowledge - a person does not breach this Clause if the person did not know and could not reasonably be expected to have known that the matter under consideration at the meeting was a matter in which he or she had a pecuniary interest.

Participation in Meetings Despite Pecuniary Interest (S 452 Act)

A Councillor is not prevented from taking part in the consideration or discussion of, or from voting on, any of the matters/questions detailed in Section 452 of the Local Government Act.

Non-pecuniary Interests - Must be disclosed in meetings.

There are a broad range of options available for managing conflicts & the option chosen will depend on an assessment of the circumstances of the matter, the nature of the interest and the significance of the issue being dealt with. Non-pecuniary conflicts of interests must be dealt with in at least one of the following ways:

- It may be appropriate that no action be taken where the potential for conflict is minimal. However, Councillors should consider providing an explanation of why they consider a conflict does not exist.
- Limit involvement if practical (eg. Participate in discussion but not in decision making or vice-versa). Care needs to be taken when exercising this option.
- Remove the source of the conflict (eg. Relinquishing or divesting the personal interest that creates the conflict)
- Have no involvement by absenting yourself from and not taking part in any debate or voting on the issue as if the provisions in S451 of the Local Government Act apply (particularly if you have a significant non-pecuniary interest)

RECORDING OF VOTING ON PLANNING MATTERS

Clause 375A of the Local Government Act 1993 – Recording of voting on planning matters

(1) In this section, **planning decision** means a decision made in the exercise of a function of a council under the Environmental Planning and Assessment Act 1979:
  (a) including a decision relating to a development application, an environmental planning instrument, a development control plan or a development contribution plan under that Act, but
  (b) not including the making of an order under Division 2A of Part 6 of that Act.

(2) The general manager is required to keep a register containing, for each planning decision made at a meeting of the council or a council committee, the names of the councillors who supported the decision and the names of any councillors who opposed (or are taken to have opposed) the decision.

(3) For the purpose of maintaining the register, a division is required to be called whenever a motion for a planning decision is put at a meeting of the council or a council committee.

(4) Each decision recorded in the register is to be described in the register or identified in a manner that enables the description to be obtained from another publicly available document, and is to include the information required by the regulations.

(5) This section extends to a meeting that is closed to the public.

BUSINESS OF MEETING

1. APOLOGIES

2. DECLARATIONS OF INTEREST – PECUNIARY AND NON-PECUNIARY

3. ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

3.1 Byron Shire Floodplain Risk Management Committee Meeting held on 29 November 2018

4. STAFF REPORTS

Infrastructure Services

ADOPTION OF MINUTES FROM PREVIOUS MEETING

3.1 That the Byron Shire Floodplain Risk Management Committee Meeting held on 29 November 2018 be confirmed.

3.2 The minutes of the ordinary meeting held on 29 November 2018 were noted and the Committee Recommendations provided to Council for adoption at the Ordinary Meeting held on 28 February 2019

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.1 **North Byron Floodplain Risk Management Study and Plan - Update**
Directorate: Infrastructure Services
Report Author: James Flockton, Drain and Flood Engineer
File No: I2019/174
Theme: Infrastructure Services
Emergency Services and Flood Management

Summary:

Since the previous North Byron Floodplain Risk Management Study and Plan update, WMA Water have been working on finalisation of the flood model calibration.

Initial calibration approval was received from the committee at the last meeting, however, further updates have occurred following investigations into the upstream model layout.

Final calibration approval will be sought at this meeting of the committee.

RECOMMENDATION:

1. **That the Byron Shire Floodplain Management Committee recommends Council approve the calibration results provided in attachment 1 (E2019/10202).**

2. **That the North Byron Flood Model is fit for purpose and be used for the preparation of the Draft Floodplain Risk Management Study.**

Attachments:

1 North Byron FRMS&P - WMA Water - Draft March 2017 Calibration Complete Report, E2019/10202 , page 9⇩

REPORT

The Floodplain Management Committee (FMC) meeting organised for 1st November was postponed due to issues with the hydrological model established as part of the Flood Study.

During the third FMC meeting it was agreed to adopt the ARR 1987 Flood Study model. Given the topographic changes and the addition of new structures in the hydraulic model, it was necessary to confirm that the results of the Flood Frequency Analysis (FFA) at the Durrumbul gauge could be reproduced by the updated models. Whilst attempting to model the design flood events it became apparent that there are more substantial issues with the flood study hydrological model (RAFTS) which limit the ability to match the FFA with these other catchment updates in place.

The primary issue identified is the impact of the storage basin modelled upstream of Williams Bridge. Following review of plan details for Williams Bridge and the topography upstream of Williams Bridge, it was found the dimensions for the basin modelled in the flood study hydrologic model is significantly over estimating the storage and restriction in the area and is not representative of the catchment.

As this model was a calibrated model, a change of this scale requires significant rework and it was necessary to additionally revisit the manning's 'n' roughness coefficient, catchment slope and losses used for each sub catchment.

Preliminary investigation indicated that if the following revisions to the BMT RAFTS model upstream of the Durrumbul gauge are undertaken, the RAFTS model will be more representative of catchment conditions. Additionally calibration of the RAFTS and TULFOW modelling package to historical events and the Flood Frequency Analysis (FFA) at Durrumbul gauge will be possible by:

a) removal of the Williams Bridge storage basin;
b) revising the manning's 'n' roughness coefficient of each sub-catchment, revising the catchment slope of each sub-catchment, and
c) revising losses.

Therefore the following works have been undertaken for the entire North Byron catchment to ensure the RAFTS model is more representative of catchment conditions and to recalibrate the RAFTS and TUFLOW modelling package:

1. Removal of the Williams Bridge storage basin from the RAFTS model;
2. Revised catchment slope in each sub catchment throughout the entire RAFTS model using the QGIS equal area slope tool;
3. Revised manning's n roughness coefficient in each sub catchment throughout the entire RAFTS model by undertaking a land use analysis and applying the weighted average roughness coefficient in each catchment;
4. Calibrate the modelling package to the March 2017 event;
5. Verify the modelling packages to the January 2012 event
6. Provide calibration memo with accompanying figures, and
7. Calibrate the design events to the FFA at Durrumbul gauge.

This work is now complete and the results are provided within WMA's memo at attachment 1.

The results show an acceptable model calibration using a model that better resembles the actual catchment conditions.

Considerable effort has been taken to ensure the BMT hydrologic and hydraulic models have received a thorough review as per the project brief. This ensures we have a robust model that can stand up to public scrutiny.

Further investigation is not considered necessary and approval of the model results is recommended.

Key issues

A rigorous review of the existing flood model is of the utmost importance for the North Byron Floodplain Risk Management Study and Plan. All potential questions around the model accuracy and set up must be removed to ensure it can stand up to public scrutiny.

Next steps

Over the coming months the Draft Floodplain Risk Management Study document will be prepared and reported to the committee as it progresses. This will include documenting works to date, design flood event mapping, flood hazard and risk mapping, flood levy failure assessment; flood mitigation option assessments and cost benefit analysis of preferred mitigation options.

Other tasks include:

1. Drainage Strategies for Mullumbimby and Brunswick Heads,
2. Land use planning assessment and cumulative development impacts assessment.
3. Emergency Management tasks include Education material, Evacuation Plans and Evacuation Centre Reviews and Flood emergency response classifications.

The Draft Floodplain Risk Management Plan will be prepared once the draft study document has been finalised and received support from the committee.

STRATEGIC CONSIDERATIONS

Legal/Statutory/Policy Considerations

NSW Councils are expected to prepare Floodplain Risk Management Studies and Plans for flood prone catchments within their local government areas. These documents must be prepared in accordance with State Government Policy.

The NSW Floodplain Development Manual 2005 is the current policy used by State Government for the preparation of such documents.

This project is following the methods prescribed in the NSW Floodplain Development Manual for completing Floodplain Risk Management Studies and Plans.

Financial Considerations

Resolution of the basin issues did require a project variation of $ 16,760 ex GST. However a grant variation has been submitted to the Office of Environment and Heritage to obtain two thirds funding towards this variation. The impact to Council will be $5,587.

Consultation and Engagement

The Office of Environment and Heritage have been consulted between FMC meetings to ensure they are aware of where the project has been heading and why a delay has occurred.

Memorandum

TO: James Flockton
FROM: Dan Morgan
DATE: 8 February 2019
SUBJECT: North Byron FRMS&P – Calibration Update for March 2017
PROJECT NUMBER: 117098

1. INTRODUCTION

On the 31 March 2017, ex-Tropical Cyclone Debbie crossed into the Northern Rivers region in New South Wales providing heavy rainfall across the Brunswick River Basin. It resulted in flooding from Brunswick River, Marshalls Creek and Simpsons Creeks and inundation in several localities such as Mullumbimby, Ocean Shores, Billinudgel, and Brunswick Heads.

Following this event BMT were commissioned to collate and review all available rainfall and flooding data on behalf of Byron Shire Council. This analysis was presented in the *Byron Shire Flood Review Ex -Tropical Cyclone Debbie* (Reference 1).

WMAwater has since been commissioned to undertake the North Byron Floodplain Risk Management Study and Plan (FRMSP). The initial stages of the FRMSP are outlined below.

WMAwater initially undertook a peer review of the hydrologic and hydraulic models developed by BMT with a final review submitted to the FMC on 9th July 2018 with an outline of the review presented in Section 2.1. A list of recommendations were made and subsequent revisions to the TUFLOW model were undertaken and the modelling package calibrated to the March 2017 event. A calibration report was submitted to the FMC on 13th September 2018.

Since the last FMC meeting, it was necessary to confirm that the results of the Flood Frequency Analysis (FFA) at the Durrumbul gauge could be replicated by the updated model. The TUFLOW model could not initially replicate the design flows from the FFA across the entire suite of design events. This process highlighted additional areas for review of the XP-RAFTS hydrologic model and revisions that would need to be addressed. These are detailed in Section 2.2. Revisions to the XP-RAFTS model were undertaken and the updated modelling package was calibrated to the March 2017 event and verified against the January 2012 event based on recorded rain gauge and stream gauge data. The calibration process and subsequent results are outlined in Section 4 to Section 7.

2. REVIEW PROCESS

There have been two peer reviews of the BMT modelling package undertaken by WMAwater:

- Initial Review - part of the FRMSP process
- Secondary Review – model updates recommended from the initial review highlighted additional issues with the modelling package.

2.1. Initial Peer Review BMT Modelling Package

WMA Water have undertaken a peer review of the hydrologic and hydraulic models developed by BMT in the *North Byron Shire Flood Study* (Reference 2). The final review submitted to the FMC on 9th July 2018 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 was 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, and
    - Sensitivity tests on the manning's n values adopted in the hydrologic model.

The recommended updates and sensitivity tests have been undertaken and submitted to Council and the FMC.

Update BMT TUFLOW Model

The TUFLOW model was updated to include the following:

- Hydraulic Structures
    - Tuckeroo Avenue Culverts (Mullumbimby),
    - Drain/Bund south of Mullumbimby,
    - Orana Road Culvert (Ocean Shores),
    - Balemo Drive South Culvert (Ocean Shores),
    - Terrara Court Culvert (Ocean Shores),
    - Golf Course Bridge (Ocean Shores),
    - Bonanza Drive Culvert (Billinudgel),
    - Wilfred Street Culvert (Billinudgel),
    - Pacific Motorway Culvert (Billinudgel),
    - Balemo Drive North Culvert (Billinudgel/Ocean Shores).
- Development
    - Tallow Wood Estate Stage 4 (Mullumbimby),
    - Waterlily Park survey (Ocean Shores),
    - Shara Boulevard Sports Field (Billinudgel).
- Model Extension
    - Model Extended 2.1km upstream of the Durrumbul gauge
    - Model extended upstream of Kallaroo Circuit culvert
- Bathymetry
    - Brunswick River and Marshalls Creek – NSW OEH
- Additional Model Domain
    - Added additional model domain for the Ocean Shores area.

2.2. Additional Review BMT Modelling Package

Following the extension of the model upstream of the Durrumbul gauge, significant topographic changes and the addition of new hydraulic structures to the model, it was necessary to confirm that the results of the Flood Frequency Analysis (FFA) at the Durrumbul gauge could be replicated by the updated model. The TUFLOW model could not initially replicate the design flows from the FFA across the entire suite of design events. This process highlighted additional areas for review and update with the BMT RAFTS hydrologic model that would need to be addressed:

- The Williams Bridge storage basin overestimated the storage and restriction of flow in the area and was not representative of the catchment;
- The slope or gradient parameter for each individual subcatchment was too steep in the upper parts of the Brunswick River catchment and not representative of catchment conditions. This led to a significant overestimation of peak flow in this area and affected calibration to the March 2017 event and the FFA results;
- The manning's 'n' roughness coefficient parameter was underestimated in heavily vegetated areas and the spatial application of the roughness coefficient was questionable;
- The variable application of initial loss and continuing loss values across the catchment based on land uses was not considered to be best practice or appropriately justified;
- The storage coefficient multiplication factor (Bx) of 1.5 initially used to modify the storage time delay in all sub-catchments except Marshalls Creek and Yelgun Creek was not appropriately justified.

Details of changes required to the hydrologic model and reasoning are listed below:

- The basin at Williams Bridge was removed from the hydrologic model;
- All catchment slope values were revisited using the equal area method, which is found to approximately match the average slope recommended by XP-RAFTS;
- The manning's 'n' roughness coefficient for each subcatchment was revised using a weighted average of the different land uses in each subcatchment and manning's 'n' values applied in line with experience and industry guidance;
- Consistent initial and continuing loss values were applied across the entire catchment, and
- The storage coefficient multiplication factor (Bx) of 1.5 was removed with no additional storage applied across the model. This is because the addition of an extra parameter did not add any improved representation of the catchment response.

3. AVAILABLE DATA

The stream gauge data, pluviometer rain gauge data and flood mark survey collected by BMT in Reference 1 were used in the calibration of the models to the March 2017 event. No further verification of the data was undertaken.

WMAwater collected additional daily read rainfall gauge data to assist in the calibration process.

3.1. Rainfall Gauge Data

Historical rainfall data for the March 2017 event was analysed, with the stations used for the calibration shown in Figure 1. Recorded rainfall depth for each gauge is shown in Table 1.

Table 1 - Historical Rainfall Data

Gauge Number	Gauge Type	Gauge Name	Rainfall Depth (mm) – 48 hrs
58019	Daily	Doon (McCabes Rd)	530
58129	Daily	Kunghur (The Junction)	575
58167	Daily	Uki (Tweed River)	602
58186	Daily	Murwillumbah (Tweed River)	460
58007	Daily	Byron Bay (Jacaranda Drive)	258
58040	Daily	Mullumbimby (Fairview Farm)	433
58070	Daily	Repentance Ck	357
58165	Daily	Upper Coopers Ck	384
58162	Daily	Nashua (Wilsons River)	234
58137	Daily	Kingscliff (Marine Parade)	209
558096	Pluviometer	Yelgun	354
558053	Pluviometer	Main Arm	494
558008	Pluviometer	Mullumbimby Ck (Mullumbimby Ck)	402
558005	Pluviometer	Lacks Ck (Middle Pocket)	433
558025	Pluviometer	Mullumbimby (Chincogan Repeater)	407
558034	Pluviometer	Mullumbimby (Upper Main Arm)	518

The variation in rainfall intensity across the storm (temporal pattern) derived from the pluviometer gauges are displayed in Figure 2. The data indicates two intense periods of rainfall during the event with a lull in between.

The totals at each available rain gauge from 9am 29th March to 9am 31st March were used to create a representation of the variation in rainfall over the catchment. This was done using the natural neighbour interpolation technique whereby the recorded rainfall depth at each gauge is used to create a rainfall depth grid over the entire catchment. This rainfall grid was then used to determine the rainfall depths for each individual sub-catchment in the hydrological model (refer Figure 3). Figure 3 displays a rainfall gradient in a south east direction from 518 mm at Upper Main Arm to 258m mm at Byron Bay. The temporal patterns from each pluviometer were applied to individual sub-catchments based on the closest pluviometer gauge to each sub-catchment.

3.2. Stream Gauge Data

Water level data was analysed for gauges shown in Table 2. The gauges and their locations are shown in Figure 4. The stage hydrographs recorded at each gauge for the March 2017 event are shown in Figure 5.

Table 2 - Historical Stream Gauge Data

Gauge Number	Gauge Name	Peak Stage Height (m)	Data Source
202001	Sherrys Bridge - Durrumbul	5.0	NSW Water
202402	Federation Bridge	4.2	MHL
202400	Billinudgel	4.5	MHL
202475	Orana Bridge	2.1	MHL
202403	Brunswick Heads	1.2	MHL

4. CALIBRATION – MARCH 2017

The key parameters considered in the calibration of the March 2017 event were:

- Initial loss
- Continuing loss
- Temporal patterns from pluviometer gauges

The calibration focused predominantly on the initial and continuing loss values. A range of initial loss values of between 50mm - 100mm and continuing loss values of between 1.5 – 2.5 mm/h were analysed, with the results documented in this memo based on the following adopted values:

Initial loss = 80 mm, Continuing loss = 2 mm/h

4.1. Durrumbul Gauge

Figure 6 shows the modelled and recorded level for the March 2017 event at Durrumbul gauge (202001). There is a good fit to the timing and shape of the recorded hydrograph except the TUFLOW model underestimates the falling limb of the flood event. Modelling produces a good match to the recorded peak flood level with results shown in Table 3.

Table 3 – Durrumbul – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
18.07	18.00	-0.07	0.37%

Figure 7 shows the modelled and estimated flow for the March 2017 event at Durrumbul gauge (202001). There is a good match to the timing and shape of the estimated hydrograph except the TUFLOW model overestimates the initial flood peak and underestimates the falling limb of the flood event. When taking into account limitations in the rainfall data this can be considered as good fit.

Modelling produces a good match to the recorded peak flow with a difference of 2%, the results are shown in Table 4.

Table 4 – Durrumbul – Recorded and Modelled Peak Flood Level

Recorded Flow (m^3/s)	Modelled Flow (m^3/s)	Difference (m^3/s)	% Difference
420	410	10	2%

4.2. Mullumbimby Federation Bridge

For the Federation Bridge (202402), water level data recorded after 5am the 31/03/2017 are missing as shown in Figure 8. Thus, the peak water level is missing and a level of uncertainty surrounds the remaining data, which should be used with caution. Modelled peak flow is 4.6m AHD while the highest recorded level is 4.2m mAHD as shown in Table 5. The overall shape of the hydrograph is reproduced.

Table 5 – Federation Bridge – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
4.2 (gauge failed)	4.6	0.4	11%

4.3. Billinudgel Railway Bridge

The comparison of modelled and recorded levels at Billinudgel Railway Bridge (202400) is shown on Figure **9**. A reasonable match to recorded flood levels is achieved at the Billinudgel gauge with levels shown in Table **6**. The initial peak is overestimated but overall a good fit to the recorded hydrograph shape is achieved.

Table 6 – Billinudgel – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
4.47	4.30	-0.17	3.8%

4.4. Ocean Shores Orana Bridge

Results at Orana Bridge (Ocean Shores/New Brighton - 202475) are presented in Figure 10. There is a good match to the timing and shape of the recorded stage hydrograph with the peak reproduced within 0.1 m as shown in Table 7.

Table 7 – Orana Bridge – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
2.05	2.16	0.11	5.34%

4.5. Brunswick Heads

Brunswick Head level gauge (202403) is located at the Brunswick River Mouth after the confluence of Brunswick River, Marshalls Creek and Simpsons Creek. This level gauge has been chosen as the downstream boundary condition of the TUFLOW model for the March 2017 event. The results at this gauges area presented in Table 8 and Figure 11. There is a good fit to the peak, shape and timing of the hydrograph.

Table 8 – Brunswick Heads – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
1.168	1.185	0.017	1.42%

5. FLOOD MARKS – MARCH 2017

Two sets of flood mark survey for the March 2017 event were supplied by Byron Shire Council. These were combined in a database (Appendix A) which also included peak flood levels measured by the gauges discussed above, comprising:

- *Commissioned Survey*: 51 flood marks have been collected and surveyed by Council based on emails supplied by the public. Each flood mark is associated with a photograph taken during the flood or at the time of the survey.
- *Bill Paterson Survey*: An additional survey of 35 flood marks. This set does not contain any photographs or detailed description of the flood mark location. Each flood mark has been referenced within the database using a unique ID commencing with B.
- *Stream Level Gauges:* Five stream level gauges are operating in the model extent, two on Brunswick River (Durrumbul and Federation Bridge), two on Marshalls Creek (Billinudgel Railway Bridge and Orana Bridge) and one at Brunswick River Mouth. The measured level at Federation Bridge has been even included though the water level recorder failed during the flood event.

There are some surveyed flood levels in the data set which are considered inconsistent. These have been included in the below analysis for completeness, but they have been flagged as potentially inaccurate. A number of these points were also identified in the BMT *Byron Shire Flood Review Ex -Tropical Cyclone* (Reference 2), with the recommendation they are excluded from future analysis.

Inaccuracies are not uncommon for flood mark datasets. Errors with the data can occur as a result of:

- wrong recording of locations;
- errors in height measurements;

- recorded levels may not actually represent the peak level, they could be higher due to localised wave action or lower if a debris mark has subsided after the peak, and
- the recorded level may be as a result of local affects which are not reflected in the hydraulic model.

As such it is important to aim for general consistency across the catchment when comparing modelled results with surveyed flood marks and to not place too much emphasis on matching individual flood marks. This is particularly true for catchment scale models such as the North Byron model, which aims to represent general flood behaviour resulting from rivers and creeks. Peak modelled flood depth mapping, surveyed flood levels and modelled flood levels are displayed on Figure **22** to Figure 26.

5.1. Main Arm

There are 16 flood marks located in the Main Arm area (Durrumbul level gauge and 15 flood marks from the Bill Paterson Survey). This includes five flood marks from the Bill Paterson data that have been flagged as inconsistent - four due to a significant difference with adjacent flood marks of the stream gauge, and one flood mark is not from the March 2017 event.

The flood marks and the corresponding modelled peak flood levels are outlined in Table 9, with those flagged shown in Table 11. When taking into the account the questionable surveyed points, margin of error and the 12.5 m grid utilised in the TUFLOW model the calibration in Main Arm for the March 2017 is considered satisfactory.

Table 9 – Main Arm Surveyed Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
L5	18.07	18	-0.07	
B13	19.39	19.05	-0.34	
B22	16.84	16.81	-0.03	
B26	20.85	20.71	-0.14	
B27	19.9	Outside Extent	Outside Extent	
B28	19.94	20.01	0.07	
B29	19.69	19.54	-0.15	
B3	19.63	19.3	-0.33	
B4	18.99	18.77	-0.22	
B5	19.07	18.86	-0.21	
B6	19.31	18.87	-0.44	

Table 10 – Main Arm – Flagged flood marks

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
B2	18.49	19.29	0.8	Flagged - inconsistent with adjacent marks
B23	16.45			Flagged - not the 2017 Flood Event
B24	19.19	18.09	-1.1	Flagged - stream gauge more accurate
B25	19.42	No Data	No Data	Flagged - stream gauge more accurate
B7	18.53	16.62	-1.91	Flagged - inconsistent with adjacent marks

5.2. Mullumbimby

There are 35 flood marks located in the Mullumbimby area including five flagged as inaccurate, namely:

- Federation Bridge water level recorder;
- Three of the 14 surveyed flood marks have been flagged. One is referring to a photo taken several hours after the peak flood, one indicates an incorrect spatial location and one is inconsistent with flood marks, and
- Two of the 20 flood marks from Bill Paterson survey have been flagged due to inconsistency with adjacent points.

The flood marks and the corresponding modelled peak flood levels are outlined in Table 11 with those flagged shown in Table 13.

The majority of flood marks are modelled within +/- 0.2 m which is considered a good match. Flood marks B12 is underestimated by 0.3 m and B10 is underestimated by 0.5 m which infers that the survey point could have been influenced by local circumstances not represented in the mode, or be questionable

There are several different hydraulic controls in and around Mullumbimby with tributaries joining and flow breakout or bypassing occurring. Any temporary change in flood dynamics like a partial blockage will impact on predicted flood behaviour. Given the complexity of this area Mullumbimby is considered satisfactorily calibrated.

There are eight flood marks outside the calibrated flood extent, with six of those marks in the urban area. There are multiple reasons why this may have occurred, including:

- Inundation caused by local runoff;
- Local blockage or debris that affected flood behavior, and
- The model not accurately representing the urban environment and terrain due to the catchment wide scale of the model.

Table 11 – Mullumbimby Surveyed Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
50	4.25	Outside Extent	Outside Extent	
51	7.12	6.96	-0.17	
2	2.99	3.24	0.25	
3	6.7	Outside Extent	Outside Extent	
7	7.58	Outside Extent	Outside Extent	
39	4.13	4.25	0.12	
47	2.98	3.23	0.25	
40	4.14	4.34	0.2	
B1	8.52	Outside Extent	Outside Extent	
B8	6.29	6.26	-0.03	
B9	6.3	6.27	-0.03	
B11	7.2	7.11	-0.09	
B12	7.39	7.11	-0.28	
B14	7.29	7.11	-0.19	
B15	7.29	7.1	-0.19	

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
B16	7.29	7.1	-0.19	
B17	7.29	7.1	-0.19	
B18	7.3	7.09	-0.21	
B19	7.3	7.1	-0.2	
B20	5.46	5.21	-0.25	
B21	5.19	5.26	0.07	
B32	7.32	Outside Extent	Outside Extent	
B33	7.31	7.1	-0.21	
B34	6.29	Outside Extent	Outside Extent	
B35	5.08	5.22	0.14	

Table 12 – Mullumbimby – Flagged flood marks

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
L1	4.35	4.8	0.45	Failed gauge
13	4.91	5.17	0.26	Flagged in event review (BMT)
18	7.17	7.11	-0.06	Flagged in event review (BMT)
10	2.7	4.23	1.53	Photo after peak / flagged in event review (BMT)
B10	7.63	7.14	-0.49	flagged – inconsistent with adjacent point / flagged in event review (BMT)
48	7.28	3.23	-4.05	Wrong location
B10	7.63	7.14	-0.49	Flagged - inconsistent with adjacent point
B30	7.67	7.37	-0.30	Flagged - inconsistent with adjacent point
B31	7.13	7.40	0.27	Flagged - inconsistent with adjacent point
14	2.7	-Outside Extent	Outside Extent	Flagged in event review (BMT)

5.3. Brunswick Heads

There are seven flood marks located in Brunswick Heads including the Brunswick River level gauge. Four flood marks are located in the Brunswick Heads urban area. The flood marks and the corresponding modelled peak flood levels are outlined in Table 13, with those flagged as inaccurate shown in Table 15.

There is a good match at the gauge to the peak but the levels in the town are overestimated by 0.25 m – 0.4 m. There is no pit or pipe data included in the model for the Brunswick urban area which could account for flood water not dispersing into the river. A good fit to recorded flood levels is achieved in the Brunswick River.

Table 13 – Brunswick Heads Surveyed Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
L4	1.168	1.18	0.01	

Table 14 – Brunswick Heads – Flagged flood marks

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
1	1.67	2.15	0.48	Flagged in event review (BMT)
9	1.96	2.02	0.06	Flagged in event review (BMT)
15	1.68	2.09	0.41	Flagged in event review (BMT)
41	1.84	2.12	0.28	Flagged in event review (BMT)
46	1.97	2.22	0.25	Flagged in event review (BMT)
11	3.97	2.26	-1.71	Flagged – inconsistent with adjacent point / flagged in event review (BMT)

5.4. Billinudgel

There are three flood marks in the Billinudgel area. The flood marks and the corresponding modelled peak flood levels are outlined in Table 16, with those flagged shown in Table 17.

There is a reasonable match at the Billinudgel gauge and point 42. Point 45 is underestimated by 0.63 m but this level does not fit in with the flood gradient between Billinudgel and Orana Bridge. The Billinudgel calibration provides a good fit with recorded levels.

Table 15 – Billinudgel Surveyed Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
L2	4.47	4.32	-0.15	
42	4.62	4.43	-0.19	

Table 16 – Billinudgel – Flagged flood marks

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
45	3.73	3.1	-0.63	Model Boundary / flagged in event review (BMT)

5.5. South Golden Beach

South Golden Beach is bisected by the Capricornia Canal. Both sides of the area are protected by a levee on the bank of the canal. Non-returns flood gates drain South Golden Beach stormwater through the levee. Flood gates are closed when the canal water level is high and a flood pumping station then operates.

The levees crest level is set to 3.2m/3.3m AHD. Evidence from commissioned survey and photos taken during the flood event suggest that the maximum flood level in the Capricornia Canal didn't exceed 3.0m AHD. No breaches nor failures of the levee system was reported during the March 2017 flood event. Thus, flooding in the South Golden Beach area are considered to have been a result of stormwater runoff and not by water overtopping the levee. The hydraulic model only represents river/creek flooding and has not been established to represent local runoff.

There were 18 flood marks surveyed in the South Golden Beach area. The flood marks and the corresponding modelled peak flood levels are outlined in Table 18, with those flagged shown in Table 19.

Most of them (11) are located on the protected side of the town and thus are not relevant for the present study. ID33 flood marks refers to the 2005 flood event and has been noted. There is a good fit to surveyed flood levels at points 44, 35 and 30. Modelled flood level points 29 and 28 are overestimated by 0.25 m.

Table 17 – South Golden Beach Surveyed Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
44	2.88	2.8	-0.08	
6	2.99	Outside Extent	Outside Extent	
30	2.77	2.77	0	
29	2.53	2.77	0.24	
28	2.53	2.75	0.22	

Table 18 – South Golden Beach – Flagged Flood Marks

Map ID	Surveyed Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference (m)	Comments
43	2.59	Outside Extent	Outside Extent	Flagged in event review (BMT)
4	2.63	Outside Extent	Outside Extent	Flagged in event review (BMT)
19	2.33	Outside Extent	Outside Extent	Flagged in event review (BMT)
20	2.55	Outside Extent	Outside Extent	Flagged in event review (BMT)
32	3.39	Outside Extent	Outside Extent	Flagged in event review (BMT)
31	2.88	Outside Extent	Outside Extent	Flagged in event review (BMT)
34	2.29	Outside Extent	Outside Extent	Flagged in event review (BMT)
35	2.86	Outside Extent	Outside Extent	Flagged in event review (BMT)
36	2.74	Outside Extent	Outside Extent	Flagged in event review (BMT)
37	2.23	Outside Extent	Outside Extent	Flagged in event review (BMT)
22	2.88	Outside Extent	Outside Extent	Flagged in event review (BMT)
23	3.16	Outside Extent	Outside Extent	Flagged in event review (BMT)
33	2.95			Not the 2017 Flood Event

5.6. Ocean Shores

There were six flood marks surveyed in the Ocean Shores area, four on Balemo Drive are outside of the modelled flood extent.

The flood marks and the corresponding modelled peak flood levels are outlined in Table 20, with those flagged as inaccurate shown in Table 21.
Overland flow from the urban area of Ocean Shores has not been independently modelled which would account for the flood marks being outside the model extent. Point 21 is overestimated by 0.1 m.

Table 19 – South Golden Beach Surveyed Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
12	2.58	Outside Extent	Outside Extent	
16	1.79	Outside Extent	Outside Extent	
17	2.7	Outside Extent	Outside Extent	

Table 20 – South Golden Beach - Flagged flood marks

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
5	2.7	Outside Extent	Outside Extent	Flagged in event review (BMT)
8	2.64	Outside Extent	Outside Extent	Flagged in event review (BMT)
21	2.76	2.64	-0.12	Flagged in event review (BMT)

5.7. New Brighton

There were five flood marks surveyed in New Brighton. The maximum recorded level at Orana Bridge level gauge is also considered. The flood marks and the corresponding modelled peak flood levels are outlined in Table 22, with those flagged shown in Table 23.

The peak flood level at the Orana Bridge gauge was overestimated by 0.1 m, with a good match at points 38, 24 and 26. Points 25 and 27 are overestimated by approximately 0.2 m.

Table 21 – New Brighton Surveyed Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
L3	2.05	2.12	0.07	
38	2.39	2.52	0.13	
27	2.50	2.73	0.23	
25	2.39	2.60	0.21	

Table 22 – New Brighton - Flagged Flood Levels

Map ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)	Comments
24	2.41	2.50	0.09	BMT Flagged
26	2.47	2.50	0.03	BMT Flagged

6. VERIFICATION – JANUARY 2012

The model structure was considered appropriate for both January 2012 and March 2017, therefore the initial loss was adjusted to represent storm conditions. A range of initial losses between 10 mm and 100 mm were analysed, the results documented in this memo based on the following adopted values:

Initial loss = 10 mm, Continuing Loss = 2 mm/h

6.1. Durrumbul Gauge

Figure 12 shows the modelled and recorded peak for the January 2012 event at the Durrumbul gauge (202001). There is a reasonable match to timing and shape of the recorded hydrograph except the model is early on the rising limb and underestimates the falling limb. Modelling produces a good match to the recorded peak with results shown in Table 23.

Table 23: Durrumbul – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
17.53	17.50	-0.03	0.2%

Figure 13 shows the modelled and recorded flow for the January 2012 event at the Durrumbul gauge (202001). Modelling produces a good match to the recorded peak with a difference of 3%, with the results shown in Table 24.

There is a good fit to the timing and shape of the hydrograph except that model is early on the rising limb and overestimates the initial peak. Even with these two issues the calibration is an improvement on the previous models calibration which underestimated flow by approximately 100 m^3/s as shown in Figure 14.

Table 24: Durrumbul – Recorded and Modelled Peak Flood Flow

Recorded Flow (m^3/s)	Modelled Flow (m^3/s)	Difference (m^3/s)	% Difference
264	273	9	3%

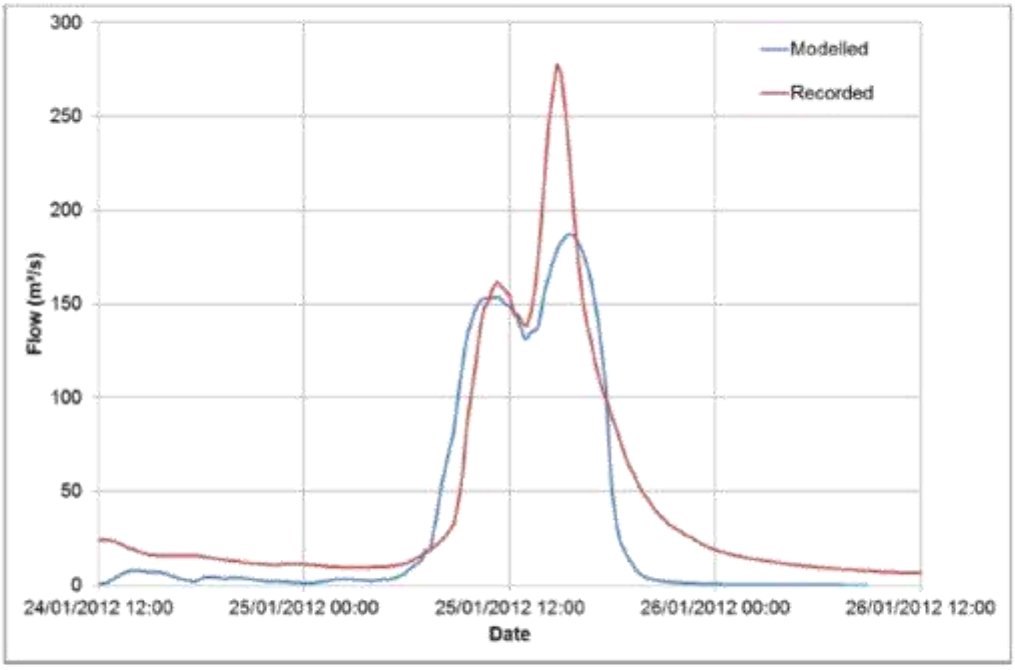


Figure 14: Graph - BMT North Byron Flood Study Report Comparing XP-RAFTS Discharge to Recorded Flow at Durrumbul – 2012 (Reference 1)

6.2. Mullumbimby Federation Bridge

A comparison of the modelled and recorded levels at Federation Bridge (202402) is shown in Figure 15. A reasonable match to the recorded hydrograph is achieved. The peak is overestimated by 0.44 m as shown in Table 25 which is approximately 11% and the timing of the rising limb is early.

When comparing the results to the calibration in the previous flood study (Reference 1) shown in Figure 16, the updated modelling package is able to reproduce the results with similar accuracy.

Table 25: Federation Bridge – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
3.89	4.33	0.44	11.25%

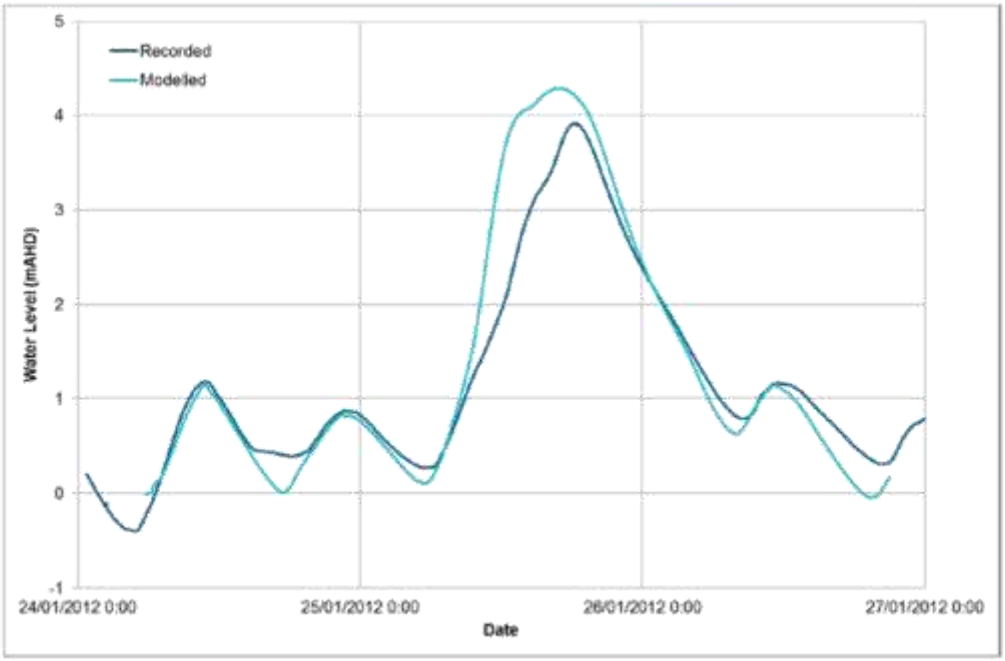


Figure 16: Graph - BMT North Byron Flood Study Report Comparing Modelled Level at Federation Bridge to the Recorded Level (Reference 1)

6.3. Billinudgel Railway Bridge

A comparison of the modelled and recorded levels of the BOM gauge and MHL gauge are shown in Figure 17. The MHL and BOM gauge are located at approximately the same location but there is a discrepancy between the recorded peak flood levels of approximately 0.25 m. A thorough investigation and analysis was undertaken to try and determine the reason for the difference, with both agencies contacted, but a resolution was not forthcoming.

It appears that in the previous flood study (Reference 1) that the BOM recorded hydrograph was used as shown in Figure 18. There is no explanation in the report as to why this gauge was chosen. As it could not be confirmed which gauge is correct the BOM gauge was selected as that is what was used in the Flood Study with the MHL gauge displayed for transparency.

A good fit to the recorded peak level was achieved with a difference of 0.13 m as shown in Table 26. A better fit to the falling limb was achieved in comparison the previous study (Reference 1).

Table 26: Marshalls Creek at Billinudgel – Recorded and Modelled Peak Flood Level

BOM Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
3.35	3.48	0.13	3.9%

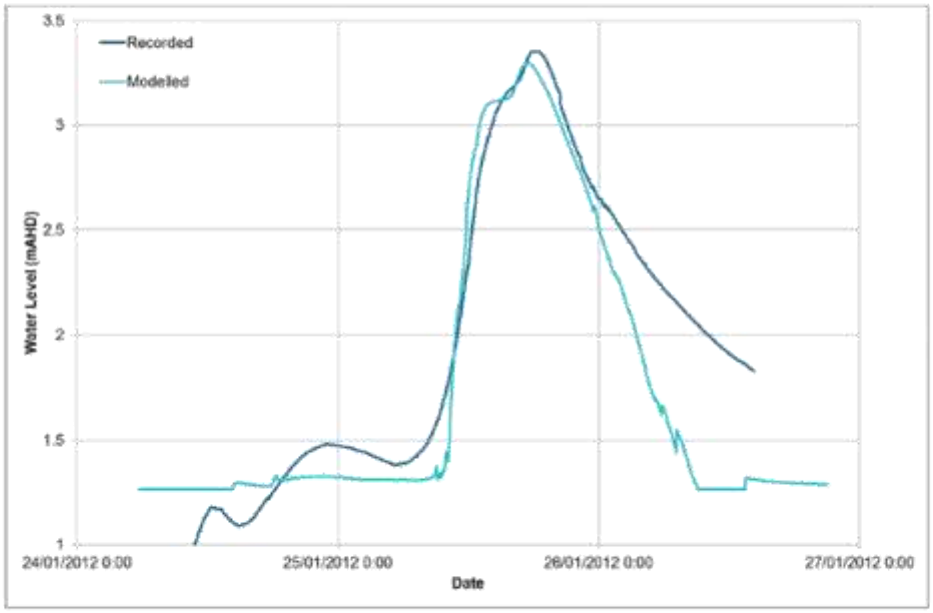


Figure 18: Graph - BMT North Byron Flood Study Report comparing Modelled Level at Marshalls Creek at Billinudgel to Recorded Level (Reference 1)

6.4. Ocean Shores Orana Bridge

The comparison of modelled and recorded levels at the Orana Bridge gauge (202475) is shown in Figure 19. A good match to the peak is achieved with results shown in Table 27. A reasonable match to timing and shape of the recorded hydrograph is achieved except that the failing limb tends to be underestimated.

In comparison to the previous flood study calibration shown in Figure 20 the updated modelling package produces a better match to the peak and replicates the shape and timing with similar accuracy.

Table 27: Marshalls Creek at Orana Bridge – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
1.39	1.43	0.04	3.06%

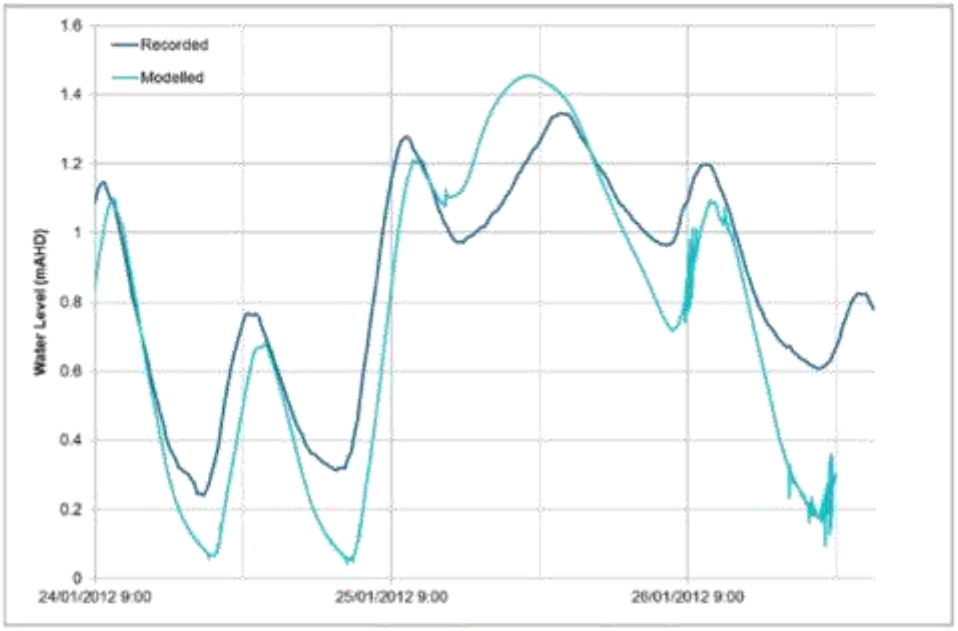


Figure 20: Graph - BMT North Byron Flood Study Report Comparing the Modelled level at Orana Bridge to the Recorded Level - 2012 (Reference 1)

6.5. Brunswick Heads

The comparison of recorded and modelled levels at the Brunswick Heads (202403) gauge is shown in Figure 21. A good match to the recorded peak is achieved with a difference of 0.08 m as shown in Table 28.

Table 28: Brunswick Heads – Recorded and Modelled Peak Flood Level

Recorded Level (mAHD)	Modelled Level (mAHD)	Difference (m)	% Difference
1.06	0.98	0.08	7%

7. CONCLUSION

Overall, the calibration achieved a good fit of the March 2017 event, with the following points of note.

- A good fit to the Durrumbul gauge was achieved for both the recorded level and flow.
- A satisfactory fit to the Main Arm surveyed flood levels was achieved when the questionable flood marks and 12.5 m grid in the TUFLOW model are taken into account.
- The Federation Bridge gauge malfunctioned therefore the remaining data at the gauge is questionable. The majority of surveyed flood marks are within +/- 0.2 m with a trend towards underestimating the peak level. The results are still within the margin of error of flood mark survey and modelling and therefore considered satisfactory.
- A good fit to the peak flood level at the Billinudgel gauge and the two flood marks upstream was achieved.

- There is a trend of overestimation of peak flood levels in the South Golden Beach, New Brighton and Ocean Shores, but the differences are still within a reasonable margin of error.
- A good fit to the Brunswick gauge was achieved although the Brunswick urban area flood marks were overestimated. However the urban drainage and culverts are not represented in the TUFLOW model would mostly accounts for these differences.

Overall the verification of the January 2012 event achieved a good fit, with the following points of note.

- A good fit to the Durrumbul gauge was achieved for both the recorded level and flow, with a substantial improvement on the previous flood study calibration.
- A reasonable fit to the Federation Bridge gauge, with a similar result to the previous flood study.
- A reasonable fit to the BOM gauge at Billinudgel, with a similar result to the previous flood study. Uncertainty remains regarding the discrepancy in levels with the MHL and BOM gauges at the same location.
- A good fit to the Orana Bridge gauge with an improvement on the previous flood study.
- A good fit to the Brunswick Heads gauge was achieved.

The North Byron model is a catchment scale model, established to represent the flood behaviour across a large area, which includes a number of creeks, towns, and hydraulic control structures. As such, the model is considered to represent the March 2017 and January 2012 event satisfactorily and is considered fit for use for the North Byron Floodplain Risk Management Study and Plan.

List of Figures

References

1. North Byron Shire Flood Study (BMT WBM, 2016)
2. Tweed-Byron Coastal Creeks Flood Study (BMT WBM, 2010)
3. Byron Shire Flood Review for Ex-Tropical Cyclone Debbie (BMT WBM, 2017)


Figures

FIGURE 1
MARCH 2017 EVENT
RAINFALL GAUGE LOCATIONS

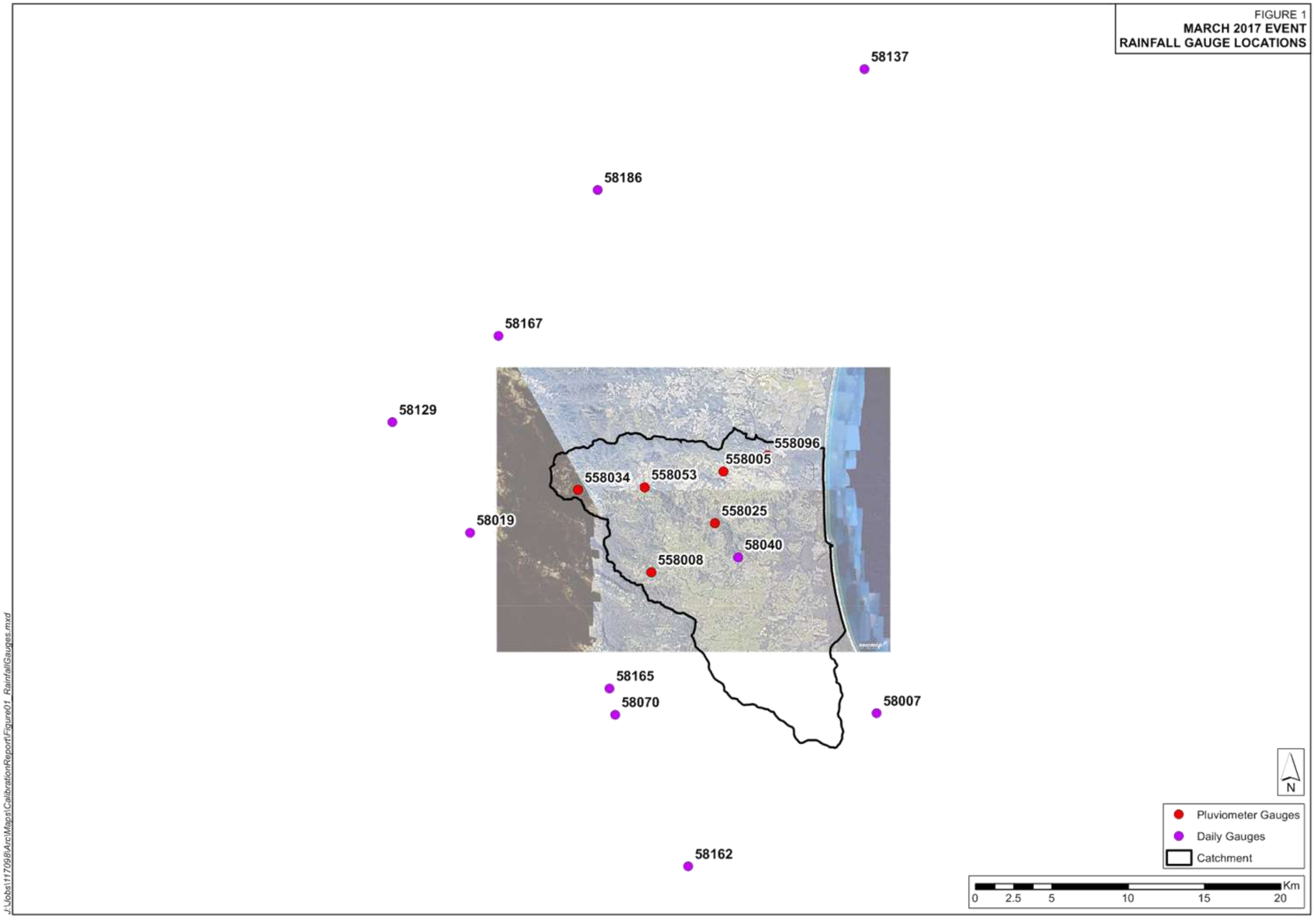
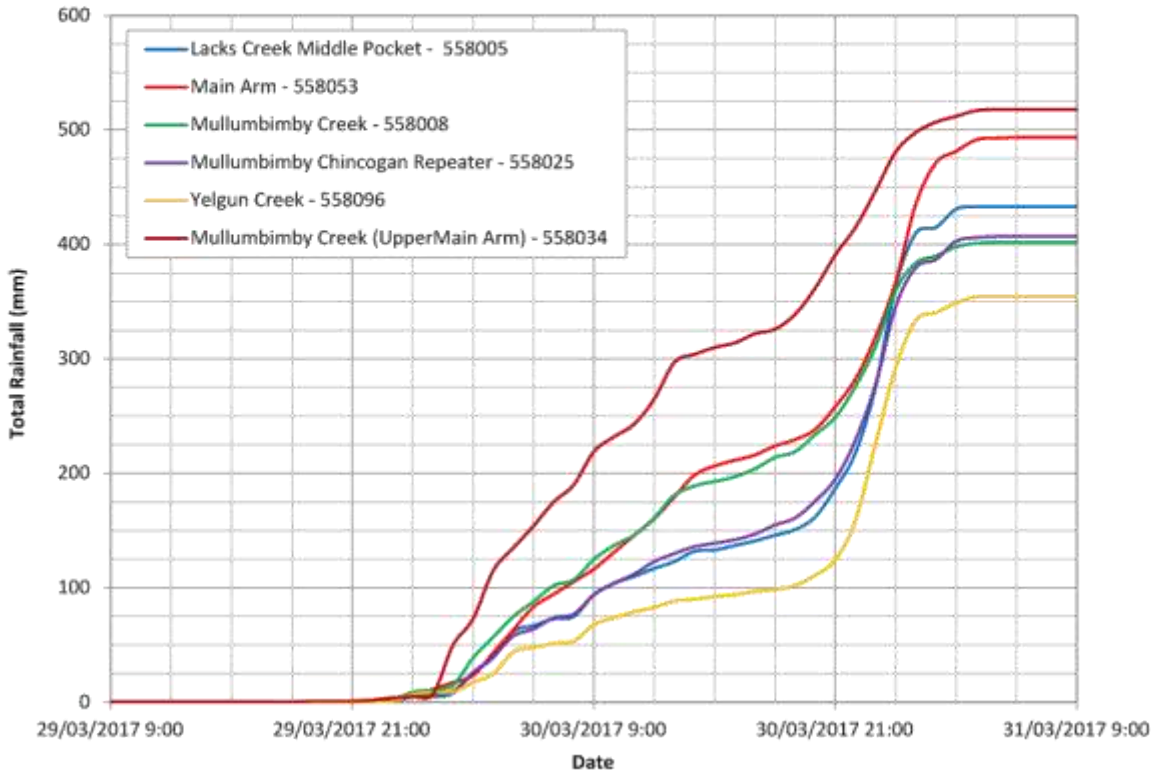
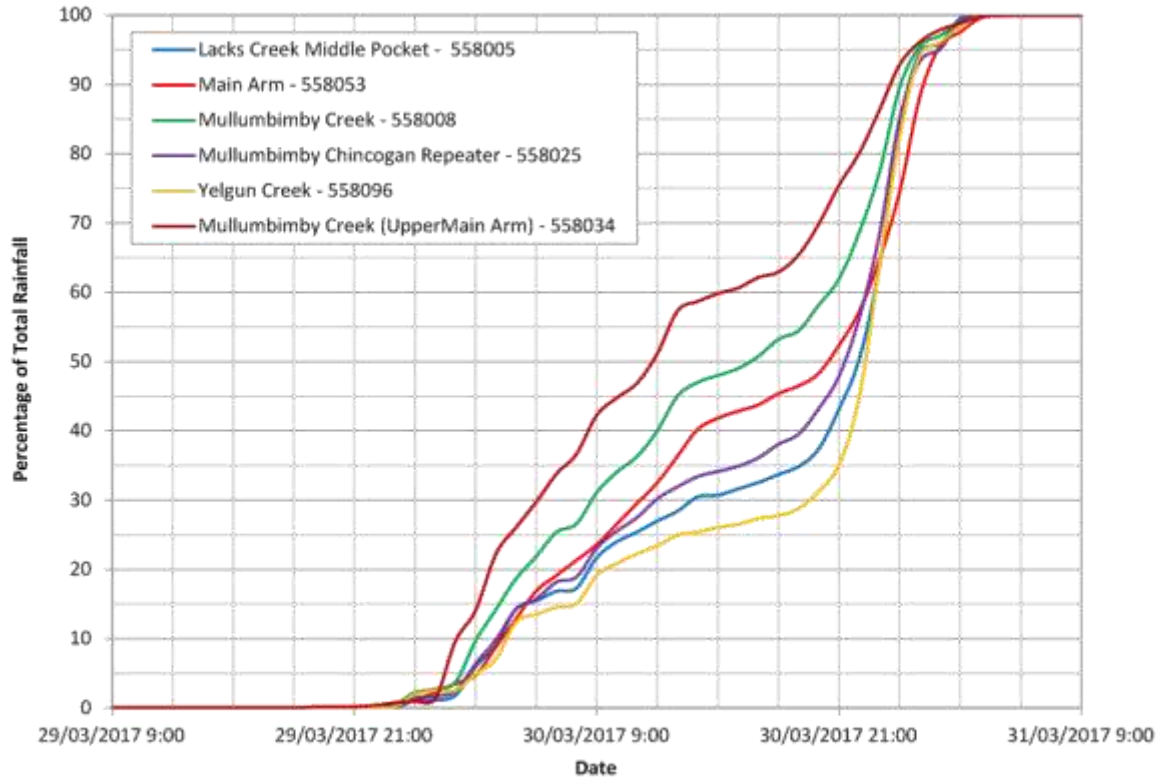


FIGURE 2
MARCH 2017 EVENT
PLUVIOMETER RAINFALL DATA





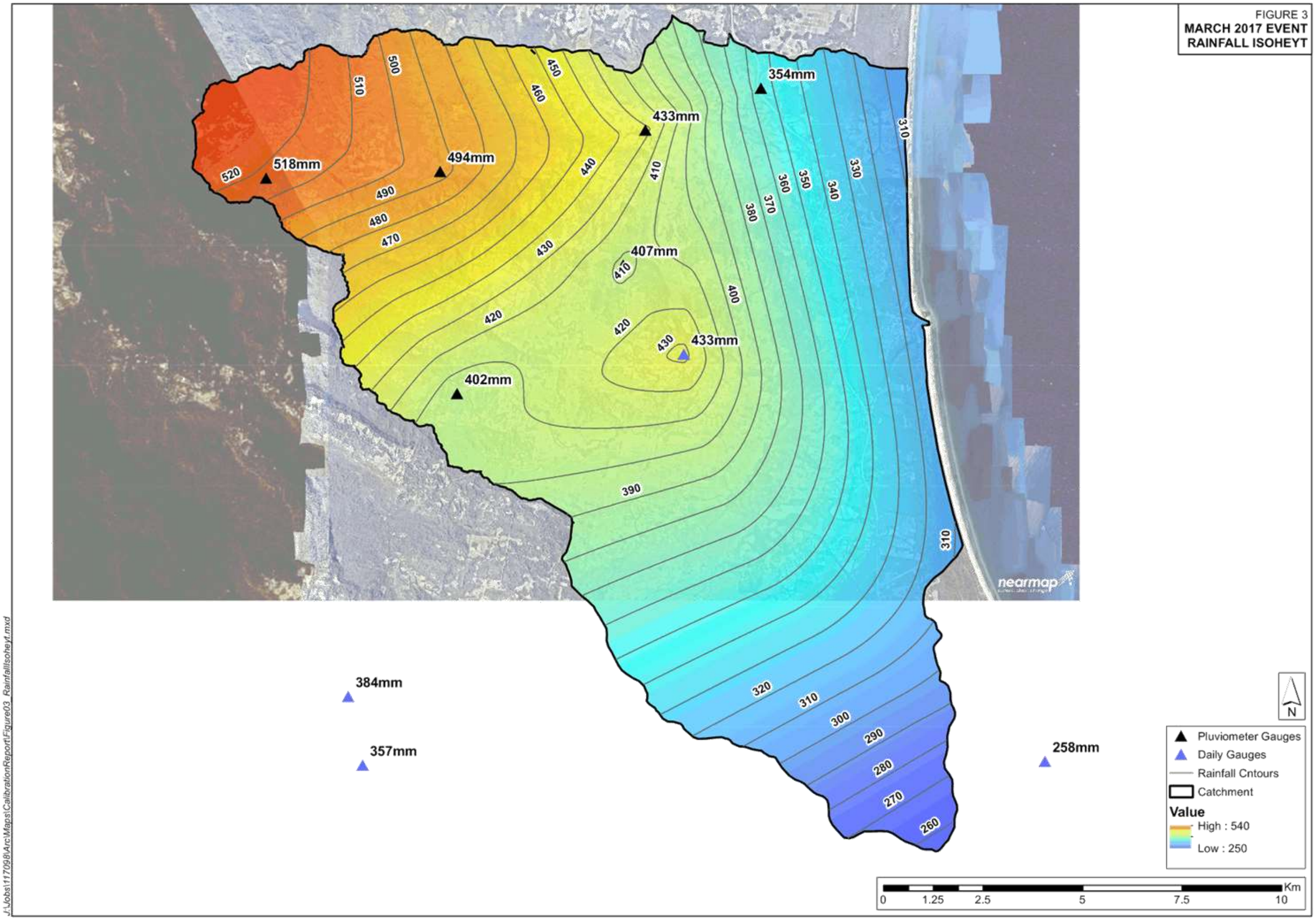


FIGURE 3
MARCH 2017 EVENT
RAINFALL ISOHEYT
354mm
433mm
518mm
494mm
407mm
433mm
402mm
384mm
357mm
258mm
520
510
500
490
480
470
460
450
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
290
280
270
260
nearmap
N
Pluviometer Gauges
Daily Gauges
Rainfall Cntours
Catchment
Value
High : 540
Low : 250
0
1.25
2.5
5
7.5
10
Km
J:\Jobs\117098\ArcMaps\CalibrationReport\Figure03_Rainfallisohey1.mxd

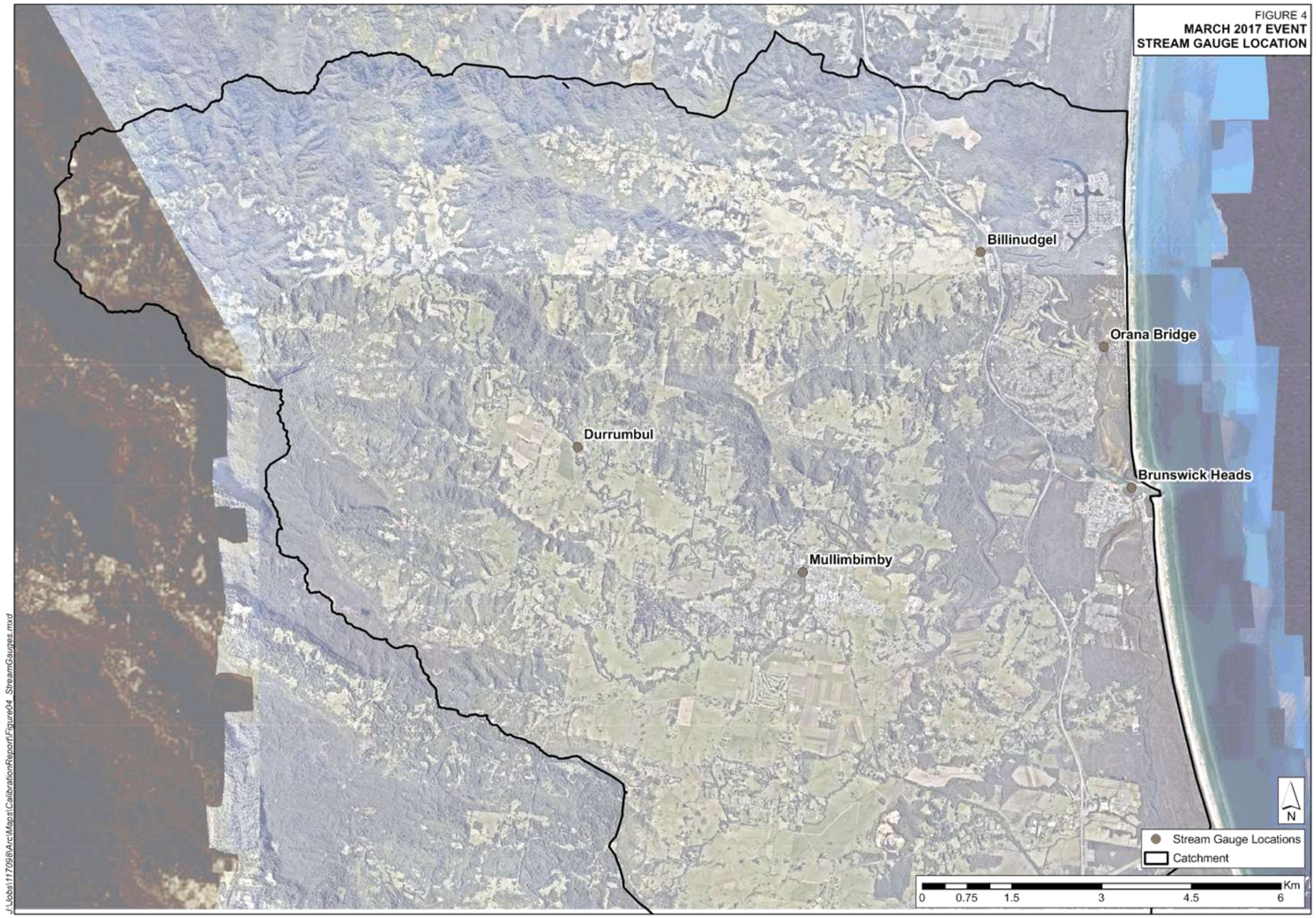


FIGURE 4
MARCH 2017 EVENT
STREAM GAUGE LOCATION
Billinudgel
Orana Bridge
Durrumbul
Brunswick Heads
Mullimbimby
N
Stream Gauge Locations
Catchment
0
0.75
1.5
3
4.5
6
Km
J:\Jobs\117098\Arc\Maps\CalibrationReport\Figure04_StreamGauges.mxd

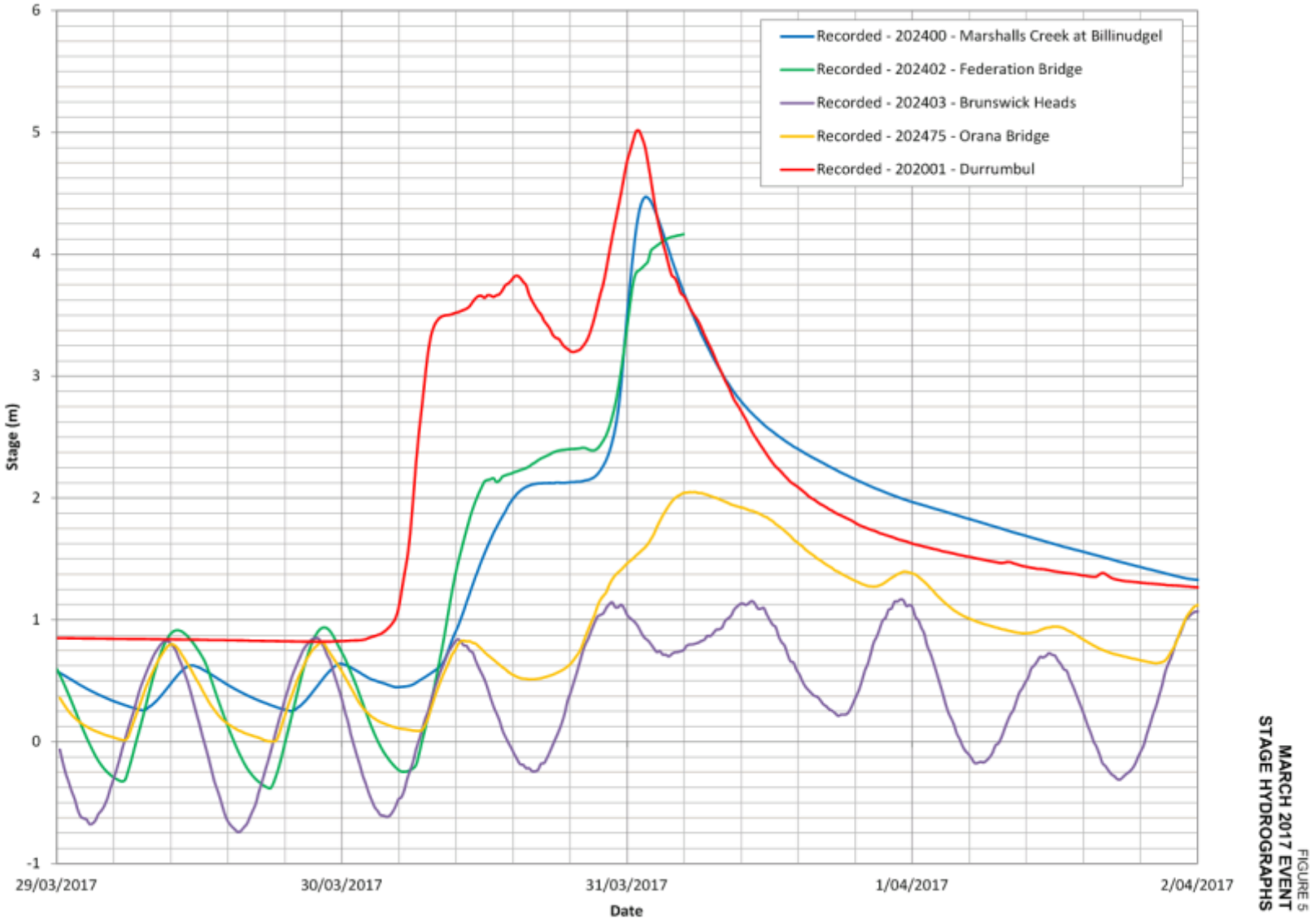
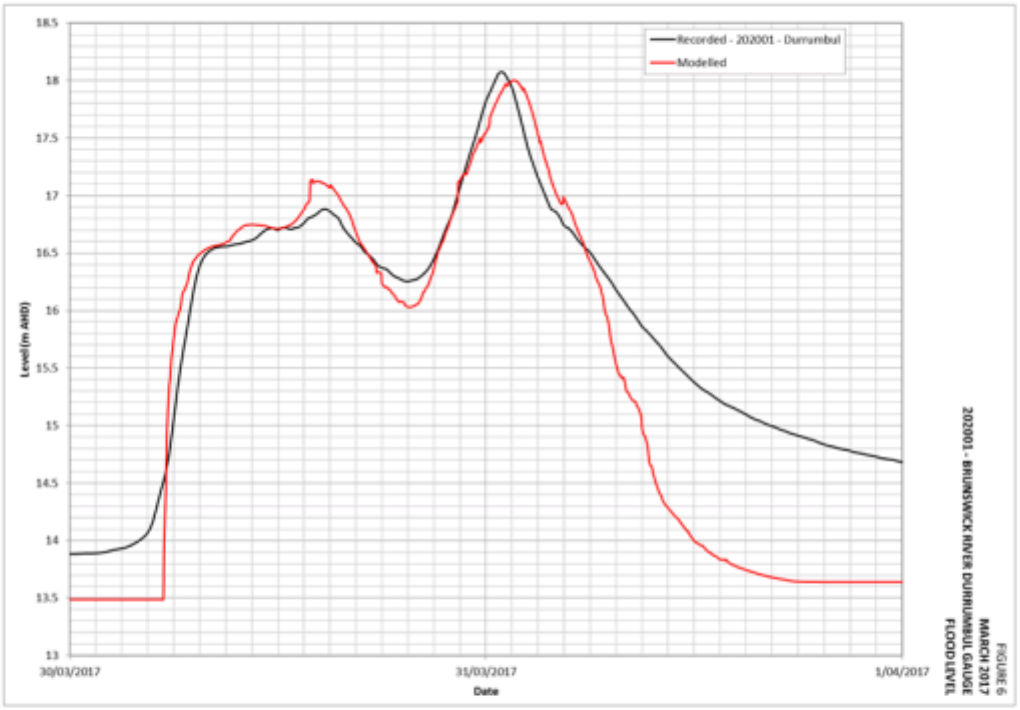
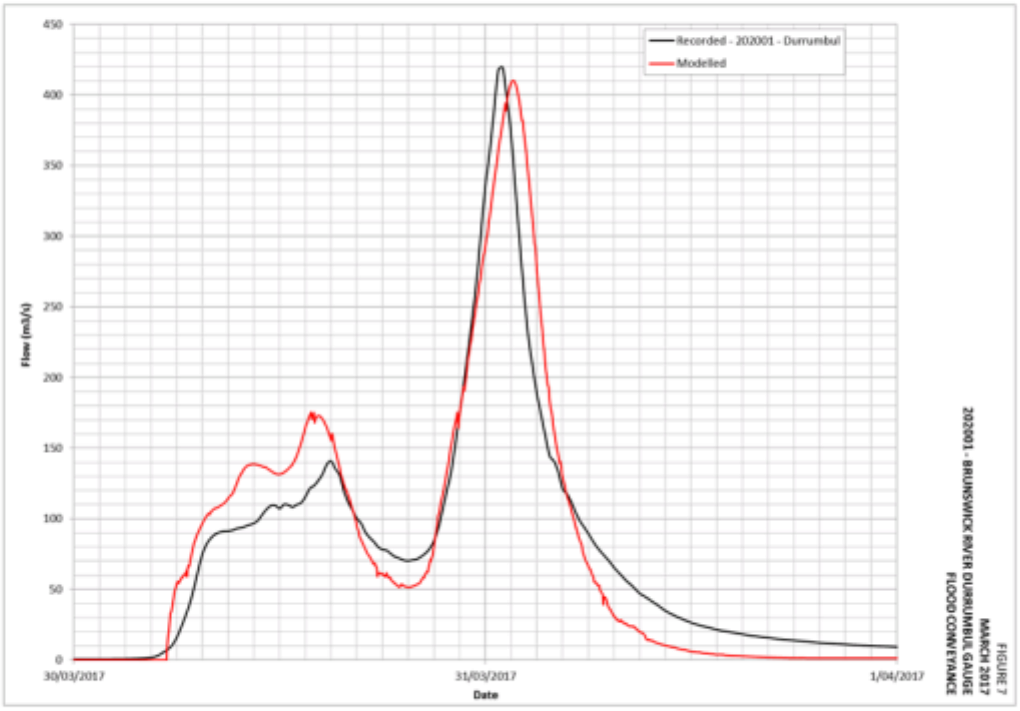
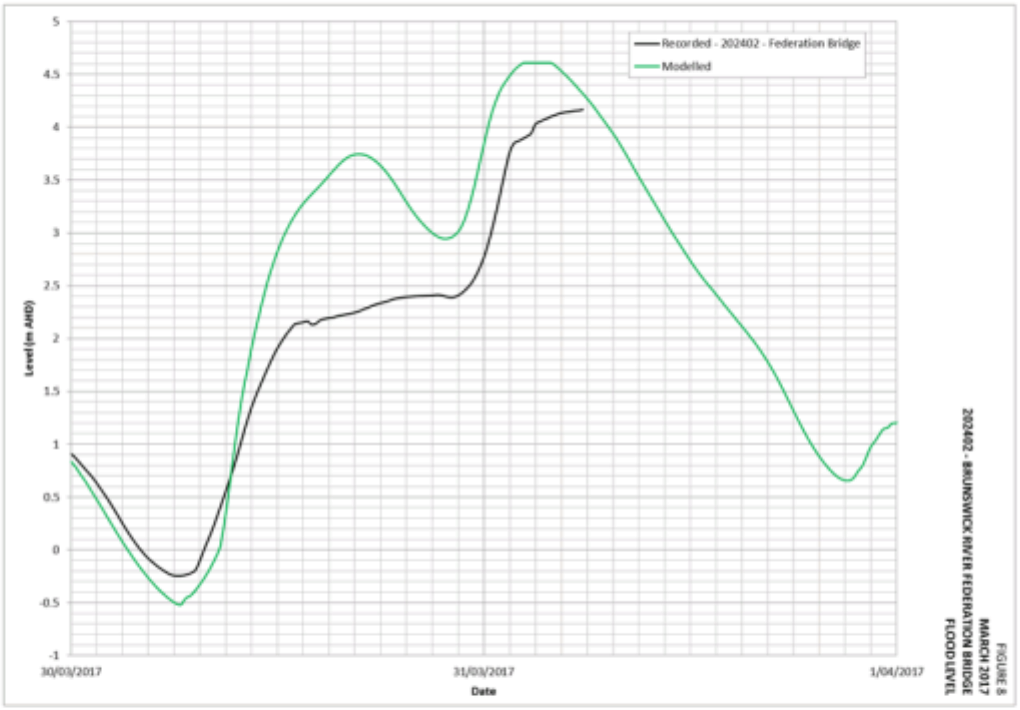
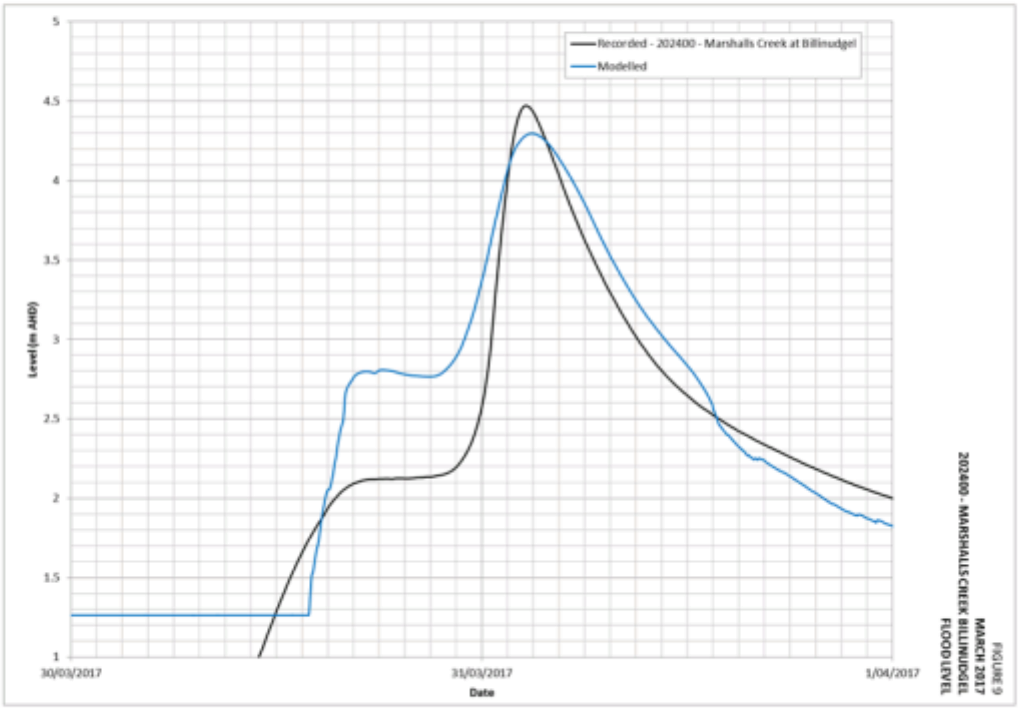


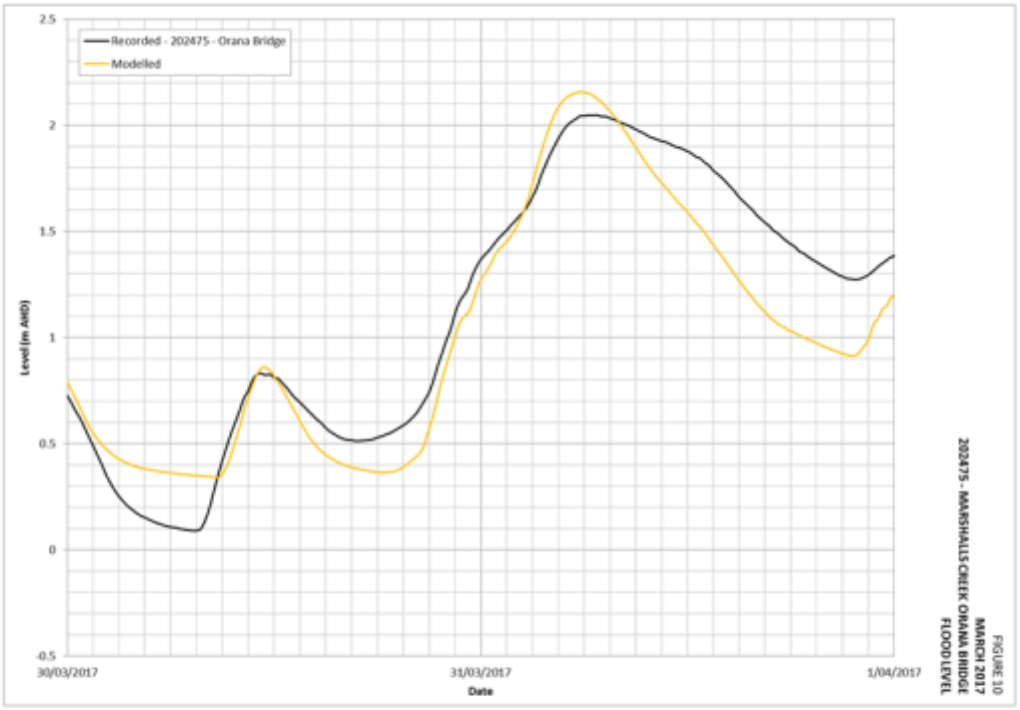
FIGURE 5
MARCH 2017 EVENT
STAGE HYDROGRAPHS

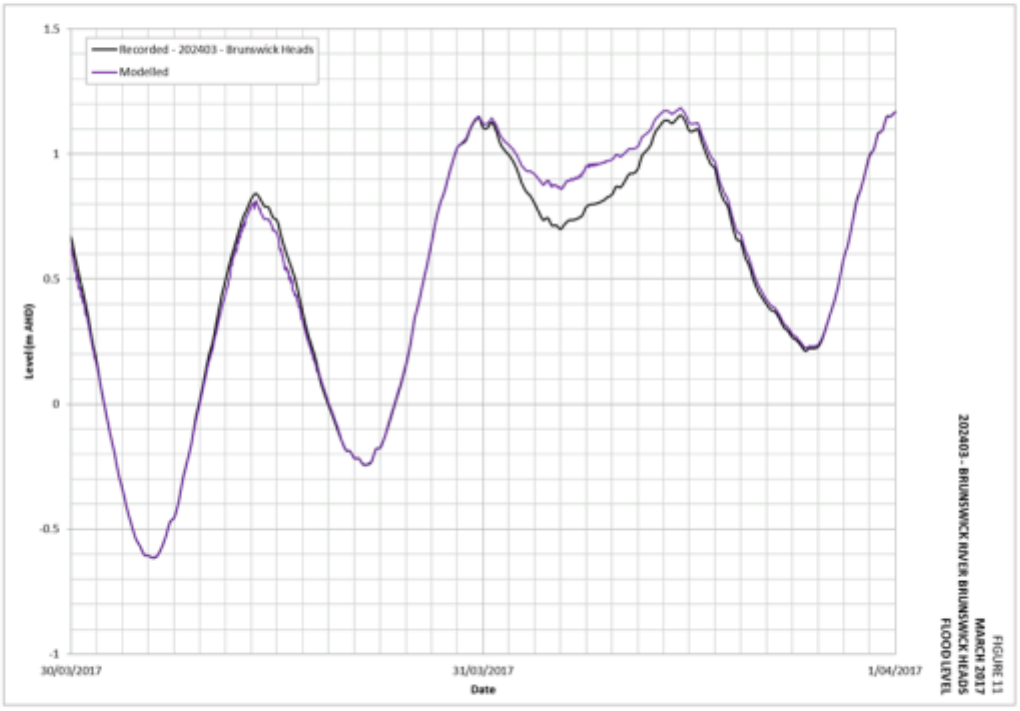

Recorded - 202001 - Durrumbul
Modelled
Level (m AHD)
18.5
18
17.5
17
16.5
16
15.5
15
14.5
14
13.5
13
30/03/2017
31/03/2017
1/04/2017
Date
202001 - BRUNSWICK RIVER DURRUMBUL GAUGE
MARCH 2017
FLOOD LEVEL
FIGURE 6

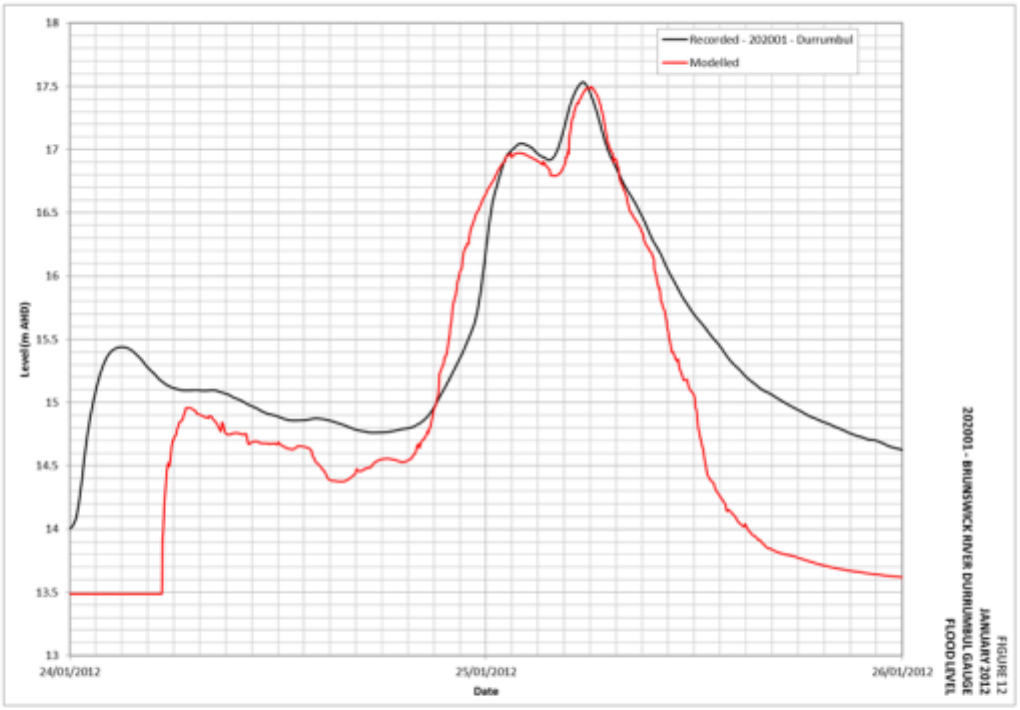

Recorded - 202001 - Durrumbul
Modelled
Flow (m3/s)
450
400
350
300
250
200
150
100
50
0
30/03/2017
31/03/2017
1/04/2017
Date
202001 - BRUNSWICK RIVER DURRUMBUL GAUGE
MARCH 2017
FLOOD CONVEYANCE
FIGURE 7

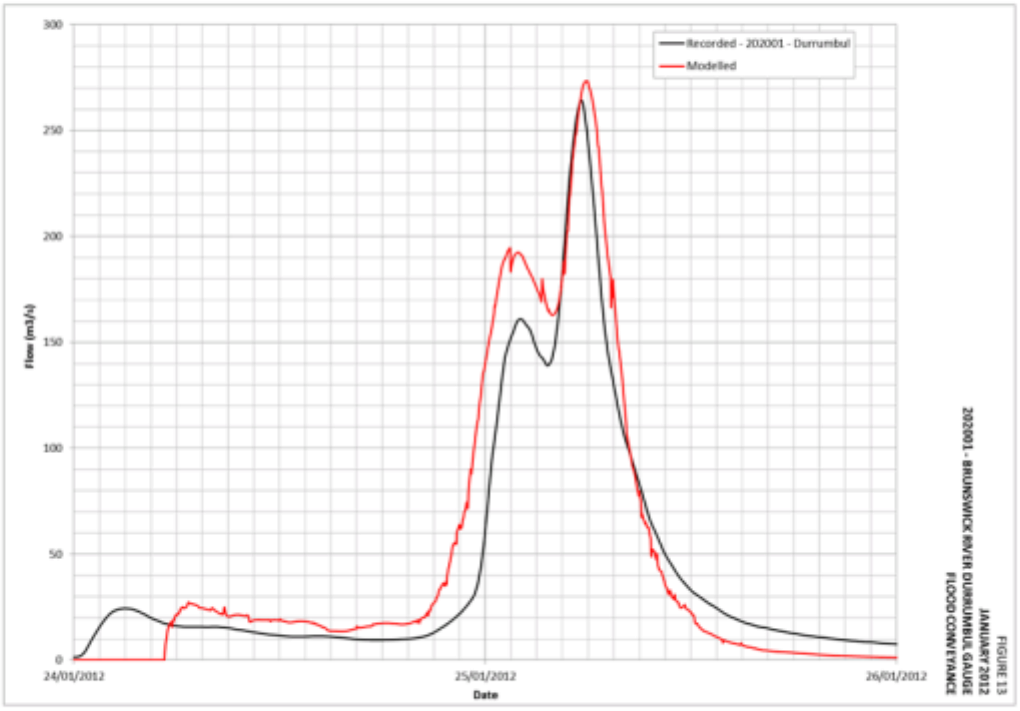

Recorded - 202402 - Federation Bridge
Modelled
Level (m AHD)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
30/03/2017
31/03/2017
1/04/2017
Date
202402 - BRUNSWICK RIVER FEDERATION BRIDGE
MARCH 2017
FLOOD LEVEL
FIGURE 8

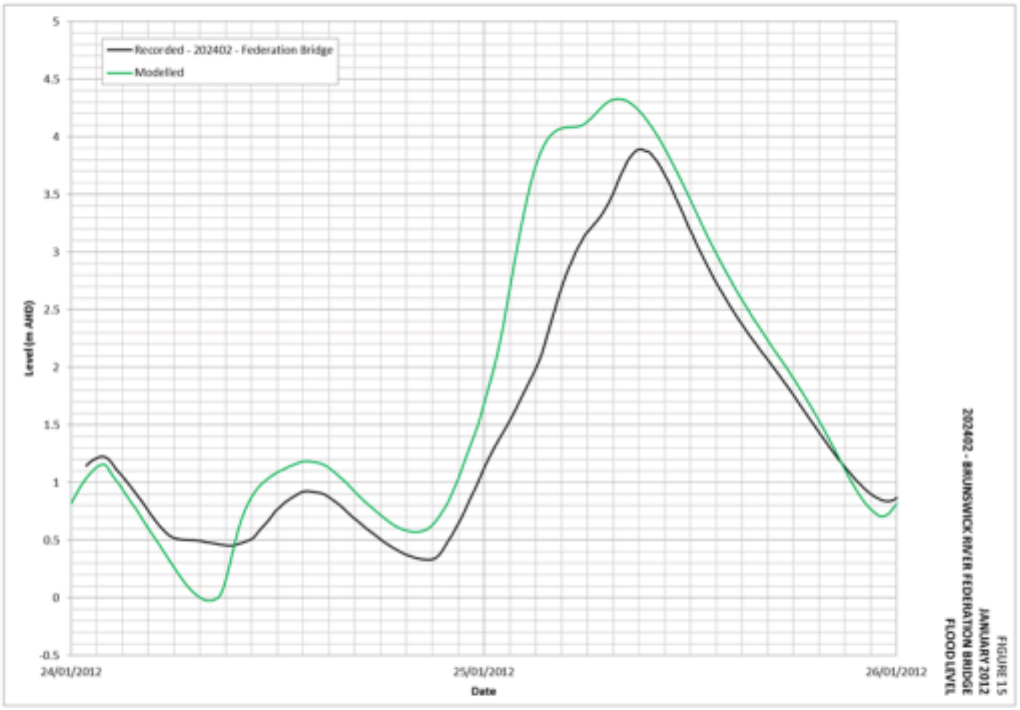

Recorded - 202400 - Marshalls Creek at Billinudgel
Modelled
Level (m AHD)
5
4.5
4
3.5
3
2.5
2
1.5
1
30/03/2017
31/03/2017
1/04/2017
Date
202400 - MARSHALLS CREEK BILLINUDGEL
MARCH 2017
FLOOD LEVEL
FIGURE 9

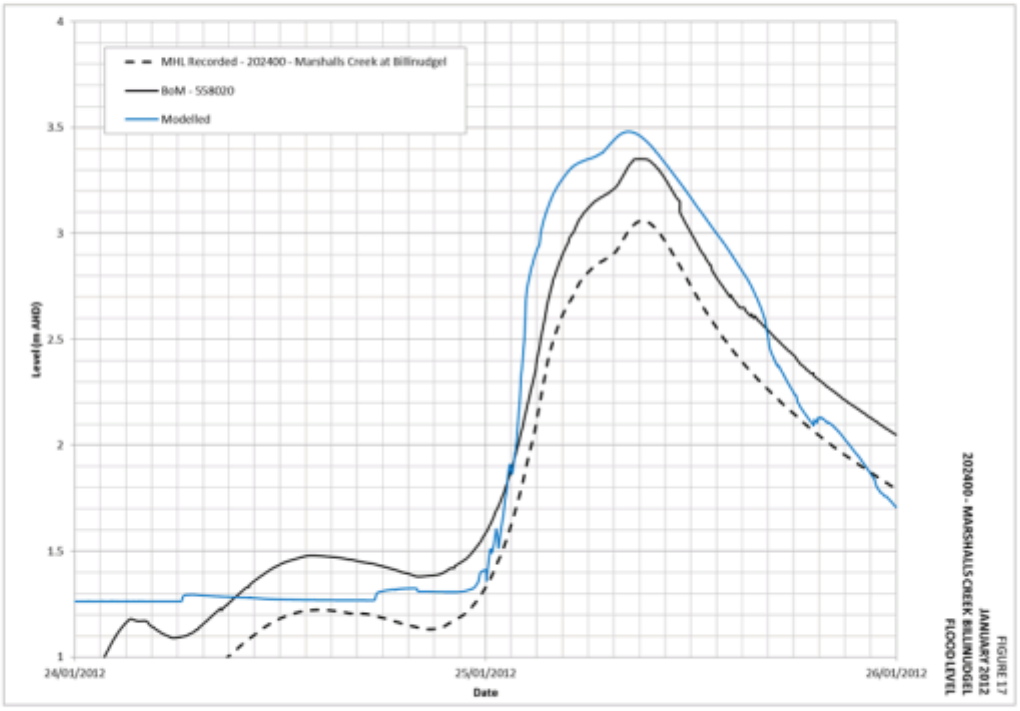

Recorded - 202475 - Orana Bridge
Modelled
Level (m AHD)
2.5
2
1.5
1
0.5
0
-0.5
30/03/2017
31/03/2017
1/04/2017
Date
FIGURE 10
202475 - MARSHALLS CREEK ORANA BRIDGE
MARCH 2017
FLOOD LEVEL

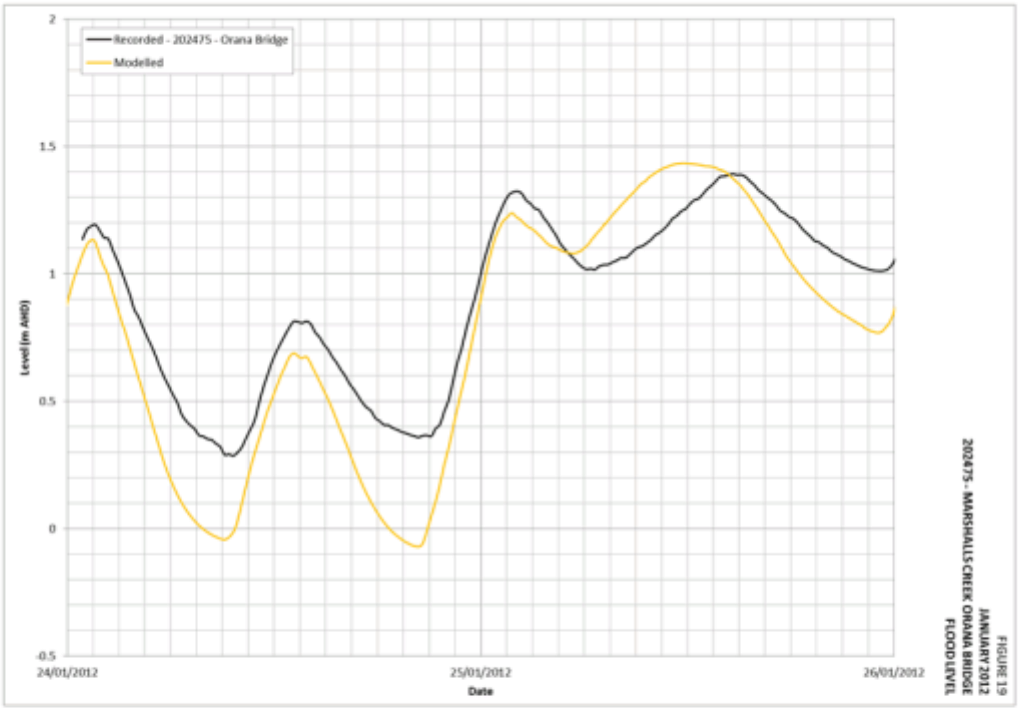

Recorded - 202403 - Brunswick Heads
Modelled
Level (m AHD)
1.5
1
0.5
0
-0.5
-1
30/03/2017
31/03/2017
1/04/2017
Date
FIGURE 11
202403 - BRUNSWICK RIVER BRUNSWICK HEADS
MARCH 2017
FLOOD LEVEL

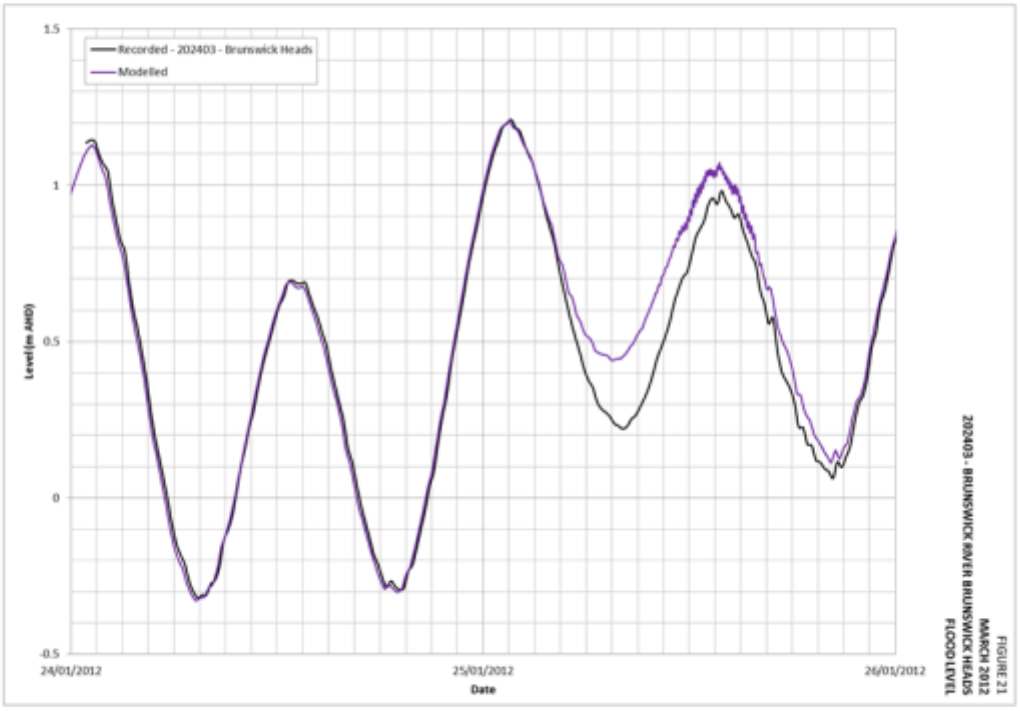

Recorded - 202001 - Durrumbul
Modelled
Level (m AHD)
18
17.5
17
16.5
16
15.5
15
14.5
14
13.5
13
24/01/2012
25/01/2012
26/01/2012
Date
FIGURE 12
JANUARY 2012
202001 - BRUNSWICK RIVER DURRUMBUL GAUGE
FLOOD LEVEL


Recorded - 202001 - Durrumbul
Modelled
Flow (m3/s)
300
250
200
150
100
50
0
24/01/2012
25/01/2012
26/01/2012
Date
FIGURE 13
JANUARY 2012
202001 - BRUNSWICK RIVER DURRUMBUL GAUGE
FLOOD CONVEYANCE


Recorded - 202402 - Federation Bridge
Modelled
Level (m AHD)
Date
24/01/2012
25/01/2012
26/01/2012
202402 - BRUNSWICK RIVER FEDERATION BRIDGE
JANUARY 2012
FLOOD LEVEL
FIGURE 15


MHL Recorded - 202400 - Marshalls Creek at Billinudgel
BoM - 558020
Modelled
Level (m AHD)
Date
24/01/2012
25/01/2012
26/01/2012
202400 - MARSHALLS CREEK BILLINUDGEL
JANUARY 2012
FLOOD LEVEL
FIGURE 17


Recorded - 202475 - Orana Bridge
Modelled
Level (m AHD)
Date
24/01/2012
25/01/2012
26/01/2012
FIGURE 19
JANUARY 2012
202475 - MARSHALLS CREEK ORANA BRIDGE
FLOOD LEVEL


Recorded - 202403 - Brunswick Heads
Modelled
Level (m AHD)
Date
24/01/2012
25/01/2012
26/01/2012
FIGURE 21
MARCH 2012
202403 - BRUNSWICK RIVER BRUNSWICK HEADS
FLOOD LEVEL

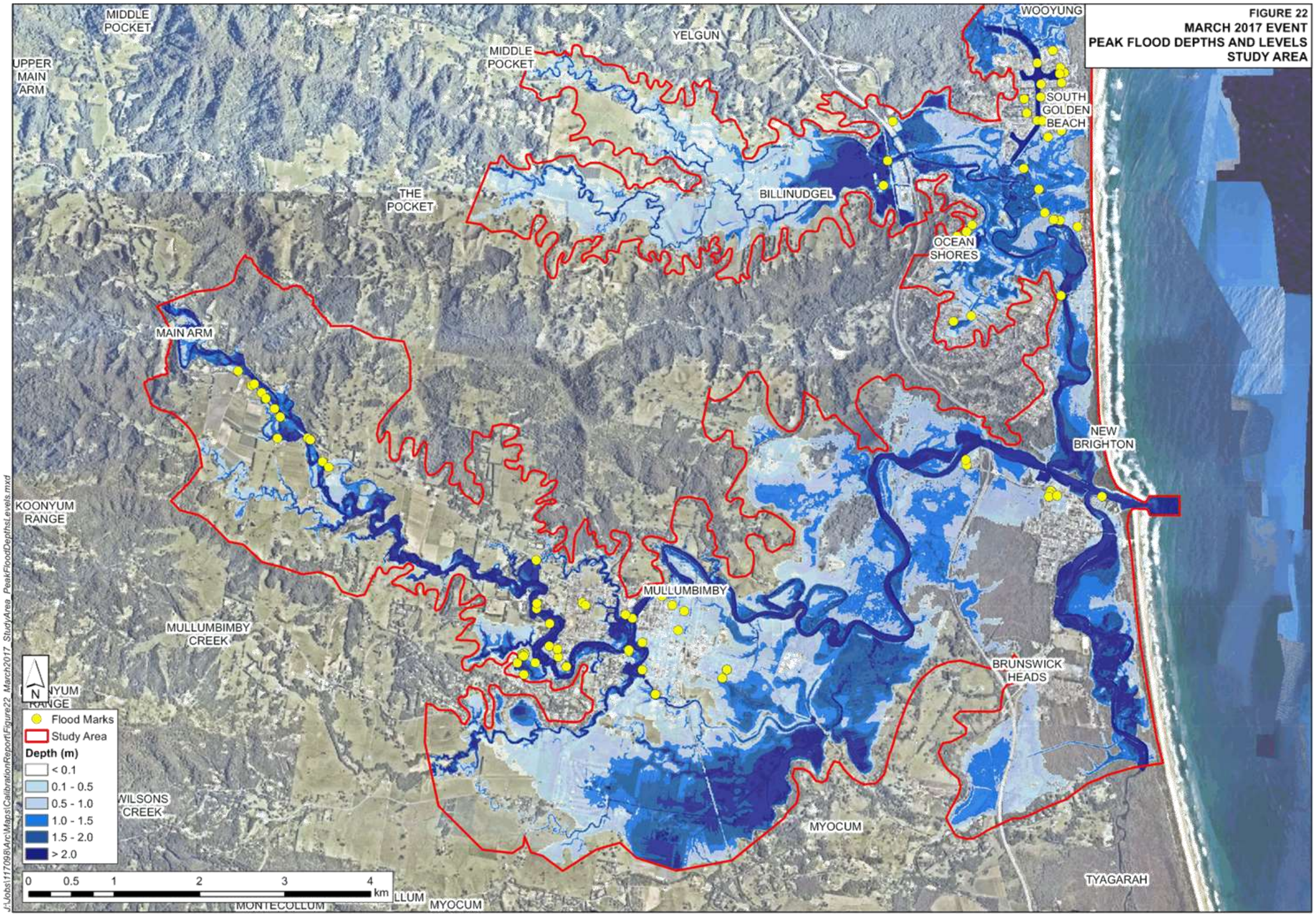


FIGURE 22
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
STUDY AREA
MIDDLE POCKET
UPPER MAIN ARM
MIDDLE POCKET
YELGUN
WOOYUNG
SOUTH GOLDEN BEACH
THE POCKET
BILLINUDGEL
OCEAN SHORES
MAIN ARM
NEW BRIGHTON
KOONYUM RANGE
MULLUMBIMBY
MULLUMBIMBY CREEK
BRUNSWICK HEADS
WILSONS CREEK
MYOCUM
TYAGARAH
MONTECOLLUM
N
Flood Marks
Study Area
Depth (m)
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
0 0.5 1 2 3 4 km
J:\Jobs\117098\Arc\Maps\CalibrationReport\Figure22_March2017_StudyArea_PeakFloodDepthsLevels.mxd

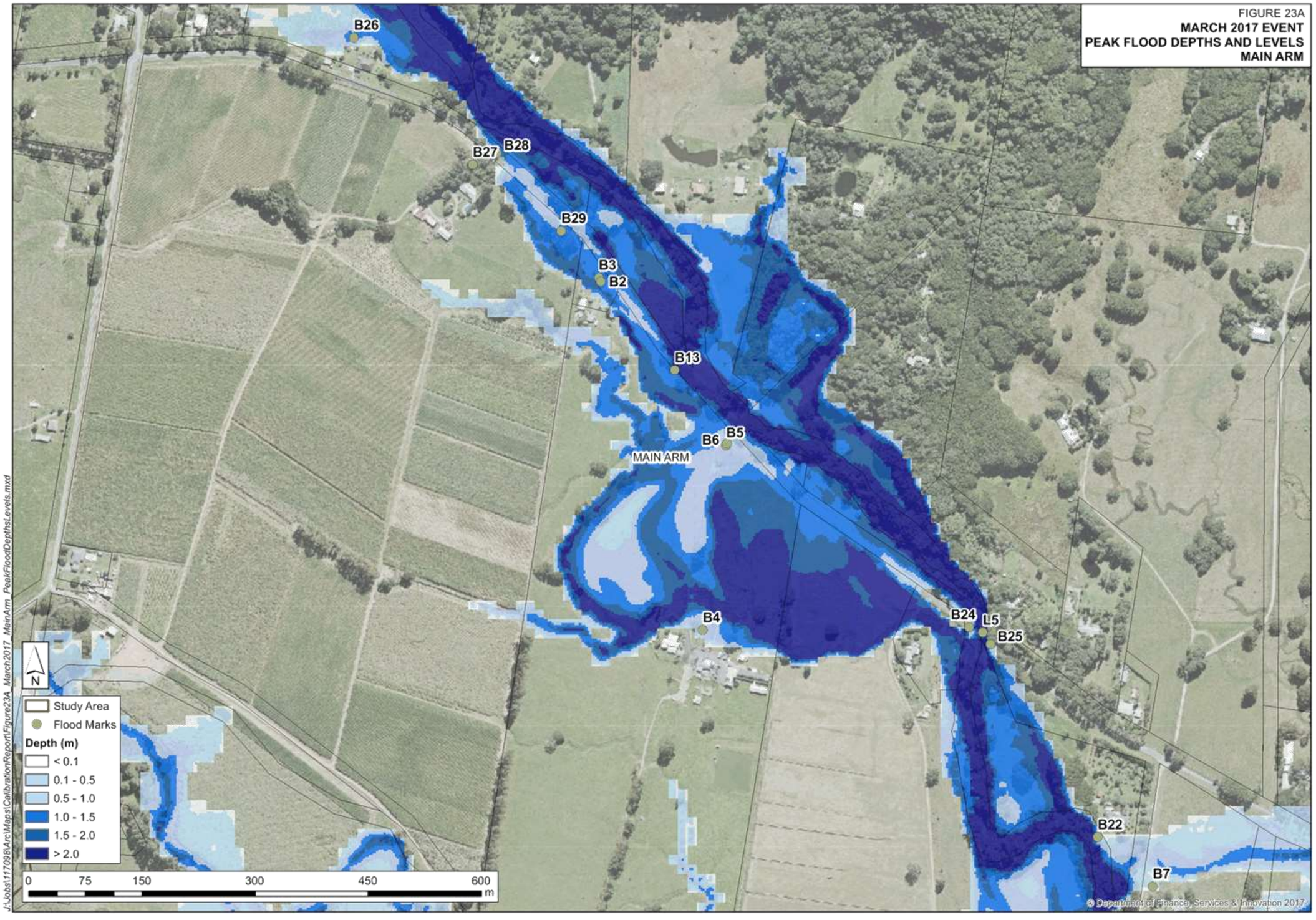


FIGURE 23A
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
MAIN ARM
B26
B27
B28
B29
B3
B2
B13
B6
B5
MAIN ARM
B4
B24
L5
B25
B22
B7
N
Study Area
Flood Marks
Depth (m)
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
0
75
150
300
450
600
m
J:\Jobs\117098\Arc\Maps\CalibrationReport\Figure23A_March2017_MainArm_PeakFloodDepthsLevels.mxd
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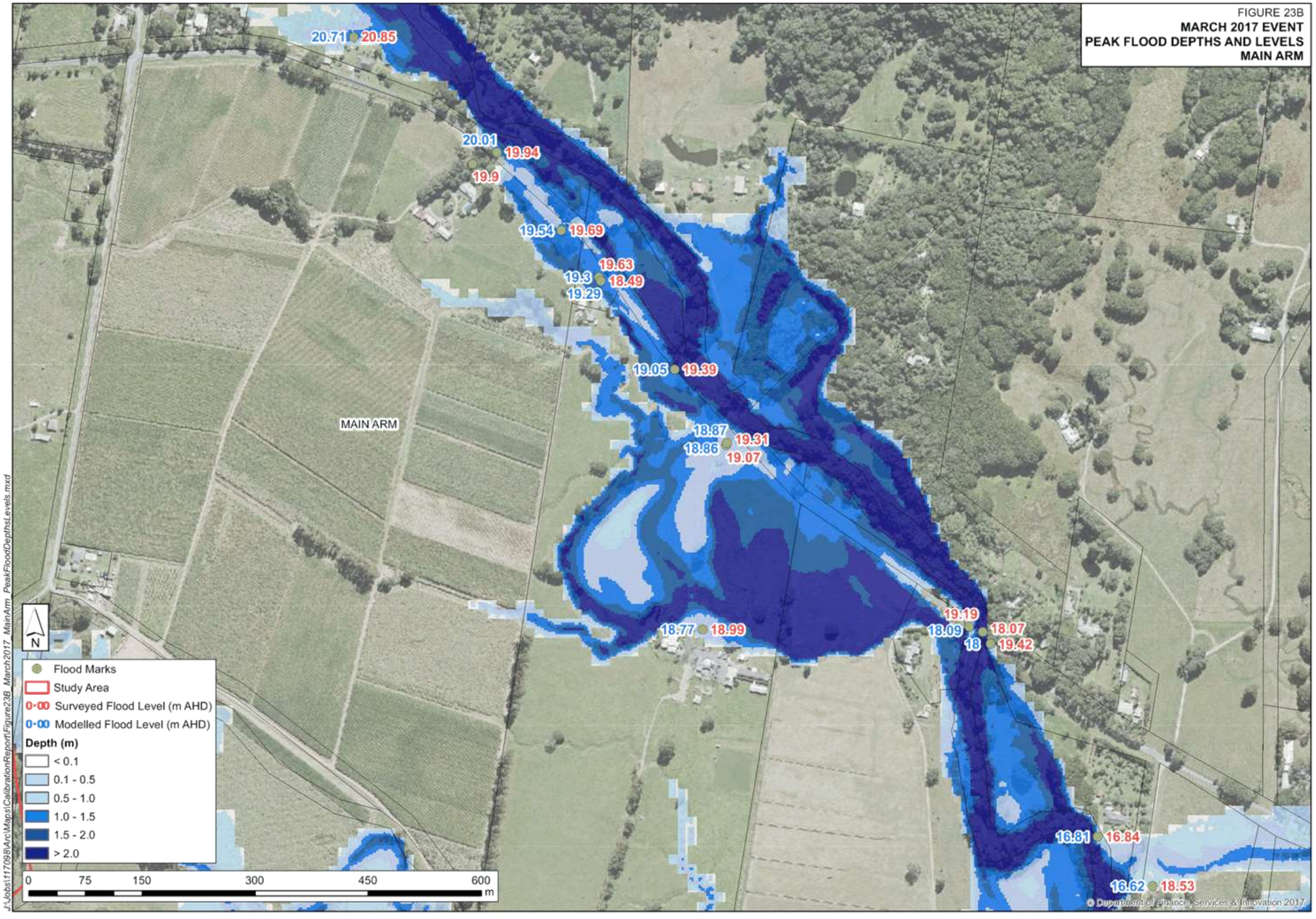
FIGURE 23B
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
MAIN ARM
20.71
20.85
20.01
19.94
19.9
19.54
19.69
19.63
19.3
18.49
19.29
19.05
19.39
MAIN ARM
18.87
19.31
18.86
19.07
18.77
18.99
19.19
18.09
18.07
18
19.42
16.81
16.84
16.62
18.53
N
Flood Marks
Study Area
Surveyed Flood Level (m AHD)
Modelled Flood Level (m AHD)
Depth (m)
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
0
75
150
300
450
600
m
J:\Jobs\117098\Arc\Maps\CalibrationReport\Figure23B_March2017_MainArm_PeakFloodDepthsLevels.mxd
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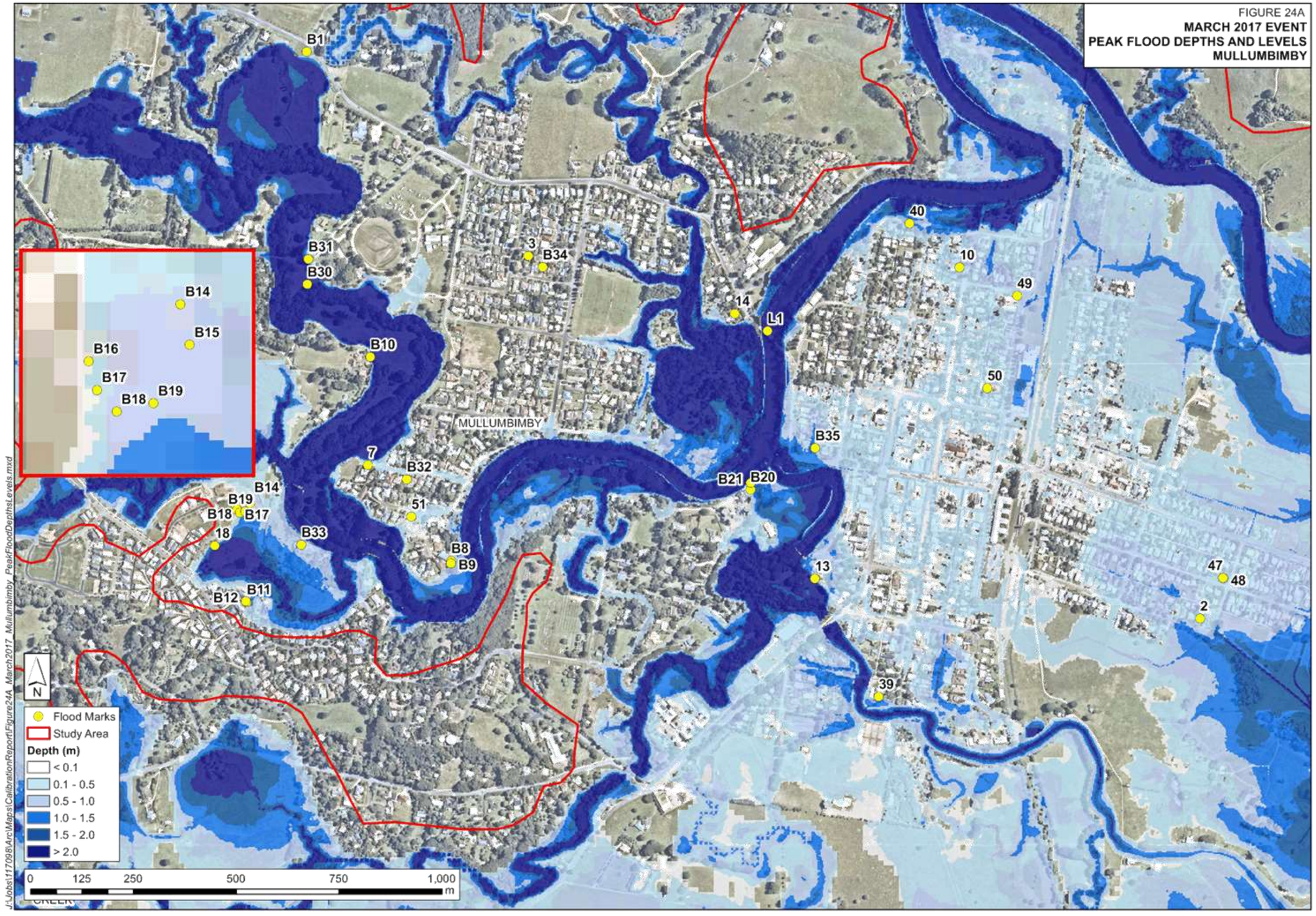
FIGURE 24A
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
MULLUMBIMBY
B1
B31
B30
B14
B15
B16
B17
B18
B19
B10
B34
3
40
10
49
14
L1
50
B35
MULLUMBIMBY
7
B32
51
B14
B19
B18
B17
18
B33
B8
B9
B21
B20
13
47
48
2
B12
B11
39
N
Flood Marks
Study Area
Depth (m)
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
0
125
250
500
750
1,000
m
J:\Jobs\117098\ArcMaps\CalibrationReport\Figure24A_March2017_Mullumbimby_PeakFloodDepthsLevels.mxd

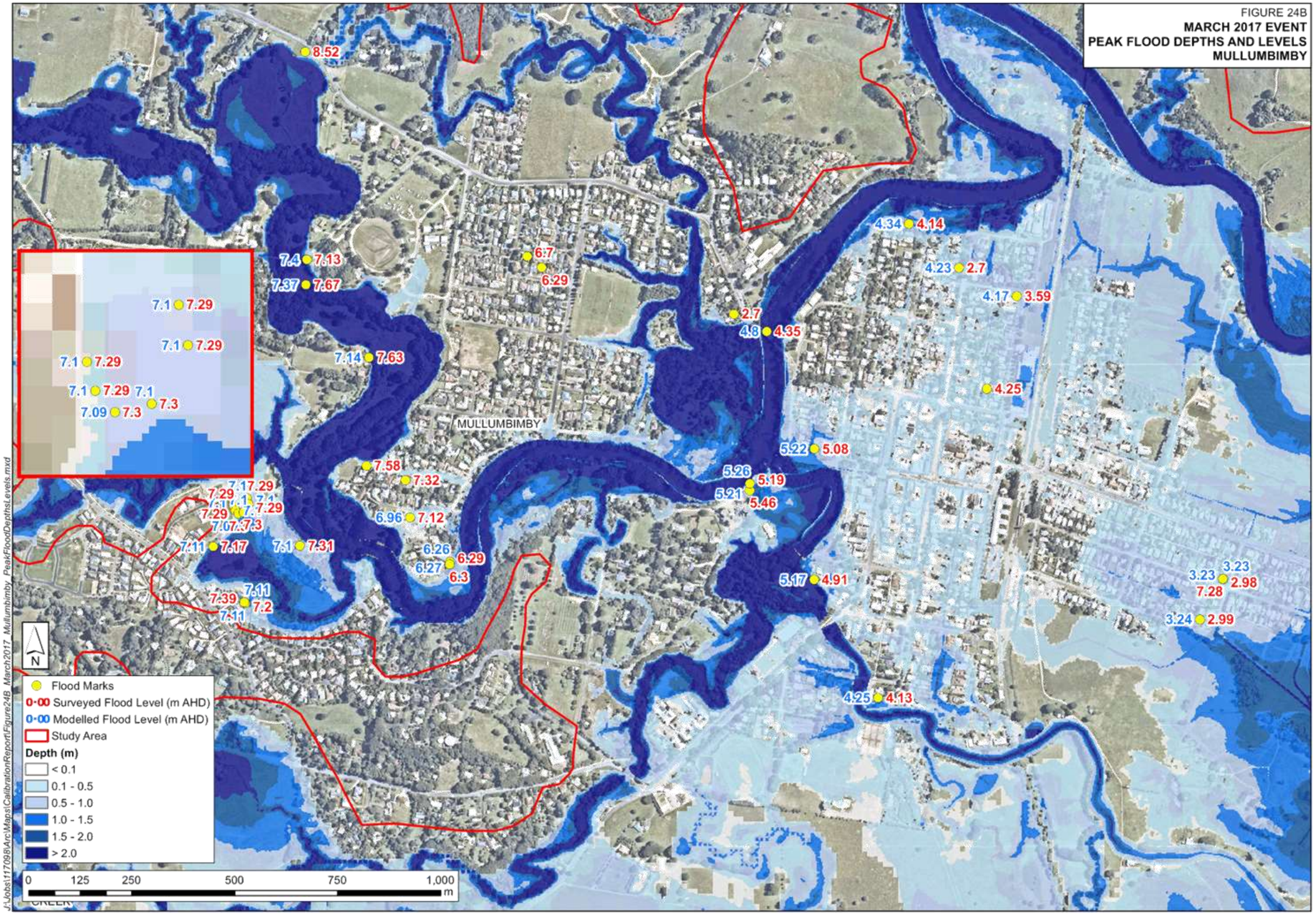
FIGURE 24B
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
MULLUMBIMBY
MULLUMBIMBY
8.52
7.4 7.13
7.37 7.67
6.7
6.29
7.14 7.63
7.1 7.29
7.1 7.29
7.1 7.29
7.1 7.29 7.1
7.3
7.09 7.3
7.58
7.32
6.96 7.12
7.11 7.17
7.1 7.31
6.26
6.27 6.29
6.3
7.39 7.11
7.2
7.11
4.34 4.14
4.23 2.7
4.17 3.59
2.7
4.8 4.35
4.25
5.22 5.08
5.26
5.19
5.21
5.46
5.17 4.91
3.23 3.23
2.98
7.28
3.24 2.99
4.25 4.13
N
Flood Marks
0·00 Surveyed Flood Level (m AHD)
0·00 Modelled Flood Level (m AHD)
Study Area
Depth (m)
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
0 125 250 500 750 1,000
m
J:\Jobs\117098\ArcMaps\CalibrationReport\Figure24B_March2017_Mullumbimby_PeakFloodDepthsLevels.mxd

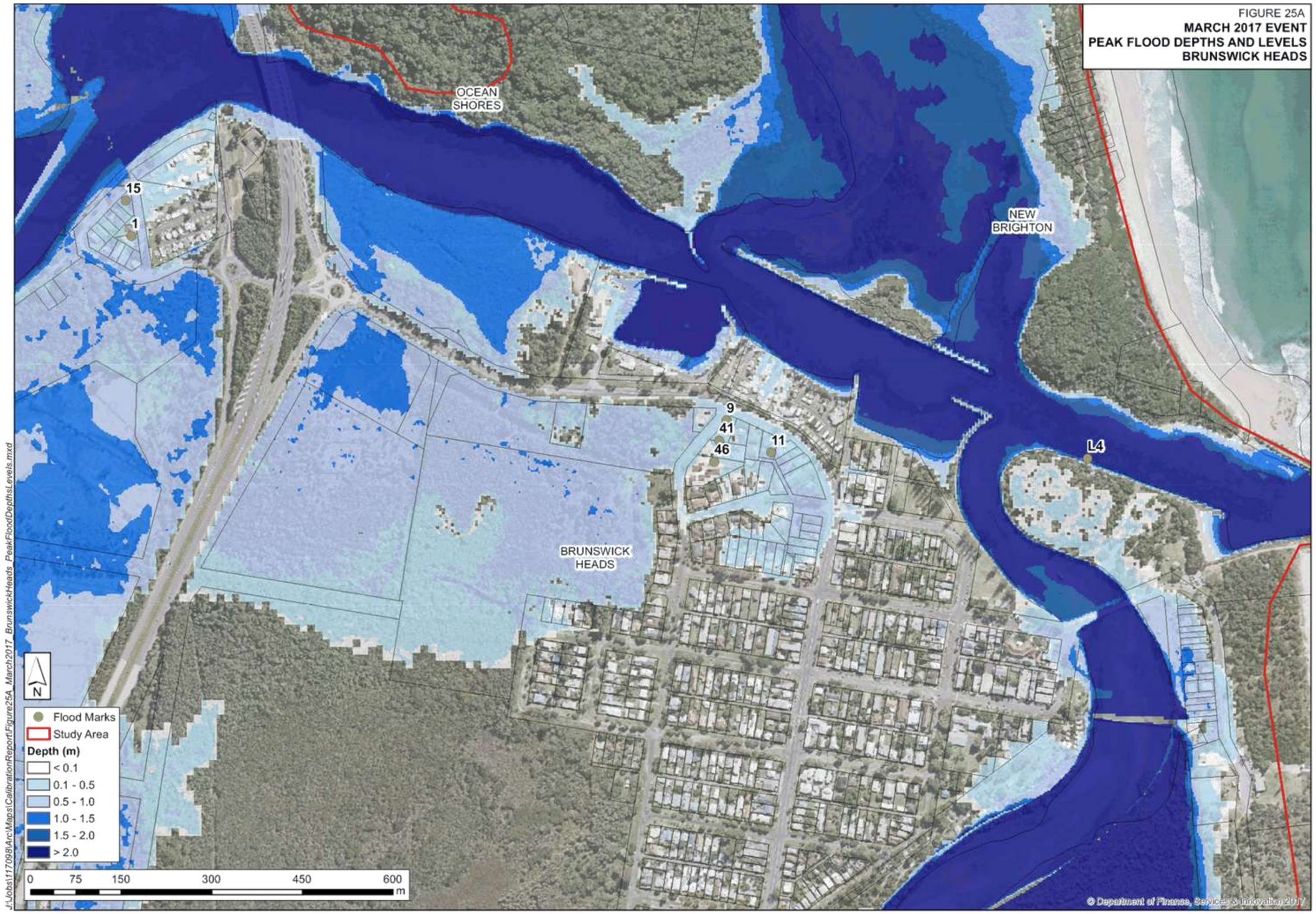
FIGURE 25A
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
BRUNSWICK HEADS
OCEAN SHORES
NEW BRIGHTON
BRUNSWICK HEADS
15
1
9
41
46
11
L4
N
Flood Marks
Study Area
Depth (m)
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
0 75 150 300 450 600
m
J:\Jobs\117098\ArcMaps\CalibrationReport\Figure25A_March2017_BrunswickHeads_PeakFloodDepthsLevels.mxd
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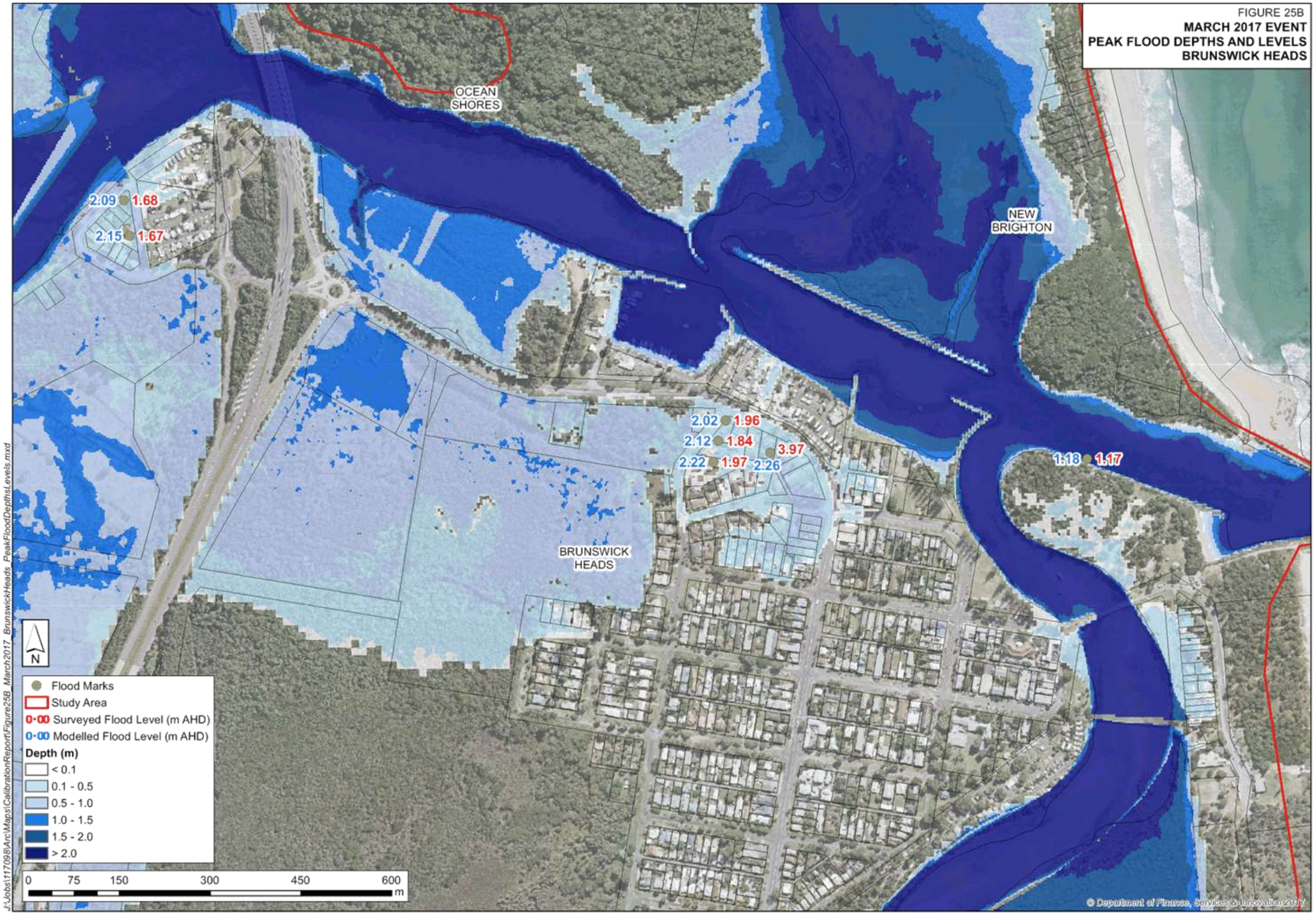
FIGURE 25B
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
BRUNSWICK HEADS
OCEAN SHORES
NEW BRIGHTON
BRUNSWICK HEADS
2.09 1.68
2.15 1.67
2.02 1.96
2.12 1.84
3.97
2.22 1.97 2.26
1.18 1.17
N
Flood Marks
Study Area
0.00 Surveyed Flood Level (m AHD)
0.00 Modelled Flood Level (m AHD)
Depth (m)
< 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
> 2.0
0 75 150 300 450 600
m
J:\Jobs\117098\ArcMaps\CalibrationReport\Figure25B_March2017_BrunswickHeads_PeakFloodDepthsLevels.mxd
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FIGURE 26A
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
SOUTH GOLDEN BEACH, BILLINUDGEL, OCEAN SHORES AND NEW BRIGHTON

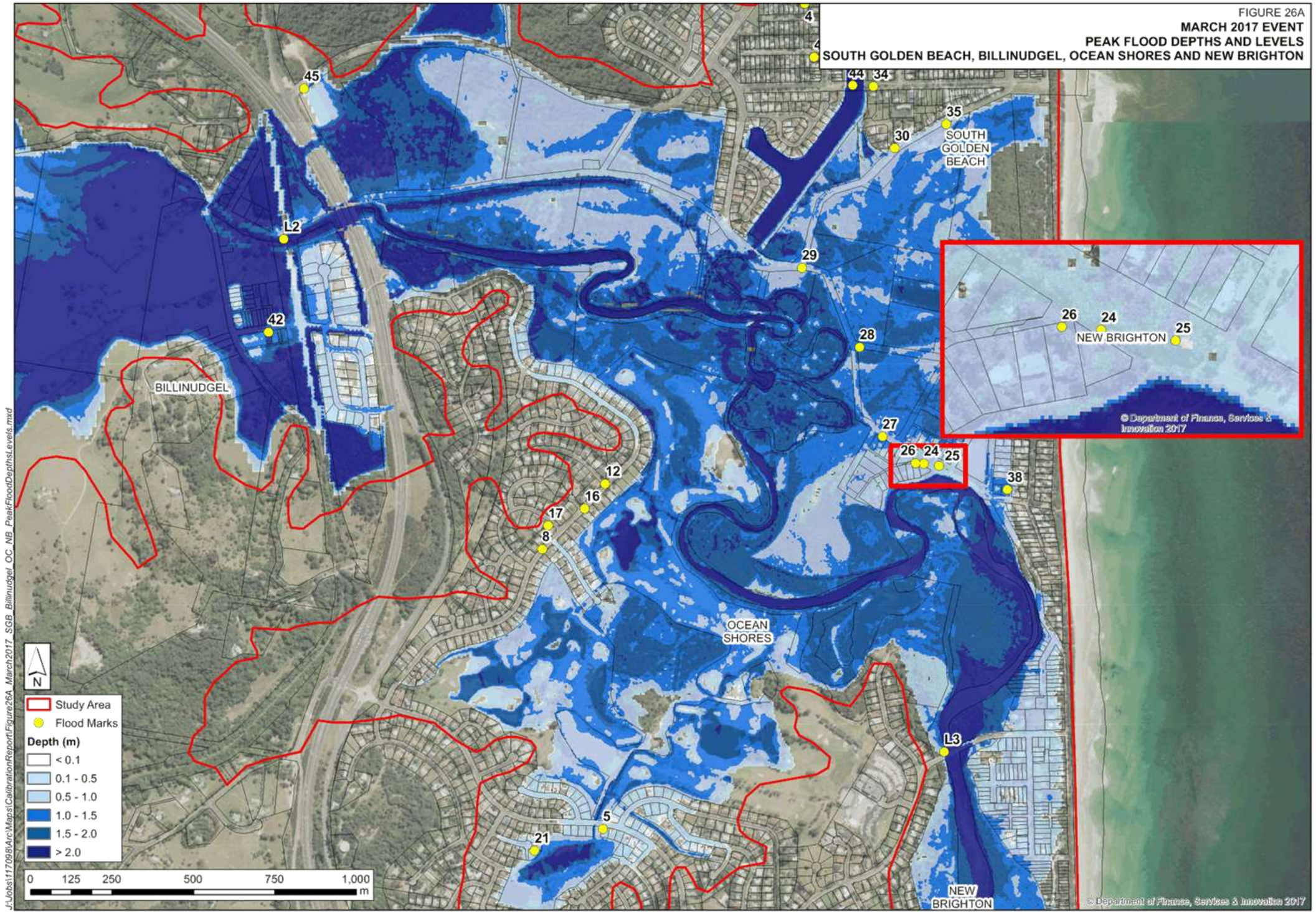
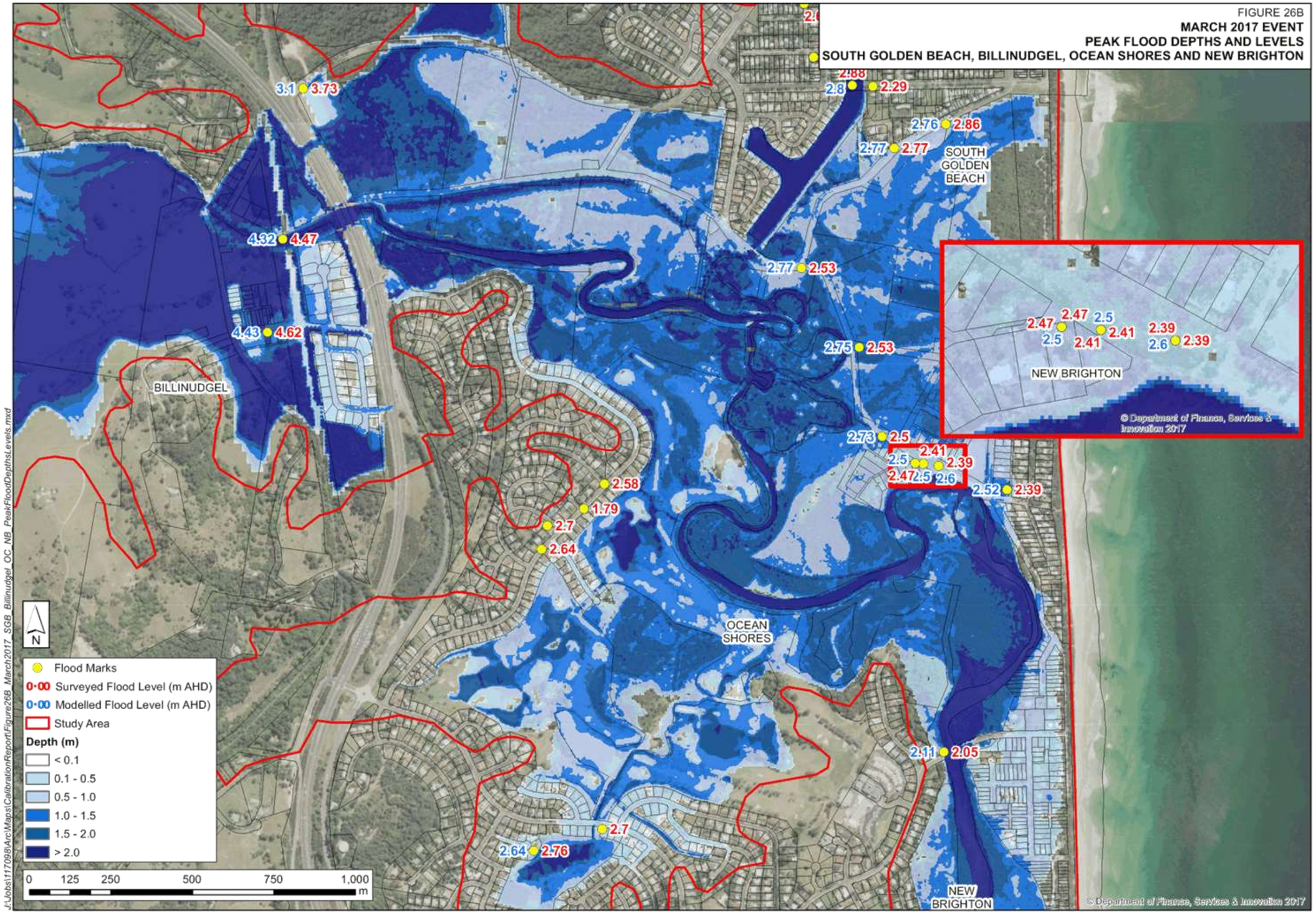


FIGURE 26B
MARCH 2017 EVENT
PEAK FLOOD DEPTHS AND LEVELS
SOUTH GOLDEN BEACH, BILLINUDGEL, OCEAN SHORES AND NEW BRIGHTON




Appendix A

Appendix A – March 2017 flood mark database

ID BMT WBM	ID Survey	ID WMA WATER	Surveyed Flood Level (m AHD)	Source		X	Y
1	ID1	1	1.67	2	Commissioned Survey	552496.4	6843553
2	ID10	2	2.99	2	Commissioned Survey	549640.7	6841060
3	ID11	3	6.7	2	Commissioned Survey	548007.5	6841941
4	ID12	4	2.63	2	Commissioned Survey	553174.2	6847830
5	ID13	5	2.7	2	Commissioned Survey	552553.5	6845296
6	ID14	6	2.99	2	Commissioned Survey	553638.7	6848136
7	ID17	7	7.58	2	Commissioned Survey	547610.9	6841426
8	ID19	8	2.64	2	Commissioned Survey	552283.6	6846174
9	ID2	9	1.96	2	Commissioned Survey	553481.9	6843248
10	ID20	10	2.7	2	Commissioned Survey	549056.2	6841913
11	ID21	11	3.97	2	Commissioned Survey	553555.5	6843194
12	ID22	12	2.58	2	Commissioned Survey	552560.6	6846355
13	ID24	13	4.91	2	Commissioned Survey	548704.1	6841157
14	ID27	14	4.35	2	Commissioned Survey	548509.6	6841802
15	ID3	15	1.68	2	Commissioned Survey	552487.1	6843611
16	ID31N	16	1.79	2	Commissioned Survey	552423	6846234
17	ID31S	17	2.7	2	Commissioned Survey	552385.5	6846226
18	ID33	18	7.17	2	Commissioned Survey	547214.6	6841258
19	ID37	19	2.33	2	Commissioned Survey	553539.1	6847846
20	ID38	20	2.55	2	Commissioned Survey	553364.3	6847853
21	ID39	21	2.76	2	Commissioned Survey	552343.6	6845229
22	ID4	22	2.88	2	Commissioned Survey	553606.8	6848020
23	ID4.1	23	3.16	2	Commissioned Survey	553583.7	6848125
24	ID4.10	24	2.41	2	Commissioned Survey	553539.3	6846417
25	ID4.11	25	2.39	2	Commissioned Survey	553586.8	6846410
26	ID4.12	26	2.47	2	Commissioned Survey	553514.1	6846419
27	ID4.13	27	2.5	2	Commissioned Survey	553412.5	6846500

ID BMT WBM	ID Survey	ID WMA WATER	Surveyed Flood Level (m AHD)	Source		X	Y
28	ID4.14	28	2.53	2	Commissioned Survey	553342.5	6846774
29	ID4.15	29	2.53	2	Commissioned Survey	553165.7	6847019
30	ID4.16	30	2.77	2	Commissioned Survey	553450	6847386
31	ID4.2	31	2.88	2	Commissioned Survey	553592.9	6848194
32	ID4.3	32	3.39	2	Commissioned Survey	553505.6	6848397
33	ID4.4	33	2.95	2	Commissioned Survey	553322.7	6848250
34	ID4.5	34	2.29	2	Commissioned Survey	553384.5	6847575
35	ID4.6	35	2.86	2	Commissioned Survey	553608.3	6847460
36	ID4.7	36	2.74	2	Commissioned Survey	553366.5	6848002
37	ID4.8	37	2.23	2	Commissioned Survey	553622.6	6847697
38	ID4.9	38	2.39	2	Commissioned Survey	553796.2	6846337
39	ID41	39	4.13	2	Commissioned Survey	548861.2	6840883
40	ID43	40	4.14	2	Commissioned Survey	548934.9	6842020
41	ID46	41	1.84	2	Commissioned Survey	553469.9	6843214
42	ID47	42	4.62	2	Commissioned Survey	551525.9	6846821
43	ID5.3	43	2.59	2	Commissioned Survey	553202.5	6847665
44	ID5.4	44	2.88	2	Commissioned Survey	553321.6	6847579
45	ID5.5	45	3.73	2	Commissioned Survey	551629.1	6847571
46	ID50	46	1.97	2	Commissioned Survey	553461.6	6843179
47	ID53	47	2.98	2	Commissioned Survey	549696.8	6841159
48	ID55	48	7.28	2	Commissioned Survey	549696.8	6841159
49	ID6	49	3.59	2	Commissioned Survey	549196.2	6841845
50	ID8	50	4.25	2	Commissioned Survey	549123.9	6841620
51	ID9	51	7.12	2	Commissioned Survey	547722.8	6841307
B1	B1	B1	8.52	3	BP_Survey	547468.5	6842438
B10	B10	B10	7.63	3	BP_Survey	547619.5	6841693
B11	B11	B11	7.2	3	BP_Survey	547323.3	6841100
B12	B12	B12	7.39	3	BP_Survey	547320.5	6841102
B13	B13	B13	19.39	3	BP_Survey	544405.8	6844210

ID BMT WBM	ID Survey	ID WMA WATER	Surveyed Flood Level (m AHD)	Source		X	Y
B14	B14	B14	7.29	3	BP_Survey	547327.7	6841354
B15	B15	B15	7.29	3	BP_Survey	547330.9	6841340
B16	B16	B16	7.29	3	BP_Survey	547296.3	6841334
B17	B17	B17	7.29	3	BP_Survey	547299.3	6841325
B18	B18	B18	7.3	3	BP_Survey	547305.9	6841317
B19	B19	B19	7.3	3	BP_Survey	547318.5	6841320
B2	B2	B2	/	3	BP_Survey	544308.1	6844327
B20	B20	B20	5.46	3	BP_Survey	548542.7	6841370
B21	B21	B21	5.19	3	BP_Survey	548548.3	6841390
B22	B22	B22	16.84	3	BP_Survey	544966.6	6843591
B23	B23	B23	16.45	3	BP_Survey	544966.1	6843584
B24	B24	B24	19.19	3	BP_Survey	544796.4	6843869
B25	B25	B25	19.42	3	BP_Survey	544824.6	6843847
B26	B26	B26	20.85	3	BP_Survey	543980.3	6844651
B27	B27	B27	19.9	3	BP_Survey	544136.9	6844480
B28	B28	B28	19.94	3	BP_Survey	544170.3	6844497
B29	B29	B29	19.69	3	BP_Survey	544255.4	6844394
B3	B3	B3	19.63	3	BP_Survey	544305.3	6844332
B30	B30	B30	7.67	3	BP_Survey	547470.2	6841872
B31	B31	B31	7.13	3	BP_Survey	547472.6	6841934
B32	B32	B32	7.315	3	BP_Survey	547704.7	6841396
B33	B33	B33	7.31	3	BP_Survey	547455.8	6841239
B34	B34	B34	6.29	3	BP_Survey	548042.8	6841914
B35	B35	B35	5.08	3	BP_Survey	548705	6841474
B4	B4	B4	18.99	3	BP_Survey	544443	6843865
B5	B5	B5	19.07	3	BP_Survey	544474.2	6844110
B6	B6	B6	19.31	3	BP_Survey	544475.2	6844113
B7	B7	B7	18.53	3	BP_Survey	545039.2	6843526
B8	B8	B8	6.29	3	BP_Survey	547819.8	6841200

ID BMT WBM	ID Survey	ID WMA WATER	Surveyed Flood Level (m AHD)	Source		X	Y
B9	B9	B9	6.3	3	BP_Survey	547819	6841194
/	Federation Br.	L1	4.35	1	Stream Gauges	548589.2	6841759
/	Billinudgel	L2	4.47	1	Stream Gauges	551573.1	6847107
/	Orana Br.	L3	2.048	1	Stream Gauges	553602.3	6845532
/	Brunswick	L4	1.168	1	Stream Gauges	554079.7	6843184
/	Durrumbul	L5	18.07	1	Stream Gauges	544814.3	6843862